## Principles of Science

Science is first and foremost a set of logical and empirical methods which provide for the systematic observation of empirical phenomena in order to understand them. We think we understand empirical phenomena when we have a satisfactory theory which explains how the phenomena work, what regular patterns they follow, or why they appear to us as they do. Scientific explanations are in terms of natural phenomena rather than supernatural phenomena, although science itself requires neither the acceptance nor the rejection of the supernatural.

Science is also the organized body of knowledge about the empirical world which issues from the application of the abovementioned set of logical and empirical methods. Science consists of several specific sciences, such as biology, physics, chemistry, geology, and astronomy, which are defined by the type and range of empirical phenomena they investigate. Finally, science is also the application of scientific knowledge, as in the altering of rice with daffodil and bacteria genes to boost the vitamin A content of rice.

**The Logical and Empirical Methods of Science**

There is no single scientific method. Some of the methods of science involve logic, e.g., drawing inferences or deductions from hypotheses, or thinking out the logical implications of causal relationships in terms of necessary or sufficient conditions. Some of the methods are empirical, such as making observations, designing controlled experiments, or designing instruments to use in collecting data. Scientific methods are impersonal. Thus, whatever one scientist is able to do qua scientist, any other scientist should be able to duplicate. When a person claims to measure or observe something by some purely subjective method, which others cannot duplicate, that person is not doing science. When scientists cannot duplicate the work of another scientist it is a clear sign that the scientist has erred either in design, methodology, observation, calculation, or calibration.

**Scientific Facts and Theories**

Science does not assume it knows the truth about the empirical world *a priori*. Science assumes it must discover its knowledge. Those who claim to know empirical truth *a priori* (such as so-called scientific creationists)cannot be talking about scientific knowledge. Science presupposes a regular order to nature and assumes there are underlying principles according to which natural phenomena work. It assumes that these principles or laws are relatively constant. But it does not assume that it can know *a priori* either what these principles are or what the actual order of any set of empirical phenomena is.

A scientific theory is a unified set of principles, knowledge, and methods for explaining the behavior of some specified range of empirical phenomena. Scientific theories attempt to understand the world of observation and sense experience. They attempt to explain how the natural world works.

A scientific theory must have some logical consequences we can test against empirical facts by making predictions based on the theory. The exact nature of the relationship of a scientific theory making predictions and being tested is something about which philosophers widely disagree, however (Kourany 1997). It is true that some scientific theories, when they are first developed and proposed, are often little more than guesses based on limited information. On the other hand, mature and well-developed scientific theories systematically organize knowledge and allow us to explain and predict wide ranges of empirical events. In either case, however, one characteristic must be present for the theory to be scientific. The distinguishing feature of scientific theories is that they are "capable of being tested by experience" (Popper, 40).

To be able to test a theory by experience means to be able to predict certain observable or measurable consequences from the theory. For example, from a theory about how physical bodies move in relation to one another, one predicts that a pendulum ought to follow a certain pattern of behavior. One then sets up a pendulum and test the hypothesis that pendulums behave in the way predicted by the theory. If they do, then the theory is confirmed. If pendulums do not behave in the way predicted by the theory, then the theory is falsified. (This assumes that the predicted behavior for the pendulum was correctly deduced from your theory and that your experiment was conducted properly.)

The fact that a theory passed an empirical test does not prove the theory, however. The greater the number of severe tests a theory has passed, the greater its degree of confirmation and the more reasonable it is to accept it. However, to confirm is not the same as to prove logically or mathematically. No scientific theory can be proved with absolute certainty. Furthermore, the more tests which can be made of the theory, the greater its empirical content (Popper, 112, 267). A theory from which very few empirical predictions can be made will be difficult to test and generally will not be very useful. A useful theory is rich or fecund, i.e., many empirical predictions can be generated from it, each one serving as another test of the theory. Useful scientific theories lead to new lines of investigation and new models of understanding phenomena that heretofore have seemed unrelated (Kitcher).

This feature of fecundity is probably the main difference between the theory of natural selection and the theory of special creation. The theory of special creation has not led to new discoveries, better understanding, or increased understanding of the relatedness of areas within the field of biology or between such fields as biology and psychology. As such, the theory of special creation is nearly useless. And, since the theory is put forth as dogma, it is the antithesis of a scientific theory. However, even if a theory is very rich and even if it passes many severe tests, it is always possible that it will fail the next test or some other theory will be proposed that explains things even better. Logically speaking, a currently accepted scientific theory could even fail the same tests it has passed many times in the past. Karl Popper calls this characteristic of scientific theories, "falsifiability."

**The Fallibility of Science**

A necessary consequence of scientific claims being falsifiable is that they are also fallible. For example, Einstein's special theory of relativity is accepted as "correct" in the sense that "its necessary inclusion in calculations leads to excellent agreement with experiments" (Friedlander 1972, 41). This does not mean the theory is infallibly certain. Scientific facts, like scientific theories, are not infallible certainties. Facts involve not only easily testable perceptual elements; they also involve interpretation.

Noted paleoanthropologist and science writer Stephen Jay Gould reminds us that in science 'fact' can only mean "confirmed to such a degree that it would be perverse to withhold provisional assent" (Gould 1983, 254). However, facts and theories are different things, notes Gould, "not rungs in a hierarchy of increasing certainty. Facts are the world's data. Theories are structures of ideas that explain and interpret facts." In Popper's words: "Theories are nets cast to catch what we call 'the world': to rationalize, to explain, and to master it. We endeavor to make the mesh ever finer and finer."

To the uninformed public, facts contrast with theories. Non-scientists commonly use the term 'theory' to refer to a speculation or guess based on limited information or knowledge. However, when we refer to a scientific theory, we are not referring to a speculation or guess, but to a systematic explanation of some range of empirical phenomena.

Nevertheless, scientific theories vary in degree of certainty from the highly improbable to the highly probable. That is, there are varying degrees of evidence and support for different theories, i.e., some is more reasonable to accept than others.

There are, of course, many more facts than theories, and once something has been established as a scientific fact (e.g., that the earth goes around the sun) it is not likely to be replaced by a "better" fact in the future. Whereas, the history of science clearly shows that scientific theories do not remain forever unchanged. The history of science is, among other things, the history of theorizing, testing, arguing, refining, rejecting, replacing, more theorizing, more testing, etc.

It is the history of theories working well for a while, anomalies occurring (i.e., new facts being discovered which do not fit with established theories) and new theories being proposed and eventually replacing the old ones partially or completely (Kuhn). It is the history of rare geniuses--such as a Newton, a Darwin or an Einstein--finding new and better ways of explaining natural phenomena.

We should remember that science, as Jacob Bronowski put it, "is a very human form of knowledge....Every judgment in science stands on the edge of error.... Science is a tribute to what we can know although we are fallible" (Bronowski, 374). One aim of the physical sciences, he said, has been to give an exact picture of the material world, another achievement of physics in the twentieth century has been to prove that its aim is unattainable.

**Scientific Knowledge**

Scientific knowledge is human knowledge and scientists are human beings. They are not gods, and science is not infallible. Yet, the general public often thinks of scientific claims as absolutely certain truths. They think that if something is not certain, it is not scientific and if it is not scientific, then any other non-scientific view is its equal. This misconception seems to be, at least in part, behind the general lack of understanding about the nature of scientific theories. Another common misconception is that since scientific theories are based on human perception, they are necessarily relative and therefore do not really tell us anything about the real world.

Science, according to certain "postmodernists" cannot claim to give us a true picture of what the empirical world is really like; it can only tell us how it appears to scientists. There is no such thing as scientific truth. All scientific theories are mere fictions. However, just because there is no one, true, final, godlike way to view reality, does not mean that every viewpoint is as good as every other. Just because science can only give us a human perspective, does not mean that there is no such thing as scientific truth. When the first atomic bomb went off as some scientists had predicted it would, another bit of truth about the empirical world was revealed. Bit by bit we are discovering what is true and what is false by empirically testing scientific theories. To claim that those theories which make it possible to explore space are "just relative" and "represent just one perspective" of reality is to profoundly misunderstand the nature of science and scientific knowledge.

**Science as a Candle in the Dark**

Science is, as Carl Sagan put it, a candle in the dark. It shines a light on the world around us and allows us to see beyond our superstitions and fears, beyond our ignorance and delusions, and beyond the magical thinking of our ancestors, who rightfully fought for their survival by fearing and trying to master occult and supernatural powers.