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A

Abbe, Ernst [**ab**uh] (1840–1905) German physicist and developer of optical instruments.

Abbe was professor of physics and observatory director at Jena. He worked on optical theory and with Carl Zeiss (1816–88), an instrument maker, and Otto Schott (1851–1935), a glass maker, was able to improve several devices. These include the Abbe condenser for converging light on microscope specimens; the achromatic lens, which is free from colour distortion (1886); and the Abbe refractometer. From 1888 he was the sole owner of the Zeiss company, whose optical instruments were of the highest standard. In 1893 he patented the now-familiar prismatic binocular.

Abegg, Richard [**ab**eg] (1869–1910) German physical chemist.

Abegg's Rule (for which he is best remembered) states that each element has a positive valence and a negative valence, whose sum is 8. This idea reflects in primitive form the 'octet rule', ie the trend shown by most elements of the second and third (short) periods to attain an outer octet of electrons, but even as a mnemonic it applies only to elements of the fourth to seventh periodic groups.

Abel, Sir Frederick (Augustus) [**ay**bel] (1827–1902) British chemist: expert on military explosives.

An early pupil of HOFMANN at the Royal College of Chemistry, he became chemist to the War Department in 1854. He showed that guncotton (obtained by nitrating cotton) could be made safe by removing traces of acid, which, if not removed, led to instability. In 1889 with DEWAR he invented 'cordite', a mixture of guncotton and nitroglycerin gelatinized with propanone and petroleum jelly, which became the standard British military propellant. It produces little smoke on firing, an important advantage on a battlefield.

Abel, John Jacob [**ay**bel] (1857–1938) US biochemist: detected adrenalin, and crystallized insulin; isolated amino acids from blood.

An Ohio farmer's son, Abel studied very widely in Europe before returning to Johns Hopkins University equipped with a wide knowledge of chemistry, biology and medicine, as professor of pharmacology. He studied the adrenal hormone now known as adrenalin (epinephrine); and in 1926 first crystallized insulin and showed it was a protein and contained zinc. He was the first to isolate amino acids from blood, in 1914. He did this by passing blood from an artery through a cellophane tube immersed in saline; the amino acids dialysed through the tube and the blood was returned to a vein of the animal. The proof that amino acids are present in blood is fundamental in animal biochemistry and the method used led the way towards dialysis in the treatment of kidney disease.

Abel, Neils Henrik [**ah**bel] (1802–29) Norwegian mathematician: pioneer of group theory; proved that no algebraic solution of the general fifth-degree equation exists.

Abel was the son of a Lutheran minister. In 1821 he went to Oslo to study at the university, but his father's death forced him to give this up in order to support the large family of which he was the eldest; he was extremely poor throughout his life. In 1825 he visited Germany and France and with Leopold Crelle (1780–1855) founded *Crelle's Journal* in which much of his work was published, since Abel could not persuade the French Académie des Sciences to do so. Having failed to find a university post in Germany, and with his health failing due to tuberculosis, he returned to Norway, where he died shortly afterwards aged 26. Two days later a letter from Crelle announced that the professorship of mathematics at Berlin, one of the most prestigious posts in the world, had been awarded to him.

Despite his tragically early death Abel largely founded the theory of groups, and in particular commutative groups, which were later known as Abelian groups. He also showed that the general fifth-degree equation is not solvable algebraically (ironically GAUSS threw this proof away unread when Abel sent it to him). He revolutionized the important area of elliptic integrals with his theory of elliptic and transcendental functions, and contributed to the theory of infinite series.

Adams, John Couch (1819–92) British astronomer: predicted existence of Neptune.

As the son of a tenant farmer, Adams had financial problems in entering Cambridge, but his career was successful and he remained there throughout his life.

By 1820 it had become apparent to astronomers that the motion of Uranus could not be explained by NEWTON's law of gravitation and the influence of the known planets alone, since a small but increasing perturbation in its orbit had been observed. While still an undergraduate, Adams proved that the deviation had to be due to the influence of an eighth, undiscovered, planet. He sent his prediction for its position to AIRY, the Astronomer Royal, who was sceptical of its value and ignored it. Only when LEVERRIER, in France, announced similar results 9 months later did Airy initiate a search by James Challis (1803–82) at the Cambridge Observatory, based on Adams's prediction. The planet, now named Neptune, was however found first by Johann Galle (1812–1910) in Berlin in 1846, using Leverrier's figures. A bitter controversy about the credit for the prediction soon developed. Adams's precedence was eventually recognized, despite his taking no part in the debate. He turned down the subsequent offers of a knighthood and the post of Astronomer Royal.

Adams, Walter Sydney (1876–1956) US astronomer: discovered first white dwarf star.

Adams was born in Syria, where his American parents were missionaries, but he returned with them when he was 9 and was educated in the USA and in Europe.

Adams's work was principally concerned with the spectroscopic study of stars. He showed how dwarf and giant stars could be distinguished by their spectra, and established the technique of spectroscopic parallax to deduce a star's distance. In 1915 he observed the spectrum of Sirius B, the faint companion of Sirius, and discovered it to be an exceptionally hot star. Since it is only 8 light years distant he realized that it must therefore be very small (otherwise it would be brighter), and hence of very high density. Sirius B proved to be a 'white dwarf' and the first of a new class of stellar objects; such stars are the final stage in the evolution of stars of similar mass to the Sun, which have collapsed to form extremely dense objects.

Adams also searched for the relativistic spectral shift expected from a heavy star's presumed intense gravitational field. This he succeeded in finding in 1924, thereby proving his hypothesis about the nature of Sirius B and strengthening the case for EINSTEIN's general relativity theory as well. Adams spent most of his working life at the Mount Wilson Observatory in southern California, and was its director from 1923 until 1946.

Addison, Thomas (1793–1860) British physician: a founder of endocrinology.

A graduate in medicine from Edinburgh and London, his early work included the first clear descriptions of appendicitis, lobar pneumonia and the action of poisons on the living body. In 1855 his small book *On the Constitutional and Local Effects of Disease of the Supra-renal Capsules* described two new diseases: one is 'pernicious' anaemia; the other, also an anaemia, is associated with bronzing of the skin and weakness, and is known as Addison's disease. He found that cases of the latter showed postmortem changes in the suprarenal capsules (one on top of each kidney). Later, physiological studies by others showed that the suprarenal capsules are glands, now known as the adrenal glands, which produce a complex group of hormones. Addison's disease was the first to be correctly attributed to endocrine failure (ie disorder of the ductless glands of internal secretion).

Adrian, Edgar Douglas, Baron Adrian (1889–1977) British neurophysiologist: showed frequency code in nerve transmission.

Adrian began his research in physiology in Cambridge before the First World War, but in 1914 he speedily qualified in medicine and tried to get to France. In fact he was kept in England working on war injuries and his later work was a mixture of 'pure' research and applications to medical treatment.

In the 1920s he began his best-known work. Already, crude methods were available for detecting electrical activity in nerve fibres. Adrian used thermionic diode amplifiers to reliably record nerve impulses in a single nerve fibre, and to show that they do not change with the nature or strength of the stimulus, confirming work by his friend K Lewis (1881–1945) in 1905 on this 'all or none' law. He went on to show that a nerve transmits information to the brain on the intensity of a stimulus by frequency modulation, ie as the intensity rises the number of discharges per second (perhaps 10–50) in the nerve also rises – a fundamental discovery. He then worked on the brain, using the discovery by BERGER in 1924 that electrical 'brainwaves' can be detected.

From 1934 he studied these brainwave rhythms, which result from the discharge of thousands of neurones and which can be displayed as an electroencephalogram (EEG). Within a few years the method was widely used to diagnose epilepsy cases, and later to locate lesions, eg those due to tumours or injury.

Adrian was linked with Trinity College Cambridge for nearly 70 years and did much to advance neurophysiology. He was a very popular figure; as a student he was a skilful night roof-climber and an excellent fencer, and he sailed and rock-climbed until late in life. He helped to organize a famous hoax exhibition of modern pictures in 1913. He was never solemn, moved very quickly and claimed his own brainwaves were as rapid as a rabbit's; as a motorist his quick reflexes alarmed his passengers. When in a hurry he would use a bicycle in the long dark basement corridors of the Physiological Laboratory. He shared a Nobel Prize in 1932.

Agassiz, Jean Louis Rodolphe [agasee] (1807–73) Swiss–US naturalist and glaciologist: proposed former existence of an Ice Age.

Agassiz owed much of his scientific distinction to the chance of his birth in Switzerland. He studied medicine in Germany, but zoology was his keen interest. He studied under CUVIER in Paris and then returned home and worked with enthusiasm on fossil fishes, becoming the world expert on them (his book describes over 1700 ancient species of fish).

Holidaying in his native Alps in 1836 and 1837, he formed the novel idea that glaciers are not static, but move. He found a hut on a glacier which had moved a mile over 12 years; he then drove a straight line of stakes across a glacier, and found they moved within a year. Finding rocks which had been moved or scoured, apparently by glaciers, he concluded that in the past, much of Northern Europe had been ice-covered. He postulated an 'Ice Age' in which major ice sheets had formed, moved and were now absent in some areas – a form of catastrophism, in contrast to the extreme uniformitarianism of LYELL. We now know that a series of ice ages has occurred.

In 1846 Agassiz was invited to the USA to lecture, enjoyed it and stayed to work at Harvard. He found evidence of past glaciation in North America; it too had undergone an Ice Age. His studies on fossil animals could have been used to support DARWIN's ideas on evolution, but in fact Agassiz was America's main opponent to Darwin's view that species had evolved.

Agnesi, Maria Gaetana [anyayzee] (1718–99) Italian mathematician and scholar: remembered in the naming of the cubic curve 'the Witch of Agnesi'.

Born in Milan, Maria was one of the 24 children of a professor of mathematics at the University of Bologna. With his encouragement she spoke seven languages by the age of 11, and by the age of 14 she was solving problems in ballistics and geometry. Her interests covered logic, physics, mineralogy, chemistry, botany, zoology and ontology; her father arranged her public debates. From this time she suffered a recurring illness in which convulsions and headaches were symptoms. Her father agreed that she should in future lead a quiet life free from social obligations. Maria thereafter devoted herself to the study of new mathematical ideas. Her *Instituzioni analitiche ad uso della gioventù* (1748, Analytical Institutions) was published as a teaching manual. In 1750, she was appointed to the chair of mathematics and philosophy at Bologna. Maria Agnesi's work was one of promise rather than fulfilment: she made no original discoveries and her major work was written as a guide to students. The cubic curve named the Witch of Agnesi was formulated by FERMAT. A mistranslation caused the use of 'witch' for 'curve'.

Agricola, Georgius (*Lat*), **Georg Bauer** (*Ger*) [agrikola] (1494–1555) German mineralogist, geologist and metallurgist: described mining and metallurgical industries of 16th-c.

Born in Saxony, Agricola trained in medicine in Leipzig and in Italy. The link between medicine and minerals led to his interest in the latter, and his work as a physician in Saxony put him in ideal places to develop this interest and to extend it to mining and metal extraction by smelting, and related chemical processes. His book *De natura fossilium* (1546, On the Nature of Fossils) classifies minerals in perhaps the first comprehensive system. Later he wrote on the origin of rocks, mountains and volcanoes. His best-known book, *De re metallica* (1556, On the Subject of Metals) is a fine illustrated survey of the mining, smelting and chemical technology of the time. An English edition (1912) was prepared by the American mining engineer H C Hoover (who became president of the USA, 1929–33) and his wife.

Airy, Sir George Biddell [ayree] (1801–92) British geophysicist and astronomer: proposed model of isostasy to explain gravitational anomalies.

Airy was successful early in life, his talent and energy leading to his appointment as Astronomer Royal in 1835, a post he held for 46 years. He much extended and improved the astronomical measurements made in Britain. Airy's researches were in the fields of both optics and geophysics. He experimented with cylindrical lenses to correct astigmatism (a condition he suffered from himself); and he studied the Airy discs in the diffraction pattern of a point source of light.

In geophysics he proposed that mountain ranges acted as blocks of differing thickness floating in hydrostatic equilibrium in a fluid mantle, rather like icebergs in the sea. He was thus able to explain gravitational anomalies that had been observed in the Himalayas as due to the partial counteraction of the gravitational attraction of the topography above sea level with that of a deep 'root' extending into the mantle. His model of isostasy satisfactorily explains the gravity field observed over mountainous terrain in much of the world.

Airy was arrogant and unlucky in his failings, now almost better known than his successes. He failed to exploit ADAMS's prediction of a new planet, Neptune; he was against FARADAY's idea of 'lines of force' (a fruitful intuition, in fact); and although he expended great effort to ensure precise measurements of the transits of Venus, observed in 1874 and 1882, the results failed to give accurate measurements of the scale of the solar system because Venus's atmosphere makes the timing of its apparent contact with the Sun's disc uncertain. An ingenious inventor of laboratory devices, he was remarkably precise, to the extent of labelling empty boxes 'empty'.

Alembert, Jean le Rond d' [dalãbair] (1717–83) French mathematician: discovered d'Alembert's principle in mechanics.

D'Alembert's forename comes from that of the church, St Jean le Rond, on whose steps he was found as a baby. He was probably the illegitimate son of a Parisian society hostess, Mme de Tenzin, and the chevalier Destouches; the latter paid for his education while he was brought up by a glazier and his wife. He studied law, and was called to the bar in 1738, but then flirted briefly with medicine before choosing to study mathematics and to live on his father's annuity.

Early research by d'Alembert clarified the concept of a limit in the calculus and introduced the idea of different orders of infinities. In 1741 he was admitted to the Académie des Sciences and 2 years later published his *Traité de dynamique* (Treatise on Dynamics), which includes d'Alembert's principle, that NEWTON's Third Law of Motion holds not only for fixed bodies but also for those free to move. A wide variety of new problems could now be treated, such as the derivation of the planar motion of a fluid. He developed the theory of partial differential equations and solved such systems as a vibrating string and the general wave equation (1747). He joined EULER, A I Clairault (1713–65), LAGRANGE and LAPLACE in applying calculus to celestial mechanics and determined the motion of three mutually gravitating bodies. This then allowed many of the celestial observations to be understood; for example, d'Alembert explained mathematically (1754) Newton's discovery of precession of the equinoxes, and also the perturbations in the orbits of the planets.

D'Alembert was then persuaded by his friend, Denis Diderot (1713–84), to participate in writing his encyclopedia, contributing on scientific topics. This project was denounced by the Church after one volume, and d'Alembert turned instead to publishing eight volumes of abstruse mathematical studies. Shortly before his death J H Lambert (1728–77) wished to name his 'newly discovered moon of Venus' after d'Alembert, but the latter was sufficiently acute to doubt (correctly) from calculations that it existed, and gently declined the offer.

Alferov, Zhores (1930–) Russian physicist: devised improved transistors, and semiconductor lasers.

Alferov and Herbert Kroemer (1928–) were jointly awarded the Nobel Prize for physics in 2000, together with KILBY. Alferov was born in Belorussia in 1930, graduating from the Electrotechnical Institute in Leningrad in 1952. Kroemer obtained his doctorate in theoretical physics from Göttingen in the same year, and five years later he was employed by RCA in New Jersey. Both men were interested in semiconductor heterostructures. These used sandwiches (stacked layers) of different semiconductors, such as arsenides, giving a smaller band gap than in conventional semiconductors. Kroemer showed that the reduced band gap makes for a smaller energy barrier for electrons in transistors made of these materials, allowing higher gain and speed. Then in 1963 both he and Alferov independently suggested building semiconductor lasers using heterostructures. Alferov designed, patented and built the first such laser able to work at room temperature, by using gallium arsenide and aluminium arsenide. Thereafter commercial applications took off rapidly, and it became a key element of the current information revolution. The lasers are used in CD players, laser printers and fibre optic communications.

Alfvén, Hannes Olof Gösta [alf**vayn**] (1908–95) Swedish theoretical physicist: pioneer of plasma physics.

Educated at Uppsala, Alfvén worked in Sweden until 1967, when he moved to California. Much of his work was on plasmas (gases containing positive and negative ions) and their behaviour in magnetic and electric fields. In 1942 he predicted magnetohydrodynamic waves in plasmas (Alfvén waves) which were later observed. His ideas have been applied to plasmas in stars and to experimental nuclear fusion reactors. He shared a Nobel Prize in 1970 for his pioneering theoretical work on magnetohydrodynamics.

Alhazen, **Abu al-Hassan ibn al Haytham** (*Arabic*) [alha**zen**] (*c*.965–1038) Egyptian physicist: made major advances in optics.

Alhazen rejected the older idea that light was emitted by the eye, and took the view that light was emitted from self-luminous sources, was reflected and refracted and was perceived by the eye. His book *The Treasury of Optics* (first published in Latin in 1572) discusses lenses (including that of the eye), plane and curved mirrors, colours and the camera obscura (pinhole camera).

His career in Cairo was nearly disastrous. Born in Basra (now in Iraq), he saw in Cairo the annual flooding of the Nile and persuaded the caliph al-Hakim to sponsor an expedition to southern Egypt with the object of controlling the river and providing an irrigation scheme. Alhazen's expedition showed him only the difficulties, and on his return he realized that the caliph would probably ensure an unpleasant death for him. To avoid this, he pretended to be mad, and maintained this successfully until the caliph died in 1021. Alhazen then considered studying religion, before turning fully to physics in middle age. His mathematical and experimental approach is the high point of Islamic physics, and his work in optics was not surpassed for 500 years.

Al-Khwarizmi [al-khwah**riz**mee] (*c*.800–*c*.850) Persian mathematician: introduced modern number notation.

Little is known of al-Khwarizmi's life; he was a member of the Baghdad Academy of Science and wrote on mathematics, astronomy and geography. His book *Algebra* introduced that name, although much of the book deals with calculations. However, he gives a general method (al-Khwarizmi's solution) for finding the two roots of a quadratic equation

$$ax^2 + bx + c = 0 \text{ (where } a \neq 0\text{)};$$

he showed that the roots are

$$x_1 = [-b + (b^2 - 4ac)^{\frac{1}{2}}]/2a$$

and $x_2 = [-b - (b^2 - 4ac)^{\frac{1}{2}}]/2a$

In his book *Calculation with the Hindu Numerals* he described the Hindu notation (misnamed 'Arabic' numerals) in which the digits depend on their position for their value and include zero. The term 'algorithm' (a rule of calculation) is said to be named after him. The notation (which came into Europe in a Latin translation after 1240) is of huge practical value and its adoption is one of the great steps in mathematics. The 10 symbols (1–9 and 0) had almost their present shape by the 14th-c, in surviving manuscripts.

Allen, James (Alfred) Van *see* **Van Allen**

Alpher, Ralph Asher (1921–) US physicist: (with Robert Herman) predicted microwave background radiation in space; and synthesis of elements in early universe.

Ralph A Alpher

A civilian physicist in the Second World War, Alpher afterwards worked in US universities and in industry. He is best known for his theoretical work concerning the origin and evolution of the universe. In 1948, Alpher, together with Bethe and Gamow, suggested for the first time the possibility of explaining the abundances of the chemical elements as the result of thermonuclear processes in the early stages of a hot, evolving universe. This work became known as the 'alpha, beta, gamma' theory. As further developed in a number of collaborative papers with R Herman (1914–97) over the years, and in another important paper with Herman and J W Follin Jr, this concept of cosmological element synthesis has become an integral part of the standard 'Big Bang' model of the universe, particularly as it explains the universal abundance of helium. The successful explanation of helium abundance is regarded as major evidence of the validity of the model. While this early work on forming the elements has been superseded by later detailed studies involving better nuclear reaction data, the ideas had a profound effect on later developments.

Again in 1948, Alpher and Herman suggested that if the universe began with a 'hot Big Bang', then the early universe was dominated by intense electromagnetic radiation, which would gradually have 'cooled' (or red-shifted) as the universe expanded, and today this radiation should be observed as having a spectral distribution characteristic of a black body at a temperature of about 5 K (based on then-current astronomical data). At that time radio astronomy was not thought capable of detecting such weak radiation. It was not until 1964 that Penzias and R W Wilson finally observed the background radiation. It was realized later that evidence for this radiation had been available in 1942 in the form of observed temperatures of certain interstellar molecules. The existence of this background radiation (current observed value 2.73 K), whose peak intensity is in the microwave region of the spectrum, is widely regarded as a major cosmological discovery and strong evidence for the validity of the 'Big Bang' model, to which Alpher, Gamow and Herman contributed the pioneering ideas.

Alter, David (1807–81) US physicist: contributed to spectral analysis.

A physician and inventor as well as a physicist, Alter was one of the earliest investigators of the spectrum. In 1854 he showed that each element had its own spectrum, conclusively proved a few years later by Bunsen and Kirchhoff in their pioneer research on the Fraunhofer lines. He also forecast the use of the spectroscope in astronomy.

Altounyan, Roger (Ernest Collingwood) [al**toon**yan] (1922–87) British medical pioneer; introducer of the anti-asthma drug sodium cromoglycate.

Of Irish–Armenian and English parentage, he was also the grandson of W G Collingwood (1854–1932), the friend and biographer of John Ruskin (1819–1900). Roger Altounyan was born in Syria, but spent summer holidays sailing in the Lake District with his sisters. Here the family met Arthur Ransome (1884–1967) and became the model for his *Swallows and Amazons* children's books. Roger's asthma, however, was fact as well as fiction. He studied medicine, and practised it at the Armenian Hospital in Aleppo run by his father and grandfather. In 1956 he returned to England and joined a pharmaceutical company. He was concerned that asthma was not taken seriously and determined to find a cure. For the next 10 years he worked in his own time testing compounds on himself, inducing asthma attacks two or three times a week with a brew of guinea pig hair, to which he was allergic, almost certainly to the detriment of his own health. Compound 670, sodium cromoglycate, has been much used to prevent attacks of allergic asthma and rhinitis. The Spinhaler device he invented to inhale the drug was based on aircraft propellers; he had been a pilot and flying instructor during the war.

Alvarez, Luis (Walter) [alva**h**rez] (1911–88) US physicist: developed the bubble-chamber technique in particle physics.

Alvarez was a student under Compton, and then joined Lawrence at the University of California at Berkeley in 1936. He remained there, becoming professor of physics in 1945.

Alvarez was an unusually prolific and diverse physicist. He discovered the phenomenon of orbital electron capture, whereby an atomic nucleus 'captures' an orbiting electron, resulting in a nuclide with a lower proton number. In 1939, together with Bloch, he made the first measurement of the magnetic moment of a neutron. During the Second World War he worked on radar, developing such devices as microwave navigation beacons and radar landing approach systems for aircraft, and also worked on the American atomic bomb project. In 1947 he built the first proton linear accelerator, and later developed the bubble-chamber technique for detecting charged subatomic particles, which in turn led to a great increase in the number of known particles. For this he received the Nobel Prize for physics in 1968.

He was ingenious in the application of physics to a variety of problems. He used the X-ray component of natural cosmic radiation to show that Chephren's pyramid in Egypt had no undiscovered chambers within it; and he used physics applied to the Kennedy assassination evidence to confirm that only one killer was involved. With his son Walter (1940–), a geologist, he studied the problem of the catastrophe of 65 000 000 years ago which killed the dinosaurs and other fossil species; they concluded from tracer analysis that a probable cause was Earth's impact with an asteroid or comet, resulting in huge fires and/or screening of the Sun by dust. His interest in optical devices led him to found two companies; one to make variable focus spectacle lenses, devised by him to replace his bifocals; the other to make an optical stabilizer, which he invented to avoid shake in his cine camera and in binoculars. He was an engaging and popular personality.

Amici, Giovan Battista [a**mee**chee] (1786–1868) Italian microscopist: improved the compound microscope.

Amici trained as an engineer and architect in Bologna; he became a teacher of mathematics but was soon invited to Florence to head the observatory and science museums there. His interest from his youth was in optical instruments, especially microscopes. At that time compound microscopes were inferior to simple types, partly because of aberrations and also because of the false idea that enlargement was the dominant target of design. Amici devised in 1818 a catadioptric (mirror) design that was free of chromatic aberration and used it to observe the circulation of protoplasm in *Chara* cells; at once he became distinguished as an optician and as a biologist. By 1837 he had a design with a resolving power of 0.001 mm and a numerical aperture of 0.4 that was able to magnify 6000 times. His objectives had up to six elements; he invented the technique of immersion microscopy, using oil.

He also much improved telescopes, but his main interest remained in biology, where he made the notable discovery of the fertilization of phanerogams, observing in 1821 the travel of the pollen tube through the pistil of the flower.

Amontons, Guillaume [amõtõ] (1663–1705) French physicist: discovered interdependence of temperature and pressure of gases.

In his teens Amontons became deaf, and his interest in mechanics seems then to have begun. He later improved the design of several instruments, notably the hygrometer, the barometer and the constant-volume air thermometer. In 1699 he discovered that equal changes in the temperature of a fixed volume of air resulted in equal variations in pressure, and in 1703 seemed near to suggesting that at a sufficiently low temperature the pressure would become zero. Unfortunately his results were ignored and it was almost a century later before CHARLES rediscovered the relationship. His work on the thermal expansion of mercury, however, contributed to the invention of the mercury thermometer by FAHRENHEIT.

Ampère, André Marie [ãpair] (1775–1836) French physicist and mathematician: pioneer of electrodynamics.

Ampère was a very gifted child, combining a passion for reading with a photographic memory and linguistic and mathematical ability. He was largely self-taught. His life was disrupted by the French Revolution when, in 1793, his father, a Justice of the Peace, was guillotined along with 1500 fellow citizens in Lyon. For a year Ampère seems to have suffered a state of shock; he was aged 18. Ten years later, his adored young wife died following the birth of his son. His second marriage, undertaken on the advice of friends, was a disaster. His professional life ran more smoothly.

In 1802 Ampère was appointed to the first of a series of professorships, and in 1808 was appointed inspector-general of the university system by Napoleon, a post he retained until his death.

A M Ampère

Ampère was a versatile scientist, interested in physics, philosophy, psychology and chemistry, and made discoveries in this last field that would have been important had he not been unfortunate in being pre-empted by others on several occasions. In 1820 he was stimulated by OERSTED's discovery, that an electric current generates a magnetic field, to carry out pioneering work on electric current and electrodynamics. Within months he had made a number of important discoveries: he showed that two parallel wires carrying currents flowing in the same direction attracted one another while when the currents ran in opposite directions they were repelled; he invented the coiled wire solenoid; and he realized that the degree of deflection of Oersted's compass needle by a current could be used as a measure of the strength of the current, the basis of the galvanometer. Perhaps his most outstanding contribution, however, came in 1827, when he provided a mathematical formulation of electromagnetism, notably Ampère's Law, which relates the magnetic force between two wires to the product of the currents flowing in them and the inverse square of the distance between them. It may be generalized to describe the magnetic force generated at any point in space by a current flowing along a conductor. The SI unit of electric current, the ampere (sometimes abbreviated to amp) is named in his honour. The ampere is defined as that steady current which, when it is flowing in each of two infinitely long, straight, parallel conductors that have negligible areas of cross-section and are 1 metre apart in a vacuum, causes each conductor to exert a force of 2×10^{-7} N on each metre of the other.

Anaximander (of Miletus) [anaksi**man**der] (611–547 BC) Ionian (Greek) natural philosopher: suggested Earth was a curved body in space.

A pupil of Thales, Anaximander's writings are now lost, but he is credited with a variety of novel ideas. He was the first Greek to use a sundial (long known in the Middle East), and with it found the dates of the two solstices (shortest and longest days) and of the equinoxes (the two annual occasions when day and night are equal). He speculated on the nature of the heavens and on the origin of the Earth and of man. Realizing that the Earth's surface was curved, he believed it to be cylindrical (with its axis east to west); and he was probably the first Greek to map the whole known world. He visualized the Earth as poised in space (a new idea).

Anderson, Carl David (1905–91) US physicist: discovered the positron and the muon.

Anderson, the only son of Swedish immigrants, was educated in Los Angeles and at the California Institute of Technology, where he remained for the rest of his career.

Anderson discovered the positron accidentally in 1932 (its existence had been predicted by Dirac in 1928). As a result, Dirac's relativistic quantum mechanics and theory of the electron were rapidly accepted and it became clear that other antiparticles existed. Anderson shared the 1936 Nobel Prize for physics with V F Hess for this discovery.

Anderson discovered the positron while studying cosmic rays, which he did by photographing their tracks in a cloud chamber in order to find the energy spectrum of secondary electrons produced by the rays. A lead plate divided the chamber so that the direction of movement of the particles could be deduced (they are slowed or stopped by the lead). Also, a magnetic field was applied to deflect particles in different directions according to their charge and by an amount related to their mass. Many positive particles were seen which were not protons; they were too light and produced too little ionization. Anderson identified their mass as about that of an electron, concluding that these were positive electrons, or positrons. The discovery was confirmed by Blackett and Occhialini the following year.

Anderson discovered another elementary particle within the same year, again by observing cosmic ray tracks. It had unit negative charge and was 130 times as heavy as an electron, and seemed a possible confirmation of Yukawa's theory of a particle communicating the strong nuclear force (now called a pi-meson or pion). However a series of experiments by Anderson in 1935 revealed that it was not and the role of this mu-meson (or muon), as it is now called, remained unclear. The true pi-meson was first found by Powell in 1947. Positrons are inherently stable, but as they are antiparticles of electrons the two annihilate each other. Mesons are intrinsically unstable and decay rapidly. (*Portrait on p. 170*)

Anderson, Elizabeth, *née* **Garrett** (1836–1917) British physician; pioneered the acceptance of women into British medical schools.

Elizabeth Garrett was born in London, where her father had a pawnbroker's shop. He later built an expanding business malting grain at Snape in Suffolk. Educated by a governess at home, followed by boarding school in London, she settled to the duties of daughter at home, helping to run the large household. She joined the Society for Promoting the Employment of Women, whose aim was to improve the status of women through education and employment. Elizabeth Blackwell, the first woman to graduate in medicine in America (1849) gave a lecture on 'Young Women Desirous of Studying Medicine', which impressed Elizabeth Garrett and her friend Emily Davies (1830–1921) who decided that Elizabeth should work to open the medical profession in England to women and that Emily Davies would pursue higher education for women (she founded Girton College, Cambridge). As she was the youngest, Elizabeth's sister Millicent (Fawcett) was to work for the vote for women.

After graduation in New York Elizabeth Blackwell was inscribed on the British Medical Register. The Medical Council decided in future to exclude all holders of foreign degrees. To practise medicine in Britain Elizabeth Garrett had to gain admission to a British medical school.

With the financial support of her father she became an unofficial medical student at the Middlesex Hospital in 1860. Although she had the approval of the Dean, students and staff objected and she had to leave. No medical school or university in Great Britain would admit a woman, so she applied to the Society of Apothecaries, which provided a minimum qualification in medicine. After taking counsel's opinion, the Society was unable to refuse her application because of the wording of its Charter, an opening closed soon after her success. She attended a course by T H Huxley on natural history and physiology and John Tyndall's course on physics at the Royal Institution, at their invitation. Only private tuition for the Apothecaries' medical course was open to her and she found tutors at the medical schools at St Andrews, Edinburgh and London. She passed the Apothecaries' Hall examination in 1865, becoming the first woman to complete a recognized course of medical training with legal qualifications in Britain.

As a woman Elizabeth Garrett was barred from any hospital appointment and was unacceptable as an assistant in general practice. She was dependent on an allowance from her father for some time. She became a consultant physician to women and children from her home in London. Although willing to attend male patients she feared that to do so might create a scandal. In 1865, just before a cholera epidemic reached London, she opened the St Mary's Dispensary for Women and Children in a poor area of London and became visiting medical officer to a children's hospital in East London.

The Sorbonne in Paris admitted women in 1868 and in 1870 Elizabeth Garrett became the first woman MD from that university. In 1871 she married James Skelton Anderson (died 1907) and combined family life with her work. The London School of Medicine for Women, which was initiated by Sophia Jex-Blake, opened in 1874 and Elizabeth Garrett Anderson served on the Executive Committee, taught in the school and worked for the students to be admitted to the University of London's examinations. In 1883 she was elected Dean, the same year that Mary Scharlieb and Edith Shove became the first women to gain medical degrees from London University. The School became a college of the University of London. From 1886 Elizabeth Garrett Anderson was concerned with the New Hospital for Women which served as the teaching hospital for the London School of Medicine for Women. In 1908 she was elected mayor of Aldeburgh, the first woman mayor in England. It was due to the efforts of Elizabeth Garrett Anderson that medical education and medical science was opened to women in Britain.

Anderson, Philip Warren (1923–95) US physicist: discovered aspects of the electronic structure of magnetic and disordered systems.

Anderson studied at Harvard, doing doctoral research with Van Vleck and spending 1943–45 involved in antenna engineering at the Naval Research Laboratory. Anderson's career was largely with Bell Telephone Laboratories, but he became professor of physics at Princeton in 1975, and he also held a visiting professorship at Cambridge, UK (1967–75). Under Van Vleck, Anderson worked on pressure broadening of spectroscopic lines. In 1958 he published a paper on electronic states in disordered media, showing that electrons would be confined to regions of limited extent (Anderson localization) rather than be able to move freely. In 1959 he calculated a model explaining 'superexchange', the way in which two magnetic atoms may interact via an intervening atom. In 1961 he published important work on the microscopic origin of magnetism in materials. The Anderson model is a quantum mechanical model that describes localized states and their possible transition to freely mobile states. This model has been used widely to study magnetic impurities, superconducting transition temperatures and related problems. Also, during his work on superconductivity and superfluidity, Anderson worked on the possible superfluid states of helium-3. For these investigations of electronic properties of materials, particularly magnetic and disordered ones, Anderson shared the 1977 Nobel Prize for physics.

Andrews, Roy Chapman (1884–1960) US naturalist and palaeontologist.

Andrews's career was mostly spent with the American Museum of Natural History, New York, and with its expeditions (especially to Asia) to collect specimens. His more dramatic finds included the fossil remains of the largest land mammal yet found, *Paraceratherium*, a relative of the rhino which stood 5.5 m high; and the first fossil dinosaur eggs. He had a special interest in whales and other cetaceans (aquatic mammals) and built up a fine collection of their fossils; and he found evidence of very early human life in central Asia.

Andrews, Thomas (1813–85) British physical chemist: showed existence of critical temperature and pressure for fluids.

The son of a Belfast merchant, Andrews studied chemistry and medicine in Scotland. In Paris he studied chemistry under Dumas and at Giessen he studied under Liebig. In Belfast he first practised medicine and later became professor of chemistry. He proved that 'ozone' is an allotrope of oxygen (ie a different form of the element; ozone was later shown to be O_3; ordinary oxygen is O_2). He was a fine experimenter and is best known for his work on the continuity of the liquid and gaseous states of matter (1869). Using carbon dioxide, he showed that above its 'critical temperature' (31 °C) it cannot be liquefied by pressure alone. This example suggested that at a suitably low temperature, any gas could be liquefied, as was later demonstrated by Cailletet.

Anfinsen, Christian (Boehmer) (1916–95) US biochemist: made discoveries related to the shape and activity of enzymes.

Educated at Swarthmore and Harvard, Anfinsen afterwards worked at Harvard and from 1950 at the National Institutes of Health in Bethesda, MD. In 1960 Moore and W H Stein (1911–80) found the sequence of the 124 amino acids which make up ribonuclease and it became the first enzyme for which the full sequence was known. However, it was clear that enzymes owe their special catalytic ability not only to the sequence of amino acid units but also to the specific shape adopted by the chain-like molecule. Anfinsen showed that, if this shape is disturbed, it can be restored merely by putting the molecule into the precise environment (of temperature, salt concentration, etc) favourable for it, when it spontaneously takes up the one shape (out of many possibilities) that restores its enzymic activity. He deduced that all the requirements for this precise three-dimensional assembly must be present in the chain sequence; and he showed that other proteins behaved similarly. He shared the Nobel Prize for chemistry with Moore and Stein in 1972.

Ångström, Anders (Jonas) (1814–74) Swedish spectroscopist: detected hydrogen in the Sun.

Ångström was educated at Uppsala and taught physics at the university there until his death. He was an early spectroscopist and deduced in 1855 that a hot gas emits light at the same wavelengths at which it absorbs light when cooler; this was proved to be so in 1859 by Kirchhoff. From 1861 he studied the Sun's spectrum, concluding that hydrogen must be present in the Sun, and mapping about 1000 of the lines seen earlier by Fraunhofer. A non-SI unit of length, the ångström (Å) is 10^{-10} m; it was used by him to record the wavelength of spectral lines.

Anning, Mary (1799–1847) British palaeontologist.

Mary Anning had the good fortune to be born in Lyme Regis in Dorset, a place of great geological interest and, when a year old, to survive a lightning strike. Her nurse sheltered with her beneath a tree during a thunderstorm with two others; only Mary survived.

Her father, a cabinetmaker, supplemented his income by selling local fossils to summer visitors. He died when Mary was 11 years old and she, apparently well trained by him, continued to help the family income by the same means. Her brother discovered the head of a marine reptile in the cliffs between Lyme Regis and Charmouth in 1811 and Mary carefully excavated the complete remains, named *Ichthyosaurus* in1817; she sold it to a collector for £23. This was the beginning of a lifetime's fruitful fossil-hunting; her value to palaeontologists was in her local knowledge, her skill in recognition and the care she took to present her finds in an uninjured state. In 1823 she discovered the complete skeleton of an little-known saurian, named *Plesiosaurus* by William Conybeare (1787–1857) and described by him at a meeting of the Geological Society in London in 1824. Another major discovery of hers at Lyme was described as *Pterodactylus macronyx* by William Buckland (1784–1856) in 1829; this fossil of a strange flying reptile attracted much attention.

Mary Anning supplied fossils to palaeontologists, collectors and museums, as well as to the visitors to her shop in Lyme Regis and attracted the general public to fossil-collecting and to herself, by her successes. She became both knowledgeable and aware of the significance of her discoveries. She left no publications and her contribution to the 'golden age' of British geology has been largely neglected; her discoveries were described and collected by others. In her later years she was assisted by a small government grant awarded by the prime minister, Lord Melbourne, at the prompting of Buckland and the Geological Society of London. When she died her work was acknowledged by the president of the Society in his anniversary address. Later a stained-glass window to her memory was placed by the Fellows in the parish church at Lyme Regis.

Apollonius (of Perga) [apaw**loh**neeuhs] (*c*.260–190 BC) Greek mathematician: wrote classic treatise on conic sections.

Apollonius was a student in Alexandria and later taught there, specialising in geometry. Of his books, one survives, *On Conic Sections*. It deals with the curves formed by intersecting a plane through a double circular cone (see diagram). These are the circle, ellipse, parabola and hyperbola (the last three were named by Apollonius). Much of the book on the properties of conics is original; it represents the high point of Greek geometry and, although at the time the work appeared to have no uses, KEPLER 1800 years later found that the planets moved in ellipses and the curves now have many applications in ballistics, rocketry and engineering.

Apollonius was also interested in astronomy and especially in the Moon, and proposed a theory of epicycles to describe the sometimes apparently retrograde motions of the outer planets.

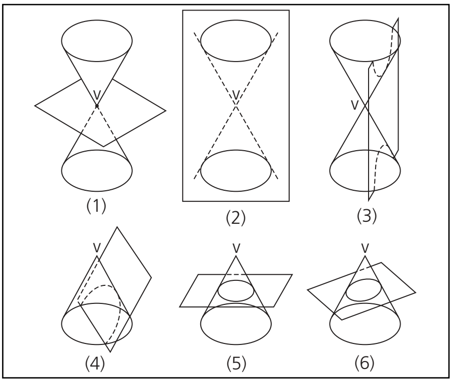
Appert, Nicholas-François [apair] (*c*.1749–1841) French chef: devised an improved method of food preservation.

As a innkeeper's son, Appert was familiar with food preparation and he became a chef and confectioner. A government prize was offered for improved methods of preserving food, especially for military use, and from 1795 Appert experimented with sealing food into glass jars using waxed cork bungs. Using heat-sterilization of the vessel and contents he was successful and in 1810 he claimed the 12 000 franc prize. He used autoclaves (pressure cookers) to give a temperature a little above the boiling point of water. Tinplate cans came into use in England after 1810 and were sealed by soldering. Appert's work was highly praised, but he died in poverty. PASTEUR's work, which rationalized Appert's success, came in the 1860s.

Appleton, Sir Edward (Victor) (1892–1965) British physicist: pioneer of ionospheric physics; discovered reflective layers within the ionosphere.

Appleton studied physics at Cambridge, but it was service in the First World War as a signals officer which led to his interest in radio. In 1924 he was appointed professor of experimental physics at King's College, London. In 1939 he was appointed secretary of the Department of Scientific and Industrial Research, and later became vice-chancellor of Edinburgh University.

In 1901 MARCONI had transmitted radio signals across the Atlantic, to the astonishment of many in the scientific community who believed that, since electromagnetic radiation travels in straight lines and the Earth's surface is curved, this was not possible. Shortly afterward, A E Kennelly (1861–1939) and HEAVISIDE proposed a reflecting layer of charged particles in the atmosphere as the explanation. In a classic experiment in 1925, Appleton became the first to demonstrate beyond doubt the existence of such a reflecting layer within the ionosphere. He transmitted signals between Bournemouth and Cambridge (a distance of 170 km); and by slowly



Conic sections – Cone (sometimes double) cut by a plane to give (1) a single point (2) a pair of straight lines (3) a hyperbola (4) a parabola (5) a circle (6) an ellipse varying the frequency and studying the received signal he showed that interference was occurring between the part of the signal that travelled in a straight line from transmitter to receiver (the direct, or ground, wave) and another part that was reflected by the ionosphere (the sky wave). Measurement of the interference caused by the different path lengths enabled him to measure the height of the reflecting layer, about 70 km. This was the first radio distance measurement. This layer is now known as the Heaviside layer or E layer. Further work revealed a second layer above the first, which is now called the Appleton layer or F layer . The E layer is more effective after dark, since the Sun's ultraviolet rays interact with the ionosphere, which is why distant radio stations are more readily picked up at night. For his achievements Appleton received the Nobel Prize for physics in 1947.

Arago, Dominique François Jean [aragoh] (1786–1853) French physicist.

Beginning his career as a secretary at the Bureau de Longitudes, Arago went with Biot to Spain in 1806 to complete the geodetic measurements of an arc of the meridian. The return journey was eventful as the ship was wrecked and he was almost enslaved at Algiers. He made distinguished researches in many branches of physics, and in 1838 suggested a crucial experiment to decide between the particle and wave theories of light, by measuring its speed in air and in water. The experiment was tried by Foucault in 1850 and pointed to the wave theory.

Arago was the first to discover that substances other than iron have magnetic properties. He discovered in 1820 the production of magnetism by electricity; a piece of iron, surrounded by a coil of wire, was briefly magnetized by passing a current from either a capacitor or a voltaic cell through the coil.

The device called Arago's disc consists of a horizontal copper disc with a central vertical spindle; the disc can be spun by a belt and pulley. Above it, and separately mounted, is a pivoted compass needle. When the disc is spun, the needle follows it; if the rotation of the plate is reversed, the needle slows, stops and also reverses. The effect is due to eddy currents in the disc, although Arago did not know this. The value of his experiments in electricity and magnetism is that they later inspired Faraday to make his major discoveries.

Arago was a close friend of Humboldt for half a century; the latter wrote of Arago as 'one gifted with the noblest of natures, equally distinguished for intellectual power and for moral excellence'.

Arber, Agnes, *née* **Robertson** (1879–1960) British botanist: her careful investigations of plant structure made a lasting contribution to botanical knowledge.

Agnes Robertson became an enthusiastic student of botany while attending the North London Collegiate School for Girls. The school was unusually good in its teaching of science and it was there that she learned about plant anatomy and classification. The school had a Science Club to which Ethel Sargant, who had also attended the school, gave talks on botany. After taking degree examinations at University College, London, and Newnham College, Cambridge, Agnes Robertson became a research assistant to Ethel Sargant at her private laboratory and worked on seedling structures. From 1903–08 she returned to London to take up research on gymnosperms.

After her marriage in 1909 she worked at the Balfour Laboratory in Cambridge until 1927 and thereafter in her own laboratory at home. For the next 50 years her researches were mainly concerned with the anatomy and morphology of monocotyledonous plants and her researches were gathered into book form. She published *Herbals, Their Origin and Evolution* (1912), *Water Plants: A Study of Aquatic Angiosperms* (1920), and *Monocotyledons* (1925). She also produced in the Cambridge Botanical Handbook series *The Gramineae: A Study of Cereal, Bamboo, and Grass* (1934). In 1946 she was elected to the fellowship of the Royal Society; she was the third woman to receive the honour. After the Second World War she turned more to philosophy and wrote *The Natural Philosophy of Plant Form* (1950), *The Mind and the Eye* (1954) and *The Manifold and the One* (1957).

Archer, Frederick (Scott) (1813–57) British inventor of the wet collodion photographic process.

Orphaned early in life, Archer was apprenticed to a London silversmith. This led him first to study coins and then to design them and to work as a portrait sculptor. To obtain likenesses for this he began in 1847 to use the primitive photographic methods of the time. He experimented to improve them and tried collodion (a solution of nitrocellulose in ether), on paper and then on glass, as part of the sensitive material. In 1851 he published his method: collodion containing iodide was flowed over a glass plate. This was followed by silver nitrate solution. The moist plate was quickly exposed in the camera and then developed, fixed and washed to give a glass negative from which positive paper prints could be made. The moist plate was much more sensitive to light than its predecessors and allowed exposures to be reduced to 2–20 s.

Archer was diffident, poor, generous and unworldly. Talbot claimed (falsely) that the whole process was covered by his patents, but by 1854 his attempts to prevent the use of collodion by legal injunctions had failed and, as the daguerrotype patents had lapsed in 1853, the public could take up photography without restraint and did so enthusiastically. Despite the need to carry a tent and portable laboratory, the wet collodion process quickly supplanted all others and was widely used by amateurs and professionals until 1880, when the more convenient gelatine dry plate was introduced.

Archer died poor and unappreciated, and his family received niggardly provision from Government and professional photographers who had profited by use of his unpatented methods. Only after many years was his contribution recognized.

Archimedes (of Syracuse) [ah(r)kimeedeez] (*c*.287–212 BC) Sicilian Greek mathematician and physicist: pioneer of statics and hydrostatics.

A member of a wealthy noble family, Archimedes studied in Alexandria but returned to Syracuse in Sicily, whose king Hieron II was a relative. Archimedes was the finest scientist and mathematician of the ancient world but little is firmly known of his life, although legends exist. He is known to have used experiments to test his theories, which he then expressed mathematically. He devised weapons against the Roman fleet when it attacked Syracuse in 215 BC; the Romans took the city in 212 BC and Archimedes was killed. Cicero found and restored his tomb in 75 BC.

In mathematics, Archimedes used geometrical methods to measure curves and the areas and volumes of solids (e.g. the volume of a sphere, $4\pi r^3/3$); he used a close approximation for π (he showed it to be between 223/71 and 220/70) and developed his results without the use of the calculus (which came nearly 2000 years later). He used a new notation to deal with very large numbers, described in his book *Sand-Reckoner*.

In applied mathematics, he created mechanics; his innovations ranged from the directly practical (eg the compound pulley and the Archimedian screw) to derivations of the theory of levers and centres of gravity, forming the basic ideas of statics. He founded hydrostatics, contributing ideas which included specific gravity and the Archimedes principle: this states that when a body is wholly or partly immersed in a fluid, it experiences a buoyant force (upthrust) which shows itself as an apparent loss of weight, equal to the weight of fluid displaced. (The fluid can be liquid or gas.)

Archimedes' water-screw for moving water up a slope has been claimed to be the helical device from which screws of all kinds developed: screw devices were certainly known to HERO, who was thought by PLINY, incorrectly, to have originated the idea of this invaluable mover and fixer. The place of the helix in molecular biology was unknown until over 2000 years later.

GAUSS thought that Archimedes had only NEWTON as a mathematical equal.

Aristarchus (of Samos) [aristah(r)kuhs] (*c*.320–*c*.250 BC) Greek astronomer: proposed heliocentric cosmology; and made first estimate of astronomical distances.

Although little is known of the life of Aristarchus, he was perhaps the first to propose that the Earth moved around the Sun, in contrast to the accepted thinking of his day. He also attempted to estimate the relative distances of the Sun and the Moon, using the fact that when the Moon is exactly half light and half dark it forms a right angle with the Earth and the Sun. Although his result was wildly inaccurate, it was the first experimental attempt at measuring an astronomical distance. His work makes him the most original of the Greek astronomers and in the modern view the most successful. His heliocentric scheme was made precise by COPERNICUS in the 16th-c.

Aristotle: from a bas-relief found in the collection of Fulvius Ursinus.

Aristotle [aristotl] (384–322 BC) Athenian (Greek) philosopher and naturalist: provided philosophical basis of science which proved dominant for 18 centuries.

Son of the court physician at Macedon, Aristotle was orphaned early and moved to Athens, where he became Plato's finest pupil. In 342 BC he returned to Macedon as tutor and then adviser to Philip II's son Alexander, who became Alexander the Great. Later he became a public teacher in Athens, using a garden he owned (the Lyceum). His collected lectures cover most of the knowledge of the time in science, and some other fields such as logic and ethics (but not mathematics), and include much of Aristotle's own work in zoology and anatomy. He was a first-class naturalist and marine biologist, whereas his record of older views in physics and cosmology contained many misguided, although defensible, ideas. Aristotle's books survived in the Arab world, and re-entered Christian Europe in Latin translation in the 12th and 13th-c. It was no fault of the writer that his books were accorded almost divine authority, and some of the erroneous ideas were not easily displaced (eg that bodies 'outside the sphere of the Moon' are perfect and unchanging). His status as a major figure in philosophy has never changed.

Armstrong, Edwin Howard (1890–1954) US radio engineer.

Many teenagers build radio receivers; Armstrong was unusual in also making a transmitter before he became a student of electrical engineering at Columbia. Then, during the First World War, he worked on the problem of locating aircraft by detecting the stray radio emission from their ignition systems; a side-result was his development of the superheterodyne circuit, which made radio tuning much easier and helped make radio popular. From

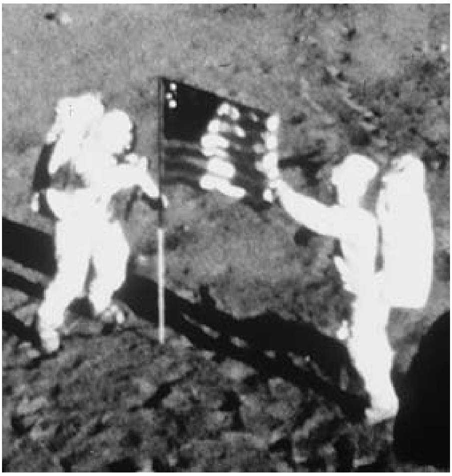
1934 he taught electrical engineering at Columbia and by 1939 he had devised a major advance in radio transmission: FM.

Previously, radio signals conveyed speech or music by changes in the amplitude of the carrier radio waves (amplitude modulation, AM). The snag of this is that electrical storms and appliances introduce random noise (static). Armstrong's method was to vary the carrier signal by changes in frequency (frequency modulation, FM) which is largely free from interference. This requires use of high frequencies that have only a limited range, but it has become the preferred mode for radio and TV use.

Armstrong, Neil (Alden) (1930–) US astronaut: the first man to walk on the Moon.

This most dramatic act of manned exploration occurred on 20 July 1969 and represented success in a curious international contest. In 1957 the USSR had placed an unmanned spacecraft (Sputnik) into orbit, and this blow to national self-esteem in the USA led to President Kennedy in 1961 committing his country to a manned moon-landing within the decade.

The Manned Spacecraft Centre, at Houston, TX, worked for this result and success came with the Apollo 11 flight commanded by Armstrong. He had served as a naval aviator in the Korean War and later studied aeronautical engineering at Purdue University, IN, and the University of Southern California before joining the organization which became NASA (the National Aeronautics and Space Administration) in 1955. By 1969 he was well equipped to land a spacecraft on the Moon, under his manual control. The scientific results of the visit were limited and were exceeded by the results from unmanned space probes. Armstrong left NASA in 1971 and, after a period as professor of aeronautical engineering at Cincinnati, OH, became a businessman from 1980.



Neil Armstrong lands on the Moon in 1969 from Apollo 11, with Edwin 'Buzz' Aldrin who is holding the edge of the US flag.

Arrhenius, Svante (August) [arayneeus] (1859–1927) Swedish physical chemist: proposed theory of ionic dissociation; he foresaw the greenhouse effect in 1896.

Arrhenius came from a family of farmers, and his father was an estate manager and surveyor. He attended Uppsala University and did very well in physical science, and then moved to Stockholm to work for a higher degree on aqueous solutions of electrolytes (acids, bases and salts); he concluded that such solutions conduct a current because the electrolyte exists in the form of charged atoms or groups of atoms (positive cations and negative anions), which move through the solution when a current is applied. He obtained good evidence for this during the 1880s but his theory was only slowly accepted, especially in Sweden. (Since then, further evidence has substantially confirmed his views, and has also shown that salts are largely ionic even in the solid state.) In 1903 he was awarded the Nobel Prize for chemistry. His work was surprisingly varied and included immunology, cosmic physics and the first recognition of the 'greenhouse effect' (heat gain by the atmosphere due to carbon dioxide). He also studied the effect of temperature on the rates of chemical reactions, and showed that

$k = \mathrm{A} \exp(-\mathrm{E}/R\mathrm{T})$

where k is the rate constant for the reaction, A is the frequency factor, E is the activation energy for the reaction, R is the gas constant and T the Kelvin temperature (this is the Arrhenius equation).

Aston, Francis William (1877–1945) British chemical physicist: invented mass spectrograph.

After graduating in chemistry in Birmingham, Aston worked for 3 years as a chemist in a nearby brewery. In his leisure at home he designed and made an improved vacuum pump and in 1903 he turned to physics as a career, working on discharge tubes in Birmingham and, from 1909, in Cambridge as J J Thomson's assistant. They worked on the 'positive rays' which Thomson had found to be generated within one part of a vacuum tube through which an electric discharge is passed. Aston and Thomson believed that their experiments on positive rays from tubes containing neon gas showed it to contain atoms with masses of about 20 and 22 units. Proof of this, and extension of the work, was interrupted by the First World War.

Aston's war work at the Royal Aircraft Establishment linked him with a talented group of physicists, including Lindemann, Taylor, Adrian, G P Thomson and H Glauert (1892–1934). Soon after the war he devised a mass spectrograph which was able to separate atoms of similar mass and measure these masses accurately (his third spectrograph to 1 in 10^5; 1 in 10^9 is now easily available on commercial machines). Aston showed clearly that over 50 elements consisted of atoms of similar but different relative atomic mass (eg for S; 32, 33 and 34) but the same atomic number (ie nuclear charge). The Aston rule is that the masses are approximately integers; the apparent deviations of relative atomic masses of the elements from integers results from the presence of these isotopes.

THE EXPLORATION OF SPACE

To transform dreams of space travel into reality and to explore space directly, rockets are needed: their power overcomes the force of gravity which pulls all objects towards the centre of the Earth.

Konstantin Edvardovich Tsiolkovsky (1857–1935) was the first to suggest multistage rockets. He also suggested the use of liquid hydrogen and liquid oxygen as propellants, burned in a combustion chamber. Independently, GODDARD successfully made rockets fuelled by gasoline (petrol) and liquid oxygen. In 1937, one of these reached a height of about 2.5 km/1.6 mi. Hermann Oberth (1894–1990) considered rocket propulsion and guidance systems theoretically. His work led to the ethanol/liquid-oxygen-fuelled German V2 rocket that was perfected by VON BRAUN during the Second World War.

After the war von Braun worked in the USA, developing rockets that could carry instruments into the uppermost part of the Earth's atmosphere. In 1954 he proposed using the Redstone rocket, similar in design to the V2, to put a satellite weighing 2 kg into orbit around the Earth. In the event, the first US satellite, the 14 kg Explorer 1, was launched by a Jupiter C rocket early in 1958. Using Geiger counters aboard it, VAN ALLEN discovered the radiation belts of energetic, charged particles that surround the Earth, and which now carry his name.

The first Earth-orbiting satellite was the 84 kg Soviet Sputnik 1. This was launched on 4 October 1957, using kerosene (paraffin oil)/liquid-oxygen fuel. The rocket engines were designed by a team led by Sergei Pavolvich Korolev (1907–66). His rockets also powered the first manned space flight on 29 April 1961 by Yuri Gagarin (1934–68), whose flight in the Vostok 1 capsule (4.7 tonnes) around the Earth lasted 108 minutes. Furthermore, Korolev's rockets launched the first space probe, Venera 3, to land on the planet Venus.

With the Soviet Luna programme and the US Ranger programme, television pictures of the Moon's surface were sent back to Earth before the spacecraft crashed into the Moon. Later, the soft landings of Surveyor spacecraft were a prelude to America's Apollo programme. It was during the Apollo 11 mission that NEIL ARMSTRONG became the first human being to set foot on the Moon, on 20 July 1969, speaking the now famous prepared words 'that's one small step for man; one giant leap for mankind'. The other Apollo 11 astronauts were Michael Collins (1930–) and Edwin E (Buzz) Aldrin (1930–).

For the Apollo programme, the gigantic 110 m-tall Saturn V rocket was developed by von Braun's team. It had to send 40 tonnes towards the Moon at a speed exceeding 11 km s^{-1}. It was needed to meet US President John F Kennedy's objective, stated in 1961, 'that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth'. In successfully accomplishing this, scientists also investigated samples of lunar material, and studied the Moon's gravitational, magnetic, and seismic properties. The Apollo 15 mission, with David R Scott (1932–), Alfred M Worden (1932–) and James B Irwin (1930–), was the first to use a battery-powered lunar rover to travel up to 103 km/63 mi from the landing site. The Apollo missions, through the rock samples they provided, led to the general acceptance, from 1984, of a novel theory of the Moon's origin, as due to impact on the early Earth of a Mars-sized planetesimal, the resulting debris coalescing to form the Moon.

Also during the 1960s, many Soviet cosmonauts and American astronauts orbited the Earth. The first American astronaut to do so was John H Glenn (1921–), later a senator and by virtue of his second spaceflight in October 1998, the oldest astronaut. In February 1962 he travelled three times round the world in less than 5 hours in his Mercury Friendship 7 capsule, which was launched by an Atlas rocket. Confidence was building up as L Gordon Cooper (1927–) survived in space for more than 24 hours aboard the Mercury Faith 7 capsule during May 1963. Aboard Vostok 6, Valentina Tereshkova (1937–) was the first woman in space, in June 1963. In March 1965, Aleksei Leonov donned a spacesuit to emerge from Voskhod 2, a three-man spacecraft, and to walk in space for the first time. Edward H White (1930–67) became the first American to walk in space 3 months later, this time for 21 min. In 1965 and 1966, 10 two-man Gemini missions were launched by Titan 2 rockets, with Armstrong on Gemini 8, Michael Collins on Gemini 10, and Buzz Aldrin on Gemini 12. The Gemini programme demonstrated that humans could survive and operate in space for at least 2 weeks, and that one space vehicle could rendezvous and dock with another. Both astronauts and flight control crews on the ground gained valuable experience for the Apollo programme.

Polar-orbiting satellites were used during the 1960s for research on both the Earth's atmosphere and the near-Earth space environment. Clouds were observed from the Tiros satellites, leading to improved weather forecasts. The Transit navigational satellite and Echo telecommunications satellite programmes commenced in 1960. Remote sensing of the Earth's surface for a variety of resource studies was successfully begun in 1972 with Landsat 1. On images taken from the Ikonos satellite, launched in September 1999, objects with a size of only 1m or so can be picked out.

From Earth-orbiting satellites in highly eccentric orbits, Norman F Ness (1933–) discovered and investigated the magnetopause, the boundary between the Earth's magnetic field and the interplanetary medium. This had been postulated by CHAPMAN in 1931. Konstantin Gringauz (1918–93) found the plasmapause, the outer boundary of the Earth's topside ionosphere, in 1963, and Lou A Frank (1938–) observed the rings of auroral light around the Earth's magnetic poles from the Dynamics Explorer 1 satellite.

Realizing the 1945 idea of CLARKE, a Syncom 2 telecommunications satellite was launched into geostationary orbit in July 1963. At an altitude of 36 000 km/22 370 mi above the equator, the orbital period is one day, and so the satellite always remains above a certain geographical position. With at least three such satellites, point-to-point communications are possible anywhere in the world (except for the polar regions). The geostationary orbit is also invaluable for making continuous meteorological observations over most of the Earth.

From 1970s onwards, the USA explored the planets of the solar system with Mariner, Pioneer, Viking and Voyager spacecraft. Striking photographs were obtained and many scientific investigations pursued. The USSR concentrated on carrying out detailed studies of Mars and Venus. Detailed knowledge of the planets was vastly increased by these programmes.

During 1973, several American scientists worked for weeks at a time in Skylab, an orbiting laboratory. First they corrected several mechanical problems with their equipment. Their subjects of study ranged from stellar astronomy and solar physics, to the behaviour of substances under almost weightless conditions, and the physiological effects of space on astronauts. From 1967, the then USSR conducted some 60 manned space flight missions, the longest lasting more than a year. In the Salyut or Cosmos spacecraft and, after 1986, the Mir space station, they accumulated a wealth of practical experience across many scientific and technological disciplines. Svetlana Savitskaia (1948–) worked outside the Salyut 7 space station for nearly 4 hours in July 1984, the first time that a woman performed extravehicular activity (EVA). The first British cosmonaut, Helen Sharman (1963–), worked aboard Mir for a week in 1991, and the second, Michael Foale (1957–) aboard the US Space Shuttle in 1992 and 1999, and Mir in 1997.

The US Space Shuttle flew for the first time in April 1981. It is a recoverable and reusable launch vehicle rather than an expendable rocket. During launch its three main engines, fuelled by liquid hydrogen and liquid oxygen, are supplemented by two solid fuel (polybutadiene) rocket boosters. The Shuttle's cargo bay is vast, 18 m/59 ft long and 4.56 m/15 ft diameter. Once in space, the cargo of satellites can be launched. Alternatively, the cargo bay can house a laboratory, such as the European Spacelab, in which experiments are performed during the mission, which typically lasts 10 days. Ulf Merbold (1941–) was the first European astronaut aboard Spacelab at the end of 1983. The Soviets used a rather similar space shuttle, called Buran ('Snowstorm'). This was launched for the first and only time in November 1988.

European, Chinese, Japanese and other national space programmes developed since the 1960s to complement the superpowers' space programmes. The Ariadne, Long March and Lambda or Mu rockets launched a wide variety of both civil and military satellites with scientific or technological payloads. For example, both Europe and Japan sent spacecraft (Giotto, and Suisei and Sakigake, respectively) as well as the Soviet Vega probes, to study HALLEY's comet when it neared the Sun in 1986. The European SPOT (*Satellite pour l'observation de la terre*) satellites have excellent spatial resolution and colour discrimination for geological and cartographic remote-sensing investigations of our planet. Besides downward-looking instruments to investigate such phenomena as the ozone hole and volcanoes, telescopes can view outwards to investigate space across the electromagnetic spectrum at wavelengths where the atmosphere absorbs radiation. New insights into the universe, and its origin, are obtained. Although initially plagued by an instrumental defect, the shuttle-launched Hubble space telescope, when repaired in orbit in 1994, gave superb observations.

The space nations are currently working towards an International Space Station and are considering the benefits of a manned mission to the Moon and/or Mars. The USA is forging ahead with its international space station, Freedom, and is considering the benefits of a manned mission to the Moon and/or to Mars, as well as smaller satellites dedicated to solving particular scientific problems. International collaboration will undoubtedly be the hallmark of future space exploration.

For the future, tele-communications satellites will transfer Internet traffic, and constellations of low Earth-orbiting satellites may be introduced. Europe is developing a satellite system for navigation, known as Galileo. There are hopes that new technologies will lead to very much cheaper access to space – that is the key to its future commercialization. Perhaps the most exciting future missions are to Mars, with launches planned every two years, investigating whether or not life ever existed there.

Prof M J Rycroft, CAESAR Consultancy, Cambridge

Aston found that isotopic masses are not exactly integral (by about 1%) and he related the discrepancy (the 'packing fraction') to the force binding the nucleus together. Atomic energy generation from nuclear reactions, on Earth or in the stars, can be calculated from packing fractions.

The modern mass spectrograph has played a central part in nuclear physics and radiochemistry, and more recently in exact analysis in organic chemistry. Aston was a 'one device' investigator, but he chose a device whose value has been immense.

He was a shy man, a poor teacher, with a passion for sports and for sea travel. He won the Nobel Prize for chemistry in 1922.

Atiyah, Sir Michael (Francis) [atty-ah] (1929–) British mathematician.

Atiyah, the son of a Lebanese father and a Scottish mother, attended schools in Cairo and Manchester before his military service and then became a student, and later a fellow, of Trinity College, Cambridge. Further work at Princeton and Oxford followed, and led to professorships at both.

In 1963 he developed the Atiyah–Singer index theorem, and his subsequent publications in topology and algebra have contributed to a variety of areas in pure mathematics. He developed further the theory of complex manifolds, which had started with the Riemann surface (a multilayered surface) being used to understand multivalued functions of a single complex variable. Atiyah considered what happened when there was more than one complex variable. He received the Fields Medal in 1966 primarily for his work on topology.

The Fields Medal is awarded every four years to two, three or four mathematicians under the age of 40 and having outstanding distinction and promise in mathematics. The Canadian mathematician John Fields initiated, and provided money for, this international medal for high mathematical ability. The first medals were awarded in Oslo in 1936; and it is recognized as the mathematical equivalent of a Nobel Prize. Later Atiyah renewed interest in quaternions (see HAMILTON) by showing their relationship with string theory, now widely used in mathematical physics. From Oxford he returned to Cambridge as Master of Trinity College and director of the Isaac Newton Institute for Mathematical Sciences, in 1990.

Atkins, Anna, *née* **Children** (1799–1871) British botanist: the first to use photography to illustrate scientific studies.

Anna was the only child of J G Children, a Fellow of the Royal Society whose wife had died shortly after Anna's birth. Her father was a friend of the Herschel family and Anna knew JOHN HERSCHEL from childhood. She had a close relationship with her father and shared his scientific interests. No doubt this position helped her acceptance in the male scientific circle. She was a skilled illustrator and provided over 200 drawings for her father's translation of LAMARCK's book *The Genera of Shells*, published in 1823. Anna married J P Atkins in 1825; there were no children and she continued her scientific interests and collaboration with her father. Children chaired the Royal Society meeting at which TALBOT announced his 'calotype' photographic process, and father and daughter took up the process enthusiastically. In the same year she became an active member of the Botanical Society of London.

The calotype process was difficult (partly because Talbot's information was inadequate), but in 1842 Herschel described his 'cyanotype' process. To illustrate her large collection of algae Anna Atkins turned to photography. As she explains in her preface 'The difficulty of making accurate drawings of objects as minute as many of the Algae and Confervae, has induced me to avail myself of Sir John Herschel's beautiful process of Cyanotype, to obtain impressions of the plants themselves.' She made contact photograms of algae, totalling 389 pages of illustration and 14 of handwritten text, and making more than a dozen copies of the whole, which were sent to scientific friends and institutions. And so with her *Photographs of British Algae: Cyanotype Impressions* (3 vols, 1843–53) she became the first to apply photography to illustrate scientific studies, predating Talbot's *Pencil of Nature* (1844–46), although the latter includes photographs made with a camera. Atkins's work is both permanent and suited to its subject, with seaweeds shown as paler images on a rich blue background.

Auerbach, Charlotte [owerbakh] (1899–1994) German–British geneticist: discoverer of chemical mutagenesis.

Lotte Auerbach, born in Germany and the daughter and grand-daughter of scientists, herself studied science at four German universities and then taught in schools in Berlin until, in 1933, all Jewish teachers were dismissed. She escaped to Edinburgh, followed by her mother, worked for a PhD and obtained a lowly job at the Institute of Animal Genetics there, becoming a lecturer in 1947.

Discussions with the geneticist H J MÜLLER led her to study mutation in animal cells (a mutation is a change, spontaneous or induced, in a gene or a

Elizabeth Anderson

GLOBAL WARMING

Before the industrial revolution (roughly pre-1800) there had been large regional or global changes in climate: notably a series of ice ages. The last ice age ended about 20 000 years ago, and we now live in an interglacial period. These pre-1800 changes, resulting from causes such as change in solar radiation, or dust and gas from volcanoes, owe nothing to human activity. However, since the mid-19th-c human activity has played an increasing part. Over a century before this was considered, the idea of the 'greenhouse effect' was born. FOURIER, in 1827, recognized that the Earth's atmosphere acts somewhat like the glass of a greenhouse in raising the temperature, and TYNDALL about 1860 showed that water vapour and carbon dioxide (CO_2) are important in the matter. The Sun's radiation is partly reflected by clouds before it reaches the Earth, but the solar energy that arrives warms it; nearly 300 W m^{-2} on average. The Earth in turn re-radiates energy, but mainly in the longer wavelength infrared region; this radiation is strongly absorbed by water vapour and CO_2 (0.03% of the atmosphere) and so the atmosphere absorbs the radiation and re-emits much of it back to Earth. The net result is that the atmosphere has a blanketing effect akin to glass. It keeps the Earth some 20° C warmer than it would be without the effect. The main constituents of air, nitrogen and oxygen, do not absorb in the infrared.

In 1896 ARRHENIUS calculated that doubling the atmospheric CO_2 content would increase the global average temperature by between 5 and 6° C; a result close to modern values based on more refined calculation. In 1940 G S Callendar calculated the warming due to a smaller increase in CO_2, which he estimated as arising from burning fossil fuels (coal and oil). Neither of these calculations aroused very much general interest at the time.

In 1957 R Revelle (1909–) and H E Suess (1909–) of the Scripps Institute of Oceanography, CA, noted that mankind's ever-increasing contribution of CO_2 to the atmosphere constituted a global climatic experiment, whose progress and outcome needed study. Measurement of atmospheric CO_2 levels began in that year at Mauna Kea in Hawaii, and other studies followed.

Water and CO_2 are the main natural greenhouse gases. The former is outside human control, as is some CO_2 emission (eg from volcanoes). But much CO_2 emission is now man-made, by burning of fuels. Of course CO_2 is absorbed by green plants for photosynthesis, a process diminished by human deforestation, especially in the tropics; CO_2 is also absorbed by the oceans. Historically, atmospheric CO_2 has steadily increased since 1800, as shown by the graph (Figure 1).

Another important greenhouse gas is methane,

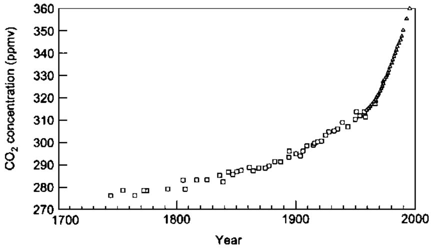


Fig. 1. The increase of atmospheric carbon dioxide since 1700 showing measurements from ice cores in Antarctica (squares) and, since 1957, direct measurements from the Mauna Loa observatory in Hawaii (triangles).

CH_4, 'marsh gas'. As the last name implies it is generated by bacterial action on wet organic matter in lakes, peatland, and increasingly in man-made landfill rubbish sites, and reservoirs. It is also released in the coal and oil extraction industries, and from termites, and both ends of cattle by enteric fermentation of their diet. Itself a potent greenhouse gas, it is ultimately converted to CO_2 in the atmosphere by oxidation.

From about 1980 the Earth as a whole has seen many unusually warm years and a high incidence of extreme climatic events – droughts, floods and storms. Figure 2 shows temperatures from 1860 to 2000; and when allowance is made for natural variations in solar energy reaching the Earth's surface, the trend roughly correlates with the increase in CO_2. Sophisticated studies led the IPCC in 2000 to conclude that man-made additions to the atmosphere, the 'enhanced greenhouse effect', provides the dominant cause of this global warming.

The IPCC conclusion is that on present trends the global average temperature will rise by about 5° C. The certain and probable effects of this will be dramatic, but difficult to predict in detail. Positive and negative feedback, and interactions between many of the primary effects of climate change make the overall climatic change a complex case for modelling.

For example, Europe in general will become warmer by 2100, but for the UK the position is less certain: if change in ocean currents diverts the Gulf Stream (which makes Britain's climate milder than its latitude would imply) this greatly affects prediction. However, some major effects are clearly foreseeable. Agricultural practices will need to change over large areas; disease patterns will alter, as will the availability of fresh water.

A dramatic and predictable effect will be that on sea level. This will rise in part because of simple expansion of water with rise in temperature; and also because of melting of glaciers and mountain ice caps, and of polar ice, notably the Antarctic continent. Sea level is predicted to rise between 60 cm and 1 m by 2100. Worldwide, half of humanity lives in coastal areas. Some islands will be inundated, as will much of

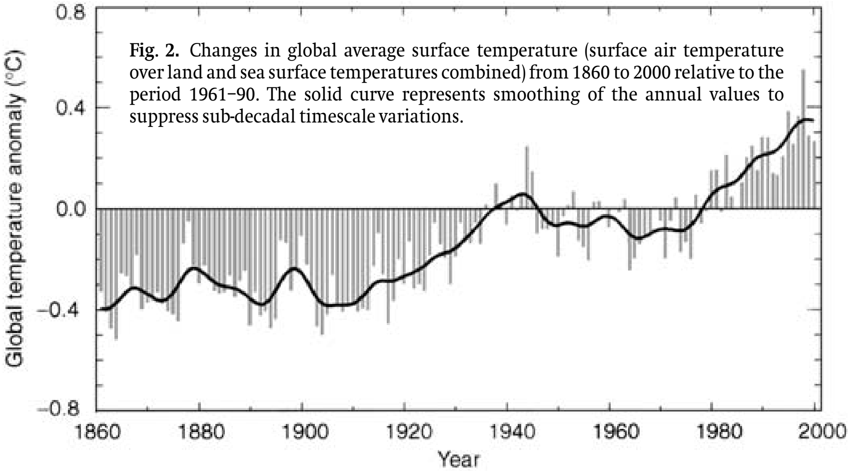


Fig. 2. Changes in global average surface temperature (surface air temperature over land and sea surface temperatures combined) from 1860 to 2000 relative to the period 1961–90. The solid curve represents smoothing of the annual values to suppress sub-decadal timescale variations.

Bangladesh, the Nile delta in Egypt, and large areas in the USA and China. The Netherlands has at least the advantage of experience, and should be able to enhance existing technology and use experience not available in other areas, where population surges will result from inability to control land loss.

Attempts to alleviate these huge global problems have led to calls for reduction of CO_2 emissions worldwide, or at least (and more realistically) reduction of the rate of CO_2 increase. The burning of fossil fuels (coal and gas) for domestic heating, industrial power use, and transport are clear targets for reduction: the industrialized northern hemisphere emits most CO_2 but the development of industry in Russia, China and India will worsen the problems. More efficient usage, and better insulation, can only slightly reduce CO_2 emissions. So also will contributions of renewable 'clean' (ie CO_2-free) power from hydroelectricity, geothermal, tide, wind and wave power, despite the enthusiasm of their supporters. More substantial help can come from wider use of nuclear fission power (as in France) but public confidence in nuclear safety has been disturbed by the Chenobyl disaster and the UK and Germany seem unwilling to follow this path. Nuclear fusion, the source of the Sun's power, has yet to prove itself as a practical earthly power source. If photovoltaic (solar) power to generate electricity can be further developed, it shows real promise: it could, for example, be used not only to meet static needs, but also for all forms of transport. Unless storage batteries can be made much lighter than existing types, it is possible that a 'hydrogen economy' will develop. In this scheme photovoltaic current is used to decompose water to give hydrogen, which is then liquefied and distributed much as petrol and diesel now is – but requiring high refrigeration (it boils at –252° C). In a vehicle, the hydrogen would feed a fuel cell, re-generating electricity to power a motor. The only exhaust product in the cycle would be water. A full-scale trial in Iceland from 2002 of part of this scheme, although valuable, is limited in so far as Iceland has a small population (276 000) and abundant hydroelectric power to generate hydrogen.

Alternative and very different ideas have also been put forward; for example TELLER'S group believe that reflective particles in the upper atmosphere, to reduce incoming solar radiation, could be cost-effective. Another philosophy is offered by the US economist Frances Cairncross (1944–), who has argued that it is hopeless to try to prevent a massive rise in CO_2 emission from the developing world. There at present the fuel consumption is only the equivalent of 1 to 2 barrels of oil per person annually, compared with 10 for Europeans and 40 for Americans. Her view is that humanity in the past has adapted to and survived great climatic changes, and can do so again; and that other globe-wide problems (eg water pollution) 'deserve greater priority than global warming'.

Global warming has become essentially a political problem. For the wealthy and democratic Western world and Japan, making the social and economic changes needed to deal with the foreseeable climatic change would be political suicide. Good general intentions conflict with national interests. International agreements made at Kyoto and elsewhere are limited in scope and are unlikely to be fulfilled. Fossil fuel interests, notably in the USA, argue that causes other than human activities are responsible for the climatic changes that are already discernible; and that action should be delayed until further evidence is available. But the weight of scientific opinion is clearly different, and scientists generally are dismayed by governmental delay and complacency.

Moving away from high dependency on fossil fuels would reduce the influence of OPEC on world economies, and defer the not-too-distant date when fossil fuel supplies become exhausted. *IM* chromosome; such a change in the hereditary material leads to an abrupt alteration in the characteristics of an organism). Müller had shown that X-rays produced mutations: Lotte Auerbach first showed that mustard gas ($[CH_2CH_2Cl]_2S$, used in the First World War) did so in the fruit fly, *Drosophila*. She became an authority on such chemical mutations, which have been of great value in research and in cancer treatment, and she directed the Medical Research Council Mutagenesis Research Unit 'for as long as she could conceal her age from her employers', not retiring until 1969. She was elected a Fellow of the Royal Society in 1957.

Auger, Pierre Victor [ohzhay] (1899–1993) French physicist: discovered the Auger effect.

Auger was educated at the École Normale Supérieure and subsequently became professor of physics at the University of Paris. After the Second World War he held a succession of posts in French and European science administration and was director general of the European Space and Research Organization at his retirement.

Auger is remembered for his discovery in 1925 of the Auger effect, in which an atom absorbs energy in the form of an X-ray photon, and loses it by emitting an electron. Auger spectroscopy uses the effect to yield information about the electronic structure of atoms, particularly if they form part of a crystal.

Avery, Oswald (Theodore) [ayveree] (1877–1955) US bacteriologist: showed that the genetic material of bacterial chromosomes is DNA.

Born in Canada, Avery went to New York when he was 10 and remained there for his working life; he qualified in medicine at Columbia in 1904, and from 1913 researched in bacteriology at the Rockefeller Institute Hospital. His special interest was pneumococci (the bacteria causing pneumonia). In 1928 he was intrigued by the claim of the British microbiologist F Griffith (1881–1941) that a non-virulent, 'rough' (ie unencapsulated) pneumococcus could be transformed into the virulent, smooth (capsulated) form in the mouse by the mere presence of some of the dead (heat-killed) smooth bacteria.

Avery found this so strange that he repeated the work, and also showed in 1944 that the substance that caused the transformation is deoxyribonucleic acid (DNA). Prudently, he did not go on to surmise that genes are simply DNA, which was surprising enough to be accepted only slowly after 1950 and formed the basic idea of molecular biology.

Avogadro, (Lorenzo Romano) Amedio (Carlo) [avohgadroh] (1776–1856) Italian physicist: proposed a method for finding molecular formulae of gases.

Trained in law like his forefathers and working as a lawyer for some time, after 1800 he turned to science and held professorships in physics for much of his life. His fame now rests on one brilliant and important idea. He considered GAY-LUSSAC's Law of combining volumes and with little evidence offered a daring explanation for it in 1811. His idea, Avogadro's Law, was that 'equal volumes of all gases, under the same conditions of temperature and pressure, contain the same number of smallest particles'. There is now ample evidence that he was right; in some cases (eg the noble gases) the smallest particles are atoms; for most other gases, they are combinations of atoms (molecules). The law gives a direct method of finding the molecular formula of a gas, and such a formula in turn gives the relative atomic masses of the elements present in it. Avogadro's Law shows that the simple gases hydrogen and oxygen are diatomic (H_2 and O_2) and that water is H_2O (and not HO as DALTON believed). However, the law was largely rejected or ignored for 50 years (although AMPÈRE accepted it) until CANNIZZARO in 1860 convinced a Chemical Congress at Karlsruhe of its value.

Amedio Avogadro

The SI base unit of amount of substance is the mole (which is related to Avogadro's Law). The mole is defined as containing as many elementary entities (usually atoms or molecules, and specified for each case) as there are atoms in 0.012 kg of carbon-12. Thus for a compound, 1 mole has a mass equal to its relative molecular mass in grams. The number of entities in a mole, the Avogadro constant, N_A, is $6.022 \times 10^{23}\,\text{mol}^{-1}$; and 1 mole of any ideal gas, at STP (standard temperature and pressure), has a molar volume of $22.415\,\text{dm}^3$.

For example: since the relative atomic masses ('atomic weights') of carbon and oxygen are 12 and 16 respectively, a mole of carbon dioxide (CO_2) will weigh $12 + (2 \times 16) = 44$ g, and will have a volume at STP close to $22.4\,\text{dm}^3$.

Ayrton, Hertha, *née* **(Phoebe) Sarah Marks** (1854–1923) British electrical engineer; the first woman to present a paper to the Royal Society.

Sarah Marks (she later adopted the name Hertha) was the daughter of a Polish Jew who fled to England following persecution under the Tsarist