Science

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Science[nb 1][1]:58[2] is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe.[nb 2]

Contemporary science is typically subdivided into the natural sciences, which study the material universe; the social sciences, which study people and societies; and the formal sciences, which study logic and mathematics. The formal sciences are often excluded as they do not depend on empirical observations.[3] Disciplines which use science, like engineering and medicine, may also be considered to be applied sciences.[4]

From classical antiquity through the 19th century, science as a type of knowledge was more closely linked to philosophy than it is now, and in the Western world the term "natural philosophy" once encompassed fields of study that are today associated with science, such as astronomy, medicine, and physics.[5][nb 3] However, during the Islamic Golden Age foundations for the scientific method were laid by Ibn al-Haytham in his *Book of Optics*.[6][7][8][9][10] While the classification of the material world by the ancient Indians and Greeks into air, earth, fire and water was more philosophical, medieval Middle Easterns used practical and experimental observation to classify materials.[11]

In the 17th and 18th centuries, scientists increasingly sought to formulate knowledge in terms of physical laws. Over the course of the 19th century, the word "science" became increasingly associated with the scientific method itself as a disciplined way to study the natural world. It was during this time that scientific disciplines such as biology, chemistry, and physics reached their modern shapes. That same time period also included the origin of the terms "scientist" and "scientific community," the founding of scientific institutions, and the increasing significance of their interactions with society and other aspects of culture.[12][13]

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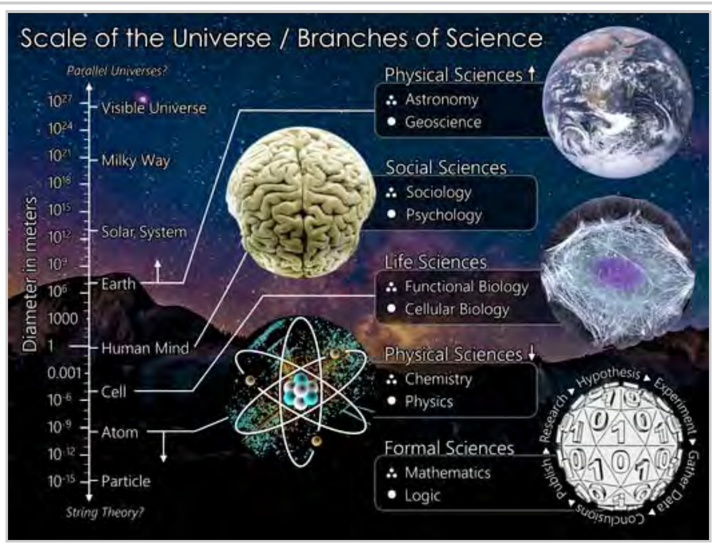


The scale of the universe mapped to the branches of science, with formal sciences as the foundation.[14]: Vol.1, Chaps.1,2,&3.

History

Science in a broad sense existed before the modern era and in many historical civilizations.[nb 4] Modern science is distinct in its approach and successful in its results, so it now defines what science is in the strictest sense of the term.[15]

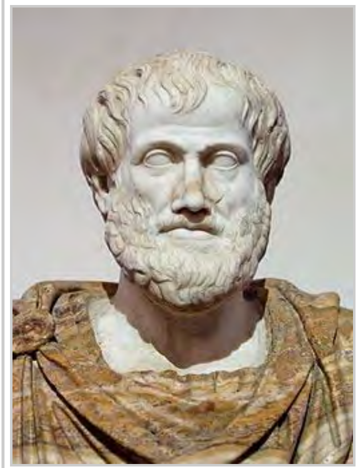
Science in its original sense was a word for a type of knowledge rather than a specialized word for the pursuit of such knowledge. In particular, it was the type of knowledge which people can communicate to each other and share. For example, knowledge about the working of natural things was gathered long before recorded history and led to the development of complex abstract thought. This is shown by the construction of complex calendars, techniques for making poisonous plants edible, and buildings such as the Pyramids. However, no consistent conscientious distinction was made between knowledge of such things, which are true in every community, and other types of communal knowledge, such as mythologies and legal systems.

Antiquity

Before the invention or discovery of the concept of "nature" (ancient Greek *phusis*) by the Pre-Socratic philosophers, the same words tend to be used to describe the *natural* "way" in which a plant grows,[16] and the "way" in which, for example, one tribe worships a particular god. For this reason, it is claimed these men were the first philosophers in the strict sense, and also the first people to clearly distinguish "nature" and "convention."[17]: p.209 Science was therefore distinguished as the knowledge of nature and things which are true for every community, and the name of the specialized pursuit of such knowledge was *philosophy* — the realm of the first philosopher-physicists. They were mainly speculators or theorists, particularly interested in

Maize, known in some English-speaking countries as corn, is a large grain plant domesticated by indigenous peoples in Mesoamerica in prehistoric times

astronomy. In contrast, trying to use knowledge of nature to imitate nature (artifice or technology, Greek *technē*) was seen by classical scientists as a more appropriate interest for lower class artisans.[18] A clear-cut distinction between formal (*eon*) and empirical science (*doxa*) was made by the pre-Socratic philosopher Parmenides (fl. late sixth or early fifth century BCE). Although his work *Peri Physeos* (*On Nature*) is a poem, it may be viewed as an epistemological essay on method in natural science. Parmenides' ἐὸν may refer to a formal system or calculus which can describe nature more precisely than natural languages. "Physis" may be identical to ἐὸν.[19]



Aristotle, 384 BCE – 322 BCE, one of the early figures in the development of the scientific method[20]

A major turning point in the history of early philosophical science was the controversial but successful attempt by Socrates to apply philosophy to the study of human things, including human nature, the nature of political communities, and human knowledge itself. He criticized the older type of study of physics as too purely speculative and lacking in self-criticism. He was particularly concerned that some of the early physicists treated nature as if it could be assumed that it had no intelligent order, explaining things merely in terms of motion and matter. The study of human things had been the realm of mythology and tradition, however, so Socrates was executed as a heretic.[21]: 30e Aristotle later created a less controversial systematic programme of Socratic philosophy which was teleological and human-centred. He rejected many of the conclusions of earlier scientists. For example, in his physics, the sun goes around the earth, and many things have it as part of their nature that they are for humans. Each thing has a formal cause and final cause and a role in the rational cosmic order. Motion and change is described as the actualization of potentials already in things, according to what types of things they are. While the Socratics insisted that philosophy should be used to consider the practical question of the best way to live for a human being (a study Aristotle divided into ethics and political philosophy), they did not argue for any other types of applied science.

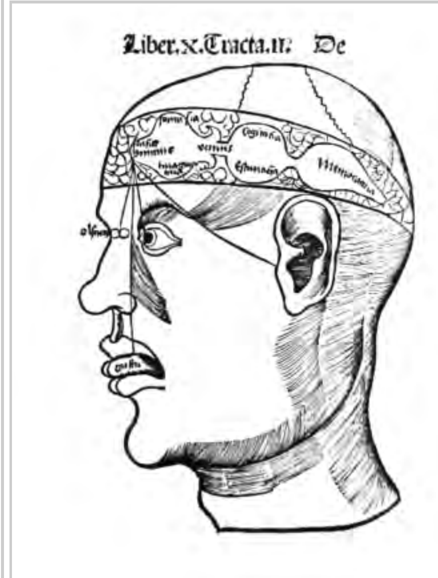
Aristotle maintained the sharp distinction between science and the practical knowledge of artisans, treating theoretical speculation as the highest type of human activity, practical thinking about good living as something less lofty, and the knowledge of artisans as something only suitable for the lower classes. In contrast to modern science, Aristotle's influential emphasis was upon the "theoretical" steps of deducing universal rules from raw data and did not treat the gathering of experience and raw data as part of science itself.[nb 5]

Medieval science

During late antiquity and the early Middle Ages, the Aristotelian approach to inquiries on natural phenomena was used. Some ancient knowledge was lost, or in some cases kept in obscurity, during the fall of the Roman Empire and periodic political struggles. However, the general fields of science (or "natural philosophy" as it was called) and much of the general knowledge from the ancient world remained preserved through the works of the early Latin encyclopedists like Isidore of Seville. In the Byzantine empire, many Greek science texts were preserved in Syriac translations done by groups such as the Nestorians and Monophysites.[24] Many of these were later on translated into Arabic under the Caliphate, during which many types of classical learning were preserved and in some cases improved upon.[24][nb 7]

Ibn al-Haytham (Alhazen), 965–1039 Basra, Buyid Emirate. The Muslim scholar who is considered by some to be the father of modern scientific methodology due to his emphasis on experimental data and reproducibility of its results.[23][nb 6]

The House of Wisdom was established in Abbasid-era Baghdad, Iraq.[25] It is considered to have been a major intellectual center during the Islamic Golden Age, where Muslim scholars such as al-Kindi and Ibn Sahl in Baghdad and Ibn al-Haytham in Cairo flourished from the ninth to the thirteenth centuries until the Mongol sack of Baghdad. Ibn al-Haytham, known later to the West as Alhazen, furthered the Aristotelian viewpoint[26] by emphasizing experimental data.[nb 8][27]



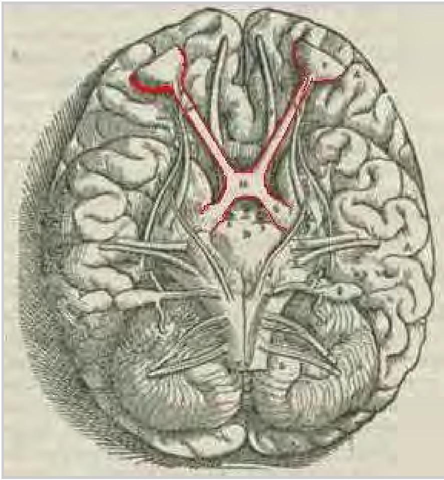
De potentiis anime sensitive, Gregor Reisch (1504) *Margarita philosophica*. Medieval science postulated a ventricle of the brain as the location for our common sense,[22] where the forms from our sensory systems commingled.

In the later medieval period, as demand for translations grew (for example, from the Toledo School of Translators), western Europeans began collecting texts written not only in Latin, but also Latin translations from Greek, Arabic, and Hebrew. In particular, the texts of Aristotle, Ptolemy,[nb 9] and Euclid, preserved in the Houses of Wisdom, were sought amongst Catholic scholars. In Europe, the Latin translation of Alhazen's *Book of Optics* directly influenced Roger Bacon (13th century) in England, who argued for more experimental science as demonstrated by Alhazen. By the late Middle Ages, a synthesis of Catholicism and Aristotelianism known as Scholasticism was flourishing in western Europe, which had become a new geographic center of science, but all aspects of scholasticism were criticized in the 15th and 16th centuries.

Renaissance and early modern science

Medieval science carried on the views of the Hellenist civilization of Socrates, Plato, and Aristotle, as shown by Alhazen's lost work *A Book in which I have Summarized the Science of Optics from the Two Books of Euclid and Ptolemy, to which I have added the Notions of the First Discourse which is Missing from Ptolemy's Book* from Ibn Abi Usaibia's catalog, as cited in (Smith 2001).:**91**(vol.1),p.xv Alhazen conclusively disproved Ptolemy's theory of vision, but he retained Aristotle's ontology; Roger Bacon, Vitello, and John Peckham each built up a scholastic ontology upon Alhazen's *Book of Optics*, a causal chain beginning with sensation, perception, and finally apperception of the individual and universal forms of Aristotle.[28] This model of vision became known as Perspectivism, which was exploited and studied by the artists of the Renaissance.

A. Mark Smith points out the perspectivist theory of vision, which pivots on three of Aristotle's four causes, formal, material, and final, "is remarkably economical, reasonable, and coherent."[30] Although Alhacen knew that a scene imaged through an aperture is inverted, he argued that vision is about perception. This was overturned by Kepler,[31]:p.102 who modelled the eye as a water-filled glass sphere with an aperture in front of it to model the entrance pupil. He found that all the light from a single point of the scene was imaged at a single point at the back of the glass sphere. The optical chain ends on the retina at the back of the eye and the image is inverted.[nb 10]



Galen (129–c. 216) noted the optic chiasm is X-shaped. (Engraving from Vesalius, 1543)

Galileo Galilei, father of modern science.[29]: Vol. 24, No. 1, p. 36

Copernicus formulated a heliocentric model of the solar system unlike the geocentric model of Ptolemy's *Almagest*.

Galileo made innovative use of experiment and mathematics. However, he became persecuted after Pope Urban VIII blessed Galileo to write about the Copernican system. Galileo had used arguments from the Pope and put them in the voice of the simpleton in the work "Dialogue Concerning the Two Chief World Systems," which greatly offended him.[32]

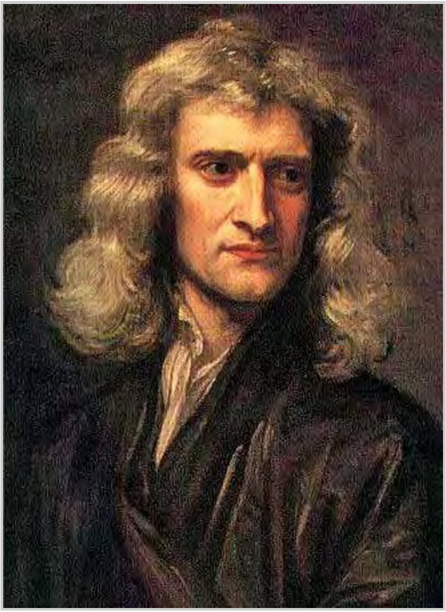
In Northern Europe, the new technology of the printing press was widely used to publish many arguments, including some that disagreed widely with contemporary ideas of nature. René Descartes and Francis Bacon published philosophical arguments in favor of a new type of non-Aristotelian science. Descartes argued that mathematics could be used in order to study nature, as Galileo had done, and Bacon emphasized the importance of experiment over contemplation. Bacon questioned the Aristotelian concepts of formal cause and final cause, and promoted the idea that science should study the laws of "simple" natures, such as heat, rather than assuming that there is any specific nature, or "formal cause," of each complex type of thing. This new modern science began to see itself as describing "laws of nature." This updated approach to studies in nature was seen as mechanistic. Bacon also argued that science should aim for the first time at practical inventions for the improvement of all human life.

Age of Enlightenment

In the 17th and 18th centuries, the project of modernity, as had been promoted by Bacon and Descartes, led to rapid scientific advance and the successful development of a new type of natural science, mathematical, methodically experimental, and deliberately innovative. Newton and Leibniz succeeded in developing a new physics, now referred to as classical mechanics, which could be confirmed by experiment and explained using mathematics. Leibniz also incorporated terms from Aristotelian physics, but now being used in a new non-teleological way, for example, "energy" and "potential" (modern versions of Aristotelian "*energeia* and *potentia*"). In the style of Bacon, he assumed that different types of things all work according to the same general laws of nature, with no special formal or final causes for each type of thing. It is during this period that the word "science" gradually became more commonly used to refer to a *type of pursuit* of a type of knowledge, especially knowledge of nature — coming close in meaning to the old term "natural philosophy."

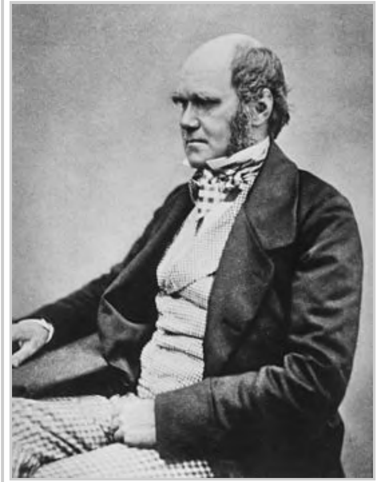
19th century

Both John Herschel and William Whewell systematized methodology: the latter coined the term scientist.[33] When Charles Darwin published *On the Origin of Species* he established evolution as the prevailing explanation of biological complexity. His theory of natural selection provided a natural explanation of how species originated, but this only gained wide acceptance a century later. John Dalton developed the idea of



Isaac Newton, shown here in a 1689 portrait, made seminal contributions to classical mechanics, gravity, and optics. Newton shares credit with Gottfried Leibniz for the development of calculus.

atoms. The laws of thermodynamics and the electromagnetic theory were also established in the 19th century, which raised new questions which could not easily be answered using Newton's framework. The phenomena that would allow the deconstruction of the atom were discovered in the last decade of the 19th century: the discovery of X-rays inspired the discovery of radioactivity. In the next year came the discovery of the first subatomic particle, the electron.



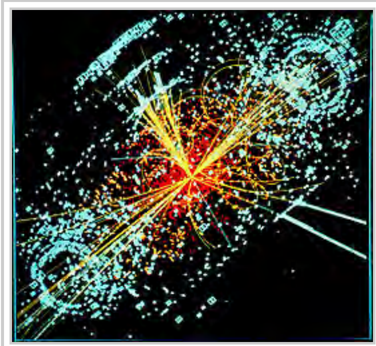
Charles Darwin in 1854, by then working towards publication of *On the Origin of Species*

20th century and beyond

Einstein's theory of relativity and the development of quantum mechanics led to the replacement of classical mechanics with a new physics which contains two parts that describe different types of events in nature.

Combustion and chemical reactions were studied by Michael Faraday and reported in his lectures before the Royal Institution: *The Chemical History of a Candle*, 1861

In the first half of the century, the development of artificial fertilizer made global human population growth possible. At the same time, the structure of the atom and its nucleus was discovered, leading to the release of "atomic energy" (nuclear power). In addition, the extensive use of scientific innovation stimulated by the wars of this century led to antibiotics and increased life expectancy, revolutions in transportation (automobiles and aircraft), the development of ICBMs, a space race, and a nuclear arms race, all giving a widespread public appreciation of the importance of modern science.



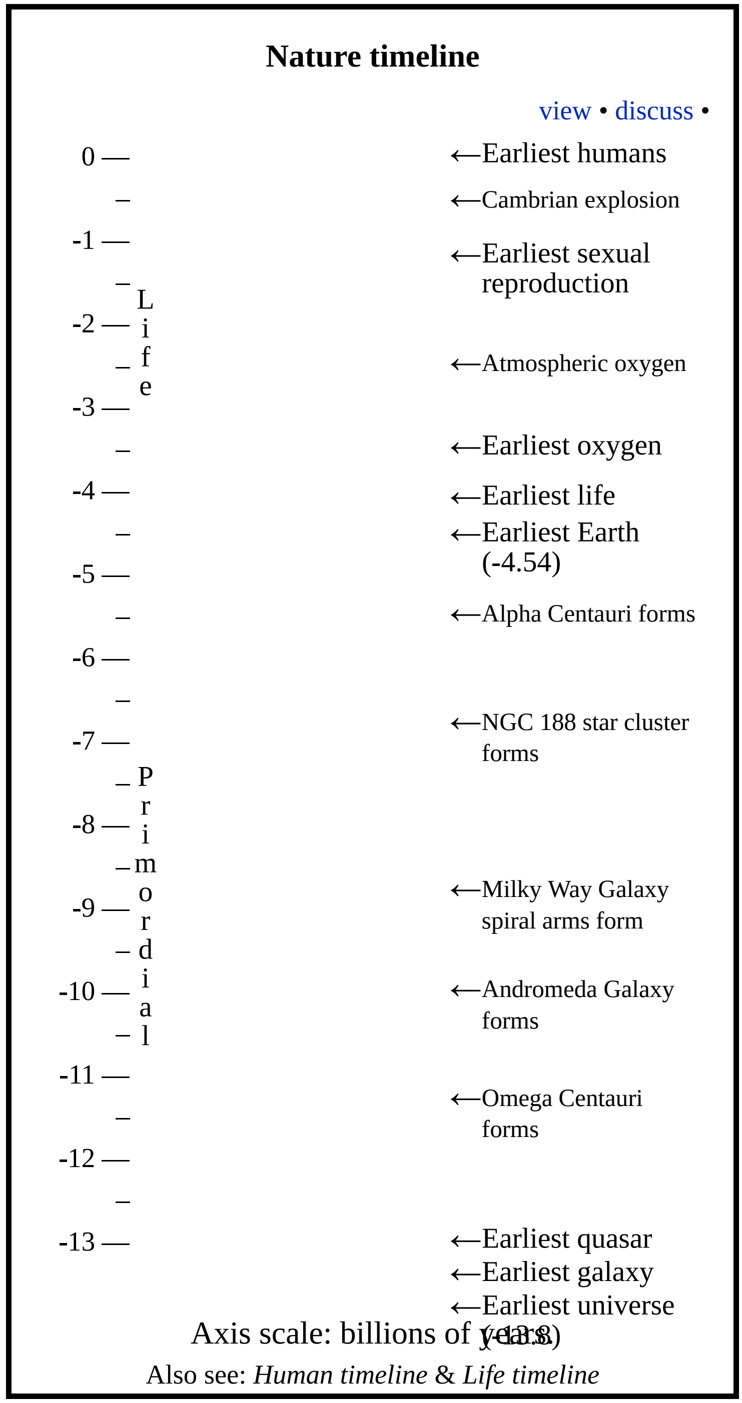
A simulated event in the CMS detector of the Large Hadron Collider, featuring a possible appearance of the Higgs boson

Widespread use of integrated circuits in the last quarter of the 20th century combined with communications satellites led to a revolution in information technology and the rise of the global internet and mobile computing, including smartphones.

More recently, it has been argued that the ultimate purpose of science is to make sense of human beings and our nature. For example, in his book *Consilience*, E. O. Wilson said: "The human condition is the most important frontier of the natural sciences." [1]:334

Scientific method

The scientific method seeks to explain the events of nature in a reproducible way.[nb 11] An explanatory thought experiment or hypothesis is put forward as explanation using principles such as parsimony (also known as "Occam's Razor") and are generally expected to seek consilience—fitting well with other accepted facts related to the phenomena.[1] This new explanation is used to make falsifiable predictions that are testable by experiment or observation. The predictions are to be posted before a confirming experiment or observation is sought, as proof that no tampering has occurred. Disproof of a prediction is evidence of progress.[nb 12][nb 13] This is done partly through observation of natural phenomena, but also through experimentation that tries to simulate natural events under controlled conditions as appropriate to the discipline (in the observational sciences, such as astronomy or geology, a predicted observation might take the place of a controlled experiment). Experimentation is especially important in science to help establish causal relationships (to avoid the correlation fallacy).



When a hypothesis proves unsatisfactory, it is either modified or discarded.[34] If the hypothesis survived testing, it may become adopted into the framework of a scientific theory, a logically reasoned, self-consistent model or framework for describing the behavior of certain natural phenomena. A theory typically describes the behavior of much broader sets of phenomena than a hypothesis; commonly, a large number of hypotheses can be logically bound together by a single theory. Thus a theory is a hypothesis explaining various other hypotheses. In that vein, theories are formulated according to most of the same scientific principles as hypotheses. In addition to testing hypotheses, scientists may also generate a model, an attempt to describe or depict the phenomenon in terms of a logical, physical or mathematical representation and to generate new hypotheses that can be tested, based on observable phenomena.[35]

While performing experiments to test hypotheses, scientists may have a preference for one outcome over another, and so it is important to ensure that science as a whole can eliminate this bias.[36][37] This can be achieved by careful experimental design, transparency, and a thorough peer review process of the experimental results as well as any conclusions.[38][39] After the results of an experiment are announced or published, it is normal practice for independent researchers to double-check how the research was performed, and to follow up by performing similar experiments to determine how dependable the results might be.[40] Taken in its entirety, the scientific method allows for highly creative problem solving while minimizing any effects of subjective bias on the part of its users (especially the confirmation bias).[41]

Mathematics and formal sciences

Mathematics is essential to the sciences. One important function of mathematics in science is the role it plays in the expression of scientific models. Observing and collecting measurements, as well as hypothesizing and predicting, often require extensive use of mathematics. For example, arithmetic, algebra, geometry, trigonometry, and calculus are all essential to physics. Virtually every branch of mathematics has applications in science, including "pure" areas such as number theory and topology.

Statistical methods, which are mathematical techniques for summarizing and analyzing data, allow scientists to assess the level of reliability and the range of variation in experimental results. Statistical analysis plays a fundamental role in many areas of both the natural sciences and social sciences.

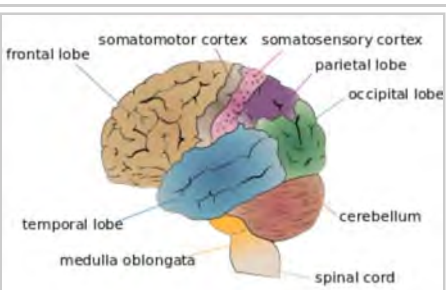
Computational science applies computing power to simulate real-world situations, enabling a better understanding of scientific problems than formal mathematics alone can achieve. According to the Society for Industrial and Applied Mathematics, computation is now as important as theory and experiment in advancing scientific knowledge.[42]

Whether mathematics itself is properly classified as science has been a matter of some debate. Some thinkers see mathematicians as scientists, regarding physical experiments as inessential or mathematical proofs as equivalent to experiments. Others do not see mathematics as a science because it does not require an experimental test of its theories and hypotheses. Mathematical theorems and formulas are obtained by logical derivations which presume axiomatic systems, rather than the combination of empirical observation and logical reasoning that has come to be known as the scientific method. In general, mathematics is classified as formal science, while natural and social sciences are classified as empirical sciences.[43]

Scientific community

The scientific community is the group of all interacting scientists. It includes many sub-communities working on particular scientific fields, and within particular institutions; interdisciplinary and cross-institutional activities are also significant.

Branches and fields



The somatosensory system is located throughout our bodies but is integrated in the brain.

Scientific fields are commonly divided into two major groups: natural sciences, which study natural phenomena (including biological life), and social sciences, which study human behavior and societies. These are both empirical sciences, which means their knowledge must be based on observable phenomena and capable of being tested for its validity by other researchers working under the same conditions.[44] There are also related disciplines that are grouped into interdisciplinary applied sciences, such as engineering and medicine. Within these categories are specialized scientific fields that can include parts of other scientific disciplines but often possess their own nomenclature and expertise.[45]

Mathematics, which is classified as a formal science,[46][47] has both similarities and differences with the empirical sciences (the natural and social sciences). It is similar to empirical sciences in that it involves an objective, careful and systematic study of an area of knowledge; it is different because of its method of verifying its knowledge, using *a priori* rather than empirical methods.[48] The formal sciences, which also include statistics and logic, are vital to the empirical sciences. Major advances in formal science have often led to major advances in the empirical sciences. The formal sciences are essential in the formation of hypotheses, theories, and laws,[49] both in discovering and describing how things work (natural sciences) and how people think and act (social sciences).

Apart from its broad meaning, the word "science" sometimes may specifically refer to fundamental sciences (maths and natural sciences) alone. Science schools or faculties within many institutions are separate from those for medicine or engineering, each of which is an applied science.

Institutions

Learned societies for the communication and promotion of scientific thought and experimentation have existed since the Renaissance period.[50] The oldest surviving institution is the Italian *Accademia dei Lincei* which was established in 1603.[51] The respective National Academies of Science are distinguished institutions that exist in a number of countries, beginning with the British Royal Society in 1660[52] and the French *Académie des Sciences* in 1666.[53]

International scientific organizations, such as the International Council for Science, have since been formed to promote cooperation between the scientific communities of different nations. Many governments have dedicated agencies to support scientific research. Prominent scientific organizations include the National Science Foundation in the U.S., the National Scientific and Technical Research Council in Argentina, CSIRO in Australia, Centre national de la recherche scientifique in France, the Max Planck Society and Deutsche Forschungsgemeinschaft in Germany, and CSIC in Spain.

Literature

An enormous range of scientific literature is published.[54] Scientific journals communicate and document the results of research carried out in universities and various other research institutions, serving as an archival record of science. The first scientific journals, *Journal des Sçavans* followed by the *Philosophical Transactions*, began publication in 1665. Since that time the total number of active periodicals has steadily increased. In 1981, one estimate for the number of scientific and technical journals in publication was 11,500.[55] The United States National Library of Medicine currently indexes 5,516 journals that contain articles on topics related to the life sciences. Although the journals are in 39 languages, 91 percent of the indexed articles are published in English.[56]

Most scientific journals cover a single scientific field and publish the research within that field; the research is normally expressed in the form of a scientific paper. Science has become so pervasive in modern societies that it is generally considered necessary to communicate the achievements, news, and ambitions of scientists to a wider populace.

Science magazines such as *New Scientist*, *Science & Vie*, and *Scientific American* cater to the needs of a much wider readership and provide a non-technical summary of popular areas of research, including notable discoveries and advances in certain fields of research. Science books engage the interest of many more people. Tangentially, the science fiction genre, primarily fantastic in nature, engages the public imagination and transmits the ideas, if not the methods, of science.

Recent efforts to intensify or develop links between science and non-scientific disciplines such as literature or more specifically, poetry, include the *Creative Writing Science* resource developed through the Royal Literary Fund.[57]

Science and society

Women in science

Marie Curie was the first person to be awarded two Nobel Prizes, Physics in 1903 and Chemistry in 1911[58]

Science has historically been a male-dominated field, with some notable exceptions.[nb 14] Women faced considerable discrimination in science, much as they did in other areas of male-dominated societies, such as frequently being passed over for job opportunities and denied credit for their work.[nb 15] For example, Christine Ladd (1847–1930) was able to enter a PhD program as "C. Ladd"; Christine "Kitty" Ladd completed the requirements in 1882, but was awarded her degree only in 1926, after a career which spanned the algebra of logic (see truth table), color vision, and psychology. Her work preceded notable researchers like Ludwig Wittgenstein and Charles Sanders Peirce. The achievements of women in science have been attributed to their defiance of their traditional role as laborers within the domestic sphere.[59]

In the late 20th century, active recruitment of women and elimination of institutional discrimination on the basis of sex greatly increased the number of women scientists, but large gender disparities remain in some fields; over half of new biologists are female, while 80% of PhDs in physics are given to men. Feminists claim this is the result of culture rather than an innate difference between the sexes, and some experiments have shown that parents challenge and explain more to boys than girls, asking them to reflect more deeply and logically.[60]: 258–261. In the early part of the 21st century, in America, women earned 50.3% bachelor's degrees, 45.6% master's degrees, and 40.7% of PhDs in science and engineering fields with women earning more than half of the degrees in three fields: Psychology (about 70%), Social Sciences (about 50%), and Biology (about 50-60%). However, when it comes to the Physical Sciences, Geosciences, Math, Engineering, and Computer Science, women earned less than half the degrees.[61] However, lifestyle choice also plays a major role in female engagement in science; women with young children are 28% less likely to take tenure-track positions due to work-life balance issues,[62] and female graduate students' interest in careers in research declines dramatically over the course of graduate school, whereas that of their male colleagues remains unchanged.[63]

Science policy

Science policy is an area of public policy concerned with the policies that affect the conduct of the scientific enterprise, including research funding, often in pursuance of other national policy goals such as technological innovation to promote commercial product development, weapons development, health care and environmental monitoring. Science policy also refers to the act of applying scientific knowledge and consensus to the development of public policies. Science policy thus deals with the entire domain of issues that involve the natural sciences. In accordance with public policy being concerned about the well-being of its citizens, science policy's goal is to consider how science and technology can best serve the public.

President Clinton meets the 1998 U.S. Nobel Prize winners in the White House

State policy has influenced the funding of public works and science for thousands of years, dating at least from the time of the Mohists, who inspired the study of logic during the period of the Hundred Schools of Thought, and the study of defensive fortifications during the Warring States period in China. In Great Britain, governmental approval of the Royal Society in the 17th century recognized a scientific community which exists to this day. The professionalization of science, begun in the 19th century, was partly enabled by the creation of scientific organizations such as the National Academy of Sciences, the Kaiser Wilhelm Institute, and state funding of universities of their respective nations. Public policy can directly affect the funding of capital equipment and intellectual infrastructure for industrial research by providing tax incentives to those organizations that fund research. Vannevar Bush, director of the Office of Scientific Research and Development for the United States government, the forerunner of the National Science Foundation, wrote in July 1945 that "Science is a proper concern of government."[64]

Science and technology research is often funded through a competitive process in which potential research projects are evaluated and only the most promising receive funding. Such processes, which are run by government, corporations, or foundations, allocate scarce funds. Total research funding in most developed countries is between 1.5% and 3% of GDP.[65] In the OECD, around two-thirds of research and development in scientific and technical fields is carried out by industry, and 20% and 10% respectively by universities and government. The government funding proportion in certain industries is higher, and it dominates research in social science and humanities. Similarly, with some exceptions (e.g. biotechnology) government provides the bulk of the funds for basic scientific research. In commercial research and development, all but the most research-oriented corporations focus more heavily on near-term commercialisation possibilities rather than "blue-sky" ideas or technologies (such as nuclear fusion).

Media perspectives

The mass media face a number of pressures that can prevent them from accurately depicting competing scientific claims in terms of their credibility within the scientific community as a whole. Determining how much weight to give different sides in a scientific debate may require considerable expertise regarding the matter.[66] Few journalists have real scientific knowledge, and even beat reporters who know a great deal about certain scientific issues may be ignorant about other scientific issues that they are suddenly asked to cover.[67][68]

Political usage

Many issues damage the relationship of science to the media and the use of science and scientific arguments by politicians. As a very broad generalisation, many politicians seek certainties and *facts* whilst scientists typically offer probabilities and caveats. However, politicians' ability to be heard in the mass media frequently distorts the scientific understanding by the public. Examples in the United Kingdom include the controversy over the MMR inoculation, and the 1988 forced resignation of a Government Minister, Edwina Currie, for revealing the high probability that battery farmed eggs were contaminated with *Salmonella*.[69]

John Horgan, Chris Mooney, and researchers from the US and Canada have described Scientific Certainty Argumentation Methods (SCAMs), where an organization or think tank makes it their only goal to cast doubt on supported science because it conflicts with political agendas.[70][71][72][73] Hank Campbell and microbiologist Alex Berezow have described "feel-good fallacies" used in politics, especially on the left, where politicians frame their positions in a way that makes people feel good about supporting certain policies even when scientific evidence shows there is no need to worry or there is no need for dramatic change on current programs.[74]: Vol. **78**, No. 1. 2–38

Science and the public

Various activities are developed to facilitate communication between the general public and science/scientists, such as science outreach, public awareness of science, science communication, science festivals, citizen science, science journalism, public science, and popular science. See Science and the public for related concepts.

Science is represented by the 'S' in STEM fields.

Philosophy of science

Working scientists usually take for granted a set of basic assumptions that are needed to justify the scientific method: (1) that there is an objective reality shared by all rational observers; (2) that this objective reality is governed by natural laws; (3) that these laws can be discovered by means of systematic observation and experimentation.[15] Philosophy of science seeks a deep understanding of what these underlying assumptions mean and whether they are valid.

The belief that scientific theories should and do represent metaphysical reality is known as realism. It can be contrasted with anti-realism, the view that the success of science does not depend on it being accurate about unobservable entities such as electrons. One form of anti-realism is idealism, the belief that the mind or consciousness is the most basic essence, and that each mind generates its own reality.[nb 16] In an idealistic world view, what is true for one mind need not be true for other minds.


The Sand Reckoner is a work by Archimedes in which he sets out to determine an upper bound for the number of grains of sand that fit into the universe. In order to do this, he had to estimate the size of the universe according to the contemporary model, and invent a way to analyze extremely large numbers.

There are different schools of thought in philosophy of science. The most popular position is empiricism,[nb 17] which holds that knowledge is created by a process involving observation and that scientific theories are the result of generalizations from such observations.[75] Empiricism generally encompasses inductivism, a position that tries to explain the way general theories can be justified by the finite number of observations humans can make and hence the finite amount of empirical evidence available to confirm scientific theories. This is necessary because the number of predictions those theories make is infinite, which means that they cannot be known from the finite amount of evidence using deductive logic only. Many versions of empiricism exist, with the predominant ones being Bayesianism[76] and the hypothetico-deductive method.[77]:p236

Empiricism has stood in contrast to rationalism, the position originally associated with Descartes, which holds that knowledge is created by the human intellect, not by observation.[77]:p20 Critical rationalism is a contrasting 20th-century approach to science, first defined by Austrian-British philosopher Karl Popper. Popper rejected the way that empiricism describes the connection between theory and observation. He claimed that theories are not generated by observation, but that observation is made in the light of theories and that the only way a theory can be affected by observation is when it comes in conflict with it.[77]:pp63–7 Popper proposed replacing verifiability with falsifiability as the landmark of scientific theories and replacing induction with falsification as the empirical method.[77]:p68 Popper further claimed that there is actually only one universal method, not specific to science: the negative method of criticism, trial and error.[78] It covers all products of the human mind, including science, mathematics, philosophy, and art.[79]

Another approach, instrumentalism, colloquially termed "shut up and multiply,"[80] emphasizes the utility of theories as instruments for explaining and predicting phenomena.[81] It views scientific theories as black boxes with only their input (initial conditions) and output (predictions) being relevant. Consequences, theoretical entities, and logical structure are claimed to be something that should simply be ignored and that scientists shouldn't make a fuss about (see interpretations of quantum mechanics). Close to instrumentalism is constructive empiricism, according to which the main criterion for the success of a scientific theory is whether what it says about observable entities is true.

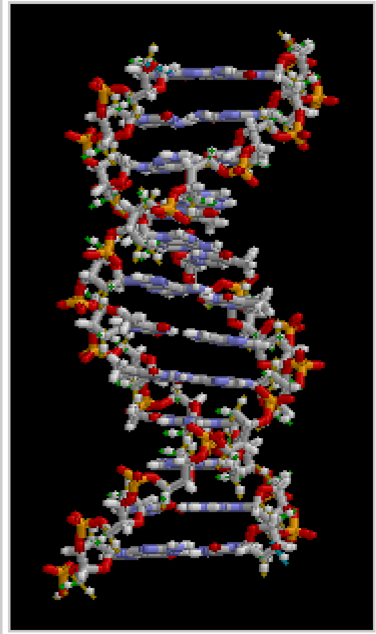
Paul Feyerabend advanced the idea of epistemological anarchism, which holds that there are no useful and exception-free methodological rules governing the progress of science or the growth of knowledge and that the idea that science can or should operate according to universal and fixed rules are unrealistic, pernicious and detrimental to science itself.[82] Feyerabend advocates treating science as an ideology alongside others such as religion, magic, and mythology, and considers the dominance of science in society authoritarian and unjustified. He also contended (along with Imre Lakatos) that the demarcation problem of distinguishing science from pseudoscience on objective grounds is not possible and thus fatal to the notion of science running according to fixed, universal rules.[82] Feyerabend also stated that science does not have evidence for its philosophical precepts, particularly the notion of uniformity of law and process across time and space.[83]

Finally, another approach often cited in debates of scientific skepticism against controversial movements like "creation science" is methodological naturalism. Its main point is that a difference between natural and supernatural explanations should be made and that science should be restricted methodologically to natural explanations.[nb 18] That the restriction is merely methodological (rather than ontological) means that science should not consider supernatural explanations itself, but should not claim them to be wrong either. Instead, supernatural explanations should be left a matter of personal belief outside the scope of science. Methodological naturalism maintains that proper science requires strict adherence to empirical study and independent verification as a process for properly developing and evaluating explanations for observable phenomena.[84] The absence of these standards, arguments from authority, biased observational studies and other common fallacies are frequently cited by supporters of methodological naturalism as characteristic of the non-science they criticize.

Certainty and science

A scientific theory is empirical[nb 17][85] and is always open to falsification if new evidence is presented. That is, no theory is ever considered strictly certain as science accepts the concept of fallibilism.[nb 19] The philosopher of science Karl Popper sharply distinguished truth from certainty. He wrote that scientific knowledge "consists in the search for truth," but it "is not the search for certainty ... All human knowledge is fallible and therefore uncertain."[86]:p4

New scientific knowledge rarely results in vast changes in our understanding. According to psychologist Keith Stanovich, it may be the media's overuse of words like "breakthrough" that leads the public to imagine that science is constantly proving everything it thought was true to be false.[87]:119–138 While there are such famous cases as the theory of relativity that required a complete reconceptualization, these are extreme exceptions. Knowledge in science is gained by a gradual synthesis of information from different experiments by various researchers across different branches of science; it is more like a climb than a leap.[87]:123 Theories vary in the extent to which they have been tested and verified, as well as their acceptance in the scientific community.[nb 20] For example, heliocentric theory, the theory of evolution, relativity theory, and germ theory still bear the name "theory" even though, in practice, they are considered factual.[88] Philosopher Barry Stroud adds that, although the best definition for "knowledge" is contested, being skeptical and entertaining the *possibility* that one is incorrect is compatible with being correct. Ironically, then, the scientist adhering to proper scientific approaches will doubt themselves even once they possess the truth.[89] The fallibilist C. S. Peirce argued that inquiry is the struggle to resolve actual doubt and that merely quarrelsome, verbal, or hyperbolic doubt is fruitless[90]—but also that the inquirer should try to attain genuine doubt rather than resting uncritically on common sense.[91] He held that the successful sciences trust not to any single chain of inference (no stronger than its weakest link) but to the cable of multiple and various arguments intimately connected.[92]



The DNA double helix is a molecule that encodes the genetic instructions used in the development and functioning of all known living organisms and many viruses.

Stanovich also asserts that science avoids searching for a "magic bullet"; it avoids the single-cause fallacy. This means a scientist would not ask merely "What is *the* cause of ...", but rather "What *are* the most significant *causes* of ...". This is especially the case in the more macroscopic fields of science (e.g. psychology, physical cosmology).[87]:141–147 Of course, research often analyzes few factors at once, but these are always added to the long list of factors that are most important to consider.[87]:141–147 For example, knowing the details of only a person's genetics, or their history and upbringing, or the current situation may not explain a behavior, but a deep understanding of all these variables combined can be very predictive.

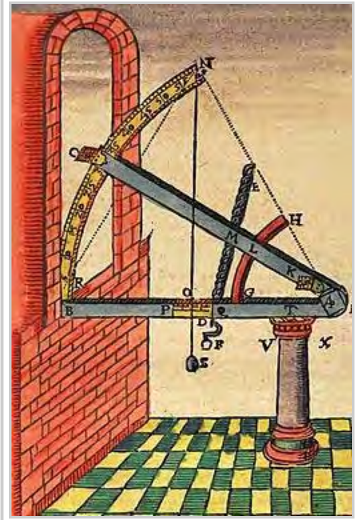
Fringe science, pseudoscience, and junk science

An area of study or speculation that masquerades as science in an attempt to claim a legitimacy that it would not otherwise be able to achieve is sometimes referred to as pseudoscience, fringe science, or junk science.[nb 21] Physicist Richard Feynman coined the term "cargo cult science" for cases in which researchers believe they are doing science because their activities have the outward appearance of science but actually lack the "kind of utter honesty" that allows their results to be rigorously evaluated.[93] Various types of commercial advertising, ranging from hype to fraud, may fall into these categories.

There can also be an element of political or ideological bias on all sides of scientific debates. Sometimes, research may be characterized as "bad science," research that may be well-intended but is actually incorrect, obsolete, incomplete, or over-simplified expositions of scientific ideas. The term "scientific misconduct" refers to situations such as where researchers have intentionally misrepresented their published data or have purposely given credit for a discovery to the wrong person.[94]

Scientific practice

Although encyclopedias such as Pliny's (fl. 77 AD) *Natural History* offered purported fact, they proved unreliable. A skeptical point of view, demanding a method of proof, was the practical position taken to deal with unreliable knowledge. As early as 1000 years ago, scholars such as Alhazen (*Doubts Concerning Ptolemy*), Roger Bacon, Witelo, John Pecham, Francis Bacon (1605), and C. S. Peirce (1839–1914) provided the community to address these points of uncertainty. In particular, fallacious reasoning can be exposed, such as "affirming the consequent."



Astronomy became much more accurate after Tycho Brahe devised his scientific instruments for measuring angles between two celestial bodies, before the invention of the telescope. Brahe's observations were the basis for Kepler's laws.

> "If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties."
>
> — Francis Bacon, "The Advancement of Learning", Book 1, v, 8

The methods of inquiry into a problem have been known for thousands of years,[95] and extend beyond theory to practice. The use of measurements, for example, is a practical approach to settle disputes in the community.

John Ziman points out that intersubjective pattern recognition is fundamental to the creation of all scientific knowledge.[96]:p44 Ziman shows how scientists can identify patterns to each other across centuries; he refers to this ability as "perceptual consensibility."[97]:p46 He then makes consensibility, leading to consensus, the touchstone of reliable knowledge.[97]:p104

Basic and applied research

Anthropogenic pollution has an effect on the Earth's environment and climate

Although some scientific research is applied research into specific problems, a great deal of our understanding comes from the curiosity-driven undertaking of basic research. This leads to options for technological advance that were not planned or sometimes even imaginable. This point was made by Michael Faraday when allegedly in response to the question "what is the *use* of basic research?" he responded: "Sir, what is the use of a new-born child?".[98] For example, research into the effects of red light on the human eye's rod cells did not seem to have any practical purpose; eventually, the discovery that our night vision is not troubled by red light would lead search and rescue teams (among others) to adopt red light in the cockpits of jets and helicopters.[87]:106–110 In a nutshell, basic research is the search for knowledge and applied research is the search for solutions to practical problems using this knowledge. Finally, even basic research can take unexpected turns, and there is some sense in which the scientific method is built to harness luck.

Research in practice

Due to the increasing complexity of information and specialization of scientists, most of the cutting-edge research today is done by well-funded groups of scientists, rather than individuals.[99] D.K. Simonton notes that due to the breadth of very precise and far reaching tools already used by researchers today and the amount of research generated so far, creation of new disciplines or revolutions within a discipline may no longer be possible as it is unlikely that some phenomenon that merits its own discipline has been overlooked. Hybridizing of disciplines and finessing knowledge is, in his view, the future of science.[99]

Practical impacts of scientific research

Discoveries in fundamental science can be world-changing. For example:

Research	Impact
Static electricity and magnetism (*c.* 1600) Electric current (18th century)	All electric appliances, dynamos, electric power stations, modern electronics, including electric lighting, television, electric heating, transcranial magnetic stimulation, deep brain stimulation, magnetic tape, loudspeaker, and the compass and lightning rod.
Diffraction (1665)	Optics, hence fiber optic cable (1840s), modern intercontinental communications, and cable TV and internet
Germ theory (1700)	Hygiene, leading to decreased transmission of infectious diseases; antibodies, leading to techniques for disease diagnosis and targeted anticancer therapies.
Vaccination (1798)	Leading to the elimination of most infectious diseases from developed countries and the worldwide eradication of smallpox.
Photovoltaic effect (1839)	Solar cells (1883), hence solar power, solar powered watches, calculators and other devices.
The strange orbit of Mercury (1859) and other research leading to special (1905) and general relativity (1916)	Satellite-based technology such as GPS (1973), satnav and satellite communications[nb 22]
Radio waves (1887)	Radio had become used in innumerable ways beyond its better-known areas of telephony, and broadcast television (1927) and radio (1906) entertainment. Other uses included – emergency services, radar (navigation and weather prediction), medicine, astronomy, wireless communications, and networking. Radio waves also led researchers to adjacent frequencies such as microwaves, used worldwide for heating and cooking food.
Radioactivity (1896) and antimatter (1932)	Cancer treatment (1896), Radiometric dating (1905), nuclear reactors (1942) and weapons (1945), PET scans (1961), and medical research (via isotopic labeling)
X-rays (1896)	Medical imaging, including computed tomography
Crystallography and quantum mechanics (1900)	Semiconductor devices (1906), hence modern computing and telecommunications including the integration with wireless devices: the mobile phone[nb 22]
Plastics (1907)	Starting with Bakelite, many types of artificial polymers for numerous applications in industry and daily life
Antibiotics (1880s, 1928)	Salvarsan, Penicillin, doxycycline etc.
Nuclear magnetic resonance (1930s)	Nuclear magnetic resonance spectroscopy (1946), magnetic resonance imaging (1971), functional magnetic resonance imaging (1990s).

See also

- Antiquarian science books
- Criticism of science
- Human timeline
- Index of branches of science
- Life timeline
- Normative science
- Outline of science
- Pathological science

- Protoscience
- Science wars
- Scientific dissent
- Sociology of scientific knowledge

Notes

1. From Latin *scientia*, meaning "knowledge". "science". Online Etymology Dictionary. Retrieved September 20, 2014.
   - "science". *Merriam-Webster Online Dictionary*. Merriam-Webster, Inc. Retrieved October 16, 2011. "**3 a:** knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method **b:** such knowledge or such a system of knowledge concerned with the physical world and its phenomena."
2. "... modern science is a discovery as well as an invention. It was a discovery that nature generally acts regularly enough to be described by laws and even by mathematics; and required invention to devise the techniques, abstractions, apparatus, and organization for exhibiting the regularities and securing their law-like descriptions."— Heilbron 2003, p. vii
3. Isaac Newton's Philosophiae Naturalis Principia Mathematica (1687), for example, is translated "Mathematical Principles of Natural Philosophy", and reflects the then-current use of the words "natural philosophy", akin to "systematic study of nature"
4. "The historian ... requires a very broad definition of "science" — one that ... will help us to understand the modern scientific enterprise. We need to be broad and inclusive, rather than narrow and exclusive ... and we should expect that the farther back we go [in time] the broader we will need to be." — David Pingree (1992), "Hellenophilia versus the History of Science" *Isis* **83** 554–63, as cited in (Lindberg 2007, p. 3), *The beginnings of Western science: the European Scientific tradition in philosophical, religious, and institutional context*, Second ed. Chicago: Univ. of Chicago Press ISBN 978-0-226-48205-7
   - See Edward Grant (1997) "When did modern science begin?" (http://www.jstor.org/stable/41212592?Search=yes&resultItemClick=true&searchText=when&searchText=did&searchText=science&searchText=begin&searchUri=%2Faction%2FdoBasicSearch%3FQuery%3Dwhen%2Bdid%2Bscience%2Bbegin%26amp%3Bfilter%3D&seq=2#page_scan_tab_contents) *The American Scholar* pp.105-113 in JSTOR:
     - *History of science#Early cultures*
     - *History of science#Ancient Near East*, Mesopotamia
     - *History of science#Ancient Near East*, Egypt
     - *History of Science in China*
     - *History of science#India*
5. "... [A] man knows a thing scientifically when he possesses a conviction arrived at in a certain way, and when the first principles on which that conviction rests are known to him with certainty—for unless he is more certain of his first principles than of the conclusion drawn from them he will only possess the knowledge in question accidentally." — Aristotle, *Nicomachean Ethics* **6** (H. Rackham, ed.) Aristot. Nic. Eth. 1139b (http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0054%3Abekker%20page%3D1139b)
6. Tracey Tokuhama-Espinosa (2010). *Mind, Brain, and Education Science: A Comprehensive Guide to the New Brain-Based Teaching*. W. W. Norton & Company. p. 39. ISBN 978-0-393-70607-9. "Alhazen (or Al-Haytham; 965–1039 C.E.) was perhaps one of the greatest physicists of all times and a product of the Islamic Golden Age or Islamic Renaissance (7th–13th centuries). He made significant contributions to anatomy, astronomy, engineering, mathematics, medicine, ophthalmology, philosophy, physics, psychology, and visual perception and is primarily attributed as the inventor of the scientific method, for which author Bradley Steffens (2006) describes him as the "first scientist"."
7. Alhacen had access to the optics books of Euclid and Ptolemy, as is shown by the title of his lost work *A Book in which I have Summarized the Science of Optics from the Two Books of Euclid and Ptolemy, to which I have added the Notions of the First Discourse which is Missing from Ptolemy's Book* From Ibn Abi Usaibia's catalog, as cited in (Smith 2001)[:**91**(vol.1),p.xv]
8. "[Ibn al-Haytham] followed Ptolemy's bridge building ... into a grand synthesis of light and vision. Part of his effort consisted in devising ranges of experiments, of a kind probed before but now undertaken on larger scale."— Cohen 2010, p. 59

9. The translator, Gerard of Cremona (c. 1114–87), inspired by his love of the Almagest, came to Toledo, where he knew he could find the Almagest in Arabic. There he found Arabic books of every description, and learned Arabic in order to translate these books into Latin, being aware of 'the poverty of the Latins'. —As cited by Charles Burnett (2001) "The Coherence of the Arabic-Latin Translation Program in Toledo in the Twelfth Century", pp. 250, 255, & 257, *Science in Context* **14**(1/2), 249–288 (2001). DOI: 10.1017/0269889701000096
10. Kepler, Johannes (1604) *Ad Vitellionem paralipomena, quibus astronomiae pars opticae traditur* (Supplements to Witelo, in which the optical part of astronomy is treated) as cited in Smith, A. Mark (2004) "What is the history of Medieval Optics Really About?" *Proceedings of the American Philosophical Society* **148**(2 — Jun. 2004), pp. 180-194 p.192 via JSTOR (http://www.jstor.org/stable/1558283?seq=13#page_scan_tab_contents)
    - The full title translation is from p.60 of James R. Voelkel (2001) *Johannes Kepler and the New Astronomy* Oxford University Press. Kepler was driven to this experiment after observing the partial solar eclipse at Graz, July 10, 1600. He used Tycho Brahe's method of observation, which was to project the image of the sun on a piece of paper through a pinhole aperture, instead of looking directly at the sun. He disagreed with Brahe's conclusion that total eclipses of the sun were impossible, because there were historical accounts of total eclipses. Instead he deduced that the size of the aperture controls the sharpness of the projected image (the larger the aperture, the more accurate the image — this fact is now fundamental for optical system design). Voelkel, p.61, notes that Kepler's experiments produced the first correct account of vision and the eye, because he realized he could not accurately write about astronomical observation by ignoring the eye.
11. di Francia 1976, p. 13: "The amazing point is that for the first time since the discovery of mathematics, a method has been introduced, the results of which have an intersubjective value!" *(Author's punctuation)*
12. di Francia 1976, pp. 4–5: "One learns in a laboratory; one learns how to make experiments only by experimenting, and one learns how to work with his hands only by using them. The first and fundamental form of experimentation in physics is to teach young people to work with their hands. Then they should be taken into a laboratory and taught to work with measuring instruments — each student carrying out real experiments in physics. This form of teaching is indispensable and cannot be read in a book."
13. Fara 2009, p. 204: "Whatever their discipline, scientists claimed to share a common scientific method that ... distinguished them from non-scientists."
14. Women in science have included:
    - Hypatia (c. 350–415 CE), of the Library of Alexandria.
    - Trotula of Salerno, a physician c. 1060 CE.
    - Caroline Herschel, one of the first professional astronomers of the 18th and 19th centuries.
    - Christine Ladd-Franklin, a doctoral student of C. S. Peirce, who published Wittgenstein's proposition 5.101 in her dissertation, 40 years before Wittgenstein's publication of Tractatus Logico-Philosophicus.
    - Henrietta Leavitt, a professional human computer and astronomer, who first published the significant relationship between the luminosity of Cepheid variable stars and their distance from Earth. This allowed Hubble to make the discovery of the expanding universe, which led to the Big Bang theory.
    - Emmy Noether, who proved the conservation of energy and other constants of motion in 1915.
    - Marie Curie, who made discoveries relating to radioactivity along with her husband, and for whom Curium is named.
    - Rosalind Franklin, who worked with X-ray diffraction.
15. Nina Byers, Contributions of 20th Century Women to Physics (http://cwp.library.ucla.edu/) which provides details on 83 female physicists of the 20th century. By 1976, more women were physicists, and the 83 who were detailed were joined by other women in noticeably larger numbers.
16. This realization is the topic of intersubjective verifiability, as recounted, for example, by Max Born (1949, 1965) *Natural Philosophy of Cause and Chance* (https://archive.org/stream/naturalphilosoph032159mbp /naturalphilosoph032159mbp_djvu.txt), who points out that all knowledge, including natural or social science, is also subjective. p. 162: "Thus it dawned upon me that fundamentally everything is subjective, everything without exception. That was a shock."

17. In his investigation of the law of falling bodies, Galileo (1638) serves as example for scientific investigation: *Two New Sciences* "A piece of wooden moulding or scantling, about 12 cubits long, half a cubit wide, and three finger-breadths thick, was taken; on its edge was cut a channel a little more than one finger in breadth; having made this groove very straight, smooth, and polished, and having lined it with parchment, also as smooth and polished as possible, we rolled along it a hard, smooth, and very round bronze ball. Having placed this board in a sloping position, by lifting one end some one or two cubits above the other, we rolled the ball, as I was just saying, along the channel, noting, in a manner presently to be described, the time required to make the descent. We . . . now rolled the ball only one-quarter the length of the channel; and having measured the time of its descent, we found it precisely one-half of the former. Next we tried other distances, comparing the time for the whole length with that for the half, or with that for two-thirds, or three-fourths, or indeed for any fraction; in such experiments, repeated many, many, times." Galileo solved the problem of time measurement by weighing a jet of water collected during the descent of the bronze ball, as stated in his *Two New Sciences*.
18. Godfrey-Smith 2003, p. 151 credits Willard Van Orman Quine (1969) "Epistemology Naturalized" *Ontological Relativity and Other Essays* New York: Columbia University Press, as well as John Dewey, with the basic ideas of naturalism — Naturalized Epistemology, but Godfrey-Smith diverges from Quine's position: according to Godfrey-Smith, "A naturalist can think that science can contribute to *answers* to philosophical questions, without thinking that philosophical questions can be replaced by science questions.".
19. "No amount of experimentation can ever prove me right; a single experiment can prove me wrong." —Albert Einstein, noted by Alice Calaprice (ed. 2005) *The New Quotable Einstein* Princeton University Press and Hebrew University of Jerusalem, ISBN 0-691-12074-9 p. 291. Calaprice denotes this not as an exact quotation, but as a paraphrase of a translation of A. Einstein's "Induction and Deduction". *Collected Papers of Albert Einstein* **7** Document 28. Volume 7 is *The Berlin Years: Writings, 1918–1921*. A. Einstein; M. Janssen, R. Schulmann, et al., eds.
20. Fleck, Ludwik (1979). Trenn, Thaddeus J.; Merton, Robert K, eds. *Genesis and Development of a Scientific Fact*. Chicago: University of Chicago Press. ISBN 0-226-25325-2. Claims that before a specific fact "existed", it had to be created as part of a social agreement within a community. Steven Shapin (1980) "A view of scientific thought" *Science* ccvii (Mar 7, 1980) 1065–66 states "[To Fleck,] facts are invented, not discovered. Moreover, the appearance of scientific facts as discovered things is itself a social construction: a *made* thing. "
21. "*Pseudoscientific – pretending to be scientific, falsely represented as being scientific*", from the *Oxford American Dictionary*, published by the Oxford English Dictionary; Hansson, Sven Ove (1996)."Defining Pseudoscience", Philosophia Naturalis, 33: 169–176, as cited in "Science and Pseudo-science" (http://plato.stanford.edu/entries/pseudo-science/#NonSciPosSci) (2008) in Stanford Encyclopedia of Philosophy. The Stanford article states: "Many writers on pseudoscience have emphasized that pseudoscience is non-science posing as science. The foremost modern classic on the subject (Gardner 1957) bears the title Fads and Fallacies in the Name of Science. According to Brian Baigrie (1988, 438), "[w]hat is objectionable about these beliefs is that they masquerade as genuinely scientific ones." These and many other authors assume that to be pseudoscientific, an activity or a teaching has to satisfy the following two criteria (Hansson 1996): (1) it is not scientific, and (2) its major proponents try to create the impression that it is scientific".
    - For example, Hewitt et al. *Conceptual Physical Science* Addison Wesley; 3 edition (July 18, 2003) ISBN 0-321-05173-4, Bennett et al. *The Cosmic Perspective* 3e Addison Wesley; 3 edition (July 25, 2003) ISBN 0-8053-8738-2; *See also*, e.g., Gauch HG Jr. *Scientific Method in Practice* (2003).
    - A 2006 National Science Foundation report on Science and engineering indicators quoted Michael Shermer's (1997) definition of pseudoscience: '"claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility"(p. 33). In contrast, science is "a set of methods designed to describe and interpret observed and inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation"(p. 17)'.Shermer M. (1997). *Why People Believe Weird Things: Pseudoscience, Superstition, and Other Confusions of Our Time*. New York: W. H. Freeman and Company. ISBN 0-7167-3090-1. as cited by National Science Board. National Science Foundation, Division of Science Resources Statistics (2006). "Science and Technology: Public Attitudes and Understanding". *Science and engineering indicators 2006*.
    - "A pretended or spurious science; a collection of related beliefs about the world mistakenly regarded as being based on scientific method or as having the status that scientific truths now have," from the *Oxford English Dictionary*, second edition 1989.

22. Evicting Einstein (http://science.nasa.gov/science-news/science-at-nasa/2004/26mar_einstein), March 26, 2004, NASA. *"Both [relativity and quantum mechanics] are extremely successful. The Global Positioning System (GPS), for instance, wouldn't be possible without the theory of relativity. Computers, telecommunications, and the Internet, meanwhile, are spin-offs of quantum mechanics."*

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13. The *Oxford English Dictionary* dates the origin of the word "scientist" to 1834.
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15. Heilbron 2003, p. vii
16. See the quotation in Homer (8th century BCE) *Odyssey* 10.302–3
17. "Progress or Return" in *An Introduction to Political Philosophy: Ten Essays by Leo Strauss* (Expanded version of *Political Philosophy: Six Essays by Leo Strauss*, 1975.) Ed. Hilail Gilden. Detroit: Wayne State UP, 1989.
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21. "Plato, Apology, section 30". *Perseus Digital Library*. Tufts University. 1966. Retrieved November 1, 2016.
22. * Smith, A. Mark (June 2004), "What is the History of Medieval Optics Really About?", *Proceedings of the American Philosophical Society*, **148** (2): 180–194, JSTOR 1558283[:p.189]
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