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HISTORY OF SCIENCE

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ABSTRACT

A scientific method seeks to explain the events of nature in a reproducible way. An explanatory thought experiment or hypothesis is put forward, as explanation, from which stem predictions. 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. 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. Taken in its entirety, a scientific method allows for highly creative problem solving while minimizing any effects of subjective bias on the part of its users.

Keywords: Science, History, Branches of Science.

INTRODUCTION

Science is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe. In an older and closely related meaning (found, for example, in Aristotle), "science" refers to the body of reliable knowledge itself, of the type that can be logically and rationally explained. Since classical antiquity science as a type of knowledge was closely linked to philosophy. In the early modern era the words "science" and "philosophy" were sometimes used interchangeably in the English language. By the 17th century, natural philosophy considered a separate branch of philosophy. However, "science" continued to be used in a broad sense denoting reliable knowledge about a topic, in the same way it is still used in modern terms such as library science or political science.

In modern use, "science" more often refers to a way of pursuing knowledge, not only the knowledge itself. It is "often treated as synonymous with ‘natural and physical science’, and thus restricted to those branches of study that relate to the phenomena of the material universe and their laws, sometimes with implied exclusion of pure mathematics. This is now the dominant sense in ordinary use." This narrower sense of "science" developed as scientists such as Johannes Kepler, Galileo Galilei and Isaac Newton began formulating *laws of nature* such as Newton's laws of motion. In this period it became more common to refer to natural philosophy as "natural science". Over the course of the 19th century, the word "science" became increasingly associated with scientific method, a disciplined way to study the natural world, including physics, chemistry, geology and biology. This sometimes left the study of human thought and society in a linguistic limbo, which was resolved by classifying these areas of academic study as social science. Similarly, several other major areas of disciplined study and knowledge exist today under the general rubric of "science", such as formal science and applied science [1].

History

Both Aristotle and Kuan Tzu (4th C. BCE), in an example of simultaneous scientific discovery, mention that some marine animals were subject to a lunar cycle, and increase and decrease in size with the waxing and waning of the moon. Aristotle was referring specifically to the sea urchin, pictured above.

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Science in a broad sense existed before the modern era, and in many historical civilizations, but modern science is so distinct in its approach and successful in its results that it now defines what science is in the strictest sense of the term. Much earlier than the modern era, another important turning point was the development of the classical natural philosophy in the ancient Greek-speaking world [2].

Pre-philosophical

Science in its original sense is a word for a type of knowledge (Latin *scientia*, Ancient Greek *epistemē*), rather than a specialized word for the pursuit of such knowledge. In particular it is one of the types 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 thinking, as shown by the construction of complex calendars, techniques for making poisonous plants edible, and buildings such as the pyramids. However no consistent 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.

Philosophical study of nature

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, 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". Science was therefore distinguished as the knowledge of nature, and the 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 astronomy. In contrast, trying to use knowledge of nature to imitate nature was seen by classical scientists as a more appropriate interest for lower class artisans.

Philosophical turn to human things

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, and Socrates was executed. 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, 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 [3].

Medieval science

During late antiquity and the early Middle Ages, the Aristotelian approach to inquiries on natural phenomenon was used. Some ancient knowledge was lost or in some cases kept in obscurity during the fall of the Roman Empire and political struggles. However, the general fields of science, or Natural Philosophy as it was called, were preserved though the works of the early encyclopedists like Isidore of Seville. Islamic science provided much of the activity for the early medieval period. In the later medieval period, Europeans recovered some ancient knowledge by translations of texts and they built their work upon the knowledge of Aristotle, Ptolemy, Euclid, and others works. In Europe, men like Roger Bacon learned Arabic and Hebrew and argued for more experimental science. 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 centre of science.

Renaissance, and early modern science

By the late Middle Ages, especially in Italy there was an influx of texts and scholars from the collapsing Byzantine empire. Copernicus formulated a heliocentric model of the solar system unlike the geocentric model of

Ptolemy's Almagest. All aspects of scholasticism were criticised in the 15th and 16th centuries; one author who was notoriously persecuted was Galileo, who made innovative use of experiment and mathematics. However the persecution began 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 caused great offense to him.

In Northern Europe, the new technology of the printing press was widely used to publish many arguments including some that disagreed with church dogma. 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 also argued that science should aim for the first time at practical inventions for the improvement of all human life.

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 [4].

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 Newtonian physics, which could be confirmed by experiment and explained in mathematics. Leibniz also incorporated terms from Aristotelian physics, but now being used in a new non-teleological way, for example "energy" and "potential". But 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 the pursuit of a type of knowledge, and especially knowledge of nature — coming close in meaning to the old term "natural philosophy" [5].

19th century

Both John Herschel and William Whewell systematised methodology: the latter coined the term scientist. When Charles Darwin published *On the Origin of Species* he established descent with modification as the prevailing evolutionary 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 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.

20th century

Einstein's Theory of Relativity and the development of quantum mechanics led to the replacement of Newtonian physics with a new physics which contains two parts, that describe different types of events in nature. The extensive use of scientific innovation during the wars of this century, led to the space race and widespread public appreciation of the importance of modern science.

Philosophy of science

Working scientists usually take for granted a set of basic assumptions that are needed to justify a 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. Philosophy of science seeks a deep understanding of what these underlying assumptions mean and whether they are valid. Most contributions to the philosophy of science have come from philosophers, who frequently view the beliefs of most scientists as superficial or naive—thus there is often a degree of antagonism between working scientists and philosophers of science.

The belief that all observers share a common reality is known as realism. It can be contrasted with anti-realism, the belief that there is no valid concept of absolute truth such that things that are true for one observer are true for all observers. The most commonly defended form of anti-realism is idealism, the belief that the mind or spirit is the most basic essence, and that each mind generates its own reality. In an idealistic world-view, what is true for one mind need not be true for other minds.

There are different schools of thought in philosophy of science. The most popular position is empiricism, which claims that knowledge is created by a process involving observation and that scientific theories are the result of generalizations from such observations. 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 the hence 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 and the hypothetico-deductive method [6].

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. A significant twentieth century version of rationalism is critical rationalism, 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. Popper proposed falsifiability as the landmark of scientific theories, and falsification as the empirical method, to replace verifiability[19] and induction by purely deductive notions. Popper further claimed that there is actually only one universal method, and that this method is not specific to science: The negative method of criticism, trial and error. It covers all products of the human mind, including science, mathematics, philosophy, and art.

Another approach, instrumentalism, colloquially termed "shut up and calculate", emphasizes the utility of theories as instruments for explaining and predicting phenomena. It claims that scientific theories are black boxes with only their input (initial conditions) and output (predictions) being relevant. Consequences, notions and logical structure of the theories are claimed to be something that should simply be ignored and that scientists shouldn't make a fuss about (see interpretations of quantum mechanics).

Finally, another approach often cited in debates of scientific skepticism against controversial movements like "scientific creationism", 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. 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. The absence of these standards, arguments from authority, biased observational studies and other common fallacies are frequently cited by supporters of methodological naturalism as criteria for the dubious claims they criticize not to be true science.

Basic and applied research

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. 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. In a nutshell: Basic research is the search for knowledge. 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 [7].

Experimentation and hypothesizing

Based on observations of a phenomenon, scientists may generate a model. This is an attempt to describe or depict the phenomenon in terms of a logical, physical or mathematical representation. As empirical evidence is gathered, scientists can suggest a hypothesis to explain the phenomenon. Hypotheses may be formulated 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. This new explanation is used to make falsifiable predictions that are testable by experiment or observation. When a hypothesis proves unsatisfactory, it is either modified or discarded. Experimentation is especially important in science to help establish causational relationships (to avoid the correlation fallacy). Operationalization also plays an important role in coordinating research in/across different fields.

Once a hypothesis has survived testing, it may become adopted into the framework of a scientific theory. This is 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.

While performing experiments, 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. This can be achieved by careful experimental design, transparency, and a thorough peer review process of the experimental results as well as any conclusions [8].

Certainty and science

A scientific theory is empirical, 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. The philosopher of science Karl Popper sharply distinguishes truth from certainty. He writes 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.

Theories very rarely result 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. 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 domains of science; it is more like a climb than a leap. Theories vary in the extent to which they have been tested and verified, as well as their acceptance in the scientific community. For example, heliocentric theory, the theory of evolution, and germ theory still bear the name "theory" even though, in practice, they are considered factual.

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 method will doubt themselves even once they possess the truth. 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—but also that the inquirer should try to attain genuine doubt rather than resting uncritically on common sense. 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 [9].

Stanovich also asserts that science avoids searching for a "magic bullet"; it avoids the single-cause fallacy. This is especially the case in the more macroscopic fields of science (e.g. psychology, cosmology). 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. For example: knowing the details of only a person's genetics, or their history and upbringing, or the current situation may not explain a behaviour, but a deep understanding of all these variables combined can be very predictive.

Scientific practice

A skeptical point of view, demanding a method of proof, was the practical position taken as early as 1000 years ago, with Alhazen, *Doubts Concerning Ptolemy*, through Bacon (1605), and C. S. Peirce (1839–1914), who note that a community will then spring up to address these points of uncertainty. The methods of inquiry into a problem have been known for thousands of years, and extend beyond theory to practice. The use of measurements, for example, are 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. Ziman shows how scientists can identify patterns to each other across centuries: Needham 1954 shows how today's trained Western botanist can identify *Artemisia alba* from images taken from a 16th c. Chinese pharmacopia, and Ziman refers to this ability as 'perceptual consensibility'. Ziman then makes consensibility, leading to consensus, the touchstone of reliable knowledge [10].

Measurement

In the SI system, there are seven fundamental units: kilogram, meter, candela, second, ampere, kelvin, and mole. Six of these units are artifact-free; the definition of one remaining unit, the kilogram is still embodied in an artifact which rests at the BIPM outside Paris. Eventually, it is hoped that new SI definitions will be uniformly artifact-free.

Charles Sanders Peirce (1839–1914) was the first to tie an SI base unit, the meter, to an experimental standard which was independent of *fiat*. Peirce's concept was to experimentally tie the meter to the wavelength of a spectral line. This directly influenced the Michelson-Morley experiment; Michelson and Morley cite Peirce, and improve on his method [11].

New SI definitions

Scientific method

A scientific method seeks to explain the events of nature in a reproducible way. An explanatory thought experiment or hypothesis is put forward, as explanation, from which stem predictions. 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. 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). Taken in its entirety, a scientific method allows for highly creative problem solving while minimizing any effects of subjective bias on the part of its users.

In the nineteenth century, the measurement of Earth's gravity was primarily dependent on pendulums for gravimetric surveys. An improved pendulum, designed by Friedrich Bessel, was manufactured by Repsold and Sons, Hamburg, Germany. The American C.S. Peirce was tasked with gravimetric research by the U.S. Coast and Geodetic Survey. Peirce developed a theory of the systematic errors in the mount of the Repsold pendulum. He was asked to present his theory for improving pendulums to a Special Committee of the International Geodetic Association. While underway to a conference of the IGA in Europe, September 1877, Peirce wrote an essay in French on scientific method, "How to Make Our Ideas Clear" and translated "The Fixation of Belief" into French. In these essays, he notes that our beliefs clash with real life, causing what Peirce denotes as the "irritation of doubt", for which he then lists multiple methods of coping, among them, scientific method.

"Model-making, the imaginative and logical steps which precede the experiment, may be judged the most important part of scientific method because skill and insight in these matters are rare. Without them we do not know what experiment to do. But it is the experiment which provides the raw material for scientific theory. Scientific theory cannot be built directly from the conclusions of conceptual models." —Herbert George Andrewartha (1907-92), Australian zoologist and entomologist, *Introduction to the study of animal population* 1961, 181 [12].

Branches and fields

Scientific fields are commonly divided into two major groups: natural sciences, which study natural phenomena, and social sciences, which study human behavior and societies. These groupings are empirical sciences, which means the knowledge must be based on observable phenomena and capable of being tested for its validity by other researchers working under the same conditions. There are also related disciplines that are grouped into interdisciplinary and 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 terminology and expertise.

Mathematics, which is classified as a formal science, has both similarities and differences with the empirical 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. 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, both in discovering and describing how things work and how people think and act (social sciences).

The word *field* has a technical meaning in physics, as occupying space, which uses the word spacetime, rather than space); that is the reason that a branch of science is taken as the meaning of field. Science divides into categories of specialized expertise, each typically embodying their own terminology and nomenclature [13].

Literature

An enormous range of scientific literature is published. 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. As of 1981, one estimate for the number of scientific and technical journals in publication was 11,500. 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.

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 [14].

Science and society

Women in science

Science is largely a male-dominated field, with notable exceptions. Evidence suggests that this is due to stereotypes (e.g. science as "manly") as well as self-fulfilling prophecies. Experiments have shown that parents challenge and explain more to boys than girls, asking them to reflect more deeply and logically. Physicist Evelyn Fox Keller argues that science may suffer for its manly stereotypes when ego and competitiveness obstruct progress, since these tendencies prevent collaboration and sharing of information.

As described in Certainty and science above: "no theory is ever considered strictly certain as science accepts the concept of fallibilism." Researchers from the United States and Canada write about a rhetorical technique focussed on shifting the burden of proof in an argument: the rhetoric involves a very public call for absolute certainty from *one side* of the debate. For instance, laws that would control cigarette smoking were combated by lobby groups emphasizing that the evidence connecting smoking to cancer was not certain. The evidence that did exist was thus trivialized. The researchers call this a SCAM (Scientific Certainty Argumentation Method), and maintain that what is really needed is a balanced approach to science; an approach that admits scientific conclusions is always tentative. This means carefully considering the risks of both Type 1 and Type 2 errors in a situation (e.g. all the risks of over-reaction, but also the risks of under-reaction). Certainty, it should be clear, will not exist on either side of the debate. The authors conclude that politicians and lobby groups are too often able to make "successful efforts to argue for full 'scientific certainty' before a regulation can be said to be 'justified' — and that, in short, is a SCAM."

Science policy

Science policy is an area of public policy concerned with the policies that affect the conduct of the science and research 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. Is 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.

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 seventeenth century recognized a scientific community which exists to this day. The professionalization of science, begun in the nineteenth 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, 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" [15].

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. 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).

Pseudoscience, fringe science, 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 "alternative science". Another term, junk science, is often used to describe scientific hypotheses or conclusions which, while perhaps legitimate in themselves, are believed to be used to support a position that is seen as not legitimately justified by the totality of evidence. Physicist Richard Feynman coined the term "cargo cult science" in reference to pursuits that have the formal trappings of science but lack "a principle of scientific thought that corresponds to a kind of utter honesty" that allows their results to be rigorously evaluated. Various types of commercial advertising, ranging from hype to fraud, may fall into these categories.

There also can be an element of political or ideological bias on all sides of such debates. Sometimes, research may be characterized as "bad science", research that is well-intentioned but is seen as 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 [16].

Critiques

Philosophical critiques

Historian Jacques Barzun termed science "a faith as fanatical as any in history" and warned against the use of scientific thought to suppress considerations of meaning as integral to human existence. Many recent thinkers, such as Carolyn Merchant, Theodor Adorno and E. F. Schumacher considered that the 17th century scientific revolution shifted science from a focus on understanding nature, or wisdom, to a focus on manipulating nature, i.e. power, and that science's emphasis on manipulating nature leads it inevitably to manipulate people, as well.[92] Science's focus on quantitative measures has led to critiques that it is unable to recognize important qualitative aspects of the world.

Philosopher of science Paul K 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 is unrealistic, pernicious and detrimental to science itself. 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 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.

Feyerabend also criticized science for not having evidence for its own philosophical precepts. Particularly the notion of Uniformity of Law and the Uniformity of Process across time and space. "We have to realize that a unified theory of the physical world simply does not exist" says Feyerabend, "We have theories that work in restricted regions, we have purely formal attempts to condense them into a single formula, we have lots of unfounded claims (such as the claim that all of chemistry can be reduced to physics), phenomena that do not fit into the accepted framework are suppressed; in physics, which many scientists regard as the one really basic science, we have now at least three different points of view...without a promise of conceptual (and not only formal) unification".

Sociologist Stanley Aronowitz scrutinizes science for operating with the presumption that the only acceptable criticisms of science are those conducted within the methodological framework that science has set up for itself. That science insists that only those who have been inducted into its community, through means of training and credentials, are qualified to make these criticisms. Aronowitz also alleges that while scientists consider it absurd that Fundamentalist Christianity uses biblical references to bolster their claim that the Bible is true, scientists pull the same tactic by using the tools of science to settle disputes concerning its own validity.

Psychologist Carl Jung believed that though science attempted to understand all of nature, the experimental method imposed artificial and conditional questions that evoke equally artificial answers. Jung encouraged, instead of these 'artificial' methods, empirically testing the world in a holistic manner. David Parkin compared the epistemological stance of science to that of divination. He suggested that, to the degree that divination is an epistemologically specific means of gaining insight into a given question, science itself can be considered a form of divination that is framed from a Western view of the nature (and thus possible applications) of knowledge.

Several academics have offered critiques concerning ethics in science. In *Science and Ethics*, for example, the philosopher Bernard Rollin examines the relevance of ethics to science, and argues in favor of making education in ethics part and parcel of scientific training [17].

Table 1. SI definitions

Base quantity	Base unit	Symbol	Current SI constants	New SI constants
time	second	s	hyperfine splitting in Cesium-133	same as current SI
length	meter	m	speed of light in vacuum, c	same as current SI
mass	kilogram	kg	mass of International Prototype Kilogram (IPK)	Planck's constant, h
electric current	ampere	A	permeability of free space, permittivity of free space	charge of the electron, e
temperature	kelvin	K	triple point of water, absolute zero	Boltzmann's constant, k
amount of substance	mole	mol	molar mass of Carbon-12	Avogadro constant N_A
luminous intensity	candela	cd	luminous efficacy of a 540 THz source	same as current SI

Fig 1. Sea Urchin

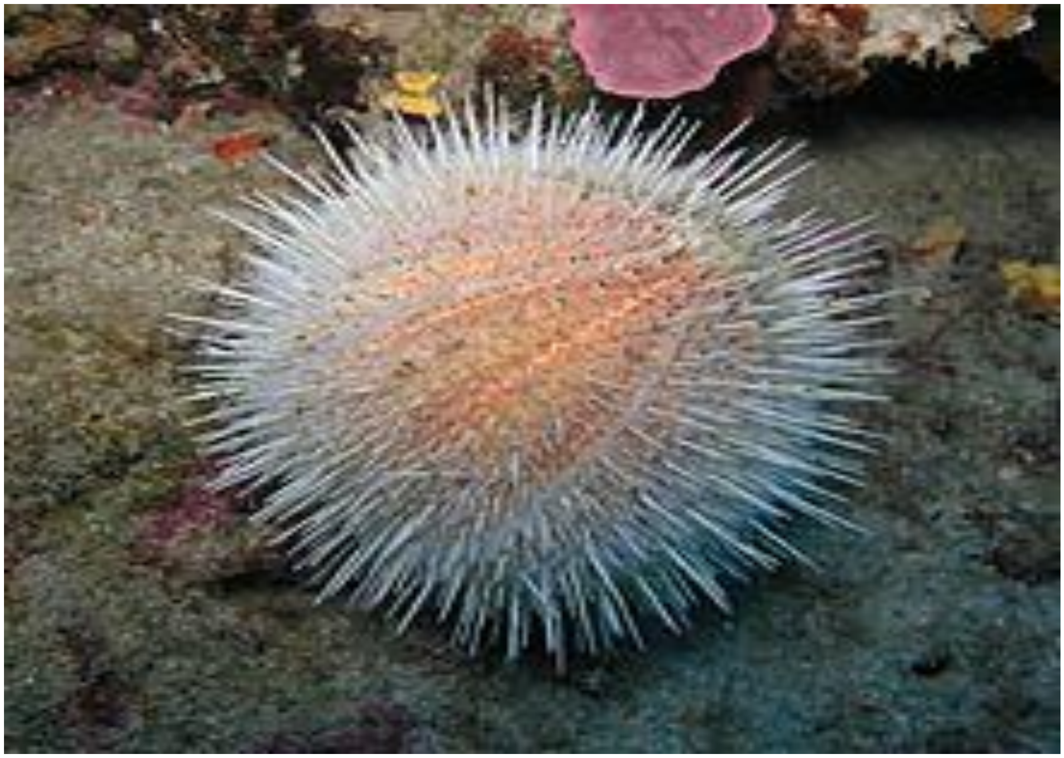


Fig 2. John Locke

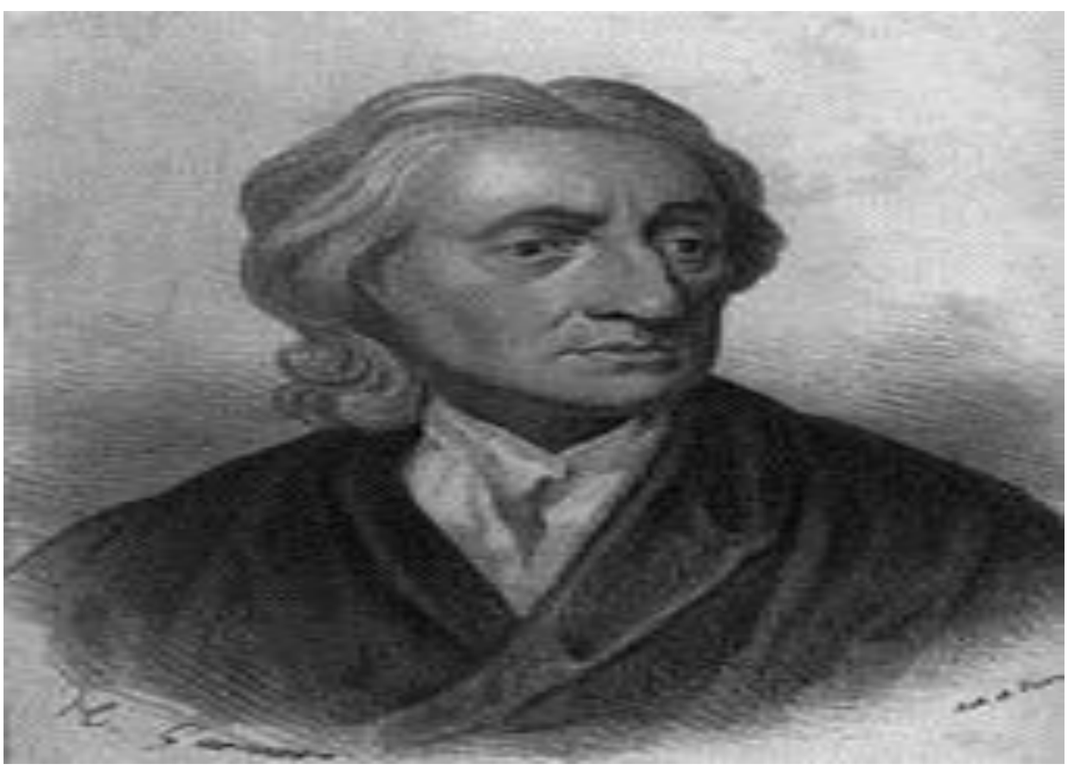


Fig 3. DNA determines the genetic structure of all known life

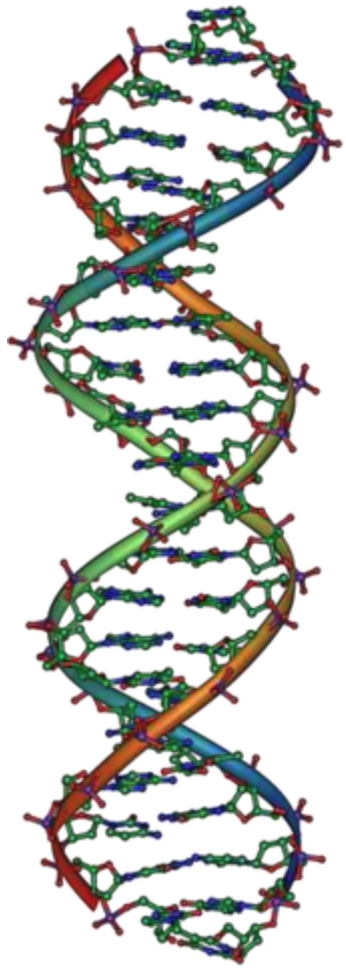


Fig 4. Although science values legitimate doubt, The Flat Earth Society is still widely regarded as an example of taking skepticism.

Fig 5. An instrument for measuring the angle observed between two celestial bodies, designed by Tycho Brahe Brahe's instrument for measuring angle was used as part of a more complex instrument

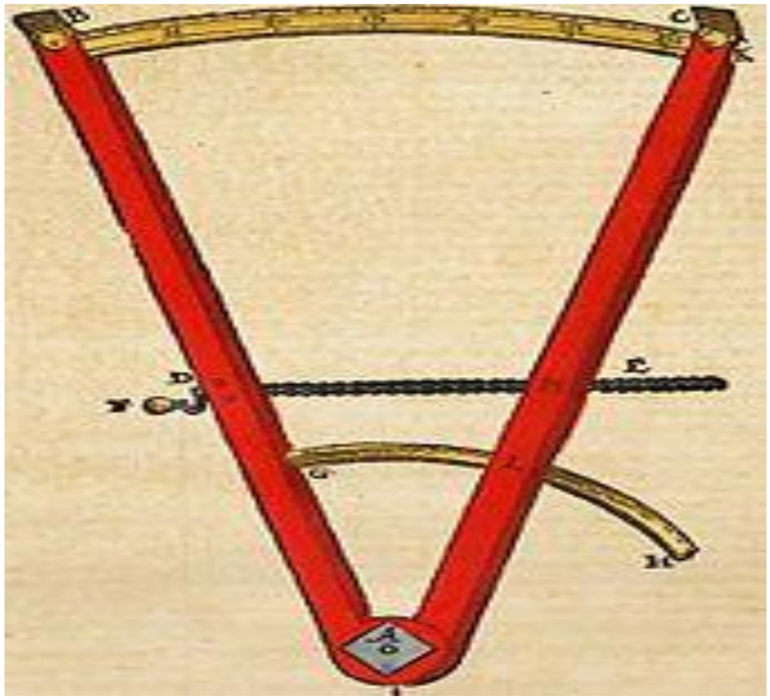
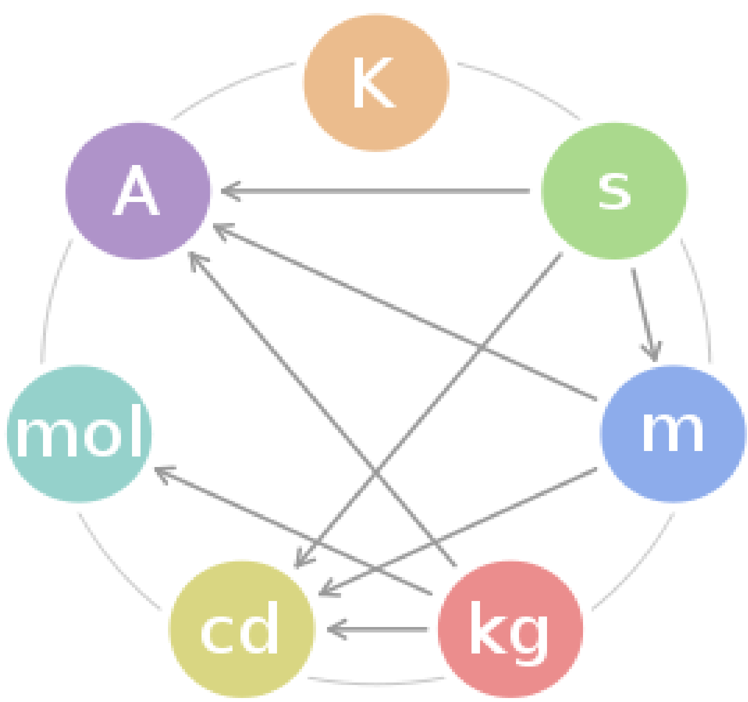


Fig 6.The seven base units in the SI system. Arrows point from units to those that depend on them; as the accuracy of the former increase, so will the accuracy of the latter



CONCLUSION

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. 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.

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 Britain 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*.

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