L

labelling **1. (isotopic labelling)** The process of replacing a stable atom in a compound with a radioisotope of the same element to enable its path through a biological or mechanical system to be traced by the radiation it emits. In some cases a different stable isotope is used and the path is detected by means of a mass spectrometer. A compound containing either a radioactive or stable isotope is called a **labelled compound** and the atom used is a **label**. If a hydrogen atom in each molecule of the compound has been replaced by a tritium atom, the compound is called a **tritiated compound**. A radioactive labelled compound will behave chemically and physically in the same way as an otherwise identical stable compound, and its presence can easily be detected using a *Geiger counter. This process of **radioactive tracing** is widely used in chemistry, biology, medicine, and engineering. For example, it can be used to follow the course of the reaction of a carboxylic acid with an alcohol to give an ester, e.g.

$$CH_3COOH + C_2H_5OH \rightarrow C_2H_5COOCH_3 + H_2O$$

To determine whether the noncarbonyl oxygen in the ester comes from the acid or the alcohol, the reaction is performed with the labelled compound $CH_3CO^{18}OH$, in which the oxygen in the hydroxyl group of the acid has been 'labelled' by using the ^{18}O isotope. It is then found that the water product is $H_2{}^{18}O$; i.e. the oxygen in the ester comes from the alcohol, not the acid. **2.** The addition to a target substance of a readily identifiable marker, such as a fluorescent dye. This enables the presence and in some cases the amount of target molecule to be determined by (for example) a fluorescence detector. Markers such as fluorescence are now widely used in automated assay techniques.

labia *See* LABIUM.

labile Describing a chemical compound in which certain atoms or groups can easily be replaced by other atoms or groups. The term is applied to coordination complexes in which ligands can easily be replaced by other ligands in an equilibrium reaction.

labium **1.** The lower lip in the *mouthparts of an insect, which is used in feeding and is formed by the fusion of a pair of appendages (the second *maxillae). **2.** Either member of two pairs of fleshy folds that form part of the *vulva. The outer and larger pair, the **labia majora**, are covered by pubic hair and contain adipose tissue; the smaller **labia minora** lack adipose tissue and pubic hair. Both pairs of labia contain sebaceous glands.

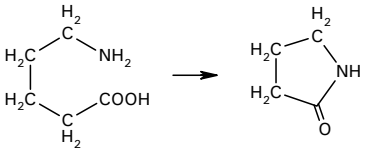
labrum The upper lip in the *mouthparts of an insect. It is formed from a plate of cuticle hinged to the head above the mouth and is used in feeding.

labyrinth The system of cavities and tubes that comprises the *inner ear of vertebrates. It consists of a system of membranous structures (**membranous labyrinth**) housed in a similar shaped bony cavity (**bony labyrinth**).

***lac* operon** The *operon that regulates lactose metabolism in the bacterium *Escherichia coli*. Its form was first postulated in 1961 by François Jacob (1920–) and Jacques Monod (1910–76) to explain control of β-galactosidase synthesis, and it is used as a model for the structure and regulation of genes in prokaryotes. *See* JACOB–MONOD HYPOTHESIS.

lacrimal gland (lachrymal gland) The tear gland, present in the eyelids of some vertebrates. The fluid (tears) produced by this gland cleanses and lubricates the exposed surface of the eye; it drains into the nose through the lacrimal duct.

lactams Organic compounds containing a ring of atoms in which the group –NH.CO.– forms part of the ring. Lactams can be formed by reaction of an $–NH_2$ group in one part of a molecule with a –COOH group in the other to give a cyclic amide (see illustration). They can exist in an alternative tautomeric form, the **lactim** form, in which the hydrogen atom on the nitrogen has migrated to the oxygen of the carbonyl to give



Lactam formation.

–N=C(OH)–. The pyrimidine base uracil is an example of a lactam.

SEE WEB LINKS

- Information about IUPAC nomenclature of lactams
- Information about IUPAC nomenclature of lactims

lactase (galactosidase) The enzyme that breaks down the milk sugar, lactose, to glucose and galactose.

lactate A salt or ester of lactic acid (i.e. a 2-hydroxypropanoate).

lactation The discharge of milk from the *mammary glands. This generally only occurs after birth of the young and is stimulated by the sucking action of the infants. Lactation is under the control of hormones, notably *prolactin and *oxytocin.

lacteal A minute blind-ended lymph vessel that occurs in each *villus of the small intestine. Digested fats are absorbed into the lacteals (*see* CHYLE) and transported to the bloodstream through the *thoracic duct.

lactic acid (2-hydroxypropanoic acid) A clear odourless hygroscopic syrupy liquid, $CH_3CH(OH)COOH$, with a sour taste; r.d. 1.206; m.p. 18°C; b.p. 122°C. It is prepared by the hydrolysis of ethanal cyanohydrin or the oxidation of propan-1,2-diol using dilute nitric acid. Lactic acid is manufactured by the fermentation of lactose (from milk) and used in the dyeing and tanning industries. It is an alpha hydroxy *carboxylic acid. *See also* OPTICAL ACTIVITY.

Lactic acid is produced from pyruvic acid in active muscle tissue when oxygen is limited and subsequently removed for conversion to glucose by the liver. During strenuous exercise it may build up in the muscles, causing cramplike pains. It is also produced by fermentation in certain bacteria and is characteristic of sour milk.

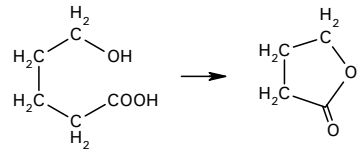
lactims *See* LACTAMS.

lactogenic hormone *See* PROLACTIN.

lactones Organic compounds containing a ring of atoms in which the group –CO.O– forms part of the ring. Lactones can be formed (or regarded as formed) by reaction of an –OH group in one part of a molecule with a –COOH group in the other to give a cyclic ester (see illustration). This type of reaction occurs with γ-hydroxy carboxylic acids such as $CH_2(OH)CH_2CH_2COOH$ (in which the hydroxyl group is on the third carbon from the carboxyl group). The resulting γ-lactone has a five-membered ring. Similarly, δ-lactones have six-membered rings. β-lactones, with a four-membered ring, are not produced directly from β-hydroxy acids, but can be synthesized by other means.

SEE WEB LINKS

- Information about IUPAC nomenclature



Lactone formation.

lactose (milk sugar) A sugar comprising one glucose molecule linked to a galactose molecule. Lactose is manufactured by the mammary gland and occurs only in milk. For example, cows' milk contains about 4.7% lactose. It is less sweet than sucrose (cane sugar).

lacuna A gap or cavity in the tissues of an organism; for example, the hollow centre of certain plant stems or any of the small cavities in bone in which the bone-forming cells are found.

Ladenburg benzene An (erroneous) structure for *benzene proposed by Albert Ladenburg (1842–1911), in which the six carbon atoms were arranged at the corners of a triangular prism and linked by single bonds to each other and to the six hydrogen atoms.

laevorotatory Designating a chemical compound that rotates the plane of plane-polarized light to the left (anticlockwise for someone facing the oncoming radiation). *See* OPTICAL ACTIVITY.

laevulose *See* FRUCTOSE.

lag *See* PHASE ANGLE.

lag phase *See* BACTERIAL GROWTH CURVE.

Lagrangian Symbol *L*. A function used to define a dynamical system in terms of functions of coordinates, velocities, and times given by:

$$L = T - V$$

where T is the kinetic energy of the system and V is the potential energy of the system. The Lagrangian formulation of dynamics has the advantage that it does not deal with many vector quantities, such as forces and accelerations, but only with two scalar functions, T and V. This leads to great simplifications in calculations. **Lagrangian dynamics** was formulated by Joseph Louis Lagrange (1736–1813).

Lagrangian coherent structure A boundary that separates a moving fluid into a region in which there is turbulence and a region in which there is not turbulence. This boundary can move with time. The concept is useful in fluid mechanics.

Lagrangian fluid dynamics A formulation of fluid mechanics in which the trajectories of small regions of the moving fluid are analysed, in contrast to *Eulerian fluid dynamics.

Lagrangian point One of two points, in the plane of two large objects orbiting each other, at which a third much smaller object can remain in stable equilibrium. There are three other theoretical Lagrangian points but they are unstable. Each stable Lagrangian point occurs on the orbit of the smaller of the two large objects, at the apex of an equilateral triangle that has as its base a line joining the two large objects. The Trojan *asteroids occupy such Lagrangian points on the orbit of Jupiter around the sun. They are named after Joseph Louis Lagrange (1736–1813).

LAH Lithium aluminium hydride; *see* LITHIUM TETRAHYDROALUMINATE(III).

lake A pigment made by combining an organic dyestuff with an inorganic compound (usually an oxide, hydroxide, or salt). Absorption of the organic compound on the inorganic substrate yields a coloured complex, as in the combination of a dyestuff with a *mordant. Lakes are used in paints and printing inks.

Lamarck, Jean-Baptiste de Monet, Chevalier de (1744–1829) French natural historian. In 1778 he published a flora of France, which included a dichotomous identification key, and later worked on the classification of invertebrates, published in a seven-volume natural history (1815–22). In 1809 he put forward a theory of *evolution that has become known as *Lamarckism (later rejected in favour of Darwinism).

Lamarckism One of the earliest superficially plausible theories of *evolution, proposed by Jean-Baptiste de Lamarck in 1809. He suggested that changes in an individual are acquired during its lifetime, chiefly by increased use or disuse of organs in response to "a need that continues to make itself felt", and that these changes are inherited by its offspring. Thus the long neck and limbs of a giraffe are explained as having evolved by the animal stretching its neck to browse on the foliage of trees. This so-called inheritance of acquired characteristics has never unquestionably been demonstrated to occur and the theory was largely displaced by *Darwinism. Lamarckism is also incompatible with the *Central Dogma of molecular biology. *See also* LYSENKOISM.

lambda particle A spin –½ electrically neutral *baryon made up of one up quark, one down quark, and one strange quark. The mass of the lambda particle is 1115.60 MeV and its average lifetime is 2.6×10^{-10} s.

lambda phage A temperate *bacteriophage that infects cells of the bacterium *Escherichia coli*, where it can either exist as a quiescent prophage (in a state called **lysogeny**) or undergo replication leading to lysis of the host cell and release of new phage particles. Lambda phage has been intensively studied as a model of viral infection and replication and is much used in genetic research and in genetic engineering. Modified lambda phages are used as *vectors in gene cloning, especially for packaging relatively large amounts of foreign DNA.

lambda point Symbol λ. The temperature of 2.186 K below which helium–4 becomes a superfluid. The name derives from the shape of the curve of specific heat capacity against temperature, which is shaped like a Greek letter lambda (λ) at this point. *See* SUPERFLUIDITY.

lambert A former unit of *luminance equal to the luminance of a uniformly diffusing

surface that emits or reflects one lumen per square centimetre. It is approximately equal to 3.18×10^3 Cd m^{-2}. It is named after Johann H. Lambert (1728–77).

Lambert's laws (1) The *illuminance of a surface illuminated by light falling on it perpendicularly from a point source is inversely proportional to the square of the distance between the surface and the source. (2) If the rays make an angle θ with the normal to the surface, the illuminance is proportional to cosθ. (3) **(Bouguer's law)** The *luminous intensity (I) of light (or other electromagnetic radiation) decreases exponentially with the distance d that it enters an absorbing medium, i.e.

$$I = I_0 \exp(-\alpha d)$$

where I_0 is the intensity of the radiation that enters the medium and α is its **linear absorption coefficient**. These laws were first stated (for light) by Johann H. Lambert (1728–77).

Lamb shift A small energy difference between two levels ($^2S_{1/2}$ and $^2P_{1/2}$) in the *hydrogen spectrum. The shift results from the quantum interaction between the atomic electron and the electromagnetic radiation. It was first explained by Willis Eugene Lamb (1913–2008).

lamella **1.** (in botany) **a.** Any of the paired folds of membranes seen between the *grana in a plant chloroplast. **b.** Any of the spore-bearing gills on the underside of the cap of many mushrooms and toadstools. *See also* MIDDLE LAMELLA. **2.** (in zoology) Any of various thin layers of membranes, especially any of the thin layers of tissue of which compact bone is formed.

lamellar solids Solid substances in which the crystal structure has distinct layers (i.e. has a layer lattice). The *micas are an example of this type of compound. *Intercalation compounds are lamellar compounds formed by interposition of atoms, ions, etc., between the layers of an existing element or compound. For example, graphite is a lamellar solid. With strong oxidizing agents (e.g. a mixture of concentrated sulphuric and nitric acids) it forms a nonstoichiometric 'graphitic oxide', which is an intercalation compound having oxygen atoms between the layers of carbon atoms.

Lamellibranchia *See* BIVALVIA.

lamina **1.** The thin and usually flattened blade of a leaf, in which photosynthesis and transpiration occurs. The bulk of the lamina is made up of *mesophyll cells interspersed by a network of veins (*vascular bundles). The mesophyll is enclosed by a protective epidermis that produces a waxy cuticle. **2.** The leaflike part of the thallus of certain algae, notably kelps. *See also* STIPE.

laminar flow *Streamline flow of a fluid in which the fluid moves in layers without fluctuations or turbulence so that successive particles passing the same point have the same velocity. It occurs at low *Reynolds numbers, i.e. low velocities, high viscosities, low densities or small dimensions. The flow of lubricating oil in bearings is normally laminar because of the thinness of the lubricant layer.

laminated core A core for a transformer or other electrical machine in which the ferromagnetic alloy is made into thin sheets (laminations), which are oxidized or varnished to provide a relatively high resistance between them. This has the effect of reducing *eddy currents, which occur when alternating currents are used.

lamp black A finely divided (microcrystalline) form of carbon made by burning organic compounds in insufficient oxygen. It is used as a black pigment and filler.

lancelet *See* CHORDATA.

Landauer's principle The principle put forward by Rolf Landauer in the 1960s that energy has to be expended to erase information. This principle links thermodynamics and information theory.

Landau level A quantized energy level that occurs when an electrically charged particle is moving in an external magnetic field. The existence of such levels was predicted by Lev Landau in 1930. The concept of Landau levels is important in the theory of the *quantum Hall effect.

Landé interval rule A rule in atomic spectra stating that if the *spin–orbit coupling is weak in a given multiplet, the energy differences between two successive J levels (where J is the total resultant angular momentum of the coupled electrons) are proportional to the larger of the two values of J. The rule was stated by the German-born US physicist Alfred Landé (1888–1975) in 1923. It can be deduced from the quantum theory of angular momentum. In addition to as-

suming *Russell–Saunders coupling, the Landé interval rule assumes that the interactions between spin magnetic moments can be ignored, an assumption that is not correct for very light atoms, such as helium. Thus the Landé interval rule is best obeyed by atoms with medium atomic numbers.

Langlands program A set of conjectures put forward in 1967 by the Canadian mathematician Robert Langlands (1936–), relating different branches of mathematics. Some of these conjectures have physical realizations in *quantum field theory and *superstring theory.

Langmuir adsorption isotherm An equation used to describe the amount of gas adsorbed on a plane surface, as a function of the pressure of the gas in equilibrium with the surface. The Langmuir adsorption isotherm can be written:

$\theta = bp/(1 + bp)$,

where θ is the fraction of the surface covered by the adsorbate, p is the pressure of the gas, and b is a constant called the **adsorption coefficient**, which is the equilibrium constant for the process of adsorption. The Langmuir adsorption isotherm was derived by the US chemist Irving Langmuir (1881–1957), using the *kinetic theory of gases and making the assumptions that:
(1) the adsorption consists entirely of a monolayer at the surface;
(2) there is no interaction between molecules on different sites and each site can hold only one adsorbed molecule;
(3) the heat of adsorption does not depend on the number of sites and is equal for all sites.
The Langmuir adsorption isotherm is of limited application since for real surfaces the energy is not the same for all sites and interactions between adsorbed molecules cannot be ignored.

Langmuir–Blodgett film A film of molecules on a surface that can contain multiple layers of film. A Langmuir–Blodgett film with multiple layers can be made by dipping a plate into a liquid so that it is covered by a monolayer and then repeating the process. This process, called the **Langmuir–Blodgett technique**, enables a multilayer to be built up, one monolayer at a time. Langmuir–Blodgett films have many potential practical applications, including insulation for optical and semiconductor devices and selective membranes in biotechnology.

lanolin An emulsion of purified wool fat in water, containing cholesterol and certain terpene alcohols and esters. It is used in cosmetics.

lansfordite A mineral form of *magnesium carbonate pentahydrate, $MgCO_3.5H_2O$.

lanthanides *See* LANTHANOIDS.

lanthanoid contraction *See* LANTHANOIDS.

lanthanoids (lanthanides; lanthanons; rare-earth elements) A series of elements in the *periodic table, generally considered to range in proton number from cerium (58) to lutetium (71) inclusive. The lanthanoids all have two outer s-electrons (a $6s^2$ configuration), follow lanthanum, and are classified together because an increasing proton number corresponds to increase in number of $4f$ electrons. In fact, the $4f$ and $5d$ levels are close in energy and the filling is not smooth. The outer electron configurations are as follows:
57 lanthanum (La) $5d^16s^2$
58 cerium (Ce) $4f5d^16s^2$ (or $4f^26s^2$)
59 praseodymium (Pr) $4f^36s^2$
60 neodymium (Nd) $4f^46s^2$
61 promethium (Pm) $4f^56s^2$
62 samarium (Sm) $4f^66s^2$
63 europium (Eu) $4f^76s^2$
64 gadolinium (Gd) $4f^75d^16s^2$
65 terbium (Tb) $4f^96s^2$
66 dysprosium (Dy) $4f^{10}6s^2$
67 holmium (Ho) $4f^{11}6s^2$
68 erbium (Er) $4f^{12}6s^2$
69 thulium (Tm) $4f^{13}6s^2$
70 ytterbium (Yb) $4f^{14}6s^2$
71 lutetium (Lu) $4f^{14}5d^16s^2$

Note that lanthanum itself does not have a $4f$ electron but it is generally classified with the lanthanoids because of its chemical similarities, as are yttrium (Yt) and scandium (Sc). Scandium, yttrium, and lanthanum are d-block elements; the lanthanoids and *actinoids make up the f-block.

The lanthanoids are sometimes simply called the **rare earths**, although strictly the 'earths' are their oxides. Nor are they particularly rare: they occur widely, usually together. All are silvery very reactive metals. The f-electrons do not penetrate to the outer part of the atom and there is no f-orbital participation in bonding (unlike the d-orbitals of the main *transition elements) and the elements form few coordination compounds. The main compounds contain M^{3+} ions. Cerium also has the highly oxidizing Ce^{4+}

state and europium and ytterbium have a M^{2+} state.

The 4*f* orbitals in the atoms are not very effective in shielding the outer electrons from the nuclear charge. In going across the series the increasing nuclear charge causes a contraction in the radius of the M^{3+} ion – from 0.1061 nm in lanthanum to 0.0848 nm in lutetium. This effect, the **lanthanoid contraction**, accounts for the similarity between the transition elements zirconium and hafnium.

lanthanons *See* LANTHANOIDS.

lanthanum Symbol La. A silvery metallic element belonging to group 3 (formerly IIIA) of the periodic table and often considered to be one of the *lanthanoids; a.n. 57; r.a.m. 138.91; r.d. 6.146 (20°C); m.p. 921°C; b.p. 3457°C. Its principal ore is bastnasite, from which it is separated by an ion-exchange process. There are two natural isotopes, lanthanum–139 (stable) and lanthanum–138 (half-life 10^{10}–10^{15} years). The metal, being pyrophoric, is used in alloys for lighter flints and the oxide is used in some optical glasses. The largest use of lanthanum, however, is as a catalyst in cracking crude oil. Its chemistry resembles that of the lanthanoids. The element was discovered by Carl Mosander (1797–1858) in 1839.

SEE WEB LINKS

- Information from the WebElements site

lapis lazuli A blue rock that is widely used as a semiprecious stone and for ornamental purposes. It is composed chiefly of the deep blue mineral **lazurite** embedded in a matrix of white calcite and usually also contains small specks of pyrite. It occurs in only a few places in crystalline limestones as a contact metamorphic mineral. The chief source is Afghanistan; lapis lazuli also occurs near Lake Baikal in Siberia and in Chile. It was formerly used to make the artists' pigment ultramarine.

Laplace equation The partial differential equation:

$$\partial^2 u/\partial x^2 + \partial^2 u/\partial y^2 + \partial^2 u/\partial z^2 = 0$$

It may also be written in the form $\nabla^2 u = 0$, where ∇^2 is called the **Laplace operator**. It was formulated by the French mathematician Pierre Laplace (1749–1827).

Large Electron-Positron Collider *See* CERN.

Large Hadron Collider (LHC) A proton collider at *CERN, which started operating in 2008. It accelerates two beams of protons to very high energies and then causes the beams to collide with each other, giving effective energies of about 14 TeV. It is hoped that the LHC will discover the *Higgs boson and provide information on physics beyond the standard model, such as *supersymmetry.

SEE WEB LINKS

- The Large Hadron Collider home page at CERN

large intestine The portion of the alimentary canal of vertebrates between the *small intestine and the *anus. It consists of the *caecum, *colon, and *rectum and its principal function is the absorption of water and formation of faeces.

large-scale structure The structure of the distribution of visible matter in the universe at very large scales. This structure includes galaxies, clusters of galaxies, superclusters, and voids. *See also* STRUCTURE FORMATION.

Larmor precession A precession of the motion of charged particles in a magnetic field. It was first deduced in 1897 by Sir Joseph Larmor (1857–1942). Applied to the orbital motion of an electron around the nucleus of an atom in a magnetic field of flux density *B*, the frequency of precession is given by $eB/4\pi m\nu\mu$, where *e* and *m* are the electronic charge and mass respectively, μ is the permeability, and ν is the velocity of the electron. This is known as the **Larmor frequency**.

larva The juvenile stage in the life cycle of most invertebrates, amphibians, and fish, which hatches from the egg, is unlike the adult in form, and is normally incapable of sexual reproduction (*see* PAEDOGENESIS). It develops into the adult by undergoing *metamorphosis. Larvae can feed themselves and are otherwise self-supporting. -- Examples are the tadpoles of frogs, the caterpillars of butterflies, and the ciliated planktonic larvae of many marine animals. *Compare* NYMPH.

larynx The anterior portion of the *trachea (windpipe) of tetrapod vertebrates, which in amphibians, reptiles, and mammals contains the *vocal cords. Movement of the cartilage in the walls of the larynx (by means of the laryngeal muscles) alters the tension of the vocal cords. This changes the pitch of the sound emitted by the vocal cords when they

vibrate. The final voiced sound is modified by resonance within the oral and nasal cavities.

laser (*l*ight *a*mplification by *s*timulated *e*mission of *r*adiation) A light amplifier usually used to produce monochromatic coherent radiation in the infrared, visible, and ultraviolet regions of the *electromagnetic spectrum. Lasers that operate in the X-ray region of the spectrum are also being developed.

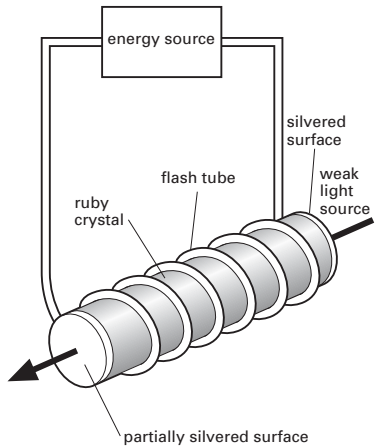
Nonlaser light sources emit radiation in all directions as a result of the spontaneous emission of photons by thermally excited solids (filament lamps) or electronically excited atoms, ions, or molecules (fluorescent lamps, etc.). The emission accompanies the spontaneous return of the excited species to the *ground state and occurs randomly, i.e. the radiation is not coherent. In a laser, the atoms, ions, or molecules are first 'pumped' to an excited state and then stimulated to emit photons by collision of a photon of the same energy. This is called **stimulated emission**. In order to use it, it is first necessary to create a condition in the amplifying medium, called **population inversion**, in which the majority of the relevant entities are excited. Random emission from one entity can then trigger coherent emission from the others that it passes. In this way amplification is achieved.

The laser amplifier is converted to an oscillator by enclosing the amplifying medium within a resonator. Radiation then introduced along the axis of the resonator is reflected back and forth along its path by a mirror at one end and by a partially transmitting mirror at the other end. Between the mirrors the waves are amplified by stimulated emission. The radiation emerges through the semitransparent mirror at one end as a powerful coherent monochromatic parallel beam of light. The emitted beam is uniquely parallel because waves that do not bounce back and forth between the mirrors quickly escape through the sides of the oscillating medium without amplification.

Some lasers are solid, others are liquid or gas devices. Population inversion can be achieved by **optical pumping** with flashlights or with other lasers. It can also be achieved by such methods as chemical reactions, discharges in gases, and recombination emission in semiconducting materials (*see* RECOMBINATION PROCESS).

Lasers have found many uses since their invention in 1960, including laser welding, surgery, *holography, printing, optical communications, and the reading of digital information. In chemistry, their main use has been in the study of photochemical reactions and in the spectroscopic investigation of molecules. *See also* DYE LASER.

laser cooling A technique for producing extremely low temperatures using lasers to slow down and trap atoms. The basic method is to direct a set of crossed laser beams at a sample of gas, with the wavelength set so that photons are absorbed by the atoms. One atom moving towards the photon beam will lose momentum on absorbing a photon and be cooled. An atom moving away from the incident photons will gain energy on absorption. Atoms moving towards the incident photons 'see' the incident photons as having a slightly different frequency than those moving away because of the *Doppler effect, and it is possible to adjust the incident laser frequency by a small amount so that atoms are more likely to absorb when they are moving towards the oncoming photons. This results in a net cooling effect, a technique known as **Doppler cooling**. It produces a region of slow moving atoms at the intersection of the laser beams – a state of matter sometimes called **optical molasses**. Further cooling, to temperatures below the theoretical limit for Doppler cooling, can be obtained by a mechanism known as **Sisyphus cooling**. Here the



Laser. A simple ruby laser.

atom moves through a standing wave created by the laser. As it moves to the top of each 'hill' it loses energy and at the top it is optically pumped to a state at the bottom of the 'valley'. Consequently, the effect is of an atom always moving up a potential gradient and losing energy. The name comes from the character Sisyphus in Greek mythology, who was condemned by the Gods continuously to push a boulder to the top of a hill, only for it to roll back down again when he reached the summit.

Work on laser cooling has also involved methods of trapping atoms. The **magneto-optical trap** (**MOT**) uses six crossed laser beams together with an applied magnetic field to keep cooled atoms together. This allows a further method of cooling in which the height of the trap is lowered so as to let the more energetic atoms escape (a method known as **evaporative cooling**). Techniques of this type have led to temperatures less than 10^{-6} K and to the discovery of the Bose–Einstein condensate (*see* BOSE–EINSTEIN CONDENSATION).

laser printer *See* PRINTER.

latent heat Symbol *L*. The quantity of heat absorbed or released when a substance changes its physical phase at constant temperature (e.g. from solid to liquid at the melting point or from liquid to gas at the boiling point). For example, the latent heat of vaporization is the energy a substance absorbs from its surroundings in order to overcome the attractive forces between its molecules as it changes from a liquid to a gas and in order to do work against the external atmosphere as it expands. In thermodynamic terms the latent heat is the *enthalpy of evaporation (ΔH), i.e. $L = \Delta H = \Delta U + p\Delta V$, where ΔU is the change in the internal energy, p is the pressure, and ΔV is the change in volume.

The **specific latent heat** (symbol l) is the heat absorbed or released per unit mass of a substance in the course of its isothermal change of phase. The **molar latent heat** is the heat absorbed or released per unit amount of substance during an isothermal change of state.

latent learning A form of *learning in which there is apparently no immediate reward for the animal, and what is learnt remains 'latent'. The prime example is an animal exploring its surroundings. Learning about the geography of its home area may bring an animal no immediate benefits, but can prove vital in the future when fleeing a predator or searching for food. Many insects learn the details of landmarks near their nest by making orientation flights. This process enables them to locate the nest when returning from distant sites.

latent period The short time that elapses between the reception of a stimulus and the start of the response. For a contracting muscle the latent period lasts about 0.02 seconds.

lateral inversion (perversion) The type of reversal that occurs with an image formed by a plane mirror. A person with a mole on his left cheek sees an image in a plane mirror of a person with a mole on his right cheek. Since, however, that is (correctly) to the observer's left, the real reversal is of front and back; the image is 'turned through' itself to face the object – hence the alternative name.

lateral velocity The component of a celestial body's velocity that is at 90° to its *line-of-sight velocity.

laterite A layer of deposits composed largely of hydroxides of iron and aluminium formed from the weathering of rocks in humid tropical and subtropical climates. Laterites range from soft earthy materials to hard dense rocks. It hardens on exposure to the atmosphere and is used as a building material. In the weathering process silica, alkalis, and alkaline earths are removed leaving behind concentrations of iron and aluminium oxides; this process is known as **laterization**.

latex A milky fluid of mixed composition found in some herbaceous plants and trees. Its function is not clear but it may assist in protecting wounds (*compare* GUM) and it may be involved in the nutrition of the plant. The latex of some species, notably rubber trees, is collected for commercial purposes.

Latimer diagram A simple diagram summarizing the standard potentials for an element in different oxidation states. The different species are written in a horizontal line in order of decreasing oxidation state, with the most highly oxidized species on the left. Arrows are written between adjacent species with the standard potential in volts indicated above the arrow. Often the oxidation number is included in the diagram. The standard electrode potential for nonadjacent species can be calculated, but values for

common couples are often indicated by additional arrows, Latimer diagrams depend on pH and are commonly given for both acidic and alkaline conditions. *See also* FROST DIAGRAM.

latitude and longitude **1.** (in geography) Imaginary lines on the earth's surface, enabling any point to be defined in terms of two angles subtended at its centre (see illustration). **Parallels of latitude** are circles drawn round the earth parallel to the equator; their diameters diminish as they approach the poles. These parallels are specified by the angle subtended at the centre of the earth by the arc formed between a point on the parallel and the equator. All points on the equator therefore have a latitude of 0°, while the north pole has a latitude of 90°N and the south pole of 90°S. Parallels of latitude 1° apart are separated on the earth's surface by about 100 km.

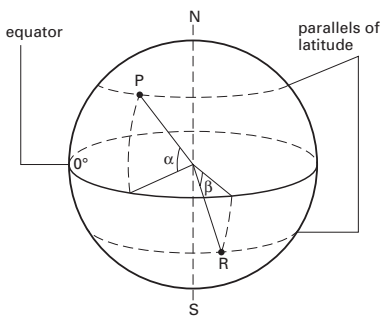
Meridians of longitude are half *great circles passing through both poles; they cross parallels of latitude at right angles. In 1884 the meridian through Greenwich, near London, was selected as the prime meridian and designated as 0°. Other meridians are defined by the angle between the plane of the meridian and the plane of the prime meridian specifying whether it is E or W of the prime meridian. At the equator meridians 1° apart are separated by about 112 km. **2.** (in astronomy) The **celestial latitude** of a star, or other celestial body, is its angular distance north (taken as positive) or south (taken as negative) of the ecliptic measured along the great circle through the body and the poles of the ecliptic. The **celestial longitude** is the angular distance from the vernal equinox measured eastwards along the ecliptic to the intersection of the body's circle of longitude; it is measured in the same direction as the sun's apparent annual motion.

lattice The regular arrangement of atoms, ions, or molecules in a crystalline solid. *See* CRYSTAL LATTICE.

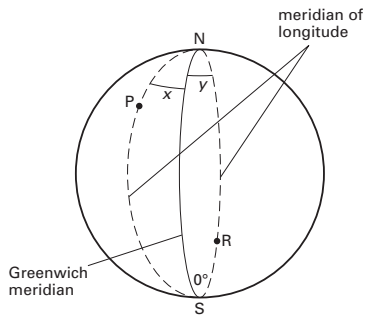
lattice energy A measure of the stability of a *crystal lattice, given by the energy that would be released per mole if atoms, ions, or molecules of the crystal were brought together from infinite distances apart to form the lattice. *See* BORN–HABER CYCLE.

lattice vibrations The periodic vibrations of the atoms, ions, or molecules in a *crystal lattice about their mean positions. On heating, the amplitude of the vibrations increases until they are so energetic that the lattice breaks down. The temperature at which this happens is the melting point of the solid and the substance becomes a liquid. On cooling, the amplitude of the vibrations diminishes. At *absolute zero a residual vibration persists, associated with the *zero-point energy of the substance. The increase in the electrical resistance of a conductor is due to increased scattering of the free conduction electrons by the vibrating lattice particles.

latus rectum *See* ELLIPSE; HYPERBOLA; PARABOLA.



The latitude of P is given by the angle α. In this case it would be α°N. The latitude of R is β°S.



The longitude of P is given by the angle *x*. In this case it would be *x*°W. R has a longitude of *y*°E.

Latitude and longitude.

Laue, Max Theodor Felix von (1879–1960) German physicist, who became a professor at Berlin in 1919, moving in 1943 to the Max Planck Institute at Göttingen. He is best known for his discovery in 1912 of *X-ray diffraction, for which he was awarded the 1914 Nobel Prize for physics.

laughing gas *See* DINITROGEN OXIDE.

launch vehicle A rocket used to launch a satellite, spaceprobe, space station, etc. Multistage rockets are usually used, the empty tanks and engine of the first two stages being jettisoned before the desired orbit is reached. The **launch window** is the time interval during which the vehicle must be launched so that it can achieve its correct orbit or the trajectory it must take in order to reach its destination.

Laurasia *See* CONTINENTAL DRIFT.

lauric acid *See* DODECANOIC ACID.

lava Molten rock (magma) that rises to the surface from below ground, usually through a volcano. A typical free-flowing lava consists of a basic rock, such as *basalt; acidic lavas are more viscous. There are various types: **aa** solidifies as rough blocks; **pahoehoe** takes the form of ropy strands; **pillow lava**, named after its shape, occurs where molten lava flows into the sea or erupts from an underwater volcano. Lava that contains volatile materials solidifies as *pumice.

Laves phase A phase that occurs for alloys of the type AB_2, in which the atoms of the element A are arranged in a diamond-like structure and the atoms of the element B are arranged in tetrahedra around the atoms of A. The phases are named after the German crystallographer Fritz Laves (1906–1978).

Lavoisier, Antoine Laurent (1743–1794) French chemist, who collected taxes for the government in Paris. In the 1770s he discovered oxygen and nitrogen in air and demolished the *phlogiston theory of combustion by demonstrating the role of oxygen in the process. In 1783 he made water by burning hydrogen in oxygen (*see* CAVENDISH, HENRY). He also devised a rational nomenclature for chemical compounds. In 1794 he was tried by the Jacobins as an opponent of the Revolution (because of his tax-gathering), found guilty, and guillotined.

law of chemical equilibrium *See* EQUILIBRIUM CONSTANT.

law of conservation of energy *See* CONSERVATION LAW.

law of conservation of mass *See* CONSERVATION LAW.

law of constant composition *See* CHEMICAL COMBINATION.

law of definite proportions *See* CHEMICAL COMBINATION.

law of mass action *See* MASS ACTION.

law of multiple proportions *See* CHEMICAL COMBINATION.

law of octaves (Newlands' law) An attempt at classifying elements made by John Newlands (1837–98) in 1863. He arranged 56 elements in order of increasing atomic mass in groups of eight, pointing out that each element resembled the element eight places from it in the list. He drew an analogy with the notes of a musical scale. **Newlands' octaves** were groups of similar elements distinguished in this way: e.g. oxygen and sulphur; nitrogen and phosphorus; and fluorine, chlorine, bromine, and iodine. In some cases it was necessary to put two elements in the same position. The proposal was rejected at the time. *See* PERIODIC TABLE.

SEE WEB LINKS

- John Newlands' paper

law of reciprocal proportions *See* CHEMICAL COMBINATION.

lawrencium Symbol Lr. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 103; mass number of the first discovered isotope 257 (half-life 8 seconds). A number of very short-lived isotopes have now been synthesized. The element was identified by Albert Ghiorso and associates in 1961. The alternative name **unniltrium** has been proposed.

SEE WEB LINKS

- Information from the WebElements site

laws of chemical combination *See* CHEMICAL COMBINATION.

Lawson criterion A condition for the release of energy from a *thermonuclear reactor first laid down by J. D. Lawson in 1957. It is usually stated as the minimum value for the product of the density (n_G) of the fusion-fuel particles and the *containment time (τ) for energy breakeven, i.e. it is a measure of the density of the reacting particles required and the time for which they need to react in

order to produce more energy than was used in raising the temperature of the reacting particles to the *ignition temperature. For a 50:50 mixture of deuterium and tritium at the ignition temperature, the value of $n_G\tau$ is between 10^{14} and 10^{15} cm^{-3} s.

laws, theories, and hypotheses In science, a law is a descriptive principle of nature that holds in all circumstances covered by the wording of the law. There are no loopholes in the laws of nature and any exceptional event that did not comply with the law would require the existing law to be discarded or would have to be described as a miracle. Eponymous laws are named after their discoverers (e.g. *Boyle's law); some laws, however, are known by their subject matter (e.g. the law of conservation of mass), while other laws use both the name of the discoverer and the subject matter to describe them (e.g. *Newton's law of gravitation).

A description of nature that encompasses more than one law but has not achieved the uncontrovertible status of a law is sometimes called a **theory**. Theories are often both eponymous and descriptive of the subject matter (e.g. Einstein's theory of relativity and Darwin's theory of evolution).

A **hypothesis** is a theory or law that retains the suggestion that it may not be universally true. However, some hypotheses about which no doubt still lingers have remained hypotheses (e.g. Avogadro's hypothesis), for no clear reason. Clearly there is a degree of overlap between the three concepts.

layer lattice A crystal structure in which the atoms are chemically bonded in plane layers, with relatively weak forces between atoms in adjacent layers. Graphite and micas are examples of substances having layer lattices (i.e. they are *lamellar solids).

lazurite *See* LAPIS LAZULI.

LCD Liquid-crystal display; a flat-panel display that is used with many computers. LCDs are also used in other digital instruments and in flat-screen televisions. Early LCDs suffered from poor contrast between light and dark combined with narrow viewing angles. Several different forms of construction now offer improved viewing characteristics.

LCD technology is based on **liquid crystals**. These are common organic compounds that, between specific temperature limits, change their crystal structure to allow them to flow like a liquid. **Supertwisted nematic displays** use rod-shaped (nematic) crystals. The crystals are organized between two transparent polarized layers with 90° between the directions of polarization. The crystals form a spiral between the two layers so that light can be rotated and passed through the material unchanged. When an electric field is applied, the orientation of the crystals is disturbed thus stopping the light passing. Controlling the electric field applied to each pixel results in an image. It is possible to switch modes up to 120 hertz. In consequence, by shuttering white light through coloured dye filters it is possible to turn a monochrome display into a colour one. The same shuttering system can be used to generate stereo images.

Supertwisted nematic displays may be **passive-matrix LCDs**, containing no active (switching) electronic components. Nowadays much higher performance, especially for colour displays, is obtained from **active-matrix LCDs**. In this construction, a thin-film transistor is added to each pixel to ensure an adequate and constant drive is maintained between refresh cycles. This gives a more uniform display and wider viewing angle.

LCP *See* LIQUID-CRYSTAL POLYMER.

LD_{50} Lethal dose 50, or median lethal dose: the amount of a pharmacological or toxic substance (such as ionizing radiation) that causes death in 50% of a group of experimental animals. For each LD_{50} the species and weight of the animal and the route of administration of the substance is specified. LD_{50}s are used both in toxicology and in the *bioassay of therapeutic compounds.

L-dopa *See* DOPA.

L–D process *See* BASIC-OXYGEN PROCESS.

leaching Extraction of soluble components of a solid mixture by percolating a solvent through it.

lead (in physics) *See* PHASE ANGLE.

lead (in chemistry) Symbol Pb. A heavy dull grey soft ductile metallic element belonging to *group 14 (formerly IVB) of the periodic table; a.n. 82; r.a.m. 207.19; r.d. 11.35; m.p. 327.5°C; b.p. 1740°C. The main ore is the sulphide galena (PbS); other minor sources include anglesite ($PbSO_4$), cerussite ($PbCO_3$), and litharge (PbO). The metal is extracted by roasting the ore to give the oxide, followed by reduction with carbon. Silver is

also recovered from the ores. Lead has a variety of uses including building construction, lead-plate accumulators, bullets, and shot, and is a constituent of such alloys as solder, pewter, bearing metals, type metals, and fusible alloys. Chemically, it forms compounds with the +2 and +4 oxidation states, the lead(II) state being the more stable.

SEE WEB LINKS

- Information from the WebElements site

lead(II) acetate *See* LEAD(II) ETHANOATE.

lead–acid accumulator An accumulator in which the electrodes are made of lead and the electrolyte consists of dilute sulphuric acid. The electrodes are usually cast from a lead alloy containing 7–12% of antimony (to give increased hardness and corrosion resistance) and a small amount of tin (for better casting properties). The electrodes are coated with a paste of lead(II) oxide (PbO) and finely divided lead; after insertion into the electrolyte a 'forming' current is passed through the cell to convert the PbO on the negative plate into a sponge of finely divided lead. On the positive plate the PbO is converted to lead(IV) oxide (PbO_2). The equation for the overall reaction during discharge is:

$$PbO_2 + 2H_2SO_4 + Pb \rightarrow 2PbSO_4 + 2H_2O$$

The reaction is reversed during charging. Each cell gives an e.m.f. of about 2 volts and in motor vehicles a 12-volt battery of six cells is usually used. The lead–acid battery produces 80–120 kJ per kilogram. *Compare* NICKEL–IRON ACCUMULATOR.

lead(II) carbonate A white solid, $PbCO_3$, insoluble in water; rhombic; r.d. 6.6. It occurs as the mineral *cerussite, which is isomorphous with aragonite and may be prepared in the laboratory by the addition of cold ammonium carbonate solution to a cold solution of a lead(II) salt (acetate or nitrate). It decomposes at 315°C to lead(II) oxide and carbon dioxide.

lead(II) carbonate hydroxide (white lead; basic lead carbonate) A powder, $2PbCO_3.Pb(OH)_2$, insoluble in water, slightly soluble in aqueous carbonate solutions; r.d. 6.14; decomposes at 400°C. Lead(II) carbonate hydroxide occurs as the mineral **hydroxycerussite** (of variable composition). It was previously manufactured from lead in processes using spent tanning bark or horse manure, which released carbon dioxide. It is currently made by electrolysis of mixed solutions (e.g. ammonium nitrate, nitric acid, sulphuric acid, and acetic acid) using lead anodes. For the highest grade product the lead must be exceptionally pure (known in the trade as 'corroding lead') as small amounts of metallic impurity impart grey or pink discolorations. The material was used widely in paints, both for art work and for commerce, but it has the disadvantage of reacting with hydrogen sulphide in industrial atmospheres and producing black lead sulphide. The poisonous nature of lead compounds has also contributed to the declining importance of this material.

lead-chamber process An obsolete method of making sulphuric acid by the catalytic oxidation of sulphur dioxide with air using a potassium nitrate catalyst in water. The process was carried out in lead containers (which was expensive) and only produced dilute acid. It was replaced in 1876 by the *contact process.

lead dioxide *See* LEAD(IV) OXIDE.

lead equivalent A measure of the absorbing power of a radiation screen, expressed as the thickness of a lead screen in millimetres that would afford the same protection as the material being considered.

lead(II) ethanoate (lead(II) acetate) A white crystalline solid, $Pb(CH_3COO)_2$, soluble in water and slightly soluble in ethanol. It exists as the anhydrous compound (r.d. 3.25; m.p. 280°C), as a trihydrate, $Pb(CH_3COO)_2.3H_2O$ (monoclinic; r.d. 2.55; loses water at 75°C), and as a decahydrate, $Pb(CH_3COO)_2.10H_2O$ (rhombic; r.d. 1.69). The common form is the trihydrate. Its chief interest stems from the fact that it is soluble in water and it also forms a variety of complexes in solution. It was once known as **sugar of lead** because of its sweet taste.

lead(IV) ethanoate (lead tetra-acetate) A colourless solid, $Pb(CH_3COO)_4$, which decomposes in water and is soluble in pure ethanoic acid; monoclinic; r.d. 2.228; m.p. 175°C. It may be prepared by dissolving dilead(II) lead(IV) oxide in warm ethanoic acid. In solution it behaves essentially as a covalent compound (no measurable conductivity) in contrast to the lead(II) salt, which is a weak electrolyte.

lead(IV) hydride *See* PLUMBANE.

lead monoxide *See* LEAD(II) OXIDE.

lead(II) oxide (lead monoxide) A solid yellow compound, PbO, which is insoluble

in water; m.p. 886°C. It exists in two crystalline forms: **litharge** (tetrahedral; r.d. 9.53) and **massicot** (rhombic; r.d. 8.0). It can be prepared by heating the nitrate, and is manufactured by heating molten lead in air. If the temperature used is lower than the melting point of the oxide, the product is massicot; above this, litharge is formed. Variations in the temperature and in the rate of cooling give rise to crystal vacancies and red, orange, and brown forms of litharge can be produced. The oxide is amphoteric, dissolving in acids to give lead(II) salts and in alkalis to give *plumbates.

lead(IV) oxide (lead dioxide) A dark brown or black solid with a rutile lattice, PbO_2, which is insoluble in water and slightly soluble in concentrated sulphuric and nitric acids; r.d. 9.375; decomposes at 290°C. Lead(IV) oxide may be prepared by the oxidation of lead(II) oxide by heating with alkaline chlorates or nitrates, or by anodic oxidation of lead(II) solutions. It is an oxidizing agent and readily reverts to the lead(II) oxidation state, as illustrated by its conversion to Pb_3O_4 and PbO on heating. It reacts with hydrochloric acid to evolve chlorine. Lead(IV) oxide has been used in the manufacture of safety matches and was widely used until the mid-1970s as an adsorbent for sulphur dioxide in pollution monitoring.

lead(II) sulphate A white crystalline solid, $PbSO_4$, which is virtually insoluble in water and soluble in solutions of ammonium salts; r.d. 6.2; m.p. 1170°C. It occurs as the mineral **anglesite**; it may be prepared in the laboratory by adding any solution containing sulphate ions to solutions of lead(II) ethanoate. The material known as **basic lead(II) sulphate** may be made by shaking together lead(II) sulphate and lead(II) hydroxide in water. This material has been used in white paint in preference to lead(II) carbonate hydroxide, as it is not so susceptible to discoloration through reaction with hydrogen sulphide. The toxicity of lead compounds has led to a decline in the use of these compounds.

lead(II) sulphide A black crystalline solid, PbS, which is insoluble in water; r.d. 7.5; m.p. 1114°C. It occurs naturally as the metallic-looking mineral *galena (the principal ore of lead). It may be prepared in the laboratory by the reaction of hydrogen sulphide with soluble lead(II) salts. Lead(II) sulphide has been used as an electrical rectifier.

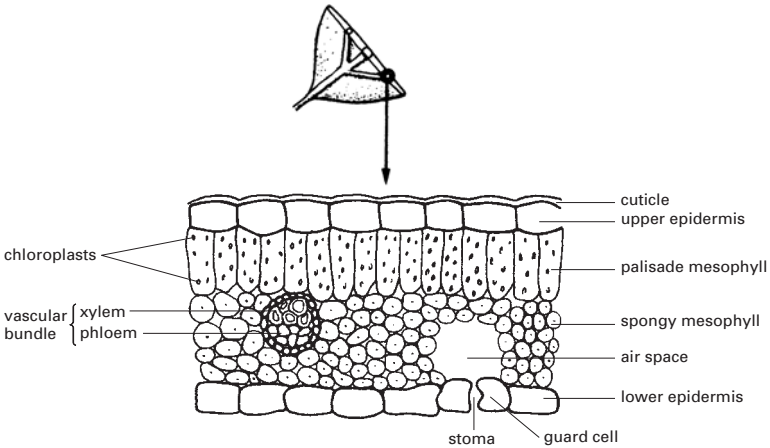
lead tetra-acetate *See* LEAD(IV) ETHANOATE.

lead(IV) tetraethyl (tetraethyl lead) A colourless liquid, $Pb(C_2H_5)_4$, insoluble in water, soluble in benzene, ethanol, ether, and petroleum; r.d. 1.659; m.p. –137°C; b.p. 200°C. It may be prepared by the reaction of hydrogen and ethene with lead but a more convenient laboratory and industrial method is the reaction of a sodium–lead alloy with chloroethane. A more recent industrial process is the electrolysis of ethylmagnesium chloride (the Grignard reagent) using a lead anode and slowly running additional chloroethane onto the cathode. Lead tetraethyl is used in fuel for internal-combustion engines (along with 1,2-dibromoethane) to increase the *octane number and reduce preignition. However, its use in petrol results in the emission of hazardous lead compounds into the atmosphere. Pressure from environmental groups has encouraged a reduction in the use of lead(IV) tetraethyl and an increasing use of lead-free petrol. *See* KNOCKING.

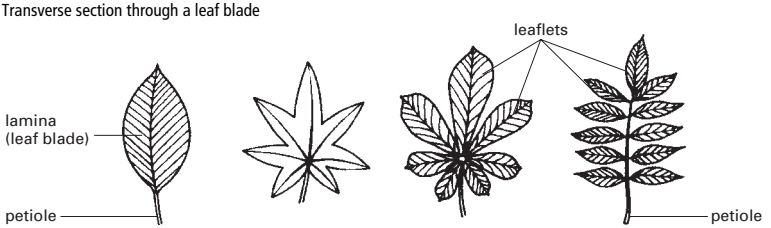
leaf A flattened structure that develops from a superficial group of tissues, the leaf buttress, on the side of the stem apex. Each leaf has a lateral bud in its axil. Leaves are arranged in a definite pattern (*see* PHYLLOTAXIS) and usually show limited growth. Each consists of a broad flat *lamina (leaf blade) and a leaf base, which attaches the leaf to the stem; a leaf stalk (**petiole**) may also be present. The leaves of bryophytes are simple appendages, which are not homologous with the leaves of vascular plants as they develop on the gametophyte generation.

Leaves show considerable variation in size, shape, arrangement of veins, type of attachment to the stem, and texture. They may be **simple** or divided into **leaflets**, i.e. **compound** (see illustration). Types of leaf include: *cotyledons (seed leaves); **scale leaves**, which lack chlorophyll and develop on rhizomes or protect the inner leaves of a bud; **foliage leaves**, which are the main organs for photosynthesis and transpiration; and *bracts and **floral leaves**, such as sepals, petals, stamens, and carpels, which are specialized for reproduction.

Leaves may be modified for special purposes. For example the leaf bases of bulbs



Transverse section through a leaf blade



Simple leaves

Compound leaves

Leaf.

are swollen with food to survive the winter. In some plants leaves are reduced to spines for protection and their photosynthetic function is carried out by another organ, such as a *cladode.

leaf buttress *See* PRIMORDIUM.

leaf litter *See* LITTER.

learning A process by which an animal's response to a particular situation may be permanently altered, usually in a beneficial way, as a result of its experience. Learning allows an animal to respond more flexibly to the situations it encounters: learning abilities in different species vary widely and are adapted to the species' environment. *See also* CONDITIONING; HABITUATION; IMPRINTING; INSIGHT LEARNING; LATENT LEARNING. See Feature overleaf.

least-squares method A method of fitting a curve (or line) to points on a *graph. The best fit occurs when the sum of the squares of the distances from the curve to the points is a minimum. It assumes that random measurement errors follow a *normal distribution.

Leblanc process An obsolete process for manufacturing sodium carbonate. The raw materials were sodium chloride, sulphuric acid, coke, and limestone (calcium carbonate), and the process involved two stages. First the sodium chloride was heated with sulphuric acid to give sodium sulphate:

$$2NaCl(s) + H_2SO_4(l) \rightarrow Na_2SO_4(s) + 2HCl(g)$$

The sodium sulphate was then heated with coke and limestone:

LEARNING IN ANIMALS

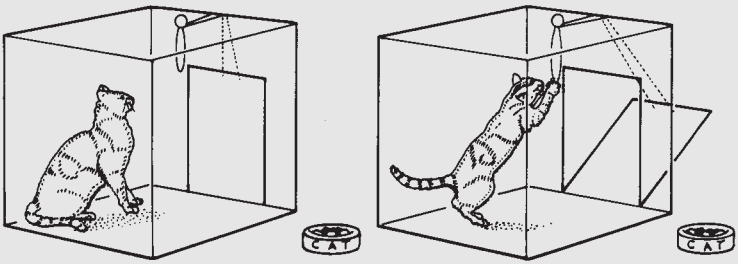
An animal's survival prospects are greatly improved if the animal alters its behaviour according to its experience. Learning increases its chances of obtaining food, avoiding predators, and adjusting to other changes in its environment. The importance of learning in the development of behaviour was stressed particularly by US experimental psychologists, such as John B. Watson (1878–1958) and B. F. Skinner (1904–90), who studied animals under carefully controlled laboratory conditions. They demonstrated how rats and pigeons could be trained, or 'conditioned', by exposing them to stimuli in the form of food rewards or electric shocks. This work was criticized by others, notably the ethologists, who preferred to observe animals in their natural surroundings and who stressed the importance of inborn mechanisms, such as instinct, in behavioural development. A synthesis between these two once-conflicting approaches has now been achieved: learning is regarded as a vital aspect of an animal's development, occurring in response to stimuli in the animal's environment but within constraints set by the animal's genes. Hence young animals are receptive to a wide range of stimuli but are genetically predisposed to respond to those that are most significant, such as those from their mother.

Conditioning

The classical demonstration of conditioning was undertaken by Ivan *Pavlov in the early 1900s. He showed how dogs could learn to associate the ringing of a bell with the presentation of food, and after a while would salivate at the sound of the bell alone. He measured the amount of saliva produced by a dog, and showed that this increased as the animal learnt to associate the sound of the bell with presentation of food. The dog became conditioned to respond to the sound of the bell. Such learning is widespread among animals. Pavlov's experiment involved positive conditioning, but negative conditioning can also occur. For example, a young bird quickly learns to associate the black-and-orange markings of the cinnabar moth's caterpillars with their unpleasant taste, and to avoid eating such caterpillars in future.

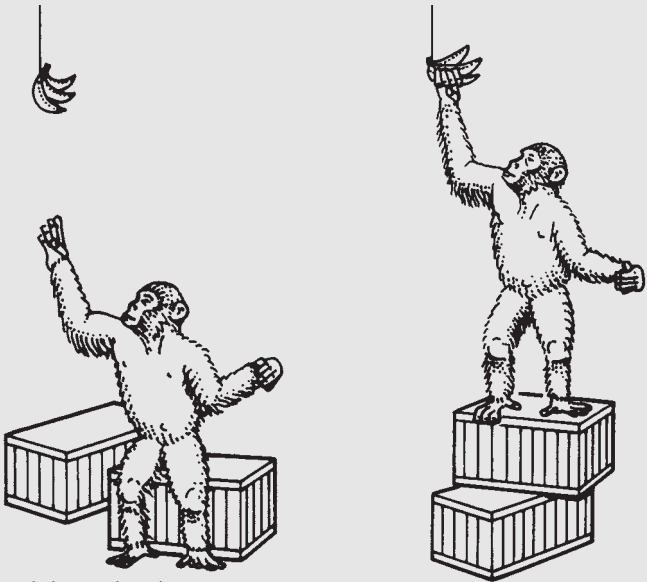
Trial-and-error learning

This occurs when the spontaneous behaviour of an animal produces a reward. For example, a hungry cat placed in a box is required to pull a string loop to open the door and gain access to food. After various scratching and reaching movements, it accidentally pulls the loop and is released from the box. Its behaviour is instrumental in securing a reward. On subsequent occasions, the cat's attention becomes increasingly focused on the loop, until eventually it pulls the loop straightaway on entering the box.



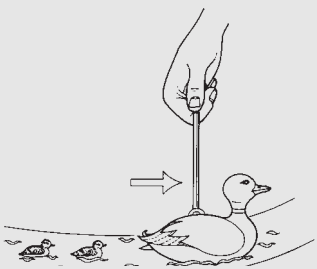
Trial-and-error learning by a cat

Insight learning
Chimpanzees can learn to stack crates or boxes to form a platform or to manipulate poles in order to reach an otherwise inaccessible bunch of bananas. A chimp may apparently solve such a problem suddenly, as if gaining insight after mental consideration of the problem. Such complex learning benefits from previous experience, in this instance by simply 'playing' with crates, boxes, or poles.



Insight learning by a chimpanzee

Imprinting
This is a form of learning found in young animals, especially young birds, in which they form an attachment to their mother in early life, thereby ensuring that they are taken care of and do not wander off. For example, chicks or ducklings follow the first large moving object that they encounter after hatching. This is normally their mother, but artifically incubated youngsters can become imprinted on a wooden decoy, as illustrated here, or even on a human being – as originally demonstrated in goslings and ducklings by Konrad *Lorenz. Imprinting occurs during a particularly sensitive period of development: the attachment formed by an animal to an imprinted individual or object lasts well into its adult life.



Imprinting in ducklings

$Na_2SO_4 + 2C + CaCO_3 \rightarrow Na_2CO_3 + CaS + 2CO_2$

Calcium sulphide was a by-product, the sodium carbonate being extracted by crystallization. The process, invented in 1783 by the French chemist Nicolas Leblanc (1742–1806), was the first for producing sodium carbonate synthetically (earlier methods were from wood ash and other vegetable sources). By the end of the 19th century it had been largely replaced by the *Solvay process.

lechatelierite A mineral form of *silicon(IV) oxide, SiO_2.

Le Chatelier's principle If a system is in equilibrium, any change imposed on the system tends to shift the equilibrium to nullify the effect of the applied change. The principle, which is a consequence of the law of conservation of energy, was first stated in 1888 by Henri Le Chatelier (1850–1936). It is applied to chemical equilibria. For example, in the gas reaction

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

an increase in pressure on the reaction mixture displaces the equilibrium to the right, since this reduces the total number of molecules present and thus decreases the pressure. The standard enthalpy change for the forward reaction is negative (i.e. the reaction is exothermic). Thus, an increase in temperature displaces the equilibrium to the left since this tends to reduce the temperature. The *equilibrium constant thus falls with increasing temperature.

SEE WEB LINKS

- Le Chatelier's original paper

lecithin (phosphatidylcholine) A phosphoglyceride (*see* PHOSPHOLIPID) containing the amino alcohol *choline esterified to the phosphate group. It is the most abundant animal phospholipid (being a component of plasma membranes) and also occurs in higher plants, but rarely in microorganisms.

Leclanché cell A primary *voltaic cell consisting of a carbon rod (the anode) and a zinc rod (the cathode) dipping into an electrolyte of a 10–20% solution of ammonium chloride. *Polarization is prevented by using a mixture of manganese dioxide mixed with crushed carbon, held in contact with the anode by means of a porous bag or pot; this reacts with the hydrogen produced. This wet form of the cell, devised in 1867 by Georges Leclanché (1839–82), has an e.m.f. of about 1.5 volts. The *dry cell based on it is widely used in torches, radios, and calculators.

lectin Any of a group of proteins, found in a variety of organisms, that bind to specific carbohydrate groups. Lectins derived from plant seeds, such as **concanavalin A**, can cause cells to clump together by forming cross links between the oligosaccharide groups on cell surfaces. Lectins are widely used for diagnosis and experimental purposes, e.g. to identify mutant cells in cell cultures, to determine blood groups by triggering *agglutination of red blood cells, or in mapping the surface of plasma membranes. In legumes lectins take part in the recognition of suitable bacterial partners for the plant in establishing root nodule symbioses.

LED *See* LIGHT-EMITTING DIODE.

leeches *See* HIRUDINEA.

LEED Low-energy electron diffraction. *See* ELECTRON DIFFRACTION.

Leeuwenhoek, Anton van (1632–1723) Dutch microscopist, who had little formal education. He is known for accurately grinding small lenses to make simple microscopes, with which he made the first observations of red blood cells, protozoa, and spermatozoa. He communicated regularly with the Royal Society in London, which published many of his findings in its *Philosophical Transactions*.

Leggett's theorem A result in *quantum mechanics that is a generalization of *Bell's theorem. This theorem, which was put forward in 2003 by the British physicist Anthony Leggett (1938–), states that nonlocal *hidden-variables theories make predictions that contradict the predictions of quantum mechanics. It was subsequently found that experiments agree with the predictions of quantum mechanics rather than of nonlocal hidden-variables theories.

legume (pod) A dry fruit formed from a single carpel and containing one or more seeds, which are shed when mature. It is the characteristic fruit of the Leguminosae (Fabaceae; pea family). It splits, often explosively, along both sides and the two halves of the fruit move apart to expose the seeds. A special form of the legume is the *lomentum.

Leishman's stain A neutral stain for blood smears devised by the British surgeon Sir William Boog Leishman (1865–1926). It

consists of a mixture of *eosin (an acidic stain), and *methylene blue (a basic stain) in alcohol and is usually diluted and buffered before use. It stains the different components of blood in a range of shades between red and blue. The similar **Wright's stain** is favoured by American workers.

Lemaître, Georges Edouard (1894–1966) Belgian astronomer, who was ordained as a priest in 1923. He went to work at Louvain University in 1925, becoming professor of astronomy two years later. He is best known for his *big-bang theory of the origin of the universe.

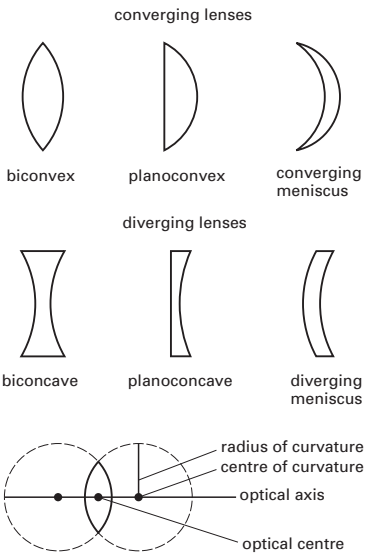
lens **1.** (in physics) A curved, ground, and polished piece of glass, moulded plastic, or other transparent material used for the refraction of light. A **converging lens** is one that brings the rays of a parallel beam of light to a real *principal focus. They include biconvex, planoconvex, and converging meniscus lenses. **Diverging lenses** cause the rays of a parallel beam to diverge as if from a virtual principal focus; these include the biconcave, planoconcave, and diverging meniscus lenses. See illustrations.

The **centre of curvature** of a lens face is the centre of the sphere of which the surface of the lens is a part. The **optical axis** is the line joining the two centres of curvature of a lens or, in the case of a lens with one plane surface, the line through one centre of curvature that is normal to the plane surface. The **optical centre** of a lens is the point within a lens on the optical axis through which any rays entering the lens pass without deviation. The distance between the optical centre and the principal focus of a lens is called the **focal length** (f). The distance (v) between the lens and the image it forms is related to the distance (u) between the lens and the object by:

$$1/v + 1/u = 1/f,$$

provided that the *real-is-positive convention is used. This takes distances to real objects, images, and foci as positive; those to virtual objects, images, and foci as negative. The equation does not always apply if the alternative New Cartesian convention (*see* SIGN CONVENTION) is used.

2. (in anatomy) A transparent biconvex structure in the eyes or analogous organs of many animals, responsible for directing light onto light-sensitive cells. In vertebrates it is a flexible structure centred behind the iris and attached by **suspensory ligaments** to the *ciliary body. In terrestrial species its main function is to focus images onto the retina. To focus on near objects, the circular muscles in the ciliary body contract and the lens becomes more convex; contraction of the radial muscles in the ciliary body flattens the lens for focusing on distant objects (*see also* ACCOMMODATION).



Lenses.

Lense–Thirring effect An effect predicted to occur in general relativity theory by J. Lense and Hans Thirring in 1918 in which a compact rotating body causes the space near it to rotate in the same direction. The phenomenon is also known as **frame dragging**. It has been reported in observations of neutron stars and black holes. Measurements have also been made using shifts in the orbits of satellites around the earth.

SEE WEB LINKS

- The home page of NASA's Gravity Probe B experiment to investigate frame dragging

lenticel Any of the raised pores in the stems of woody plants that allow gas exchange between the atmosphere and the internal tissues. The pore is formed by the *cork cambium, which, at certain points, produces a loose bulky form of cork that

pushes through the outer tissues to create the lenticel.

Lenz's law An induced electric current always flows in such a direction that it opposes the change producing it. This law, first stated by Heinrich Lenz (1804–65) in 1835, is a particular example of the law of conservation of energy.

LEP Large Electron-Positron Collider. *See* CERN.

Lepidoptera An order of insects comprising the butterflies and moths, found mainly in tropical regions. Adults possess two pairs of membranous wings, often brightly coloured and usually coupled together. The wings, body, and legs are covered with minute scales. Adult mouthparts are generally modified to form a long proboscis for sucking nectar, fruit juices, etc. Butterflies are typically small-bodied, active during daylight, and rest with their wings folded vertically; moths have larger bodies, are nocturnal, and rest with their wings in various positions. The larvae (caterpillars) have a prominent head and a segmented wormlike body, most segments bearing a pair of legs. They chew leaves and stems, sometimes causing considerable damage to crop plants. The larvae undergo metamorphosis via a *pupa (chrysalis) to the adult form. In some groups, the pupa is enclosed in a cocoon of silk derived from silk glands (modified salivary glands); others use leaves, etc. to build a cocoon.

leptin A protein hormone, comprising 167 amino acids in humans, that is secreted by adipose tissue and regulates adipose tissue mass and energy balance. It acts on leptin receptors in the hypothalamus and inhibits expression of *neuropeptide Y, thereby countering the appetite-stimulating effects of the latter and inhibiting food intake. It also promotes synthesis of the appetite suppressant *melanocyte-stimulating hormone. Deficiency of leptin or its receptors leads to severe obesity.

lepton Any of a class of *elementary particles that consists of the *electron, muon, tau particle, and three types of *neutrino (one associated with each of the other types of lepton). For each lepton there is an equivalent antiparticle. The antileptons have a charge opposite that of the leptons; the antineutrinos, like the neutrinos, have no charge. The electron, muon, and tau particle all have a charge of –1. These three particles differ from each other only in mass: the muon is 200 times more massive than the electron and the tau particle is 3500 times more massive than the electron. Leptons interact by the electromagnetic interaction and the weak interaction (*see* FUNDAMENTAL INTERACTIONS).

lepton number *See* ELEMENTARY PARTICLES.

leptotene The beginning of the first prophase of *meiosis, when the chromatids can be seen and *pairing begins.

Leslie's cube A metal box in the shape of a cube in which each of the four vertical sides have different surface finishes. When hot water is placed in the cube, the emissivity of the finishes can be compared. The device was first used by Sir John Leslie (1766–1832).

lethal allele (lethal gene) A mutant form of a gene that eventually results in the death of an organism if expressed in the phenotype. Most lethal genes are recessive; for example, sickle-cell anaemia (*see* POLYMORPHISM) results from a recessive lethal gene that causes the production of abnormal and inefficient haemoglobin.

lethal dose 50 *See* LD_{50}.

leucine *See* AMINO ACID.

leucocyte (white blood cell) A colourless cell with a nucleus, found in blood and lymph. Leucocytes are formed in lymph nodes and red bone marrow and are capable of amoeboid movement. They can produce *antibodies and move through the walls of vessels to migrate to the sites of injuries, where they surround and isolate dead tissue, foreign bodies, and bacteria. There are two major types: those without granules in the cytoplasm, such as *lymphocytes and *monocytes (*see* AGRANULOCYTE), and those with granular cytoplasm (*granulocytes), which include *basophils and *neutrophils.

leuco form *See* DYES.

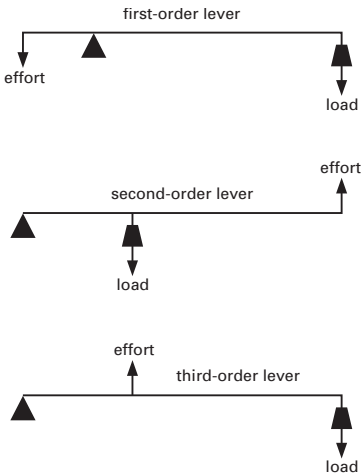
leucomalachite green test A *presumptive test for blood. The reagent is the dye leucomalachite green dissolved in water along with sodium perborate ($NaBO_3$). A blue-green colour indicates a positive result.

leucoplast Any *plastid in plant cells that contains no pigment and is therefore colourless. Leucoplasts are usually found in tissues not normally exposed to light and frequently

contain reserves of starch, protein, or oil. *Compare* CHROMOPLAST.

leukaemia *See* CANCER.

level An instrument used in *surveying to determine heights. It usually consists of a telescope and attached spirit level mounted on a tripod. The level is set up between a point of known height and a point for which the height is required. Before use it is adjusted until the line of sight is exactly horizontal. Sightings are then made onto a graduated levelling staff at the two points. The difference in elevation between the two points can then be calculated from the readings taken at these points.



Lever.

lever A simple machine consisting of a rigid bar pivoted about a fulcrum. The mechanical advantage or *force ratio of a lever (the ratio of load to effort) is equal to the ratio of the perpendicular distance of the line of action of the effort from the fulcrum to the perpendicular distance of the line of action of the load from the fulcrum. In a first-order lever the fulcrum comes between load and effort. In a second-order lever the load comes between the fulcrum and the effort. In a third-order lever the effort comes between the fulcrum and the load. See illustrations.

Lewis acid and base *See* ACID.

Leyden jar An early form of *capacitor consisting of a glass jar with a layer of metal foil on the outside and a similar layer on the inside. Contact to the inner foil is by means of a loose chain hanging inside the jar. It was invented in the Dutch town of Leyden in about 1745.

LF *See* LOW FREQUENCY.

LH *See* LUTEINIZING HORMONE.

LHC *See* LARGE HADRON COLLIDER.

libration The phenomenon that enables 59% of the moon's surface to be observed from earth over a 30-year period, in spite of its *synchronous rotation. **Physical libration** arises from slight variations in the rotation of the moon on its axis, caused by minor distortions in its physical shape. **Geometric librations** are apparent oscillations arising from the fact that the moon is observed from slightly different directions at different times. The geometric **libration in longitude** results from the nonuniform orbital motion of the moon. The geometric **libration in latitude** arises because the moon's axis of rotation is not perpendicular to its orbital plane; it enables more of the lunar polar regions to be observed.

lice *See* MALLOPHAGA (bird lice); SIPHUNCULATA (sucking lice).

lichens A group of organisms that are symbiotic associations (*see* SYMBIOSIS) between a fungus (usually one of the *Ascomycota) and a green alga or a cyanobacterium. The fungus usually makes up most of the plant body and the cells of the alga or bacterium are distributed within it. The alga or bacterium photosynthesizes and passes most of its food to the fungus and the fungus protects its partner's cells. The lichen reproduces by means of fungal spores, which must find a suitable partner on germination. Lichens are slow growing but can live in regions that are too cold or exposed for other plants. They may form a flattened crust or be erect and branching. Many grow as *epiphytes, especially on tree trunks. Some species are very sensitive to air pollution and have been used as *indicator species. Lichens are classified as fungi, usually being placed in the taxon of the fungal partner; some authorities group them together in the phylum Mycophycophyta.

Liebermann test A *presumptive test sometimes used for cocaine and morphine.

The **Liebermann reagent** is a solution of potassium nitrite (KNO_2) in sulphuric acid. With morphine a black colour is produced; cocaine gives a yellow colour.

Liebig condenser A laboratory condenser having a straight glass tube surrounded by a coaxial glass jacket through which cooling water is passed. It is named after the German organic chemist Justus von Liebig (1803–73).

life cycle The complete sequence of events undergone by organisms of a particular species from the fusion of gametes in one generation to the same stage in the following generation. In most animals gametes are formed by *meiosis of germ cells in the reproductive organs of the parents. The zygote, formed by the fusion of two gametes, eventually develops into an organism essentially similar to the parents. In plants, however, the products of meiosis are spores, which develop into plants (the *gametophyte generation) often very different in form from the spore-forming (*sporophyte) generation. The sporophyte generation is restored when gametes, formed by the gametophyte generation, fuse. *See* ALTERNATION OF GENERATIONS.

ligament A resilient but flexible band of tissue (chiefly *collagen) that holds two or more bones together at a movable *joint. Ligaments restrain the movement of bones at a joint and are therefore important in preventing dislocation.

ligand **1.** (in chemistry) An ion or molecule that donates a pair of electrons to a metal atom or ion in forming a coordination *complex. Molecules that function as ligands are acting as Lewis bases (*see* ACID). For example, in the complex hexaquocopper(II) ion $[Cu(H_2O)_6]^{2+}$ six water molecules coordinate to a central Cu^{2+} ion. In the tetrachloroplatinate(II) ion $[PtCl_4]^{2-}$, four Cl^- ions are coordinated to a central Pt^{2+} ion. A feature of such ligands is that they have lone pairs of electrons, which they donate to empty metal orbitals. A certain class of ligands also have empty *p*- or *d*-orbitals in addition to their lone pair of electrons and can produce complexes in which the metal has low oxidation state. A double bond is formed between the metal and the ligand: a sigma bond by donation of the lone pair from ligand to metal, and a pi bond by **back donation** of electrons on the metal to empty *d*-orbitals on the ligand. Carbon monoxide is the most important such ligand, forming metal carbonyls (e.g. $Ni(CO)_4$).

The examples given above are examples of **monodentate** ligands (literally: 'having one tooth'), in which there is only one point on each ligand at which coordination can occur. Some ligands are **polydentate**; i.e. they have two or more possible coordination points. For instance, 1,2-diaminoethane, $H_2NC_2H_4NH_2$, is a **bidentate** ligand, having two coordination points. Certain polydentate ligands can form *chelates.
2. (in cell biology) A molecule that binds to a protein with a high degree of specificity. Examples are the substrate of an enzyme and a hormone binding to a cell receptor.

ligand-field theory An extension of *crystal-field theory describing the properties of compounds of transition-metal ions or rare-earth ions in which covalent bonding between the surrounding molecules (*see* LIGAND) and the transition-metal ions is taken into account. This may involve using valence-bond theory or molecular-orbital theory. Ligand-field theory was developed extensively in the 1930s. As with crystal-field theory, ligand-field theory indicates that energy levels of the transition-metal ions are split by the surrounding ligands, as determined by *group theory. The theory has been very successful in explaining the optical, spectroscopic, and magnetic properties of the compounds of transition-metal and lanthanide ions.

ligase Any of a class of enzymes that catalyse the formation of covalent bonds using the energy released by the cleavage of ATP. Ligases are important in the synthesis and repair of many biological molecules, including DNA (*see* DNA LIGASE), and are used in genetic engineering to insert foreign DNA into cloning *vectors.

light The form of *electromagnetic radiation to which the human eye is sensitive and on which our visual awareness of the universe and its contents relies (*see* COLOUR).

The finite velocity of light was suspected by many early experimenters in optics, but it was not established until 1676 when Ole Rømer (1644–1710) measured it. Sir Isaac Newton investigated the optical *spectrum and used existing knowledge to establish a primarily **corpuscular theory** of light, in which it was regarded as a stream of particles that set up disturbances in the 'aether' of space. His successors adopted the corpuscles but ignored the wavelike disturbances until Thomas Young rediscovered the *inter-

ference of light in 1801 and showed that a **wave theory** was essential to interpret this type of phenomenon. This view was accepted for most of the 19th century and it enabled James Clerk Maxwell to show that light forms part of the *electromagnetic spectrum. He believed that waves of electromagnetic radiation required a special medium to travel through, and revived the name 'luminiferous ether' for such a medium. The *Michelson–Morley experiment in 1887 showed that, if the medium existed, it could not be detected; it is now generally accepted that the ether is an unnecessary hypothesis. In 1905 Albert Einstein showed that the *photoelectric effect could only be explained on the assumption that light consists of a stream of discrete *photons of electromagnetic energy. This renewed conflict between the corpuscular and wave theories has gradually been resolved by the evolution of the *quantum theory and *wave mechanics. While it is not easy to construct a model that has both wave and particle characteristics, it is accepted, according to Bohr's theory of *complementarity, that in some experiments light will appear wavelike, while in others it will appear to be corpuscular. During the course of the evolution of wave mechanics it has also become evident that electrons and other elementary particles have dual wave and particle properties.

light bulb *See* ELECTRIC LIGHTING.

light-dependent reaction *See* PHOTOSYNTHESIS.

light-emitting diode (LED) A *semiconductor device that converts electrical energy into light or infrared radiation in the range 550 nm (green light) to 1300 nm (infrared radiation). The most commonly used LED (see illustration) emits red light and consists of gallium arsenide–phosphide on a gallium arsenide substrate, light being emitted at a *p–n* junction, when electrons and holes recombine (*see* RECOMBINATION PROCESS). LEDs are extensively used for displaying letters and numbers in digital instruments in which a self-luminous display is required.

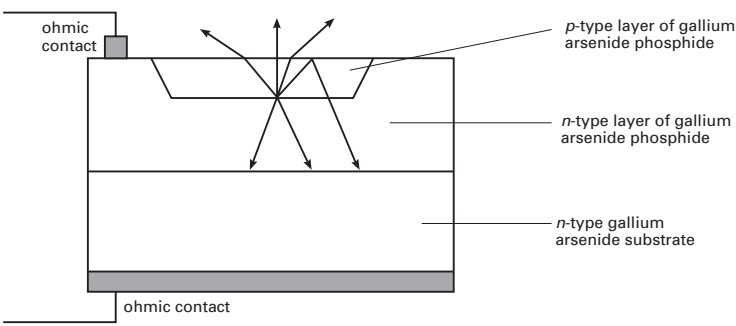
light green *See* FAST GREEN.

light-independent reaction *See* PHOTOSYNTHESIS.

lightning A high-energy luminous electrical discharge that passes between a charged cloud and a point on the surface of the earth, between two charged clouds, or between oppositely charged layers of the same cloud. In general, the upper parts of clouds are positively charged and the lower parts are negatively charged; the reasons for this separation of charge are complex.

Lightning usually occurs in the form of a downward step leader followed by an intensely luminous return stroke, which can produce instantaneous temperatures as high as 30 000°C. In the typical step leader a surge of electrons descends in approximately 50-metre steps with about 50-microsecond pauses between steps. When this leader reaches the earth a surge of charge returns up the preionized path taken by the leader. Cloud-to-cloud strokes also involve a leader and return stroke. The average current in a lightning stroke is about 10 000 amperes, but maximum currents in the return stroke can reach 20 000 A. *See also* BALL LIGHTNING.

light year A unit of distance used in astronomy; the distance travelled by light in a



Light-emitting diode.

vacuum during one year. It is equal to 9.4650×10^{15} metres or 5.8785×10^{12} miles.

lignin A complex organic polymer that is deposited within the cellulose of plant cell walls during secondary thickening. Lignification makes the walls woody and therefore rigid. *See* SCLERENCHYMA.

lignite *See* COAL.

ligule **1.** A membranous scalelike outgrowth from the leaves of certain flowering plants. Many grasses have a ligule at the base of the leaf blade. **2.** A small membranous structure that develops on the upper surface of a young leaf base in certain clubmosses, for example *Selaginella*. It withers as the plant matures. **3.** A strap-shaped extension from the corolla tube in certain florets of a *capitulum, termed **ligulate** (or **ray**) **florets**.

limb **1.** An appendage of a vertebrate animal, such as the leg or arm of a mammal or the wing of a bird. *See also* PENTADACTYL LIMB. **2.** The expanded upper part of a sepal, petal, or leaf. **3.** The widened upper section of a gamopetalous *corolla.

lime *See* CALCIUM OXIDE.

limestone A sedimentary rock that is composed largely of carbonate minerals, especially carbonates of calcium and magnesium. *Calcite and *aragonite are the chief minerals; *dolomite is also present in the dolomitic limestones. There are many varieties of limestones but most are deposited in shallow water. **Organic limestones** (e.g. *chalk) are formed from the calcareous skeletons of organisms; **precipitated limestones** include oolite, which is composed of ooliths – spherical bodies formed by the precipitation of carbonate around a nucleus; and **clastic limestones** are derived from fragments of pre-existing calcareous rocks.

limewater A saturated solution of *calcium hydroxide in water. When carbon dioxide gas is bubbled through limewater, a 'milky' precipitate of calcium carbonate is formed:

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

If the carbon dioxide continues to be bubbled through, the calcium carbonate eventually redissolves to form a clear solution of calcium hydrogencarbonate:

$$CaCO_3(s) + CO_2(g) + H_2O(g) \rightarrow Ca(HCO_3)_2(aq)$$

If cold limewater is used the original calcium carbonate precipitated has a calcite structure; hot limewater yields an aragonite structure.

liming The application of lime (calcium hydroxide) to soils to increase levels of calcium and decrease acidity.

limit The value that a function approaches as the independent variable approaches a specified value.

limit cycle *See* ATTRACTOR.

limiting factor Any environmental factor that – by its decrease, increase, absence, or presence – limits the growth, metabolic processes, or distribution of organisms or populations. In a desert ecosystem, for example, low rainfall and high temperature will be factors limiting colonization. When a metabolic process is affected by more than one factor, the **law of limiting factors** states that its rate is limited by the factor that is nearest its minimum value. For example, photosynthesis is affected by many factors, such as light, temperature, and carbon dioxide concentration, but on a warm sunny day carbon dioxide concentration will be the limiting factor as light and temperature will be at optimum levels.

limiting friction The friction force that just balances a moving force applied to a solid body resting on a solid surface when the body fails to move. If the moving force exceeds the limiting friction, the body will begin to move.

limnology The study of the physical and biological characteristics of lakes and other bodies of fresh water.

limonite A generic term for a group of hydrous iron oxides, mostly amorphous. *Goethite and *haematite are important constituents, together with colloidal silica, clays, and manganese oxides. Limonite is formed by direct precipitation from marine or fresh water in shallow seas, lagoons, and bogs (thus it is often called **bog iron ore**) and by oxidation of iron-rich minerals. It is used as an ore of iron and as a pigment.

linac *See* LINEAR ACCELERATOR.

Linde process A process for the *liquefaction of gases by the Joule–Thomson effect. In this process, devised by Carl von Linde

(1842–1934) for liquefying air, the air is freed of carbon dioxide and water and compressed to 150 atmospheres. The compressed gas is passed through a copper coil to an expansion nozzle within a Dewar flask. The emerging air is cooled by the Joule–Thomson effect as it expands and then passes back within a second copper coil that surrounds the first coil. Thus the expanded gas cools the incoming gas in a process that is said to be **regenerative**. Eventually the air is reduced to its *critical temperature and, at the pressure of 150 atmospheres (well above its critical pressure), liquefies. The process is also used for other gases, especially hydrogen and helium. Hydrogen has first to be cooled below its inversion temperature (*see* JOULE–THOMSON EFFECT) using liquid air; helium has first to be cooled below its inversion temperature using liquid hydrogen.

linear absorption coefficient *See* LAMBERT'S LAWS.

linear accelerator (linac) A type of particle *accelerator in which charged particles are accelerated in a straight line, either by a steady electric field or by means of radio-frequency electric fields.

Van de Graaff accelerator. This device accelerates charged particles by applying a high electrical potential difference generated by a *Van de Graaff generator. The potential difference can be kept steady to within one part in a thousand, forming a beam of accelerated particles of uniform energy. The maximum electrical potential attainable is typically about 10 MV and depends on the insulating properties of the gas around the Van de Graaff sphere. It is increased by enclosing the whole generator in a pressure vessel containing an inert gas at a pressure of about 20 atmospheres. A source, at the same potential as the sphere, produces charged particles, which enter a column of cylindrical electrodes, each of which is at a lower potential than the one above it. The ions are accelerated as they pass through the gaps between the cylinders. The nonuniform electric fields between the gaps have the effect of focusing the beam of charged particles.

Drift-tube accelerator. In this device charged particles are accelerated inside a line of hollow metal cylinders called **drift tubes**. The cylinders are connected alternately to opposite terminals of an alternating potential difference produced by either a *magnetron or a *klystron. The arrangement ensures that adjacent cylinders are always at opposite electrical potentials. For example, a proton beam may be injected into the first of the line of drift tubes from a Van de Graaff accelerator. Protons reaching the gap between the first two tubes will be accelerated into the second tube, when the alternating potential makes the first tube positive and the second tube negative. This enables the protons emerging into the gap between two cylinders to be accelerated into the next cylinder. All parts of a particular tube are at the same potential, since the metal acts as an equipotential surface. Therefore within a cylinder the particles travel at a constant speed (hence 'drift tube'). It follows that the energy of the beam is increased every time the protons cross between drift tubes, and therefore a device with a large number of gaps can produce extremely high-energy beams using only moderate supply voltages. The Berkeley proton accelerator has a drift-tube arrangement of 47 cylinders, 12 miles long, and accelerates protons up to 31.5 GeV.

Travelling-wave accelerator. This apparatus uses radio-frequency electromagnetic waves to accelerate charged particles. Charged particles are fed into the travelling-wave accelerator at close to the speed of light and are carried down a *wave guide by the electric field component of a radio wave. The very high initial speeds for charged particles are needed to match the phase velocity of radio signals propagating down the wave guide. However, this means that travelling-wave accelerators are suitable only for accelerating light particles, such as electrons. The electrons can be accelerated to initial speeds of 98% of the speed of light by a Van de Graaff accelerator. At such high initial speeds, there is little scope for further acceleration and any increase in electron energy provided by the accelerator results from the relativistic increase in mass. The Stanford linear accelerator (SLAC) uses the travelling-wave principle. SLAC is capable of accelerating electrons and positrons to 50 GeV in a tube two miles long.

linear energy transfer (LET) The energy transferred per unit path length by a moving high-energy charged particle (such as an electron or a proton) to the atoms and molecules along its path. It is of particular importance when the particles pass through living tissue as the LET modifies the effect of a specific dose of radiation. LET is proportional to the square of the charge on the par-

ticle and increases as the velocity of the particle decreases.

linear equation An equation between two variables that gives a straight line when plotted on a graph. It has the general form $y = mx + c$, where m is the gradient of the line and c is the intercept of the line on the y-axis (in Cartesian coordinates).

linear expansivity *See* EXPANSIVITY.

linear molecule A molecule in which the atoms are in a straight line, as in carbon dioxide, O=C=O.

linear momentum *See* MOMENTUM.

linear motor A form of induction motor in which the stator and armature are linear and parallel, rather than cylindrical and coaxial. In some experimental trains the magnetic force between the primary winding in the vehicle and the secondary winding on the ground support the vehicle on an air cushion thus eliminating track friction. However, because of the high cost of the installation and the low efficiency the device has not yet found commercial application.

line defect *See* CRYSTAL DEFECT (Feature).

line notation A notation system for writing the structure of a chemical compound as a string of letters, numbers, and symbols. Examples of line notation are Wiswesser line notation (WLN), SMILES, SYBYL line notation (SLN), ROSDAL, and InChI.

line-of-sight velocity (radial velocity) The component of a celestial body's velocity along the line of sight of the observer. It is usually given in relation to the sun to avoid complications arising from the earth's orbital motion. Line-of-sight velocity is normally calculated from the *Doppler effect on the body's spectrum, a *redshift indicating a receding body (taken as a positive velocity) and a blueshift indicating an approaching body (taken as negative).

line printer *See* PRINTER.

lines of force Imaginary lines in a *field of force that enable the direction and strength of the field to be visualized. They are used primarily in electric and magnetic fields; in electric fields they are sometimes called **tubes of force**, to express their characteristic of being perpendicular to a conducting surface. The tangent to a line of force at any point gives the direction of the field at that point and the number of lines per unit area perpendicular to the force represents the *intensity of the field.

line spectrum *See* SPECTRUM.

linkage The tendency for two different genes on the same chromosome to remain together during the separation of *homologous chromosomes at meiosis. Linkage can be broken by *crossing over or by a *chromosome mutation, when sections of chromosomes are exchanged and new combinations of genes are produced. *See also* SEX LINKAGE.

linkage map A *chromosome map showing the relative positions of *genes along the length of the chromosomes of an organism. It is constructed by making crosses and observing whether certain characteristics tend to be inherited together. The closer together two allele pairs are situated on *homologous chromosomes, the less often will they be separated and rearranged as the reproductive cells are formed (*see* CHIASMA; CROSSING OVER). The proportion of offspring that show *recombination of the alleles concerned thus reflects their spacing and is used as a unit of length in mapping chromosomes. The information obtained from such a **classical linkage map** can be combined with a restriction map, which is a linkage map of sites cleaved by restriction enzymes (*see* RESTRICTION MAPPING), providing a huge number of potential marker sites for genes of interest. Linkage maps provide valuable frameworks for constructing detailed *physical maps giving the base sequence of the chromosomal DNA.

Linnaean system *See* BINOMIAL NOMENCLATURE.

Linnaeus, Carolus (Carl Linné; 1707–78) Swedish botanist. He travelled round Europe and by 1735 had described more than 100 new species of plants. In 1749 he announced his system of *binomial nomenclature, which, with modification, has been used ever since for all organisms.

linoleic acid A liquid polyunsaturated *fatty acid with two double bonds, $CH_3(CH_2)_4CH{:}CHCH_2CH{:}CH(CH_2)_7COOH$. Linoleic acid is abundant in many plant fats and oils, e.g. linseed oil, groundnut oil, and soya-bean oil. It is an *essential fatty acid.

linolenic acid A liquid polyunsaturated *fatty acid with three double bonds in its structure: $CH_3CH_2CH{:}CHCH_2CH{:}CHCH_2$-$CH{:}CH(CH_2)_7COOH$. Linolenic acid occurs

in certain plant oils, e.g. linseed and soyabean oil, and in algae. It is one of the *essential fatty acids.

linseed oil A pale yellow oil pressed from flax seed. It contains a mixture of glycerides of fatty acids, including linoleic acid and linolenic acid. It is a *drying oil, used in oil paints, varnishes, linoleum, etc.

Linz–Donawitz process *See* BASIC-OXYGEN PROCESS.

lipase An enzyme secreted by the pancreas that catalyses the breakdown of fats into fatty acids and glycerol in the small intestine.

lipid Any of a diverse group of organic compounds, occurring in living organisms, that are insoluble in water but soluble in organic solvents, such as chloroform, benzene, etc. Lipids are broadly classified into two categories: **complex lipids**, which are esters of long-chain fatty acids and include the *glycerides (which constitute the *fats and *oils of animals and plants), glycolipids, *phospholipids, and *waxes; and **simple lipids**, which do not contain fatty acids and include the *steroids and *terpenes.

Lipids have a variety of functions in living organisms. Fats and oils are a convenient and concentrated means of storing food energy in plants and animals. Phospholipids and *sterols, such as cholesterol, are major components of cell membranes (*see* LIPID BILAYER). Waxes provide vital waterproofing for body surfaces. Terpenes include vitamins A, E, and K, and phytol (a component of chlorophyll) and occur in essential oils, such as menthol and camphor. Steroids include the adrenal hormones, sex hormones, and bile acids.

Lipids can combine with proteins to form *lipoproteins, e.g. in plasma membranes. In bacterial cell walls, lipids may associate with polysaccharides to form **lipopolysaccharides**.

SEE WEB LINKS

- Information about IUPAC nomenclature of lipids

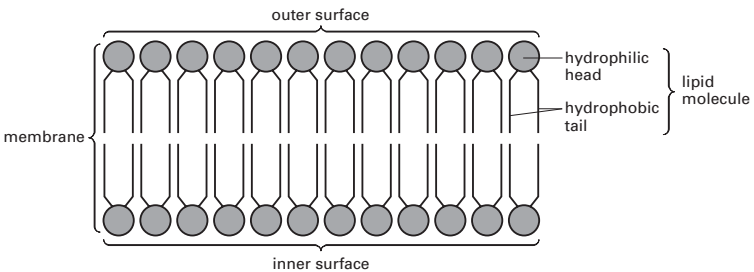
lipid bilayer The arrangement of lipid molecules in biological *membranes, which takes the form of a double sheet. Each lipid molecule comprises a hydrophilic 'head' (having a high affinity for water) and a hydrophobic 'tail' (having a low affinity for water). In the lipid bilayer the molecules are aligned so that their hydrophilic heads face outwards, forming the outer and inner surfaces of the membrane, while the hydrophobic tails face inwards, away from the external aqueous environment. See illustration.

Lipmann, Fritz *See* KREBS, SIR HANS ADOLF.

lipoic acid A vitamin of the *vitamin B complex. It is one of the *coenzymes involved in the decarboxylation of pyruvate by the enzyme pyruvate dehydrogenase. This reaction has to take place before carbohydrates can enter the *Krebs cycle during aerobic respiration. Good sources of lipoic acid include liver and yeast.

lipolysis The breakdown of storage lipids in living organisms. Most long-term energy reserves are in the form of triglycerides in fats and oils. When these are needed, e.g. during starvation, lipase enzymes convert the triglycerides into glycerol and the component fatty acids. These are then transported to tissues and oxidized to provide energy.

lipoprotein One of a group of compounds consisting of a lipid combined with a protein. Lipoproteins are the main structural



Lipid bilayer.

materials of the membranes of cells and cell organelles. They also occur in blood and lymph, being the form in which lipids are transported in these media. *Cholesterol is transported in the bloodstream mainly in the form of **low-density lipoproteins** (**LDLs**) and is removed by means of LDL receptors in cell membranes; the LDLs are bound to the receptors, which are then taken into the cells. Lack of LDL receptors, occurring as a genetic defect in some individuals, is believed to be a cause of high levels of cholesterol in the blood, predisposing to atherosclerosis. **Very low-density lipoproteins** (**VLDLs**) are formed in the liver and are the precursors of LDLs, while **high-density lipoproteins** (**HDLs**), the smallest of all lipoproteins, transport cholesterol from tissues to the liver.

liposome A microscopic spherical membrane-enclosed vesicle or sac (20–30 nm in diameter) made artificially in the laboratory by the addition of an aqueous solution to a phospholipid gel. The membrane resembles a cell membrane and the whole vesicle is similar to a cell organelle. Liposomes can be incorporated into living cells and are used to transport relatively toxic drugs into diseased cells, where they can exert their maximum effects. For example, liposomes containing the drug methotrexate, used in the treatment of cancer, can be injected into the patient's blood. The cancerous organ is at a higher temperature than normal body temperature, so that when the liposome passes through its blood vessels, the membrane melts and the drug is released. The study of the behaviour of liposome membranes is used in research into membrane function, particularly to observe the behaviour of membranes during anaesthesia with respect to permeability changes.

lipotropin Either of two peptide hormones produced in the anterior pituitary gland that trigger the mobilization of fat deposits and the transfer of lipid components to the bloodstream. β-lipotropin is formed by cleavage of the precursor proopiomelanocortin, and is itself cleaved to form γ-lipotropin and other peptides, including endorphins.

liquation The separation of mixtures of solids by heating to a temperature at which lower-melting components liquefy.

liquefaction of gases The conversion of a gaseous substance into a liquid. This is usually achieved by one of four methods or by a combination of two of them:
(1) by vapour compression, provided that the substance is below its *critical temperature;
(2) by refrigeration at constant pressure, typically by cooling it with a colder fluid in a countercurrent heat exchanger;
(3) by making it perform work adiabatically against the atmosphere in a reversible cycle;
(4) by the *Joule–Thomson effect (*see also* LINDE PROCESS).

Large quantities of liquefied gases are now used commercially, especially *liquefied petroleum gas and liquefied natural gas.

liquefied natural gas (LNG) *See* LIQUEFIED PETROLEUM GAS.

liquefied petroleum gas (LPG) Various petroleum gases, principally propane and butane, stored as a liquid under pressure. It is used as an engine fuel and has the advantage of causing very little cylinder-head deposits.

Liquefied natural gas (**LNG**) is a similar product and consists mainly of methane. However, it cannot be liquefied simply by pressure as it has a low critical temperature of 190 K and must therefore be cooled to below this temperature before it will liquefy. Once liquefied it has to be stored in well-insulated containers. It provides a convenient form in which to ship natural gas in bulk from oil wells or gas-only wells to users. It is also used as an engine fuel.

liquid A phase of matter between that of a crystalline solid and a *gas. In a liquid, the large-scale three-dimensional atomic (or ionic or molecular) regularity of the solid is absent but, on the other hand, so is the total disorganization of the gas. Although liquids have been studied for many years there is still no simple comprehensive theory of the liquid state. It is clear, however, from diffraction studies that there is a short-range structural regularity extending over several molecular diameters. These bundles of ordered atoms, molecules, or ions move about in relation to each other, enabling liquids to have almost fixed volumes, which adopt the shape of their containers.

liquid crystal A substance that flows like a liquid but has some order in its arrangement of molecules. **Nematic crystals** have long molecules all aligned in the same direction, but otherwise randomly arranged. **Cholesteric** and **smectic** liquid crystals also have

aligned molecules, which are arranged in distinct layers. In cholesteric crystals, the axes of the molecules are parallel to the plane of the layers; in smectic crystals they are perpendicular. Concepts from the theory of *phase transitions, such as *order parameters and *broken symmetry, have proved useful in analysing the properties of liquid crystals.

liquid-crystal display *See* LCD.

liquid-crystal polymer A polymer with a liquid-crystal structure, this being the most thermodynamically stable. Liquid-crystal polymers contain long rigid chains and combine strength with lightness. They are, however, difficult to produce commercially.

liquid-drop model A model of the atomic nucleus in which the nucleons are regarded as being analogous to the molecules in a liquid, the interactions between which maintain the droplet shape by surface tension. The model has been useful in the theory of nuclear fission.

liquidus A line on a phase diagram above which a substance is liquid.

***l*-isomer** *See* OPTICAL ACTIVITY.

L-isomer *See* ABSOLUTE CONFIGURATION.

Lissajous figures A curve in one plane traced by a point moving under the influence of two independent harmonic motions. In the common case the harmonic motions are simple, perpendicular to each other, and have a simple frequency ratio. They can be displayed by applying sinusoidal alternating potentials to the X- and Y-inputs of a *cathode-ray oscilloscope. They are named after Jules Lissajous (1822–80).

SEE WEB LINKS

- An interactive simulation of an oscilloscope producing Lissajou's figures from the University of Florida

Listeria A genus of rod-shaped aerobic motile Gram-positive bacteria. Only one species, *L. monocytogenes*, causes disease (**listeriosis**). It is resistant to physical and chemical treatments and can occur as a contaminant in certain foods, in faeces, etc. Listeriosis can take various forms, depending on the site of infection: localization in the central nervous system causes meningoencephalitis, while uterine infection can result in abortion or congenital handicap in the fetus.

litharge *See* LEAD(II) OXIDE.

lithia *See* LITHIUM OXIDE.

lithium Symbol Li. A soft silvery metal, the first member of group 1 (formerly IA) of the periodic table (*see* ALKALI METALS); a.n. 3; r.a.m. 6.939; r.d. 0.534; m.p. 180.54°C; b.p. 1347°C. It is a rare element found in spodumene ($LiAlSi_2O_6$), petalite ($LiAlSi_4O_{10}$), the mica lepidolite, and certain brines. It is usually extracted by treatment with sulphuric acid to give the sulphate, which is converted to the chloride. This is mixed with a small amount of potassium chloride, melted, and electrolysed. The stable isotopes are lithium–6 and lithium–7. Lithium–5 and lithium–8 are short-lived radioisotopes. The metal is used to remove oxygen in metallurgy and as a constituent of some Al and Mg alloys. It is also used in batteries and is a potential tritium source for fusion research. Lithium salts are used in psychomedicine. The element reacts with oxygen and water; on heating it also reacts with nitrogen and hydrogen. Its chemistry differs somewhat from that of the other group 1 elements because of the small size of the Li^+ ion.

SEE WEB LINKS

- Information from the WebElements site

lithium aluminium hydride *See* LITHIUM TETRAHYDROALUMINATE(III).

lithium battery A type of voltaic cell containing lithium or lithium compounds. The most commonly used has a metallic lithium anode and a manganese dioxide (MnO_2) cathode, the electrolyte being a solution of lithium salts in an organic solvent. Batteries of this type have an output of about 3 volts. They are more expensive than alkaline batteries, but last longer. Li–MnO_2 batteries are also produced in a flat disk form for use in digital watches and other small portable devices. A number of other more specialized lithium primary batteries are available but are not in general use. *See also* LITHIUM-ION BATTERY.

lithium carbonate A white solid, Li_2CO_3; r.d. 2.11; m.p. 723°C; decomposes above 1310°C. It is produced commercially by treating the ore with sulphuric acid at 250°C and leaching the product to give a solution of lithium sulphate. The carbonate is then obtained by precipitation with sodium carbonate solution. Lithium carbonate is used in the prevention and treatment of manic-

depressive (bipolar) disorders. It is also used industrially in ceramic glazes.

lithium deuteride *See* LITHIUM HYDRIDE.

lithium hydride A white solid, LiH; cubic; r.d. 0.82; m.p. 680°C; decomposes at about 850°C. It is produced by direct combination of the elements at temperatures above 500°C. The bonding in lithium hydride is believed to be largely ionic; i.e. Li^+H^- as supported by the fact that hydrogen is released from the anode on electrolysis of the molten salt. The compound reacts violently and exothermically with water to yield hydrogen and lithium hydroxide. It is used as a reducing agent to prepare other hydrides and the ^2H isotopic compound, **lithium deuteride**, is particularly valuable for deuterating a range of organic compounds. Lithium hydride has also been used as a shielding material for thermal neutrons.

lithium hydrogencarbonate A compound, $LiHCO_3$, formed by the reaction of carbon dioxide with aqueous lithium carbonate and known only in solution. It has found medicinal uses similar to those of lithium carbonate and is sometimes included in proprietary mineral waters.

lithium hydroxide A white crystalline solid, LiOH, soluble in water, slightly soluble in ethanol and insoluble in ether. It is known as the monohydrate (monoclinic; r.d. 1.51) and in the anhydrous form (tetragonal, r.d. 1.46; m.p. 450°C; decomposes at 924°C). The compound is made by reacting lime with lithium salts or lithium ores. Lithium hydroxide is basic but has a closer resemblance to group 2 hydroxides than to the other group 1 hydroxides (an example of the first member of a periodic group having atypical properties).

lithium-ion battery A type of rechargeable cell in which the anode is carbon and the cathode is a metal oxide (e.g. cobalt(IV) oxide, CoO_2). The electrolyte is a lithium salt such as the borate ($LiBO_4$) or chlorate ($LiClO_4$) in an organic solvent. The action of the cell depends on movement of Li ions between anode and cathode with oxidation of the cobalt ions during charging and reduction during discharge. Lithium-ion batteries are light and have a low self-discharge rate, although the capacity does deteriorate with age. They are extensively used in mobile phones, laptops, camcorders, and similar devices, as well as electric cars. *See also* LITHIUM BATTERY.

lithium oxide (lithia) A white crystalline compound, Li_2O; cubic; r.d. 2.01; m.p. 1700°C. It can be obtained from a number of lithium ores; the main uses are in lubricating greases, ceramics, glass and refractories, and as a flux in brazing and welding.

lithium sulphate A white or colourless crystalline material, Li_2SO_4, soluble in water and insoluble in ethanol. It forms a monohydrate (monoclinic; r.d. 1.88) and an anhydrous form, which exists in α- (monoclinic), β- (hexagonal) and γ- (cubic) forms; r.d. 2.23. The compound is prepared by the reaction of the hydroxide or carbonate with sulphuric acid. It is not isomorphous with other group 1 sulphates and does not form alums.

lithium tetrahydroaluminate(III) (lithium aluminium hydride; LAH) A white or light grey powder, $LiAlH_4$; r.d. 0.917; decomposes at 125°C. It is prepared by the reaction of excess lithium hydride with aluminium chloride. The compound is soluble in ethoxyethane, reacts violently with water to release hydrogen, and is widely used as a powerful reducing agent in organic chemistry. It should always be treated as a serious fire risk in storage.

lithosphere The earth's crust (*see* EARTH). Sometimes the lithosphere is also understood to include the mantle and sometimes the mantle and the core.

litmus A water-soluble dye extracted from certain lichens. It turns red under acid conditions and blue under alkaline conditions, the colour change occurring over the pH range 4.5–8.3 (at 25°C). It is not suitable for titrations because of the wide range over which the colour changes, but is used as a rough *indicator of acidity or alkalinity, both in solution and as litmus paper (absorbent paper soaked in litmus solution).

litre Symbol l or L. A unit of volume in the metric system regarded as a special name for the cubic decimetre. It was formerly defined as the volume of 1 kilogram of pure water at 4°C at standard pressure, which is equivalent to 1.000 028 dm^3.

litter Dead organic matter in the soil that has not yet decomposed. It consists of fallen leaves and other plant remains (**leaf litter**), animal excrement, etc. After decomposition

by *decomposers and *detritivores litter becomes *humus.

littoral Designating or occurring in the marginal shallow-water zone of a sea or lake, especially (in the sea) between high and low tide lines. In this zone enough light penetrates to the bottom to support rooted aquatic plants. *Compare* PROFUNDAL; SUBLITTORAL.

liver A large lobed organ in the abdomen of vertebrates that plays an essential role in many metabolic processes by regulating the composition and concentration of nutrients and toxic materials in the blood. It receives the products of digestion dissolved in the blood via the *hepatic portal vein and its most important functions are to convert excess glucose to the storage product *glycogen, which serves as a food reserve; to break down excess amino acids to ammonia, which is converted to *urea or *uric acid and excreted via the kidneys; and to store and break down fats (*see* LIPOLYSIS). Other functions of the liver are (1) the production of *bile; (2) the breakdown (*detoxification) of poisonous substances in the blood; (3) the removal of damaged red blood cells; (4) the synthesis of vitamin A and the blood-clotting substances prothrombin and fibrinogen; and (5) the storage of iron.

SEE WEB LINKS

- Summary of liver anatomy, functions, and diseases, compiled by the British Liver Trust

liverworts *See* HEPATOPHYTA.

living fossil Any organism whose closest relatives are extinct and that was once itself thought to be extinct. An example is the coelacanth, a primitive fish that was common in the Devonian era, the first recent living specimen of which was discovered in 1938.

lixiviation The separation of mixtures by dissolving soluble constituents in water.

lizards *See* SQUAMATA.

Lloyd's mirror An optical arrangement for producing interference fringes. A slit is illuminated by monochromatic light and placed close to a plane mirror. Interference occurs between direct light from the slit and light reflected from the mirror. It was first used by Humphrey Lloyd (1800–81) in 1834.

LNG *See* LIQUEFIED PETROLEUM GAS.

loaded concrete Concrete containing elements (such as iron or lead) with a high mass number; it is used in making the radiation shield around nuclear reactors.

loam A fertile *soil that is made up of organic matter mixed with clay, sand, and silt. Loams differ in their ratios of clay, sand, and silt, which influences which types of plants they can support.

Local Group The group of *galaxies of which our own Galaxy is a member. It consists of some 30–40 known members, the most massive of which are the Galaxy and the Andromeda galaxy.

localization **1.** The confinement of electrons to a particular atom in a molecule or to a particular chemical bond. **2.** In the theory of *disordered solids, the concept that an electron is concentrated around a specific site and cannot contribute to the solid's electrical conductivity (at *absolute zero) by moving through the system. In one dimension any amount of disorder makes all electron states localized. In three dimensions a small amount of disorder makes electron states near the top and the bottom of the *energy bands localized; states in the centre of the bands are called **extended** states because they can propagate through the system and hence contribute to electrical conductivity. The dividing energies between localized and extended states are called **mobility edges**. Given sufficient disorder all states become localized. In two dimensions all electron states in disordered solids are thought to be localized, with some states being strongly localized around specific sites while other states are weakly localized around specific sites. Localization also occurs in disordered solids for other *excitations, such as *phonons and *spin waves.

localized bond A *chemical bond in which the electrons forming the bond remain between (or close to) the linked atoms. *Compare* DELOCALIZATION.

local oscillator An *oscillator in a *heterodyne or *superheterodyne radio receiver. It supplies the radio-frequency signal that beats with the incoming signal to produce the intermediate frequency.

Local Supercluster The flattened *galaxy cluster of which the *Local Group is a member. It is about 100 million light-years across, with the Virgo cluster at its centre.

lock-and-key mechanism A mechanism

proposed in 1890 by Emil Fischer (1852–1919) to explain binding between the active site of an enzyme and a substrate molecule. The active site was thought to have a fixed structure (the lock), which exactly matched the structure of a specific substrate (the key). Thus the enzyme and substrate interact to form an *enzyme–substrate complex. The substrate is converted to products that no longer fit the active site and are therefore released, liberating the enzyme. Observations made by X-ray diffraction studies have shown that the active site of an enzyme is more flexible than the lock-and-key theory would suggest.

locomotion The ability of an organism to move in a particular direction in its environment, which requires a propulsive force acting against a supporting structure. Most animals and many single-celled organisms have powers of locomotion. Some protists possess contractile fibres that exert force on the plasma membrane to change the shape of the cell; this may be combined with *cytoplasmic streaming to bring about locomotion (*see* AMOEBOID MOVEMENT). In many other protists and bacteria the propulsive force is provided by the action of *undulipodia or *flagella. In animals the force required to initiate locomotion is generated by *muscles, which act against a supporting framework provided by a *skeleton. *See also* FINS; FLIGHT.

locule (loculus) A small cavity in a plant or animal body. In plants the locule of the ovary is the cavity containing the ovules and the locules of the anther contain the developing pollen grains.

locus **1.** (in mathematics) A set of points whose location is specified by an equation. For example, if a point moves so that the sum of its distances from two fixed points is constant, the locus of the point is an *ellipse. **2.** (in genetics) The position of a gene on a chromosome or within a DNA (or RNA) molecule. The alleles of a gene occupy the same locus on *homologous chromosomes.

lodestone *See* MAGNETITE.

Lodge, Sir Oliver Joseph (1851–1940) British physicist, who became principal of the new Birmingham University in 1900. His best-known work was in *radio, particularly his invention in 1894 of the 'coherer', used as a detector in early radio receivers (*see* DEMODULATION). After 1910 he became increasingly interested in spiritualism and reconciling science and religion.

logarithm The power to which a number, called the **base**, has to be raised to give another number. Any number y can be written in the form $y = x^n$. n is then the logarithm to the base x of y, i.e. $n = \log_x y$. If the base is 10, the logarithms are called **common logarithms**. **Natural** (or **Napierian**) **logarithms** (named after John Napier) are to the base e = 2.718 28…, written $\log_e y$ or $\ln y$. Logarithms were formerly used to facilitate calculations, before the advent of electronic calculators.

A logarithm contains two parts, an integer and a decimal. The integer is called the **characteristic**, and the decimal is called the **mantissa**. For example, the logarithm to the base 10 of 210 is 2.3222, where 2 is the characteristic and 0.3222 is the mantissa.

logarithmic scale **1.** A scale of measurement in which an increase or decrease of one unit represents a tenfold increase or decrease in the quantity measured. Decibels and pH measurements are common examples of logarithmic scales of measurement. **2.** A scale on the axis of a graph in which an increase of one unit represents a tenfold increase in the variable quantity. If a curve $y = x^n$ is plotted on graph paper with logarithmic scales on both axes, the result is a straight line of slope n, i.e. $\log y = n \log x$, which enables n to be determined.

logarithmic series The expansion of a logarithmic function, such as $\log_e(1 + x)$, i.e. $x - x^2/2 + x^3/3 - \ldots + (-1)^n x^n/n$, or $\log_e(1 - x)$, i.e. $-x - x^2/2 - x^3/3 \ldots - x^n/n$.

logic circuits The basic switching circuits or *gates used in digital computers and other digital electronic devices. The output signal, using a *binary notation, is controlled by the logic circuit in accordance with the input system. The three basic logic circuits are the **AND**, **OR**, and **NOT circuits**. The **AND** circuit gives a binary 1 output if a binary 1 is present on each input circuit; otherwise the output is a binary 0. The **OR** circuit gives a binary 1 output if a binary 1 is present on at least one input circuit; otherwise the output is binary 0. The **NOT** circuit inverts the input signal, giving a binary 1 output for a binary 0 input or a 0 output for a 1 input.

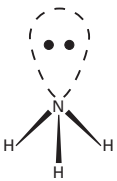
Often these basic logic circuits are used in combination, e.g. a **NAND circuit** consists of **NOT** + **AND** circuits. In terms of electronic equipment, logic circuits are now almost exclusively embodied into *integrated circuits.

log phase *See* BACTERIAL GROWTH CURVE.

lomentum A type of dry dehiscent fruit formed from a single carpel but divided into one-seeded compartments by constrictions between the seeds. *Legumes (e.g. those of *Acacia*) and *siliquas (e.g. those of wild radish) can be divided in this way.

lone pair A pair of electrons having opposite spin in an orbital of an atom. For instance, in ammonia the nitrogen atom has five electrons, three of which are used in forming single bonds with hydrogen atoms. The other two occupy a filled atomic orbital and constitute a lone pair (see illustration). The orbital containing these electrons is equivalent to a single bond (sigma orbital) in spatial orientation, accounting for the pyramidal shape of the molecule. In the water molecule, there are two lone pairs on the oxygen atom. In considering the shapes of molecules, repulsions between bonds and lone pairs can be taken into account:

lone pair–lone pair > lone pair–bond > bond–bond.



Lone pair. Lone pair of electrons in ammonia.

long-day plant A plant in which flowering can be induced or enhanced by long days, usually of more than 12 hours of daylight. Examples are spinach and spring barley. *See* PHOTOPERIODISM. *Compare* DAY-NEUTRAL PLANT; SHORT-DAY PLANT.

longitude *See* LATITUDE AND LONGITUDE.

longitudinal wave *See* WAVE.

long period *See* PERIODIC TABLE.

long-sightedness *See* HYPERMETROPIA.

loop of Henle The hairpin-shaped section of a kidney tubule situated between the proximal and distal tubules in the *nephron. The loop of Henle extends from the cortex into the medulla; it consists of a thin descending limb, which is permeable to water, and a thick ascending limb, which is impermeable to water. Complex movements of ions and water across the walls of the loop results in the production of concentrated urine in the *collecting duct. It is named after Friedrich Henle (1809–85).

loop variable A quantity that is used to characterize field theories as an alternative to characterizing them in terms of fields and potentials. A loop variable is like a line of force or flux line that is closed to form a loop. Loop variables have been used with great success in *quantum electrodynamics, *quantum chromodynamics, and *quantum gravity.

Lorentz–Fitzgerald contraction (Fitzgerald contraction) The contraction of a moving body in the direction of its motion. It was proposed independently by Hendrik Lorentz (1853–1928) and George Fitzgerald (1851–1901) in 1892 to account for the null result of the *Michelson–Morley experiment. The contraction was given a theoretical background in Einstein's special theory of *relativity. In this theory, an object of length l_0 at rest in one *frame of reference will appear, to an observer in another frame moving with relative velocity v with respect to the first, to have length

$$l_0\sqrt{(1 - v^2/c^2)},$$

where c is the speed of light. The original hypothesis regarded this contraction as a real one accompanying the absolute motion of the body. The contraction is in any case negligible unless v is of the same order as c.

Lorentz–Lorenz equation A relation between the *polarizability α of a molecule and the *refractive index n of a substance made up of molecules with this polarizability. The Lorentz–Lorenz equation can be written in the form $\alpha = (3/4\pi N)\,[(n^2–1)/(n^2 + 2)]$, where N is the number of molecules per unit volume. The equation provides a link between a microscopic quantity (the polarizability) and a macroscopic quantity (the refractive index). It was derived using macroscopic electrostatics in 1880 by Hendrik Lorentz and independently by the Danish physicist Ludwig Valentin Lorenz also in 1880. *Compare* CLAUSIUS–MOSSOTTI EQUATION.

Lorentz transformations A set of equations for transforming the position and motion parameters from a frame of reference with origin at O and coordinates (x,y,z) to a frame moving relative to it with origin at O′ and coordinates (x',y',z'). They replace the *Galilean transformations used in *Newton-

ian mechanics and are used in relativistic mechanics. They are:
$x' = \beta(x - vt)$
$y' = y$
$z' = z$
$t' = \beta(t - vx/c^2)$,
where v is the relative velocity of separation of O and O′, c the speed of light, and $\beta = 1/\sqrt{(1 - v^2/c^2)}$. The above equations apply for constant v in the xx' direction with O and O′ coinciding at $t = t' = 0$.

Lorenz, Konrad Zacharias (1903–89) Austrian ethologist who studied medicine, becoming a lecturer at Vienna in 1937. Watching the behaviour of birds on his private estate, he made his studies of *imprinting. For this work he shared the 1973 Nobel Prize for physiology or medicine with Karl von Frisch (1886–1982) and Niko *Tinbergen.

Loschmidt's constant (Loschmidt number) Symbol N_L. The number of particles per unit volume of an *ideal gas at STP. It has the value $2.686\,763(23) \times 10^{25}\ m^{-3}$ and was first worked out by the Bohemian physical chemist Joseph Loschmidt (1821–95).

Lotka–Volterra mechanism A simple chemical reaction mechanism proposed as a possible mechanism of *oscillating reactions. The process involves a conversion of a reactant R into a product P. The reactant flows into the reaction chamber at a constant rate and the product is removed at a constant rate, i.e. the reaction is in a steady state (but not in chemical equilibrium). The mechanism involves three steps:

$R + X \rightarrow 2X$

$X + Y \rightarrow 2Y$

$Y \rightarrow P$

The first two steps involve *autocatalysis: the first step is catalysed by the reactant X and the second by the reactant Y. The kinetics of such a reaction can be calculated numerically, showing that the concentrations of both X and Y increase and decrease periodically with time. This results from the autocatalytic action. Initially, the concentration of X is small, but, as it increases, there is a rapid increase in the rate of the first reaction because of the autocatalytic action of X. As the concentration of X builds up, the rate of the second reaction also increases. Initially, the concentration of Y is low but there is a sudden surge in the rate of step 2, resulting from the autocatalytic action of Y. This lowers the concentration of X and slows down step 1, so the concentration of X falls. Less X is now available for the second step and the concentration of Y also starts to fall. With this fall in the amount of Y, less X is removed, and the first reaction again begins to increase. These processes are repeated, leading to repeated rises and falls in the concentrations of both X and Y. The cycles are not in phase, peaks in the concentration of Y occurring later than peaks in X.

In fact, known oscillating chemical reactions have different mechanisms to the above, but the scheme illustrates how oscillation may occur. This type of process is found in fields other than chemistry; they were investigated by the Italian mathematician Vito Volterra (1860–1940) in models of biological systems (e.g. predator–prey relationships).

loudness The physiological perception of sound intensity. As the ear responds differently to different frequencies, for a given intensity loudness is dependent on frequency. Sounds with frequencies between 1000 hertz and 5000 Hz are louder than sounds of the same intensity at higher or lower frequencies. Duration is also a factor in loudness, long bursts of sound being louder than short bursts. Loudness increases up to a duration of about 0.2 second; above this limit loudness does not increase with duration.

Relative loudness is usually measured on the assumption of proportionality to the logarithm of the intensity (for a given frequency), i.e. proportionality to the relative intensity on the *decibel scale. A subjective judgment is made of the relative intensity above threshold that a note of 1000 Hz must have to match the specimen sound; the loudness of this, in *phons, is then equal to that relative intensity in decibels.

loudspeaker A transducer for converting an electrical signal into an acoustic signal. Usually it is important to preserve as many characteristics of the electrical waveform as possible. The device must be capable of reproducing frequencies in the range 150–8000 hertz for speech and 20–20 000 Hz for music.

The most common loudspeaker consists of a moving-coil device. In this a cone-shaped diaphragm is attached to a coil of wire and made to vibrate in accordance with the electrical signal by the interaction between the current passing through the coil and a steady magnetic field from a permanent magnet surrounding it.

low *See* DEPRESSION.

low-dimensional system A *condensed-matter system in which the spatial dimension is less than three. In practice, a **two-dimensional system** is a thin film or layer and a **one-dimensional system** is a thin wire. Two-dimensional systems have applications to *semiconductor technology, in devices such as MOSFETs (*see* TRANSISTOR). The behaviour of low-dimensional systems is of interest because the problems for low-dimensional systems (particularly one-dimensional systems) are much easier to solve than the corresponding problems in three dimensions. Clusters of atoms and very small crystals can be considered as **zero-dimensional systems**.

lowering of vapour pressure A reduction in the saturated vapour pressure of a pure liquid when a solute is introduced. If the solute is a solid of low vapour pressure, the decrease in vapour pressure of the liquid is proportional to the concentration of particles of solute; i.e. to the number of dissolved molecules or ions per unit volume. To a first approximation, it does not depend on the nature of the particles. *See* COLLIGATIVE PROPERTIES; RAOULT'S LAW.

low frequency (LF) A radio frequency in the range 30–300 kilohertz; i.e. having a wavelength in the range 1–10 kilometre.

Lowry–Brønsted theory *See* ACID.

low-temperature physics Physics at low temperatures, especially at temperatures close to absolute zero.

LSD *See* LYSERGIC ACID DIETHYLAMIDE.

L-series *See* ABSOLUTE CONFIGURATION.

lubrication The use of a substance to prevent contact between solid surfaces in relative motion in order to reduce friction, wear, overheating, and rusting. Liquid hydrocarbons (oils), either derived from petroleum or made synthetically, are the most widely used lubricants as they are relatively inexpensive, are good coolants, provide the appropriate range of viscosities, and are thermally stable. Additives include polymeric substances that maintain the desired viscosity as the temperature increases, antioxidants that prevent the formation of a sludge, and alkaline-earth phenates that neutralize acids and reduce wear.

At high temperatures, solid lubricants, such as graphite or molybdenum disulphide, are often used. Semifluid lubricants (greases) are used to provide a seal against moisture and dirt and to remain attached to vertical surfaces. They are made by adding gelling agents, such as metallic soaps, to liquid lubricants.

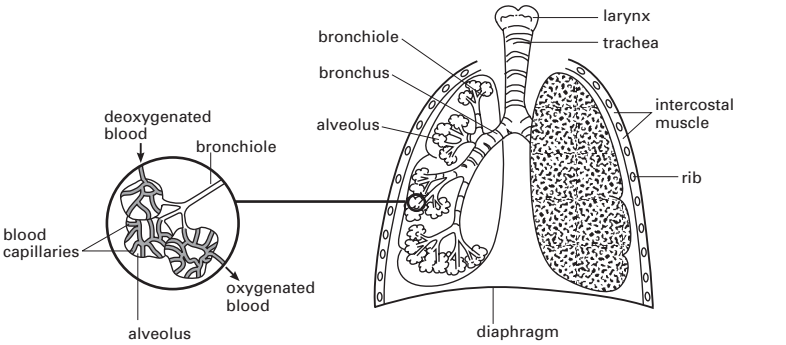
Recent technology has made increasing use of gases as lubricants, usually in air bearings. Their very low viscosities minimize energy losses at the bearings but necessitate some system for pumping the gas continuously to the bearings. The principle is that of the hovercraft.

lumbar vertebrae The *vertebrae in the region of the lower back. They occur below the *thoracic vertebrae and above the *sacral vertebrae. In mammals they bear processes for the attachment of back muscles.

lumen **1.** The space enclosed by a vessel, duct, or other tubular or saclike organ. The central cavity of blood vessels and of the digestive tract are examples. **2.** Symbol lm. The SI unit of *luminous flux equal to the flux emitted by a uniform point source of 1 candela in a solid angle of 1 steradian.

luminance (photometric brightness) Symbol L. The *luminous intensity of any surface in a given direction per unit projected area of the surface, viewed from that direction. It is given by the equation $L = \mathrm{d}I/(\mathrm{d}A\cos\theta)$, where I is the luminous intensity and θ is the angle between the line of sight and the normal to the surface area A being considered. It is measured in candela per square metre.

luminescence The emission of light by a substance for any reason other than a rise in its temperature. In general, atoms of substances emit *photons of electromagnetic energy when they return to the *ground state after having been in an excited state (*see* EXCITATION). The causes of the excitation are various. If the exciting cause is a photon, the process is called **photoluminescence**; if it is an electron it is called **electroluminescence**. **Chemiluminescence** is luminescence resulting from a chemical reaction (such as the slow oxidation of phosphorus); *bioluminescence is the luminescence produced by a living organism (such as a firefly). If the luminescence persists significantly after the exciting cause is removed it is called **phosphorescence**; if it does not it is called **fluorescence**. This distinction is arbitrary since there must always be some delay; in some definitions a persistence of more than



Lung. The lungs and air passages of a mammal (right lung cut open to show internal structure).

10 nanoseconds (10^{-8} s) is treated as phosphorescence.

luminol test A *presumptive test for blood. The reagent is a mixture of 3-aminophthalhydrazide, sodium carbonate, and sodium perborate. When sprayed with the reagent, traces of blood (even old blood) emit a faint chemoluminescence.

luminosity **1.** *Luminous intensity in a particular direction; the apparent brightness of an image. **2.** The brightness of a star defined as the total energy radiated in unit time. It is related to the surface area (A) and the **effective temperature** (T_e; the temperature of a black body having the same radius as the star and radiating the same amount of energy per unit area in one second) by a form of *Stefan's law, i.e.

$$L = A\sigma T_e^4$$

where σ is the Stefan constant and L is the luminosity.

luminous exitance *See* EXITANCE.

luminous flux Symbol Φ_v. A measure of the rate of flow of light, i.e. the radiant flux in the wavelength range 380–760 nanometres, corrected for the dependence on wavelength of the sensitivity of the human eye. It is measured by reference to emission from a standard source, usually in lumens.

luminous intensity Symbol I_v. A measure of the light-emitting ability of a light source, either generally or in a particular direction. It is measured in candelas.

lunar eclipse *See* ECLIPSE.

lunation *See* SYNODIC MONTH.

lung The *respiratory organ of air-breathing vertebrates. A pair of lungs is situated in the thorax, within the ribcage. Each consists essentially of a thin moist membrane that is folded to increase its surface area. Exchange of oxygen and carbon dioxide takes place between blood capillaries on one side of the membrane and air on the other. The lung is supplied with air through a *bronchus. In mammals and reptiles the membrane of the lung takes the form of numerous sacs (*see* ALVEOLUS) that are connected to the bronchus via *bronchioles (see illustration). The lungs themselves contain no muscular tissue and are ventilated by *respiratory movements, the mechanisms of which vary with the species.

lungfish *See* DIPNOI.

luteinizing hormone (LH; interstitial-cell-stimulating hormone; ICSH) A hormone, secreted by the anterior pituitary gland in mammals, that stimulates in males the production of sex hormones (*androgens) by the *interstitial cells of the testes and in females ovulation, *progesterone synthesis, and *corpus luteum formation.

luteotrophic hormone *See* PROLACTIN.

lutetium Symbol Lu. A silvery metallic element belonging to the *lanthanoids; a.n. 71; r.a.m. 174.97; r.d. 9.8404 (20°C); m.p. 1663°C; b.p. 3402°C. Lutetium is the least abundant of the elements and the little quantities that are available have been obtained by processing other metals. There are two natural isotopes, lutetium–175 (stable) and lutetium–176 (half-life 2.2×10^{10} years). The element is used as a catalyst. It was first

identified by Gerges Urbain (1872–1938) in 1907.

SEE WEB LINKS

- Information from the WebElements site

Luttinger liquid (Tomonaga–Luttinger liquid) A model of interacting fermions in one dimension proposed by the Japanese physicist Sin-Itiro Tomonaga (1906–1979) in 1950 and analysed further by the American physicist Joaquin Luttinger (1923–97) in 1963. A Luttinger liquid is a *non-Fermi liquid and hence has different properties from, for example, the properties of electrons in ordinary metals. The electrons in one-dimensional chains of certain organic molecules form a Luttinger liquid.

lux Symbol lx. The SI unit of *illuminance equal to the illumination produced by a *luminous flux of 1 lumen distributed uniformly over an area of 1 square metre.

lyase Any of a class of enzymes that catalyse either the cleavage of a double bond and the addition of new groups to a substrate, or the formation of a double bond.

Lycophyta (Lycopodophyta) A phylum of *tracheophyte plants containing the club-mosses (genus *Lycopodium*) and related genera (including *Selaginella*) as well as numerous extinct forms, which reached their peak in the Carboniferous period with giant coal-forming tree species. Lycophytes have roots and their stems are covered with numerous small leaves. Reproduction is by means of spores; the sporangia are usually grouped into cones.

lye *See* POTASSIUM HYDROXIDE.

Lyell, Sir Charles (1797–1875) British geologist, born in Scotland. Poor eyesight made him change from his legal studies to geology, which resulted in his theory that rocks are formed by a slow continuous process. He is also known for his three-volume *The Principles of Geology* (1831–33), which was to become the standard textbook for generations.

Lyman series *See* HYDROGEN SPECTRUM.

lymph The colourless liquid found within the *lymphatic system, into which it drains from the spaces between the cells. Lymph (called **tissue fluid** in the intercellular spaces) resembles *blood plasma, consisting mostly of water with dissolved salts and proteins. Fats are found in suspension and their presence varies with food intake. The lymph eventually enters the bloodstream near the heart.

lymphatic system The network of vessels that conveys *lymph from the tissue fluids to the bloodstream. Tiny *lacteals (in the small intestine) and **lymph capillaries** (in other tissues) drain into larger tubular vessels that converge to form the right lymphatic duct and the *thoracic duct, which connect with the venous blood supply to the heart. Associated with the lymphatic vessels at intervals along the system are the *lymph nodes. The lymph capillary walls are very permeable, so lymph bathing the body's tissues can drain away molecules that are too large to pass through blood capillary walls. Lymph is pumped by cycles of contraction and relaxation of the lymphatic vessels and also by the action of adjoining muscles.

lymph capillary *See* LYMPHATIC SYSTEM.

lymph node A mass of *lymphoid tissue, many of which occur at intervals along the *lymphatic system. Lymph in the lymphatic vessels flows through the lymph nodes, which filter out bacteria and other foreign particles, so preventing them from entering the bloodstream and causing infection. The lymph nodes also produce *lymphocytes. In humans, major lymph nodes occur in the neck, under the arms, and in the groin.

lymphocyte A type of white blood cell (*leucocyte) that has a large nucleus and little cytoplasm. Lymphocytes are formed in the *lymph nodes and provide about a quarter of all leucocytes. They are important in the body's defence and are responsible for immune reactions as the presence of *antigens stimulates them to produce *antibodies. There are two principal populations of lymphocytes: **B lymphocytes** (*see* B CELL), which produce circulating antibodies and are responsible for humoral *immunity; and **T lymphocytes** (*see* T CELL), which are responsible for cell-mediated immunity.

lymphoid tissue The type of tissue found in the *lymph nodes, *tonsils, *spleen, and *thymus. It is responsible for producing lymphocytes and therefore contributes to the body's defence against infection.

lymphokine *See* CYTOKINE.

lymphoma *See* CANCER.

lyophilic Having an affinity for a solvent

('solvent-loving'; if the solvent is water the term **hydrophilic** is used). *See* COLLOIDS.

lyophobic Lacking any affinity for a solvent ('solvent-hating'; if the solvent is water the term **hydrophobic** is used). *See* COLLOIDS.

Lysenkoism The official Soviet science policy governing the work of geneticists in the USSR from about 1940 to 1960. It was named after its chief promoter, the agriculturalist Trofim Lysenko (1898–1976). Lysenkoism dismissed all the advances that had been made in classical genetics, denying the existence of genes, and held that the variability of organisms was produced solely by environmental changes. There was also a return to a belief in the inheritance of acquired characteristics (*see* LAMARCKISM). This state of affairs continued, despite overwhelming conflicting evidence from Western scientists, because it provided support for communist theory.

lysergic acid diethylamide (LSD) A chemical derivative of lysergic acid that has potent hallucinogenic properties (*see* HALLUCINOGEN). It occurs in the cereal-fungus ergot and was first synthesized in 1943. LSD acts as an *antagonist at *serotonin receptors.

lysigeny The localized disruption of plant cells to form a cavity (surrounded by remnants of the broken cells) in which secretions accumulate. Examples are the oil cavities in the leaves of citrus trees. *Compare* SCHIZOGENY.

lysine *See* AMINO ACID.

lysis The destruction of a living cell. This may be effected by *lysosomes or *lymphocytes, either as part of the normal metabolic process (as when cells are damaged or worn out) or as a reaction against invading cells (e.g. bacteria). *Bacteriophages eventually cause lysis of their host cells.

lysogeny *See* LAMBDA PHAGE; PROPHAGE.

lysosome A membrane-bound sac (organelle) found in animal cells and in single-celled eukaryotes. It contains hydrolytic enzymes that degrade aged or defective cell components or material taken in by the cell from its environment, such as food particles or bacteria. In plant cells, the *vacuole contains hydrolytic enzymes equivalent to those in the lysosome and can degrade materials in a manner similar to a lysosome.

lysozyme An antibacterial enzyme widely distributed in body fluids and secretions, including tears and saliva. It disrupts the polysaccharide components of bacterial cell walls, leaving them susceptible to destruction.