O

OB association An area in space in which young high-mass O and B type stars predominate (*see* SPECTRAL CLASS). The stars emit strong ultraviolet radiation, which ionizes the surrounding hydrogen and forms emission nebulae. Shock waves compress dust and gas, which may collapse under the force of gravity and begin the formation of more stars.

objective The *lens or system of lenses nearest to the object being examined through an optical instrument.

occipital condyle A single or paired bony knob that protrudes from the occipital bone of the skull and articulates with the first cervical vertebra (the *atlas). In humans there is a pair of occipital condyles, one on each side of the *foramen magnum. Occipital condyles are absent in most fish, which cannot move their heads.

occluded front *See* FRONT.

occlusion **1.** The trapping of small pockets of liquid in a crystal during crystallization. **2.** The absorption of a gas by a solid such that atoms or molecules of the gas occupy interstitial positions in the solid lattice. Palladium, for example, can occlude hydrogen.

occultation The obscuring of a star, planet, or other celestial body by the moon or another planet. A solar *eclipse is a form of occultation.

oceanic zone The region of the open sea beyond the edge of the continental shelf, where the depth is greater than 200 metres. *Compare* NERITIC ZONE.

oceanography The study of the oceans. It includes the origin, structure, and form of the oceans, the nature of the seafloor and its sediments, the characteristics of the ocean waters (e.g. tides, salinity, and currents), and the types of flora and fauna living within the oceans. The effects of human intervention also form an important aspect of oceanography.

ocean trench A deep narrow depression in the ocean floor, often thousands of metres deep (the Mariana Trench in the Pacific Ocean is 10 850 m deep). Trenches usually form near the edge of a continent where the tectonic plate carrying the ocean is being subducted beneath the continental plate (*see* PLATE TECTONICS). They are often associated with earthquakes and island arcs.

ocellus A simple eye occurring in insects and other invertebrates. It typically consists of light-sensitive cells and a single cuticular lens.

ochre A yellow or red mineral form of iron(III) oxide, Fe_2O_3, used as a pigment.

octadecanoate *See* STEARATE.

octadecanoic acid *See* STEARIC ACID.

octadecenoic acid A straight-chain unsaturated fatty acid with the formula $C_{17}H_{33}COOH$. **Cis-octadec-9-enoic acid** (*see* OLEIC ACID) has the formula $CH_3(CH_2)_7CH{:}CH(CH_2)_7COOH$. The glycerides of this acid are found in many natural fats and oils.

octahedral *See* COMPLEX.

octahydrate A crystalline hydrate that has eight moles of water per mole of compound.

octane A straight-chain liquid *alkane, C_8H_{18}; r.d. 0.7; m.p. –56.79°C; b.p. 125.66°C. It is present in petroleum. The compound is isomeric with 2,2,4-trimethylpentane, $(CH_3)_3CCH_2CH(CH_3)_2$, **iso-octane**). *See* OCTANE NUMBER.

octane number A number that provides a measure of the ability of a fuel to resist *knocking when it is burnt in a spark-ignition engine. It is the percentage by volume of iso-octane (C_8H_{18}; 2,2,4-trimethylpentane) in a blend with normal heptane (C_7H_{16}) that matches the knocking behaviour of the fuel being tested in a single cylinder four-stroke engine of standard design. *Compare* CETANE NUMBER.

octanitrocubane *See* CUBANE.

octanoic acid (caprylic acid) A colourless liquid straight-chain saturated *carboxylic acid, $CH_3(CH_2)_6COOH$; b.p. 239.3°C.

octavalent Having a valency of eight.

octave **1.** The interval between two musical notes that have fundamental frequencies in the ratio 2:1; the word describes the interval in terms of the eight notes of the diatonic scale. **2.** *See* LAW OF OCTAVES.

octet A stable group of eight electrons in the outer shell of an atom (as in an atom of a noble gas).

octogen *See* HMX.

ocular *See* EYEPIECE.

odd–even nucleus An atomic nucleus containing an odd number of protons and an even number of neutrons.

odd–odd nucleus An atomic nucleus containing an odd number of protons and an odd number of neutrons. There are very few stable odd–odd nuclei.

Odonata An order of insects containing the dragonflies and damselflies, most of which occur in tropical regions. Adult dragonflies have a pair of prominent *compound eyes, a compact thorax bearing two pairs of delicate membranous wings, and a long slender abdomen. They are strong fliers and prey on other insects, either in flight or at rest. The eggs are laid near or in water, and the newly hatched nymphs are aquatic and resemble the adults, with rudimentary wings. They breathe through gills and feed on small aquatic animals. The nymph leaves the water for its final moult into the terrestrial adult.

odontoblast A cell that is responsible for producing the *dentine of vertebrate teeth. Odontoblasts are found around the lining of the *pulp cavity and have processes that extend into the dentine.

oersted Symbol Oe. The unit of magnetic field strength in the *c.g.s. system. A field has a strength of one oersted if it exerts a force of one dyne on a unit magnetic pole placed in it. It is equivalent to $10^3/4\pi$ A m^{-1}. The unit was named after Hans Oersted.

Oersted, Hans Christian (1777–1851) Danish physicist, who became a professor at Copenhagen in 1806. His best-known discovery came during a lecture in 1820, when he observed the deflection of a compass needle near a wire carrying an electric current. He had discovered electromagnetism.

oesophagus (gullet) The section of the *alimentary canal that lies between the *pharynx and the stomach. It is a muscular tube whose function is to transfer food to the stomach by means of wavelike contractions (*peristalsis) along its length.

oestrogen One of a group of female sex hormones, produced principally by the ovaries, that promote the onset of *secondary sexual characteristics (such as breast enlargement and development in women) and control the *oestrous cycle (*menstrual cycle in humans). **Oestradiol** is the most important. Oestrogens are secreted at particularly high levels during ovulation, stimulating the uterus to prepare for pregnancy. They are used in *oral contraceptives (with *progestogens) and as treatment for various disorders of the female reproductive organs. Small amounts of oestrogens are produced by the adrenal glands and testes.

oestrous cycle The cycle of reproductive activity shown by most sexually mature nonpregnant female mammals except most primates (*compare* MENSTRUAL CYCLE). There are four phases:
(1) **pro-oestrus** – *Graafian follicles develop in the ovary and secrete oestrogens;
(2) **oestrus** (**heat**) – ovulation normally occurs, the female is ready to mate and becomes sexually attractive to the male;
(3) **metoestrus** – *corpus luteum develops from ruptured follicle;
(4) **dioestrus** – *progesterone secreted by corpus luteum prepares uterus for implantation.

The length of the cycle depends on the species: larger mammals typically have a single annual cycle with a well-defined breeding season (they are described as **monoestrous**). The males have a similar cycle of sexual activity. Other species may have many cycles per year (i.e. they are **polyoestrous**) and the male may be sexually active all the time.

oestrus (heat) *See* OESTROUS CYCLE.

offset *See* RUNNER.

offspring (progeny) New individual organisms that result from the process of sexual or asexual reproduction. *See also* F_1; F_2.

ohm Symbol Ω. The derived *SI unit of electrical resistance, being the resistance between two points on a conductor when a constant potential difference of one volt, applied between these points, produces a current of one ampere in the conductor. The

former **international ohm** (sometimes called the 'mercury ohm') was defined in terms of the resistance of a column of mercury. The unit is named after Georg Ohm.

Ohm, Georg Simon (1787–1854) German physicist, who taught in Cologne, Berlin, Nuremberg, and finally (1849) Munich. He is best known for formulating *Ohm's law in 1827. The unit of electrical resistance is named after him.

ohmmeter Any direct-reading instrument for measuring the value of a resistance in ohms. The instrument commonly used is a *multimeter capable of measuring also both currents and voltages. To measure resistance a dry cell and resistor are switched in series with the moving coil *galvanometer and the unknown resistance is connected across the instrument's terminals. The value of the resistance is then read off an ohms scale. Such instruments are increasingly being replaced by electronic digital multimeters.

Ohm's law The ratio of the potential difference between the ends of a conductor to the current flowing through it is constant. This constant is the *resistance of the conductor, i.e. $V = IR$, where V is the potential difference in volts, I is the current in amperes, and R is the resistance in ohms. The law was discovered in 1827 by Georg Ohm. Most materials do not obey this simple linear law; those that do are said to be **ohmic** but remain so only if physical conditions, such as temperature, remain constant. Metals are the most accurately ohmic conductors.

oil Any of various viscous liquids that are generally immiscible with water. Natural plant and animal oils are either volatile mixtures of terpenes and simple esters (e.g. *essential oils) or are *glycerides of fatty acids. Mineral oils are mixtures of hydrocarbons (e.g. *petroleum).

oil-immersion lens *See* IMMERSION OBJECTIVE.

oil of vitriol *See* SULPHURIC ACID.

oil of wintergreen Methyl salicylate (methyl 2-hydroxybenzoate, $C_8H_8O_3$), a colourless aromatic liquid ester, b.p. 223°C. It occurs in the essential oils of some plants, and is manufactured from salicylic acid. It is easily absorbed through the skin and used in medicine for treating muscular and sciatic pain. Because of its attractive smell it is also used in perfumes and food flavourings.

oil sand (tar sand; bituminous sand) A sandstone or porous carbonate rock that is impregnated with hydrocarbons. The largest deposit of oil sand occurs in Alberta, Canada (the Athabasca tar sands); there are also deposits in the Orinoco Basin of Venezuela, Russia, USA, Madagascar, Albania, Trinidad, and Romania.

oil shale A fine-grained carbonaceous sedimentary rock from which oil can be extracted. The rock contains organic matter – **kerogen** – which decomposes to yield oil when heated. Deposits of oil shale occur on every continent, the largest known reserves occurring in Colorado, Utah, and Wyoming in the USA. Commercial production of oil from oil shale is generally considered to be uneconomic unless the price of petroleum rises above the recovery costs for oil from oil shale. However, threats of declining conventional oil resources have resulted in considerable interest and developments in recovery techniques.

Oklo reactors Naturally occurring nuclear fission reactors that are believed to have existed in uranium deposits at Oklo in Gabon, West Africa, about 2000 million years ago. In 1972, French scientists noticed a slight difference in the normal $^{235}U/^{238}U$ ratio in uranium ore from Oklo. Further detailed investigations showed that there had been 15 natural reactors in the ore deposits at Oklo, operating intermittently for about 1 million years. It is thought that the geology of the mine was an important factor in the creation of these reactors, in particular, the seepage of water through overlying rock, which functioned as a moderator. A similar natural reactor has been found at Bangombe, some miles south of Oklo, but no other comparable reactors have been found anywhere in the world. The Oklo reactors are of considerable interest. They involve basic nuclear processes occurring occurring 2000 million years ago and might give insights into the time dependence of *fundamental constants. More practically, Oklo can be regarded as a 2000-million-year experiment in the containment of nuclear waste. The reactors shut down naturally when the proportion of ^{235}U decreased, and – for the same reason – natural reactors of this type could not occur today. The products of the reactor have, however, been localized because of the

geology of the region, in particular, beds of granite underlying the ore deposits.

Olbers' paradox If the universe is infinite, uniform, and unchanging the sky at night would be bright, as in whatever direction one looked one would eventually see a star. The number of stars would increase in proportion to the square of the distance from the earth; the intensity of light reaching the earth from a given star is inversely proportional to the square of the distance. Consequently, the whole sky should be about as bright as the sun. The paradox, that this is not the case, was stated by Heinrich Olbers (1758–1840) in 1826. (It had been discussed earlier, in 1744, by J. P. L. Chesaux.) The paradox is resolved by the fact that, according to the *big-bang theory, the universe is not infinite, not uniform, and not unchanging. For instance, light from the most distant galaxies displays an extreme *redshift and ceases to be visible.

oleate A salt or ester of *oleic acid.

olefines *See* ALKENES.

oleic acid An unsaturated *fatty acid with one double bond, $CH_3(CH_2)_7$-$CH{:}CH(CH_2)_7COOH$; r.d. 0.9; m.p. 13°C. Oleic acid is one of the most abundant constituent fatty acids of animal and plant fats, occurring in butterfat, lard, tallow, groundnut oil, soya-bean oil, etc. Its systematic chemical name is **cis-octadec-9-enoic acid**.

oleum *See* DISULPHURIC(VI) ACID.

olfaction The sense of smell or the process of detecting smells. This is achieved by receptors in **olfactory organs** (such as the *nose) that are sensitive to air- or water-borne chemicals. Stimulation of these receptors results in the transmission of information to the brain via the **olfactory nerve**.

SEE WEB LINKS

- Entertaining tutorial on the sense of smell compiled by Tim Jacob of Cardiff University

Oligocene The third geological epoch of the *Palaeogene period. It began about 34 million years ago, following the Eocene epoch, and extended for about 11 million years to the beginning of the Miocene epoch. The epoch was characterized by the continued rise of mammals; the first pigs, rhinoceroses, and tapirs made their appearance.

Oligochaeta A class of hermaphrodite annelid worms that bear only a few bristles (*chaetae). Oligochaetes are very abundant in freshwater and terrestrial habitats. The most familiar members of the class are the earthworm (*Lumbricus*) and the freshwater bloodworm (*Tubifex*).

oligopeptide *See* PEPTIDE.

oligosaccharide A carbohydrate (a type of *sugar) whose molecules contain a chain of up to 20 united monosaccharides. Oligosaccharides are formed as intermediates during the digestion of *polysaccharides, such as cellulose and starch.

oligotrophic Describing a body of water (e.g. a lake) with a poor supply of nutrients and a low rate of formation of organic matter by photosynthesis. *Compare* DYSTROPHIC; EUTROPHIC.

olivine An important group of rock-forming silicate minerals crystallizing in the orthorhombic system. Olivine conforms to the general formula $(Mg,Fe)_2SiO_4$ and comprises a complete series from pure magnesium silicate (forsterite, Mg_2SiO_4) to pure iron silicate (fayalite, Fe_2SiO_4). It is green, brown-green, or yellow-green in colour.

omasum The third of four chambers that form the stomach of ruminants. *See* RUMINANTIA.

omega fatty acid *See* ESSENTIAL FATTY ACIDS.

omega-minus particle A spin 3/2 *baryon made up three strange quarks (*see* STRANGENESS). The existence of the omega-minus particle, as well as its properties, were predicted by Murray Gell-Mann in 1962 as part of a scheme to classify baryons, called the **eightfold way**. The omega-minus particle was subsequently discovered experimentally, thus demonstrating the validity of the eightfold way. This discovery was historically very important in the theoretical understanding of the strong interactions (*see* FUNDAMENTAL INTERACTIONS). The mass of the omega mass particle is 1672.5 MeV and its average lifetime is 0.8×10^{-10} s. The omega minus particle has an electric charge of –1 (its *antiparticle has a charge of +1). *See* ELEMENTARY PARTICLES.

SEE WEB LINKS

- A bubble-chamber photograph of the discovery of the omega-minus particle

O

ommatidium *See* COMPOUND EYE.

omnivore An animal that eats both animal and vegetable matter. Pigs, for example, are omnivorous. *Compare* CARNIVORE; HERBIVORE.

oncogene A dominant mutant allele of a cellular gene (a **proto-oncogene**) that disrupts cell growth and division and is capable of transforming a normal cell into a cancerous cell. Mutations in proto-oncogenes tend to relax mechanisms that control the cell cycle and accelerate cell division, leading to the cell proliferation that is characteristic of cancer. Some oncogenic mutations cause inhibition of programmed cell death (*apoptosis), so that cancerous cells are less likely to be destroyed by the body's defences. Certain oncogenes of vertebrates are derived from viruses (*see* ONCOGENIC).

oncogenic Describing a chemical, organism, or environmental factor that causes the development of cancer. Some viruses are oncogenic to vertebrates, notably the *retroviruses (including the Rous sarcoma virus of chickens), human papillomavirus, and human adenovirus. These viruses contain genes (known as *oncogenes) that become integrated into the host cell's DNA and are responsible for the transformation of a normal cell into a cancerous cell. *See also* GROWTH FACTOR.

one gene–one polypeptide hypothesis The theory that each *gene is responsible for the synthesis of a single *polypeptide. It was originally stated as the **one gene–one enzyme hypothesis** by the US geneticist George Beadle (1903–89) in 1945 but later modified when it was realized that genes also encoded nonenzyme proteins and individual polypeptide chains. It is now known that some genes code for various types of RNA involved in protein synthesis.

one-pot synthesis A method of synthesizing organic compounds in which the materials used are mixed together in a single vessel and allowed to react, rather than conducting the reaction in a sequence of separate stages.

onium ion An ion formed by adding a proton to a neutral molecule, e.g. the hydroxonium ion (H_3O^+) or the ammonium ion (NH_4^+).

ontogeny The developmental course of an organism from the fertilized egg through to maturity. It has been suggested that "ontogeny recapitulates *phylogeny", i.e. the stages of development, especially of the embryo, reflect the evolutionary history of the organism. This idea is now discredited.

ontology A specification of the assumptions, terms, or concepts underlying a particular field of knowledge. For example, the **Gene Ontology** (GO) project is an international collaboration between various databases in the field of genomics to standardize terminology used by researchers. Standardization of terms in this way is vital for efficient searching of databases, particularly for devising and using automated search programs.

oocyte *See* OOGENESIS.

oogamy Sexual reproduction involving the formation and subsequent fusion of a large, usually stationary, female gamete and a small motile male gamete. The female gamete may contain nourishment for the development of the embryo, which is often retained and protected by the parent organism.

oogenesis The production and growth of the ova (egg cells) in the animal ovary. Special cells (**oogonia**) within the ovary divide repeatedly by mitosis to produce large numbers of prospective egg cells (**oocytes**). When mature, these undergo meiosis, which halves the number of chromosomes. During the first meiotic division a **polar body** and a secondary oocyte are produced. At the second meiotic division the secondary oocyte produces an ovum and a second polar body. Oocytes may be present in the ovaries at birth and may represent the total number of eggs to be produced.

oogonium **1.** The female sex organ (*gametangium) of algae and fungi. **2.** Any of the immature sex cells in the animal ovary that give rise to oocytes by mitotic divisions (*see* OOGENESIS).

Oort cloud (Öpik-Oort cloud) A spherical cloud of *comets that is believed to surround the entire solar system and provide a reservoir of long-period comets. It is estimated to contain up to 10^{12} comets and to extend from between 2000 and 5000 *astronomical units (AU) to 50 000 AU from the sun. Disturbances caused by a passing star push comets into eccentric solar orbits that may bring them to the inner solar system or else eject them from the solar system altogether. It is

named after Ernst Öpik (1893–1985) and Jan Oort (1899–1971).

oosphere (ovum; egg cell) The nonmotile female gamete in plants and some algae. In angiosperms (flowering plants) it is a cell in the *embryo sac of the ovule. In other plants it is situated in an *archegonium. In algae, such as *Fucus*, the oosphere is protected by an **oogonium** until it is shed into the water prior to fertilization. Many oospheres store food in the form of starch or oil droplets.

oospore A zygote that is produced as a result of *oogamy in certain algae and fungi. It contains food reserves, develops a protective outer covering, and enters a resting phase before germination. *Compare* ZYGOSPORE.

opacity The extent to which a medium is opaque to electromagnetic radiation, especially to light. It is the reciprocal of the *transmittance. A medium that is opaque to X-rays and gamma rays is said to be **radiopaque**.

opal A hydrous amorphous form of silica. Many varieties of opal occur, some being prized as gemstones. Common opal is usually milk white but the presence of impurities may colour it yellow, green, or red. Precious opals, which are used as gemstones, display the property of **opalescence** – a characteristic internal play of colours resulting from the interference of light rays within the stone. Black opal has a black background against which the colours are displayed. The chief sources of precious opals are Australia and Mexico. Geyserite is a variety deposited by geysers or hot springs. Another variety, diatomite, is made up of the skeletons of diatoms.

open chain *See* CHAIN.

open cluster (galactic cluster) *See* STAR CLUSTER.

open-hearth process A traditional but now obsolete method for manufacturing steel by heating together scrap, pig iron, etc., in a refractory-lined shallow open furnace heated by burning producer gas in air. It has been replaced by the *basic-oxygen process.

open reading frame *See* READING FRAME.

opera glasses *See* BINOCULARS.

operator A mathematical symbol indicating that a specified operation should be carried out. For example, the operator $\sqrt{}$ in $\sqrt{x}$ indicates that the square root of x should be taken; the operator $\mathrm{d}/\mathrm{d}x$ in $\mathrm{d}y/\mathrm{d}x$ indicates that y should be differentiated with respect to x, etc.

operculum **1.** (in zoology) A lid or flap of skin covering an aperture, such as the gill slit cover of fish and larval amphibians and the horny calcareous operculum secreted by many gastropod molluscs, which closes the opening of the shell when the animal is inside. **2.** (in botany) The cone-shaped lid of the *capsule of mosses, which is forcibly detached to release the spores.

operon A functionally integrated genetic unit for the control of gene expression in bacteria, as proposed in the *Jacob–Monod hypothesis. Typically it comprises a closely linked group of **structural genes**, coding for protein, and adjacent loci controlling their expression – an **operator site** and a **promoter site**. The structural genes tend to encode enzymes concerned with a particular biochemical pathway. *Transcription of the structural genes is prevented by binding of a **repressor** molecule to the operator site. Another molecule, the **inducer**, can bind to the repressor molecule, preventing it from binding to the operator and thus allowing the promoter site to bind the enzyme RNA polymerase, thereby initiating transcription. The repressor molecule is encoded by a **regulator gene**, which may be close to or distant from the operon. Some operons also have an **attenuator region** preceding the first structural gene, where transcription may either stall or proceed according to the amount of end-product in the cell. *See also* LAC OPERON.

opiate One of a group of drugs derived from **opium**, an extract of the poppy plant *Papaver somniferum* that depresses brain function (a **narcotic** action). Opiates include *morphine and its synthetic derivatives, such as *heroin and codeine. They are used in medicine chiefly to relieve pain, but the use of morphine and heroin is strictly controlled since they can cause drug dependence and tolerance.

opioid Any one of a group of substances that produce pharmacological and physiological effects similar to those of morphine. The **endogenous opioids**, which occur naturally in the body, include the *endorphins and *enkephalins.

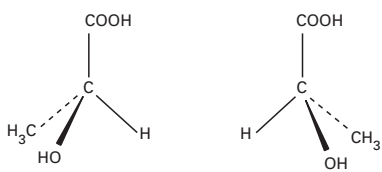
Oppenheimer–Volkoff limit The maximum mass a neutron star can have before it undergoes gravitational collapse to a *black

hole. It is more difficult to estimate this limit than the analogous *Chandrasekhar limit for white dwarf stars. It is thought that the Oppenheimer–Volkoff limit is between two and three times the mass of the sun. It was first calculated by Robert Oppenheimer and George Volkoff in 1939.

opposition The point at which a planet having its orbit outside that of the earth is in a line with the earth and the sun. When a planet is in opposition it can be observed during the night and is near to its closest point to the earth; it is therefore a favourable opportunity for observation.

opsin The lipoprotein component of *rhodopsin, the light-sensitive pigment that occurs in the rod cells of the retina.

optical activity The ability of certain substances to rotate the plane of plane-polarized light as it passes through a crystal, liquid, or solution. It occurs when the molecules of the substance are asymmetric, so that they can exist in two different structural forms each being a mirror image of the other (*see* CHIRALITY ELEMENT). The two forms are **optical isomers** or **enantiomers**. The existence of such forms is also known as **enantiomorphism** (the mirror images being **enantiomorphs**). One form will rotate the light in one direction and the other will rotate it by an equal amount in the other. The two possible forms are described as *dextrorotatory or *laevorotatory according to the direction of rotation. An equimolar mixture of the two forms is not optically active. It is called a **racemic mixture** (or **racemate**). Prefixes are used to designate the isomer: (+)- (dextrorotatory), (–)- (laevorotatory), and (±)- (racemic mixture) are now preferred to, and increasingly used for, the former *d*-, *l*-, and *dl*-, respectively. In addition, certain molecules can have a **meso-isomer** in which one part of the molecule is a mirror image of the other. Such molecules are not optically active.



D-form L-form

Optical activity.

Molecules that show optical activity have no plane of symmetry. The commonest case of this is in organic compounds in which a carbon atom is linked to four different groups. An atom of this type is said to be a **chiral centre**. Asymmetric molecules showing optical activity can also occur in inorganic compounds. For example, an octahedral complex in which the central ion coordinates to six different ligands would be optically active. Many naturally occurring compounds show optical isomerism and usually only one isomer occurs naturally. For instance, glucose is found in the dextrorotatory form. The other isomer, (–)- or *l*-glucose, can be synthesized in the laboratory, but cannot be synthesized by living organisms. *See also* ABSOLUTE CONFIGURATION.

optical axis (principal axis; optic axis) The line passing through the *optical centre and the centre of a curvature of a *lens or spherical *mirror.

optical brightener *See* BRIGHTENERS.

optical centre The point at the geometrical centre of a *lens through which a ray of light entering the lens passes without deviation.

optical fibre A *wave guide through which light can be transmitted with very little leakage through the sidewalls. In the **step-index fibre** a pure glass core, with a diameter between 6 and 250 micrometres, is surrounded by a coaxial glass or plastic cladding of lower refractive index. The cladding is usually between 10 and 150 micrometres thick. The interface between core and cladding acts as a cylindrical mirror at which *total internal reflection of the transmitted light takes place. This structure enables a beam of light to travel through many kilometres of fibre. In the **graded-index fibre**, each layer of glass, from the fibre axis to its outer wall, has a slightly lower refractive index than the layer inside it. This arrangement also prevents light from escaping through the fibre walls by a combination of refraction and total internal reflection, and can be made to give the same transit time for rays at different angles.

Fibre-optic systems use optical fibres to transmit information, in the form of coded pulses or fragmented images (using bundles of fibres), from a source to a receiver. They are also used in medical instruments (**fibrescopes**) to examine internal body cavities, such as the stomach and bladder.

optical flat A flat glass disc having very accurately polished surfaces so that the deviation from perfect flatness does not exceed (usually) 50 nanometres. It is used to test the flatness of such plane surfaces as gauge anvils by means of the *interference patterns formed when parallel beams of light pass through the flat and are reflected by the surface being inspected.

Surfaces are said to be **optically flat** if the deviation from perfect flatness is smaller than the wavelength of light.

optical glass Glass used in the manufacture of lenses, prisms, and other optical parts. It must be homogeneous and free from bubbles and strain. Optical **crown glass** may contain potassium or barium in place of the sodium of ordinary crown glass and has a refractive index in the range 1.51 to 1.54. **Flint glass** contains lead oxide and has a refractive index between 1.58 and 1.72. Higher refractive indexes are obtained by adding lanthanoid oxides to glasses; these are now known as lanthanum crowns and flints.

optical isomers *See* OPTICAL ACTIVITY.

optical lattice A periodic array produced by interference between laser beams propagating in opposite directions. The interference results in a periodic potential, and it is possible to trap atoms at the minima of this potential. Optical lattices can be formed in two or three dimensions. They have been used to study many aspects of quantum mechanics, particularly the theory of many-body systems, and as *optical traps.

optical lever An experimental device used to measure angular rotation (e.g. in a *galvanometer or *torsion balance). Typically, a small mirror is attached to the rotating object, and a beam of light is directed onto the mirror and reflected onto a scale. The angle turned through by the beam is twice the angle turned through by the mirror.

optical microscope *See* MICROSCOPE.

optical molasses *See* LASER COOLING.

optical pumping *See* LASER.

optical pyrometer *See* PYROMETRY.

optical rotary dispersion (ORD) The effect in which the amount of rotation of plane-polarized light by an optically active compound depends on the wavelength. A graph of rotation against wavelength has a characteristic shape showing peaks or troughs.

optical rotation Rotation of plane-polarized light. *See* OPTICAL ACTIVITY.

optical telescope *See* TELESCOPE.

optical temperature *See* RADIATION TEMPERATURE.

optical trap A device for trapping small particles using electromagnetic radiation. Both *optical lattices and *optical tweezers can be used as optical traps.

optical tweezers A device that is used to manipulate particles such as atoms or molecules. It works by pushing the particles about by *radiation pressure associated with a laser. Since optical tweezers can be used to manipulate strands of DNA they may have important applications in biotechnology.

optic axis **1.** The direction in a doubly refracting crystal in which light is transmitted without double refraction. **2.** *See* OPTICAL AXIS.

optic lobes *See* MIDBRAIN.

optic nerve The second *cranial nerve: a paired sensory nerve that runs from each eye to the brain. It is responsible for conveying visual stimuli received by the rods and cones in the retina to the brain for interpretation.

optics The study of *light and the phenomena associated with its generation, transmission, and detection. In a broader sense, optics includes all the phenomena associated with infrared and ultraviolet radiation. **Geometrical optics** assumes that light travels in straight lines and is concerned with the laws controlling the reflection and refraction of rays of light. **Physical optics** deals with phenomena that depend on the wave nature of light, e.g. diffraction, interference, and polarization.

oral cavity *See* BUCCAL CAVITY.

oral contraceptive Any hormonal preparation taken in the form of a pill to prevent conception (*see* BIRTH CONTROL). The most common form is the combined pill, which contains an *oestrogen and a *progestogen. Both act to suppress ovulation, while the progestogen additionally causes changes in the viscosity of cervical mucus and alters the lining of the womb, both of which decrease the chances of fertilization should ovulation occur. The so-called 'minipill' contains only

a progestogen and has fewer side effects than the combined pill. Emergency contraception (the so-called 'morning-after pill'), to prevent pregnancy after unprotected sexual intercourse, consists of two spaced doses of either a combined oestrogen–progestogen preparation or an oestrogen alone, the first dose being taken within 72 hours of intercourse.

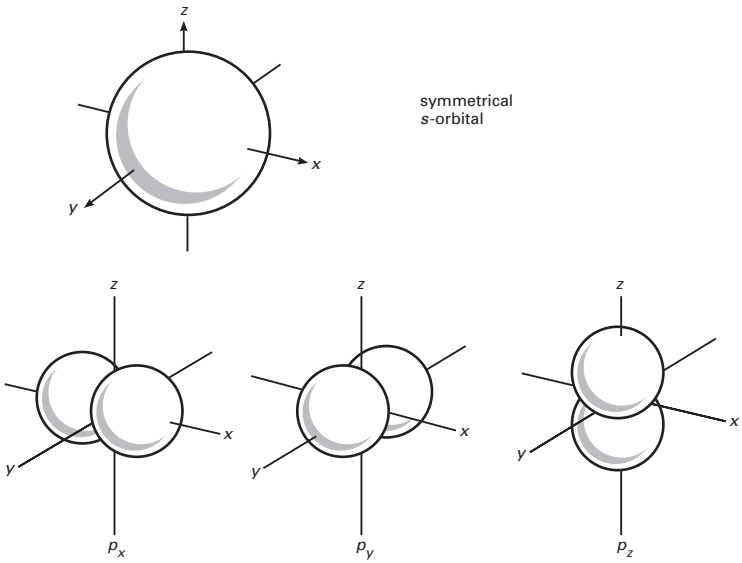
orbit **1.** (in astronomy) The path through space of one celestial body about another. For one small body moving in the gravitational field of another the orbit is a *conic section. Most such orbits are elliptical and most planetary orbits in the solar system are nearly circular. The shape and size of an elliptical orbit is specified by its eccentricity, *e*, and the length of its semimajor axis, *a*. **2.** (in physics) The path of an electron as it travels round the nucleus of an atom. *See* ORBITAL. **3.** (in anatomy) Either of the two sockets in the skull of vertebrates that house the eyeballs.

orbital A region in which an electron may be found in an atom or molecule. In the original *Bohr theory of the atom the electrons were assumed to move around the nucleus in circular orbits, but further advances in quantum mechanics led to the view that it is not possible to give a definite path for an electron. According to *wave mechanics, the electron has a certain probability of being in a given element of space. Thus for a hydrogen atom the electron can be anywhere from close to the nucleus to out in space but the maximum probability in spherical shells of equal thickness occurs in a spherical shell around the nucleus with a radius equal to the Bohr radius of the atom. The probabilities of finding an electron in different regions can be obtained by solving the Schrödinger wave equation to give the wave function ψ, and the probability of location per unit volume is then proportional to $|\psi|^2$. Thus the idea of electrons in fixed orbits has been replaced by that of a probability distribution around the nucleus – an **atomic orbital** (see illustration). Alternatively, the orbital can be thought of as an electric charge distribution (averaged over time). In representing orbitals it is convenient to take a surface enclosing the space in which the electron is likely to be found with a high probability.

The possible atomic orbitals correspond to subshells of the atom. Thus there is one *s*-orbital for each shell (orbital quantum number $l = 0$). This is spherical. There are three *p*-orbitals (corresponding to the three values of l) and five *d*-orbitals. The shapes of orbitals depend on the value of l. For instance, *p*-orbitals each have two lobes; most *d*-orbitals have four lobes.

In molecules, the valence electrons move under the influence of two nuclei (in a bond involving two atoms) and there are corresponding **molecular orbitals** for electrons (see illustration). It is convenient in considering these to regard them as formed by overlap of atomic orbitals. In a hydrogen molecule the *s*-orbitals on the two atoms overlap and form a molecular orbital between the two nuclei. This is an example of a **sigma orbital**. In a double bond, as in ethene, one bond is produced by overlap along the line of axes to form a sigma orbital. The other is produced by sideways overlap of the lobes of the *p*-orbitals (see illustration). The resulting molecular orbital has two parts, one on each side of the sigma orbital – this is a **pi orbital**. It is also possible for a **delta orbital** to form by lateral overlap of two *d*-orbitals. In fact, the combination of two atomic orbitals produces two molecular orbitals with different energies. The one of lower energy is the **bonding orbital**, holding the atoms together; the other is the **antibonding orbital**, which would tend to push the atoms apart. In the case of valence electrons, only the lower (bonding) orbital is filled.

In considering the formation of molecular orbitals it is often useful to think in terms of **hybrid** atomic orbitals. For instance, carbon has in its outer shell one *s*-orbital and three *p*-orbitals. In forming methane (or other tetrahedral molecules) these can be regarded as combining to give four equivalent sp^3 hybrid orbitals, each with a lobe directed to a corner of a tetrahedron. It is these that overlap with the *s*-orbitals on the hydrogen atoms. In ethene, two *p*-orbitals combine with the *s*-orbital to give three sp^2 hybrids with lobes in a plane pointing to the corners of an equilateral triangle. These form the sigma orbitals in the C–H and C–C bonds. The remaining *p*-orbitals (one on each carbon) form the pi orbital. In ethyne, sp^2 hybridization occurs to give two hybrid orbitals on each atom with lobes pointing along the axis. The two remaining *p*-orbitals on each carbon form two pi orbitals. Hybrid atomic orbitals can also involve *d*-orbitals. For instance, square-planar complexes use sp^2d hybrids; octahedral complexes use sp^3d^2.



molecular orbitals: formation of the double bond in ethene

Orbitals.

orbital quantum number *See* ATOM.

orbital resonance An effect in *celestial mechanics resulting from a situation in which two bodies have periods of revolution that are in a simple whole-number ratio, allowing each body to have a regularly recurring gravitational effect upon the other. Depending on the mass of each body concerned, orbital resonance can either stabilize the orbits and protect them from being perturbed, or destabilize the orbit of one of the bodies, ejecting it from its path into a new one or making its path more elliptical. *See also* KIRKWOOD GAP.

orbital velocity (orbital speed) The speed of a satellite, spacecraft, or other body

travelling in an *orbit around the earth or around some other celestial body. If the orbit is elliptical, the orbital speed, v, is given by:

$$v = \sqrt{[gR^2(2/r - 1/a)]},$$

where g is the accceleration of free fall, R is the radius of the orbited body, a is the semi-major axis of the orbit, and r is the distance between the orbiting body and the centre of mass of the system. If the orbit is circular, $r = a$ and $v = \sqrt{(gR^2/r)}$.

OR circuit *See* LOGIC CIRCUITS.

order **1.** (in chemistry) In the expression for the rate of a chemical reaction, the sum of the powers of the concentrations is the overall order of the reaction. For instance, in a reaction

$$A + B \rightarrow C$$

the rate equation may have the form

$$R = k[A][B]^2$$

This reaction would be described as **first order** in A and **second order** in B. The overall order is three. The order of a reaction depends on the mechanism and it is possible for the rate to be independent of concentration (**zero order**) or for the order to be a fraction. *See also* MOLECULARITY; PSEUDO ORDER.
2. (in mathematics) The number of times a variable is differentiated. dy/dx represents a first-order derivative, d^2y/dx^2 a second-order derivative, etc. In a *differential equation the order of the highest derivative is the order of the equation. $d^2y/dx^2 + 2dy/dx = 0$ is a second-order equation of the first degree. *See also* DEGREE.
3. (in taxonomy) A category used in the *classification of organisms that consists of one or several similar or closely related families. Similar orders form a class. Order names typically end in *-ales* in botany, e.g. Rosales (roses and orchard fruits), and in *-a* in zoology, e.g. Carnivora (flesh eaters).
4. (in physics) A category of *phase transition.

order of magnitude A value expressed to the nearest power of ten.

order parameter A quantity that characterizes the order of a phase of a system below its *transition temperature. An order parameter has a non-zero value below the transition temperature and a zero value above the transition temperature. An example of an order parameter is magnetization (*see* MAGNETISM) in a ferromagnetic system. If the phase transition is continuous (i.e. there is no *latent heat), the order parameter goes to zero continuously as the transition temperature is approached from below. **Disorder parameters** are quantities that are non-zero above the transition temperature and zero beneath it. Order parameters are associated with the *broken symmetry of a system.

ordinary ray *See* DOUBLE REFRACTION.

ordinate *See* CARTESIAN COORDINATES.

Ordovician The second geological period of the Palaeozoic era, following the Cambrian and preceding the Silurian periods. It began about 488 million years ago and lasted for about 44 million years. The period was named by the British geologist Charles Lapworth (1842–1920) in 1879. *Graptolites, in deep-water deposits, are the dominant fossils. Other fossils include *trilobites, brachiopods, bryozoans, gastropods, bivalves, echinoids, crinoids, nautiloid cephalopods, and the first corals.

ore A naturally occurring mineral from which a metal and certain other elements (e.g. phosphorus) can be extracted, usually on a commercial basis. Metals may be present in ores in the native form, but more commonly they occur combined as oxides, sulphides, sulphates, silicates, etc.

ore dressing *See* BENEFICIATION.

oregonator A type of chemical reaction mechanism that causes an *oscillating reaction. It is the type of mechanism responsible for the *B–Z reaction, and involves five steps of the form:

$$A + Y \rightarrow X$$

$$X + Y \rightarrow C$$

$$A + X \rightarrow 2X + Z$$

$$2X \rightarrow D$$

$$Z \rightarrow Y$$

Autocatalysis occurs as in the *Lotka–Volterra mechanism and the *brusselator. The mechanism was named after Oregon in America, where the research group that discovered it is based.

organ Any distinct part of an organism that is specialized to perform one or a number of functions. Examples are ears, eyes, lungs, and kidneys (in animals) and leaves, roots, and flowers (in plants). A given organ will contain many different *tissues.

organ culture The culture of complete living organs (**explants**) of animals and plants outside the body in a suitable culture medium. Animal organs must be small enough to allow the nutrients in the culture medium to penetrate all the cells. Whole plant roots and even root systems can be kept alive in such conditions for a considerable period of time. *See also* EXPLANTATION.

organelle A minute structure within a eukaryotic *cell that has a particular function. Examples of organelles are the nucleus, mitochondria, and lysosomes.

organic chemistry The branch of chemistry concerned with compounds of carbon.

organic evolution The process by which changes in the genetic composition of populations of organisms occur in response to environmental changes. *See* ADAPTATION; EVOLUTION. *Compare* BIOCHEMICAL EVOLUTION.

organism An individual living system, such as an animal, plant, or *microorganism, that is capable of reproduction, growth, and maintenance.

organizer An area of an animal embryo that causes adjacent areas of the embryo to develop in a certain way. The **primary organizer** (blastopore lip or archenteron roof) directs the overall development of the *gastrula.

organo- Prefix used before the name of an element to indicate compounds of the elements containing organic groups (with the element bound to carbon atoms). For example, lead(IV) tetraethyl is an organolead compound.

organogenesis The formation of organs during embryonic development. In animals this begins following the rearrangement of the cells at gastrulation, when the three germ layers are fully formed in their correct positions. Dividing cells of the *gastrula begin to differentiate and the rudimentary organs and organ systems begin to form. *See* DIFFERENTIATION; ECTODERM; ENDODERM; MESODERM.

organometallic compound A compound in which a metal atom or ion is bound to an organic group. Organometallic compounds may have single metal–carbon bonds, as in the aluminium alkyls (e.g. $Al(CH_3)_3$). In some cases, the bonding is to the pi electrons of a double bond, as in complexes formed between platinum and ethene, or to the pi electrons of a ring, as in *ferrocene.

SEE WEB LINKS

- Information about IUPAC nomenclature
- Further information about nomenclature

orgasm The climax of sexual excitement in humans, which – in males – coincides with *ejaculation. A sense of physiological and emotional release is accompanied by a feeling of extreme pleasure.

origin *See* CARTESIAN COORDINATES.

origin of life The process by which living organisms developed from inanimate matter, which is generally thought to have occurred on earth between 3500 and 4000 million years ago. It is supposed that the primordial atmosphere was like a chemical soup containing all the basic constituents of organic matter: ammonia, methane, hydrogen, and water vapour. These underwent a process of chemical evolution using energy from the sun and electric storms to combine into ever more complex molecules, such as amino acids, proteins, and vitamins. Eventually self-replicating nucleic acids, the basis of all life, could have developed. The very first organisms may have consisted of such molecules bounded by a simple membrane. *See* PROTEINOID.

origin of the elements The nuclear processes that give rise to chemical elements. There is not one single process that can account for all the elements. The abundance of the chemical elements is determined not just by the stability of the nuclei of the atoms but also how readily the nuclear processes leading to the existence of these atoms occur. Most of the helium in the universe was produced by fusion in the early universe when the temperature and the pressure were very high. Most of the elements between helium and iron were made in nuclear fusion reactions inside stars. Since iron is at the bottom of an energy valley of stability, energy needs to be put into a nucleus heavier than iron for a fusion reaction to occur. Inside stars some heavy elements are built up by the **s-process**, where s stands for slow, in which high-energy neutrons are absorbed by a nucleus, with the resulting nucleus undergoing beta decay to produce a nucleus with a higher atomic number. Other heavy elements are produced by the **r-**

process, where r stands for rapid, which occurs in supernova explosions.

ornithine (Orn) An *amino acid, $H_2N(CH_2)_3CH(NH_2)COOH$, that is not a constituent of proteins but is important in living organisms as an intermediate in the reactions of the *urea cycle and in arginine synthesis.

ornithine cycle *See* UREA CYCLE.

orogenesis The process by which major mountain chains are formed. This includes the deformational processes of thrusting, folding, and faulting that result from the collision of two continents. Examples of mountains formed through orogenesis include the Alpine–Himalayan, Appalachian, and Cordilleran orogenic belts.

orpiment A natural yellow mineral form of arsenic(III) sulphide, As_2S_3. The name is also used for the synthetic compound, which is used as a pigment.

ortho- **1.** Prefix indicating that a benzene compound has two substituted groups in the 1,2 positions (i.e. on adjacent carbon atoms). The abbreviation *o-* is used; for example *o*-dichlorobenzene is 1,2-dichlorobenzene. *Compare* META-; PARA-. **2.** Prefix formerly used to indicate the most hydrated form of an acid. For example, phosphoric(V) acid, H_3PO_4, was called orthophosphoric acid to distinguish it from the lower metaphosphoric acid, HPO_3, which is actually $(HPO_3)_n$.

orthoboric acid *See* BORIC ACID.

orthoclase *See* FELDSPARS.

orthogenesis An early theory of the nature of evolutionary change, which proposed that organisms evolve along particular paths predetermined by some factor in their genetic make-up. More recent understanding of selection pressure and other external forces that can be shown experimentally to affect the survival of organisms has proved the improbability of the theory.

orthohydrogen *See* HYDROGEN.

orthophosphoric acid *See* PHOSPHORIC(V) ACID.

orthoplumbate *See* PLUMBATE.

orthopositronium *See* POSITRONIUM.

Orthoptera A large order of insects containing the grasshoppers, locusts, crickets, and – in some classification systems – the cockroaches (*see* DICTYOPTERA). They are characterized by enlarged hind legs modified for jumping and biting mouthparts and produce sounds by *stridulation. The crickets and long-horned grasshoppers (e.g. *Gryllus*, *Tettigonia*) have long threadlike antennae and stridulate by rubbing together modified veins on their forewings. The hearing organs are on the front legs. The short-horned grasshoppers and locusts (e.g. *Chorthippus*, *Locusta*) have short antennae and stridulate by rubbing pegs on the hind leg against a hardened vein on the forewing. The hearing organs are on the abdomen.

orthorhombic *See* CRYSTAL SYSTEM.

orthosilicate *See* SILICATE.

orthostannate *See* STANNATE.

orthotropism The tendency for a *tropism (growth response of a plant) to be orientated directly in line with the stimulus concerned. An example is the vertical growth of main stems and roots in response to gravity (**orthogeotropism**). *Compare* PLAGIOTROPISM.

oscillating reaction (clock reaction) A type of chemical reaction in which the concentrations of the products and reactants change periodically, either with time or with position in the reacting medium. Thus, the concentration of a component may increase with time to a maximum, decrease to a minimum, then increase again, and so on, continuing the oscillation over a period of time. Systems are also known in which spirals and other patterns spread through the reacting medium, demonstrating a periodic spatial variation. Oscillating chemical reactions have certain features in common. They all occur under conditions far from chemical equilibrium and all involve *autocatalysis, i.e. a product of a reaction step acts as a catalyst for that step. This autocatalysis drives the oscillation by a process of positive feedback. Moreover, oscillating chemical reactions are associated with the phenomenon known as **bistability**. In this, a reaction may be in a steady-state condition, with reactants flowing into a reaction zone while products are flowing out of it. Under these conditions, the concentrations in the reaction zone may not change with time, although the reaction is not in a state of chemical equilibrium. Bistable systems have two possible stable steady states. Interaction with an additional

substance in the reaction medium causes the system to oscillate between the states as the concentrations change. Oscillating chemical reactions are thought to occur in a number of biochemical processes. For example, they occur in glycolysis, in which ATP is produced by enzyme-catalysed reactions. They are also known to regulate the rhythm of the heartbeat. Most have highly complex reaction mechanisms. *See* LOTKA–VOLTERRA MECHANISM; BRUSSELATOR; OREGONATOR. *See also* CHAOTIC REACTION.

oscillator An electronic device that produces an alternating output of known frequency. If the output voltage or current has the form of a sine wave with respect to time, the device is called a **sinusoidal** (or **harmonic**) **oscillator**. If the output voltage changes abruptly from one level to another (as in a *square wave or *sawtooth wave) it is called a **relaxation oscillator**. A harmonic oscillator consists of a frequency-determining circuit or device, such as a *resonant circuit, maintained in oscillation by a source of power that by positive feedback also makes up for the resistive losses. In some relaxation oscillators the circuit is arranged so that in each cycle energy is stored in a reactive element (a capacitor or inductor) and subsequently discharged over a different time interval. *See also* MULTIVIBRATOR.

oscillatory universe A cosmological model in which the universe has repeated periods of expansion followed by contraction; i.e. a series of big bangs interspersed with big crunches. It was originally put forward in 1922 by the Russian physicist Alexander Friedman (1888–1925). The theory was criticized because it led eventually to an increasing entropy (i.e. heat death). *See also* EKPYROTIC UNIVERSE.

oscilloscope *See* CATHODE-RAY OSCILLOSCOPE.

osmiridium A hard white naturally occurring alloy consisting principally of osmium (17–48%) and iridium (49%). It also contains small quantities of platinum, rhodium, and ruthenium. It is used for making small items subject to wear, e.g. electrical contacts or the tips of pen nibs.

osmium Symbol Os. A hard blue-white metallic *transition element; a.n. 76; r.a.m. 190.2; r.d. 22.57; m.p. 3045°C; b.p. 5027°C. It is found associated with platinum and is used in certain alloys with platinum and iridium (*see* OSMIRIDIUM). Osmium forms a number of complexes in a range of oxidation states. It was discovered by Smithson Tennant (1761–1815) in 1804.

SEE WEB LINKS

- Information from the WebElements site

osmium(IV) oxide (osmium tetroxide) A yellow solid, OsO_4, made by heating osmium in air. It is used as an oxidizing agent in organic chemistry, as a catalyst, and as a fixative in electron microscopy.

osmometer *See* OSMOSIS.

osmoreceptor A receptor situated in the hypothalamus of the brain that responds to an increase in the concentration of the extracellular fluid. This results in the release of *antidiuretic hormone (ADH) and the subsequent conservation of water, thereby maintaining the *homeostasis of the body fluids.

osmoregulation The control of the water content and the concentration of salts in the body of an animal or protist. In freshwater species osmoregulation must counteract the tendency for water to pass into the animal by *osmosis. Various methods have been developed to eliminate the excess, such as *contractile vacuoles in protozoans and *kidneys with well-developed glomeruli in freshwater fish. Marine vertebrates have the opposite problem: they prevent excessive water loss and enhance the excretion of salts by having kidneys with few glomeruli and short tubules. In terrestrial vertebrates the dangers of desiccation are reduced by the presence of long convoluted kidney tubules, which increase the reabsorption of water and salts.

osmosis The passage of a solvent through a **semipermeable membrane** separating two solutions of different concentrations. A semipermeable membrane is one through which the molecules of a solvent can pass but the molecules of most solutes cannot. There is a thermodynamic tendency for solutions separated by such a membrane to become equal in concentration, the water (or other solvent) flowing from the weaker to the stronger solution. Osmosis will stop when the two solutions reach equal concentration, and can also be stopped by applying a pressure to the liquid on the stronger-solution side of the membrane. The pressure required to stop the flow from a pure solvent into a solution is a characteristic of the solution, and is called the **osmotic pressure** (symbol Π). Osmotic pressure de-

pends only on the concentration of particles in the solution, not on their nature (i.e. it is a *colligative property). For a solution of n moles in volume V at thermodynamic temperature T, the osmotic pressure is given by $\Pi V = nRT$, where R is the gas constant. Osmotic-pressure measurements are used in finding the relative molecular masses of compounds, particularly macromolecules. A device used to measure osmotic pressure is called an **osmometer**.

The distribution of water in living organisms is dependent to a large extent on osmosis, water entering the cells through their membranes. A cell membrane is not truly semipermeable as it allows the passage of certain solute molecules; it is described as **partially permeable**. Osmosis in plants is now usually described in terms of *water potential: water moves from an area of high (less negative) water potential to an area of low (more negative) water potential (*see also* PLASMOLYSIS; TURGOR; WILTING). Animals have evolved various means to counteract the effects of osmosis (*see* OSMOREGULATION); in water relations in animals solutions are still described in terms of osmotic pressure.

osmotic pressure *See* OSMOSIS.

ossification The process of *bone formation. It is brought about by the action of special cells called *osteoblasts, which deposit layers of bone in connective tissue. Some bones are formed directly in connective tissue (*see* MEMBRANE BONE); others are formed by the replacement of cartilage (*see* CARTILAGE BONE).

Osteichthyes The class of vertebrates comprising the bony fishes – marine and freshwater fish with a bony skeleton. All have gills covered with a bony operculum, and a layer of thin overlapping bony *scales covers the entire body surface. Bony fish have a *swim bladder, which acts as a hydrostatic organ enabling the animal to remain suspended in the water at any depth. In some fish this bladder acts as a lung. *See also* DIPNOI; TELEOSTEI. *Compare* CHONDRICHTHYES.

osteoblast Any of the cells, found in *bone, that secrete collagen and other substances that form the matrix of bone. Osteoblasts are derived from **osteoprogenitor cells** in the bone marrow; they eventually become *osteocytes (bone cells). *See also* OSSIFICATION.

osteoclast Any of the cells in *bone that are involved in the breakdown of bone matrix to enable the further development and remodelling of bone during growth and repair.

osteocyte Any of the cells, found in bone, that are derived from *osteoblasts and perform activities required for the maintenance of the bone tissue.

Ostrogradsky's theorem *See* DIVERGENCE THEOREM.

Ostwald's dilution law An expression for the degree of dissociation of a weak electrolyte. For example, if a weak acid dissociates in water

$$HA \rightleftharpoons H^+ + A^-$$

the dissociation constant K_a is given by

$$K_a = \alpha^2 n/(1-\alpha)V$$

where α is the degree of dissociation, n the initial amount of substance (before dissociation), and V the volume. If α is small compared with 1, then $\alpha^2 = KV/n$; i.e. the degree of dissociation is proportional to the square root of the dilution. The law was first put forward by the German physical chemist Wilhelm Ostwald (1853–1932) to account for electrical conductivities of electrolyte solutions.

otolith A gelatinous mass containing a high concentration of particles of calcium carbonate, which forms part of the *macula of the inner ear.

Otto engine *See* INTERNAL-COMBUSTION ENGINE.

ounce **1.** One sixteenth of a pound (avoirdupois), equal to 0.028 349 kg. **2.** Eight drachms (Troy), equal to 0.031 103 kg. **3. (fluid ounce)** Eight fluid drachms, equal to 0.028 413 dm^3.

outbreeding Mating between unrelated or distantly related individuals of a species. Outbreeding populations usually show more variation than *inbreeding ones and have a greater potential for adapting to environmental changes. Outbreeding increases the number of *heterozygous individuals, so that disadvantageous recessive characteristics tend to be masked by dominant alleles.

outer ear (external ear) The part of the ear external to the *tympanum (eardrum). It is present in mammals, birds, and some reptiles and consists of a tube (the **external auditory meatus**) that directs sound waves onto the tympanum. In mammals it may in-

clude an external *pinna, which extends beyond the skull.

oval window (fenestra ovalis) A membrane-covered opening between the middle ear and the inner ear (*see* EAR), situated above the *round window. Vibrations of the tympanum are transferred across the middle ear by the *ear ossicles and transmitted to the inner ear by the oval window, which is connected to the third ear ossicle (stapes).

ovarian follicle *See* GRAAFIAN FOLLICLE.

ovary **1.** The reproductive organ in female animals in which eggs (ova) are produced. In most vertebrates there are two ovaries (in some fish the ovaries fuse together to form a single structure and in birds the left ovary only is functional). As well as eggs, they produce steroid hormones (*see* OESTROGEN; PROGESTERONE). In mammals each ovary is situated close to the opening of a *fallopian tube; it contains numerous follicles in which the eggs develop and from which they are released in a regular cycle. *See also* GRAAFIAN FOLLICLE; MENSTRUAL CYCLE; OOGENESIS; OVULATION; REPRODUCTIVE SYSTEM. **2.** The hollow base of the *carpel of a flower, containing one or more *ovules. After fertilization, the ovary wall develops into the fruit enclosing the seeds. In some species, the carpels are fused together to form a complex ovary.

overdamped *See* DAMPING.

overpopulation The situation that arises when rapid growth of a population, usually a human population, results in numbers that cannot be supported by the available resources, such as space and food. This occurs when the birth rate exceeds the death rate, or when immigration exceeds emigration, or when a combination of these factors exists. *See* POPULATION GROWTH.

overpotential A potential that must be applied in an electrolytic cell in addition to the theoretical potential required to liberate a given substance at an electrode. The value depends on the electrode material and on the current density. It is a kinetic effect occurring because of the significant activation energy for electron transfer at the electrodes, and is particularly important for the liberation of such gases as hydrogen and oxygen. For example, in the electrolysis of a solution of zinc ions, hydrogen ($E^{\ominus}$ = 0.00 V) would be expected to be liberated at the cathode in preference to zinc ($E^{\ominus}$ = –0.76 V). In fact, the high overpotential of hydrogen on zinc (about 1 V under suitable conditions) means that zinc can be deposited instead.

overtones *See* HARMONIC.

oviduct The tube that conveys an animal egg cell from the ovary to other parts of the reproductive system or to the outside. Eggs are passed along the oviduct by the action of muscles and cilia. *See* FALLOPIAN TUBE.

oviparity Reproduction in which fertilized eggs are laid or spawned by the mother and hatch outside her body. It occurs in most animals except marsupial and placental mammals. *Compare* OVOVIVIPARITY; VIVIPARITY.

ovipositor An organ at the hind end of the abdomen of female insects through which eggs are laid. It consists of a pair of modified appendages and is often long and piercing, so that eggs can be laid in otherwise inaccessible places. The sting of bees and wasps is a modified ovipositor.

ovoviviparity Reproduction in which fertilized eggs develop and hatch in the oviduct of the mother. It occurs in many invertebrates and in some fish and reptiles (e.g. the viper). *Compare* OVIPARITY; VIVIPARITY.

ovulation The release of an egg cell from the ovary, which in mammals is stimulated by *luteinizing hormone. The developing egg cell within its follicle migrates to the ovary surface; when mature, it is released from the follicle (which breaks open) into the body cavity, from where it passes into the oviduct. *See also* MENSTRUAL CYCLE.

ovule The part of the female reproductive organs of seed plants that consists of the *nucellus, *embryo sac, and *integuments. The ovules of gymnosperms are situated on ovuliferous scales of the female cones while those of angiosperms are enclosed in the carpel. After fertilization, the ovule becomes the seed.

ovuliferous scale One of a group of large woody specialized leaves that form the female *cone of conifers and related trees. It bears the ovules, which develop into seeds.

ovum (egg cell) (*pl.* **ova**) **1.** (in zoology) The mature reproductive cell (*see* GAMETE) of female animals, which is produced by the ovary (*see* OOGENESIS). It is spherical, has a nucleus, is covered with a vitelline membrane, and is not mobile. **2.** (in botany) The *oosphere of plants.

oxalate A salt or ester of *oxalic acid.

oxalic acid (ethanedioic acid) A crystalline solid, $(COOH)_2$, that is slightly soluble in water. Oxalic acid is strongly acidic and very poisonous. It occurs in certain plants, e.g. sorrel and the leaf blades of rhubarb.

oxaloacetic acid A compound, $HO_2CCH_2COCO_2H$, that plays an integral role in the *Krebs cycle. The anion, oxaloacetate, reacts with the acetyl group from acetyl coenzyme A to form citrate.

oxazole A heterocyclic compound having a nitrogen atom and an oxygen atom in a five-membered ring, C_3H_3NO.

oxbow lake A crescent-shaped lake formed when a meander of a slow-flowing river is cut off from the main channel after the river, in flood, crosses the neck of land between two bends. Most oxbow lakes, or cutoffs, soon silt up.

oxfuel A liquid fuel containing added alcohols or ethers to act as an additional source of oxygen during combustion of the fuel. It has been claimed that such additives help to lower the concentration of carbon monoxide in engine emissions.

oxidant *See* OXIDIZING AGENT.

oxidase Any enzyme that catalyses *oxidation–reduction reactions that involve the transfer of electrons to molecular oxygen.

O

oxidation *See* OXIDATION–REDUCTION.

oxidation number (oxidation state) *See* OXIDATION–REDUCTION.

oxidation–reduction (redox) Originally, **oxidation** was simply regarded as a chemical reaction with oxygen. The reverse process – loss of oxygen – was called **reduction**. Reaction with hydrogen also came to be regarded as reduction. Later, a more general idea of oxidation and reduction was developed in which oxidation was loss of electrons and reduction was gain of electrons. This wider definition covered the original one. For example, in the reaction

$$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$$

the sodium atoms lose electrons to give Na^+ ions and are oxidized. At the same time, the oxygen atoms gain electrons and are reduced. These definitions of oxidation and reduction also apply to reactions that do not involve oxygen. For instance in

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

the sodium is oxidized and the chlorine reduced. Oxidation and reduction also occurs at the electrodes in *cells.

This definition of oxidation and reduction applies only to reactions in which electron transfer occurs – i.e. to reactions involving ions. It can be extended to reactions between covalent compounds by using the concept of **oxidation number** (or **state**). This is a measure of the electron control that an atom has in a compound compared to the atom in the pure element. An oxidation number consists of two parts:
(1) Its sign, which indicates whether the control has increased (negative) or decreased (positive).
(2) Its value, which gives the number of electrons over which control has changed.

The change of electron control may be complete (in ionic compounds) or partial (in covalent compounds). For example, in SO_2 the sulphur has an oxidation number +4, having gained partial control over 4 electrons compared to sulphur atoms in pure sulphur. The oxygen has an oxidation number –2, each oxygen having lost partial control over 2 electrons compared to oxygen atoms in gaseous oxygen. Oxidation is a reaction involving an increase in oxidation number and reduction involves a decrease. Thus in

$$2H_2 + O_2 \rightarrow 2H_2O$$

the hydrogen in water is +1 and the oxygen –2. The hydrogen is oxidized and the oxygen is reduced.

The oxidation number is used in naming inorganic compounds. Thus in H_2SO_4, sulphuric(VI) acid, the sulphur has an oxidation number of +6. Compounds that tend to undergo reduction readily are *oxidizing agents; those that undergo oxidation are *reducing agents.

oxidative decarboxylation The reaction in the *Krebs cycle in which oxygen, derived from two water molecules, is used to oxidize two carbon atoms to two molecules of carbon dioxide. The two carbon atoms result from the *decarboxylation reactions that occur during the Krebs cycle as the six-carbon compound citrate is converted to the four-carbon compound oxaloacetate.

oxidative phosphorylation A reaction occurring during the final stages of *aerobic respiration, in which ATP is formed from ADP and phosphate coupled to electron transport in the *electron transport chain. The reaction occurs in the mitochondria and

is the cell's principal method of storing the energy released by the oxidation of food. *See also* PHOSPHORYLATION.

oxides Binary compounds formed between elements and oxygen. Oxides of nonmetals are covalent compounds having simple molecules (e.g. CO, CO_2, SO_2) or giant molecular lattices (e.g. SiO_2). They are typically acidic or neutral. Oxides of metals are ionic, containing the O^{2-} ion. They are generally basic or *amphoteric. Various other types of ionic oxide exist (*see* OZONIDES; PEROXIDES; SUPEROXIDES).

oxidizing acid An acid that can act as a strong oxidizing agent as well as an acid. Nitric acid is a common example. It is able to attack metals, such as copper, that are below hydrogen in the electromotive series, by oxidizing the metal:

$$2HNO_3 + Cu \rightarrow CuO + H_2O + 2NO_2$$

This is followed by reaction between the acid and the oxide:

$$2HNO_3 + CuO \rightarrow Cu(NO_3)_2 + H_2O$$

oxidizing agent (oxidant) A substance that brings about oxidation in other substances. It achieves this by being itself reduced. Oxidizing agents contain atoms with high oxidation numbers; that is the atoms have suffered electron loss. In oxidizing other substances these atoms gain electrons.

oxidoreductase Any of a class of enzymes that catalyse *oxidation–reduction reactions, i.e. they are involved in the transfer of hydrogen or electrons between molecules. They include the *oxidases and *dehydrogenases.

oximes Compounds containing the group C:NOH, formed by reaction of an aldehyde or ketone with hydroxylamine (H_2NOH) (see illustration). Ethanal (CH_3CHO), for example, forms the oxime $CH_3CH{:}NOH$.

SEE WEB LINKS

- Information about IUPAC nomenclature

oxo- Prefix indicating the presence of oxygen in a chemical compound.

oxoacid An acid in which the acidic hydrogen is part of a hydroxyl group bound to an atom that is bound to an oxo group (=O). Sulphuric acid is an example. *Compare* HYDROXOACID.

3-oxobutanoic acid (acetoacetic acid) A colourless syrupy liquid, CH_3COCH_2COOH. It is an unstable compound, decomposing into propanone and carbon dioxide. The acid can be prepared from its ester, *ethyl 3-oxobutanoate.

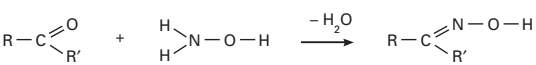
oxonium ion An ion of the type R_3O^+, in which R indicates hydrogen or an organic group, especially the ion H_3O^+, which is formed when *acids dissociate in water. This is also called the **hydroxonium ion** or the **hydronium ion**.

oxo process An industrial process for making aldehydes by reaction between alkanes, carbon monoxide, and hydrogen (cobalt catalyst using high pressure and temperature).

oxyacetylene burner A welding or cutting torch that burns a mixture of oxygen and acetylene (ethyne) in a specially designed jet. The flame temperature of about 3300°C enables all ferrous metals to be welded. For cutting, the point at which the steel is to be cut is preheated with the oxyacetylene flame and a powerful jet of oxygen is then directed onto the steel. The oxygen reacts with the hot steel to form iron oxide and the heat of this reaction melts more iron, which is blown away by the force of the jet.

oxycodone An opioid, $C_{18}H_{21}N_2$, similar in structure to codeine but with a –OH group in codeine replaced by a carbonyl group. It is an analgesic often used for the treatment of chronic pain. It is also used illegally and is a controlled substance in most countries.

oxygen Symbol O. A colourless odourless gaseous element belonging to *group 16 (formerly VIB) of the periodic table; a.n. 8; r.a.m. 15.9994; d. 1.429 g dm^{-3}; m.p. –218.4°C; b.p. –183°C. It is the most abundant element in the earth's crust (49.2% by weight) and is present in the atmosphere (28% by volume). Atmospheric oxygen is of vital importance for all organisms that carry out *aerobic res-



Oximes.

piration. For industrial purposes it is obtained by fractional distillation of liquid air. It is used in metallurgical processes, in high-temperature flames (e.g. for welding), and in breathing apparatus. The common form is diatomic (**dioxygen**, O_2); there is also a reactive allotrope *ozone (O_3). Chemically, oxygen reacts with most other elements forming *oxides. The element was discovered by Joseph Priestley in 1774.

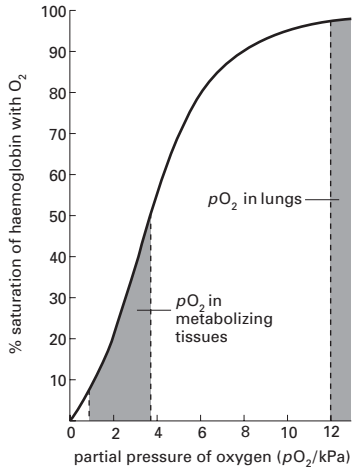
SEE WEB LINKS

- Information from the WebElements site

oxygen cycle The cycling of oxygen between the biotic and abiotic components of the environment (*see* BIOGEOCHEMICAL CYCLE). The oxygen cycle is closely linked to the *carbon cycle and the water cycle (*see* HYDROLOGICAL CYCLE). In the process of respiration oxygen is taken in by living organisms and released into the atmosphere, combined with carbon, in the form of carbon dioxide. Carbon dioxide enters the carbon cycle or is taken up by plants for *photosynthesis. During photosynthesis oxygen is evolved by the chemical splitting of water and returned to the atmosphere. In the upper atmosphere, *ozone is formed from oxygen and dissociates to release oxygen (*see* OZONE LAYER).

oxygen debt The physiological state that exists in a normally aerobic animal when insufficient oxygen is available for metabolic requirements (e.g. during a period of strenuous physical activity). To meet the body's increased demand for energy, pyruvate is converted anaerobically (i.e. in the absence of oxygen) to lactic acid, which requires oxygen for its breakdown and accumulates in the tissues. When oxygen is available again lactic acid is oxidized in the liver, thus repaying the debt.

oxygen dissociation curve The S-shaped curve produced when the percentage saturation of haemoglobin with oxygen (i.e. the percentage of binding sites of haemoglobin that are occupied by oxygen molecules) is plotted against the partial pressure of oxygen (pO_2), which is a measure of the oxygen concentration in the surrounding medium. The steep rise of the curve indicates the high affinity of haemoglobin for oxygen: a small increase in pO_2 results in a relatively sharp increase in the percentage saturation of haemoglobin with oxygen. Therefore in the lungs, where the pO_2 is high, the blood is rapidly saturated with oxygen. Conversely, a small drop in pO_2 results in a large drop in percentage saturation of haemoglobin. Thus in tissues that utilize oxygen at a high rate, where the pO_2 is low, oxygen readily dissociates from haemoglobin and is released for use by the tissues. *See also* BOHR EFFECT.



Oxygen dissociation curve.

oxyhaemoglobin *See* HAEMOGLOBIN.

oxyntic cell (parietal cell) Any of the cells in the wall of the stomach that produce hydrochloric acid, which forms part of the *gastric juice. Hydrochloric acid is required for the conversion of pepsinogen to pepsin in the lumen of the stomach and kills various microorganisms that enter with food. The oxyntic cells also produce intrinsic factor, which is involved in the absorption of vitamin B_{12} in the small intestine (*see* VITAMIN B COMPLEX).

oxytocin A hormone, produced by birds and mammals, that in mammals causes both contraction of smooth muscle in the uterus during birth and expulsion of milk from the mammary glands during suckling. Oxytocin is produced in the neurosecretory cells of the hypothalamus (*see* NEUROSECRETION) but is stored and secreted by the posterior pituitary gland.

ozonation The formation of *ozone (O_3) in the earth's atmosphere. In the upper atmosphere (stratosphere) about 20–50 km above the surface of the earth, oxygen molecules

(O_2) dissociate into their constituent atoms under the influence of *ultraviolet light of short wavelength (below about 240 nm). These atoms combine with oxygen molecules to form ozone (*see* OZONE LAYER). Ozone is also formed in the lower atmosphere (troposphere) from nitrogen oxides and other pollutants by photochemical reactions (*see* PHOTOCHEMICAL SMOG). Tropospheric ozone is increasingly a cause of impaired plant growth and reduced crop yields.

ozone (trioxygen) A colourless gas, O_3, soluble in cold water and in alkalis; m.p. –192.7°C; b.p. –111.9°C. Liquid ozone is dark blue in colour and is diamagnetic (dioxygen, O_2, is paramagnetic). The gas is made by passing oxygen through a silent electric discharge and is usually used in mixtures with oxygen. It is produced in the stratosphere by the action of high-energy ultraviolet radiation on oxygen (*see* OZONATION) and its presence there acts as a screen for ultraviolet radiation (*see* OZONE LAYER). Ozone is also one of the greenhouse gases (*see* GREENHOUSE EFFECT). It is a powerful oxidizing agent and is used to form ozonides by reaction with alkenes and subsequently by hydrolysis to carbonyl compounds.

ozone hole *See* OZONE LAYER.

ozone layer (ozonosphere) A layer of the *earth's atmosphere in which most of the atmosphere's ozone is concentrated. It occurs 15–50 km above the earth's surface and is virtually synonymous with the stratosphere. In this layer most of the sun's *ultraviolet radiation is absorbed by the ozone molecules, causing a rise in the temperature of the stratosphere and preventing vertical mixing so that the stratosphere forms a stable layer. By absorbing most of the solar ultraviolet radiation the ozone layer protects living organisms on earth. The fact that the ozone layer is thinnest at the equator is believed to account for the high equatorial incidence of skin cancer as a result of exposure to unabsorbed solar ultraviolet radiation. In the 1980s it was found that depletion of the ozone layer was occurring over both the poles, creating **ozone holes**. This is thought to have been caused by a series of complex photochemical reactions involving *nitrogen oxides produced from aircraft and, more seriously, *chlorofluorocarbons (CFCs) and halons. CFCs rise to the stratosphere, where they react with ultraviolet light to release chlorine atoms; these atoms, which are highly reactive, catalyse the destruction of ozone. Use of CFCs is now much reduced in an effort to reverse this human-induced damage to the ozone layer. *See also* AIR POLLUTION.

SEE WEB LINKS

- Description of the ozone layer, its depletion, and steps to protect it, produced by the US Environmental Protection Agency

ozonides **1.** A group of compounds formed by reaction of ozone with alkali metal hydroxides and formally containing the ion O_3^-. **2.** Unstable compounds formed by the addition of ozone to the C=C double bond in alkenes. *See* OZONOLYSIS.

ozonolysis A reaction of alkenes with ozone to form an ozonide. It was once used to investigate the structure of alkenes by hydrolysing the ozonide to give aldehydes or ketones, for instance:

$$R_2C{:}CHR' \rightarrow R_2CO + R'CHO$$

These could be identified, and the structure of the original alkene determined.