N

NAD (nicotinamide adenine dinucleotide) A *coenzyme, derived from the B vitamin *nicotinic acid, that participates in many biological dehydrogenation reactions. NAD is characteristically loosely bound to the enzymes concerned. It normally carries a positive charge and can accept one hydrogen atom and two electrons to become the reduced form, NADH. NADH is generated during the oxidation of food, especially by the reactions of the *Krebs cycle. It then gives up its two electrons (and single proton) to the *electron transport chain, thereby reverting to NAD^+ and generating three molecules of ATP per molecule of NADH.

NADP (**nicotinamide adenine dinucleotide phosphate**) differs from NAD only in possessing an additional phosphate group. It functions in the same way as NAD although anabolic reactions (*see* ANABOLISM) generally use NADPH (reduced NADP) as a hydrogen donor rather than NADH. Enzymes tend to be specific for either NAD or NADP as coenzyme.

nadir The point diametrically opposite the *zenith on the *celestial sphere.

NAND circuit *See* LOGIC CIRCUITS.

nano- Symbol n. A prefix used in the metric system to denote 10^{-9}. For example, 10^{-9} metre = 1 nanometre (nm).

nanoarray *See* MICROARRAY.

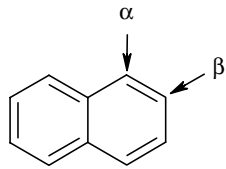
nanotechnology The development and use of devices that have a size of only a few nanometres. Research has been carried out into very small components, which depend on electronic effects and may involve movement of a countable number of electrons in their action. Such devices would act much faster than larger components. Considerable interest has been shown in the production of structures on a molecular level by suitable sequences of chemical reactions. It is also possible to manipulate individual atoms on surfaces using *atomic force microscopy.

nanotube *See* BUCKMINSTERFULLERENE.

napalm A substance used in incendiary bombs and flame throwers, made by forming a gel of petrol with aluminium soaps (aluminium salts of long-chain carboxylic acids, such as palmitic acid).

naphtha Any liquid hydrocarbon or mixture obtained by the fractional distillation of petroleum. It is generally applied to higher *alkane fractions with nine or ten carbon atoms. Naphtha is used as a solvent and as a starting material for *cracking into more volatile products, such as petrol.

naphthalene A white volatile solid, $C_{10}H_8$ (see formula); r.d. 1.025; m.p. 80.55°C; b.p. 218°C. Naphthalene is an aromatic hydrocarbon with an odour of mothballs and is obtained from crude oil. It is a raw material for making certain synthetic resins.



Naphthalene.

naphthols Two phenols derived from naphthalene with the formula $C_{10}H_7OH$, differing in the position of the –OH group. The most important is naphthalen-2-ol (β-naphthol), with the –OH in the 2-position. It is a white solid (r.d. 1.28; m.p. 123–124°C; b.p. 295°C) used in rubber as an antioxidant. Naphthalen-2-ol will couple with diazonium salts at the 1-position to form red *azo compounds, a reaction used in testing for the presence of primary amines (by making the diazonium salt and adding naphthalen-2-ol).

naphthyl group The group $C_{10}H_7$– obtained by removing a hydrogen atom from naphthalene. There are two forms depending on whether the hydrogen is removed from the 1- or 2-position.

Napier, John (1550–1617) Scottish mathematician, who is best known for devising *logarithms, announced in 1614. His tables,

which used the base e, were later modified by Henry Briggs (1561–1630) to base 10.

Napierian logarithm *See* LOGARITHM.

narcotic Any drug that induces stupor and relieves pain, especially morphine and other *opiates. Such narcotics are addictive and cause dependence, and their medical use is strictly controlled.

nares (nostrils) The paired openings of the *nasal cavity in vertebrates. All vertebrates have **external nares**, which open to the exterior; in some species these are situated on a *nose. **Internal nares** (or **choanae**) are present only in air-breathing vertebrates (including lungfish) and open into the mouth cavity. In mammals they open posteriorly, beyond the secondary *palate.

nasal cavity The cavity in the head of a vertebrate that is lined by a membrane rich in sensitive olfactory receptors (*see* OLFACTION). It is connected to the exterior by external nostrils and (in air-breathing vertebrates) to the respiratory system by internal *nares.

nascent hydrogen A reactive form of hydrogen generated *in situ* in the reaction mixture (e.g. by the action of acid on zinc). Nascent hydrogen can reduce elements and compounds that do not readily react with 'normal' hydrogen. It was once thought that the hydrogen was present as atoms, but this is not the case. Probably hydrogen molecules are formed in an excited state and react before they revert to the ground state.

nastic movements Movements of plant organs in response to external stimuli that are independent of the direction of the stimuli. Examples are the opening of crocus and tulip flowers in response to a rise in temperature (**thermonasty**), the opening of evening primrose flowers at night (**photonasty**), and the folding up and drooping of leaves of the sensitive plant (*Mimosa pudica*) when lightly touched (**haptonasty**). *Compare* TROPISM. *See also* NYCTINASTY.

natality *See* BIRTH RATE.

natron A mineral form of hydrated sodium carbonate, $Na_2CO_3.H_2O$.

Natta process *See* ZIEGLER PROCESS.

natural abundance *See* ABUNDANCE.

natural frequency **1.** The frequency of the free oscillation of a system. **2.** The frequency at which resonance occurs in an electrical circuit.

natural gas A naturally occurring mixture of gaseous hydrocarbons that is found in porous sedimentary rocks in the earth's crust, usually in association with *petroleum deposits. It consists chiefly of methane (about 85%), ethane (up to about 10%), propane (about 3%), and butane. Carbon dioxide, nitrogen, oxygen, hydrogen sulphide, and sometimes helium may also be present. Natural gas, like petroleum, originates in the decomposition of organic matter. It is widely used as a fuel and also to produce carbon black and some organic chemicals. Natural gas occurs on every continent, the major reserves occurring in the USA, Russia, Kazakhstan, Turkmenistan, Ukraine, Algeria, Canada, and the Middle East. *See also* LIQUEFIED PETROLEUM GAS.

natural group A group of organisms of any taxonomic rank that are believed to be descended from a common ancestor (*see* MONOPHYLETIC). In an ideal natural classification all taxa should be natural groups. *See also* CLADISTICS.

natural history **1.** The study of living organisms in their natural habitats. **2.** The study of all natural phenomena.

natural killer cell (NK cell) A lymphoid cell that recognizes and destroys tissue cells infected with pathogenic organisms. NK cells are important as an early line of defence against infection, and they play a significant role in combating infections by, for example, herpesviruses. They become activated in response to interferons or the release of cytokines by macrophages, bind to target cells, and release cytotoxic granules onto the surface of their target. The toxic effector molecules penetrate the target's plasma membrane and induce programmed cell death (*see* APOPTOSIS).

natural logarithm *See* LOGARITHM.

natural selection The process that, according to *Darwinism, brings about the evolution of new species of animals and plants. Darwin noted that the size of any population tends to remain constant despite the fact that more offspring are produced than are needed to maintain it. He also saw that variations existed between individuals of the population and concluded that disease, competition, and other forces acting on the population eliminated those individ-

uals less well adapted to their environment. The survivors would pass on any heritable advantageous characteristics (i.e. characteristics with survival value) to their offspring and in time the composition of the population would change in adaptation to a changing environment. Over a long period of time this process could give rise to organisms so different from the original population that new species are formed. *See also* ADAPTIVE RADIATION. *Compare* PUNCTUATED EQUILIBRIUM.

natural units A system of units, used principally in particle physics, in which all quantities that have dimensions involving length, mass, and time are given dimensions of a power of energy (usually expressed in electronvolts). This is equivalent to setting the rationalized *Planck constant and the speed of light both equal to unity. *See also* GAUSSIAN UNITS; GEOMETRIZED UNITS; HEAVISIDE–LORENTZ UNITS; PLANCK UNITS.

nature and nurture The combined effects of inherited factors (nature) and environmental factors (nurture) on the development of an organism. The genetic potential of an organism will only be realized under appropriate environmental conditions. *See also* PHENOTYPE.

nautical mile A measure of distance used at sea. In the UK it is defined as 6080 feet but the international definition is 1852 metres. 1 international nautical mile is therefore equivalent to 1.15078 land (statute) miles.

navigation (in biology) The complex process that enables animals to travel along a particular course in order to reach a specific destination. Navigation is an important aspect of behaviour in many animals, particularly those, such as birds, fish, and some insects, that undergo *migrations. Landmarks, such as coastlines and mountain ranges, are important reference points for navigation but many animals can navigate successfully without the aid of these, by using the sun, stars, magnetic fields, odours, and polarized light. For example, birds use the sun and stars as landmarks and are sensitive to the earth's magnetic fields, while salmon can identify the unique odour of their home river. *See also* DANCE OF THE BEES.

NBS *See N*-BROMOSUCCINIMIDE.

Neanderthal man A form of fossil human that lived in Europe and western Asia between about 200 000 and 28 000 years ago, when the climate was much colder than today. Neanderthals were thought to be a subspecies of *Homo sapiens* but are now generally regarded as a distinct species, *H. neanderthalensis*. The fossil remains indicate that Neanderthals were fairly short, strongly built, and had low brows but that the brain size was the same as, or larger than, modern humans'. They were nomadic cave dwellers who buried their dead. Neanderthals became extinct abruptly; they may have been exterminated by incoming modern humans, with their more advanced stone tool technology. The name is derived from the site in the Neander valley, Germany, where fossils were found in 1856.

near point The nearest point at which the human eye can focus an object. As the lens becomes harder with age, the extent to which accommodation can bring a near object into focus decreases. Therefore with advancing age the near point recedes – a condition known as *presbyopia.

nebula A cloud of interstellar dust and/or gas. There are two classes: **bright nebulae**, which are visible as misty patches of light; and **dark nebulae**, which can only be seen if they happen to lie in front of something bright, such as a bright nebula. **Emission nebulae** are bright nebulae in which the gas atoms have been ionized by ultraviolet radiation from nearby stars and light is emitted as these ions interact with free electrons in the gas. **Reflection nebulae** are dark dust clouds that become visible by reflecting light from nearby stars. Some nebulae are the cradles of star formation. *See also* GIANT MOLECULAR CLOUD.

nebular hypothesis The theory that the solar system evolved from a vast rotating cloud of interstellar gas and dust particles (*see* NEBULA), which collapsed under its own gravitational attraction to form a flattened spinning disc called the **solar nebula** from which the sun and the other bodies evolved. The nebular hypothesis was advanced in 1796 by the French astronomer Pierre-Simon de Laplace (1749–1827). Laplace's model formed the starting point for the currently accepted **solar nebular disc model**. *See* SOLAR SYSTEM (Feature).

nectar A sugary liquid produced in plants by **nectaries**, regions of secretory cells on the receptacle or other parts of a flower. It attracts pollinating insects or other animals.

Néel temperature The temperature above which an antiferromagnetic substance becomes paramagnetic (*see* MAGNETISM). The *susceptibility increases with temperature, reaching a maximum at the Néel temperature, after which it abruptly declines. The phenomenon was discovered around 1930 by the French physicist Louis Néel (1904–2000).

Ne'eman, Yuval *See* GELL-MANN, MURRAY.

negative binomial distribution *See* PASCAL'S DISTRIBUTION.

negative charge *See* CHARGE.

negative feedback *See* FEEDBACK.

nekton *Pelagic organisms that actively swim through the water. Examples are fish, jellyfish, turtles, and whales. *Compare* PLANKTON.

nematic crystal *See* LIQUID CRYSTAL.

nematoblast *See* THREAD CELL.

Nematoda A phylum of invertebrates comprising the roundworms. They are characterized by a smooth narrow cylindrical unsegmented body tapered at both ends. They shed their tough outer cuticle four times during life to allow growth. The microscopic free-living forms are found in all parts of the world, where they play an important role in the destruction and recycling of organic matter. The many parasitic nematodes are much larger; they include the filaria (*Wuchereria*) and Guinea worm (*Dracunculus*), which cause serious diseases in humans.

SEE WEB LINKS

- Website of the Society of Nematologists. Education Committee link accesses many images of nematodes

neo-Darwinism (modern synthesis) The current theory of the process of *evolution, formulated between about 1920 and 1950, that combines evidence from classical genetics with the Darwinian theory of evolution by *natural selection (*see* DARWINISM). It makes use of modern knowledge of genes and chromosomes to explain the source of the genetic variation upon which selection works. This aspect was unexplained by traditional Darwinism.

neodymium Symbol Nd. A soft silvery metallic element belonging to the *lanthanoids; a.n. 60; r.a.m. 144.24; r.d. 7.004 (20°); m.p. 1021°C; b.p. 3068°C. It occurs in bastnasite and monazite, from which it is recovered by an ion-exchange process. There are seven naturally occurring isotopes, all of which are stable, except neodymium–144, which is slightly radioactive (half-life 10^{10}–10^{15} years). Seven artificial radioisotopes have been produced. The metal is used to colour glass violet-purple and to make it dichroic. It is also used in misch metal (18% neodymium) and in neodymium–iron–boron alloys for magnets. It was discovered by Carl von Welsbach (1856–1929) in 1885.

SEE WEB LINKS

- Information from the WebElements site

Neogene The current geological period of the *Cenozoic era, consisting of the *Miocene, *Pliocene, *Pleistocene, and *Holocene epochs. The Neogene began 23 million years ago, following the *Palaeogene period, and corresponds to the latter third of the *Tertiary period and the entire *Quaternary period, both of which are no longer officially recognized divisions.

neo-Lamarckism Any of the comparatively modern theories of evolution based on Lamarck's theory of the inheritance of acquired characteristics (*see* LAMARCKISM). These include the unfounded dogma of *Lysenkoism and the controversial experiments on the inheritance of acquired immunological tolerance in mice.

Neolithic The New Stone Age: a stage of human cultural and technological evolution that began in the Middle East in approximately 8500 BC. It was characterized by farming using wild and domesticated crops and herding of livestock and (in the mid- and late Neolithic) by the making of pottery. Grinding and polishing of stone tools was also practised. The Bronze Age superseded Neolithic cultures from around 3500 BC in the Middle East.

neon Symbol Ne. A colourless gaseous element belonging to group 18 (formerly group 0) of the periodic table (the *noble gases); a.n. 10; r.a.m. 20.179; d. 0.9 g dm^{-3}; m.p. –248.67°C; b.p. –246.05°C. Neon occurs in air (0.0018% by volume) and is obtained by fractional distillation of liquid air. It is used in discharge tubes and neon lamps, in which it has a characteristic red glow. It forms hardly any compounds (neon fluorides have been reported). The element

was discovered in 1898 by Sir William Ramsey and M. W. Travers.

SEE WEB LINKS

- Information from the WebElements site

neon lamp A small lamp consisting of a pair of electrodes, treated to emit electrons freely, sealed in a glass bulb containing neon gas at low pressure. When a minimum voltage of between 60 and 90 volts is applied across the electrodes, the kinetic energy of the electrons is sufficient to ionize the neon atoms around the cathode, causing the emission of a reddish light. With d.c. the glow is restricted to the cathode; with a.c. both electrodes act alternately as cathodes and a glow appears to emanate from both electrodes. The device consumes a very low power and is widely used as an indicator light showing that a circuit is live.

neoplasm (tumour) Any new abnormal growth of cells, forming either a harmless (benign) tumour or a malignant one (*see* CANCER).

neoprene A synthetic rubber made by polymerizing the compound 2-chlorobuta-1,2-diene. Neoprene is often used in place of natural rubber in applications requiring resistance to chemical attack.

neoteny The retention of the juvenile body form, or particular features of it, in a mature animal. For example, the axolotl, a salamander, retains the gills of the larva in the adult. Neoteny is thought to have been an important mechanism in the evolution of certain groups, such as humans, who are believed to have developed from juvenile forms of apes.

neper A unit used to express a ratio of powers, currents, etc., used especially in telecommunications to denote the attenuation of an amplitude A_1 to an amplitude A_2 as N nepers, where

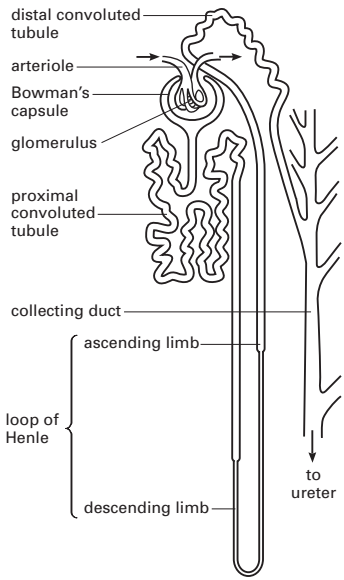
$$N = \log_e (A_2/A_1).$$

1 neper = 8.686 decibels. The unit is named after John Napier.

nephelometry The measurement of the turbidity (cloudiness) of a liquid. Nephelometers generally have a light source (often a laser) and a detector to measure the amount of light scattered by suspended particles. They are used in a number of fields including water quality control and blood analysis (for protein content).

nephrite *See* JADE.

nephron The excretory unit of the vertebrate *kidney (see illustration). Many constituents of the blood are filtered from the glomerulus into the Bowman's capsule at one end of the nephron. The *glomerular filtrate passes along the length of the nephron and some of its water, plus some salts, glucose, and amino acids, are reabsorbed into the surrounding blood capillaries (*see* PROXIMAL CONVOLUTED TUBULE; LOOP OF HENLE; DISTAL CONVOLUTED TUBULE). More water is reabsorbed in the *collecting duct, and the resulting concentrated solution of nitrogen-containing waste matter (*urea) plus inorganic salts drains from the collecting ducts of the nephrons and is discharged as urine into the ureter.



A nephron.

Neptune The fourth largest *planet in the *solar system and the eighth in order from the *sun. Its mean distance from the sun is 4452.94×10^6 km, its mass is 1.0243×10^{26} kg (more than 17 times that of earth), and its mean diameter is 49 528 km; it has a *sidereal period of 164.79 years. Its period of axial rotation is 16h 6.6m. Neptune was discovered in 1846 by Johann Galle (1812–1910) on

the basis of predictions made by John Couch Adams and Urbain Leverrier (1811–77), who had separately observed perturbations in the orbit of *Uranus. Neptune is a *gas giant; traces of methane in its outer atmosphere absorb red and infrared light, giving it its blue colour. Inside, Neptune is composed of ice and rock. At the planet's cloud tops, the temperature is only 55 K. Neptune has a faint fragmentary ring system. **Triton**, the largest of the 13 Neptunian satellites, measures 2707 km in diameter.

SEE WEB LINKS

- NASA's introduction to the planet and its moons

neptunium Symbol Np. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 93; r.a.m. 237.0482. The most stable isotope, neptunium–237, has a half-life of 2.2×10^6 years and is produced in small quantities as a by-product by nuclear reactors. Other isotopes have mass numbers 229–236 and 238–241. The only other relatively long-lived isotope is neptunium–236 (half-life 5×10^3 years). The element was first produced by Edwin McMillan (1907–91) and Philip Abelson (1913–2004) in 1940.

SEE WEB LINKS

- Information from the WebElements site

neptunium series *See* RADIOACTIVE SERIES.

neritic zone The region of the sea over the continental shelf, which is less than 200 metres deep (approximately the maximum depth for organisms carrying out photosynthesis). *Compare* OCEANIC ZONE.

Nernst effect An effect in which a temperature gradient along an electric conductor or semiconductor placed in a perpendicular magnetic field, causes a potential difference to develop in the third perpendicular direction between opposite edges of the conductor. This effect, an analogue of the *Hall effect, was discovered in 1886 by the German physicist Walter Nernst (1864–1941).

Nernst heat theorem A statement of the third law of *thermodynamics in a restricted form: if a chemical change takes place between pure crystalline solids at *absolute zero there is no change of entropy.

nerve A strand of tissue comprising many *nerve fibres plus supporting tissues (*see* GLIA), enclosed in a connective-tissue sheath. Nerves connect the central nervous system with the organs and tissues of the body. A nerve may carry only motor nerve fibres (**motor nerve**) or only sensory fibres (**sensory nerve**) or it may be mixed and carry both types (**mixed nerve**). Although the nerve fibres are in close proximity within the nerve, their physiological responses are independent of each other.

nerve agents A class of highly toxic compounds that act by affecting the action of acetylcholine, a neurotransmitter regulated by the enzyme acetylcholinesterase (AChE). The nerve agents, which are organophosphates, bind to AChE and block its action. Consequently there is nothing to stop the build-up of acetylcholine, and exposure to small amounts of nerve gas can kill in minutes. There are two series of agents. The **G-series** was produced by German scientists in the 1930s and 1940s (the G stands for German). The main ones are *tabun (GA), *sarin (GB), *soman (GD), and *cyclosarin (GF). A further series of nerve agents is the **V-series**. The most common of these is *VX, which was discovered at Porton Down in the UK in 1952. Nerve agents are classified as weapons of mass destruction by the UN.

nerve cell *See* NEURON.

nerve cord A large bundle of nerve fibres, running down the longitudinal axis of the body, that forms an important part of the *central nervous system. Most invertebrates have a pair of solid nerve cords, situated ventrally and bearing segmentally arranged *ganglia. All animals of the phylum *Chordata have a dorsal hollow nerve cord; in vertebrates this is the *spinal cord.

nerve fibre The *axon of a *neuron together with the tissues associated with it (such as a *myelin sheath). The length and diameter of nerve fibres are very variable, even within the same organism. *See also* GIANT FIBRE.

nerve growth factor (NGF) *See* NEUROTROPHIN.

nerve impulse *See* IMPULSE.

nerve net A network of nerve cells connected with each other by synapses or fusion. The nervous system of certain invertebrates (e.g. coelenterates and echinoderms) consists exclusively of a nerve net in the body wall.

nervous system The system of cells and tissues in multicellular animals by which in-

formation is conveyed between sensory cells and organs and effectors (such as muscles and glands). It consists of the *central nervous system (in vertebrates the *brain and *spinal cord; in invertebrates the *nerve cord and *ganglia) and the *peripheral nervous system. Its function is to receive, transmit, and interpret information and then to formulate appropriate responses for the effector organs. It also serves to coordinate responses that require more than one physiological process. Nervous tissue consists of *neurons, which convey the information in the form of *impulses, and supporting tissue.

SEE WEB LINKS

- Basic interactive guide to the anatomy of the human nervous system; from Human Anatomy Online

nesquehonite A mineral form of *magnesium carbonate trihydrate, $MgCO_3.3H_2O$.

Nessler's reagent A solution of mercury(II) iodide (HgI_2) in potassium iodide and potassium hydroxide. It is used in testing for ammonia, with which it forms a brown coloration or precipitate.

Net *See* INTERNET.

n

Neumann's law The magnitude of an electromagnetically induced e.m.f. (E) is given by $E = -d\Phi/dt$, where Φ is the magnetic flux. This is a quantitative statement of *Faraday's second law of electromagnetic induction and is sometimes known as the Faraday–Neumann law.

neural network A network of processors designed to mimic the transmission of impulses in the human brain. Neural networks are either electronic constructions or, often, computer-simulated structures. Each processor ('neurone') multiplies its input signal by a weighting factor and the final output signal depends on these factors, which can be adjusted. Such networks can be 'taught' to recognize patterns in large amounts of data. They are used in research into artificial intelligence and have also been applied in predicting financial market trends.

neural tube A hollow tube of tissue in the early embryo of vertebrates that subsequently develops into the brain and spinal cord. It forms by folding of the ectodermal **neural plate**, and has a central canal running through it. Sometimes the folds of the neural plate fail to close properly, resulting in **neural tube defects** (such as spina bifida) in the fetus.

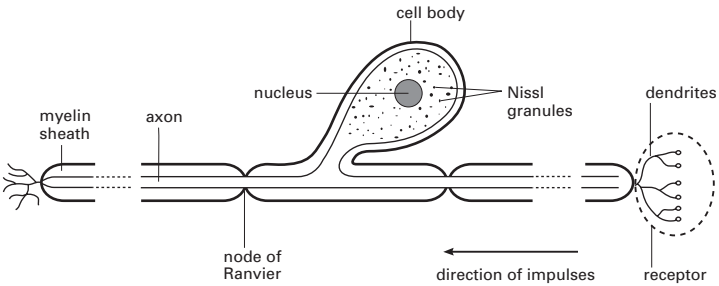
neuroendocrine system Any of the systems of dual control of certain activities in the body of some higher animals by nervous and hormonal stimulation. For example, the posterior *pituitary gland and the medulla of the *adrenal gland receive direct nervous stimulation to secrete their hormones, whereas the anterior pituitary gland is stimulated by *releasing hormones from the hypothalamus.

neurohormone Any hormone that is produced not by an endocrine gland but by a specialized nerve cell and is secreted from nerve endings into the bloodstream or directly to the tissue or organ whose growth or function it controls (*see* NEUROSECRETION). Examples of neurohormones are *noradrenaline, *antidiuretic hormone, and hormones associated with metamorphosis and moulting in insects (*see* ECDYSONE; JUVENILE HORMONE). *Compare* NEUROPEPTIDE.

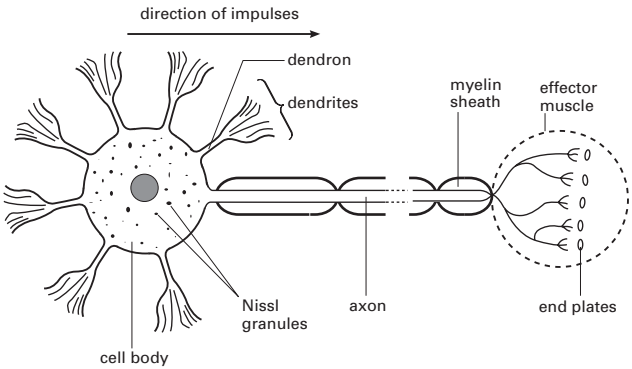
neuromuscular junction The point where a muscle fibre comes into contact with a motor neuron carrying nerve impulses from the central nervous system. The impulses travel from the neuron to the muscle fibre by means of a neurotransmitter, in a similar way to the transmission of impulses across a *synapse between two neurons. The neurotransmitter is released from vesicles at the end of the motor neuron into a small gap (the cleft), where it diffuses to the *end plate of the muscle fibre and depolarizes the membrane. When depolarization has reached a certain threshold an action potential is triggered in the muscle fibre.

neuron (neurone; nerve cell) An elongated branched cell that is the fundamental unit of the *nervous system, being specialized for the conduction of *impulses. A neuron consists of a *cell body, containing the nucleus and *Nissl granules; *dendrites, which receive incoming impulses and pass them towards the cell body; and an *axon, which conducts impulses away from the cell body, sometimes over long distances. Impulses are passed from one neuron to the next via *synapses. *Sensory neurons transmit information from receptors to the central nervous system. *Motor neurons conduct information from the central nervous system to *effectors (e.g. muscles). See illustration.

neuropeptide Any of numerous peptides



Sensory neuron



Motor neuron

Neuron.

that influence the activity of neurons. Examples include the hypothalamic *releasing hormones, *antidiuretic hormone, and the gastric peptides (e.g. *VIP) released from cells in the duodenal wall. Neuropeptides may act as neurotransmitters, as cotransmitters to modify the action of neurotransmitters, and/or as *neurohormones.

neuropeptide Y (NPY) A 36-amino acid peptide that has key roles in energy metabolism and in regulating the activity of the heart and blood vessels. It is a potent stimulant of appetite, being released from cells in the hypothalamus, where it activates NPY receptors, which are *G-protein-coupled receptors. It also regulates secretion of gonadotrophin-releasing hormone from the hypothalamus. Its release is triggered by the gut hormone *ghrelin and inhibited by the hormone *leptin. NPY is widely distributed in the brain and sympathetic nervous system and commonly occurs in nerve cells that secrete the neurotransmitter noradrenaline. In general it modulates the effects of adrenaline and noradrenaline, for example by decreasing contraction of heart muscle and reducing blood flow through coronary vessels. It is also significant in the reduction of anxiety and control of blood pressure.

neurosecretion The secretion of *neurohormones by **neurosecretory cells**, which possess characteristics of both nerve cells and endocrine cells. They are found, for example, in the hypothalamus, where they receive nerve impulses from other parts of the brain but transmit these signals to the pituitary gland by neurohormones that are released into the blood.

neurotransmitter A chemical that mediates the transmission of a nerve impulse across a *synapse. Examples are *adrenaline and *noradrenaline (in adrenergic nerves) and *acetylcholine (in cholinergic nerves). The neurotransmitter is released at the synaptic knob at the tip of the axon into the synaptic cleft. It diffuses across to the opposite membrane (the postsynaptic membrane), where it initiates the propagation of a nerve impulse in the next neuron.

neurotrophin (NT) Any of several growth factors that promote the development, maintenance, and repair of neurons. Each consists of two identical polypeptides held together by disulphide bonds. The first to be discovered, **nerve growth factor** (**NGF**), is essential for the normal growth and survival of neurons of the sympathetic nervous system and also sensory neurons. It is produced by the neurons themselves and by astrocytes. Schwann cells, fibroblasts, and certain other cells.

neuter An organism that does not possess either male or female reproductive organs. Cultivated ornamental flowers that have neither pistils nor stamens are called neuters.

neutral Describing a compound or solution that is neither acidic nor basic. A neutral solution is one that contains equal numbers of both protonated and deprotonated forms of the solvent.

neutralization The process in which an acid reacts with a base to form a salt and water.

neutrino A *lepton (*see also* ELEMENTARY PARTICLES) that exists in three forms, one in association with the electron, one with the muon, and one with the tau particle. Each form has its own antiparticle. The neutrino, which was postulated in 1930 to account for the 'missing' energy in *beta decay, was identified tentatively in 1953 and, more definitely, in 1956. Neutrinos have no charge and travel at speeds very close to the speed of light. In some *grand unified theories they are predicted to have nonzero mass and there is now a large amount of indirect evidence for this, although the values of neutrino masses have not been determined.

neutrino astronomy A branch of astronomy that gives information about objects by studying the neutrinos they emit, using detectors based at earth observatories. Since neutrinos are very difficult to detect, the only bodies that have been studied in this way are the sun and the supernova SN1987A, which exploded in 1987. It is hoped that in the future it will be possible to investigate other aspects of neutrino astronomy, including the *cosmic neutrino background.

SEE WEB LINKS

- The US website for the Super-Kamiokande neutrino observatory

neutron A neutral hadron (*see* ELEMENTARY PARTICLES) that is stable in the atomic nucleus but decays into a proton, an electron, and an antineutrino with a mean life of 12 minutes outside the nucleus. Its rest mass (symbol m_n) is slightly greater than that of the proton, being $1.674\ 9286(10) \times 10^{-27}$ kg. Neutrons occur in all atomic nuclei except normal hydrogen. The neutron was first reported in 1932 by James Chadwick (1891–1974).

SEE WEB LINKS

- Chadwick's 1932 letter to *Nature* on the discovery of the neutron
- Chadwick's 1932 paper in *Proceedings of the Royal Society*

neutron activation analysis *See* ACTIVATION ANALYSIS.

neutron bomb *See* NUCLEAR WEAPONS.

neutron diffraction The scattering of neutrons by atoms in solids, liquids, or gases. This process has given rise to a technique, analogous to *X-ray diffraction techniques, using a flux of thermal neutrons from a nuclear reactor to study solid-state structure and phenomena. Thermal neutrons have average kinetic energies of about 0.025 eV (4×10^{-21} J) giving them an equivalent wavelength of about 0.1 nanometre, which is suitable for the study of interatomic interference. There are two types of interaction in the scattering of neutrons by atoms: one is the interaction between the neutrons and the atomic nucleus, the other is the interaction between the *magnetic moments of the neutrons and the spin and orbital magnetic moments of the atoms. The latter interaction has provided valuable information on antiferromagnetic and ferrimagnetic materials (*see* MAGNETISM). Interaction with the atomic nucleus gives diffraction patterns that complement those from X-rays. X-rays, which interact with the extranuclear electrons, are not suitable for investigating light elements (e.g. hydrogen), whereas neutrons

do give diffraction patterns from such atoms because they interact with nuclei.

neutron drip *See* NEUTRON STAR.

neutron excess *See* ISOTOPIC NUMBER.

neutron interferometer A type of interferometer that uses the interference caused by the wave nature of neutrons to investigate many phenomena described by quantum mechanics. Neutron interferometers use large single crystals of silicon. They have been used to demonstrate the *spinor nature of wavefunctions for fermions. Neutron interferometers have also been used to investigate the structure of matter.

neutron number Symbol N. The number of neutrons in an atomic nucleus of a particular nuclide. It is equal to the difference between the *nucleon number and the *atomic number.

neutron star A compact stellar object that is supported against collapse under self-gravity by the *degeneracy pressure of the neutrons of which it is primarily composed. Neutron stars are believed to be formed as the end products of the evolution of stars of mass greater than a few (4–10) solar masses. The core of the evolved star collapses and (assuming that its mass is greater than the *Chandrasekhar limit for a *white dwarf), at the very high densities involved (about 10^{14} kg m^{-3}), electrons react with protons in atomic nuclei to produce neutrons. The neutron-rich nuclei thus formed release free neutrons in a process known as **neutron drip**. The density increases to about 10^{17} kg m^{-3}, at which most of the electrons and protons have been converted to a *degenerate gas of neutrons and the atomic nuclei have lost their separate identities. If the mass of the core exceeds the Oppenheimer–Volkoff limit for a neutron star, then further collapse will occur, leading to the formation of a *black hole.

*Pulsars are believed to be rapidly rotating magnetized neutron stars and many X-ray sources are thought to be neutron stars in binary systems with another star, from which material is drawn into an accretion disc. This material, heated to a very high temperature, emits radiation in the X-ray region.

neutron temperature A concept used to express the energies of neutrons that are in thermal equilibrium with their surroundings, assuming that they behave like a monatomic gas. The neutron temperature T, on the Kelvin scale, is given by $T = 2E/3k$, where E is average neutron energy and k the *Boltzmann constant.

neutrophil A type of white blood cell (*leucocyte) that has a lobed nucleus and granular cytoplasm (*see* GRANULOCYTE). Neutrophils engulf bacteria (*see* PHAGOCYTOSIS) and release various substances, such as *lysozyme and oxidizing agents.

New General Catalogue (NGC) A list of nonstellar objects, originally published (with 7840 entries) in 1888 by J. L. E. Dreyer. Such objects are referred to by their New General Catalogue numbers; e.g. the Orion nebula is NGC1976.

SEE WEB LINKS

- The interactive NGC Catalogue online, hosted by the Students for the Exploration and Development of Space [SEDS]

Newlands' law *See* LAW OF OCTAVES.

newton Symbol N. The *SI unit of force, being the force required to give a mass of one kilogram an acceleration of 1 m s^{-2}. It is named after Sir Isaac Newton.

Newton, Sir Isaac (1642–1727) English mathematician and physicist, one of the world's greatest scientists. He went to Cambridge University in 1661 and stayed for nearly 40 years except for 1665–67, when he returned to his home at Woolsthorpe in Lincolnshire (because of the Plague), where some of his best work was done. In 1699 he was made Master of the Royal Mint. He was reluctant to publish his work and his great mathematical masterpiece, the *Principia*, did not appear until 1687. In it he introduced *calculus and formulated *Newton's laws of motion. In 1665 he derived *Newton's law of gravitation, and in optics he produced *Newton's formula for a lens and, in 1672, his theories about *light and the spectrum (*see also* NEWTON'S RINGS); these were summarized in his *Opticks* of 1704. Also in the late 1660s he constructed a reflecting *telescope. The SI unit of force is named after him.

Newtonian fluid A fluid in which the velocity gradient is directly proportional to the shear stress. If two flat plates of area A are separated by a layer of fluid of thickness d and move relative to each other at a velocity v, then the rate of shear is v/d and the shear stress is F/A, where F is the force applied to each (see illustration). For a Newtonian fluid $F/A = \mu v/d$, where μ is the constant of pro-

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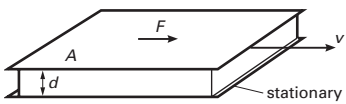
portionality and is called the Newtonian *viscosity. Many liquids are Newtonian fluids over a wide range of temperatures and pressures. However, some are not; these are called **non-Newtonian fluids**. In such fluids there is a departure from the simple Newtonian relationships. For example, in some liquids the viscosity increases as the velocity gradient increases, i.e. the faster the liquid moves the more viscous it becomes. Such liquids are said to be **dilatant** and the phenomenon they exhibit is called **dilatancy**. It occurs in some pastes and suspensions. More common, however, is the opposite effect in which the viscosity depends not only on the velocity gradient but also on the time for which it has been applied. These liquids are said to exhibit **thixotropy**. The faster a **thixotropic liquid** moves the less viscous it becomes. This property is used in nondrip paints (which are more viscous on the brush than on the wall) and in lubricating oils (which become thinner when the parts they are lubricating start to move). Another example is the non-Newtonian flow of macromolecules in solution or in polymer melts. In this case the shearing force F is not parallel to the shear planes and the linear relationship does not apply. In general, the many types of non-Newtonian fluid are somewhat complicated and no theory has been developed to accommodate them fully.



Newtonian fluid.

Newtonian mechanics The system of *mechanics that relies on *Newton's laws of motion. Newtonian mechanics is applicable to bodies moving at speeds relative to the observer that are small compared to the speed of light. Bodies moving at speeds comparable to the speed of light require an approach based on *relativistic mechanics, in which the mass of a body changes with its speed.

Newtonian telescope *See* TELESCOPE.

Newton's formula For a lens, the distances p and q between two conjugate points and their respective foci is given by $pq = f^2$, where f is the focal length of the lens.

Newton's law of cooling The rate at which a body loses heat is proportional to the difference in temperature between the body and the surroundings. It is an empirical law that is only true for substantial temperature differences if the heat loss is by forced convection or conduction.

Newton's law of gravitation There is a force of attraction between any two massive particles in the universe. For any two point masses m_1 and m_2, separated by a distance d, the force of attraction F is given by $F = m_1 m_2 G/d^2$, where G is the *gravitational constant. Real bodies having spherical symmetry act as point masses positioned at their centres of mass.

Newton's laws of motion The three laws of motion on which *Newtonian mechanics is based. (1) A body continues in a state of rest or uniform motion in a straight line unless it is acted upon by external forces. (2) The rate of change of momentum of a moving body is proportional to and in the same direction as the force acting on it, i.e. $F = \mathrm{d}(mv)/\mathrm{d}t$, where F is the applied force, v is the velocity of the body, and m its mass. If the mass remains constant, $F = m\mathrm{d}v/\mathrm{d}t$ or $F = ma$, where a is the acceleration. (3) If one body exerts a force on another, there is an equal and opposite force, called a **reaction**, exerted on the first body by the second.

Newton's rings **1.** (in optics) *Interference fringes formed by placing a slightly convex lens on a flat glass plate. If monochromatic light is reflected by the two close surfaces into the observer's eye at a suitable angle, the point of contact of the lens is seen as a dark spot surrounded by a series of bright and dark rings. The radius of the nth dark ring is given by $r_n = \sqrt{nR\lambda}$, where λ is the wavelength and R is the radius of curvature of the lens. The phenomenon is used in the quality testing of lens surfaces. With white light, coloured rings are formed. **2.** (in photography) The irregular patterns produced by thin film interference between a projected transparency and its cover glass.

niacin *See* NICOTINIC ACID.

niche *See* ECOLOGICAL NICHE.

Nichrome Trade name for a group of nickel–chromium alloys used for wire in heating elements as they possess good resistance to oxidation and have a high resistivity. Typical is Nichrome V containing 80% nickel and 19.5% chromium, the balance

consisting of manganese, silicon, and carbon.

nickel Symbol Ni. A malleable ductile silvery metallic *transition element; a.n. 28; r.a.m. 58.70; r.d. 8.9; m.p. 1450°C; b.p. 2732°C. It is found in the minerals pentlandite (NiS), pyrrhoite ((Fe,Ni)S), and garnierite ($(Ni,Mg)_6(OH)_6Si_4O_{11}.H_2O$). Nickel is also present in certain iron meteorites (up to 20%). The metal is extracted by roasting the ore to give the oxide, followed by reduction with carbon monoxide and purification by the *Mond process. Alternatively electolysis is used. Nickel metal is used in special steels, in Invar, and, being ferromagnetic, in magnetic alloys, such as *Mumetal. It is also an effective catalyst, particularly for hydrogenation reactions (*see also* RANEY NICKEL). The main compounds are formed with nickel in the +2 oxidation state; the +3 state also exists (e.g. the black oxide, Ni_2O_3). Nickel was discovered by Axel Cronstedt (1722–65) in 1751.

SEE WEB LINKS

- Information from the WebElements site

nickel arsenide structure A type of ionic crystal structure in which the anions have a distorted hexagonal close packed arrangement with the cations occupying the octahedral holes. Each type of ion has a coordination number of 6. Examples of compounds with this structure are NiAs, NiS, FeS, and CoS.

SEE WEB LINKS

- An interactive version of the structure

nickel–cadmium cell *See* NICKEL–IRON ACCUMULATOR.

nickel carbonyl A colourless volatile liquid, $Ni(CO)_4$; m.p. –25°C; b.p. 43°C. It is formed by direct combination of nickel metal with carbon monoxide at 50–60°C. The reaction is reversed at higher temperatures, and the reactions are the basis of the *Mond process for purifying nickel. The nickel in the compound has an oxidation state of zero, and the compound is a typical example of a complex with pi-bonding *ligands, in which filled *d*-orbitals on the nickel overlap with empty *p*-orbitals on the carbon.

nickelic compounds Compounds of nickel in its +3 oxidation state; e.g. nickelic oxide is nickel(III) oxide (Ni_2O_3).

nickel–iron accumulator (Edison cell; NIFE cell) A *secondary cell devised by Thomas Edison (1847–1931) having a positive plate of nickel oxide and a negative plate of iron both immersed in an electrolyte of potassium hydroxide. The reaction on discharge is

$$2NiOOH.H_2O + Fe \rightarrow 2Ni(OH)_2 + Fe(OH)_2,$$

the reverse occurring during charging. Each cell gives an e.m.f. of about 1.2 volts and produces about 100 kJ per kilogram during each discharge. The **nickel–cadmium cell** is a similar device with a negative cadmium electrode. It is often used as a *dry cell. *Compare* LEAD–ACID ACCUMULATOR.

nickelous compounds Compounds of nickel in its +2 oxidation state; e.g. nickelous oxide is nickel(II) oxide (NiO).

nickel(II) oxide A green powder, NiO; r.d. 6.6. It can be made by heating nickel(II) nitrate or carbonate with air excluded.

nickel(III) oxide (nickel peroxide; nickel sesquioxide) A black or grey powder, Ni_2O_3; r.d. 4.8. It is made by heating nickel(II) oxide in air and used in *nickel–iron accumulators.

nickel silver *See* GERMAN SILVER.

Nicol prism A device for producing plane-polarized light (*see* POLARIZER). It consists of two pieces of calcite cut with a 68° angle and stuck together with Canada balsam. The extraordinary ray (*see* DOUBLE REFRACTION) passes through the prism while the ordinary ray suffers total internal reflection at the interface between the two crystals, as the refractive index of the calcite is 1.66 for the ordinary ray and that of the Canada balsam is 1.53. Modifications of the prism using different shapes and cements are used for special purposes. It was devised in 1828 by William Nicol (1768–1851).

nicotinamide *See* NICOTINIC ACID.

nicotinamide adenine dinucleotide *See* NAD.

nicotinamide adenine dinucleotide phosphate (NADP) *See* NAD.

nicotine A colourless poisonous *alkaloid present in tobacco. It is used as an insecticide.

nicotinic acid (niacin) A vitamin of the *vitamin B complex. It can be manufactured by plants and animals from the amino acid tryptophan. The amide derivative, **nicotinamide**, is a component of the coenzymes *NAD and NADP. These take part in many metabolic reactions as hydrogen acceptors.

Deficiency of nicotinic acid causes the disease *pellagra in humans. Apart from tryptophan-rich protein, good sources are liver and groundnut and sunflower meals.

nictitating membrane A clear membrane forming a third eyelid in amphibians, reptiles, birds, and some mammals (but not humans). It can be drawn across the cornea independently of the other eyelids, thus clearing the eye surface and giving added protection without interrupting the continuity of vision.

nidation *See* IMPLANTATION.

nido-structure *See* BORANE.

nielsbohrium *See* TRANSACTINIDE ELEMENTS.

NIFE cell *See* NICKEL–IRON ACCUMULATOR.

ninhydrin A brown crystalline solid, $C_9H_4O_3.H_2O$, which decomposes at 242°C. It is used as a test for amino acids, peptides, and proteins, with which it gives a deep blue colour. For this reason it has been used as a spray reagent for 'developing' paper chromatograms. It is also used in forensic science to develop latent fingerprints.

niobium Symbol Nb. A soft ductile grey-blue metallic transition element; a.n. 41; r.a.m. 92.91; r.d. 8.57; m.p. 2468°C; b.p. 4742°C. It occurs in several minerals, including niobite ($Fe(NbO_3)_2$), and is extracted by several methods including reduction of the complex fluoride K_2NbF_7 using sodium. It is used in special steels and in welded joints (to increase strength). Niobium–zirconium alloys are used in superconductors. Chemically, the element combines with the halogens and oxidizes in air at 200°C. It forms a number of compounds and complexes with the metal in oxidation states 2, 3, or 5. The element was discovered by Charles Hatchett (*c.* 1765–1847) in 1801 and first isolated by Christian Blomstrand (1826–97) in 1864. Formerly, it was called **columbium**.

SEE WEB LINKS

- Information from the WebElements site

nipple *See* MAMMARY GLANDS.

Nissl granules (Nissl bodies) Particles seen within the cell bodies of *neurons. They are rich in RNA and stain strongly with basic dyes. They are named after F. Nissl (1860–1919), the German neurologist who discovered them.

nit A unit of *luminance equal to one *candela per square metre.

nitrate A salt or ester of nitric acid.

nitrating mixture A mixture of concentrated sulphuric and nitric acids, used to introduce a nitro group ($–NO_2$) into an organic compound. Its action depends on the presence of the nitronium ion, NO_2^+. It is mainly used to introduce groups into the molecules of *aromatic compounds (the nitro group can subsequently be converted into or replaced by others) and to make commercial *nitro compounds, such as the explosives cellulose trinitrate (nitrocellulose), glyceryl trinitrate (nitroglycerine), trinitrotoluene (TNT), and picric acid (trinitrophenol).

nitration A type of chemical reaction in which a nitro group ($–NO_2$) is added to or substituted in a molecule. Nitration can be carried out by a mixture of concentrated nitric and sulphuric acids. An example is electrophilic substitution of benzene (and benzene compounds), where the electrophile is the nitryl ion NO_2^+.

nitre (saltpetre) Commercial *potassium nitrate; the name was formerly applied to natural crustlike efflorescences, occurring in some arid regions.

nitre cake *See* SODIUM HYDROGENSULPHATE.

nitric acid A colourless corrosive poisonous liquid, HNO_3; r.d. 1.50; m.p. –42°C; b.p. 83°C. Nitric acid may be prepared in the laboratory by the distillation of a mixture of an alkali-metal nitrate and concentrated sulphuric acid. The industrial production is by the oxidation of ammonia to nitrogen monoxide, the oxidation of this to nitrogen dioxide, and the reaction of nitrogen dioxide with water to form nitric acid and nitrogen monoxide (which is recycled). The first reaction (NH_3 to NO) is catalysed by platinum or platinum/rhodium in the form of fine wire gauze. The oxidation of NO and the absorption of NO_2 to form the product are noncatalytic and proceed with high yields but both reactions are second-order and slow. Increases in pressure reduce the selectivity of the reaction and therefore rather large gas absorption towers are required. In practice the absorbing acid is refrigerated to around 2°C and a commercial 'concentrated nitric acid' at about 67% is produced.

Nitric acid is a strong acid (highly dissociated in aqueous solution) and dilute solu-

tions behave much like other mineral acids. Concentrated nitric acid is a strong oxidizing agent. Most metals dissolve to form nitrates but with the evolution of nitrogen oxides. Concentrated nitric acid also reacts with several nonmetals to give the oxo acid or oxide. Nitric acid is generally stored in dark brown bottles because of the photolytic decomposition to dinitrogen tetroxide. *See also* NITRATION.

nitric oxide *See* NITROGEN MONOXIDE.

nitrides Compounds of nitrogen with a more electropositive element. Boron nitride is a covalent compound having macromolecular crystals. Certain electropositive elements, such as lithium, magnesium, and calcium, react directly with nitrogen to form ionic nitrides containing the N^{3-} ion. Transition elements form a range of interstitial nitrides (e.g. Mn_4N, W_2N), which can be produced by heating the metal in ammonia.

nitriding The process of hardening the surface of steel by producing a layer of iron nitride. One technique is to heat the metal in ammonia gas. Another is to dip the hot metal in a bath of molten sodium cyanide.

nitrification A chemical process in which nitrogen (mostly in the form of ammonia) in plant and animal wastes and dead remains is oxidized at first to nitrites and then to nitrates. These reactions are effected mainly by the nitrifying bacteria *Nitrosomonas* and *Nitrobacter* respectively. Unlike ammonia, nitrates are readily taken up by plant roots; nitrification is therefore a crucial part of the *nitrogen cycle. Nitrogen-containing compounds are often applied to soils deficient in this element, as fertilizer. *Compare* DENITRIFICATION.

nitrile rubber A copolymer of buta-1,3-diene and propenonitrile. Nitrile rubbers are commercially important synthetic rubbers because of their resistance to oil and many solvents.

nitriles (cyanides) Organic compounds containing the group –CN bound to an organic group. Nitriles are made by reaction between potassium cyanide and haloalkanes in alcoholic solution, e.g.

$$KCN + CH_3Cl \rightarrow CH_3CN + KCl$$

An alternative method is dehydration of amides

$$CH_3CONH_2 - H_2O \rightarrow CH_3CN$$

They can be hydrolysed to amides and carboxylic acids and can be reduced to amines.

SEE WEB LINKS

- Information about IUPAC nomenclature

nitrite A salt or ester of nitrous acid. The salts contain the dioxonitrate (III) ion, NO_2^-, which has a bond angle of 115°.

nitrobenzene A yellow oily liquid, $C_6H_5NO_2$; r.d. 1.2; m.p. 6°C; b.p. 211°C. It is made by the *nitration of benzene using a mixture of nitric and sulphuric acids.

nitrocellulose *See* CELLULOSE NITRATE.

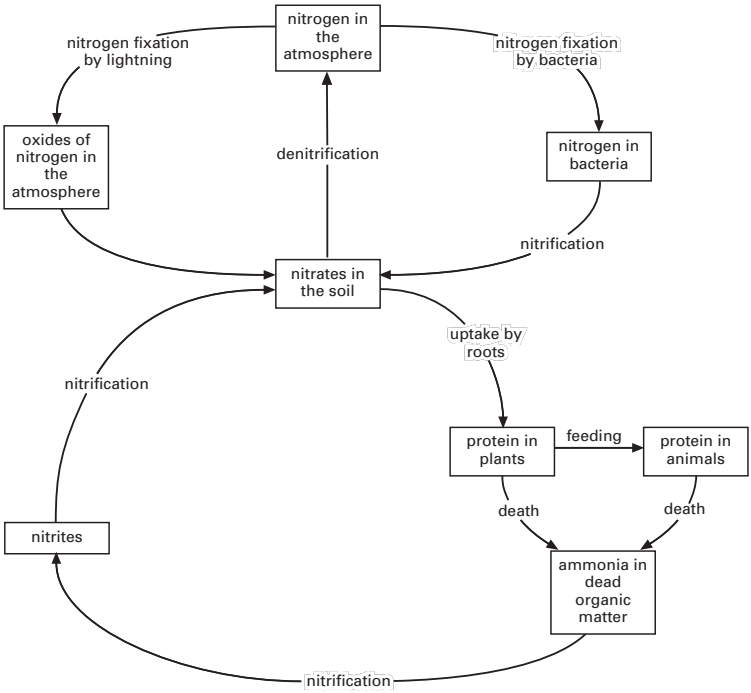
nitro compounds Organic compounds containing the group $–NO_2$ (the **nitro group**) bound to a carbon atom. Nitro compounds are made by *nitration reactions. They can be reduced to aromatic amines (e.g. nitrobenzene can be reduced to phenylamine). *See also* EXPLOSIVE.

nitrogen Symbol N. A colourless gaseous element belonging to *group 15 (formerly VB) of the periodic table; a.n. 7; r.a.m. 14.0067; d. 1.2506 g dm^{-3}; m.p. –209.86°C; b.p. –195.8°C. It occurs in air (about 78% by volume) and is an essential constituent of proteins and nucleic acids in living organisms (*see* NITROGEN CYCLE). Nitrogen is obtained for industrial purposes by fractional distillation of liquid air. Pure nitrogen can be obtained in the laboratory by heating a metal azide. There are two natural isotopes: nitrogen–14 and nitrogen–15 (about 3%). The element is used in the *Haber process for making ammonia and is also used to provide an inert atmosphere in welding and metallurgy. The gas is diatomic and relatively inert – it reacts with hydrogen at high temperatures and with oxygen in electric discharges. It also forms *nitrides with certain metals. Nitrogen was discovered in 1772 by Daniel Rutherford (1749–1819).

SEE WEB LINKS

- Information from the WebElements site

nitrogenase An important enzyme complex that is present in those microorganisms that are capable of fixing atmospheric nitrogen (*see* NITROGEN FIXATION). Nitrogenase catalyses the conversion of atmospheric nitrogen into ammonia, which can then be used to synthesize nitrites, nitrates, or amino acids. The two main enzymes within the nitrogenase complex are **dinitrogenase reductase** and **dinitrogenase**.



The nitrogen cycle.

nitrogen cycle One of the major cycles of chemical elements in the environment (*see* BIOGEOCHEMICAL CYCLE). Nitrates in the soil are taken up by plant roots and may then pass along *food chains into animals. Decomposing bacteria convert nitrogen-containing compounds (especially ammonia) in plant and animal wastes and dead remains back into nitrates, which are released into the soil and can again be taken up by plants (*see* NITRIFICATION). Though nitrogen is essential to all forms of life, the huge amount present in the atmosphere is not directly available to most organisms (*compare* CARBON CYCLE). It can, however, be assimilated by some specialized bacteria (*see* NITROGEN FIXATION) and is thus made available to other organisms indirectly. Lightning flashes also make some nitrogen available to plants by causing the combination of atmospheric nitrogen and oxygen to form oxides of nitrogen, which enter the soil and form nitrates. Some nitrogen is returned from the soil to the atmosphere by denitrifying bacteria (*see* DENITRIFICATION). See illustration.

nitrogen dioxide *See* DINITROGEN TETROXIDE.

nitrogen fixation A chemical process in which atmospheric nitrogen is assimilated into organic compounds in living organisms and hence into the *nitrogen cycle. The ability to fix nitrogen is limited to certain bacteria (e.g. *Azotobacter, Anabaena*). Some bacteria (e.g. *Rhizobium*) are able to fix nitrogen in association with cells in the roots of leguminous plants, such as peas and beans, in which they form characteristic *root nodules; cultivation of legumes is therefore one way of increasing soil nitrogen. Various chemical processes are used to fix atmospheric nitrogen in the manufacture of *fertilizers. These include the *Birkeland–Eyde process, the cyanamide process (*see* CALCIUM DICARBIDE), and the *Haber process.

nitrogen monoxide (nitric oxide) A colourless gas, NO; m.p. –163.6°C; b.p. –151.8°C. It is soluble in water, ethanol, and ether. In the liquid state nitrogen monoxide is blue in colour (r.d. 1.26). It is formed in many reactions involving the reduction of nitric acid, but more convenient reactions for the preparation of reasonably pure NO are reactions of sodium nitrite, sulphuric acid, and either sodium iodide or iron(II) sulphate. Nitrogen monoxide reacts readily with oxygen to give nitrogen dioxide and with the halogens to give the nitrosyl halides XNO (X = F,Cl,Br). It is oxidized to nitric acid by strong oxidizing agents and reduced to dinitrogen oxide by reducing agents. The molecule has one unpaired electron, which accounts for its paramagnetism and for the blue colour in the liquid state. This electron is relatively easily removed to give the **nitrosyl ion** NO^+, which is the ion present in such compounds as $NOClO_4$, $NOBF_4$, $NOFeCl_4$, $(NO)_2PtCl_6$ and a ligand in complexes, such as $Co(CO)_3NO$.

In mammals and other vertebrates, nitrogen monoxide plays several important roles. For example, it acts as a gaseous mediator in producing such responses as dilation of blood vessels, relaxation of smooth muscle, and inhibition of platelet aggregation, and it acts as a neurotransmitter in the central nervous systems. In certain cells of the immune system it is converted to the peroxynitrite ion ($^-$O–O–N=O), which has activity against pathogens.

nitrogen mustards A group of nitrogen compounds similar to *sulphur mustard. They were used as chemotherapy agents in cancer treatment. Like sulphur mustard, they are powerful blistering agents. Large quantities were made during World War II, although none were used in combat.

nitrogenous base A basic compound containing nitrogen. The term is used especially of organic ring compounds, such as adenine, guanine, cytosine, and thymine, which are constituents of nucleic acids. *See* AMINE SALTS.

nitrogen oxides Oxides of nitrogen (NO_x), such as nitrogen monoxide (NO) and dinitrogen oxide (N_2O), many of which are pollutants contributing to *acid rain. Nitrogen oxides are expelled in the emissions from car exhausts, aircraft, and factories. *See also* AIR POLLUTION.

nitroglycerine An explosive made by reacting 1,2,3-trihydroxypropane (glycerol) with a mixture of concentrated sulphuric and nitric acids. Despite its name and method of preparation, it is not a nitro compound, but an ester of nitric acid, $CH_2(NO_3)CH(NO_3)CH_2(NO_3)$. It is used in dynamites.

nitro group *See* NITRO COMPOUNDS.

nitronium ion *See* NITRYL ION.

nitrosonium ion The positive ion NO^+, present in certain salts such as the chlorate (NO^+ClO_4) and the borofluoride (NO^+BF_4).

nitrosyl ion The ion NO^+. *See* NITROGEN MONOXIDE.

nitrous acid A weak acid, HNO_2, known only in solution and in the gas phase. It is prepared by the action of acids upon nitrites, preferably using a combination that removes the salt as an insoluble precipitate (e.g. $Ba(NO_2)_2$ and H_2SO_4). The solutions are unstable and decompose on heating to give nitric acid and nitrogen monoxide. Nitrous acid can function both as an oxidizing agent (forms NO) with I^- and Fe^{2+}, or as a reducing agent (forms NO_3^-) with, for example, Cu^{2+}; the latter is most common. It is widely used (prepared *in situ*) for the preparation of diazonium compounds in organic chemistry. The full systematic name is **dioxonitric(III) acid**.

nitrous oxide *See* DINITROGEN OXIDE.

nitryl ion (nitronium ion) The ion NO_2^+, found in mixtures of nitric acid and sulphuric acid and solutions of nitrogen oxides in nitric acid. Nitryl salts, such as $NO_2^+ClO_4^-$, can be isolated but are extremely reactive. Nitryl ions generated *in situ* are used for *nitration in organic chemistry.

NMR *See* NUCLEAR MAGNETIC RESONANCE.

nobelium Symbol No. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 102; mass number of most stable element 254 (half-life 55 seconds). Seven isotopes are known. The element was first identified with certainty by Albert Ghiorso and Glenn Seaborg (1912–99) in 1966.

SEE WEB LINKS

- Information from the WebElements site

noble gases (inert gases; rare gases; group 18 elements) A group of monatomic gaseous elements forming group 18 (for-

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merly group 0) of the *periodic table: helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn). The electron configuration of helium is $1s^2$. The configurations of the others terminate in ns^2np^6 and all inner shells are fully occupied. The elements thus represent the termination of a period and have closed-shell configuration and associated high ionization energies (He 2370 to Rn 1040 kJ mol^{-1}) and lack of chemical reactivity. Being monatomic the noble gases are spherically symmetrical and have very weak interatomic interactions and consequent low enthalpies of vaporization. The behaviour of the lighter members approaches that of an ideal gas at normal temperatures; with the heavier members increasing polarizability and dispersion forces lead to easier liquefaction under pressure. Four types of 'compound' have been described for the noble gases but of these only one can be correctly described as compounds in the normal sense. One type consists of such species as HHe^+, He_2^+, Ar_2^+, $HeLi^+$, which form under highly energetic conditions, such as those in arcs and sparks. They are short-lived and only detected spectroscopically. A second group of materials described as inert-gas–metal compounds do not have defined compositions and are simply noble gases adsorbed onto the surface of dispersed metal. The third type, previously described as 'hydrates' are in fact clathrate compounds with the noble gas molecule trapped in a water lattice. True compounds of the noble gases were first described in 1962 and several fluorides, oxyfluorides, fluoroplatinates, and fluoroantimonates of *xenon are known. A few krypton fluorides and a radon fluoride are also known although the short half-life of radon and its intense alpha activity restrict the availability of information. Apart from argon, the noble gases are present in the atmosphere at only trace levels. Helium may be found along with natural gas (up to 7%), arising from the radioactive decay of heavier elements (via alpha particles).

noble metal A metal characterized by it lack of chemical reactivity, particularly to acids and atmospheric corrosion. Examples include gold, palladium, platinum, and rhodium.

no-cloning theorem A result stating that it is not possible to copy quantum information perfectly. This is the case because the Heisenberg uncertainty principle means that it is not possible to obtain complete information about a quantum state and because examining a quantum state alters that state. This theorem was proved by William Wootters and Wojciech Zurek in 1982.

nodal points Two points on the axis of a system of lenses; if the incident ray passes through one, the emergent ray will pass through the other.

node **1.** (in botany) The part of a plant stem from which one or more leaves arise. The nodes at the stem apex are very close together and remain so in species of monocotyledons that form bulbs. In older regions of the stem they are separated by areas of stem called **internodes**. **2.** (in anatomy) A natural thickening or bulge in an organ or part of the body. Examples are the **sinoatrial node** that controls the heartbeat (*see* PACEMAKER) and the *lymph nodes. **3.** (in physics) A point of minimum disturbance in a *stationary-wave system. **4.** (in astronomy) Either of two points at which the orbit of a celestial body intersects a reference plane, usually the plane of the *ecliptic or the celestial equator (*see* CELESTIAL SPHERE).

node of Ranvier *See* MYELIN SHEATH.

nodule (in botany) *See* ROOT NODULE.

no-hair theorem *See* BLACK HOLE.

noise **1.** Any undesired sound. It is measured on a *decibel scale ranging from the threshold of hearing (0 dB) to the threshold of pain (130 dB). Between these limits a whisper registers about 20 dB, heavy urban traffic about 90 dB, and a heavy hammer on steel plate about 110 dB. A high noise level (industrial or from overamplified music, for example) can cause permanent hearing impairment. **2.** Any unwanted disturbance within a useful frequency band in a communication channel.

nomad (in cytology) A cell that migrates or wanders from its site of formation. Certain types of *phagocytes are nomads.

Nomarski microscope A type of light microscope that is useful for viewing live transparent unstained specimens, such as cells or microscopic organisms. The shadow-cast images give the illusion of depth to the outlines and surface features of organelles or other structures. An incident beam of plane-polarized light is split into parallel beams by a prism (**Nomarski prism**) so that different parts of the beam pass through closely adja-

cent areas of the specimen. Slight differences in thickness and refractive index within the specimen cause interference between the beams as they exit the specimen and are recombined by a second prism: parts of the beam that are in phase will reinforce each other and produce a bright image, whereas parts that are out of phase will cancel each other out and produce a dark image. It is named after the Polish-born physicist Georges Nomarski (1919–97).

SEE WEB LINKS

- Overview of Nomarski microscopy with interactive tutorials, from Olympus Microscopy Resource Center

nomogram A graph consisting of three lines, each with its own scale, each line representing the values of a variable over a specified range. A ruler laid between two points on two of the lines enables the value of the third variable to be read off the third line.

nonahydrate A crystalline compound that has nine moles of water per mole of compound.

nonanoic acid (perargonic acid) A clear oily liquid carboxylic acid, $CH_3(CH_2)_7COOH$; r.d. 0.9; m.p. 12.5°C; b.p. 254°C. It is found as esters in oil of pelargonium and certain esters are used as flavourings.

nonbenzenoid aromatics Aromatic compounds that have rings other than benzene rings. Examples are the cyclopentadienyl anion, $C_5H_5^-$, and the tropylium cation, $C_7H_7^+$. *See also* ANNULENES.

noncompetitive inhibition *See* INHIBITION.

noncyclic phosphorylation (noncyclic photophosphorylation) *See* PHOTOPHOSPHORYLATION.

non-equilibrium statistical mechanics The statistical mechanics of systems not in thermal equilibrium. One of the main purposes of non-equilibrium statistical mechanics is to calculate *transport coefficients and inverse transport coefficients, such as *conductivity and *viscosity, from first principles and to provide a basis for *transport theory. The non-equilibrium systems easiest to understand are those near thermal equilibrium. For systems far from equilibrium, such possibilities as *chaos, *turbulence, and *self-organization can arise due to nonlinearity.

non-equilibrium thermodynamics The thermodynamics of systems not in thermal *equilibrium. The non-equilibrium systems easiest to understand are those near thermal equilibrium. For systems far from equilibrium, more complicated patterns, such as *chaos and *self-organization, can arise due to nonlinearity. Which behaviour is observed depends on the value of certain parameters in the system.

non-Euclidean geometry A type of geometry that does not comply with the basic postulates of *Euclidean geometry, particularly a form of geometry that does not accept Euclid's postulate that only one straight line can be drawn through a point in space parallel to a given straight line. Several types of non-Euclidean geometry exist.

non-Fermi liquid A many-fermion system that, unlike the electrons in ordinary metals, cannot readily be decribed in terms of *quasiparticles. Examples of non-Fermi liquids include *Luttinger liquids and high-temperature *superconductivity. The theoretical analysis of non-Fermi liquids is more difficult than for ordinary many-fermion systems.

nonferrous metal Any metal other than iron or any alloy that does not contain iron. In commercial terms this usually means aluminium, copper, lead, nickel, tin, zinc, or their alloys.

nonlinear optics A branch of optics concerned with the optical properties of matter subjected to intense electromagnetic fields. For nonlinearity to manifest itself, the external field should not be negligible compared to the internal fields of the atoms and molecules of which the matter consists. *Lasers are capable of generating external fields sufficiently intense for nonlinearity to occur. Indeed, the subject of nonlinear optics has been largely developed as a result of the invention of the laser. In nonlinear optics the induced electric polarization (*see* DIELECTRIC) of the medium is not a linear function of the strength of the external *electromagnetic radiation. This leads to more complicated phenomena than can occur in **linear optics**, in which the induced polarization is proportional to the strength of the external electromagnetic radiation.

nonmetal An element that is not a *metal. Nonmetals can either be *insulators or *semiconductors. At low temperatures non-

metals are poor conductors of both electricity and heat as few free electrons move through the material. If the conduction band is near to the valence band (*see* ENERGY BANDS) it is possible for nonmetals to conduct electricity at high temperatures but, in contrast to metals, the conductivity increases with increasing temperature. Nonmetals are electronegative elements, such as carbon, nitrogen, oxygen, phosphorus, sulphur, and the halogens. They form compounds that contain negative ions or covalent bonds. Their oxides are either neutral or acidic.

non-Newtonian fluid *See* NEWTONIAN FLUID.

nonpolar compound A compound that has covalent molecules with no permanent dipole moment. Examples of nonpolar compounds are methane and benzene.

nonpolar solvent *See* SOLVENT.

nonreducing sugar A sugar that cannot donate electrons to other molecules and therefore cannot act as a reducing agent. Sucrose is the most common nonreducing sugar. The linkage between the glucose and fructose units in sucrose, which involves aldehyde and ketone groups, is responsible for the inability of sucrose to act as a *reducing sugar.

nonrelativistic quantum theory *See* QUANTUM THEORY.

nonrenewable energy sources *See* RENEWABLE ENERGY SOURCES.

nonsense mutation A mutation in one of the nucleotides in a DNA sequence that generates a *stop codon, resulting in the premature termination of synthesis of a protein.

nonstoichiometric compound (Berthollide compound) A chemical compound in which the elements do not combine in simple ratios. For example, rutile (titanium(IV) oxide) is often deficient in oxygen, typically having a formula $TiO_{1.8}$.

noradrenaline (norepinephrine) A hormone produced by the *adrenal glands and also secreted from nerve endings in the *sympathetic nervous system as a chemical transmitter of nerve impulses (*see* NEUROTRANSMITTER). Many of its general actions are similar to those of *adrenaline, but it is more concerned with maintaining normal body activity than with preparing the body for emergencies.

Nordhausen sulphuric acid *See* DISULPHURIC(VI) ACID.

norepinephrine *See* NORADRENALINE.

normal **1.** (in mathematics) A line drawn at right angles to a surface. **2.** (in chemistry) Having a concentration of one gram equivalent per dm^3.

normal distribution (Gaussian distribution) The type of statistical distribution followed by, for example, the same measurement taken several times, where the variation of a quantity (x) about its mean value (μ) is entirely random. A normal distribution has the probability density function

$$f(x) = \exp[-(x-\mu)^2/2\sigma^2]/\sigma\sqrt{2\pi}$$

where σ is known as the **standard deviation**. The distribution is written $N(\mu,\sigma^2)$. The graph of $f(x)$ is bell-shaped and symmetrical about $x = \mu$. The standard normal distribution has $\mu = 0$ and $\sigma^2 = 1$. x can be standardized by letting $z = (x-\mu)/\sigma$. The values z_α, for which the area under the curve from $-\infty$ to z_α is α, are tabulated; i.e. z is such that

$$P(z \leq z_\alpha) = \alpha$$

Hence

$$P(a<x\leq b) = P(a-\mu)/\sigma < z \leq (b-\mu)/\sigma$$

can be found. *See also* POISSON DISTRIBUTION; T-DISTRIBUTION.

normalizing The process of heating steel to above an appropriate critical temperature followed by cooling in still air. The process promotes the formation of a uniform internal structure and the elimination of internal stress.

Northern blotting *See* SOUTHERN BLOTTING.

nose The protuberance on the face of some vertebrates that contains the nostrils (*see* NARES) and part of the *nasal cavity. It therefore forms part of the olfactory system (*see* OLFACTION) and the external opening of the respiratory system.

nostrils *See* NARES.

NOT circuit *See* LOGIC CIRCUITS.

note **1.** A musical sound of specified pitch. **2.** A representation of such a sound in a musical score. Such a representation has a specified duration as well as a specified pitch.

notochord An elastic skeletal rod lying lengthwise beneath the nerve cord and above the alimentary canal in the embryos or adults of all chordate animals (*see* CHORDATA). Its function is to strengthen and support the body and act as a protagonist for the muscles. It is found in both adult and larval lancelets but in adult vertebrates it is largely replaced by the *vertebral column.

nova A star that, over a period of only a few days, becomes 10^3–10^4 times brighter than it was. Some 10–15 such events occur in the Milky Way each year. Novae are believed to be close *binaries, one component of which is usually a *white dwarf and the other a *red giant. Matter is transferred from the red giant to the white dwarf, on whose surface it accumulates, eventually leading to a thermonuclear explosion. *See also* SUPERNOVA.

NSOM Near-field scanning optical microscopy. A form of scanning probe microscopy in which a probe with a very small aperture is used, giving high resolving power.

SEE WEB LINKS

- An account of the technique

N.T.P. *See* S.T.P.

***n*-type conductivity** *See* SEMICONDUCTOR; TRANSISTOR.

nucellus The tissue that makes up the greater part of the ovule of seed plants. It contains the *embryo sac and nutritive tissue. It is enclosed by the integuments except for a small gap, the *micropyle. In certain flowering plants it may persist after fertilization and provide nutrients for the embryo.

nuclear battery A single cell, or battery of cells, in which the energy of particles emitted from the atomic nucleus is converted internally into electrical energy. In the high-voltage type, a beta-emitter, such as strontium–90, krypton–85, or tritium, is sealed into a shielded glass vessel, the electrons being collected on an electrode that is separated from the emitter by a vacuum or by a solid dielectric. A typical cell delivers some 160 picoamperes at a voltage proportional to the load resistance. It can be used to maintain the voltage of a charged capacitor. Of greater use, especially in space technology, are the various types of low-voltage nuclear batteries. Typical is the gas-ionization device in which a beta-emitter ionizes a gas in an electric field. Each beta-particle produces about 200 ions, thus multiplying the current. The electric field is obtained by the contact potential difference between two electrodes, such as lead dioxide and magnesium. Such a cell, containing argon and tritium, gives about 1.6 nanoamperes at 1.5 volts. Other types use light from a phosphor receiving the beta-particles to operate photocells or heat from the nuclear reaction to operate a thermopile.

nuclear–cytoplasmic ratio A measure of the size of a cell nucleus in relation to the cytoplasm. The nuclear–cytoplasmic ratio is often used as an index in the comparison of cells from normal and abnormal tissues. For example, cultured cancer cells show an increase in the nuclear–cytoplasmic ratio.

nuclear energy Energy obtained as a result of *nuclear fission or *nuclear fusion. The nuclear fission of one uranium atom yields about 3.2×10^{-11} joule, whereas the combustion of one carbon atom yields about 6.4×10^{-19} joule. Mass for mass, uranium yields about 2 500 000 times more energy by fission than carbon does by combustion. The nuclear fusion of deuterium to form helium releases about 400 times as much energy as the fission of uranium (on a mass basis).

nuclear fission A nuclear reaction in which a heavy nucleus (such as uranium) splits into two parts (**fission products**), which subsequently emit either two or three neutrons, releasing a quantity of energy equivalent to the difference between the rest mass of the neutrons and the fission products and that of the original nucleus. Fission may occur without external influence (**spontaneous fission**) or as a result of irradiation by neutrons (**induced fission**). For example, the fission of a uranium–235 nucleus by a *slow neutron may proceed thus:

$$^{235}\mathrm{U} + \mathrm{n} \rightarrow {}^{148}\mathrm{La} + {}^{85}\mathrm{Br} + 3\mathrm{n}$$

The energy released is approximately 3×10^{-11} J per ^{235}U nucleus. For 1 kg of ^{235}U this is equivalent to 20 000 megawatt-hours – the amount of energy produced by the combustion of 3×10^6 tonnes of coal. Nuclear fission is the process used in *nuclear reactors and atom bombs (*see* NUCLEAR WEAPONS).

SEE WEB LINKS

- Meitner and Frish's original paper (1939) in *Nature* on induced fission

nuclear force A strong attractive force (resulting from the strong interaction) between *nucleons in the atomic nucleus that holds the nucleus together. At close range (up to

about 2×10^{-15} metre) these forces are some 100 times stronger than electromagnetic forces. *See* FUNDAMENTAL INTERACTIONS.

nuclear fuel A substance that will sustain a fission chain reaction so that it can be used as a source of *nuclear energy. The fissile isotopes are uranium–235, uranium–233, plutonium–241, and plutonium–239 (*see* FISSILE MATERIAL). The first occurs in nature as 1 part in 140 of natural uranium, the others have to be made artificially. ^{233}U is produced when thorium–232 captures a neutron and ^{239}Pu is produced by neutron capture in ^{238}U. ^{232}Th and ^{238}U are called fertile isotopes (*see* FERTILE MATERIAL).

nuclear fusion A type of *nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of large amounts of energy. In *nuclear fission reactions a neutron is used to break up a large nucleus, but in nuclear fusion the two reacting nuclei themselves have to be brought into collision. As both nuclei are positively charged there is a strong repulsive force between them, which can only be overcome if the reacting nuclei have very high kinetic energies. These high kinetic energies imply temperatures of the order of 10^8 K. As the kinetic energy required increases with the nuclear charge (i.e. atomic number), reactions involving low atomic-number nuclei are the easiest to produce. At these elevated temperatures, however, fusion reactions are self-sustaining; the reactants at these temperatures are in the form of a *plasma (i.e. nuclei and free electrons) with the nuclei possessing sufficient energy to overcome electrostatic repulsion forces. The fusion bomb (*see* NUCLEAR WEAPONS) and the stars generate energy in this way. It is hoped that the method will be harnessed in the *thermonuclear reactor as a source of energy for man's use.

Typical fusion reactions with the energy release in joules are:

$$D + D = T + p + 6.4 \times 10^{-13}\ J$$

$$T + D = {}^4He + n + 28.2 \times 10^{-13}\ J$$

$$^6Li + D = 2\,{}^4He + 35.8 \times 10^{-13}\ J$$

By comparison the formation of a water molecule from atoms of hydrogen and oxygen is accompanied by the release of 1.5×10^{-19} J.

A large amount of work has been done on **cold fusion**; i.e. fusion that can occur at lower temperatures than those necessary to overcome the electrostatic repulsion between nuclei. The most productive approach is **meson-catalysed fusion**, in which the deuterium atoms have their electrons replaced by negative muons to give 'muonic atoms' of deuterium. The muon is 207 times heavier than the electron, so the muonic deuterium atom is much smaller and is able to approach another deuterium atom more closely, allowing nuclear fusion to occur. The muon is released to form another muonic atom, and the process continues. The limiting factor is the short lifetime of the muon, which restricts the number of fusion reactions it can catalyse. The term 'cold fusion' is also applied to the technique of producing new *transactinide elements by bombarding nuclei of one element with nuclei of another at an energy precisely chosen to allow the fusion reaction to occur.

SEE WEB LINKS

- Rutherford's 1934 paper in *Proceedings of the Royal Society*

nuclear isomerism A condition in which atomic nuclei with the same number of neutrons and protons have different lifetimes. This occurs when nuclei exist in different unstable quantum states, from which they decay to lower excited states or to the ground state, with the emission of gamma-ray photons. If the lifetime of a particular excited state is unusually long it is said to be isomeric, although there is no fixed limit separating isomeric decays from normal decays.

nuclear magnetic resonance (NMR) The absorption of electromagnetic radiation at a suitable precise frequency by a nucleus with a nonzero magnetic moment in an external magnetic field. The phenomenon occurs if the nucleus has nonzero *spin, in which case it behaves as a small magnet. In an external magnetic field, the nucleus's magnetic moment vector precesses about the field direction but only certain orientations are allowed by quantum rules. Thus, for hydrogen (spin of ½) there are two possible states in the presence of a field, each with a slightly different energy. Nuclear magnetic resonance is the absorption of radiation at a photon energy equal to the difference between these levels, causing a transition from a lower to a higher energy state. For practical purposes, the difference in energy levels is small and the radiation is in the radiofrequency region of the electromagnetic spectrum. It depends on the field strength.

MAGNETIC RESONANCE IMAGING

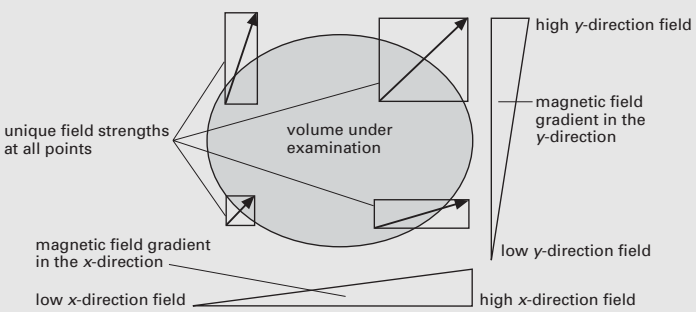
A diagnostic imaging technique based on the phenomenon of *nuclear magnetic resonance (NMR). NMR is a process in which *protons interact with a strong magnetic field and with radio waves to generate electrical pulses that can be processed in a similar way to computerized *tomography. The medical application of NMR, began in the 1950s, but the first images of live patients were not produced until the late 1970s. Images produced by MRI are similar to those produced by computerized tomography using X-rays, but without the radiation hazard.

A major factor in the high costs of MRI is the need for a *superconducting magnet to produce the very strong magnetic fields (0.1 – 2 tesla). A niobium–titanium alloy, which becomes superconducting at –269°C, is used to construct the field coils. These need to be immersed in liquid helium. Superimposed on this large magnetic field are smaller fields, with known gradients in two directions. These gradient fields produce a unique value of the magnetic field strength at each point within the instrument (see illustration).

Some nuclei in the atoms of a patient's tissues have a *spin, which makes them behave as tiny nuclear magnets. The purpose of the large magnetic field is to align these nuclear magnets. Having achieved this alignment, the area under xamination is subjected to pulses of radiofrequency (RF) radiation. At a resonant frequency of RF pulses the nuclei under examination undergo *Larmor precession. This phenomenon may be thought of as a 'tipping' of the nuclear magnets away from the strong field alignment. The nuclear magnets then precess or 'wobble', about the axis of the main field as the nuclei regain their alignment with that field.

The speed at which the nuclei return to the steady stage gives rise to two parameters, known as **relaxation times**. Because these relaxation times for nuclei depend on their atomic environment, they may be used to identify nuclei. Small changes in the magnetic field produced as the nuclei precess induce currents in a receiving coil. These signals are digitized before being stored in the memory of a computer.

The resulting set of RF pulse sizes and sequences identify a variety of resonance situations. By analysing these sequences and knowing the unique value of magnetic field strength within the volume under investigation, the resonance signals may be decoded to give estimates of the compositions of the patient's tissues. A three dimensional map of the composition can then be produced, using colour to indicate contrast between differing tissue compositions.



MRI. The way unique field strengths are produced at different points in a specimen

NMR can be used for the accurate determination of nuclear moments. It can also be used in a sensitive form of magnetometer to measure magnetic fields. In medicine, **magnetic resonance imaging** (**MRI**) has been developed, in which images of tissue are produced by magnetic-resonance techniques. **Functional MRI** (**fMRI**) can detect changes in blood flow that accompany neural activity and is therefore used to study brain function. See Feature.

The main application of NMR is as a technique for chemical analysis and structure determination, known as **NMR spectroscopy**. It depends on the fact that the electrons in a molecule shield the nucleus to some extent from the field, causing different atoms to absorb at slightly different frequencies (or at slightly different fields for a fixed frequency). Such effects are known as **chemical shifts**. There are two methods of NMR spectroscopy. In **continuous wave** (**CW**) **NMR**, the sample is subjected to a strong field, which can be varied in a controlled way over a small region. It is irradiated with radiation at a fixed frequency, and a detector monitors the field at the sample. As the field changes, absorption corresponding to transitions occurs at certain values, and this causes oscillations in the field, which induce a signal in the detector. **Fourier transform** (**FT**) **NMR** uses a fixed magnetic field and the sample is subjected to a high-intensity pulse of radiation covering a range of frequencies. The signal produced is analysed mathematically to give the NMR spectrum. The most common nucleus studied is ^{1}H. For instance, an NMR spectrum of ethanol (CH_3CH_2OH) has three peaks in the ratio 3:2:1, corresponding to the three different hydrogen-atom environments. The peaks also have a fine structure caused by interaction between spins in the molecule. Other nuclei can also be used for NMR spectroscopy (e.g. ^{13}C, ^{14}N, ^{19}F) although these generally have lower magnetic moment and natural abundance than hydrogen. *See also* ELECTRON PARAMAGNETIC RESONANCE.

- A comprehensive online textbook covering all aspects of magnetic resonance imaging

nuclear moment A property of atomic nuclei in which lack of spherical symmetry of the nuclear charge gives rise to electric moments and the intrinsic spin and rotational motion of the component nucleons give rise to magnetic moments.

nuclear physics The physics of atomic nuclei and their interactions, with particular reference to the generation of *nuclear energy.

nuclear power Electric power or motive power generated by a *nuclear reactor.

nuclear reaction Any reaction in which there is a change to an atomic nucleus. This may be a natural spontaneous disintegration or an artificial bombardment of a nucleus with an energetic particle, as in a *nuclear reactor. Nuclear reactions are commonly represented by enclosing within a bracket the symbols for the incoming and outgoing particles; the initial nuclide is shown before the bracket and the final nuclide after it. For example, the reaction:

$$^{12}C + {}^{2}H \rightarrow {}^{13}N + {}^{1}n$$

is shown as $^{12}C(d,n)^{13}N$, where d is the symbol for a deuteron.

nuclear reactor A device in which a *nuclear fission *chain reaction is sustained and controlled in order to produce *nuclear energy, radioisotopes, or new nuclides. The fuels available for use in a fission reactor are uranium–235, uranium–233, and plutonium–239; only the first occurs in nature (as 1 part in 140 of natural uranium), the others have to be produced artificially (*see* NUCLEAR FUEL). When a uranium–235 nucleus is made to undergo fission by the impact of a neutron it breaks into two roughly equal fragments, which release either two or three very high-energy neutrons. These *fast neutrons need to be slowed down to increase the probability that they will cause further fissions of ^{235}U nuclei and thus sustain the chain reaction. This slowing down process occurs naturally to a certain extent when the neutrons collide with other nuclei; unfortunately, however, the predominant uranium isotope, ^{238}U, absorbs fast neutrons to such an extent that in natural uranium the fission reaction is not self-sustaining. In order to create a controlled self-sustaining chain reaction it is necessary either to slow down the neutrons (using a *moderator in a **thermal reactor**) to greatly reduce the number absorbed by ^{238}U, or to reduce the predominance of ^{238}U in natural uranium by enriching it with more ^{235}U than it normally contains. In a **fast reactor** the fuel used is enriched uranium and no moderator is employed.

In thermal reactors, neutrons are slowed down by collisions with light moderator atoms (such as graphite, deuterium, or

beryllium); they are then in thermal equilibrium with the surrounding material and are known as **thermal neutrons**. In a **heterogeneous thermal reactor** the fuel and moderator are in separate solid and liquid phases (e.g. solid uranium fuel and a heavy water moderator). In the **homogeneous thermal reactor** the fuel and moderator are mixed together, for example in a solution, molten dispersion, slurry, or suspension.

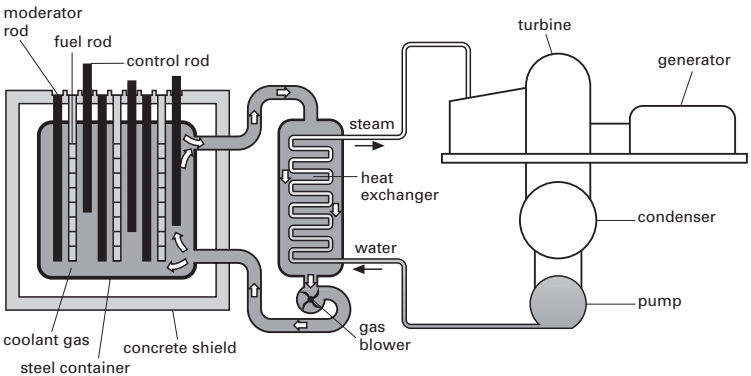
In the reactor **core** the **fuel elements** encase the fuel; in a heterogeneous reactor the fuel elements may fit into a lattice that also contains the moderator. The progress of the reaction is controlled by *control rods, which when lowered into the core absorb neutrons and so slow down or stop the chain reaction. The heat produced by the nuclear reaction in the core is used to generate electricity by the same means as in a conventional power station, i.e. by raising steam to drive a steam turbine that turns a generator. The heat is transferred to the steam-raising boiler or heat-exchanger by the *coolant. Water is frequently used as the coolant; in the case of the **boiling-water reactor** (**BWR**) and the **pressurized-water reactor** (**PWR**) water is both coolant and moderator. In the BWR the primary coolant drives the turbine; in the PWR the primary coolant raises steam in a secondary circuit for driving the turbine. In the **gas-cooled reactor** the coolant is a gas, usually carbon dioxide with an outlet temperature of about 350°C, or 600°C in the case of the **advanced gas-cooled reactor** (**AGR**).

In fast reactors, in which there is no moderator, the temperature is higher and a liquid-metal coolant is used, usually liquid sodium. Some fast reactors are used as converters or breeders. A **converter reactor** is one that converts *fertile material (such as ^{238}U) into *fissile material (such as ^{239}Pu). A **breeder reactor** produces the same fissile material as it uses. For example, a **fast breeder reactor** using uranium enriched with ^{239}Pu as the fuel can produce more ^{239}Pu than it uses by converting ^{238}U to ^{239}Pu. *See also* THERMONUCLEAR REACTOR.

SEE WEB LINKS

- The website of the World Nuclear Association, an association of companies in the nuclear industry

nuclear transfer A technique used in cloning animals in which a nucleus from a donor cell (adult or embryo) is injected into an unfertilized egg cell from which the chromosomes have been removed by micropipette; this is then stimulated by electrical pulses to begin dividing and develop as an embryo (*see* CLONE). The technique has been used successfully with various mammal species, most famously producing Dolly the sheep in 1997. Dolly was the first mammal to be cloned from a fully differentiated adult body cell. The donor cells were taken from a culture of sheep udder cells and starved into a state of quiescence in a low-nutrient medium. This was done to switch off all but essential genes and better mimic a natural fertilization. There are several advantages in using adult body cells: cultures are easier to obtain and maintain, and there is greater scope for genetically engineering such cells and screening



Nuclear reactor. A schematic diagram of a gas-cooled reactor.

them to select successfully modified cells. Nuclear transfer is now used increasingly to replicate elite animals in the livestock industry, to produce genetically engineered mammals for commercial use (e.g. goats that secrete human proteins in their milk), and to replicate endangered species. However, the failure rate is generally high, and even the few live clones produced often have congenital defects that shorten their lives. This shows that 'reprogramming' differentiated body cells poses formidable technical obstacles.

nuclear waste *See* RADIOACTIVE WASTE.

nuclear weapons Weapons in which an explosion is caused by *nuclear fission, *nuclear fusion, or a combination of both. In the fission bomb (**atomic bomb** or **A-bomb**) two subcritical masses (*see* CRITICAL MASS) of a *fissile material (uranium–235 or plutonium–239) are brought together by a chemical explosion to produce one supercritical mass. The resulting nuclear explosion is typically in the *kiloton range with temperatures of the order 10^8 K being reached. The fusion bomb (**thermonuclear weapon**, **hydrogen bomb**, or **H-bomb**) relies on a nuclear-fusion reaction, which becomes self-sustaining at a critical temperature of about 35×10^6 K. Hydrogen bombs consist of either two-phase fission-fusion devices in which an inner fission bomb is surrounded by a hydrogenous material, such as heavy hydrogen (deuterium) or lithium deuteride, or a three-phase fission-fusion-fission device, which is even more powerful. The *megaton explosion produced by such a thermonuclear reaction has not yet been used in war. A special type of fission-fusion bomb is called a **neutron bomb**, in which most of the energy is released as high-energy neutrons. This neutron radiation destroys people but provides less of the shock waves and blast that destroy buildings.

nuclease Any enzyme that breaks down nucleic acids to nucleotides. Nucleases are found in the small intestine. *See also* DNASE; ENDONUCLEASE; EXONUCLEASE.

nucleic acid A complex organic compound in living cells that consists of a chain of *nucleotides. There are two types: *DNA (deoxyribonucleic acid) and *RNA (ribonucleic acid).

SEE WEB LINKS

- Information about IUPAC nomenclature

nucleoid (nuclear region) The part of a cell of a bacterium (i.e. a prokaryotic *cell) that contains the genetic material *DNA and therefore controls the activity of the cell. It corresponds to the nucleus of the more advanced eukaryotic cells but is not bounded by a membrane.

nucleolus A small dense round body within the nondividing *nucleus of eukaryotic cells that consists of protein, DNA, and ribosomal *RNA. It plays an important role in *ribosome manufacture (and therefore protein synthesis).

nucleon A *proton or a *neutron.

nucleon emission A decay mechanism in which a particularly unstable *nuclide regains some stability by the emission of a nucleon, i.e. a proton or neutron. Proton emitters have fewer neutrons than their stable isotopes. Proton emitters are therefore found below the *Segrè plot stability line. For example, ^{17}Ne has three fewer neutrons than its most abundant stable isotope, ^{20}Ne. There are no naturally occurring proton emitters. Neutron emitters have many more neutrons than their stable isotopes. For this reason, neutron emitters are found above the stability line on the Segrè plot and in most cases can also decay by negative *beta decay. There are no naturally occurring neutron emitters. They are usually produced in nuclear reactors by the negative beta decay of fission products. An example is ^{99}Y, which has 10 more neutrons than the stable isotope ^{89}Y.

nucleonics The technological aspects of *nuclear physics, including the design of nuclear reactors, devices to produce and detect radiation, and nuclear transport systems. It is also concerned with the technology of *radioactive waste disposal and with radioisotopes.

nucleon number (mass number) Symbol A. The number of *nucleons in an atomic nucleus of a particular nuclide.

nucleophile An ion or molecule that can donate electrons. Nucleophiles are often oxidizing agents and Lewis bases. They are either negative ions (e.g. Cl^-) or molecules that have electron pairs (e.g. NH_3). In organic reactions they tend to attack positively charged parts of a molecule. *Compare* ELECTROPHILE.

nucleophilic addition A type of addition

reaction in which the first step is attachment of a *nucleophile to a positive (electron-deficient) part of the molecule. *Aldehydes and *ketones undergo reactions of this type because of polarization of the carbonyl group (carbon positive).

nucleophilic substitution A type of substitution reaction in which a *nucleophile displaces another group or atom from a compound. For example, in

$$CR_3Cl + OH^- \rightarrow CR_3OH + Cl^-$$

the nucleophile is the OH^- ion. There are two possible mechanisms of nucleophilic substitution. In **S_N1 reactions**, a positive carbonium ion is first formed:

$$CR_3Cl \rightarrow CR_3^+ + Cl^-$$

This then reacts with the nucleophile

$$CR_3^+ + OH^- \rightarrow CR_3OH$$

The CR_3^+ ion is planar and the OH^- ion can attack from either side. Consequently, if the original molecule is optically active (the three R groups are different) then a racemic mixture of products results.

The alternative mechanism, the **S_N2 reaction**, is a concerted reaction in which the nucleophile approaches from the side of the R groups as the other group (Cl in the example) leaves. In this case the configuration of the molecule is inverted. If the original molecule is optically active, the product has the opposite activity, an effect known as **Walden inversion**. The notations S_N1 and S_N2 refer to the kinetics of the reactions. In the S_N1 mechanism, the slow step is the first one, which is unimolecular (and first order in CR_3Cl). In the S_N2 reaction, the process is bimolecular (and second order overall).

nucleoplasm (karyoplasm) The material contained within the *nucleus of a cell. The nucleoplasm is bound by the nuclear envelope, which separates it from the cytoplasm.

nucleoprotein Any compound present in cells of organisms that consists of a nucleic acid (DNA or RNA) combined with a protein. Chromosomes consist of DNA and proteins, mostly histones, as do ribosomes (*see* RIBONUCLEOPROTEIN).

nucleoside An organic compound consisting of a nitrogen-containing *purine or *pyrimidine base linked to a sugar (ribose or deoxyribose). An example is *adenosine. *Compare* NUCLEOTIDE.

nucleosynthesis The synthesis of chemical elements by nuclear processes. There are several ways in which nucleosynthesis can take place. **Primordial nucleosynthesis** took place very soon after the *big bang, when the universe was extremely hot. This process was responsible for the cosmic abundances observed for light elements, such as helium. Explosive nucleosynthesis can also occur during the explosion of a *supernova. However, **stellar nucleosynthesis**, which takes place in the centre of stars at very high temperatures, is now the principal form of nucleosynthesis. The exact process occurring in stellar nucleosynthesis depends on the temperature, density, and chemical composition of the star. The synthesis of helium from protons and of carbon from helium can both occur in stellar nucleosynthesis. Some light elements, such as boron, are made by *spallation. *See also* CARBON CYCLE; EARLY UNIVERSE; STELLAR EVOLUTION.

nucleotide An organic compound consisting of a nitrogen-containing *purine or *pyrimidine base linked to a sugar (ribose or deoxyribose) and a phosphate group. *DNA and *RNA are made up of long chains of nucleotides (i.e. **polynucleotides**). *Compare* NUCLEOSIDE.

nucleus (of atom) The central core of an atom that contains most of its mass. It is positively charged and consists of one or more nucleons (protons or neutrons). The positive charge of the nucleus is determined by the number of protons it contains (*see* ATOMIC NUMBER) and in the neutral atom this is balanced by an equal number of electrons, which move around the nucleus. The simplest nucleus is the hydrogen nucleus, consisting of one proton only. All other nuclei also contain one or more neutrons. The neutrons contribute to the atomic mass (*see* NUCLEON NUMBER) but not to the nuclear charge. The most massive nucleus that occurs in nature is uranium–238, containing 92 protons and 146 neutrons. The symbol used for this *nuclide is $^{238}_{92}U$, the upper figure being the nucleon number and the lower figure the atomic number. In all nuclei the nucleon number (A) is equal to the sum of the atomic number (Z) and the neutron number (N), i.e. $A = Z + N$.

nucleus (of cell) The large body embedded in the cytoplasm of all plant and animal *cells (but not bacterial cells) that contains the genetic material *DNA organized into

*chromosomes. The nucleus functions as the control centre of the cell. It is bounded by a double membrane (the **nuclear envelope**), which is perforated by many **nuclear pores** for the selective transfer of water-soluble molecules between the nucleus and cytoplasm. When the cell is not dividing, a *nucleolus is present in the nucleus and the chromosomal material (*chromatin) is dispersed throughout the nucleus. In dividing cells the chromosomes become much shorter and thicker and the nucleolus disappears. The contents of the nucleus constitute the **nucleoplasm**. In certain protozoans there are two nuclei per cell, a **macronucleus** (or **meganucleus**) concerned with vegetative functions and a **micronucleus** involved in sexual reproduction.

nuclide A type of atom as characterized by its *atomic number and its *neutron number. An *isotope is a member of a series of different atoms that have the same atomic number but different neutron numbers (e.g. uranium–238 and uranium–235 are isotopes of uranium); a nuclide refers only to a particular nuclear species (e.g. the nuclides uranium–235 and plutonium–239 are fissile). The term is also used for a type of nucleus.

SEE WEB LINKS

- An interactive chart giving detailed information on all nuclides, from the National Nuclear Data Center, Brookhaven National Laboratory

null method A method of making a measurement in which the quantity to be measured is balanced by another similar reading by adjusting the instrument to read zero (*see* WHEATSTONE BRIDGE).

numerical analysis The analysis of problems by means of calculations involving numbers rather than analytical formulae. Numerical analysis is used extensively for problems too complicated to be solved analytically (either exactly or approximately). Numerical analysis can be performed using either electronic calculators or computers.

numerical taxonomy *See* TAXONOMY.

nut A dry single-seeded fruit that develops from more than one carpel and does not shed its seed when ripe. The fruit wall is woody or leathery. Many nuts are enclosed in a hard or membranous cup-shaped structure, the *cupule. The term nut is often loosely used of any hard fruit. For example, the walnut is in fact a *drupe and the Brazil nut is a seed.

nutation **1.** (in astronomy) An irregular periodic oscillation of the earth's poles. It causes an irregularity of the precessional circle traced by the celestial poles and results from the varying distances and relative directions of the sun and the moon. **2.** (in botany) The spiral movement of a plant organ during growth, also known as **circumnutation**. It is seen in climbing plants and helps the plant find a suitable support to twine around. Examples are the coiling movements of the shoot tips of runner beans and of the tendrils of sweet peas.

nutrient Any substance that is required for the nourishment of an organism, providing a source of energy or structural components. In animals nutrients form part of the *diet and include the **major nutrients**, i.e. carbohydrates, proteins (*see also* ESSENTIAL AMINO ACID), and lipids (*see also* ESSENTIAL FATTY ACIDS), as well as vitamins and certain minerals (*see* ESSENTIAL ELEMENT). Plant nutrients, derived from carbon dioxide in the atmosphere and water (containing minerals) absorbed from the soil by the roots, are *macronutrients or *micronutrients.

nutrition The process by which organisms obtain energy (in the form of food) for growth, maintenance, and repair. There are two main types of nutrition: *heterotrophic nutrition, employed by animals, fungi, and certain bacteria; and *autotrophic nutrition, found in most plants and bacteria.

nyctinasty (sleep movements) *Nastic movements of plant organs in response to the changes in light and temperature that occur between day and night (and vice versa). Examples are the opening and closing of many flowers and the folding together of the leaflets of clover and other plants at night.

nylon Any of various synthetic polyamide fibres having a protein-like structure formed by the condensation between an amino group of one molecule and a carboxylic acid group of another. There are three main nylon fibres, nylon 6, nylon 6,6, and nylon 6,10. Nylon 6, for example Enkalon and Celon, is formed by the self-condensation of 6-aminohexanoic acid. Nylon 6,6, for example Bri nylon, is made by polycondensation of hexanedioic acid (adipic acid) and 1,6-di-

aminohexane (hexamethylenediamine) having an average formula weight between 12 000 and 15 000. Nylon 6,10 is made by polymerizing decanedioic acid and 1,6-diaminohexane.

nymph The juvenile stage of certain insects, such as dragonflies, grasshoppers, and earwigs, which resembles the adult except that the wings and reproductive organs are undeveloped. There is no pupal stage, and the nymph develops directly into the adult. *Compare* LARVA.