Definition: science from The Penguin Dictionary of Psychology

1
A body of knowledge, particularly that which has resulted from the systematic application of the SCIENTIFIC METHOD.

2
A branch of study or a discipline focused on the derivation of basic principles and general laws.

3
A system of methods and procedures for the investigation of natural phenomena based upon scientific principles.

Summary Article: science from The Columbia Encyclopedia

[Lat. scientia=knowledge]. For many the term science refers to the organized body of knowledge concerning the physical world, both animate and inanimate, but a proper definition would also have to include the attitudes and methods through which this body of knowledge is formed; thus, a science is both a particular kind of activity and also the results of that activity.

The Scientific Method

The scientific method has evolved over many centuries and has now come to be described in terms of a well-recognized and well-defined series of steps. First, information, or data, is gathered by careful observation of the phenomenon being studied. On the basis of that information a preliminary generalization, or hypothesis, is formed, usually by inductive reasoning, and this in turn leads by deductive logic to a number of implications that may be tested by further observations and experiments (see induction; deduction). If the conclusions drawn from the original hypothesis successfully meet all these tests, the hypothesis becomes accepted as a scientific theory or law; if additional facts are in disagreement with the hypothesis, it may be modified or discarded in favor of a new hypothesis, which is then subjected to further tests. Even an accepted theory may eventually be overturned if enough contradictory evidence is found, as in the case of Newtonian mechanics, which was shown after more than two centuries of acceptance to be an approximation valid only for speeds much less than that of light.

Role of Measurement and Experiment

All of the activities of the scientific method are characterized by a scientific attitude, which stresses rational impartiality. Measurement plays an important role, and when possible the scientist attempts to test his theories by carefully designed and controlled experiments that will yield quantitative rather than qualitative results. Theory and experiment work together in science, with experiments leading to new theories that in turn suggest further experiments. Although these methods and attitudes are generally shared by scientists, they do not provide a guaranteed means of scientific discovery; other factors, such as intuition, experience, good judgment, and sometimes luck, also contribute to new developments in science.
Branches of Specialization

Science may be roughly divided into the physical sciences, the earth sciences, and the life sciences. Mathematics, while not a science, is closely allied to the sciences because of their extensive use of it. Indeed, it is frequently referred to as the language of science, the most important and objective means for communicating the results of science. The physical sciences include physics, chemistry, and astronomy; the earth sciences (sometimes considered a part of the physical sciences) include geology, paleontology, oceanography, and meteorology; and the life sciences include all the branches of biology such as botany, zoology, genetics, and medicine. Each of these subjects is itself divided into different branches—e.g., mathematics into arithmetic, algebra, geometry, and analysis; physics into mechanics, thermodynamics, optics, acoustics, electricity and magnetism, and atomic and nuclear physics. In addition to these separate branches, there are numerous fields that draw on more than one branch of science, e.g., astrophysics, biophysics, biochemistry, geochemistry, and geophysics.

All of these areas of study might be called pure sciences, in contrast to the applied, or engineering, sciences, i.e., technology, which is concerned with the practical application of the results of scientific activity. Such fields include mechanical, civil, aeronautical, electrical, architectural, chemical, and other kinds of engineering; agronomy, horticulture, and animal husbandry; and many aspects of medicine. Finally, there are distinct disciplines for the study of the history and philosophy of science.

The Beginnings of Science

Science as it is known today is of relatively modern origin, but the traditions out of which it has emerged reach back beyond recorded history. The roots of science lie in the technology of early toolmaking and other crafts, while scientific theory was once a part of philosophy and religion. This relationship, with technology encouraging science rather than the other way around, remained the norm until recent times. Thus, the history of science is essentially intertwined with that of technology.

Practical Applications in the Ancient Middle East

The early civilizations of the Tigris-Euphrates valley and the Nile valley made advances in both technology and theory, but separate groups within each culture were responsible for the progress. Practical advances in metallurgy, agriculture, transportation, and navigation were made by the artisan class, such as the wheelwrights and shipbuilders. The priests and scribes were responsible for record keeping, land division, and calendar determination, and they developed written language and early mathematics for this purpose. The Babylonians devised methods for solving algebraic equations, and they compiled extensive astronomical records from which the periods of the planets’ revolution and the eclipse cycle could be calculated; they used a year of 12 months and a week of 7 days, and also originated the division of the day into hours, minutes, and seconds. In Egypt there were also developments in mathematics and astronomy and the beginnings of the science of medicine. Wheeled vehicles and bronze metallurgy, both known to the Sumerians in Babylonia as early as 3000 B.C., were imported to Egypt c.1750 B.C. Between 1400 B.C. and 1100 B.C. iron smelting was discovered in Armenia and spread from there, and alphabets were developed in Phoenicia.

Early Greek Contributions to Science

The early Greek, or Hellenic, culture marked a different approach to science. The Ionian natural philosophers removed the gods from the personal roles they had played in the cosmologies of Babylonia and Egypt and sought to order the world according to philosophical principles. Thales of Miletus (6th cent. B.C.) was one of the earliest of these and contributed to astronomy, geometry, and
cosmology. He was followed by Anaximander, who extended Thales' ideas and proposed that the universe is composed of four basic elements, i.e., earth, air, fire, and water; this theory was also taught by Empedocles (5th cent. B.C.) in Sicily. The philosophers Leucippus and Democritus (both 5th cent. B.C.) held that everything is composed of tiny, indivisible atoms. In the school founded at Croton, S Italy, by the Greek philosopher Pythagoras of Samos (6th cent. B.C.) the principal concept was that of number. The Pythagoreans tried to explain the workings of the universe in terms of whole numbers and their ratios; in addition to contributions to mathematics and philosophy, they also made notable studies in the area of biology and anatomy, e.g., by Alcmaeon of Croton (fl. c.500 B.C.). The most important developments in medicine were made by Hippocrates of Cos (4th cent. B.C.), known as the Father of Medicine, who formulated the science of diagnosis based on accurate descriptions of the symptoms of various diseases. The greatest figures of the earlier Greek period were the philosophers Plato (427–347 B.C.) and Aristotle (384–322 B.C.), each of whom exerted an influence that has extended down to modern times.

Influence of the Alexandrian Schools

The later Greek, or Hellenistic, culture was centered not in Greece itself but in Greek cities elsewhere, particularly Alexandria, Egypt, which was founded in 332 B.C. by Alexander the Great. The so-called first Alexandrian school included Euclid (fl. c.300 B.C.), who organized the axiomatic system of geometry that has served as the model for many other scientific presentations since then; Eratosthenes (3d cent. B.C.), who made a remarkably accurate estimate of the size of the earth; and Aristarchus (3d cent. B.C.), who showed that the sun is larger than the earth and suggested a heliocentric model for the solar system. Archimedes (287–212 B.C.) worked at Syracuse, Sicily, and made contributions to mathematics and mechanics that were surprisingly modern in spirit. The second Alexandrian school flourished in the first centuries of the Christian era, after Rome had become the leading power in the Mediterranean; it included Ptolemy (2d cent. A.D.), who presented the geocentric system of the universe that was to dominate astronomical thought for 1400 years, and his contemporary Heron, who contributed to geometry and pneumatics. Galen (2d cent. A.D.) studied at Pergamum and Alexandria and later practiced medicine and made important anatomical studies at Rome. The Romans assimilated the more practical scientific accomplishments of the Greeks but added relatively little of their own. With the collapse of the Roman Empire in the 5th cent., science ceased to develop in the West.

Scientific Progress in China and India

In the East some accomplishments in science had been made paralleling the early developments in the West. However, although many societies were quick to adopt the fruits of technology, they tended to discourage the development of science on the classical model, which is based on the unbiased interaction of theory and experiment.

In China scientific theories were largely subservient to the main schools of philosophy and theology, particularly those of Confucianism, Taoism, and, later, Buddhism. The agricultural society, which endured until modern times, encouraged the separation of theory and experiment, the former falling to the educated, scholar classes and the latter to the lower, craftsman classes. Astronomy and mathematics were used for practical purposes, such as calendar determination, and there was little interest in theory in these fields. Theories of metallurgy, alchemy, and medicine were all tied to the prevailing religious and philosophical doctrines. Nevertheless, many important practical discoveries were made. Paper was invented in the 2d cent. A.D.; block printing was known in the 7th cent. A.D., with movable clay type by the 11th cent. and cast-metal type in Korea by the beginning of the 15th cent.; gunpowder was invented

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in the 3d cent. A.D. and firearms were in use by the 13th cent.; and the magnetic compass came into use during the 11th and 12th cent.

In India an alphabetic script was developed, as well as a numeral system based on place value and including a zero; this latter Hindu contribution was adopted by the Arabs and combined with their numeral system. Important Hindu scientists flourished in the 6th and 7th cent. A.D. and also in the 12th cent., making contributions to astronomy and mathematics. Many of these early Indian works showed the influence of Greek science, as in the geocentric systems of astronomy, or of Babylonian science, as in their development of algebraic methods for solving many problems.

Science in the Middle Ages

Muslim Preservation of Learning

With the eclipse of the Greek and Roman cultures, many of their works passed into the hands of the Muslims, who by the 7th and 8th cent. A.D. had extended their influence through much of the world surrounding the Mediterranean. All of the Greek works were translated into Arabic, and commentaries were added. Important developments from the East were also transmitted, and the Hindu numeral system was introduced, as well as the manufacture of paper and gunpowder, learned from the Chinese. Scholars gathered at cities like Damascus, Baghdad, and Cairo, at one end of the Mediterranean, and at Cordova and Toledo, in Spain, at the other end. Many astronomical observations were made at different locations, but there was little effort to improve or modify the Greek model of Ptolemy. In medicine important contributions were made by Al-Razi (Rhazes, 865–925) and Ibn-Sina (Avicenna, 980–1037), and in alchemy and pharmacology by Jabir (Geber, 9th cent.), whose work was expanded in the 10th cent. by a mystical sect aligned with the Sufi tradition. At Cairo, Al-Hazen (965–1038) studied optics, particularly the properties of lenses, and Maimonides (1135–1204), the Jewish philosopher, came there from Spain to practice medicine as physician to Saladin, the Sultan. The Arabs thus preserved the scientific works of the Greeks and added to them, and also introduced other contributions from Asia. This body of learning first began to be discovered by Europeans in the 11th cent.

The Craft Tradition and Early Empiricism in Europe

Certain technical innovations during the Early Middle Ages, e.g., development of the heavy plow, the windmill, and the magnetic compass, as well as improvements in ship design, had increased agricultural productivity and navigation and contributed to the rise of cities, with their craft guilds and universities. These changes were more pronounced in N Europe than in the south. The introduction of papermaking (12th cent.) and printing (1436–50) made possible the recording of craft traditions that had been handed down orally in previous centuries. This served to reduce the gap between the artisan classes and the scholar classes and contributed to the development of certain individuals who combined elements of both traditions—the artist-engineers such as Leonardo da Vinci, whose studies of flight and other technological problems were far beyond their time, and the artist-mathematicians, such as Albrecht Dürer, who examined the laws of perspective and wrote a textbook on geometry. Many artists came to study anatomy in detail.

Beginning in the 12th cent. the Arabic versions of Greek works were translated into Latin, an edition of Ptolemy's *Almagest* being translated at Toledo, and one of Aristotle's biological works in Sicily. Leonardo da Pisa (Fibonacci) presented some of the new Hindu-Arabic mathematics in the early 13th cent., and the medical and alchemical works were also translated. Also in the 13th cent., a trend toward
Empiricism was promoted by Roger Bacon and others, but this was short-lived. The dominant philosophy of science and other fields was the Christianized version of Aristotelian philosophy created by Albertus Magnus and Thomas Aquinas in the 13th cent. This view tended to treat scientific theories as extensions of philosophy and, for example, postulated the existence of angelic agents to account for the movements of the heavenly bodies. Even so, the craft traditions continued to develop in an independent manner, particularly medieval alchemy, and certain schools grew up that were not dominated by the main scholastic philosophy. The rebirth, or Renaissance, of learning spread throughout the West from the 14th to the 16th cent. and was further enhanced by the great voyages of discovery that began in the 15th cent.

The Scientific Revolution

Science, in the modern sense of the term, came into being in the 16th and 17th cent., with the merging of the craft tradition with scientific theory and the evolution of the scientific method. The feeling of dissatisfaction with the older philosophical approach had begun much earlier and had produced other results, such as the Protestant Reformation, but the revolution in science began with the work of Copernicus, Paracelsus, Vesalius, and others in the 16th cent. and reached full flower in the 17th cent.

The Rejection of Traditional Paradigms

Copernicus broke with the traditional belief, supported by both scientists and theologians, that the earth was at the center of the universe; his work, finally published in the year of his death (1543), proposed that the earth and other planets move in circular orbits around the sun. Paracelsus rejected the older alchemical and medical theories and founded iatrochemistry, the forerunner of modern medical chemistry. Andreas Vesalius, like Paracelsus, turned away from the medical teachings of Galen and other early authorities and through his anatomical studies helped to found modern medicine and biology. The philosophical basis for the scientific revolution was expressed in the writings of Francis Bacon, who urged that the experimental method plays the key role in the development of scientific theories, and of René Descartes, who held that the universe is a mechanical system that can be described in mathematical terms. The science of mechanics was established by Galileo, Simon Stevin, and others. The astronomical system of Copernicus gained support from the accurate observations of Tycho Brahe; the modification of Johannes Kepler, who used Tycho's work to show that the planetary orbits are elliptical rather than circular; and the writings of Galileo, who based his arguments on his own mechanical theories and observations with the newly invented telescope. Other instruments were also of major importance in the discoveries of the scientific revolution. The microscope extended human knowledge of living things just as the telescope had extended human knowledge of the heavens. The mechanical clock was perfected in the late 16th cent. by Christian Huygens, who also made improvements in the telescope, and thus events, both celestial and terrestrial, could be timed with greater precision—an essential factor in the development of the exact sciences, such as mechanics. The 17th cent. also saw the discovery of the circulation of the blood by William Harvey and the founding of modern chemistry by Robert Boyle.

Improved Communication of Scientific Knowledge

Another important factor in the scientific revolution was the rise of learned societies and academies in various countries. The earliest of these were in Italy and Germany and were short-lived. More influential were the Royal Society in England (1660) and the Academy of Sciences in France (1666). The former was a private institution in London and included such scientists as Robert Hooke, John Wallis, William
Brouncker, Thomas Sydenham, John Mayow, and Christopher Wren (who contributed not only to architecture but also to astronomy and anatomy); the latter, in Paris, was a government institution and included as a foreign member the Dutchman Huygens. In the 18th cent. important royal academies were established at Berlin (1700) and at St. Petersburg (1724). The societies and academies provided the principal opportunities for the publication and discussion of scientific results during and after the scientific revolution.

The Impact of Sir Isaac Newton

The greatest figure of the scientific revolution, Sir Isaac Newton, was a fellow of the Royal Society of England. To earlier discoveries in mechanics and astronomy he added many of his own and combined them in a single system for describing the workings of the universe; the system is based on the concept of gravitation and uses a new branch of mathematics, the calculus, that he invented for the purpose. All of this was set forth in his Philosophical Principles of Natural Philosophy (1687), the publication of which marked the beginning of the modern period of mechanics and astronomy. Newton also discovered that white light can be separated into a spectrum of colors, and he theorized that light is composed of tiny particles, or corpuscles, whose behavior can be described by the laws of mechanics. A rival theory, holding that light is composed of waves, was proposed by Huygens about the same time. However, Newton's influence was so great and the acceptance of the mechanistic philosophy of Descartes and others so widespread that the corpuscular philosophy was the dominant one for more than a century.

The Age of Classical Science

The history of science during the 18th and 19th cent. is largely the history of the individual branches as they developed into the traditional forms by which they are still recognized today.

The Evolution of Mathematics and Physics

In mathematics the calculus invented by Newton and G. W. Leibniz was developed by the Bernoullis, Leonhard Euler, and J. L. Lagrange into a powerful tool that was to be used not only in mathematics but also in physics and astronomy. Newtonian physics spread to the Continent slowly, its acceptance being hindered by adherents of the older Cartesian philosophy and by disputes over priority in the invention of the calculus. However, by the late 18th cent. it was firmly established. Other branches of physics came into their own during this period. The study of electricity expanded to include electric currents and magnetism, and it was finally synthesized in the theory of electromagnetic radiation of J. C. Maxwell in the second half of the 19th cent. These discoveries provided the foundation for the technological advances in communications and in other fields using electrical energy. The wave theory of light was revived at the beginning of the 19th cent. by Thomas Young and developed by others; Maxwell's theory showed that light was one form of electromagnetic energy. In the 18th cent. scientists thought that heat was a kind of fluid called caloric. However, by the early 19th cent. it became apparent that heat is a form of motion—the motion of the particles of which substances are composed. The classical theory of heat and thermodynamics was developed by J. P. Joule, Lord Kelvin, R. J. E. Clausius, and others, who showed the relation between heat and other forms of energy and formulated the law of conservation of energy. Maxwell, Ludwig Boltzmann and others developed statistical mechanics, which treats matter as a large aggregate of many particles and applies statistical methods to the prediction of its behavior.

Innovations in Chemistry

Chemistry became increasingly quantitative and experimental during the 18th cent. Joseph Priestley and...
other English scientists made a number of discoveries which served as the basis for A. L. Lavoisier's explanation of the role of oxygen in combustion and respiration. John Dalton proposed the modern version of the atomic theory in the early 19th cent. and Dmitri Mendeleev, in his periodic table, showed how the chemical elements described by the atomic theory could be arranged in a systematic way. In the mid-19th cent. R. W. Bunsen and G. R. Kirchhoff developed spectroscopy as a tool for chemical analysis. Also in the 19th cent., the synthesis of urea by Friedrich Wöhler (1828) established that organic substances are composed of the same kinds of atoms as inorganic substances, thus opening a new era in the study of organic chemistry.

**Advances in Astronomy**

Astronomy progressed on the theoretical level through the contributions to celestial mechanics of P. S. Laplace and others, and on the observational level through the work of many scientists. They included William Herschel, who built telescopes and discovered Uranus (1781), the first planet found in modern times, and his son John Herschel, who extended his father's observations to the Southern Hemisphere skies and pioneered in astrophotography, which in modern astronomy is the chief method of observation. Another tool that found important application in astronomy was the spectroscope. Increasingly astronomers made use of the instruments, techniques, and theories of other fields, particularly physics.

**Birth of Modern Geology**

Modern geology may be said to date from the work of James Hutton, who postulated (1785) that the geologic processes and forces that had shaped the earth were still in operation and could be observed directly. Georges Cuvier, the French naturalist, founded the field of comparative anatomy and applied its principles to geology in the study of the fossil remains of animals of the distant past, thus also founding the field of paleontology.

**New Ideas in Biology**

In biology Carolus Linnaeus instituted a system of classification of animals and plants, and improvements in this system helped scientists to arrange different forms of life according to complexity, suggesting to some that organisms may evolve from simple to complex forms. In the 19th cent. K. E. von Baer founded the field of embryology, the study of the earliest stages of different forms of life, and Matthias Schleiden and Theodor Schwann identified the cell as the basic unit of living matter. In medicine the treatment of disease was furthered by the introduction of smallpox vaccination by Edward Jenner and the recognition of the role of germs and viruses in causing diseases. A number of ways of reducing the growth of such organisms were introduced, including pasteurization of foods and antiseptic surgery. Anesthetics were introduced in the 19th cent. by several scientists, and, through chemistry, new medications were developed that aimed at treatment of specific ailments.

**Science and the Industrial Revolution**

Some of the greatest changes were in the area of technology, in the development of new sources of energy and their application in transportation, communications, and industry. Among the important aspects of the Industrial Revolution were the invention of the steam engine by James Watt and its use in factories, mines, ships, and railroad engines; the development of the internal-combustion engine and the companion growth of petroleum technology to provide fuel for it; the invention of many different kinds of agricultural machinery and the resulting enormous increase in productivity; the improvement of many metallurgical processes, particularly those involving iron and steel; and the invention of the electric
Revolution in Modern Science
The enormous growth of science during the classical period engendered an optimistic attitude on the part of many that all the major scientific discoveries had been made and that all that remained was the working out of minor details. Faith in the absolute truth of science was in some ways comparable to the faith of earlier centuries in such ancient authorities as Aristotle and Ptolemy. This optimism was shattered in the late 19th and early 20th cent. by a number of revolutionary discoveries. These in turn attracted increasing numbers of individuals into science, so that whereas a particular problem might have been studied by a single investigator a century ago, or by a small group of scientists a few decades ago, today such a problem is attacked by a virtual army of highly trained, technically proficient scholars. The growth of science in the 20th cent. has been unprecedented.

In much of modern science the idea of progressive change, or evolution, has been of fundamental importance. In addition to biological evolution, astronomers have been concerned with stellar and galactic evolution, and astrophysicists and chemists with nucleosynthesis, or the evolution of the chemical elements. The study of the evolution of the universe as a whole has involved such fields as non-Euclidean geometry and the general theory of relativity. Geologists have discovered that the continents are not static entities but are also evolving; according to the theory of plate tectonics, some continents are moving away from each other while others are moving closer together.

The Impact of Elementary Particles
Physics in particular was shaken to the core around the turn of the century. The atom had been presumed indestructible, but discoveries of X rays (1895), radioactivity (1896), and the electron (1897) could not be explained by the classical theories. The discovery of the atomic nucleus (1911) and of numerous subatomic particles in addition to the electron opened up the broad field of atomic and nuclear physics. Atoms were found to change not only by radioactive decay but also by more dramatic processes—nuclear fission and fusion—with the release of large amounts of energy; these discoveries found both military and peaceful applications.

Quantum Theory and the Theory of Relativity
The explanation of atomic structure required the abandonment of older, commonsense, classical notions of the nature of space, time, matter, and energy in favor of the new view of the quantum theory and the theory of relativity. The first of these two central theories of modern physics was developed by many scientists during the first three decades of the 20th cent.; the latter theory was chiefly the product of a single individual, Albert Einstein. These theories, particularly the quantum theory, revolutionized not only physics but also chemistry and other fields.

Advances in Chemistry
Knowledge of the structure of matter enabled chemists to synthesize a sweeping variety of substances, especially complex organic substances with important roles in life processes or with technological applications. Radioactive isotopes have been used as tracers in complicated chemical and biochemical reactions and have also found application in geological dating. Chemists and physicists have cooperated to create many new chemical elements, extending the periodic table beyond the naturally occurring elements.

Biology Becomes an Interdisciplinary Science
In biology the modern revolution began in the 19th cent. with the publication of Charles Darwin's theory of evolution (1859) and Gregor Mendel's theory of genetics, which was largely ignored until the end of the century. With the work of Hugo de Vries around the turn of the century biological evolution came to be interpreted in terms of mutations that result in a genetically distinct species; the survival of a given species was thus related to its ability to adapt to its environment through such mutations. The development of biochemistry and the recognition that most important biological processes take place at the molecular level led to the rapid growth of the field of molecular biology, with such fundamental results as the discovery of the structure of deoxyribonucleic acid (DNA), the molecule carrying the genetic code. Modern medicine has profited from this explosion of knowledge in biology and biochemistry, with new methods of treatment ranging from penicillin, insulin, and a vast array of other drugs to pacemakers for weak hearts and implantation of artificial or donated organs.

**The Abstraction of Mathematics**

In mathematics a movement toward the abstract, axiomatic approach began early in the 19th cent. with the discovery of two different types of non-Euclidean geometries and various abstract algebras, some of them noncommutative. While there has been a tendency to consolidate and unify under a few general concepts, such as those of group, set, and transformation, there has also been considerable research in the foundations of mathematics, with a close examination of the nature of these and other concepts and of the logical systems underlying mathematics.

**Astronomy beyond the Visual Spectrum**

In astronomy ever larger telescopes have assisted in the discovery that the sun is a rather ordinary star in a huge collection of stars, the Milky Way, which itself is only one of countless such collections, or galaxies, that in general are expanding away from each other. The study of remote objects, billions of light-years from the earth, has been carried out at all wavelengths of electromagnetic radiation, with some of the most notable results being made in radio astronomy, which has been used to map the Milky Way, study quasars, pulsars, and other unusual objects, and detect relatively complex organic molecules floating in space. The latter, coupled with the discovery of extrasolar planetary systems and possible microscopic fossils in meteorites of Martian origin, have raised new questions about the origin of life and the possible existence of intelligent life elsewhere in the universe.

**Modern Science and Technology**

The technological advances of modern science, which in the public mind are often identified with science itself, have affected virtually every aspect of life. The electronics industry, born in the early 20th cent., has advanced to the point where a complex device, such as a computer, that once might have filled an entire room can now be carried in an attaché case. The electronic computer has become one of the key tools of modern industry. Electronics has also been fundamental in developing new communications devices (radio, television, laser). In transportation there has been a similar leap of astounding range, from the automobile and the early airplane to the modern supersonic jet and the giant rocket that has taken astronauts to the moon. Perhaps the most overwhelming aspect of modern science is not its accomplishments but its magnitude in terms of money, equipment, numbers of workers, scope of activity, and impact on society as a whole. Never before in history has science played such a dominant role in so many areas.

**Promise and Problems of Modern Science**

Modern science holds out a number of promises, as well as a number of problems. In the foreseeable
future researchers may solve the riddle of life and create life itself in a test tube. Most diseases may be brought under control. Science is also working toward control over the environment, e.g., dispersing hurricanes before they can endanger life or property. New sources of energy are being developed, and these together with the capacity to manipulate alien environments may make life possible on the moon or other planets.

Among the challenges faced by modern science are practical ones such as the production and distribution of enough energy to meet increased demands and the elimination or reduction of pollutants in the environment. Some of these problems are political and sociological as well as scientific, as are such problems as control over nuclear and other forms of weapons (biological, chemical) and regulation of the use of computers and other electronic devices that may seriously infringe on individual privacy and freedom. Some have profound ethical implications, e.g., those associated with gene manipulation, organ transplantation, and the capacity to sustain life beyond the point at which it once would have ended. There are also philosophical problems raised by science, as in the uncertainty principle of the quantum theory, which places an absolute limit on the accuracy of certain physical measurements and thus on the predictions that may be made on the basis of such measurements; in the quantum theory itself, with its suggestion that at the atomic level much depends on chance; and in certain paradoxical discoveries in mathematics and mathematical logic. Even a detailed account of the history of science cannot be complete, for scientific activity is not isolated but takes place within a larger matrix that also includes, for example, political and social events, developments in the arts, philosophy, and religion, and forces within the life of the individual scientist. In other words, science is a human activity and is affected by all that affects human beings in any way.

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