M

machine A device capable of making the performance of mechanical work easier, usually by overcoming a force of resistance (the load) at one point by the application of a more convenient force (the effort) at some other point. In physics, the six so-called **simple machines** are the lever, wedge, inclined plane, screw, pulley, and wheel and axle.

Mach number The ratio of the relative speeds of a fluid and a rigid body to the speed of sound in that fluid under the same conditions of temperature and pressure. If the Mach number exceeds 1 the fluid or body is moving at a **supersonic speed**. If the Mach number exceeds 5 it is said to be **hypersonic**. The number is named after Ernst Mach (1838–1916).

Mach's principle The *inertia of any particular piece of matter is attributable to the interaction between that piece of matter and the rest of the universe. A body in isolation would have zero inertia. This principle was stated by Ernst Mach in the 1870s and was made use of by Einstein in his general theory of *relativity. The significance of Mach's principle in general relativity theory is still a contentious issue.

Maclaurin's series *See* TAYLOR SERIES.

macrofauna The larger animals, collectively, which can be observed without the aid of a microscope (*compare* MICROFAUNA). The macrofauna sometimes includes small soil-dwelling invertebrates, such as annelids and nematodes, but these may be separated into an intermediate category, the **mesofauna**.

macromolecular crystal A crystalline solid in which the atoms are all linked together by covalent bonds. Carbon (in diamond), boron nitride, and silicon carbide are examples of substances that have macromolecular crystals. In effect, the crystal is a large molecule (hence the alternative description **giant-molecular**), which accounts for the hardness and high melting point of such materials.

macromolecule A very large molecule. Natural and synthetic polymers have macromolecules, as do many proteins and nucleic acids. *See also* COLLOIDS.

macronutrient A chemical element required by plants in relatively large amounts. Macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, magnesium, calcium, and iron. *See also* ESSENTIAL ELEMENT. *Compare* MICRONUTRIENT.

macrophage A large phagocytic cell (*see* PHAGOCYTE) that can ingest pathogenic microorganisms (e.g. bacteria, protozoa) or cell debris and forms part of the body's immune system. Macrophages develop from precursor cells (promonocytes) in bone marrow, become wandering *monocytes in the bloodstream, and then settle as mature macrophages in various tissues, including lymph nodes, connective tissues (as **histiocytes**), lungs, the linings of liver sinusoids and the spleen, skin, and nervous tissues (**microglia**). Collectively the macrophages make up the **mononuclear phagocyte system**.

macrophagous Describing a method of feeding in heterotrophic organisms in which food is ingested in the form of relatively large chunks. *Compare* MICROPHAGOUS.

macrophyll *See* MEGAPHYLL.

macroscopic Designating a size scale very much larger than that of atoms and molecules. Macroscopic objects and systems are described by *classical physics although *quantum mechanics can have macroscopic consequences. *Compare* MESOSCOPIC; MICROSCOPIC.

macula **1.** A patch of sensory hair cells in the *utriculus and *sacculus of the inner ear that provides information about the position of the body in relation to gravity. The hairs of the cells are embedded in an **otolith**, a gelatinous cap containing particles of calcium carbonate. Movement of the particles in response to gravity pulls the gelatinous mass downwards, which bends the hairs and triggers a nerve impulse to the brain. **2.** An

area of the *retina of the vertebrate eye with increased *visual acuity. Maculae occur in some animals that lack *foveae and often surround foveae in those animals that possess them.

Madelung constant A constant arising in calculations of the cohesion of ionic crystals. The electrostatic interaction per ion pair, U, is given by $U(r) = -\alpha e^2/r$, where α is the Madelung constant and e^2/r is the Coulomb interaction between the ions, with r being the lattice constant. The value of α depends on the type of lattice. For the sodium chloride lattice, α has a value of about 1.75. A more realistic calculation of cohesion is obtained if short-range repulsions with an inverse power law are included, i.e.

$$U(r) = \alpha e^2/r - C/r^n,$$

where C and n are constants. The value of α can be used in calculations to determine C and n. It was first introduced by the German physicist Erwin Madelung (1881–1972) in 1918.

Madelung's rule An empirical rule for determining the order in which atomic orbitals are filled. This rule, which was proposed in 1936 by Erwin Madelung, comes in two parts. The first part states that the order of filling is the order of increasing $n + l$, where n is the principal quantum number and l is the azimuthal quantum number. The second part states that for two orbitals with an equal value of $n + l$ the order of filling is the order of increasing n. The first part arises because increasing $n + l$ increases the number of nodes of the wavefunction, and hence increases the energy. The second part arises because the approximate *Fock degeneracy of many-electron atoms means that the value of n has a stronger effect on the energy than the value of l.

mafic (from *ma*gnesium + *f*err*ic*) Denoting any dark-coloured ferromagnesian mineral or a rock in which such minerals predominate. Mafic minerals incude amphibole, olivine, and pyroxine. *See also* FELSIC.

Magellanic clouds Two small galaxies that are members of the *Local Group and are situated close to the Milky Way. They are visible from the southern hemisphere of the earth and were first recorded by Ferdinand Magellan (1480–1521) in 1519.

magic numbers Numbers of neutrons or protons that occur in atomic nuclei to produce very stable structures. The magic numbers for both protons and neutrons are 2, 8, 20, 28, 50, and 82. For neutrons 126 and 184 are also magic numbers and for protons 114 is a magic number. The relationship between stability and magic numbers led to a nuclear *shell model in analogy to the electron shell model of the atom.

magma Hot molten material that originates within the earth's crust or mantle and when cooled and solidified forms igneous rock. Most magmas are composed largely of silicates with suspended crystals and dissolved gases. Magma is extruded as *lava onto the surface of the earth as a result of volcanic activity; magma that cools and solidifies within the earth's crust may form either plutonic (at great depths) or hypabyssal (at intermediate depths) rocks.

Magnadur A trade name for a ceramic material used to make permanent magnets. It consists of sintered iron oxide and barium oxide.

Magnalium A trade name for an aluminium-based alloy of high reflectivity for light and ultraviolet radiation that contains 1–2% of copper and between 5% and 30% of magnesium. Strong and light, these alloys also sometimes contain other elements, such as tin, lead, and nickel.

magnesia *See* MAGNESIUM OXIDE.

magnesite A white, colourless, or grey mineral form of *magnesium carbonate, $MgCO_3$, crystallizing in the trigonal system. It is formed as a replacement mineral of magnesium-rich rocks when carbon dioxide is available. Magnesite is mined both as an ore for magnesium and as a source of magnesium carbonate. It occurs in Austria, USA, Greece, Norway, India, Australia, and South Africa.

magnesium Symbol Mg. A silvery metallic element belonging to group 2 (formerly IIA) of the periodic table (*see* ALKALINE-EARTH METALS); a.n. 12; r.a.m. 24.312; r.d. 1.74; m.p. 648.8°C; b.p. 1090°C. The element is found in a number of minerals, including magnesite ($MgCO_3$), dolomite ($MgCO_3.CaCO_3$), and carnallite ($MgCl_2.KCl.6H_2O$). It is also present in sea water, and it is an *essential element for living organisms. Extraction is by electrolysis of the fused chloride. The element is used in a number of light alloys (e.g. for aircraft). Chemically, it is very reactive. In air it forms a protective oxide coating but when ignited it burns with an intense

white flame. It also reacts with the halogens, sulphur, and nitrogen. Magnesium was first isolated by Sir Humphry Davy in 1808.

SEE WEB LINKS

- Information from the WebElements site

magnesium bicarbonate *See* MAGNESIUM HYDROGENCARBONATE.

magnesium carbonate A white compound, $MgCO_3$, existing in anhydrous and hydrated forms. The anhydrous material (trigonal; r.d. 2.96) is found in the mineral *magnesite. There is also a trihydrate, $MgCO_3.3H_2O$ (rhombic; r.d. 1.85), which occurs naturally as **nesquehonite**, and a pentahydrate, $MgCO_3.5H_2O$ (monoclinic; r.d. 1.73), which occurs as **lansfordite**. Magnesium carbonate also occurs in the mixed salt *dolomite ($CaCO_3.MgCO_3$) and as **basic magnesium carbonate** in the two minerals **artinite** ($MgCO_3.Mg(OH)_2.3H_2O$) and **hydromagnesite** ($3MgCO_3.Mg(OH)_2.3H_2O$). The anhydrous salt can be formed by heating magnesium oxide in a stream of carbon dioxide:

$$MgO(s) + CO_2(g) \rightarrow MgCO_3(s)$$

Above 350°C, the reverse reaction predominates and the carbonate decomposes. Magnesium carbonate is used in making magnesium oxide and is a drying agent (e.g. in table salt). It is also used as a medical antacid and laxative (the basic carbonate is used) and is a component of certain inks and glasses.

magnesium chloride A white solid compound, $MgCl_2$. The anhydrous salt (hexagonal; r.d. 2.32; m.p. 714°C; b.p. 1412°C) can be prepared by the direct combination of dry chlorine with magnesium:

$$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$

The compound also occurs naturally as a constituent of carnallite ($KCl.MgCl_2$). It is a deliquescent compound that commonly forms the hexahydrate, $MgCl_2.6H_2O$ (monoclinic; r.d. 1.57). When heated, this hydrolyses to give magnesium oxide and hydrogen chloride gas. The fused chloride is electrolysed to produce magnesium and it is also used for fireproofing wood, in magnesia cements and artificial leather, and as a laxative.

magnesium hydrogencarbonate (magnesium bicarbonate) A compound, $Mg(HCO_3)_2$, that is stable only in solution. It is formed by the action of carbon dioxide on a suspension of magnesium carbonate in water:

$$MgCO_3(s) + CO_2(g) + H_2O(l) \rightarrow Mg(HCO_3)_2(aq)$$

On heating, this process is reversed. Magnesium hydrogencarbonate is one of the compounds responsible for temporary *hardness of water.

magnesium hydroxide A white solid compound, $Mg(OH)_2$; trigonal; r.d. 2.36; decomposes at 350°C. Magnesium hydroxide occurs naturally as the mineral **brucite** and can be prepared by reacting magnesium sulphate or chloride with sodium hydroxide solution. It is used in the refining of sugar and in the processing of uranium. Medicinally it is important as an antacid (**milk of magnesia**) and as a laxative.

magnesium oxide (magnesia) A white compound, MgO; cubic; r.d. 3.58; m.p. 2800°C. It occurs naturally as the mineral **periclase** and is prepared commercially by thermally decomposing the mineral *magnesite:

$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

It has a wide range of uses, including reflective coatings on optical instruments and aircraft windscreens and in semiconductors. Its high melting point makes it useful as a refractory lining in metal and glass furnaces.

magnesium peroxide A white solid, MgO_2. It decomposes at 100°C to release oxygen and also releases oxygen on reaction with water:

$$2MgO_2(s) + 2H_2O \rightarrow 2Mg(OH)_2 + O_2$$

The compound is prepared by reacting sodium peroxide with magnesium sulphate solution and is used as a bleach for cotton and silk.

magnesium sulphate A white soluble compound, $MgSO_4$, existing as the anhydrous compound (rhombic; r.d. 2.66; decomposes at 1124°C) and in hydrated crystalline forms. The monohydrate $MgSO_4.H_2O$ (monoclinic; r.d. 2.45) occurs naturally as the mineral **kieserite**. The commonest hydrate is the heptahydrate, $MgSO_4.7H_2O$ (rhombic; r.d. 1.68), which is called **Epsom salt(s)**, and occurs naturally as the mineral **epsomite**. This is a white powder with a bitter saline taste, which loses $6H_2O$ at 150°C and $7H_2O$ at 200°C. It is used in sizing and fireproofing cotton and silk, in tanning leather, and in the manufacture of

fertilizers, explosives, and matches. In medicine, it is used as a laxative. It is also used in veterinary medicine for treatment of local inflammations and infected wounds.

magnet A piece of magnetic material (*see* MAGNETISM) that has been magnetized and is therefore surrounded by a *magnetic field. A magnet, often in the shape of a bar or horseshoe, that retains appreciable magnetization indefinitely (provided it is not heated, beaten, or exposed to extraneous magnetic fields) is called a **permanent magnet**. *See also* ELECTROMAGNET.

magnetic bottle A nonuniform *magnetic field used to contain the plasma in a *thermonuclear reactor. At the temperature of a thermonuclear reaction (10^8 K) any known substance would vaporize and the plasma has therefore to be contained in such a way that it does not come into contact with a material surface. The magnetic bottle provides a means of achieving this, by deflecting away from its boundaries the moving charged particles that make up the plasma.

magnetic bubble memory A form of computer memory in which a small magnetized region of a substance is used to store information. Bubble memories consist of materials, such as magnetic garnets, that are easily magnetized in one direction but hard to magnetize in the perpendicular direction. A thin film of these materials deposited on a nonmagnetic substrate constitutes a bubble-memory chip. When a magnetic field is applied to such a chip, by placing it between two permanent magnets, cylindrical domains (called magnetic bubbles) are formed. These bubbles constitute a magnetic region of one polarity surrounded by a magnetic region of the opposite polarity. Information is represented as the presence or absence of a bubble at a specified storage location and is retrieved by means of a rotating magnetic field. Typically a chip measures 15 mm^2, or 25 mm^2 enclosed in two permanent magnets and two rotating field coils; each chip can store up to one million bits.

magnetic circuit A closed path containing a *magnetic flux. The path is clearly delimited only if it consists mainly or wholly of ferromagnetic or other good magnetic materials; examples include transformer cores and iron parts in electrical machines. The design of these parts can often be assisted by analogy with electrical circuits, treating the *magnetomotive force as the analogue of e.m.f., the magnetic flux as current, and the *reluctance as resistance. There is, however, no actual flow around a magnetic circuit.

magnetic compass *See* COMPASS.

magnetic constant *See* PERMEABILITY.

magnetic declination *See* GEOMAGNETISM.

magnetic dip *See* GEOMAGNETISM.

magnetic disk A smooth aluminium disk, usually 35.6 cm in diameter, both surfaces of which are coated with magnetic iron oxide. The disks are used as a recording medium in computers. Data is recorded in concentric tracks on both surfaces with up to 236 tracks per centimetre. The disks rotate at 3600 revolutions per minute, information being put onto the disk and removed from it by a record-playback head. *See also* FLOPPY DISK.

magnetic domain *See* MAGNETISM.

magnetic elements *See* GEOMAGNETISM.

magnetic equator *See* EQUATOR; GEOMAGNETISM.

magnetic field A *field of force that exists around a magnetic body (*see* MAGNETISM) or a current-carrying conductor. Within a magnetic field a magnetic dipole may experience a torque and a moving charge may experience a force. The strength and direction of the field can be given in terms of the **magnetic flux density** (or **magnetic induction**), symbol B; it can also be given in terms of the **magnetic field strength** (**magnetizing force** or **magnetic intensity**), symbol H.

The magnetic flux density is a vector quantity and is the *magnetic flux per unit area of a magnetic field at right angles to the magnetic force. It can be defined in terms of the effects the field has, for example by $B = F/qv\sin\theta$, where F is the force a moving charge q would experience if it was travelling at a velocity v in a direction making an angle θ with that of the field. The *SI unit is the tesla.

The magnetic field strength is also a vector quantity and is related to B by: $H = B/\mu$, where μ is the *permeability of the medium. The SI unit of field strength is the ampere per metre (A m^{-1}).

magnetic field strength *See* MAGNETIC FIELD.

magnetic flux Symbol Φ. A measure of quantity of magnetism, taking account of the

strength and the extent of a *magnetic field. The flux dΦ through an element of area dA perpendicular to B is given by dΦ = BdA. The *SI unit of magnetic flux is the weber.

magnetic flux density *See* MAGNETIC FIELD.

magnetic force The attractive or repulsive force exerted on a *magnetic pole or a moving electric charge in a *magnetic field.

magnetic induction *See* MAGNETIC FIELD.

magnetic intensity *See* MAGNETIC FIELD.

magnetic meridian *See* MERIDIAN.

magnetic mirror A device used to contain *plasma in thermonuclear experimental devices. It consists of a region of high magnetic field strength at the end of a containment tube. Ions entering the region reverse their motion and return to the plasma from which they have emerged. *See also* MAGNETIC BOTTLE.

magnetic moment The ratio between the maximum torque (T_{max}) exerted on a magnet, current-carrying coil, or moving charge situated in a *magnetic field and the strength of that field. It is thus a measure of the strength of a magnet or current-carrying coil. In the Sommerfeld approach this quantity (also called **electromagnetic moment** or **magnetic area moment**) is T_{max}/B. In the Kennelly approach the quantity (also called **magnetic dipole moment**) is T_{max}/H.

In the case of a magnet placed in a magnetic field of field strength H, the maximum torque T_{max} occurs when the axis of the magnet is perpendicular to the field. In the case of a coil of N turns and area A carrying a current I, the magnetic moment can be shown to be $m = T/B = NIA$ or $m = T/H = \mu NIA$. Magnetic moments are measured in *SI units in A m^2.

An orbital electron has an orbital magnetic moment IA, where I is the equivalent current as the electron moves round its orbit. It is given by $I = q\omega/2\pi$, where q is the electronic charge and ω is its angular velocity. The orbital magnetic moment is therefore $IA = q\omega A/2\pi$, where A is the orbital area. If the electron is spinning there is also a spin magnetic moment (*see* SPIN); atomic nuclei also have magnetic moments (*see* NUCLEAR MOMENT).

magnetic monopole A hypothetical magnetic entity consisting of an isolated elementary north or south pole. It has been postulated as a source of a *magnetic field by analogy with the way in which an electrically charged particle produces an electric field. Numerous ingenious experiments have been designed to detect the monopole but so far none has produced an unequivocal result. Magnetic monopoles are predicted to exist in certain *gauge theories with *Higgs bosons. In particular, some *grand unified theories predict very heavy monopoles (with mass of order 10^{16} GeV). Magnetic monopoles are also predicted to exist in *Kaluza–Klein theories and *superstring theory.

magnetic permeability *See* PERMEABILITY.

magnetic poles **1.** *See* GEOMAGNETISM. **2.** The regions of a *magnet from which the magnetic forces appear to originate. A magnetized bar has a pole at each end; if it is freely suspended in the earth's magnetic field (*see* GEOMAGNETISM) it will rotate so that one end points approximately towards the earth's geographical north pole. This end is called the north-seeking end or the north pole of the magnet. The other end is accordingly called the south-seeking end or south pole. In the obsolete theory associated with the *c.g.s. system of units, a **unit magnetic pole** was treated as one of a pair, which repelled each other with a force of 1 dyne when separated by 1 cm in space.

magnetic potential *See* MAGNETOMOTIVE FORCE.

magnetic quantum number *See* ATOM.

magnetic resonance imaging (MRI) *See* NUCLEAR MAGNETIC RESONANCE.

magnetic susceptibility *See* SUSCEPTIBILITY.

magnetic tape A plastic tape coated with a ferromagnetic material – iron oxide powder, chromium dioxide, or, for the best results, particles of pure iron. The tape is used for recording data in tape recorders and computers. To record, the tape is passed over a recording head containing a gap in a magnetic circuit whose magnetization is modulated by the information to be recorded; the information is imprinted on the tape in the form of the direction of magnetization of the individual particles of iron oxide. The playback procedure is the reverse of recording; the tape containing its orientation of tiny magnets is fed over the gap of the

same (now the playback) head, in whose coil corresponding e.m.f.s are generated by induction.

magnetic trap A device for trapping electrically neutral particles that have magnetic moments using nonuniform magnetic fields. Magnetic traps have been used in research on very low temperatures and the formation of Bose–Einstein condensates.

magnetic variation (secular magnetic variation) *See* GEOMAGNETISM.

magnetism A group of phenomena associated with *magnetic fields. Whenever an electric current flows a magnetic field is produced; as the orbital motion and the *spin of atomic electrons are equivalent to tiny current loops, individual atoms create magnetic fields around them, when their orbital electrons have a net *magnetic moment as a result of their angular momentum. The magnetic moment of an atom is the vector sum of the magnetic moments of the orbital motions and the spins of all the electrons in the atom. The macroscopic magnetic properties of a substance arise from the magnetic moments of its component atoms and molecules. Different materials have different characteristics in an applied magnetic field; there are four main types of magnetic behaviour:

(a) In **diamagnetism** the magnetization is in the opposite direction to that of the applied field, i.e. the *susceptibility is negative. Although all substances are diamagnetic, it is a weak form of magnetism and may be masked by other, stronger, forms. It results from changes induced in the orbits of electrons in the atoms of a substance by the applied field, the direction of the change (in accordance with *Lenz's law) opposing the applied flux. There is thus a weak negative susceptibility and a relative permeability that is slightly less than one.

(b) In **paramagnetism** the atoms or molecules of the substance have net orbital or spin magnetic moments that are capable of being aligned in the direction of the applied field. They therefore have a positive (but small) susceptibility and a relative permeability slightly in excess of one. Paramagnetism occurs in all atoms and molecules with unpaired electrons; e.g. free atoms, free radicals, and compounds of transition metals containing ions with unfilled electron shells. It also occurs in metals as a result of the magnetic moments associated with the spins of the conducting electrons.

(c) In **ferromagnetic** substances, within a certain temperature range, there are net atomic magnetic moments, which line up in such a way that magnetization persists after the removal of the applied field. Below a certain temperature, called the *Curie point (or Curie temperature) an increasing magnetic field applied to a ferromagnetic substance will cause increasing magnetization to a high value, called the **saturation magnetization**. This is because a ferromagnetic substance consists of small (1–0.1 mm across) magnetized regions called **domains**. The total magnetic moment of a sample of the substance is the vector sum of the magnetic moments of the component domains. Within each domain the individual atomic magnetic moments are spontaneously aligned by **exchange forces**, related to whether or not the atomic electron spins are parallel or antiparallel. However, in an unmagnetized piece of ferromagnetic material the magnetic moments of the domains themselves are not aligned; when an external field is applied those domains that are aligned with the field increase in size at the expense of the others. In a very strong field all the domains are lined up in the direction of the field and provide the high observed magnetization. Iron, nickel, cobalt, and their alloys are ferromagnetic. Above the Curie point, ferromagnetic materials become paramagnetic. A variant of exchange is **superexchange**, i.e. a magnetic interaction that can occur when two magnetic ions are separated by a nonmagnetic ion, with the interaction being mediated by the electrons in the nonmagnetic ion. Superexchange is important in magnetic insulators.

(d) Some metals, alloys, and transition-element salts exhibit another form of magnetism called **antiferromagnetism**. This occurs below a certain temperature, called the *Néel temperature, when an ordered array of atomic magnetic moments spontaneously forms in which alternate moments have opposite directions. There is therefore no net resultant magnetic moment in the absence of an applied field. In manganese fluoride, for example, this antiparallel arrangement occurs below a Néel temperature of 72 K. Below this temperature the spontaneous ordering opposes the normal tendency of the magnetic moments to align with the applied field. Above the Néel temperature the substance is paramagnetic.

A special form of antiferromagnetism is **ferrimagnetism**, a type of magnetism exhibited by the *ferrites. In these materials the magnetic moments of adjacent ions are antiparallel and of unequal strength, or the number of magnetic moments in one direction is greater than those in the opposite direction. By suitable choice of rare-earth ions in the ferrite lattices it is possible to design ferrimagnetic substances with specific magnetizations for use in electronic components. *See also* GEOMAGNETISM.

SEE WEB LINKS

- Values for the magnetic properties of materials at the NPL website

magnetite A black mineral form of iron oxide crystallizing in the cubic system. It is a mixed iron(II)-iron(III) oxide, Fe_3O_4, and is one of the major ores of iron. It is strongly magnetic and some varieties, known as **lodestone**, are natural magnets; these were used as compasses in the ancient world. Magnetite is widely distributed and occurs as an accessory mineral in almost all igneous and metamorphic rocks. The largest deposits of the mineral occur in N Sweden.

magneto An alternating-current generator used as a high-tension source in the ignition systems of petrol engines in which there are no batteries, e.g. in some tractor, marine, and aviation engines. Most modern magnetos consist of a permanent-magnet rotor revolving within a primary (low-voltage) winding around which a secondary winding is placed in which to induce the high voltage needed to produce the spark across the points of the plugs. Magnetos are geared to the engine shaft, the speed depending on the number of poles of the magneto and the number of engine cylinders. A make-and-break device is incorporated in the primary winding; when the primary current stops the change of flux within the secondary induces in it a large e.m.f.

magnetobremsstrahlung *See* SYNCHROTRON RADIATION.

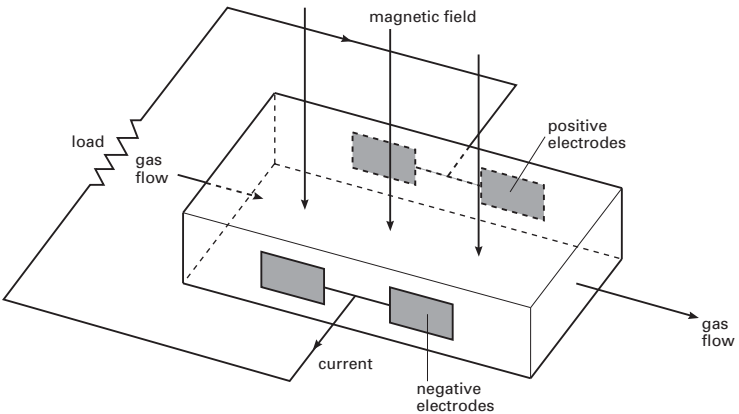
magnetocaloric effect A reversible change of temperature resulting from a change in the magnetization of a ferromagnetic or paramagnetic substance (*see* MAGNETISM). The change in temperature ΔT, accompanying an adiabatic change of magnetic field ΔH, is:

$$\Delta T/\Delta H = -T/C_H(\partial M/\partial T)_H$$

C_H is the specific heat capacity per unit volume at constant H and M is the magnetization.

magnetochemistry The branch of physical chemistry concerned with measuring and investigating the magnetic properties of compounds. It is used particularly for studying transition-metal complexes, many of which are paramagnetic because they have unpaired electrons. Measurement of the magnetic susceptibility allows the magnetic moment of the metal atom to be calculated, and this gives information about the bonding in the complex.

magnetohydrodynamics (MHD) The



Magnetohydrodynamics. Magnetohydrodynamic generator.

study of the interactions between a conducting fluid and a *magnetic field. MHD is important in the study of controlled thermonuclear reactions in which the conducting fluid is a *plasma confined by a magnetic field. Other important applications include the **magnetohydrodynamic power generator** (see illustration). In the open-cycle MHD generator a fossil fuel, burnt in oxygen or preheated compressed air, is seeded with an element of low *ionization potential (such as potassium or caesium). This element is thermally ionized at the combustion temperature (usually over 2500 K) producing sufficient free electrons (e.g. $K \rightarrow K^+ + e$) to provide adequate electrical conductivity. The interaction between the moving conducting fluid and the strong applied magnetic field across it generates an e.m.f. on the Faraday principle, except that the solid conductor of the conventional generator is replaced by a fluid conductor. The power output per unit fluid volume (W) is given by $W = k\sigma v^2 B^2$, where σ is the conductivity of the fluid, v is its velocity, B is the magnetic flux density, and K is a constant. Devices of this kind are in use in some power stations, where they are suitable for helping to meet high short-term demands and have the ability of increasing the thermal efficiency of a steam-turbine generator from about 40% to 50%. In experimental closed-cycle systems the fluid is continuously recirculated through a compressor; the fluid consists of a heated and seeded noble gas or a liquid metal.

magnetomechanical ratio *See* GYROMAGNETIC RATIO.

magnetometer An instrument for measuring the magnitude, and sometimes the direction, of a magnetic field. **Absolute magnetometers** measure the field without reference to a standard magnetic instrument. The most widely used are the **vibration magnetometer**, the **deflection galvanometer**, and the more modern **nuclear magnetometer**. The vibration instrument was devised by Gauss in 1832 and depends on the rate of oscillation of a small bar magnet suspended in a horizontal plane. The same magnet is then used as a fixed deflector to deflect a second similarly suspended magnet. The deflection galvanometer uses a Helmholtz coil system of known dimensions with a small magnet suspended at its centre. The deflected magnet comes to rest at a position controlled by the earth's magnetic field, the coil's magnetic field, and the angle through which the coil must be turned to keep the magnet and the coil in alignment. The sensitive nuclear magnetometers are based on measuring the audiofrequency voltage induced in a coil by the precessing protons in a sample of water. Various **relative magnetometers** are also in use, especially for measuring the earth's magnetic field and in calibrating other equipment.

magnetomotive force (m.m.f.) The analogue of *electromotive force in a *magnetic circuit. Mathematically, it is the circular integral of $H\cos\theta\, ds$, where $H\cos\theta$ is the component of the *magnetic field strength in the direction of a path of length ds. The m.m.f. is measured in *SI units in ampere-turns. It was formerly called the **magnetic potential**.

magneton A unit for measuring *magnetic moments of nuclear, atomic, or molecular magnets. The **Bohr magneton**, μ_B, has the value of the classical magnetic moment of an electron, given by

$$\mu_B = eh/4\pi m_e = 9.274 \times 10^{-24}\ \text{A m}^2,$$

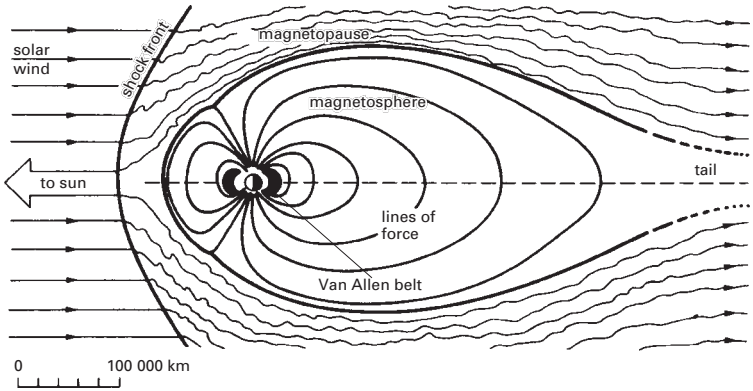
where e and m_e are the charge and mass of the electron and h is the Planck constant. The **nuclear magneton**, μ_N, is obtained by replacing the mass of the electron by the mass of the proton and is therefore given by

$$\mu_N = \mu_B m_e / m_p = 5.05 \times 10^{-27}\ \text{A m}^2.$$

magneto-optical effects Effects resulting from the influence of a *magnetic field upon matter that is in the process of emitting or absorbing light. Examples are the *Faraday effect and the *Zeeman effect.

magneto-optical trap *See* LASER COOLING.

magnetoresistance An increase in the resistance of a metal due to the presence of a magnetic field, which alters the paths of the electrons. At normal temperatures the change in resistance resulting from the magnetic field is small but at very low temperatures the increase is considerable. The theory of magnetoresistance is too complicated to be explained quantitatively by the simple model of electrical *conductivity in metals, which assumes that it results from the movement of free electrons. To obtain a quantitative explanation, it is necessary to take into account the *energy-band structure of metals. Usually magnetoresistance is a



Magnetosphere.

fairly small effect (about 5%). However, under certain circumstances much larger effects are possible.

magnetosphere A comet-shaped region surrounding the earth and other magnetic planets in which the charged particles of the *solar wind are controlled by the planet's magnetic field rather than the sun's magnetic field. It extends for some 60 000 km on the side facing the sun but on the opposite side it extends to a much greater extent. The boundary of the magnetosphere is known as the **magnetopause** (see illustration). The magnetosphere of the earth includes the *Van Allen belts.

magnetostriction The change in length of a ferromagnetic material (*see* MAGNETISM) when it is magnetized. It results from changes in the boundaries of the domains. A ferromagnetic rod exposed to an alternating field will vibrate along its length. This appears to be a major source of transformer hum, which can be removed by using a magnetic steel containing 6.5% silicon. Magnetostriction of a nickel transducer is used to generate and receive ultrasonic waves.

magnetron A microwave generator in which electrons, generated by a heated cathode, move under the combined force of an electric field and a magnetic field. The cathode consists of a central hollow cylinder, the outer surface of which carries the barium and strontium oxide electron emitters. The anode is also a cylinder, arranged concentrically around the cathode, and it contains a series of quarter-wavelength *resonant cavities arranged around its inner surface. The electric field is applied radially between anode and cathode, the magnetic field is coaxial with the cathode. The whole device is maintained in a vacuum enclosure. The magnetron is extensively used as a generator for radar installations and can produce microsecond pulses of up to 10 MW.

magnification A measure of the extent to which an optical system enlarges or reduces an image. The **linear magnification**, m, is the ratio of the image height to the object height. If this ratio is greater than one the system is enlarging, if it is less than one, it is reducing. The **angular magnification**, M or γ, is the ratio of the angles formed by the final image and the object (when viewed directly, in the most favourable position available) at the eye. This is also sometimes called the **magnifying power** of an optical system.

magnifying power *See* MAGNIFICATION.

magnitude A measure of the relative brightness of a star or other celestial object. The **apparent magnitude** depends on the star's *luminosity, its distance, and the absorption of light between the object and the earth. In 1856 the astronomer N. R. Pogson devised a scale in which a difference of five magnitudes corresponds to a brightness ratio of 100 to 1. Two stars that differ by one magnitude therefore have a brightness ratio of $(100)^{0.2}:1 = 2.512$, known as the **Pogson ratio**. This scale is now universally adopted. Apparent magnitudes are not a measure of

luminosity, which is defined in terms of the **absolute magnitude**. This is the apparent magnitude of a body if it was situated at a standard distance of 10 parsecs.

Magnoliophyta *See* ANTHOPHYTA.

magnon *See* SPIN WAVE.

Magnox A group of magnesium alloys used to enclose uranium fuel elements in *nuclear reactors. They usually contain some aluminium as well as other elements, such as beryllium.

mainframe computer *See* COMPUTER.

main-sequence stars *See* HERTZSPRUNG–RUSSELL DIAGRAM.

major histocompatibility complex (MHC) A large gene cluster that encodes various components of the immune system, including the histocompatibility antigens and components of the *complement system. In humans the MHC contains over 200 genes, is located on chromosome 6, and includes the *HLA system. Other vertebrate species have similar MHC regions. Certain MHC genes can have many variant alleles; this produces an enormous diversity of antigens in a population, each individual possessing a unique set.

majority carrier *See* SEMICONDUCTOR.

Maksutov telescope *See* TELESCOPE.

malachite A secondary mineral form of copper carbonate–hydroxide, $CuCO_3$. $Cu(OH)_2$. It is bright green and crystallizes in the monoclinic system but usually occurs as aggregates of fibres or in massive form. It is generally found with *azurite in association with the more important copper ores and is itself mined as an ore of copper (e.g. in the Democratic Republic of Congo). It is also used as an ornamental stone and as a gemstone.

MALDI Matrix absorption laser desorption ionization. A technique for producing ions for mass spectroscopy, used especially for large biological compounds. The sample is absorbed on an inert matrix from which ions are desorbed by a laser.

male **1.** Denoting the gamete (sex cell) that, during *sexual reproduction, fuses with a *female gamete in the process of fertilization. Male gametes are generally smaller than the female gametes and are usually motile (*see* SPERMATOZOON). **2.** (Denoting) an individual whose reproductive organs produce only male gametes. *Compare* HERMAPHRODITE.

maleic acid *See* BUTENEDIOIC ACID.

maleic anhydride A colourless solid, $C_4H_2O_3$, m.p. 53°C, the anhydride of *cis*-butenedioic acid (maleic acid). It is a cyclic compound with a ring containing four carbon atoms and one oxygen atom, made by the catalytic oxidation of benzene or its derivatives at high temperatures. It is used mainly in the manufacture of alkyd and polyester resins and copolymers.

malic acid (2-hydroxybutanedioic acid) A white crystalline solid, $HOOCCH(OH)CH_2COOH$. L-malic acid occurs in living organisms as an intermediate metabolite in the *Krebs cycle and also (in certain plants) in photosynthesis. It is found especially in the juice of unripe fruits, e.g. green apples, and contributes to their sour taste.

malleus (hammer) The first of the three *ear ossicles of the mammalian *middle ear.

Mallophaga An order of wingless insects comprising the bird lice. Bird lice are minute with dorsoventrally flattened ovoid bodies, reduced eyes, and biting mouthparts. They are ectoparasites of birds, feeding on particles of dead skin, feather fragments, and sometimes blood. The eggs hatch to form nymphs resembling the adults.

malnutrition The condition arising due to the lack of one or more of the *nutrients that are required in the *diet to maintain health. Malnutrition can result from a reduced intake of nutrients (**undernourishment**), an inability to use absorbed nutrients, failure to meet a required increase in nutrient intake, or nutrient losses. There are three stages in the process of malnutrition: first, the carbohydrate stores in the body are depleted; secondly, the fat reserves are metabolized (*see* FATTY-ACID OXIDATION); and finally, proteins are broken down to provide energy. Death may result after protein levels have been reduced to half their normal value. **Kwashiorkor** is a type of malnutrition that develops when the diet lacks proteins and hence *essential amino acids. Malnutrition due to reduced absorption of nutrients in the intestine can develop with a cereal-based diet, due to sensitivity of the intestinal lining to gluten, a protein found in cereals. *See also* MINERAL DEFICIENCY.

malonic acid *See* PROPANEDIOIC ACID.

Malpighian body (Malpighian corpuscle) The part of a *nephron in the kidney that consists of its cup-shaped end together with the *glomerulus that it encloses. It is named after its discoverer, the Italian anatomist Marcello Malpighi (1628–94).

Malpighian layer (stratum germinativum) The innermost layer of the *epidermis of mammalian *skin, separated from the underlying dermis by a fibrous *basement membrane. It is only in this layer of the epidermis that active cell division (*mitosis) occurs. As the cells produced by these divisions age and mature, they migrate upwards through the layers of the epidermis to replace the cells being continuously worn away at the surface.

maltase A membrane-bound enzyme in the small intestine that hydrolyses the disaccharide maltose into glucose.

maltose (malt sugar) A sugar consisting of two linked glucose molecules that results from the action of the enzyme *amylase on starch. Maltose occurs in high concentrations in germinating seeds; malt, used in the manufacture of beer and malt whisky, is produced by allowing barley seeds to germinate and then slowly drying them.

malt sugar *See* MALTOSE.

Mammalia A class of vertebrates containing some 4250 species. Mammals are warm-blooded animals (*see* HOMOIOTHERMY), typically having sweat glands whose secretion cools the skin and an insulating body covering of hair. All female mammals have *mammary glands, which secrete milk to nourish the young. Mammalian teeth are differentiated into incisors, canines, premolars, and molars and the middle ear contains three sound-conducting *ear ossicles. The four-chambered heart enables complete separation of oxygenated and deoxygenated blood and a muscular *diaphragm takes part in breathing movements, both of which ensure that the tissues are well supplied with oxygen. This, together with well-developed sense organs and brain, have enabled mammals to pursue an active life and to colonize a wide variety of habitats.

Mammals evolved from carnivorous reptiles in the Triassic period about 225 million years ago. There are two subclasses: the primitive egg-laying *Prototheria (monotremes) and the Theria, which includes all other mammals and consists of the infraclasses *Metatheria (marsupials) and *Eutheria (placental mammals).

SEE WEB LINKS

- The Life of Mammals website from the BBC

mammary glands The milk-producing organs (possibly modified sweat glands) of female mammals, which provide food for the young (*see* MILK; COLOSTRUM). Their number (2 to 20) and position (on the chest or abdomen) vary according to the species. In most mammals the gland openings project as a **nipple** or **teat**. Nipples have a number of milk-duct openings; teats have one duct leading from a storage cavity.

Mandelbrot set A *fractal that produces complex self-similar patterns. In mathematical terms, it is the set of values of c that make the series $z_n + 1 = (z_n)^2 + c$ converge, where c and z are complex numbers and z begins at the origin (0,0). It was discovered by and named after the Polish-born French mathematician Benoit Mandelbrot (1924–).

Mandelin test A *presumptive test for amphetamines and alkaloids. The **Mandelin reagent** is a 1% solution of ammonium vanadate (NH_4VO_3) in concentrated sulphuric acid. Different substances give different colours. Mescaline, for example, produces an orange colour, heroin a brown colour, and amphetamine a blue-green colour.

mandible **1.** One of a pair of horny *mouthparts in insects, crustaceans, centipedes, and millipedes. The mandibles lie in front of the weaker *maxillae and their lateral movements assist in biting and crushing the food. **2.** The lower jaw of vertebrates. **3.** Either of the two parts of a bird's beak.

Mandibulata *See* ARTHROPOD.

manganate(VI) A salt containing the ion MnO_4^{2-}. Manganate(VI) ions are dark green; they are produced by manganate(VII) ions in basic solution.

manganate(VII) (permanganate) A salt containing the ion MnO_4^-. Manganate(VII) ions are dark purple and strong oxidizing agents.

manganese Symbol Mn. A grey brittle metallic *transition element, a.n. 25; r.a.m. 54.94; r.d. 7.2; m.p. 1244°C; b.p. 1962°C. The main sources are pyrolusite (MnO_2) and rhodochrosite ($MnCO_3$). The metal can be extracted by reduction of the oxide using

magnesium (*Kroll process) or aluminium (*Goldschmidt process). Often the ore is mixed with iron ore and reduced in an electric furnace to produce ferromanganese for use in alloy steels. The element is fairly electropositive; it combines with oxygen, nitrogen, and other nonmetals when heated (but not with hydrogen). Salts of manganese contain the element in the +2 and +3 oxidation states. Manganese(II) salts are the more stable. It also forms compounds in higher oxidation states, such as manganese(IV) oxide and manganate(VI) and manganate(VII) salts. The element was discovered in 1774 by Karl Scheele.

SEE WEB LINKS

- Information from the WebElements site

manganese nodule An irregular lump of rock containing manganese, found on the deep ocean floor, particularly the north Pacific. The nodules range in size from 0.5 to 25 cm across and have a banded structure, built up on a central particle, such as a pebble or even a shark's tooth. They contain up to 24% manganese, with some iron (14%), nickel (1%), and copper (0.5%), and sometimes cobalt (0.5%). They form when metal-bearing solutions well up from the ocean floor. Various methods have been tried to 'mine' them, although none has yet been adopted commercially.

manganese(IV) oxide (manganese dioxide) A black oxide made by heating manganese(II) nitrate. The compound also occurs naturally as pyrolusite. It is a strong oxidizing agent, used as a depolarizing agent in voltaic cells.

manganic compounds Compounds of manganese in its +3 oxidation state; e.g. manganic oxide is manganese(III) oxide, Mn_2O_3.

manganin A copper alloy containing 13–18% of manganese and 1–4% of nickel. It has a high electrical resistance, which is relatively insensitive to temperature changes. It is therefore suitable for use in resistance wire.

manganous compounds Compounds of manganese in its +2 oxidation state; e.g. manganous oxide is manganese(II) oxide, MnO.

mangrove swamp A region of vegetation, found along tropical coasts, in which mangrove trees (*Rhizophora* species) predominate. The waterlogged soil is highly saline, and – like other *halophytes – mangroves are adapted to withstand these conditions; they also possess aerial roots (**pneumatophores**) through which gaseous exchange occurs, to counteract effects of the badly aerated soil. Mangroves play a vital role in protecting coastal regions from the effects of tropical storms and high tides.

Mannich reaction A reaction in which a primary or secondary amine reacts with methanal (formaldehyde) and a carbonyl compound to produce an amino-carbonyl compound. It takes place in two stages. First the amine reacts with methanol to form a Schiff base:

$$R_2N + H_2CO \rightarrow R_2N^+{=}CH_2.$$

This then reacts with the carbonyl compound:

$$R_2N^+{=}CH_2 + R^1R^2CHCOR^3 \rightarrow R_2N{-}CH_2{-}C(R^1R^2)COR^3.$$

The reaction was first reported by Carl Mannich in 1912.

mannitol A polyhydric alcohol, $CH_2OH(CHOH)_4CH_2OH$, derived from mannose or fructose. It is the main soluble sugar in fungi and an important carbohydrate reserve in brown algae. Mannitol is used as a sweetener in certain foodstuffs.

mannose A *monosaccharide hexose, $C_6H_{12}O_6$, stereoisomeric with glucose, that occurs naturally only in polymerized forms called **mannans**. These are found in plants, fungi, and bacteria, serving as food energy stores.

manometer A device for measuring pressure differences, usually by the difference in height of two liquid columns. The simplest type is the U-tube manometer, which consists of a glass tube bent into the shape of a U. If a pressure to be measured is fed to one side of the U-tube and the other is open to the atmosphere, the difference in level of the liquid in the two limbs gives a measure of the unknown pressure.

mantissa *See* LOGARITHM.

mantle **1.** (in zoology) The fold of skin covering the dorsal surface of the body of molluscs, which extends into lateral flaps that protect the gills in the **mantle cavity** (the space between the body and mantle). The outer surface of the mantle secretes the shell (in species that have shells). **2.** (in geology) *See* EARTH.

many-body problem The problem that it is very difficult to obtain exact solutions to systems involving interactions between more than two bodies – using either classical mechanics or quantum mechanics. To understand the physics of many-body systems it is necessary to make use of *approximation techniques or *model systems that capture the essential physics of the problem. For some problems, such as the **three-body problem** in classical mechanics, it is possible to obtain qualitative information about the system. Useful concepts in the quantum theory of many-body systems are *quasiparticles and *collective excitations. If there are a great many bodies interacting, such as the molecules in a gas, the problem can be analysed using the techniques of *statistical mechanics.

map projections The methods used to represent the spherical surface of the earth on a plane surface. The circles of latitude and longitude are represented by a network or graticule of lines. Directions, areas, distances, and shape can never all be recreated accurately and the map projection chosen for a particular area will thus depend on the purpose for which the map is to be used and on the part of the world represented. There are three main groups of projections:
(1) **Cylindrical projections** are obtained by projecting the globe onto a cylinder that intersects the earth. If the axis of the cylinder is parallel to the axis of the earth the meridians and parallels will appear as straight lines. The three basic types of cylindrical projection are the simple cylindrical, the equal-area, and Mercator's projections. A modified equal-area form of cylindrical projection was invented in 1973 by the German historian Arno Peters – and is known as the **Peters' projection**. It draws attention to Third World countries, which are prominently placed in the centre of the map. Landforms close to the equator are elongated, while those in high lattitudes are compressed.
(2) **Conic** (**conical**) **projections** result from the projection of the meridians and parallels onto a cone. In conic projections the axis of the cone is usually parallel to the earth's axis; as a result the meridians appear as radiating straight lines and the parallels are shown as concentric arcs. Scale is correct only along the standard parallel (i.e. the parallel along which the cone intersects the globe).
(3) **Azimuthal** (**zenithal**) **projections** are constructed as if a plane is placed at a tangent to the earth's surface and the portion of the earth covered is transferred onto the plane. On this projection all great circles that pass through the centre of the projection appear as straight lines; all points have their true compass bearings. Examples of azimuthal projections include the polar azimuthal and Lambert's azimuthal.

marble A metamorphic rock composed of recrystallized *calcite or *dolomite. Pure marbles are white but such impurities as silica or clay minerals result in variations of colour. Marble is extensively used for building purposes and ornamental use; the pure white marble from Carrara in Italy is especially prized by sculptors. The term is applied commercially to any limestone or dolomite that can be cut and polished.

Marchantiophyta *See* HEPATOPHYTA.

Marconi, Guglielmo (1874–1937) Italian electrical engineer, who in 1894 began experimenting with Hertzian waves (*see* HERTZ, HEINRICH RUDOLF), making the first *radio transmissions. Moving to London in 1896, for the next few years he worked on improving the range and reliability of his equipment. This enabled him in late 1901 to transmit Morse signals across the Atlantic Ocean, establishing radio telegraphy and more importantly the use of radio waves as a communications medium. In 1909 he and Karl *Braun were awarded the Nobel Prize for physics.

margaric acid *See* HEPTADECANOIC ACID.

marijuana *See* CANNABIS.

marker gene A gene used to identify a particular bacterial colony or bacteriophage plaque. Such genes are incorporated into cloning *vectors to enable the isolation and replication of colonies containing a desired vector. Typically, marker genes confer resistance to specific antibiotics or produce colour changes (**genetic marker**). A gene that acts as a tag for another, closely linked, gene. Such markers are used in mapping the order of genes along chromosomes and in following the inheritance of particular genes: genes closely linked to the marker will generally be inherited with it. Markers must be readily identifiable in the phenotype, for instance by controlling an easily observable feature (such as eye colour). *See also* MOLECULAR MARKER.

Markov chain In *statistics, a series of

random events or states, chosen from a specific collection, in which the probability of each event is determined only by its predecessor. It was named after the Russian mathematician Andrei Markov (1856–1922).

Markovnikoff's rule When an acid HA adds to an alkene, a mixture of products can be formed if the alkene is not symmetrical. For instance, the reaction between $C_2H_5CH{:}CH_2$ and HCl can give $C_2H_5CH_2CH_2Cl$ or $C_2H_5CHClCH_3$. In general, a mixture of products occurs in which one predominates over the other. In 1870, Vladimir Markovnikoff (1837–1904) proposed the rule that the main product would be the one in which the hydrogen atom adds to the carbon having the larger number of hydrogen atoms (the latter product above). This occurs when the mechanism is *electrophilic addition, in which the first step is addition of H^+. The electron-releasing effect of the alkyl group (C_2H_5) distorts the electron-distribution in the double bond, making the carbon atom furthest from the alkyl group negative. This is the atom attacked by H^+ giving the carbonium ion $C_2H_5C^+HCH_3$, which further reacts with the negative ion Cl^-.

Under certain circumstances **anti-Markovnikoff** behaviour occurs, in which the opposite effect is found. This happens when the mechanism involves free radicals and is common in addition of hydrogen bromide when peroxides are present.

Marquis test A widely used *presumptive test that gives a variety of colour changes with a range of compounds. It is particularly useful for detecting opiate alkaloids and for amphetamines and methamphetamine. **Marquis reagent** is a mixture of methanal (formaldehyde) solution in water with sulphuric acid. Mescaline gives an orange coloration. With morphine, a violet colour is produced. Amphetamines give an orange-red colour and methamphetamine gives an orange colour (the two can be distinguished by the Simon test). The mechanism involves attack of the aldehyde and a substituted aromatic ring to form a carbocation. Further reaction forms a coloured dimer of the original molecule.

Mars The seventh largest *planet in the *solar system and the fourth in order from the *sun. Its mean distance from the sun is 227.94×10^6 km, its mass is 6.4219×10^{23} kg (about 11% that of earth), and its mean diameter is 6795 km; it has a *sidereal period of 686.98 days. Its period of axial rotation is known as a **sol** and is equal to 24h 37.4m. The bulk of our knowledge about Mars has come from the orbiters, landers, and rovers that have visited the planet since 1965. They reveal it as a barren, rocky world with a thin atmosphere (less than 1% of the pressure at the earth's surface) consisting of about 95% carbon dioxide with the remaining 5% made up of nitrogen, argon, oxygen, and water vapour. The surface material is largely basalt and covered with a thin layer of reddish iron-rich claylike soil and light dust. The terrain includes volcanic plateaux and calderas as well as vast and deep impact basins and lunar-like craters. Olympus Mons, the highest mountain in the solar system, rises more than 26 km above the Martian surface, and Valles Marineris is the largest known canyon system, at 4000 km long, 200 km wide, and up to 7 km deep. Mars's *axial tilt of 25.19° means that it experiences seasons similar to earth. Like earth, Mars has polar ice caps. Because Mars is more than 37 million km closer to the sun at *perihelion than at *aphelion, climatic fluctuations can be extreme. Owing to the thinness of the atmosphere, temperatures range between 133 K and 293 K. Mars has two small satellites, Phobos (approximately $20 \times 23 \times 28$ km) and Deimos ($10 \times 12 \times 16$ km), neither of which is sufficiently massive to have contracted to a sphere.

SEE WEB LINKS

- A comprehensive guide to Mars and how to observe it
- Google Mars – interactive images of the planet

marsh gas Methane formed by rotting vegetation in marshes.

Marsh's test A chemical test for arsenic in which hydrochloric acid and zinc are added to the sample, arsine being produced by the nascent hydrogen generated. Gas from the sample is led through a heated glass tube and, if arsine is present, it decomposes to give a brown deposit of arsenic metal. The arsenic is distinguished from antimony (which gives a similar result) by the fact that antimony does not dissolve in sodium chlorate(I) (hypochlorite). The test was devised in 1836 by the British chemist James Marsh (1789–1846).

marsupials *See* METATHERIA.

martensite A solid solution of carbon in

alpha-iron (*see* IRON) formed when *steel is cooled too rapidly for pearlite to form from austenite. It is responsible for the hardness of quenched steel.

mascagnite A mineral form of *ammonium sulphate, $(NH_4)_2SO_4$.

mascon A gravitational anomaly on the surface of the moon resulting from a concentration of mass below the lunar surface. They occur in circular lunar maria and were caused either by the mare basalt as it flooded the basins or by uplift of high-density mantle material when the basins were formed.

maser (*m*icrowave *a*mplification by *s*timulated *e*mission of *r*adiation) A device for amplifying or generating *microwaves by means of stimulated emission (*see* LASER). As oscillators, masers are used in *atomic clocks, while they are used as amplifiers in *radio astronomy, being especially suitable for amplifying feeble signals from space.

In the **ammonia gas maser** (devised in 1954) a molecular beam of ammonia passes through a small orifice into a vacuum chamber, where it is subjected to a nonuniform electric field. This field deflects ground-state ammonia molecules, shaped like a pyramid with the three hydrogen atoms forming the plane of the base and the single nitrogen atom forming the apex. The ground-state molecule has a dipole moment on account of its lack of symmetry and it is for this reason that it suffers deflection. Excited molecules, in which the nitrogen atom vibrates back and forth through the plane of the hydrogen atoms, have no resultant dipole moment and are not deflected. The beam, now consisting predominately of excited molecules, is passed to a resonant cavity fed with the microwave radiation corresponding to the energy difference between the excited and the ground states. This causes stimulated emission as the excited molecules fall to the ground state and the input microwave radiation is amplified coherently. This arrangement can also be made to oscillate and in this form is the basis of the *ammonia clock.

In the more versatile **solid-state maser** a magnetic field is applied to the electrons of paramagnetic (*see* MAGNETISM) atoms or molecules. The energy of these electrons is quantized into two levels, depending on whether or not their spins are parallel to the magnetic field. The situation in which there are more parallel magnetic moments than antiparallel can be reversed by sudden changes in the magnetic field. This electron-spin resonance in paramagnetic materials allows amplification over broader bandwidths than gas masers.

mass A measure of a body's *inertia, i.e. its resistance to acceleration. According to Newton's laws of motion, if two unequal masses, m_1 and m_2, are allowed to collide, in the absence of any other forces both will experience the same force of collision. If the two bodies acquire accelerations a_1 and a_2 as a result of the collision, then $m_1a_1 = m_2a_2$. This equation enables two masses to be compared. If one of the masses is regarded as a standard of mass, the mass of all other masses can be measured in terms of this standard. The body used for this purpose is a 1-kg cylinder of platinum–iridium alloy, called the international standard of mass. Mass defined in this way is called the **inertial mass** of the body.

Mass can also be defined in terms of the gravitational force it produces. Thus, according to Newton's law of gravitation, $m_g = Fd^2/MG$, where M is the mass of a standard body situated a distance d from the body of mass m_g; F is the gravitational force between them and G is the *gravitational constant. The mass defined in this way is the **gravitational mass**. In the 19th century Lóránd Eötvös (1848–1919) showed experimentally that gravitational and inertial mass are indistinguishable, i.e. $m_i = m_g$. Experiments performed in the 20th century confirmed this to greater accuracy.

Although mass is formally defined in terms of its inertia, it is usually measured by gravitation. The **weight** (W) of a body is the force by which a body is gravitationally attracted to the earth corrected for the effect of rotation and equals the product of the mass of the body and the *acceleration of free fall (g), i.e. $W = mg$. In the general language, weight and mass are often used synonymously; however, for scientific purposes they are different. Mass is measured in kilograms; weight, being a force, is measured in newtons. Weight, moreover, depends on where it is measured, because the value of g varies at different localities on the earth's surface. Mass, on the other hand, is constant wherever it is measured, subject to the special theory of *relativity. According to this theory, announced by Albert Einstein in 1905, the mass of a body is a measure of its total energy content. Thus, if the energy of a

body increases, for example by an increase in kinetic energy or temperature, then its mass will increase. According to this law an increase in energy ΔE is accompanied by an increase in mass Δm, according to the **mass–energy equation** $\Delta m = \Delta E/c^2$, where c is the speed of light. Thus, if 1 kg of water is raised in temperature by 100 K, its internal energy will increase by 4×10^{-12} kg. This is, of course, a negligible increase and the mass–energy equation is only significant for extremely high energies. For example, the mass of an electron is increased sevenfold if it moves relative to the observer at 99% of the speed of light.

The origin of mass is not yet fully understood.

mass action The law of mass action states that the rate at which a chemical reaction takes place at a given temperature is proportional to the product of the **active masses** of the reactants. The active mass of a reactant is taken to be its molar concentration. For example, for a reaction

$$x\text{A} + y\text{B} \rightarrow \text{products}$$

the rate is given by

$$R = k[\text{A}]^x[\text{B}]^y$$

where k is the *rate constant. The principle was introduced by C. M. Guldberg and P. Waage in 1863. It is strictly correct only for ideal gases. In real cases *activities can be used. *See also* EQUILIBRIUM CONSTANT.

mass concentration *See* CONCENTRATION.

mass decrement *See* MASS DEFECT.

mass defect **1.** The difference between the rest mass of an atomic nucleus and the sum of the rest masses of its individual nucleons in the unbound state. It is thus the mass equivalent of the *binding energy on the basis of the mass–energy equation (*see* MASS; RELATIVITY). **2. (mass decrement)** The difference between the rest mass of a radioactive nucleus before decay and the total rest mass of the decay products.

mass–energy equation *See* MASS; RELATIVITY.

mass extinction The extinction of a large number of species within a relatively short interval of the geological time scale. The fossil record provides evidence for several mass extinctions, perhaps as many as 20, since the start of the Phanerozoic eon about 570 million years ago. Such extinctions cause radical changes in the characteristic fossil assemblages of rock, which have been reflected in the naming of strata by geologists. Hence, mass extinctions often mark the boundaries between geological strata and between the corresponding geological time intervals. The biggest mass extinctions occurred at the end of the Permian period (about 245 million years ago), when over 80% of all marine invertebrate genera disappeared (including the trilobites), and at the end of the Cretaceous (*see* ALVAREZ EVENT).

mass flow A hypothesis to explain the movement of sugars in the phloem tissue of plants. At a **source** (site of production) sugars are loaded into *companion cells and thence into the *sieve elements, causing water to follow by osmosis. The pressure of water in the tubes (the hydrostatic pressure) causes it to move along the tubes to a **sink** (site of utilization), where the reverse process occurs. Here sugars diffuse or are actively transported from the sieve elements into the companion cells and then into the surrounding tissues, establishing a concentration gradient from source to sink. However, the mass flow hypothesis does not explain how different solutes can be transported in the phloem in different directions at the same time.

massicot *See* LEAD(II) OXIDE.

mass number *See* NUCLEON NUMBER.

mass spectrometry (mass spectroscopy) A technique used to determine relative atomic masses and the relative abundance of isotopes, and for chemical analysis and the study of ion reactions. In a **mass spectrometer** a sample (usually gaseous) is ionized and the positive ions produced are accelerated into a high-vacuum region containing electric and magnetic fields. These fields deflect and focus the ions onto a detector. The fields can be varied in a controlled way so that ions of different types can impinge on the detector. A **mass spectrum** is thus obtained consisting of a series of peaks of variable intensity to which mass/charge (m/e) values can be assigned. The original ions are usually produced by electron impact, although ion impact, photoionization, and field ionization are also used. For organic molecules, the mass spectrum consists of a series of peaks, one corresponding to the parent ion and the others to fragment ions produced by the ionization process. Different molecules can be identified by their characteristic pattern of lines. Analysis of mixtures

can be done by gas chromatography–mass spectroscopy (*see* GAS CHROMATOGRAPHY). Other types of mass spectrometer exist. In a **quadrupole mass spectrometer** the ions pass along a region surrounded by four parallel rods. Variable voltages applied to the rods produce an oscillating electric field. Varying the frequency of oscillation allows different ions to pass through to a detector. In a **time-of-flight mass spectrometer** the ions are accelerated by an electric field and then enter a drift tube through which they pass to a detector. Different types of ion are distinguished by their time of flight in the drift tube.

mass spectrum *See* SPECTRUM.

mast cell A large cell with densely granular cytoplasm that is found in connective tissues, for example around blood vessels and in the skin. Mast-cell granules contain mediators of inflammation, such as *histamine and prostaglandin D_2, as well as various *cytokines, which cause a local increase in blood flow. The granule contents are released from the cell in response to tissue injury or as part of an allergic response. Release is triggered by binding of antigen to a type of antibody (IgE) that is bound to the mast cell. The cell also releases *heparin.

mastication The process of chewing food, which involves movements of the jaws and teeth. Mastication breaks up the food into small particles, which provides a greater surface area for digestion and enables the formation of a *bolus, which is small enough to pass through the oesophagus.

mastoid process An outgrowth from the temporal bone of the skull containing air cavities that communicate with the cavity of the middle ear. In humans it is a route through which infection may spread from the middle ear.

masurium A former name for *technetium.

maternal effect genes Genes expressed in maternal follicle cells whose products (messenger RNAs and proteins) diffuse into the egg cell to influence its early development. Gradients of the products are established in the egg cytoplasm; following fertilization and subsequent cell division of the zygote, these gradients influence zygotic gene expression and cause regional differentiation of the embryo. For example, in many types of embryo, maternal effect genes are responsible for determining polarity, i.e. which end is the 'head' and which is the 'tail'.

mating *See* SEXUAL INTERCOURSE.

matrix (*pl.* **matrices**) **1.** (in chemistry) A continuous solid phase in which particles (atoms, ions, etc.) are embedded. Unstable species, such as free radicals, can be trapped in an unreactive substrate, such as solid argon, and studied by spectroscopy. The species under investigation are separated by the matrix, hence the term **matrix isolation** for this technique. **2.** (in geology) The fine-grained material of rock in which the coarser-grained material is embedded. **3.** (in mathematics) A set of quantities in a rectangular array, used in certain mathematical operations. The array is usually enclosed in large parentheses or in square brackets. **4.** (in histology) The component of tissues (e.g. bone and cartilage) in which the cells of the tissue are embedded. *See also* EXTRACELLULAR MATRIX.

matrix mechanics A formulation of *quantum mechanics using matrices (*see* MATRIX) to represent states and operators. Matrix mechanics was the first formulation of quantum mechanics to be stated (by Werner Heisenberg in 1925) and was developed by Heisenberg and Max Born (1882–1970) and the German physicist Pascual Jordan (1902–80). It was shown by Erwin Schrödinger in 1926 to be equivalent to the *wave mechanics formulation of quantum mechanics.

Matura diamond *See* ZIRCON.

maturity **1.** The stage in a life cycle that is reached when a developing organism has taken on the appearance of the adult form and is capable of reproduction. **2.** The stage reached in the formation of gametes (*gametogenesis) following meiotic division of precursor cells and their development into fully functional gametes. **Maturation** comprises the divisions and other processes leading to the formation of gametes.

maxilla **1.** One of a pair of *mouthparts in insects, crustaceans, centipedes, and millipedes. They lie behind the *mandibles and their lateral movements assist in feeding. Crustaceans have two pairs of maxillae but in insects the second pair are fused together forming the *labium. **2.** One of a pair of large tooth-bearing bones in the upper jaw

of vertebrates. In mammals they carry all the upper teeth except the incisors.

maximum and minimum thermometer A thermometer designed to record both the maximum and minimum temperatures that have occurred over a given time period. It usually consists of a graduated capillary tube at the base of which is a bulb containing ethanol. The capillary contains a thin thread of mercury with a steel index at each end. As the temperature rises the index is pushed up the tube, where it remains in position to show the maximum temperature reached; as the temperature falls the lower index is pushed down the tube and similarly remains in position at the lowest temperature. The indexes are reset by means of a permanent magnet.

maximum permissible dose *See* DOSE.

maxwell A unit of magnetic flux in the *c.g.s. system, equal to the flux through 1 square centimetre perpendicular to a magnetic field of 1 gauss. 1 maxwell is equal to 10^{-8} weber. It is named after James Clerk Maxwell.

m

Maxwell, James Clerk (1831–79) British physicist, born in Edinburgh, who held academic posts at Aberdeen, London, and Cambridge. In the 1860s he was one of the founders of the *kinetic theory of gases, but his best-known work was a mathematical analysis of electricity, magnetism, and *electromagnetic radiation, published in 1865.

Maxwell–Boltzmann distribution A law describing the distribution of speeds among the molecules of a gas. In a system consisting of N molecules that are independent of each other except that they exchange energy on collision, it is clearly impossible to say what velocity any particular molecule will have. However, statistical statements regarding certain functions of the molecules were worked out by James Clerk Maxwell and Ludwig Boltzmann. One form of their law states that $n = N\exp(-E/RT)$, where n is the number of molecules with energy in excess of E, T is the thermodynamic temperature, and R is the *gas constant.

Maxwell's equations A set of differential equations describing the space and time dependence of the electromagnetic field and forming the basis of classical electrodynamics. In *SI units the equations are:

(1) $\mathrm{div}\boldsymbol{D} = \rho$

(2) $\mathrm{curl}\boldsymbol{E} = -\partial\boldsymbol{B}/\partial t$

(3) $\mathrm{div}\boldsymbol{B} = 0$

(4) $\mathrm{curl}\boldsymbol{H} = \partial\boldsymbol{D}/\partial t + \boldsymbol{J}$

where $\boldsymbol{D}$ is the electric displacement, $\boldsymbol{E}$ is the electric field strength, $\boldsymbol{B}$ is the magnetic flux density, $\boldsymbol{H}$ is the magnetic field strength, ρ is the volume charge density, and $\boldsymbol{J}$ is the electric current density. Note that in relativity and particle physics it is common to use *Gaussian or *Heaviside–Lorentz units, in which case Maxwell's equations include 4π and the speed of light c. Maxwell's equations have the following interpretation. Equation (1) represents *Coulomb's law; equation (2) represents *Faraday's laws of electromagnetic induction; equation (3) represents the absence of *magnetic monopoles; equation (4) represents a generalization of *Ampère's law.

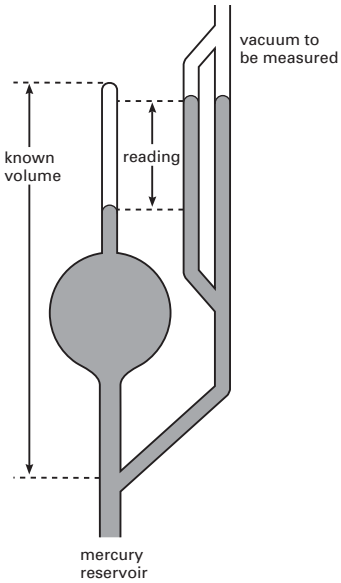
Mayer's test A general *presumptive test for cocaine, morphine, heroin, and other alkaloids. **Mayer's reagent** is a solution of potassium mercury iodide in water. A positive result is indicated by a cream precipitate.

MDA (methylenedioxyamphetamine) A hallucinogenic drug, $C_{10}H_{13}CO_2$, originally designed for medical use but now extensively used as a club drug its effects are similar to those of MDMA (*see* ECSTASY).

MDMA Methylenedioxymethamphetamine. *See* ECSTASY.

McClintock, Barbara (1902–92) US botanist and geneticist, who joined the Cold Spring Harbor Laboratory of the Carnegie Institute. She is best known for her discovery of 'jumping genes' (*see* TRANSPOSON), which move along a chromosome and exert control over other genes. She carried out her work with maize plants, but such controlling elements were later found in bacteria and other organisms. For this work she was awarded the 1983 Nobel Prize for physiology or medicine.

McLeod gauge A vacuum pressure gauge in which a relatively large volume of a low-pressure gas is compressed to a small volume in a glass apparatus (see illustration). The volume is reduced to an extent that causes the pressure to rise sufficiently to support a column of fluid high enough to read. This simple device, which relies on *Boyle's law, is suitable for measuring pressures in the range 10^3 to 10^{-3} pascal.



McLeod gauge.

mean A representative or expected value for a set of numbers.
1. The **arithmetic mean** or **average** (usually just called the **mean**) of n values x_1, x_2, …, x_n is given by:

$$(x_1 + x_2 + x_3 + \ldots + x_n)/n$$

If x_1, x_2, …, x_k occur with frequencies (weights) w_1, w_2, …, w_k then the **weighted mean** is:

$$(w_1x_1 + w_2x_2 + \ldots + w_kx_k)/(w_1 + w_2 + \ldots + w_k)$$

2. The **harmonic mean** H is given by:

$$n/[(1/x_1) + (1/x_2) + \ldots + (1/x_n)]$$

3. The **geometric mean** G is given by:

$$(x_1,x_2, \ldots, x_n)^{1/n}$$

mean deviation *See* DEVIATION.

mean free path The average distance travelled between collisions by the molecules in a gas, the electrons in a metallic crystal, the neutrons in a moderator, etc. According to the *kinetic theory the mean free path between elastic collisions of gas molecules of diameter d (assuming they are rigid spheres) is $1/\sqrt{2}n\pi d^2$, where n is the number of molecules per unit volume in the gas. As n is proportional to the pressure of the gas, the mean free path is inversely proportional to the pressure.

mean free time The average time that elapses between the collisions of the molecules in a gas, the electrons in a crystal, the neutrons in a moderator, etc. *See* MEAN FREE PATH.

mean life *See* DECAY.

mean solar day *See* DAY.

mean-spherical approximation An approximation used in the theory of liquids that relates pair distribution functions to correlation functions. The mean-spherical approximation enables exact solutions to be found for several potentials describing the interactions between molecules in a liquid.

measurements of central tendency The general name given for the types of average used in statistics, i.e. the *mean, the *median, and the *mode.

meatus A small canal or passage in the body. An example is the **external auditory meatus** of the *outer ear in mammals, which connects the exterior opening to the eardrum.

mebi- *See* BINARY PREFIXES.

mechanical advantage *See* FORCE RATIO.

mechanical bonding Bonding that involves a mechanical constraint preventing two parts of a molecule separating, rather than a chemical linkage based on transfer or sharing of electrons. It is found in *rotaxanes, *catenanes, and *molecular knots.

mechanical equivalent of heat Symbol J. The ratio of a unit of mechanical energy to the equivalent unit of thermal energy, when a system of units is used in which they differ. J has the value 4.1868×10^7 ergs per calorie. The concept loses its usefulness in *SI units in which all forms of energy are expressed in joules and J therefore has a value of 1.

mechanics The study of the interactions between matter and the forces acting on it. *Statics is broadly concerned with the action of forces when no change of momentum is concerned, while *dynamics deals with cases in which there is a change of momentum. *Kinematics is the study of the motion of bodies without reference to the forces affecting the motion. These classical sciences are

concerned with macroscopic bodies in the solid state, while *fluid mechanics is the science of the interaction between forces and fluids.

mechanism (in chemistry) The way in which a particular chemical reaction occurs, described in terms of the steps involved. For example, the hydrolysis of an alkyl chloride proceeds by the S_N1 mechanism (*see* NUCLEOPHILIC SUBSTITUTION).

mechanoreceptor A *receptor that responds to such mechanical stimuli as touch, sound, and pressure. The skin is rich in mechanoreceptors.

Mecke's test A *presumptive test for amphetamines, methamphetamines, and heroin. **Mecke's reagent** consists of 1 gram of selenious acid in 100 ml of concentrated sulphuric acid. Different substances give different results. Ecstasy, for example, gives a light blue colour, turning to turquoise, and then dark blue. Heroin gives a yellow colour changing to green. LSD gives an olive-green colour, changing to black. Mescaline gives a brownish-orange colour.

Medawar, Sir Peter Brian (1915–87) British immunologist. Born in Brazil and educated at Oxford, he held posts in zoology there and at Birmingham and London. He turned to medical biology and studied rejection in tissue grafts, experimenting with mouse embryos and demonstrating the phenomenon of acquired immunological tolerance – the failure of the immune response to particular antigens when these are injected before birth. For this work he shared the 1960 Nobel Prize for physiology or medicine with Sir Macfarlane *Burnet.

median **1.** The middle number of a set of numbers arranged in order. When there is an even number of numbers the median is the average of the middle two. For example, the median of 1,7,21,33,37 is 21, and of 1,7,21,33,37,54 is (21 + 33)/2 = 27. **2.** A straight line in a triangle that joins the vertex to the mid-point of the base.

median eye (pineal eye) An eyelike structure, with a lens and retina, found on the top of the head of some lizards, *Sphenodon*, and the Cyclostomata (lampreys) as well as in many fossil vertebrates. It corresponds to the *pineal gland of other vertebrates and is thought to act as a photoreceptor.

median lethal dose *See* LD_{50}.

mediastinum **1.** A membrane in the midline of the *thorax of mammals that separates the lungs. **2.** The space between the two lungs, which is occupied by the heart and oesophagus.

medium frequency (MF) A radio frequency in the range 0.3–3 megahertz; i.e. having a wavelength in the range 100–1000 metres.

MEDLINE (Medical Literature Analysis and Retrieval System Online) A bibliographic database administered by the US National Library of Medicine (NLM) that contains over 16 million references to journal articles in life sciences and medicine. Coverage extends to more than 5000 journals, with particular emphasis on US journals, and over half a million new records are added annually. The articles are indexed using the NLM's Medical Subject Heading (MeSH) thesaurus, which permits searching using both alphabetical and hierarchical approaches. MEDLINE is the major component of the NLM's **PubMed** database and can be accessed via *Entrez.

medulla **1.** (in zoology) The central tissue of various organs, including the adrenal glands (**adrenal medulla**) and kidneys (**renal medulla**). **2.** (in botany) *See* PITH.

medulla oblongata Part of the vertebrate *brainstem, derived from the *hindbrain, that is continuous with the spinal cord. Its function is to regulate the autonomic pathways controlling respiration, heart beat, blood pressure, and other involuntary processes. It relays nerve signals between the brain and spinal cord and gives rise to many of the *cranial nerves.

medullary ray (ray) Any of the vertical plates of *parenchyma cells running radially through the cylinder of vascular tissue in the stems and roots of plants. Each may be one to many cells in width. **Primary medullary rays** occur in young plants and in those not showing secondary thickening; they pass from the cortex through to the pith. **Secondary medullary rays** are produced by the vascular *cambium and terminate in xylem and phloem tissues. Medullary rays store and transport food materials.

medullated nerve fibre A nerve fibre that is characterized by a *myelin sheath, which insulates the axon.

medusa The free-swimming stage in the life cycle of the *Cnidaria. Medusae are umbrella-shaped, with tentacles round the edge and the mouth in the centre underneath. They swim by pulsations of the body and reproduce sexually. In the Hydrozoa (e.g. *Hydra*) they alternate in the life cycle with *polyps, from which they are produced by budding. In the Scyphozoa, which includes all the common jellyfish, the medusa is the dominant form and the polyp is reduced or absent.

mega- **1.** Symbol M. A prefix used in the metric system to denote one million times. For example, 10^6 volts = 1 megavolt (MV). **2.** A prefix denoting large size; e.g. meganucleus, megasporangium.

megaphyll A type of foliage leaf in ferns and seed plants that has branched or parallel vascular bundles running through the lamina. The megaphylls of ferns are large pinnate leaves called **fronds**. A megaphyll was formerly called a **macrophyll**. *Compare* MICROPHYLL.

megaspore *See* SPOROPHYLL.

megasporophyll *See* SPOROPHYLL.

megaton weapon A nuclear weapon with an explosive power equivalent to one million tons of TNT. *Compare* KILOTON WEAPON.

meiosis (reduction division) A type of cell division that gives rise to four reproductive cells (gametes) each with half the chromosome number of the parent cell. Two consecutive divisions occur (see illustration overleaf). In the first, *homologous chromosomes become paired and may exchange genetic material (*see* CROSSING OVER) before moving away from each other into separate daughter nuclei. This is the actual reduction division because each of the two nuclei so formed contains only half of the original chromosomes. The daughter nuclei then divide by mitosis and four *haploid cells are produced. *See also* PROPHASE; METAPHASE; ANAPHASE; TELOPHASE.

Meissner effect The falling off of the magnetic flux within a superconducting metal when it is cooled to a temperature below the critical temperature in a magnetic field. It was discovered by Walther Meissner (1882–1974) in 1933 when he observed that the earth's magnetic field was expelled from the interior of tin crystals below 3.72 K, indicating that as *superconductivity appeared the material became perfectly diamagnetic. *See* MAGNETISM.

Meitner, Lise (1878–1968) Austrian-born Swedish physicist, who went to Berlin to study *radioactivity with Otto *Hahn. In 1917 they discovered *protactinium. After World War I Meitner and Hahn returned to Berlin, where in 1935 they bombarded uranium with neutrons. In 1938 she left Germany, with other Jewish scientists, and went to the Nobel Institute in Stockholm. In 1939 she and Otto Frisch (1904–79) explained Hahn's results in terms of *nuclear fission.

meitnerium Symbol Mt. A radioactive *transactinide element; a.n. 109. It was first made in 1982 by Peter Armbruster and a team in Darmstadt, Germany, by bombarding bismuth–209 nuclei with iron–58 nuclei. Only a few atoms have ever been detected.

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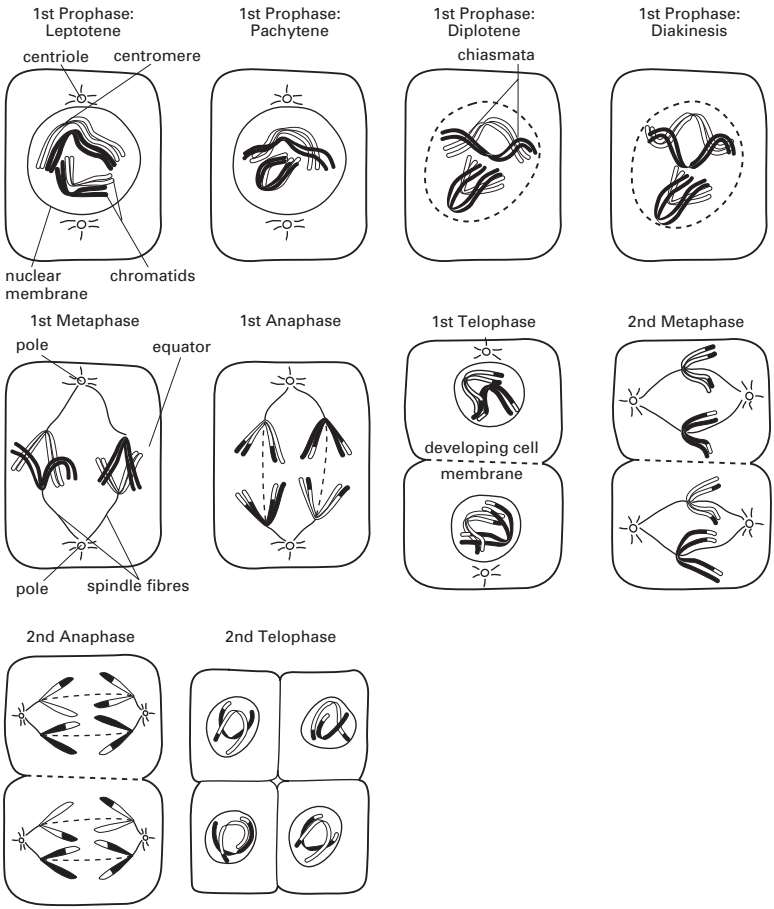
melamine A white crystalline compound, $C_3N_6H_6$. Melamine is a cyclic compound having a six-membered ring of alternating C and N atoms, with three NH_2 groups. It can be copolymerized with methanal to give thermosetting **melamine resins**, which are used particularly for laminated coatings.

melanin Any of a group of polymers, derived from the amino acid tyrosine, that cause pigmentation of eyes, skin, and hair in vertebrates. Melanins are produced by specialized epidermal cells called **melanophores** (or **melanocytes**); their dispersion in these cells is controlled by *melanocyte-stimulating hormone and *melatonin. Certain invertebrates, fungi, and microorganisms also produce melanin pigments. The 'ink' of the octopus and squid is a notable example. Hereditary *albinism is caused by the absence of the enzyme tyrosinase, which is necessary for melanin production.

melanism Black coloration of the body caused by overproduction of the pigment melanin, often as a reaction to the environment. There are several species of melanic moths in industrially polluted areas (*see* INDUSTRIAL MELANISM) and the panther is a melanic form of leopard.

melanocyte-stimulating hormone (MSH) Any of several related peptide hormones that are produced from the precursor



Meiosis. The stages of meiosis in a cell containing two pairs of homologous chromosomes.

pro-opiomelanocortin (POMC) and secreted by the anterior or intermediate lobe of the pituitary gland. MSH stimulates dispersal of melanin in the *chromatophores of amphibian skin, causing the skin to darken; in humans it stimulates production and dispersal of melanin in the pigment cells (melanocytes) of the skin. Certain neurons in the hypothalamus release α-MSH, which is a potent suppressor of appetite and has a key role in regulating energy balance; it has potential as an antiobesity agent. α-MSH also stimulates sexual activity and is involved in regulation of heart rate and blood pressure.

melatonin A hormone derived from *serotonin and secreted by the pineal gland and retinas of vertebrates. Melatonin secretion by the pineal is linked to the dark–light cycle of the organism's environment, being greatest at night and lowest by day. It is used as a drug to treat sleep disorders and symptoms of jet lag. The hormone is involved in regulating certain diurnal and seasonal changes in the body, such as the reproductive cycle in

seasonally breeding animals. Melatonin also controls pigmentation changes; it triggers aggregation of the pigment *melanin into melanophores in the skin, causing the skin to turn pale.

melting point (m.p.) The temperature at which a solid changes into a liquid. A pure substance under standard conditions of pressure (usually 1 atmosphere) has a single reproducible melting point. If heat is gradually and uniformly supplied to a solid the consequent rise in temperature stops at the melting point until the fusion process is complete.

membrane A thin sheet of tissue or other material that lines a body cavity, forms a partition, or connects various structures. Any of the various flexible sheetlike structures, composed predominantly of lipids and proteins, that occur in living cells, such as the *plasma membrane forming the cell boundary. *See* CELL MEMBRANE.

membrane bone (dermal bone) *Bone formed directly in connective tissue, rather than by replacing cartilage (*compare* CARTILAGE BONE). Some face bones, skull bones, and part of the clavicle are membrane bones. Small areas of membrane become jelly-like and attract calcium salts. Bone-forming cells break down these areas forming a bone lattice, which eventually fills in.

membranous labyrinth The soft tubular sensory structures that form the *inner ear of vertebrates and are housed within the bony labyrinth.

meme A self-replicating unit of cultural inheritance analogous to a gene. The term was introduced by British biologist Richard Dawkins in his book *The Selfish Gene* (1976) to denote a cultural entity, such as a song, a method for making paper aeroplanes, a religion, or a recipe, that is transmitted between individuals and across generations, so that it is inherited and (potentially) can change over time.

memory **1.** (in biology) The means by which information is stored in the brain. The exact mechanism of processing and storing information is not known but is thought to involve the construction of circuits of *neurons, which are strengthened by repeated use. Memory is essential to the processes of *learning and recognition of individuals and objects. **2.** (in computing) The part of a computer in which data is stored while it is being worked on. A typical microcomputer, for example, has a comparatively small amount of read-only memory (*see* ROM) and a large amount of random-access memory (*see* RAM). Only data in ROM is preserved when the machine is switched off; any data in RAM must be saved to disk if it is wanted again.

memory cell *See* B CELL.

Mendel, Johann Gregor (1822–84) Austrian geneticist, who from 1843 lived as a monk in Brünn (now Brno, in the Czech Republic). His fame rests on the plant-breeding experiments he began in 1856, which eventually produced the rules of inheritance summarized in *Mendel's laws. His work was ignored during his lifetime and only rediscovered in 1900 by Hugo de Vries (1848–1935) and others. *See* MENDELISM.

Mendeleev, Dmitri Ivanovich (1834–1907) Russian chemist, who became professor of chemistry at St Petersburg in 1866. His most famous work, published in 1869, was the compilation of the *periodic table of the elements, based on the *periodic law.

Mendeleev's law *See* PERIODIC LAW.

mendelevium Symbol Md. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 101; mass number of the first discovered nuclide 256 (half-life 1.3 hours). Several short-lived isotopes have now been synthesized. The element was first identified by Albert Ghiorso, Glenn Seaborg (1912–99) and associates in 1955. The alternative name **unnilunium** has been proposed.

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Mendelism The theory of heredity that forms the basis of classical *genetics, proposed by Gregor Mendel in 1866 and formulated in two laws (*see* MENDEL'S LAWS; PARTICULATE INHERITANCE). Mendel suggested that individual characteristics were determined by inherited 'factors', and when improved microscopes revealed details of cell structure the behaviour of Mendel's factors could be related to the behaviour of chromosomes during *meiosis.

Mendel's laws Two laws summarizing Gregor Mendel's theory of inheritance (*see also* MENDELISM). The **Law of Segregation** states that each hereditary characteristic is

controlled by two 'factors' (now called *alleles), which segregate (separate) and pass into separate germ (reproductive) cells. The **Law of Independent Assortment** states that pairs of 'factors' segregate independently of each other when germ cells are formed (*see also* INDEPENDENT ASSORTMENT). These laws are the foundation of genetics.

Mendius reaction A reaction in which an organic nitrile is reduced by nascent hydrogen (e.g. from sodium in ethanol) to a primary amine:

$$RCN + 2H_2 \rightarrow RCH_2NH_2$$

meninges The three membranes that surround the brain and spinal cord of vertebrates: the *pia mater, the *arachnoid membrane, and the outer *dura mater. The pia and arachnoid are separated by the **subarachnoid space**, which contains *cerebrospinal fluid.

meniscus **1.** A concave or convex upper surface that forms on a liquid in a tube as a result of *surface tension. **2.** *See* CONCAVE.

menopause The time in a woman's life when ovulation and menstruation cease (*see* MENSTRUAL CYCLE). It normally occurs between the ages of 45 and 55. The effects of the gonadotrophic hormones, *follicle-stimulating hormone and *luteinizing hormone, in the ovaries decrease so that the follicles do not develop properly. There is a change in the balance of the hormones oestrogen and progesterone, secreted by the ovaries, which may be associated with certain physical symptoms, such as weight gain and 'hot flushes', and there may also be mood changes. These symptoms can be treated by hormone replacement therapy (HRT) with oestrogens and progestogens.

menstrual cycle The approximately monthly cycle of events associated with *ovulation that replaces the *oestrous cycle in most primates (including humans). The lining of the uterus becomes progressively thicker with more blood vessels in preparation for the *implantation of a fertilized egg cell (blastocyst). Ovulation occurs during the middle of the cycle (the fertile period). If fertilization does not occur the uterine lining breaks down and is discharged from the body (**menstruation**); the discharge is known as a 'period'. In women the fertile period is 11–15 days after the end of the last menstruation.

menstruation *See* MENSTRUAL CYCLE.

menthol A white crystalline terpene alcohol, $C_{10}H_{19}OH$; r.d. 0.89; m.p. 42°C; b.p. 103–104°C. It has a minty taste and is found in certain essential oils (e.g. peppermint) and used as a flavouring.

mercaptans *See* THIOLS.

mercapto group *See* THIOLS.

mercuric compounds Compounds of mercury in its +2 oxidation state; e.g. mercuric chloride is mercury(II) chloride, $HgCl_2$.

mercurous compounds Compounds of mercury in its +1 oxidation state; e.g. mercury(I) chloride is mercurous chloride, HgCl.

mercury Symbol Hg. A heavy silvery liquid metallic element belonging to the *zinc group; a.n. 80; r.a.m. 200.59; r.d. 13.55; m.p. –38.87°C; b.p. 356.58°C. The main ore is the sulphide cinnabar (HgS), which can be decomposed to the elements. Mercury is used in thermometers, barometers, and other scientific apparatus, and in dental amalgams. The element is less reactive than zinc and cadmium and will not displace hydrogen from acids. It is also unusual in forming mercury(I) compounds containing the Hg_2^{2+} ion, as well as mercury(II) compounds containing Hg^{2+} ions. It also forms a number of complexes and organomercury compounds.

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Mercury The smallest *planet in the *solar system and the closest to the sun. Its mean distance from the *sun is 57.91×10^6 km, its mass is 3.3022×10^{23} kg (about 5.5% that of earth), and its mean equatorial diameter is 4879.4 km; it has a *sidereal period of 87.97 days. Mercury's period of axial rotation of 58.65 days is two-thirds of its sidereal period. Flybys in 1974–75 by the US probe Mariner 10 revealed Mercury to be a rocky world with surface features similar to those on the earth's *moon, with many impact craters and plains similar to the lunar maria. It has a negligible atmosphere consisting mostly of traces of hydrogen and helium. Its relative density, at 5.427, puts it second only to the earth and, given its small size, implies that it has a large, iron-rich core, which may be surrounded by a mantle up to 700 km thick and a crust 100–300 km thick. The temperature at the equator soars to 700 K at perihelion rapidly plunging to 110 K at night. In 2004 the US Mercury Surface, Space Environ-

ment, Geochemistry, and Ranging (MESSENGER) probe was launched to examine Mercury's physical characteristics and environment from orbit. MESSENGER is scheduled to enter orbit around Mercury in 2011 for a year-long mission.

mercury cell A primary *voltaic cell consisting of a zinc anode and a cathode of mercury(II) oxide (HgO) mixed with graphite. The electrolyte is potassium hydroxide (KOH) saturated with zinc oxide, the overall reaction being:

$$Zn + HgO \rightarrow ZnO + Hg$$

The e.m.f. is 1.35 volts and the cell will deliver about 0.3 ampere-hour per cm^3.

mercury(I) chloride A white salt, Hg_2Cl_2; r.d. 7.15; sublimes at 400°C. It is made by heating mercury(II) chloride with mercury and is used in calomel cells (so called because the salt was formerly called **calomel**) and as a fungicide.

mercury(II) chloride A white salt, $HgCl_2$; r.d. 5.4; m.p. 276°C; b.p. 302°C. It is made by reacting mercury with chlorine and used in making other mercury compounds.

mercury(II) fulminate A grey crystalline solid, $Hg(CNO)_2.\frac{1}{2}H_2O$, made by the action of nitric acid on mercury and treating the solution formed with ethanol. It is used as a detonator for cartridges and can be handled safely only under cold water.

mercury(II) oxide A yellow or red oxide of mercury, HgO. The red form is made by heating mercury in oxygen at 350°C; the yellow form, which differs from the red in particle size, is precipitated when sodium hydroxide solution is added to a solution of mercury(II) nitrate. Both forms decompose to the elements at high temperature. The black precipitate formed when sodium hydroxide is added to mercury(I) nitrate solution is sometimes referred to as mercury(I) oxide (Hg_2O) but is probably a mixture of HgO and free mercury.

mercury(II) sulphide A red or black compound, HgS, occurring naturally as the minerals cinnabar (red) and metacinnabar (black). It can be obtained as a black precipitate by bubbling hydrogen sulphide through a solution of mercury(II) nitrate. The red form is obtained by sublimation. The compound is also called **vermilion** (used as a pigment).

mercury-vapour lamp A type of discharge tube in which a glow discharge takes place in mercury vapour. The discharge takes place in a transparent tube of fused silica or quartz into the ends of which molybdenum and tungsten electrodes are sealed; this tube contains argon and a small amount of pure mercury. A small arc is struck between a starter electrode and one of the main electrodes causing local ionization of some argon atoms. The ionized atoms diffuse through the tube causing the main discharge to strike; the heat from this vaporizes the mercury droplets, which become ionized current carriers. Radiation is confined to four visible wavelengths in the visible spectrum and several strong ultraviolet lines. The light is bluish but can be changed by the use of *phosphors on an outer tube. The outer tube is also usually used to filter out excessive ultraviolet radiation. The lamp is widely used for street lighting on account of its low cost and great reliability and as a source of ultraviolet radiation.

mericarp *See* SCHIZOCARP.

meridian **1.** *See* LATITUDE AND LONGITUDE. **2. (magnetic meridian)** An imaginary great circle on the earth's surface that passes through the north and south magnetic poles. A compass needle on the earth's surface influenced only by the earth's magnetic field (*see* GEOMAGNETISM) comes to rest along a magnetic meridian. **3. (celestial meridian)** A great circle of the *celestial sphere that passes through the zenith and the celestial poles. It meets the horizon at the north and south points.

mer-isomer *See* ISOMERISM.

meristem A plant tissue consisting of actively dividing cells that give rise to cells that differentiate into new tissues of the plant. The most important meristems are those occurring at the tip of the shoot and root (*see* APICAL MERISTEM) and the lateral meristems in the older parts of the plant (*see* CAMBIUM; CORK CAMBIUM).

merocrine secretion *See* SECRETION.

meromictic lake *See* DIMICTIC LAKE.

mescaline A powerful hallucinogenic compound obtained from **peyote** – the flowering head of a type of Mexican cactus. Mescaline is a class A drug in the UK. It can be detected by the Mecke test.

mesencephalon *See* MIDBRAIN.

mesentery A thin sheet of tissue, bounded on each side by *peritoneum, that supports the gut and other organs in the body cavities of animals. Vertebrates have a well-developed dorsal mesentery that anchors the stomach and intestine and contains blood vessels and nerves supplying the gut. The reproductive organs and their ducts are also supported by mesenteries.

mesocarp *See* PERICARP.

mesoderm The layer of cells in the *gastrula that lies between the *ectoderm and *endoderm. It develops into the muscles, circulatory system, and sex organs and in vertebrates also into the excretory system and skeleton. *See also* GERM LAYERS.

mesoglea The gelatinous noncellular layer between the endoderm and ectoderm in the body wall of coelenterates. It may be thin, as in *Hydra*, or tough and fibrous, as in the larger jellyfish and sea anemones. It often contains cells that have migrated from the two body layers but these do not form tissues and organs and the mesoglea is not homologous with the mesoderm of *triploblastic animals.

***meso*-isomer** *See* OPTICAL ACTIVITY.

mesomerism A former name for *resonance in molecules.

meson Any of a class of *elementary particles that are a subclass of the *hadrons. According to current quark theory mesons consist of quark–antiquark pairs. They exist with positive, negative, and zero charges, but when charged the charge has the same magnitude as that of the electron. They include the **kaon**, **pion**, and **psi** particles. Mesons are believed to participate in the forces that hold nucleons together in the nucleus. The muon, originally called a mu-meson, was thought to be a meson but is now recognized as a *lepton.

meson-catalysed fusion *See* NUCLEAR FUSION.

mesophyll The internal tissue of a leaf blade (lamina), consisting of *parenchyma cells. There are two distinct forms. **Palisade mesophyll** lies just beneath the upper epidermis and consists of cells elongated at right angles to the leaf surface. They contain a large number of *chloroplasts and their principal function is photosynthesis. **Spongy mesophyll** occupies most of the remainder of the lamina. It consists of spherical loosely arranged cells containing fewer chloroplasts than the palisade mesophyll. Between these cells are air spaces leading to the *stomata.

mesophyte Any plant adapted to grow in soil that is well supplied with water and mineral salts. Such plants wilt easily when exposed to drought conditions as they are not adapted to conserve water. The majority of flowering plants are mesophytes. *Compare* HALOPHYTE; HYDROPHYTE; XEROPHYTE.

mesoscopic Designating a size scale intermediate between those of the *microscopic and the *macroscopic states. Mesoscopic objects and systems require *quantum mechanics to describe them. Many devices in *electronics are mesoscopic.

mesothelium A single layer of thin platelike cells covering the surface of the inside of the abdominal cavity and thorax and surrounding the heart, forming part of the *peritoneum and *pleura (*see* SEROUS MEMBRANE). It is derived from the *mesoderm. *Compare* ENDOTHELIUM; EPITHELIUM.

mesotrophic Describing a body of water, such as a lake, that is intermediate between a *eutrophic lake and an *oligotrophic lake in the amount of nutrients contained within it.

Mesozoic The geological era that extended from the end of the *Palaeozoic era, about 251 million years ago, to the beginning of the *Cenozoic era, about 65 million years ago. It comprises the *Triassic, *Jurassic, and *Cretaceous periods. The Mesozoic era is often known as the **Age of Reptiles** as these animals, which included the dinosaurs, pterosaurs, and ichthyosaurs, became the dominant lifeform; most became extinct before the end of the era.

messenger RNA *See* RNA.

Messier Catalogue A list of nebulae, galaxies, and star clusters, originally published (with 45 entries) in 1774. Such objects are referred to by their Messier numbers; e.g. the Andromeda galaxy is M31. It is named after its originator, Charles Messier (1730–1817).

meta- **1.** Prefix designating a benzene compound in which two substituents are in the 1,3 positions on the benzene ring. The abbreviation *m-* is used; for example, *m*-xylene is 1,3-dimethylbenzene. *Compare* ORTHO-; PARA-. **2.** Prefix designating a lower oxo acid, e.g. metaphosphoric acid. *Compare* ORTHO-.

metabolic pathway *See* METABOLISM.

metabolic rate A measure of the energy used by an animal in a given time period. The metabolic rate of an animal is affected by several interacting factors, including temperature and the level of activity. The metabolic rate of a resting animal is known as the *basal metabolic rate (BMR).

metabolic waste The *waste products, collectively, of metabolism.

metabolism The sum of the chemical reactions that occur within living organisms. The various compounds that take part in or are formed by these reactions are called **metabolites**. In animals many metabolites are obtained by the digestion of food, whereas in plants only the basic starting materials (carbon dioxide, water, and minerals) are externally derived. The synthesis (*anabolism) and breakdown (*catabolism) of most compounds occurs by a number of reaction steps, the reaction sequence being termed a **metabolic pathway**. Some pathways (e.g. *glycolysis) are linear; others (e.g. the *Krebs cycle) are cyclic. The changes at each step in a pathway are usually small and are promoted by efficient biological catalysts – the enzymes. In this way the amounts of energy required or released at any given stage are minimal, which helps in maintaining a constant *internal environment. Various *feedback mechanisms exist to govern *metabolic rates.

metabolite *See* METABOLISM.

metabolome The entire complement of metabolites found within a cell under defined conditions, such as a particular physiological or developmental state. The metabolome is determined using various forms of high-throughput mass spectroscopy. It excludes nucleic acids and other large molecules, giving a 'snapshot' of the cell's metabolic state. *See* METABOLOMICS.

metabolomics The study of how the pool of metabolites (*see* METABOLOME) of cells changes under various physiological or developmental conditions or in response to genetic modification (e.g. mutation).

metaboric acid *See* BORIC ACID.

metacarpal One of the bones in the *metacarpus.

metacarpus The hand (or corresponding part of the forelimb) in terrestrial vertebrates, consisting of a number of rod-shaped bones (**metacarpals**) that articulate with the bones of the wrist (*see* CARPUS) and those of the fingers (*see* PHALANGES). The number of metacarpals varies between species: in the basic *pentadactyl limb there are five, but this number is reduced in many species.

metal Any of a class of chemical elements that are typically lustrous solids that are good conductors of heat and electricity. Not all metals have all these properties (e.g. mercury is a liquid). In chemistry, metals fall into two distinct types. Those of the *s*- and *p*-blocks (e.g. sodium and aluminium) are generally soft silvery reactive elements. They tend to form positive ions and so are described as electropositive. This is contrasted with typical nonmetallic behaviour of forming negative ions. The *transition elements (e.g. iron and copper) are harder substances and generally less reactive. They form coordination complexes. All metals have oxides that are basic, although some, such as aluminium, have *amphoteric properties.

metaldehyde A solid compound, $C_4O_4H_4(CH_3)_4$, formed by polymerization of ethanal (acetaldehyde) in dilute acid solutions below 0°C. The compound, a tetramer of ethanal, is used in slug pellets and as a fuel for portable stoves.

metal fatigue A cumulative effect causing a metal to fail after repeated applications of *stress, none of which exceeds the ultimate *tensile strength. The **fatigue strength** (or **fatigue limit**) is the stress that will cause failure after a specified number (usually 10^7) of cycles. The number of cycles required to produce failure decreases as the level of stress or strain increases. Other factors, such as corrosion, also reduce the fatigue life.

metallic bond A chemical bond of the type holding together the atoms in a solid metal or alloy. In such solids, the atoms are considered to be ionized, with the positive ions occupying lattice positions. The valence electrons are able to move freely (or almost freely) through the lattice, forming an 'electron gas'. The bonding force is electrostatic attraction between the positive metal ions and the electrons. The existence of free electrons accounts for the good electrical and thermal conductivities of metals. *See also* ENERGY BANDS.

metallic crystal A crystalline solid in which the atoms are held together by *metal-

lic bonds. Metallic crystals are found in some *interstitial compounds as well as in metals and alloys.

metallized dye *See* DYES.

metallocene A type of organometallic complex in which one or more aromatic rings (e.g. $C_5H_5^-$ or C_6H_6) coordinate to a metal ion or atom by the pi electrons of the ring. *Ferrocene was the first such compound to be discovered.

metallography The microscopic study of the structure of metals and their alloys. Both optical *microscopes and *electron microscopes are used in this work.

metalloid (semimetal) Any of a class of chemical elements intermediate in properties between metals and nonmetals. The classification is not clear cut, but typical metalloids are boron, silicon, germanium, arsenic, and tellurium. They are electrical semiconductors and their oxides are amphoteric.

metallurgy The branch of applied science concerned with the production of metals from their ores, the purification of metals, the manufacture of alloys, and the use and performance of metals in engineering practice. **Process metallurgy** is concerned with the extraction and production of metals, while **physical metallurgy** concerns the mechanical behaviour of metals.

metamagnet A material that is an antiferromagnet in the absence of an external magnetic field but undergoes a first-order transition to a phase in which there is a nonzero ferromagnetic moment when the external magnetic field becomes sufficiently large. Iron(II) chloride is an example of a metamagnet.

metamaterial A type of synthetic composite material with a complex nanostructure, constructed so as to have unusual properties that do not occur naturally. A particular type consists of materials that have a negative refractive index. There has been a considerable amount of research into using these as 'invisibility cloaks' for microwaves and possibly visible radiation.

metameric segmentation (metamerism; segmentation) The division of an animal's body (except at the head region – *see* CEPHALIZATION) into a number of compartments (**segments** or **metameres**) each containing the same organs. Metameric segmentation is most strongly marked in annelid worms (e.g. earthworms), in which the muscles, blood vessels, nerves, etc. are repeated in each segment. In these animals the segmentation is obvious both externally and internally. It also occurs internally in arthropods and in the embryonic development of all vertebrates, in which it is confined to parts of the muscular, skeletal, and nervous systems and does not show externally.

metamict state The amorphous state of a substance that has lost its crystalline structure as a result of the radioactivity of uranium or thorium. **Metamict minerals** are minerals whose structure has been disrupted by this process. The metamictization is caused by alpha particles and the recoil nuclei from radioactive disintegration.

metamorphic rocks One of the three major rock categories (*see also* IGNEOUS ROCKS; SEDIMENTARY ROCKS). Metamorphic rock is formed when pre-existing rock is subjected to either chemical or physical alteration by heat, pressure, or chemically active fluids. It involves three main processes of formation. **Contact metamorphism** results from the intrusion of a mass of molten rock into sedimentary rock. Heat from the intrusion spreads into the surrounding sediments causing mineralogical changes to take place. **Regional metamorphism** is developed over large areas and is associated with mountain building. Sediments collect in large depressions, known as geosynclines, in the earth's crust. As successive layers accumulate the lower layers subside into the crust and are subjected to increasing heat and pressure, causing the rocks to be metamorphosed. Eventually these rocks may also be uplifted and folded to form mountain chains. **Dislocation metamorphism** results from the more localized mechanical shearing and crushing of rocks, for example along fault planes.

Metamorphic rocks are characteristically resistant and tend to form upland areas. Examples of metamorphic rocks include marble (metamorphosed limestone) and slate (metamorphosed shale).

metamorphosis The rapid transformation from the larval to the adult form that occurs in the life cycle of many invertebrates and amphibians. Examples are the changes from a tadpole to an adult frog and from a pupa to an adult insect. Metamorphosis often involves considerable destruction of

larval tissues by lysosomes, and in both insects and amphibians it is controlled by hormones.

metaphase The stage of cell division during which the membrane around the nucleus breaks down, the *spindle forms, and centromeres attach the chromosomes to the equator of the spindle. In the first metaphase of *meiosis pairs of chromosomes (bivalents) are attached, while in *mitosis and the second metaphase of meiosis, individual chromosomes are attached.

metaphosphoric acid *See* PHOSPHORIC(V) ACID.

metaplasia The transformation of a tissue into a different type. This is an abnormal process; for example, metaplasia of the epithelium of the bronchi may be an early sign of cancer.

metaplumbate *See* PLUMBATE.

metastable state A condition of a system in which it has a precarious stability that can easily be disturbed. It is unlike a state of stable equilibrium in that a minor disturbance will cause a system in a metastable state to fall to a lower energy level. A book lying on a table is in a state of stable equilibrium; a thin book standing on edge is in metastable equilibrium. Supercooled water is also in a metastable state. It is liquid below 0°C; a grain of dust or ice introduced into it will cause it to freeze. An excited state of an atom or nucleus that has an appreciable lifetime is also metastable.

metastannate *See* STANNATE.

metastasis *See* CANCER.

metatarsal One of the bones in the *metatarsus.

metatarsus The foot (or corresponding part of the hindlimb) in terrestrial vertebrates, consisting of a number of rod-shaped bones (**metatarsals**) that articulate with the bones of the ankle (*see* TARSUS) and those of the toes (*see* PHALANGES). The number of metatarsals varies between species: in the basic *pentadactyl limb there are five, but this number is reduced in some species.

Metatheria An infraclass of mammals containing the marsupials. The female bears an abdominal pouch (**marsupium**) into which the newly born young, which are in a very immature state, move to complete their development. They obtain nourishment from the mother's mammary teats. Modern marsupials are restricted to Australasia (where they include the kangaroos, koala bears, phalangers, and bandicoots) and America (the opossums). Marsupials evolved during the early to mid- Cretaceous period, 140–125 million years ago. In Australia, where the marsupials have been isolated for millions of years, they show the greatest diversity of form, having undergone *adaptive radiation to many of the niches occupied by placental mammals elsewhere. *Compare* EUTHERIA; PROTOTHERIA.

metathesis A type of reaction in which radicals are exchanged. In inorganic chemistry, it is also called **double decomposition**. A simple example is

$$KCL + A_gNO_3 \rightarrow KNO_3 + A_gCl.$$

Metathesis of alkenes is an important type of reaction in synthetic organic chemistry. It involves exchange of groups. For example

$$RHC{=}CH_2 + RHC{=}CH_2 \rightarrow RHC{=}CHR + H_2C{=}CH_2.$$

Reactions of this type are catalysed by metal alkylides (containing an $M{=}CR_2$ grouping) and the intermediate is a four-membered ring containing the metal ion. The catalysts most often used are the **Schrock catalysts** based on molybdenum and the **Grubbs catalysts** based on ruthenium. The American chemists Richard Schrock and Robert Grubbs shared the Nobel prize for chemistry in 2005 for work in this field.

Metazoa (Eumetazoa) A subkingdom comprising all multicellular animals. In some classifications it also includes the *Porifera (sponges) and *Placozoa, which some authorities place in a separate subkingdom, Parazoa.

meteor A streak of light observable in the sky when a particle of matter enters the earth's atmosphere and becomes incandescent as a result of friction with atmospheric atoms and molecules. These particles of matter are known collectively as **meteoroids**. Meteoroids that survive their passage through the atmosphere and strike the earth's surface are known as **meteorites**. Only some 2500 meteorites are known, excluding the **micrometeorites** (bodies less than 1 mm in diameter). Meteorites consist mainly of silicate materials (stony meteorites) or iron (iron meteorites). It is estimated that the earth collects over 10^8 kg of meteoritic material every year, mostly in the

form of micrometeorites. Micrometeorites survive atmospheric friction because their small size enables them to radiate away the heat generated by friction before they vaporize.

meteorite *See* METEOR.

meteoroid A particle of dust (from a comet) or rock (from an asteroid) in space on a collision course with the earth. When it enters the earth's atmosphere, it burns up as a *meteor or hits the ground as a meteorite.

meteorology The study of the physical phenomena and processes taking place in the atmosphere and its interactions with the ground surface. This knowledge is applied to weather forecasting. The chief branches of meteorology are *dynamical meteorology, *micrometeorology, and *synoptic meteorology.

methacrylate A salt or ester of methacrylic acid (2-methylpropenoic acid).

methacrylate resins *Acrylic resins obtained by polymerizing 2-methylpropenoic acid or its esters.

m

methacrylic acid *See* 2-METHYLPROPENOIC ACID.

methadone A synthetic opioid, $C_{21}H_{27}NO$, used medically as an analgesic for chronic pain and also as a substitute for heroin in the treatment of addiction. Methadone is itself addictive and considerable quantities of 'street' methadone are used in the UK.

methamphetamine *See* AMPHETAMINE.

methanal (formaldehyde) A colourless gas, HCHO; r.d. 0.815 (at –20°C); m.p. –92°C; b.p. –21°C. It is the simplest *aldehyde, made by the catalytic oxidation of methanol (500°C; silver catalyst) by air. It forms two polymers: *methanal trimer and polymethanal. *See also* FORMALIN.

methanal trimer A cyclic trimer of methanal, $C_3O_3H_6$, obtained by distillation of an acidic solution of methanal. It has a six-membered ring of alternating –O– and $–CH_2–$ groups.

methane A colourless odourless gas, CH_4; m.p. –182.5°C; b.p. –164°C. Methane is the simplest hydrocarbon, being the first member of the *alkane series. It is the main constituent of natural gas (~99%) and as such is an important raw material for producing other organic compounds. It can be converted into methanol by catalytic oxidation.

methanide *See* CARBIDE.

methanoate (formate) A salt or ester of methanoic acid.

methanogen Any of various archaebacteria (*see* BACTERIA) that produce methane; they include such genera as *Methanobacillus* and *Methanothrix*. Methanogens are obligate anaerobes (*see* ANAEROBIC RESPIRATION) found in oxygen-deficient environments, such as marshes, swamps, sludge (formed during *sewage treatment), and the digestive systems of ruminants. They mostly obtain their energy by reducing carbon dioxide and oxidizing hydrogen, with the production of methane:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O.$$

Formate, methanol, or acetate may also be used as substrates by certain methanogens. Methanogenic bacteria are important in the production of *biogas.

methanoic acid (formic acid) A colourless pungent liquid, HCOOH; r.d. 1.2; m.p. 8°C; b.p. 101°C. It can be made by the action of concentrated sulphuric acid on the sodium salt (sodium methanoate), and occurs naturally in ants and stinging nettles. Methanoic acid is the simplest of the *carboxylic acids.

methanol (methyl alcohol) A colourless liquid, CH_3OH; r.d. 0.79; m.p. –93.9°C; b.p. 64.96°C. It is made by catalytic oxidation of methane (from natural gas) using air. Methanol is used as a solvent (*see* METHYLATED SPIRITS) and as a raw material for making methanal (mainly for urea–formaldehyde resins). It was formerly made by the dry distillation of wood (hence the name **wood alcohol**).

methionine *See* AMINO ACID.

method of mixtures A method of determining the specific heat capacities of liquids or a liquid and a solid by mixing known masses of the substances at different temperatures and measuring the final temperature of the mixture.

methoxy group The organic group $CH_3O–$.

methyl acetate *See* METHYL ETHANOATE.

methyl alcohol *See* METHANOL.

methylamine A colourless flammable gas,

CH_3NH_2; m.p. –93.5°C; b.p. –6.3°C. It can be made by a catalytic reaction between methanol and ammonia and is used in the manufacture of other organic chemicals.

methylated spirits A mixture consisting mainly of ethanol with added methanol (~9.5%), pyridine (~0.5%), and blue dye. The additives are included to make the ethanol undrinkable so that it can be sold without excise duty for use as a solvent and a fuel (for small spirit stoves).

methylation A chemical reaction in which a methyl group (CH_3–) is introduced in a molecule. A particular example is the replacement of a hydrogen atom by a methyl group, as in a *Friedel–Crafts reaction.

methylbenzene (toluene) A colourless liquid, $CH_3C_6H_5$; r.d. 0.9; m.p. –95°C; b.p. 111°C. Methylbenzene is derived from benzene by replacement of a hydrogen atom by a methyl group. It can be obtained from coal tar or made from methylcyclohexane (extracted from crude oil) by catalytic dehydrogenation. Its main uses are as a solvent and as a raw material for producing TNT.

methyl bromide *See* BROMOMETHANE.

2-methylbuta-1,3-diene *See* ISOPRENE.

methyl chloride *See* CHLOROMETHANE.

methylene The highly reactive *carbene, :CH_2. The divalent CH_2 group in a compound is the **methylene group**.

methylene blue A blue dye used in optical microscopy to stain nuclei of animal tissues. It is also suitable as a vital stain and a bacterial stain.

methylenedioxymethamphetamine (MDMA) *See* ECSTASY.

methyl ethanoate (methyl acetate) A colourless volatile fragrant liquid, CH_3COOCH_3; r.d. 0.92; m.p. –98°C; b.p. 54°C. A typical *ester, it can be made from methanol and methanoic acid and is used mainly as a solvent.

methyl ethyl ketone *See* BUTANONE.

methyl group (methyl radical) The organic group CH_3–.

methyl methacrylate An ester of methacrylic acid (2-methylpropenoic acid), CH_2:$C(CH_3)COOCH_3$, used in making *methacrylate resins.

methyl orange An organic dye used as an acid–base *indicator. It changes from red below pH 3.1 to yellow above pH 4.4 (at 25°C) and is used for titrations involving weak bases.

methylphenols (cresols) Organic compounds having a methyl group and a hydroxyl group bound directly to a benzene ring. There are three isomeric methylphenols with the formula $CH_3C_6H_4OH$, differing in the relative positions of the methyl and hydroxyl groups. A mixture of the three can be obtained by distilling coal tar and is used as a germicide and antiseptic.

2-methylpropenoic acid (methacrylic acid) A white crystalline unsaturated soluble carboxylic acid, CH_2:$C(CH_3)COOH$, used in making *methacrylate resins.

methyl red An organic dye similar in structure and use to methyl orange. It changes from red below pH 4.4 to yellow above pH 6.0 (at 25°C).

methylxanthines Derivatives of xanthine in which one or more hydrogen atoms have been substituted by methyl groups. The common ones are the trimethylxanthine *caffeine and the dimethylxanthines *theophylline and *theobromine.

metre Symbol m. The SI unit of length, being the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second. This definition, adopted by the General Conference on Weights and Measures in October 1983, replaced the 1960 definition based on the krypton lamp, i.e. 1 650 763.73 wavelengths in a vacuum of the radiation corresponding to the transition between the levels $2p^{10}$ and $5d^5$ of the nuclide krypton–86. This definition replaced the older (1927) definition of a metre based on a platinum–iridium bar of standard length. When the *metric system was introduced in 1791 in France, the metre was intended to be one ten-millionth of the earth's meridian quadrant passing through Paris. However, the original geodetic surveys proved the impractibility of such a standard and the original platinum metre bar, the *mètre des archives*, was constructed in 1793.

metre bridge *See* WHEATSTONE BRIDGE.

metric system A decimal system of units originally devised by a committee of the French Academy, which included J. L. Lagrange and P. S. Laplace, in 1791. It was based on the *metre, the gram defined in

terms of the mass of a cubic centimetre of water, and the second. This centimetre-gram-second system (*see* C.G.S. UNITS) later gave way for scientific work to the metre-kilogram-second system (*see* M.K.S. UNITS) on which *SI units are based.

metric ton (tonne) A unit of mass equal to 1000 kg or 2204.61 lb. 1 tonne = 0.9842 ton.

metrology The scientific study of measurement, especially the definition and standardization of the units of measurement used in science.

MHC *See* MAJOR HISTOCOMPATIBILITY COMPLEX.

MHD *See* MAGNETOHYDRODYNAMICS.

mho A reciprocal ohm, the former name of the unit of electrical *conductance now known as the siemens.

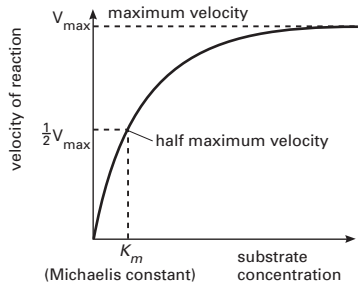
mica Any of a group of silicate minerals with a layered structure. Micas are composed of linked SiO_4 tetrahedra with cations and hydroxyl groupings between the layers. The general formula of the micas is $X_2Y_{4-6}Z_8O_{20}(OH,F)_4$, where X = K,Na,Ca; Y = Al,Mg,Fe,Li; and Z = Si,Al. The three main mica minerals are:
*muscovite, $K_2Al_4(Si_6Al_2O_{20})(OH,F)_4$;
*biotite, $K_2(Mg,Fe^{2+})_{6-4}(Fe^{3+},Al,Ti)_{0-2}(Si_{6-5}Al_{2-3}O_{20})(OH,F)_4$;
lepidolite, $K_2(Li,Al)_{5-6}(Si_{6-7}Al_{2-1}O_{20})(OH,F)_4$.
Micas have perfect basal cleavage and the thin cleavage flakes are flexible and elastic. Flakes of mica are used as electrical insulators and as the dielectric in capacitors.

micelle An aggregate of molecules in a *colloid. For example, when soap or other *detergents dissolve in water they do so as micelles – small clusters of molecules in which the nonpolar hydrocarbon groups are in the centre and the hydrophilic polar groups are on the outside solvated by the water molecules. Phospholipids in aqueous solution also form micelles. The products of fat digestion are dispersed into micelles by the action of bile salts, which facilitates their absorption in the small intestine.

Michaelis–Menten curve A graph that shows the relationship between the concentration of a substrate and the rate of the corresponding enzyme-controlled reaction. It is named after Leonor Michaelis (1875–1949) and L. M. Menten. The curve only applies to enzyme reactions involving a single substrate. The graph can be used to calculate the **Michaelis constant** (K_m), which is the concentration of a substrate required in order for an enzyme to act at half of its maximum velocity (V_{max}). The Michaelis constant is a measure of the affinity of an enzyme for a substrate. A low value corresponds to a high affinity, and vice versa. *See also* ENZYME KINETICS.

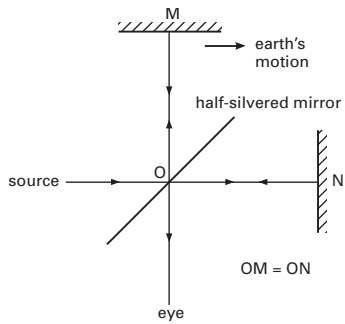
SEE WEB LINKS

- Original paper on Michaelis–Menten kinetics



Michaelis–Menten curve.

Michelson–Morley experiment An experiment, conducted in 1887 by the US physicists Albert Michelson (1852–1931) and Edward Morley (1838–1923), that attempted to measure the velocity of the earth through the *ether. Using a modified **Michelson interferometer** (see illustration) they expected to observe a shift in the interference fringes formed when the instrument was rotated through 90°, showing that the speed of light measured in the direction of the earth's rota-



Michelson-Morley experiment. Michelson interferometer.

tion, or orbital motion, is not identical to its speed at right angles to this direction. No shift was observed. An explanation was finally provided by the *Lorentz–Fitzgerald contraction, which provided an important step in the formulation of Einstein's special theory of *relativity and the abandonment of the ether concept.

SEE WEB LINKS

- The original 1887 paper in *The American Journal of Science*

micro- **1.** A prefix denoting very small size; e.g. microgamete, micronucleus. **2.** Symbol μ. A prefix used in the metric system to denote one millionth. For example, 10^{-6} metre = 1 micrometre (μm).

microarray A glass slide or bead on which are deposited biomolecules or other material in a regular micro-scale pattern to enable automated simultaneous multiple assays of target substances or activities. Microarrays are powerful analytical tools with wide-ranging applications. They can be designed to carry small DNA molecules (*see* DNA MICROARRAY), proteins (e.g. antibodies or antigens), carbohydrates or other organic molecules, or even individual living cells. These reagents are applied to the glass substrate in a regular microscopic grid pattern, each being identified by its unique coordinate, or address, on the grid. Interaction of a target substance (e.g. an antibody or a complementary nucleic acid) with a particular address on the microarray activates or attaches a label (e.g. a fluorescent dye). The microarray can then be 'read' by a scanner, which automatically assesses the amount of label at each address, and hence the amount of target substance. Even smaller-scale **nanoarrays** are already being developed, to increase further the scope and speed of this technology.

microbalance A sensitive *balance capable of weighing masses of the order 10^{-6} to 10^{-9} kg.

microbiology The scientific study of microorganisms (e.g. bacteria, viruses, and fungi). Originally this was directed towards their effects (e.g. in causing disease and decay), but during the 20th century the emphasis shifted to their physiology, biochemistry, and genetics. Microbes are now recognized as important vehicles for the study of biochemical and genetic processes common to all living organisms, and their rapid growth enables their laboratory culture in large numbers for studies in genetics.

SEE WEB LINKS

- Home page of the Society for General Microbiology

microcavity A cavity with reflecting faces that is so small that specifically quantum mechanical aspects of quantum electrodynamics, such as spontaneous emission, can be investigated. Microcavities range in size from nanometres to micrometres.

microclimate The local climate of a small area or of a particular *habitat, which is different from the **macroclimate** of the larger surrounding geographical area.

microcomputer A *computer in which the central processing unit is implemented by means of a semiconductor chip or chip set, known as a **microprocessor**. The power of a microcomputer is determined not only by the speed and power of the processor but also by features of the other components in the computer, such as the storage capacity of the main (*RAM) memory and the disks used as *backing store, as well as the operating system and other software used. Microcomputers are used in a wide variety of forms, including *personal computers, electronic point-of-sales terminals, and cash-dispensing automated teller machines.

microcrystal test *See* CRYSTAL TEST.

microdissection (micromanipulation) A technique used for the dissection of living cells under the high power of an optical microscope. It utilizes minute mechanically manipulated instruments, such as needles, scalpels, *micropipettes, and lasers. For example, the instruments may be used to remove a single nucleus from one cell and to implant it in another (*see* NUCLEAR TRANSFER).

microelectronics The techniques of designing and making electronic circuits of very small size. As a result of these techniques a single *silicon chip measuring less than a centimetre in either direction can contain many thousands of transistors and may constitute the central processing unit of a microcomputer. In addition to an enormous drop in size, compared to an equivalent valve-operated device, these microelectronic circuits are some 100 000 times more reliable than their thermionic predecessors.

microfauna **1.** Animals that cannot be seen with the naked eye. They are normally observed with the aid of a microscope. *Compare* MACROFAUNA. **2.** The animals that live in a particular *microhabitat.

microfibril A microscopic fibre. Plant cell walls contain microfibrils, about 5 nm in diameter, each consisting of parallel cellulose chains that are associated together to form a rod or a flat ribbon. Cellulose microfibrils are arranged in layers at right angles to each other.

microflora **1.** Plants and algae that cannot be seen with the naked eye. They are normally observed with the aid of a microscope. **2.** The plants and algae that live in a particular *microhabitat.

microfossil A *fossil that is so small that it can only be studied under a microscope. Microfossils include bacteria, diatoms, and protozoa and parts of organisms, such as plant pollen and skeletal fragments. Microfossils are important in the correlation of rocks where only small samples are available. The study of microfossils, particularly pollen, is known as *palynology.

microglia *See* GLIA; MACROPHAGE.

microhabitat The local habitat of a particular organism or microorganism. There are normally a number of different microhabitats within a large *habitat (**macrohabitat**), each with its distinct set of environmental conditions. For example, in a stream macrohabitat there will exist different microhabitats, depending on oxygen content, pH, speed of water flow, and other factors in localized areas of the stream.

micromanipulation *See* MICRODISSECTION.

micrometeorite *See* METEOR.

micrometeorology The branch of meteorology concerned with small-scale processes at work within the lowest layers of the atmosphere, including the interaction of the atmosphere with the ground surface. Examples of the processes studied include mountain and valley winds and land and sea breezes.

micrometer A gauge for measuring small diameters, thicknesses, etc., accurately. It consists of a G-shaped device in which the gap between the measuring faces is adjusted by means of an accurately calibrated screw, the end of which forms one of the measuring faces.

micron The former name for the *SI unit now called the micrometre, i.e. 10^{-6} m.

micronutrient A chemical element required by plants in relatively small quantities. Micronutrients are typically found in cofactors and coenzymes. They include copper, zinc, molybdenum, manganese, cobalt, and boron. *See* ESSENTIAL ELEMENT. *Compare* MACRONUTRIENT.

microorganism (microbe) Any organism that can be observed only with the aid of a microscope. Microorganisms include bacteria, viruses, protozoans, and some algae and fungi. *See* MICROBIOLOGY.

microphagous Describing the method of feeding of those heterotrophic organisms that take in their food in the form of tiny particles. *Filter feeding and *ciliary feeding are examples of this type of feeding. *Compare* MACROPHAGOUS.

microphone A *transducer in which sound waves are converted into corresponding variations in an electrical signal for amplification, transmission to a distant point, or recording. Various types of device are used. In the **dynamic microphone** the sound waves impinge on a conductor of low mass supported in a magnetic field and cause it to oscillate at the frequency of the sound waves. These movements induce an e.m.f. in the conductor that is proportional to its velocity. The moving conductor consists of a metal ribbon, a wire, or a coil of wire. In the **moving-iron microphone**, sound waves cause a light armature to oscillate so that it varies the reluctance of a magnetic circuit. In a coil surrounding this path the varying reluctance is experienced as a variation in the magnetic flux within it, which induces a corresponding e.m.f. In the **carbon microphone**, widely used in telephones, a diaphragm constitutes a movable electrode in contact with carbon granules, which are also in contact with a fixed electrode. The movement of the diaphragm, in response to the sound waves, varies the resistance of the path through the granules to the fixed electrode. *See also* CAPACITOR MICROPHONE; CRYSTAL MICROPHONE.

microphyll A type of foliage leaf in clubmosses and horsetails that has a single unbranched midrib. Such leaves are generally

no more than a few millimetres long. *Compare* MEGAPHYLL.

micropipette A glass pipette with an ultrafine tip, typically less than 1 µm in diameter. It can be inserted into single cells or other microscopic structures and used, for example, to inject materials. The micropipette is usually held by a **micromanipulator**, a mechanical device that allows precise movement of the tip.

microprocessor *See* COMPUTER.

micropropagation The *in vitro* propagation of plants by cloning (*see* CLONE). Typically, this involves culturing excised meristematic tissue on a special medium that encourages axillary bud development. The new shoots are then separated and cultures, and the cycle is repeated until finally the shoots are transferred to a medium that promotes root development, to produce plantlets. Micropropagation is used in agriculture, horticulture, and forestry as special genotypes can be bred and maintained, the process is rapid, and plants can be kept disease-free.

micropyle **1.** A small opening in the surface of a plant ovule through which the pollen tube passes prior to fertilization. It results from the incomplete covering of the nucellus by the integuments. It remains as an opening in the testa of most seeds through which water is absorbed. **2.** A small pore in some animal cells or tissues; for example, in insect eggs (*see* CHORION).

microRNA (miRNA) A small RNA molecule that is encoded by a cell and can 'silence' the expression of a particular target gene within the cell (*see* RNA INTERFERENCE). miRNAs bind to target messenger RNA (mRNA) molecules and suppress translation of the mRNA into protein. They regulate expression of perhaps a third of all protein-coding genes and are involved in many aspects of embryological development, cell differentiation, cell death, and cancer.

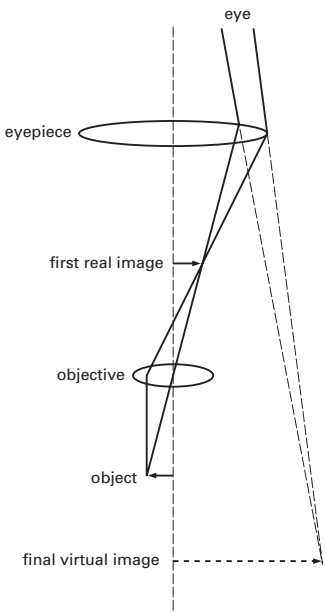
microsatellite DNA *See* REPETITIVE DNA.

microscope Any device for forming a magnified image of a small object. The **simple microscope** consists of a biconvex magnifying glass or an equivalent system of lenses, either hand-held or in a simple frame. The **compound microscope** (see illustration) uses two lenses or systems of lenses, the second magnifying the real image formed by the first. The lenses are usually mounted at the opposite ends of a tube that has mechanical controls to move it in relation to the object. An optical condenser and mirror, often with a separate light source, provide illumination of the object. The widely used **binocular microscope** consists of two separate instruments fastened together so that one eye looks through one while the other eye looks through the other. This gives stereoscopic vision and reduces eye strain. *See also* ATOMIC FORCE MICROSCOPY; ELECTRON MICROSCOPE; FIELD-EMISSION MICROSCOPE; FIELD-IONIZATION MICROSCOPE; PHASE-CONTRAST MICROSCOPE; SCANNING TUNNELLING MICROSCOPY; ULTRAVIOLET MICROSCOPE. See also Chronology: Microscopy.

SEE WEB LINKS

- Webpages from Botany online, describing the basic microscopical techniques used in biology

microscopic Designating a size scale comparable to the subatomic particles, atoms, and molecules. Microscopic objects and systems are described by *quantum mechanics. *Compare* MACROSCOPIC; MESOSCOPIC.



Microscope. Compound microscope.

MICROSCOPY

c.1590	Dutch spectacle-makers Hans and Zacharias Janssen invent the compound microscope.
1610	German astronomer Johannes Kepler (1571–1630) invents the modern compound microscope.
1675	Anton van Leeuwenhoek invents the simple microscope.
1826	British biologist Dames Smith (d. 1870) constructs a microscope with much reduced chromatic and spherical aberrations.
1827	Italian scientist Giovanni Amici (1786–1863) invents the reflecting achromatic microscope.
1861	British chemist Joseph Reade (1801–70) invents the kettledrum microscope condenser.
1912	British microscopist Joseph Barnard (1870–1949) invents the ultramicroscope.
1932	Dutch physicist Frits Zernike (1888–1966) invents the phase-contrast microscope.
1936	German-born US physicist Erwin Mueller (1911–77) invents the field-emission microscope.
1938	German engineer Ernst Ruska (1906–88) develops the electron microscope.
1940	Canadian scientist James Hillier (1915–2007) makes a practical electron microscope.
1951	Erwin Mueller invents the field-ionization microscope.
1978	US scientists of the Hughes Research Laboratory invent the scanning ion microscope.
1981	Swiss physicists Gerd Binning (1947–) and Heinrich Rohrer (1933–) invent the scanning tunnelling microscope.
1985	Gerd Binning invents the atomic force microscope.
1987	James van House and Arthur Rich invent the positron microscope.

microsome A fragment of *endoplasmic reticulum formed when cells or tissues are disrupted. Microsomes can be isolated by centrifugation and are commonly used to investigate the functional properties of endoplasmic reticulum, such as enzymic activity and protein synthesis.

microspore *See* SPOROPHYLL.

microsporophyll *See* SPOROPHYLL.

microtome A machine used to cut thin sections (3–5 μm thick) of plant or animal tissue for microscopical observation. There are various designs of microtome, each basically consisting of a steel knife, a block for supporting the specimen, and a device for moving the specimen towards the knife. The specimen is usually supported by being embedded in wax; if a **freezing microtome** is used, the specimen is frozen. An **ultramicrotome** is used to cut much thinner sections (20–100 nm thick) for electron microscopy. The biological material is embedded in plastic or resin, sectioned with a glass or diamond knife, and the cut sections are allowed to float on the surface of water in an adjacent water bath.

microtubule A microscopic tubular structure in eukaryotic cells that is composed of the protein **tubulin** and occurs singly or in pairs, triplets, or bundles. Microtubules help cells to maintain their shape (*see* CYTOSKELETON); they also occur in cilia and flagella (*see* UNDULIPODIUM) and in the *centrioles

and they form the *spindle during nuclear division.

microvillus One of a number of minute finger-like projections on the free surfaces of epithelial cells. Microvilli are covered with plasma membrane and their cytoplasm is continuous with the main cell cytoplasm. Their purpose is to increase the absorptive or secretory surface area of the cell, and they are abundant on the villi of the intestine, where they form a *brush border.

microwave background radiation A cosmic background of radiation in the frequency range 3×10^{11} hertz to 3×10^{8} hertz discovered in 1965. Believed to have emanated from the primordial fireball of the big bang with which the universe is thought to have originated (*see* BIG-BANG THEORY), the radiation has an energy density in intergalactic space of some 4×10^{-14} J m^{-3}. *See also* COBE; WMAP.

microwave optics The study of the behaviour of microwaves by analogy with the behaviour of light waves. On the large scale microwaves are propagated in straight lines and, like light waves, they undergo reflection, refraction, diffraction, and polarization.

microwaves Electromagnetic waves with wavelengths in the range 10^{-3} to 0.03 m.

microwave spectroscopy A sensitive technique for chemical analysis and the determination of molecular structure (bond lengths, bond angles, and dipole moments), and also relative atomic masses. It is based on the principle that microwave radiation (*see* MICROWAVES) causes changes in the rotational energy levels of molecules and absorption consequently occurs at characteristic frequencies. In a microwave spectrometer a microwave source, usually a klystron valve, produces a beam that is passed through a gaseous sample. The beam then impinges on the detector, usually a crystal detector, and the signal (wavelength against intensity) is displayed, either as a printed plot or on an oscilloscope. As microwaves are absorbed by air the instrument is evacuated.

midbrain (mesencephalon) One of the three sections of the brain of a vertebrate embryo. Unlike the *forebrain and the *hindbrain, the midbrain does not undergo further subdivision to form additional zones. In mammals it becomes part of the *brainstem, but in amphibians, reptiles, and birds the roof of the midbrain becomes enlarged as the **tectum**, a dominant centre for integration, and may include a pair of **optic lobes**.

middle ear (tympanic cavity) The air-filled cavity within the skull of vertebrates that lies between the *outer ear and the *inner ear. It is linked to the pharynx (and therefore to outside air) via the *Eustachian tube and in mammals contains the three *ear ossicles, which transmit auditory vibrations from the outer ear (via the *tympanum) to the inner ear (via the oval window).

middle lamella A thin layer of material, consisting mainly of pectins, that binds together the walls of adjacent plant cells.

midgut **1.** The middle section of the alimentary canal of vertebrates, which is concerned with digestion and absorption. It comprises most of the small intestine. **2.** The middle section of the alimentary canal of arthropods. *See also* FOREGUT; HINDGUT.

mid-ocean ridge A long chain of underwater mountains, several thousand metres high, that runs for a total of about 50 000 km across the floors of the major oceans. The ridge corresponds to tectonic plate margins (*see* PLATE TECTONICS), at which upwelling magma breaches the comparatively thin oceanic crust. The sea floor spreads as the plates gradually move apart. Underwater volcanoes are a feature of some ridges.

migration **1.** (in chemistry) The movement of a group, atom, or double bond from one part of a molecule to another. **2.** (in physics) The movement of ions under the influence of an electric field. **3.** (in biology) The seasonal movement of complete populations of animals to a more favourable environment. It is usually a response to lower temperatures resulting in a reduced food supply, and is often triggered by a change in day length (*see* PHOTOPERIODISM). Migration is common in mammals (e.g. porpoises), fish (e.g. eels and salmon), and some insects but is most marked in birds. The Arctic tern, for example, migrates annually from its breeding ground in the Arctic circle to the Antarctic – a distance of some 17 600 km. Migrating animals possess considerable powers of orientation; birds seem to possess a compass sense, using the sun, pole stars, and (in cloud) the earth's magnetic lines of force as reference points (*see* NAVIGATION).

milk The fluid secreted by the *mammary glands of mammals. It provides a balanced and highly nutritious food for offspring. Cows' milk comprises about 87% water, 3.6% lipids (triglycerides, phospholipids, cholesterol, etc.), 3.3% protein (largely casein), 4.7% lactose (milk sugar), and, in much smaller amounts, vitamins (especially vitamin A and many B vitamins) and minerals (notably calcium, phosphorus, sodium, potassium, magnesium, and chlorine). Composition varies among species; human milk contains less protein and more lactose.

milk of magnesia *See* MAGNESIUM HYDROXIDE.

milk sugar *See* LACTOSE.

milk teeth *See* DECIDUOUS TEETH.

Milky Way *See* GALAXY.

Miller indices A set of three numbers that characterize a face of a crystal. The French mineralogist René Just Haüy (1743–1822) proposed the **law of rational intercepts**, which states that there is always a set of axes, known as **crystal axes**, that allows a crystal face to be characterized in terms of intercepts of the face with these axes. The reciprocals of these intercepts are small rational numbers. When the fractions are cleared there is a set of three integers. These integers are known as the Miller indices of the crystal face after the British mineralogist William Hallowes Miller (1810–80), who pointed out that crystal faces could be characterized by these indices. If a plane is parallel to one of the crystal axes then its intercept is at infinity and hence its reciprocal is 0. If a face cuts a crystal axis on the negative side of the origin then the intercept, and hence its reciprocal, i.e. the Miller index for that axis, are negative. This is indicated by a bar over the Miller index. For example, the Miller indices for the eight faces of an octahedron are (III), ($\bar{1}$II), (I$\bar{1}$I), (II$\bar{1}$), ($\bar{1}\bar{1}$I), ($\bar{1}$I$\bar{1}$), (I$\bar{1}\bar{1}$), and ($\bar{1}\bar{1}\bar{1}$).

milli- Symbol m. A prefix used in the metric system to denote one thousandth. For example, 0.001 volt = 1 millivolt (mV).

millibar *See* BAR.

Millikan, Robert Andrews (1868–1953) US physicist, who after more than 20 years at the University of Chicago went to the California Institute of Technology in 1921. His best-known work, begun in 1909, was to determine the charge on the *electron in his oil-drop experiment, which led to the award of the 1923 Nobel Prize for physics. He then went on to do important work on *cosmic radiation.

SEE WEB LINKS

- One of Millikan's original papers (1911) in *The Physical Review*

millipedes *See* DIPLOPODA.

mimicry The resemblance of one animal to another, which has evolved as a means of protection. In one form of mimicry the markings of certain harmless insects closely resemble the *warning coloration of another insect (the **model**). Predators that have learnt to avoid the model will also avoid good mimics of it. This phenomenon is often found among butterflies. A second form of mimicry involves the mutual resemblance of a group of animals, all harmful, such as the wasp, bee, and hornet, so that a predator, having experienced one, will subsequently avoid them all.

mineral A naturally occurring substance that has a characteristic chemical composition and, in general, a crystalline structure. The term is also often applied generally to organic substances that are obtained by mining (e.g. coal, petroleum, and natural gas) but strictly speaking these are not minerals, being complex mixtures without definite chemical formulas. Rocks are composed of mixtures of minerals. Minerals may be identified by the properties of their crystal system, hardness (measured on the Mohs' scale), relative density, lustre, colour, cleavage, and fracture. Many names of minerals end in *-ite*.

mineral acid A common inorganic acid, such as hydrochloric acid, sulphuric acid, or nitric acid.

mineral deficiency Lack of any essential mineral nutrient, such as nitrogen, phosphorus, or potassium, in living organisms, which can result in mineral deficiency diseases. In humans, for example, lack of calcium causes poor bone development, and lack of nitrogen can cause the disease kwashiorkor, due to a deficiency in protein intake (*see* MALNUTRITION). In plants mineral deficiency results in stunted growth and *chlorosis. A deficiency of trace elements (*see* ESSENTIAL ELEMENT) also leads to diseases; for example, a deficiency of iron can cause anaemia in humans and chlorosis in plants.

mineralocorticoid *See* CORTICOSTEROID.

mineralogy The branch of geology concerned with the study of *minerals.

mineral salts Inorganic salts that need to be ingested or absorbed by living organisms for healthy growth and maintenance. They comprise the salts of the trace elements in animals (*see* ESSENTIAL ELEMENT) and the *micronutrients of plants.

minicomputer A *computer that is intermediate between a mainframe and a *microcomputer in processing power, and can be used by several people at once.

minimal supersymmetric standard model (MSSM) The smallest possible model that combines the standard model of elementary particle theory with *supersymmetry. It predicts that all the fermions and gauge bosons of the standard model should have supersymmetric partners and that there should be five *Higgs bosons.

minisatellite DNA *See* REPETITIVE DNA.

minority carrier *See* SEMICONDUCTOR.

minor planets Small solar system bodies directly orbiting the sun that include *dwarf planets, *asteroids, and *centaurs, but not comets and meteoroids. The term 'minor planet' was originally an alternative name for asteroid, but the discovery in the late 20th century of anomalous objects such as (2060) Chiron (now classified as centaurs) and the first *trans-Neptunian objects led to its broader use.

minute **1.** One sixtieth of an hour. **2.** One sixtieth of a degree (angle).

Miocene The first epoch of the *Neogene period, stretching from the end of the Oligocene, about 23 million years ago, to the start of the Pliocene, roughly 5 million years ago. It saw the radiation of several modern mammal groups, including the ruminants, certain rodents (beavers, porcupines, and cavies), and the apes. Cooling of the climate during the Oligocene resulted in a continuous shift to deciduous hardwood species, such as oak and maple, at the expense of conifers during the Miocene.

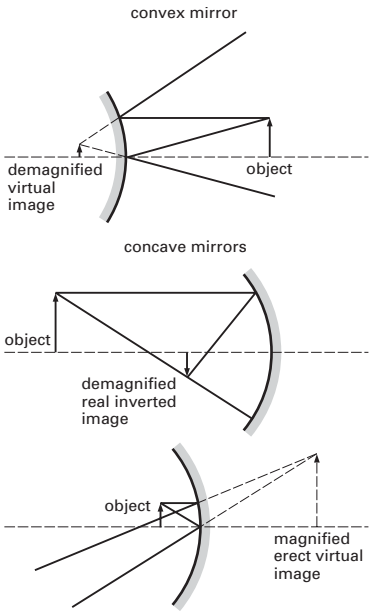
mirabilite A mineral form of *sodium sulphate, $Na_2SO_4.10H_2O$.

mirage An optical phenomenon that occurs as a result of the bending of light rays through layers of air having very large temperature gradients. An **inferior mirage** occurs when the ground surface is strongly heated and the air near the ground is much warmer that the air above. Light rays from the sky are strongly refracted upwards near the surface giving the appearance of a pool of water. A **superior mirage** occurs if the air close to the ground surface is much colder than the air above. Light is bent downwards from the object towards the viewer so that it appears to be elevated or floating in the air.

Mira-type variable star (Mira Ceti variable) A star in the red giant or red supergiant category whose radiated energy varies regularly over a quite long period. Pulsation of the surface layers is thought to be the cause of the variation, which recurs every 2 to 30 months. The stars are named after their prototype, Mira Ceti.

miRNA *See* MICRORNA.

mirror A surface that reflects most of the light falling on it. A **plane mirror** is a flat surface that produces an erect virtual *image of a real object, in which front and back are reversed. **Spherical mirrors** are formed from the surfaces of spheres and form images of real objects in much the same way as lenses.



Mirrors.

A convex mirror forms erect virtual images. They are commonly used as rear-view mirrors in road vehicles, and give a diminished wide-angle image. A concave mirror can form either inverted real images or erect virtual images. (See illustrations.) Spherical mirrors obey the *lens equation (using the real-positive sign convention) and are subject to some *aberrations similar to those of lenses.

misch metal An alloy of cerium (50%), lanthanum (25%), neodymium (18%), praseodymium (5%), and other rare earths. It is used alloyed with iron (up to 30%) in lighter flints, and in small quantities to improve the malleability of iron. It is also added to copper alloys to make them harder, to aluminium alloys to make them stronger, to magnesium alloys to reduce creep, and to nickel alloys to reduce oxidation.

missing mass The mass of matter in the universe that cannot be observed by direct observations of its emitted or absorbed electromagnetic radiation. There are a number of astrophysical observations that suggest that the actual mass of the universe is much greater than that estimated by observations using optical telescopes, radio telescopes, etc. It is thought that there is a considerable amount of **dark matter** (or **hidden matter**) causing this discrepancy. Various explanations have been put forward for the missing mass, including black holes, brown dwarfs, cosmic strings, axions, neutrinos, monopoles, and various exotic particles, such as **weakly interacting massive particles** (**WIMPS**), which are predicted to exist by supersymmetry. The universe contains far more missing matter than directly observable matter.

mitochondrial DNA (mtDNA) A circular ring of DNA found in mitochondria. In mammals mtDNA makes up less than 1% of the total cellular DNA, but in plants the amount is variable. It codes for ribosomal and transfer RNA but only some mitochondrial proteins (up to 30 proteins in animals), the nuclear DNA being required for encoding most of these. Human mtDNA contains 37 genes encoding 13 proteins and some RNAs and is generally inherited only via the female line. *See also* MITOCHONDRIAL EVE.

mitochondrial Eve The hypothetical female claimed by some biologists to be the ancestor of all humankind. Analysis of *mitochondrial DNA (mtDNA) from groups of people throughout the world suggests that mitochondrial Eve lived around 140 000 years ago, probably in Africa (hence she is also known as 'African Eve'). Mitochondrial DNA is particularly useful for investigating recent genetic history as it mutates quickly (ten times more rapidly than nuclear DNA) and in humans is inherited solely through the female line (therefore it does not undergo recombination by *crossing over). The uniformity of the different samples of mtDNA indicates that modern humans evolved relatively recently from a single region in Africa. This view has been reinforced by studies of Y chromosomes from different groups around the world, which are transmitted only through the male line.

mitochondrion A structure within the cytoplasm of eukaryotic *cells that carry out aerobic respiration: it is the site of the *Krebs cycle and *electron transport chain, and therefore the cell's energy production. Mitochondria vary greatly in shape, size, and number but are typically oval or sausage-shaped and bounded by two membranes, the inner one being folded into finger-like projections (**cristae**); they contain their own DNA (*see* MITOCHONDRIAL DNA). They are most numerous in cells with a high level of metabolic activity.

mitosis The division of a cell to form two daughter cells each having a nucleus containing the same number and kind of chromosomes as the mother cell. The changes during divisions are clearly visible with a light microscope. Each chromosome divides lengthwise into two *chromatids, which separate and form the chromosomes of the resulting daughter nuclei. The process is divided into four stages, *prophase, *metaphase, *anaphase, and *telophase, which merge into each other (see illustration). Mitotic divisions ensure that all the cells of an individual are genetically identical to each other and to the original fertilized egg. *See also* CELL CYCLE.

mitral valve *See* BICUSPID VALVE.

Mitscherlich's law (law of isomorphism) Substances that have the same crystal structure have similar chemical formulae. The law can be used to determine the formula of an unknown compound if it is isomorphous with a compound of known formula. It is named after Eilhard Mitscherlich (1794–1863).

mixed function oxidase (mixed function oxygenase) *See* MONOOXYGENASE.

mixed-valence compounds (intermediate-valence compounds) Compounds in which energy levels of *f* electrons coexist with energy bands of *s* and/or *d* electrons. Such compounds have unusual thermal and magnetic properties.

mixture A system of two or more distinct chemical substances. **Homogeneous mixtures** are those in which the atoms or molecules are interspersed, as in a mixture of gases or in a solution. **Heterogeneous mixtures** have distinguishable phases, e.g. a mixture of iron filings and sulphur. In a mixture there is no redistribution of valence electrons, and the components retain their individual chemical properties. Unlike compounds, mixtures can be separated by physical means (distillation, crystallization, etc.).

m.k.s. units A *metric system of units devised by A. Giorgi (and sometimes known as **Giorgi units**) in 1901. It is based on the metre, kilogram, and second and grew from the earlier *c.g.s. units. The electrical unit chosen to augment these three basic units was the ampere and the *permeability of space (magnetic constant) was taken as 10^{-7} H m^{-1}. To simplify electromagnetic calculations the magnetic constant was later changed to $4\pi \times 10^{-7}$ H m^{-1} to give the **rationalized MKSA system**. This system, with some modifications, formed the basis of *SI units, now used in most scientific work.

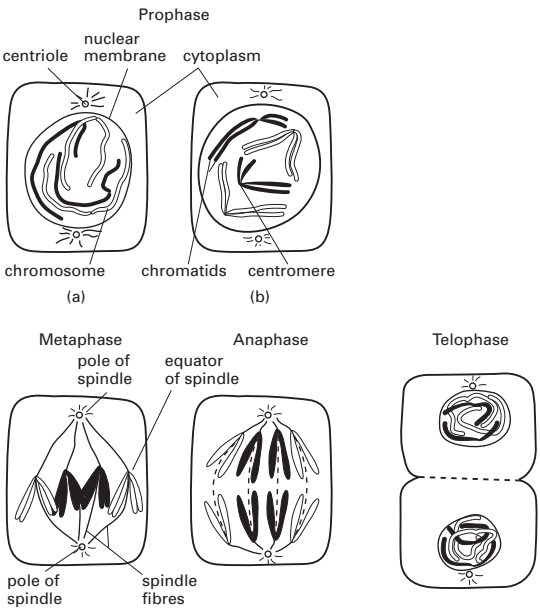
m.m.f. *See* MAGNETOMOTIVE FORCE.

mmHg A unit of pressure equal to that exerted under standard gravity by a height of one millimetre of mercury, or 133.322 pascals.

mobility (of an ion) Symbol u. The terminal speed of an ion in an electric field divided by the field strength.

mobility edge *See* LOCALIZATION.

mode The number that occurs most frequently in a set of numbers. For example, the mode (modal value) of {7, 6, 2, 1, 2, 1, 2, 4} is 2. If a continuous random variable has probability density function f(x), the mode is the value of x for which f(x) is a maximum. If such a variable has a frequency curve that is



Mitosis. The stages of mitosis in a cell containing two pairs of homologous chromosomes.

approximately symmetrical and has only one mode, then

(mean – mode) = 3(mean – median).

model A simplified description of a physical system intended to capture the essential aspects of the system in a sufficiently simple form to enable the mathematics to be solved. In practice some models require *approximation techniques to be used, rather than being exactly soluble. When exact solutions are available they can be used to examine the validity of the approximation techniques.

modem (derived from modulator/demodulator) A device that can convert a digital signal (consisting of a stream of *bits) into an analogue (smoothly varying) signal, and vice versa. Modems are therefore required to link digital devices, such as computers, over an analogue telephone line.

moderator A substance that slows down free neutrons in a *nuclear reactor, making them more likely to cause fissions of atoms of uranium–235 and less likely to be absorbed by atoms of uranium–238. Moderators are light elements, such as deuterium (in heavy water), graphite, and beryllium, to which neutrons can impart some of their kinetic energy on collision without being captured. Neutrons that have had their energies reduced in this way (to about 0.025 eV, equivalent to a speed of 2200 m s^{-1}) are said to have been **thermalized** or to have become **thermal neutrons**.

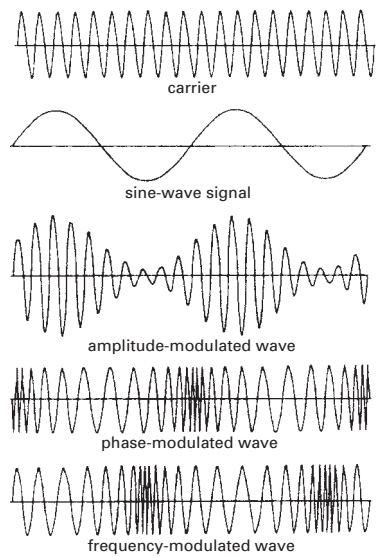
modern synthesis *See* NEO-DARWINISM.

modified Newtonian dynamics (MOND) A modification of the Newtonian theory of gravity that has been used as an alternative to the idea of dark matter (*see* MISSING MASS) to explain why the motion of stars in galaxies is not in accord with the expectations of standard Newtonian theory. It is very difficult to provide a theorical justification for MOND by deriving it from a more general theory of gravity than Newtonian gravity. It is generally, but not universally, thought that MOND is less good at describing observations on the motions of stars in galaxies than are theories involving the existence of dark matter.

modifier gene A gene that influences the expression of another gene. For example, one gene controls whether eye colour is blue or brown but other (modifier) genes can also influence the colour by affecting the amount or distribution of pigment in the iris.

modulation The process of changing an electrical signal. In radio transmission, it is the process of superimposing the characteristics of a periodic signal onto a *carrier wave so that the information contained in the signal can be transmitted by the wave. The simplest form of modulation is **amplitude modulation** (**AM**), in which the amplitude of the carrier is increased or diminished as the signal amplitude increases and diminishes. The modulated wave is composed of the carrier wave plus upper and lower sidebands. In **single-sideband modulation** (**SSB**) the carrier and one of the sidebands of an amplitude-modulated waveform are suppressed. This saves on bandwidth occupancy and signal power. In **frequency modulation** (**FM**), the frequency of the carrier is increased or diminished as the signal amplitude increases and diminishes but the carrier amplitude remains constant. In **phase modulation**, the relative phase of the carrier is varied in accordance with the signal amplitude. (See illustrations.) Both frequency modulation and phase modulation are forms of **angle modulation**.

In **pulse modulation** the information is



Modulation.

transmitted by controlling the amplitude, duration, position, or presence of a series of pulses. Morse code is a simple form of a pulse modulation.

modulus *See* ABSOLUTE VALUE.

modulus of elasticity *See* ELASTIC MODULUS.

Moho (Mohorovičić discontinuity) A discontinuity within the *earth that marks the junction between the crust and the underlying mantle. Below the discontinuity earthquake seismic waves undergo a sudden increase in velocity, a feature that was first observed in 1909 by the Croatian geophysicist Andrija Mohorovičić (1857–1936), after whom the discontinuity was named. The Moho lies at a depth of about 10–12 km below the oceans and about 33–35 km below the continents.

Mohs' scale A hardness scale in which a series of ten minerals are arranged in order, each mineral listed being scratched by and therefore softer than those below it. The minerals are: (1) talc; (2) gypsum; (3) calcite; (4) fluorite; (5) apatite; (6) orthoclase; (7) quartz; (8) topaz; (9) corundum; (10) diamond. As a rough guide a mineral with a value up to 2.5 on this scale can be scratched by a fingernail, up to 4 can be scratched by a coin, and up to 6 by a knife. The scale was devised by Friedrich Mohs (1773–1839).

moissanite A clear form of silicon carbide used as an inexpensive substitute for diamond. It is named after the French chemist Henri Moissan (1852–1907), who discovered it in 1893.

molal concentration *See* CONCENTRATION.

molality *See* CONCENTRATION.

molar **1.** (in physics and chemistry) Denoting that an extensive physical property is being expressed per *amount of substance, usually per mole. For example, the molar heat capacity of a compound is the heat capacity of that compound per unit amount of substance; in SI units it would be expressed in $J\ K^{-1}\ mol^{-1}$. **2.** (in chemistry) Having a concentration of one mole per dm^3. **3.** (in anatomy) A broad ridged tooth in the adult dentition of mammals (*see* PERMANENT TEETH), found at the back of the jaws behind the premolars. There are two or more molars on each side of both jaws; their surfaces are raised into ridges or *cusps for grinding food during chewing. In man the third (and most posterior) molar does not appear until young adulthood: these molars are known as **wisdom teeth**.

molar conductivity Symbol Λ. The conductivity of that volume of an electrolyte that contains one mole of solution between electrodes placed one metre apart.

molar heat capacity *See* HEAT CAPACITY.

molarity *See* CONCENTRATION.

molar latent heat *See* LATENT HEAT.

molar volume (molecular volume) The volume occupied by a substance per unit amount of substance.

mole Symbol mol. The SI unit of *amount of substance. It is equal to the amount of substance that contains as many elementary units as there are atoms in 0.012 kg of carbon–12. The elementary units may be atoms, molecules, ions, radicals, electrons, etc., and must be specified. 1 mole of a compound has a mass equal to its *relative molecular mass expressed in grams.

molecular beam A beam of atoms, ions, or molecules at low pressure, in which all the particles are travelling in the same direction and there are few collisions between them. They are formed by allowing a gas or vapour to pass through an aperture into an enclosure, which acts as a collimator by containing several additional apertures and vacuum pumps to remove any particles that do not pass through the apertures. Molecular beams are used in studies of surfaces and chemical reactions and in spectroscopy.

molecular biology The study of the structure and function of large molecules associated with living organisms, in particular proteins and the nucleic acids *DNA and *RNA. **Molecular genetics** is a specialized branch, concerned with the analysis of genes (*see* DNA SEQUENCING).

SEE WEB LINKS

- Webpage from the Stanford Encyclopedia of Philosophy summarizing the history, concepts and experimental approaches of molecular biology

molecular chaperone Any of a group of proteins in living cells that assist newly synthesized or denatured proteins to fold into their functional three-dimensional structures. The chaperones bind to the protein and prevent improper interactions within

the polypeptide chain, so that it assumes the correct folded orientation. This process may require energy in the form of ATP. There are several families of chaperones, including five classes of **heat-shock proteins**. These are manufactured in response to raised temperature or other forms of stress, and are presumed to help protect the cell from damage by refolding proteins that have been partially denatured by heat.

molecular clock The concept that during evolution the number of substitutions in the nucleotides of nucleic acids (DNA or RNA), and hence in the proteins encoded by the nucleic acids, is proportional to time. Hence, by comparing the DNA or proteins of species that diverged a known length of time ago (e.g. determined from fossil evidence), it is possible to calculate the average substitution rate, thereby calibrating the 'molecular clock'. Comparative studies of different proteins in various groups of organisms tend to show that the average number of amino-acid substitutions per site per year is typically around 10^{-9}. These results indicate a fairly constant rate of molecular evolution in comparable sequences of macromolecules in different organisms.

molecular distillation Distillation in high vacuum (about 0.1 pascal) with the condensing surface so close to the surface of the evaporating liquid that the molecules of the liquid travel to the condensing surface without collisions. This technique enables very much lower temperatures to be used than are used with distillation at atmospheric pressure and therefore heat-sensitive substances can be distilled. Oxidation of the distillate is also eliminated as there is no oxygen present.

molecular flow (Knudsen flow) The flow of a gas through a pipe in which the mean free path of gas molecules is large compared to the dimensions of the pipe. This occurs at low pressures; because most collisions are with the walls of the pipe rather than other gas molecules, the flow characteristics depend on the relative molecular mass of the gas rather than its viscosity. The effect was studied by M. H. C. Knudsen (1871–1949).

molecular formula *See* FORMULA.

molecular imprinting *See* GENE IMPRINTING.

molecularity The number of molecules involved in forming the activated complex in a step of a chemical reaction. Reactions are said to be **unimolecular**, **bimolecular**, or **trimolecular** according to whether 1, 2, or 3 molecules are involved.

molecular knot (knotane) A type of compound in which one or more chains of atoms in the molecule are looped in the configuration of a knot. The molecule may have only one closed chain forming the knot. If the knot is a trefoil knot the compound is chiral. Alternatively, molecular knots may have two or more separate loops tied together in a knot. In such cases there is no formal chemical bonding between the rings and they are held by *mechanical bonding. Molecular knots can be produced synthetically and also occur naturally in certain proteins.

molecular marker Any site (locus) in the genome of an organism at which the DNA base sequence varies among the different individuals of a population. Such markers generally have no apparent effect on the phenotype of the individual, but they can be determined by biochemical analysis of the DNA and are used for a variety of purposes, including chromosome mapping, DNA profiling, and genetic screening. Genetic tools, such as restriction, enzymes and the polymerase chain reaction plus the growing abundance of DNA sequence data, coupled with automated high-throughput assays, have revealed several classes of molecular markers, including *restriction fragment length polymorphisms (RFLPs), minisatellite and microsatellite DNA (*see* REPETITIVE DNA), and *single nucleotide polymorphisms (SNPs).

molecular orbital *See* ORBITAL.

molecular sieve Porous crystalline substances, especially aluminosilicates (*see* ZEOLITE), that can be dehydrated with little change in crystal structure. As they form regularly spaced cavities, they provide a high surface area for the adsorption of smaller molecules.

The general formula of these substances is $M_nO.Al_2O_3.xSiO_2.yH_2O$, where M is a metal ion and n is twice the reciprocal of its valency. Molecular sieves are used as drying agents and in the separation and purification of fluids. They can also be loaded with chemical substances, which remain separated from any reaction that is taking place around them, until they are released by heating or by displacement with a more strongly ad-

sorbed substance. They can thus be used as cation exchange mediums and as catalysts and catalyst supports. They are also used as the stationary phase in certain types of *chromatography (**molecular-sieve chromatography**).

molecular systematics (biochemical taxonomy) The use of amino-acid or nucleotide-sequence data in determining the evolutionary relationships of different organisms. Essentially it involves comparing the sequences of functionally homologous molecules from each organism being studied, and determining the number of differences between them. The greater the number of differences, the more distantly related the organisms are likely to be. Moreover, since the number of nucleotide substitutions, and hence substitutions of corresponding amino acids, is generally proportional to time, some indication of the time scale involved can be obtained (*see* MOLECULAR CLOCK). This information has proved particularly useful where there are gaps in the fossil record and can be combined with other evidence from morphology, physiology, and embryology to produce more accurate phylogenetic trees. In microbiology molecular systematics has transformed bacterial phylogeny, in particular establishing the view that there are two quite distinct lineages of *bacteria, the archaebacteria and eubacteria. There has been an equally radical reassessment of the classification of eukaryotes, which on current molecular evidence form an unrooted phylogenetic tree of eight or nine assemblages.

molecular volume *See* MOLAR VOLUME.

molecular weight *See* RELATIVE MOLECULAR MASS.

molecule One of the fundamental units forming a chemical compound; the smallest part of a chemical compound that can take part in a chemical reaction. In most covalent compounds, molecules consist of groups of atoms held together by covalent or coordinate bonds. Covalent substances that form *macromolecular crystals have no discrete molecules (in a sense, the whole crystal is a molecule). Similarly, ionic compounds do not have single molecules, being collections of oppositely charged ions.

mole fraction Symbol X. A measure of the amount of a component in a mixture. The mole fraction of component A is given by $X_A = n_A/N$, where n_A is the amount of substance of A (for a given entity) and N is the total amount of substance of the mixture (for the same entity).

Molisch's test *See* ALPHA-NAPHTHOL TEST.

Mollusca A phylum of soft-bodied invertebrates characterized by an unsegmented body differentiated into a **head**, a ventral muscular **foot** used in locomotion, and a dorsal **visceral hump** covered by a fold of skin – the *mantle – which secretes a protective shell in many species. Respiration is by means of gills or a lunglike organ and the feeding organ is a *radula. Molluscs occur in marine, freshwater, and terrestrial habitats and there are six classes, including the *Gastropoda (snails, slugs, limpets, etc.), *Bivalvia (e.g. mussels, oysters), and *Cephalopoda (squids and octopuses).

SEE WEB LINKS

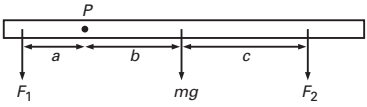
- Website of the Malacological Society of London, dedicated to the advancement of knowledge and research on molluscs

molybdenum Symbol Mo. A silvery hard metallic *transition element; a.n. 42; r.a.m. 95.94; r.d. 10.22; m.p. 2617°C; b.p. 4612°C. It is found in molybdenite (MoS_2), the metal being extracted by roasting to give the oxide, followed by reduction with hydrogen. The element is used in alloy steels. Molybdenum(IV) sulphide (MoS_2) is used as a lubricant. Chemically, it is unreactive, being unaffected by most acids. It oxidizes at high temperatures and can be dissolved in molten alkali to give a range of molybdates and polymolybdates. Molybdenum was discovered in 1778 by Karl Scheele.

SEE WEB LINKS

- Information from the WebElements site

moment of a force A measure of the turning effect produced by a force about an axis. The magnitude of the moment is the product of the force and the perpendicular distance from the axis to the line of action of the force. An object will be in rotational equilibrium if the algebraic sum of all the



Moment of a force. For equilibrium $mgb + F_2(b + c) = F_1a$, where mg is the weight of the beam acting through its centre of mass.

moments of the forces on it about any axis is zero. See illustration.

moment of inertia Symbol *I*. The moment of inertia of a massive body about an axis is the sum of all the products formed by multiplying the magnitude of each element of mass (δm) by the square of its distance (r) from the line, i.e. $I_m = \Sigma r^2 \delta m$. It is the analogue in rotational dynamics of mass in linear dynamics. The basic equation is $T = I\alpha$, where T is the torque causing angular acceleration α about the specified axis.

momentum The **linear momentum** (p) of a body is the product of its mass (m) and its velocity (v), i.e. $p = mv$. *See also* ANGULAR MOMENTUM.

monatomic molecule A 'molecule' consisting of only one atom (e.g. Ar or He), distinguished from diatomic and polyatomic molecules.

MOND *See* MODIFIED NEWTONIAN DYNAMICS.

Mond process A method of obtaining pure nickel by heating the impure metal in a stream of carbon monoxide at 50–60°C. Volatile nickel carbonyl ($Ni(CO)_4$) is formed, and this can be decomposed at higher temperatures (180°C) to give pure nickel. The method was invented by the German–British chemist Ludwig Mond (1839–1909).

Monel metal An alloy of nickel (60–70%), copper (25–35%), and small quantities of iron, manganese, silicon, and carbon. It is used to make acid-resisting equipment in the chemical industry.

monoamine oxidase (MAO) An enzyme that breaks down monoamines (e.g. *adrenaline and *noradrenaline) in the body by oxidation. Drugs that inhibit this enzyme are used to treat forms of depression.

monobasic acid An *acid that has only one acidic hydrogen atom in its molecules. Hydrochloric (HCl) and nitric (HNO_3) acids are common examples.

monochasium *See* CYMOSE INFLORESCENCE.

monochromatic radiation Electromagnetic radiation, especially visible radiation, of only one frequency or wavelength. Completely monochromatic radiation cannot be produced, but *lasers produce radiation within a very narrow frequency band. *Compare* POLYCHROMATIC RADIATION.

monochromator A device that provides *monochromatic radiation from a polychromatic source. In the case of visible radiation, for example, a prism can be used together with slits to select a small range of wavelengths.

monoclinic *See* CRYSTAL SYSTEM.

monoclonal antibody A specific *antibody produced by one of numerous identical cells derived from a single parent cell. (The population of these cells comprises a *clone and each cell is said to be **monoclonal**.) The parent cell is obtained by the fusion of a normal antibody-producing cell (a lymphocyte) with a cell derived from a malignant tumour of *lymphoid tissue of a mouse. This hybrid cell then multiplies rapidly and yields large amounts of antibody. Monoclonal antibodies are used to identify a particular antigen within a mixture and can therefore be used for identifying blood groups; they also enable the production of highly specific, and therefore effective, *vaccines.

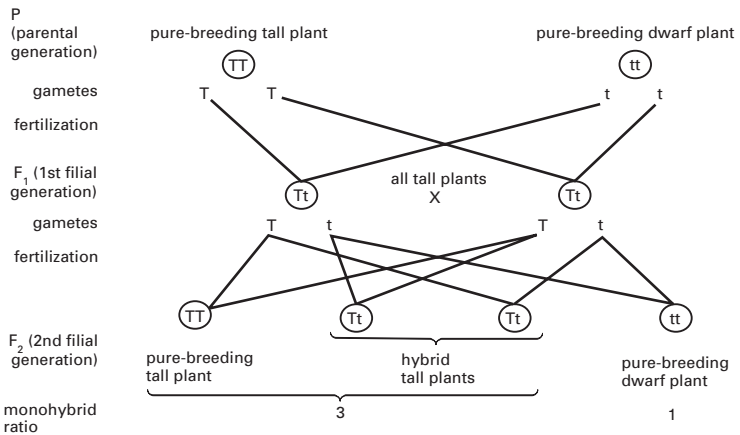
Monocotyledoneae A class of flowering plants (*see* ANTHOPHYTA), distinguished by having one seed leaf (*cotyledon) within the seed. The monocotyledons generally have parallel leaf veins, scattered vascular bundles within the stems, and flower parts in threes or multiples of three. Monocotyledon species include some crop plants (e.g. cereals, onions, fodder grasses), ornamentals (e.g. tulips, orchids, lilies), and a very limited number of trees (e.g. the palms). *Compare* DICOTYLEDONEAE; EUDICOT.

monoculture *See* AGRICULTURE.

monocyte The largest form of white blood cell (*leucocyte) in vertebrates. Monocytes have a kidney-shaped nucleus, are actively phagocytic, and are the precursors of macrophages.

monoecious Describing plant species that have separate male and female flowers on the same plant. Examples of monoecious plants are maize and birch. *Compare* DIOECIOUS.

monohybrid cross A genetic cross between parents that differ in the alleles they possess for one particular gene, one parent having two dominant alleles and the other two recessives. All the offspring (called **monohybrids**) have one dominant and one recessive allele for that gene (i.e. they are hybrid at that one locus). Crossing between



Monohybrid cross. The inheritance of stem lengths in garden peas.

these offspring yields a characteristic 3:1 (monohybrid) ratio in the following generation of dominant:recessive phenotypes (see illustration). *Compare* DIHYBRID CROSS.

monohydrate A crystalline compound having one mole of water per mole of compound.

monomer A molecule (or compound) that joins with others in forming a dimer, trimer, or polymer.

mononuclear phagocyte system (reticuloendothelial system) *See* MACROPHAGE.

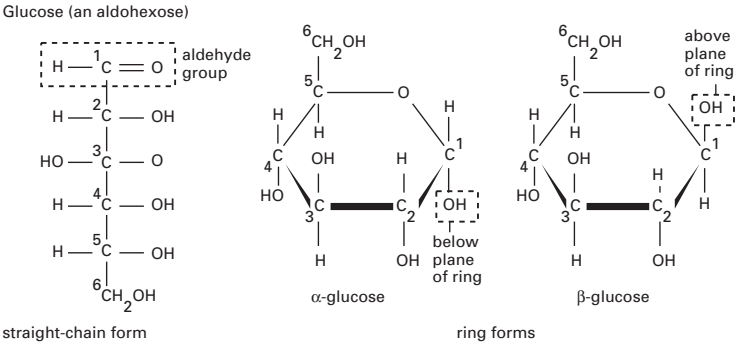
monooxygenase (mixed function oxidase; mixed function oxygenase) Any of a large group of enzymes that perform oxidation–reduction reactions in which one atom of the oxygen molecule is incorporated into the chemical donor substrate and the other oxygen atom is combined with hydrogen ions to form water. Such enzymes are commonly involved in the detoxification of harmful substances by tissues, being located in the vertebrate liver. *Cytochrome oxidase is an example.

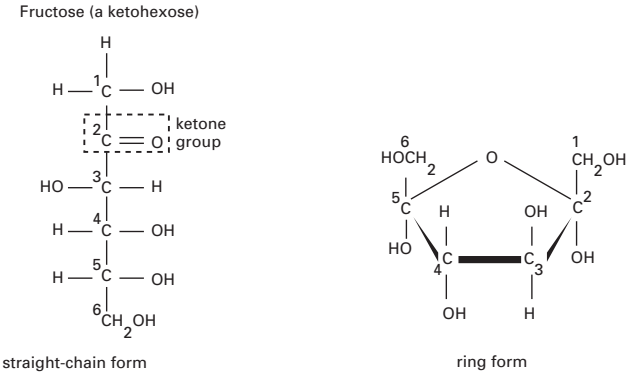
monophyletic Denoting any group of organisms that are assumed to have originated from the same ancestor, i.e. any family, class, etc., of a natural classification. Sometimes the term has a more limited meaning and designates only those groups that include *all* the descendants of a common ancestor. In this restricted sense the birds are considered monophyletic because they are the sole descendants of a group of arboreal Triassic reptiles but the modern reptiles are not, because their common amphibian ancestor also gave rise to the birds and mammals. Such groups as the reptiles are described as **paraphyletic**. *Compare* POLYPHYLETIC.

monophyodont Describing a type of dentition that consists of a single set of teeth that last for the entire lifespan of an animal. *Compare* DIPHYODONT; POLYPHYODONT.

monopodium The primary axis of growth in such plants as pine trees. It consists of a single main stem that continues to grow from the tip and gives rise to lateral branches. *Compare* SYMPODIUM.

monosaccharide (simple sugar) A carbohydrate that cannot be split into smaller units by the action of dilute acids. Monosaccharides are classified according to the number of carbon atoms they possess: **trioses** have three carbon atoms; **tetroses**, four; **pentoses**, five; **hexoses**, six; etc. Each of these is further divided into **aldoses** and **ketoses**, depending on whether the molecule contains an aldehyde group (–CHO) or a ketone group (–CO–). For example glucose, having six carbon atoms and an aldehyde group, is an **aldohexose** whereas fructose is a **ketohexose**. These aldehyde and ketone groups confer reducing properties on monosaccharides: they can be oxidized to yield sugar acids. They also react with phosphoric acid to produce phosphate esters (e.g. in *ATP), which are important in cell metabo-





Monosaccharides.

lism. Monosaccharides can exist as either straight-chain or ring-shaped molecules (see illustration). They also exhibit *optical activity, giving rise to both dextrorotatory and laevorotatory forms.

monosodium glutamate (MSG) A white solid, $C_8H_8NNaO_4.H_2O$, used extensively as a flavour enhancer, especially in convenience foods. It is a salt of glutamic acid (an *amino acid), from which it is prepared. It can cause an allergic reaction in some susceptible people who consume it.

monotremes *See* PROTOTHERIA.

monotropy *See* ALLOTROPY.

monovalent (univalent) Having a valency of one.

monozygotic twins *See* IDENTICAL TWINS.

Monte Carlo simulation A method that involves random sampling for the mathematical simulation of physical systems. Monte Carlo calculations are applied to problems that can be formulated in terms of probability and are usually carried out by computer. Such calculations have been performed for nuclei, atoms, molecules, solids, liquids, and nuclear reactors. The technique is named after the gambling centre in Monaco, renowned for its casino.

moon The earth's only natural satellite, and the only body outside the earth to have been reached by human beings (1969). It is located at a mean distance of 384 400 km and orbits around the common centre of mass that it shares with our planet once every 27.322 days. It has a diameter of 3476 km. Locked by the earth into *synchronous rotation, the moon always presents the same face to an earth-based observer. The moon is

MOON EXPLORATION

c.150 BC	Greek astronomer Hipparcus of Nicaea (c. 190–c. 120 BC) determines the distance to the moon.
1610	Galileo uses a telescope to observe the surface features of the moon.
1647	German astronomer Johannes Hevelius (1611–87) draws first map of the moon.
1757	French mathematician Alexis Clairaut (1713–65) calculates the mass of the moon.
1840	British-born US chemist William Draper (1811–82) takes photographs (daguerrotypes) of the moon.
1959	Soviet space probe Lunik I flies past the moon; Lunik II crashes on the moon; Lunik III bypasses the moon and returns pictures of the far side.
1962	US Ranger 4 space probe hits the moon.
1964	US Ranger 7 photographs the moon before crash-landing.
1965	US Ranger 8 returns TV pictures from the surface of the moon.
1966	US Lunar Orbiters 1 and 2 orbit the moon, returning photographs; US Surveyors 5 and 6 make soft landings. Soviet Luna 9 and 13 make soft landings; Luna 10 and 11 orbit the moon.
1967	US Surveyors 3, 5, and 6 make soft landings; Lunar Orbiters 3 and 4 photograph the surface.
1968	US Surveyor 7 lands on the moon. Soviet Zond 5 and 6 orbit the moon and return to earth.
1969	Astronauts from Apollo 11 and 12 land on the moon.
1970	Soviet Luna 16 lands on the moon and releases Lunakod I robot vehicle.
1971	Astronauts from Apollo 14 and 15 land on the moon.
1972	Astronauts from Apollo 16 and 17 land on the moon.
1973	Soviet Luna 21 lands on the moon and releases Lunakod II robot vehicle.
1990	Japanese scientists launch satellite Hagoromo (from another space probe) to orbit the moon.
1994	US orbiting probe Clementine maps the moon.
1998	US Lunar Prospector orbits the moon.

visible because it reflects light from the sun. As it orbits the earth, increasing and then decreasing portions of its surface are illuminated producing apparent changes of shape called *phases of the moon. On average, the moon completes one **lunation** (cycle of phases) every 29.530 59 days. Its gravitational influence on the earth plays the main role in the production of *tides.

The moon has no atmosphere or surface water. Its surface temperature varies between 80 K (night minimum) and 400 K (noon at the equator). The moon's surface consists of craters, mountains, and dark lava plains called **maria** (from the Latin *mare*, 'sea' and is scarred by long channels called **rilles**. In addition, almost all the surface is covered with a loose layer of soil and dust known as the **regolith**. See Chronology: Moon Exploration.

SEE WEB LINKS

- Lunar Navigator Full moon atlas
- Exploring the moon: a site devoted to the US Mercury, Gemini and Apollo missions

Moore's law The statement that the number of transistors that can be placed on an integrated circuit doubles every two years.

This statement was first made by Gordon Moore (1929–), the president of Intel, in 1965 and it has remained valid for the first fifty years of the existence of integrated circuits. However, there are various reasons for thinking that this will come to an end in the future. For example, as circuits become smaller, the quantum effects associated with individual atoms and electrons become more significant.

moraine A deposit of rock debris scoured from a valley floor by a glacier and left behind when the ice melts. The pieces of rock vary in size from boulders to fine sand, typically resembling *boulder clay. There are various types: a ground moraine forms underneath the glacier; a lateral moraine forms at the sides; a medial moraine occurs where two lateral moraines, from different glaciers, meet; and a terminal moraine is deposited at the lower end or toe of the glacier, usually indicating the farthest point reached by the ice. *See also* ESKER; KAME.

mordant A substance used in certain dyeing processes. Mordants are often inorganic oxides or salts, which are absorbed on the fabric. The dyestuff then forms a coloured complex with the mordant, the colour depending on the mordant used as well as the dyestuff. *See also* LAKE.

Morgan, Thomas Hunt (1866–1945) US geneticist, who held professorships at Bryn Mawr College (1891–1904), Columbia University (1904–28), and the California Institute of Technology (1928–45). He is best known for his discovery of *crossing over during *meiosis, so modifying Mendel's law of *independent assortment. For this work Morgan was awarded the 1933 Nobel Prize for physiology or medicine.

morph Any of the distinct common forms found in a population displaying *polymorphism.

morphine An opiate that is the main active constituent of opium. It is used medically in the relief of severe pain, and can be acetylated to produce heroin. Morphine can be detected by the *Marquis test.

morphogenesis The development, through growth and differentiation, of form and structure in an organism.

morphology The study of the form and structure of organisms, especially their external form. *Compare* ANATOMY.

mortality *See* DEATH RATE.

mosaic evolution The evolution of different parts of an organism at different rates. For example, many aspects of the human phenotype have evolved relatively slowly or not at all since the hominids diverged from their primate ancestors, one notable exception being the nervous system, which has given humans their overwhelming selective advantage. This high degree of evolutionary independence among different aspects of the phenotype permits flexibility; for example, when a population is faced with new selection pressures in a changing environment, only the most crucial components need to evolve, not the entire phenotype.

mosaic gold *See* TIN(IV) SULPHIDE.

Moseley's law The frequencies of the lines in the *X-ray spectra of the elements are related to the atomic numbers of the elements. If the square roots of the frequencies of corresponding lines of a set of elements are plotted against the atomic numbers a straight line is obtained. The law was discovered by Henry Moseley (1887–1915).

SEE WEB LINKS

- Original paper on the law

moss agate *See* AGATE.

Mössbauer effect An effect occurring when certain nuclides decay with emission of gamma radiation. For an isolated nucleus, the gamma radiation would usually have a spread of energies because the energy of the process is partitioned between the gamma-ray photon and the recoil energy of the nucleus. In 1957 Rudolph Mössbauer (1929–) found that in certain solids, in which the emitting nucleus is held by strong forces in the lattice, the recoil energy is taken up by the whole lattice. Since this may typically contain 10^{10}–10^{20} atoms, the recoil energy is negligible and the energy of the emitted photon is sharply defined in a very narrow energy spread.

The effect is exploited in **Mössbauer spectroscopy** in which a gamma-ray source is mounted on a moving platform and a similar sample is mounted nearby. A detector measures gamma rays scattered by the sample. The source is moved slowly towards the sample at a varying speed, so as to continuously change the frequency of the emitted gamma radiation by the Doppler effect. A sharp decrease in the signal from the detector at a particular speed (i.e. frequency) indi-

cates resonance absorption in the sample nuclei. The effect is used to investigate nuclear energy levels. In chemistry, Mössbauer spectroscopy can also give information about the bonding and structure of compounds because **chemical shifts** in the resonance energy are produced by the presence of surrounding atoms.

mosses *See* BRYOPHYTA.

MOT *See* LASER COOLING.

moths *See* LEPIDOPTERA.

motion A change in the position of a body or system with respect to time, as measured by a particular observer in a particular *frame of reference. Only relative motion can be measured; absolute motion is meaningless. *See also* EQUATION OF MOTION; NEWTON'S LAWS OF MOTION.

motivation The internal conditions responsible for temporary reversible changes in the responsiveness of an animal to external stimulation. Thus an animal that has been deprived of food will accept less palatable food than one that has not been deprived: the difference is attributed to a change in feeding motivation. Changes in responsiveness due to maturation, *learning, or injury are not usually readily reversible and are therefore not considered to be due to changes in motivation. Early attempts to describe motivation in terms of a number of separate 'drives' (e.g. food drive, sex drive) have not found general favour, partly because 'drives' interact with one another; for example, water deprivation often affects an animal's willingness to feed.

motor Any device for converting chemical energy or electrical energy into mechanical energy. *See* ELECTRIC MOTOR; INTERNAL-COMBUSTION ENGINE; LINEAR MOTOR.

motor generator An electric motor mechanically coupled to an electric generator. The motor is driven by a supply of specified voltage, frequency, or number of phases and the generator provides an output in which one or more of these parameters is different to suit a particular purpose.

motor neuron A *neuron that transmits nerve impulses from the central nervous system to an effector organ (such as a muscle or gland) and thereby initiates a physiological response (e.g. muscle contraction).

Mott insulator A substance that is an insulator because of electron correlation and in which the highest occupied energy band is not necessarily full. Certain transition metal oxides in which there are narrow bands are Mott insulators. The concept was put forward and developed by the British physicist Sir Nevill Francis Mott (1905–1996), starting in 1949.

moulting **1.** The seasonal loss of hair, fur, or feathers that occurs in mammals and birds. **2.** The periodic loss of the integument of arthropods and reptiles. *See* ECDYSIS.

mouse A simple device that is connected to a personal computer by cable and can be moved by hand over a flat surface, its movements being sensed by the rotation of a ball in its base. These movements are communicated to the computer and cause corresponding movements of the cursor on the screen; the cursor indicates the active position on the screen. One or more buttons on the mouse can be pressed to initiate an action, for example to indicate a desired cursor position for typing or to select an item from a menu of options.

mouth The opening of the *alimentary canal, which in most animals is used for the *ingestion of food. It leads to the *buccal cavity (mouth cavity).

mouth cavity *See* BUCCAL CAVITY.

mouthparts Modified paired appendages on the head segments of arthropods, used for feeding. A typical insect has a *labium (lower lip), one pair each of *mandibles and *maxillae, and a *labrum (upper lip), although in many the mouthparts are modified to form piercing stylets or a sucking proboscis. Crustaceans, centipedes, and millipedes have one pair of mandibles and two pairs of maxillae used for cutting and holding the food. Crustaceans also have several pairs of **maxillipedes**.

moving-coil instrument A measuring instrument in which current or voltage is determined by the couple on a small coil pivoted between the poles of a magnet with curved poles, giving a radial magnetic field. When a current flows through the coil it turns against a return spring. If the angle through which it turns is α, the current I is given by $I = k\alpha/BAN$, where B is the magnetic flux density, A is the area of the coil, and N is its number of turns; k is a constant depending on the strength of the return spring. The instrument is suitable for measuring d.c. but

can be converted for a.c. by means of a rectifier network. It is usually made as a *galvanometer and converted to an ammeter or voltmeter by means of a *shunt or a *multiplier.

moving-iron instrument A measuring instrument in which current or voltage is determined by the force of attraction on a bar of soft iron pivoted within the magnetic field of a fixed coil or by the repulsion between the poles induced in two soft iron rods within the coil. As the deflection caused by the passage of a current through the coil does not depend on the direction of the current, moving-iron instruments can be used with either d.c. or a.c. without a rectifier. They are, however, less sensitive than *moving-coil instruments.

moving-iron microphone *See* MICROPHONE.

mRNA *See* RNA.

MRSA *See* STAPHYLOCOCCUS.

MSG *See* MONOSODIUM GLUTAMATE.

MSH *See* MELANOCYTE-STIMULATING HORMONE.

MSSM *See* MINIMAL SUPERSYMMETRIC STANDARD MODEL.

mtDNA *See* MITOCHONDRIAL DNA.

mucilage Any of a large group of complex polysaccharides frequently present in the cell walls of aquatic plants and in the seed coats of certain other species. Mucilages are hard when dry and slimy when wet. Like *gums they probably have a general protective function or serve to anchor the plant.

mucopolysaccharide *See* GLYCOSAMINOGLYCAN.

mucous membrane (mucosa) A layer of tissue comprising an epithelium supported on connective tissue. Within the epithelium are special **goblet cells**, which secrete *mucus onto the surface, and the epithelium often bears cilia. Mucous membranes line body cavities communicating with the exterior, including the alimentary and respiratory tracts. *Compare* SEROUS MEMBRANE.

mucus The slimy substance secreted by goblet cells onto the surface of a *mucous membrane to protect and lubricate it and to trap bacteria, dust particles, etc. Mucus consists of water, various **mucoproteins** (glycoproteins), cells, and salts. The mucoprotein chains, in which the carbohydrate component is a large polysaccharide, are joined by disulphide bridges to form long **mucin** strands, which readily form gels with water.

muffle furnace An insulated furnace, usually electrically heated, used for producing controlled high temperatures. In the laboratory, muffle furnaces are used for drying solids, sintering, and studying high-temperature reactions. They typically operate in the range 100–1200°C.

multiaccess system A system allowing several users of a computer, at different terminals, to make apparently simultaneous use of the computer without being aware of each other.

multicellular Describing tissues, organs, or organisms that are composed of a number of cells. *Compare* UNICELLULAR.

multicentre bond A bond formed between three, and sometimes more, atoms that contains only a single pair of electrons. The structure of *boranes can be explained by considering them to be *electron-deficient compounds containing multicentre bonds.

multidecker sandwich *See* SANDWICH COMPOUND.

multidimensional spectroscopy A type of spectroscopy used to study complex systems and large molecules such as proteins, for which traditional spectroscopy does not give clear results. The basic technique is to excite all possible resonances in the system and analyse the radiation produced using Fourier analysis. Originally used with *nuclear magnetic resonance, versions of multidimensional spectroscopy have been developed for optical and infrared regions of the spectrum.

multifactorial inheritance *See* QUANTITATIVE INHERITANCE.

multimedia A combination of various media, such as text, sound, and moving and still images, now often held on *CD-ROM. The user can make use of the different media in an integrated way.

multimeter An electrical measuring instrument designed to measure potential differences or currents over a number of ranges. It also usually has an internal dry cell enabling resistances to be measured. Most multimeters are moving-coil instruments with a

switch to enable series resistors or parallel resistors to be incorporated into the circuit.

multiple alleles Three or more alternative forms of a gene (*alleles) that can occupy the same *locus. However, only two of the alleles can be present in a single organism. For example, the *ABO system of blood groups is controlled by three alleles, only two of which are present in an individual.

multiple bond A bond between two atoms that contains more than one pair of electrons. Such bonds primarily involve sigma bonding with secondary contribution from pi bonding (or, sometimes, delta bonding). *See* ORBITAL.

multiple proportions *See* CHEMICAL COMBINATION.

multiplet **1.** A spectral line formed by more than two (*see* DOUBLET) closely spaced lines. **2.** A group of *elementary particles that are identical in all respects except that of electric charge.

multiplication factor Symbol k. The ratio of the average number of neutrons produced in a *nuclear reactor per unit time to the number of neutrons lost by absorption or leakage in the same time. If $k = 1$, the reactor is said to be **critical**. If $k > 1$ it is **supercritical** and if $k < 1$ it is **subcritical**. *See also* CRITICAL REACTION.

multiplicity A quantity used in atomic *spectra to describe the energy levels of many-electron atoms characterized by *Russell–Saunders coupling given by $2S + 1$, where S is the total electron *spin quantum number. The multiplicity of an energy level is indicated by a left superscript to the value of L, where L is the resultant electron *orbital angular momentum of the individual electron orbital angular momenta l.

multiplier A fixed resistance used with a voltmeter, usually a *moving-coil instrument, to vary its range. Many voltmeters are provided with a series of multipliers from which the appropriate value can be selected. If the original instrument requires i amperes for full-scale deflection and the resistance of the moving coil is r ohms, the value R of the resistance of the multiplier required to give a full-scale deflection when a voltage V is applied across the terminals is given by $R = V/i - r$.

multivibrator An electronic *oscillator consisting of two active devices, usually transistors, interconnected in an electrical network. The purpose of the device is to generate a continuous square wave with which to store information in binary form in a logic circuit. This is achieved by applying a portion of the output voltage or current of each active device to the input of the other with the appropriate magnitude and polarity, so that the devices are conducting alternately for controllable periods.

mu-mesic atom *See* MUONIC ATOM.

Mumetal The original trade name for a ferromagnetic alloy, containing 78% nickel, 17% iron, and 5% copper, that had a high *permeability and a low *coercive force. More modern versions also contain chromium and molybdenum. These alloys are used in some transformer cores and for shielding various devices from external magnetic fields.

Muntz metal A form of *brass containing 60% copper, 39% zinc, and small amounts of lead and iron. Stronger than alpha-brass, it is used for hot forgings, brazing rods, and large nuts and bolts. It is named after G. F. Muntz (1794–1857).

muon *See* LEPTON; ELEMENTARY PARTICLES.

muonic atom (mu-mesic atom) An *exotic atom in which one of the electrons has been replaced by a muon. Since the mass of a muon is 207 times that of an electron, the average radius of the orbit of a muon is much smaller than that of a corresponding electron. Muonic atoms provide tests for quantum electrodynamics. They are also used in research into muon-catalysed fusion (*see* NUCLEAR FUSION).

Musci *See* BRYOPHYTA.

muscle A tissue consisting of sheets or bundles of cells (**muscle fibres**) that are capable of contracting, so producing movement or tension in the body. There are three types of muscle. *Voluntary muscle produces voluntary movement (e.g. at joints); *involuntary muscle mainly effects the movements of hollow organs (e.g. intestine and bladder); and *cardiac muscle occurs only in the heart.

SEE WEB LINKS

- Interactive tutorial identifying the principal muscles of the human body

muscle spindle A receptor in vertebrate muscle that is sensitive to stretch (*see* PROPRIOCEPTOR). Muscle spindles run parallel to

normal muscle fibres; each consists of a capsule containing small striated muscle fibres (**intrafusal fibres**). Muscle spindles are responsible for the adjustment of muscle tone and play an important role in the subconscious maintenance of posture and movement. *See also* STRETCH REFLEX.

muscovite (white mica; potash mica) A mineral consisting of potassium aluminosilicate, $K_2Al_4(Si_6Al_2)O_{20}(OH,F)_4$; one of the most important members of the *mica group of minerals. It is chemically complex and has a sheetlike crystal structure (*see* INTERCALATION COMPOUND). It is usually silvery-grey in colour, sometimes tinted with green, brown, or pink. Muscovite is a common constituent of certain granites and pegmatites. It is also common in metamorphic and sedimentary rocks. It is widely used in industry, for example in the manufacture of electrical equipment and as a filler in roofing materials, wallpapers, and paint.

mustard gas *See* SULPHUR MUSTARD; NITROGEN MUSTARDS.

mutagen An agent that causes an increase in the number of mutants (*see* MUTATION) in a population. Mutagens operate either by causing changes in the DNA of the *genes, so interfering with the coding system, or by causing chromosome damage. Various chemicals (e.g. *colchicine) and forms of radiation (e.g. X-rays) have been identified as mutagens.

mutant (Denoting) a gene or an organism that has undergone a heritable change, especially one with visible effects (i.e. the change in *genotype is associated with a change in *phenotype). *See* MUTATION.

mutarotation Change of optical activity with time as a result of spontaneous chemical reaction.

mutation A sudden random change in the genetic material of a cell that potentially can cause it and all cells derived from it to differ in appearance or behaviour from the normal type. An organism affected by a mutation (especially one with visible effects) is described as a **mutant**. **Somatic mutations** affect the nonreproductive cells and are therefore restricted to the tissues of a single organism but **germ-line mutations**, which occur in the reproductive cells or their precursors, may be transmitted to the organism's descendants and cause abnormal development.

Mutations occur naturally at a low rate but this may be increased by radiation and by some chemicals (*see* MUTAGEN). Most are *point mutations, which consist of invisible changes in the DNA of the chromosomes, but some (the *chromosome mutations) affect the appearance or the number of the chromosomes. An example of a chromosome mutation is that giving rise to *Down's syndrome.

Mutations that alter phenotypes are generally harmful, but a very small proportion may increase an organism's *fitness; these spread through the population over successive generations by natural selection. Mutation is therefore essential for evolution, being the ultimate source of genetic variation.

SEE WEB LINKS

- First of two topics on mutation from the online resource DNA From The Beginning

mutual inductance *See* INDUCTANCE.

mutualism An interaction between two species in which both species benefit. (The term *symbiosis is often used synonymously with mutualism.) A well-known example of mutualism is the association between termites and the specialized protozoans that inhabit their guts. The protozoans, unlike the termites, are able to digest the cellulose of the wood that the termites eat and release sugars that the termites absorb. The termites benefit by being able to use wood as a foodstuff, while the protozoans are supplied with food and a suitable environment. *See also* MYCORRHIZA.

mycelium A network of *hyphae that forms the body of a fungus. It consists of feeding hyphae together with reproductive hyphae, which produce *sporangia and *gametangia.

mycology The scientific study of *fungi.

Mycophycophyta *See* LICHENS.

mycoplasmas A group of bacteria that lack a rigid cell wall and are among the smallest living cells (diameter 0.1 μm–0.8 μm). They are either saprotrophic or parasitic and are found on animal mucous and synovial membranes, in insects, and in plants (in which they seem to inhabit sieve tubes). They cause a variety of diseases, including pleuropneumonia in cattle – hence they were formerly also known as **pleuropneumonia-like organisms** (**PPLO**). Due to

their small size and flexible cell wall they can pass through a 0.2-µm-diameter filter and they represent a major contaminant of biotechnological products, such as monoclonal antibodies and vaccines, and of other cell cultures, in which they may exist symbiotically with the cells. Eight genera have been described (including *Mycoplasma*) with over 120 species.

mycorrhiza The mutually beneficial association (*see* MUTUALISM) formed between fungi and the roots of plants. This is a very common form of mutualism; the absorption of mineral ions by the plant roots is enhanced by the presence of the fungus, which benefits by obtaining soluble organic nutrients from the root cells. **Ectotrophic mycorrhizas** form a network of hyphae around the root and grow into the air spaces between the cells of the root. The hyphae of **endotrophic mycorrhizas** enter the cortex cells of the roots.

Mycota In older classification systems, a kingdom comprising the *fungi.

myelin A *phospholipid produced by the *Schwann cells of the nervous system. Myelin forms an insulating layer around the nerve fibres (*see* MYELIN SHEATH).

myelin sheath (medullary sheath) The layer of fatty material that surrounds and electrically insulates the axons of most vertebrate and some invertebrate neurons. The myelin sheath enables a more rapid transmission of nerve impulses (at speeds up to 120 m s^{-1}). It consists of layers of membrane derived from *Schwann cells. The sheath is interrupted at intervals along the axon by **nodes of Ranvier**; myelinated sections of axon are called **internodes**.

myeloid tissue Tissue within red *bone marrow that produces the blood cells. It is found around the blood vessels and contains various cells that are precursors of the blood cells. *See* HAEMOPOIETIC TISSUE.

myeloma *See* CANCER.

myofibril *See* VOLUNTARY MUSCLE.

myogenic Originating in or produced by muscle cells. The contractions of *cardiac muscle fibres are described as myogenic, since they are produced spontaneously, without requiring stimulation from nerve cells (*see* PACEMAKER).

myoglobin A globular protein occurring widely in muscle tissue as an oxygen carrier. It comprises a single polypeptide chain and a *haem group, which reversibly binds a molecule of oxygen. This is only relinquished at relatively low external oxygen concentrations, e.g. during strenuous exercise when muscle oxygen demand outpaces supply from the blood. Myoglobin thus acts as an emergency oxygen store.

myopia Short-sightedness. It results from the lens of the eye refracting the parallel rays of light entering it to a focus in front of the retina generally because of an abnormally long eyeball. The condition is corrected by using diverging spectacle lenses to move the image back to the retina.

myosin A contractile protein that interacts with *actin to bring about contraction of muscle or cell movement. The type of myosin molecule found in muscle fibres consists of a tail, by which it aggregates with other myosin molecules to form so-called 'thick filaments'; and a globular head, which has sites for the attachment of actin and ATP molecules. *See* SARCOMERE.

myotatic reflex *See* STRETCH REFLEX.

myotome One of a series of segmented muscle blocks found in fishes and lancelets. Myotomes are arranged in pairs on either side of the body that work antagonistically (*see* ANTAGONISM) against the backbone (or notochord), providing a means of locomotion by causing the tail to sweep from side to side.

Myriapoda In some classifications, a subphylum of arthropods that comprises the classes *Chilopoda (centipedes), *Diplopoda (millipedes), Pauropoda (pauropods), and Symphyla (symphilids). In other classifications the Myriapoda is a class containing only the centipedes and millipedes.

myristic acid *See* TETRADECANOIC ACID.

Myxomycota *See* SLIME MOULDS.

myxovirus One of a group of RNA-containing viruses associated with various diseases of humans and other vertebrates. **Orthomyxoviruses** produce diseases of the respiratory tract, e.g. influenza; **paramyxoviruses** include the causal agents of mumps, measles, and fowl pest.