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Scientific Revolutions

By L. James Gibson

Occasionally, the scientific community rejects an idea that was previously widely accepted and replaces it with a new idea, which becomes the current consensus. This rapid change in scientific opinion is known as a "scientific revolution."

These revolutions do not come easily because science is widely regarded as the most reliable, or even the only, pathway to truth. When an idea is said to be "unscientific," this is generally interpreted to mean it is unreliable at best, and dangerously wrong at worst. In contrast, to describe a statement as "scientific" usually means it is believed to be true.

The high epistemological value placed on science is understandable but unwise. It is understandable because science has made discoveries that have been used in technologies to make our lives more comfortable and enable us to pursue learning and pleasure to an extent far greater than in the past. We are all grateful for the benefits received from scientific discovery. However, it is unwise to uncritically accept the pronouncements of "scientists" as though they are empirically confirmed, for at least two reasons. First, it is unwise because the prestige of science is often exploited by materialists to promote personal agendas with destructive outcomes. Second, the history of science tells us that scientists are often wrong, as seen in the occasional scientific revolution. This essay will focus on the latter phenomenon—revolutions in science.

Although not adequately appreciated in the popular press, many of those who study the history of science have come to see it more as a human enterprise than an application of pure reason. A major factor in this view was the publication of the book *The Structure of Scientific Revolutions* in 1962, and more widely in the 1970 revision of the book.[1] In this book, Thomas Kuhn proposed that science is normally carried on as individuals seek application of general principles to more and more situations. Anomalies occur occasionally, but are ignored until they accumulate and people notice that there is a problem with the reigning paradigm. Attention is then focused on the anomalies, the paradigm is challenged and may be overthrown and replaced by a new paradigm. When this happens, a scientific revolution has occurred. Acceptance of a new paradigm may involve conversion of scientists, but often has to wait until the old guard dies out and is replaced by younger scientists who grew up with the new idea. In other words, new ideas are often accepted due to an influx of new people rather than by changing people's opinions.

The Scientific Revolution[2]

The first scientific revolution was the development of scientific methodology, utilizing experiment, mathematical analysis, and testing. This revolution transformed the study of the natural world from an exercise in cataloguing to an attempt to describe nature in mechanical terms and to make predictions. Key developments in this revolution were the application of mathematics to objects in motion by Galileo and Newton in the seventeenth century, and Harvey's discovery of capillaries in the human body. Methodological developments were accompanied by formation of scientific societies with official journals, thus establishing a scientific community for the first time. This, the first scientific revolution, laid the foundation for the methodology and philosophy of modern science, and may rightly be called *the* scientific revolution.

The practice of science has expanded greatly since the original scientific revolution, and the term "revolution" has been applied[3] to certain structural changes in the way scientific findings are funded and communicated.

However, I prefer to apply the term “revolution” in a Kuhnian sense, that is, to relatively abrupt and radical changes in the way nature is understood. These are conceptual revolutions rather than sociological revolutions.

Conceptual Revolutions in “the” Scientific Revolution

Several different conceptual revolutions contributed to “the scientific revolution.” Chief among them were the contributions of Nicolaus Copernicus (1473–1543) and Galileo Galilei (1564–1642), René Descartes (1596–1650), William Harvey (1578–1657), and Isaac Newton (1643–1727). The first of these was the “Copernican Revolution,” which radically changed our view of the place of the earth. Previously, the earth had been regarded as the center of the solar system, in a scheme formalized by Claudius Ptolemy in the second century, A.D. Unfortunately, the Christian church incorporated Ptolemy’s scheme into church dogma, using Biblical texts to attempt to support it. Copernicus proposed a different scheme in which the sun is the center of our solar system. The new view was vigorously opposed by the church, but eventually prevailed under the influence of Galileo and others. The Copernican revolution changed the public perception of humanity’s place in the universe from the center to the periphery, with corresponding changes in our relationship to God. It was truly a revolutionary idea.

René Descartes is credited with advances in mathematics and philosophy that produced a revolution in science. Descartes developed a system of mathematical graphing we still call “Cartesian coordinates,” which transformed mathematics, led to the development of general algebra, and enabled Newton to develop the calculus. Descartes also advocated a “mechanical philosophy,” which eschewed teleology in favor of a reductionist approach involving only matter and motion. Descartes’ influence was a major factor in the secularization of science, changing the scientific viewpoint from seeing the world as the handiwork of God to the point where LaPlace famously quipped to Napoleon, “I have no need of that hypothesis,” meaning he intentionally left God out of his thinking in trying to explain the formation of the solar system.

William Harvey showed that the blood circulated in a single system linking the heart with the rest of the body, rather than being supernaturally moved by God. He accomplished this by meticulous dissection and study of the blood vessels and heart, and by direct measurement of the capacity of the heart, not only of humans, but also of sheep and dogs. Harvey’s application of experiment and observation, and especially his emphasis on quantitative measurements, transformed biology from a purely descriptive endeavor largely based on ancient authorities to an experimental science based on careful observation and measurement. The discovery that blood is pumped through the body by a mechanical heart removed the need for supernatural cause of blood flow and helped bring biology into the realm of quantitative science.

Isaac Newton’s work was the capstone on the scientific revolution. Newton’s major contribution was the mathematization of physics. He developed the calculus and applied it to the study of motion. He developed generalized laws of motion, including curved motion, wave motion, and pendulums. His most dramatic contribution was the discovery and quantification of the force of gravity. He applied this to develop a model of the universe in which the planets and other heavenly bodies were guided in their orbits by gravitational forces. He also explained the tides as the result of gravitational forces of the sun and moon. In developing his model of a “clockwork universe,” Newton transformed the common perception of cause of the motion of the planets and stars. Previously, this was explained by the direct activity of God; now it was explained by the natural law of gravity.

The scientific revolution permanently changed the way we view our world. Before the revolution, nature was seen as the handiwork of God, and was studied mostly by clergymen. After the revolution, nature was seen as autonomous, and was studied mostly by professional scientists, many of whom were deists who believed God had no interaction with the universe. This view of nature as independent of any outside influence, dominant for the past two or three centuries, is itself under attack today as science continues to uncover the precise structure and complexity of the universe and the living organisms that inhabit it. Perhaps we are on the threshold of a new scientific revolution in which the reality of the supernatural is recognized. If so, it would be one more example in a list of revolutions in science.

Revolutions in the Life Sciences

The life sciences have experienced fewer revolutions than the physical sciences. The first major revolution in the biological sciences was initiated by William Harvey, as noted above. The next revolution was the Darwinian Revolution, which in some ways has had greater impact than any other scientific revolution. Darwin (1809–1882) published his famous theory in 1859, with an almost immediate effect. Opposition was swift and strong but was mostly expressed as opposition to the implication that humans descended from apes rather than focusing on the evidence Darwin used. Darwin's friends occupied positions of power and influence and used them effectively to neutralize opposition and to give evolutionary theory a prominent place. Darwin's arguments contained significant flaws, and the theory went into decline after the deaths of himself and his supporters. It was resurrected and strengthened during the 1930s and 1940s, and is now the standard view, although it appears ripe for replacement through another scientific revolution. Darwinism may be the only paradigm in science whose believers often actively persecute dissenters from the theory. The revolutionary nature of Darwin's theory was due to its central thesis that living organisms evolved without any divine activity or purpose. This view is in direct contradiction to the general belief that our lives have purpose and are influenced by divine Providence.

Experimental refutation of the theory of spontaneous generation could be considered another revolution in biology, although a form of the theory is still advocated today. From the ancient Romans until the 17th century, people widely believed that living organisms could form from decaying material. Frogs were thought to come from mud, mice from moldy grain, flies from decaying meat, etc. Francesco Redi (1626–1697) challenged this belief in what may well be the first scientific experiment. Redi showed that flies do not grow in decaying meat unless the meat is accessible to other flies. This convinced most people that ordinary, visible organisms do not come into existence by spontaneous generation, but most still believed that microorganisms could. Lazzaro Spallanzani (1729–1799) performed a similar experiment that cast doubt on the spontaneous generation of microorganisms from soup, but the experiment was not conclusive. Finally in 1862, Louis Pasteur (1822–1895) was awarded a prize by the French Academy of Science for his famous experiment in which he showed that microorganisms come from other microorganisms and not from spontaneous generation. Pasteur's experiments overturned the previous theory that living organisms can arise from non-living material and showed that living organisms come from other living organisms. Modern evolutionists appeal to gaps in our knowledge to justify continued belief in spontaneous generation of the first living organism, but this is driven by philosophical biases rather than on scientific evidence.

There are few other developments in biology that could be considered as revolutions. Most developments in biology have come about stepwise, as new discoveries accumulate. Among the major advances are: the discovery of the cellular nature of life; the distinction of the germline cells and the soma; the germ theory of disease; and the particulate nature of heredity. The discovery of the DNA double helix is a candidate for a revolution. This discovery changed biology from primarily an organismal approach to a chemical approach and ushered in the age of molecular biology. Many other factors contributed to this transformation, but discovery of the structure of DNA seems to be the key that opened the way for the larger changes.

Revolutions in Earth Sciences

Charles Lyell (1797–1875) is responsible for a revolution in the earth sciences. Lyell strongly opposed the catastrophism of his day and promoted the idea of stability of the earth over long ages of time. This is known as the principle of uniformitarianism. Lyell was opposed by the scriptural geologists and others who held that at least parts of the geological record were produced in the Biblical flood. Through force of argument and political affiliations, Lyell's views became dominant, and catastrophism was banned, at least temporarily, from the study of earth history.

A second revolution in geology occurred in the 1960s, with acceptance of the theory of plate tectonics. Several scientists contributed to the new theory. Among these the key contribution may have been Harry Hess's 1962 publication of the idea that the earth's crust might be made of movable plates. Other evidence seemed to corroborate this idea, and the idea of a stable, unmoving crust was quickly replaced by the idea of a dynamic, mobile crust made of separate pieces, or plates. This represented a major change from the views of Lyell and opened the way for a reconsideration of catastrophism.

The re-emergence of catastrophism was another major revolution in earth sciences. The revolution began in earnest with the 1980 publication of Walter Alvarez and others, which appealed to extraterrestrial impacts as a major factor in earth history. Subsequent exploration has identified nearly 200 impact craters and confirmed the role of global catastrophes in earth history. An ongoing controversy rages over the relationship of impacts and mass extinctions. Other types of catastrophes have been identified or postulated, including massive volcanism, release of methane from the sea floor, and nearby supernovas. Recognition of catastrophes of global scale has transformed our view of earth history from a relatively quiet past to a dynamic history punctuated by numerous world-wide catastrophes, producing mass extinctions, and major geographical changes.

Revolutions in Physical Sciences

Scientific revolutions are best known among the physical sciences. The work of Lavoisier (1743–1794) on combustion resulted in replacement of the phlogiston theory with a theory involving the action of oxygen. This breakthrough can be considered a scientific revolution and initiated further discoveries in chemistry.

James Clerk Maxwell (1831–1879) was able to discover and quantify the links between electricity, magnetism, and light. He showed that light is a form of electromagnetism. His discoveries united phenomena that were previously regarded as unrelated and expressed the relationship quantitatively in a famous series of equations. Maxwell's work is considered the most important development in physics during the 19th century, and foundational to the new ideas that would arise in the 20th century.

Several developments in the 20th century combined to overturn the view of "clockwork nature" that dominated science since the time of Newton. The contributors to this new revolution in physics included Albert Einstein (1879–1955), Niels Bohr (1885–1962), Werner Heisenberg (1901–1976), and Kurt Gödel (1906–1978).

Albert Einstein proposed the theory of general relativity, in which time is relative to the velocity of the observer, mass varies with velocity of the object, and gravity is regarded as a result of curvature of space-time by the presence of matter. Einstein's revolution was to change our perception of time and space from being fixed to being variable in nature. He also changed our perception of matter and energy being distinct phenomena, showing they are interchangeable.

Werner Heisenberg and Niels Bohr played a central role in the development of quantum mechanics theory. Heisenberg determined that one cannot know both the position and momentum of a subatomic particle, a rule known as the Heisenberg Uncertainty Principle. Bohr studied the energy levels of electrons in atoms and proposed that they can take only certain values rather than any intermediate value. He also proposed the principle of complementarity, which states that a subatomic particle may have both wave-like and particle-like properties, but both cannot be observed at the same time. The theory of quantum mechanics includes the conclusion that matter can in an indeterminate state until it is observed, the resulting state will depend on what type of observation is made, and we cannot observe all aspects of a particle at one time.

Gödel is known for his incompleteness theorem, which showed mathematically that we cannot prove anything significant without making unprovable assumptions. This came at a time when other mathematician-philosophers were searching for a philosophical basis for certainty. Gödel proved mathematically, not only that attempts to derive mathematical certainty had not been successful, but that they could not, even in theory, be successful. Gödel's incompleteness theorem had enormous consequences for the philosophy of science, and helped scientists recognize that absolute proof is unattainable.

All these developments together have contributed to a new view of the universe. Rather than being static, clock-like and deterministic, the universe is now seen as being dynamic, contingent, and probabilistic. This change has produced corresponding changes in philosophy and even in popular culture.

Conclusions

Among the fallout from these various scientific revolutions has come the realization that science is not a straight pathway to total reality and truth, but involves numerous tentative conclusions, reversals of opinion, and inherent uncertainty. Its utility is not that it is always true, but that it is useful and leads to further discovery. Accordingly, science is properly respected but not unconditionally trusted. Ideas that everyone "knows" to be true may not be true at all, as is seen in the numerous cases of scientific revolutions. Christian faith must reckon with scientific arguments, but it must not sacrifice its own integrity on the unstable altar of "science du jour." There is more to be learned, even by science.

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[1] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd rev. ed. (Chicago, IL: University of Chicago Press, 1970).
[2] This and the next section are based largely on I. B. Cohen, *Revolution in Science* (Cambridge, MA: Harvard University Press, 1985).
[3] See Cohen, ibid.

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