What is Science?

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Abstract

This paper is a redo of an article that first appeared in the *Arizona Journal of Natural Philosophy*, October, 1995, under the title of *Philosophy of Science*. This paper reviews many beliefs about the nature of science from various experts and some nonexpert interested parties, and ends with a few personal comments about the whole thing. (This review is 25 years old. Perhaps I'll find some time to rigorously update it.)

1 Introduction

In the literal sense science means "knowledge," and on this basis some choose to refer to any branch of knowledge as a science. However, due to the distinctive importance that science plays in modern practical and philosophical life, the term science as used today has taken on much subtlety. Let's get right to the quotes – some of which attempt to define science, while others more or less characterize it in some way.

2 Now for the quotes

According to Walker (1963, iv):

> Science is concerned with prediction of events in the physical and biological universe.

According to Campbell (1921; reprinted 1953, 1):

> There are two aspects of science. First, science is a body of useful and practical knowledge and a method of obtaining it....In its second form or aspect, science has nothing to do with practical life and cannot affect it, except in the most indirect manner, either for good or ill. Science of this form is a pure study.

According to Kuhn (1962), "normal" science is a problem-solving enquiry about the natural realm, which restricts the kinds of problems to be solved and limits the experimental techniques to be permitted according to the dictates of a philosophical superstructure called the "paradigm."

According to Morris (1974, 2):

> Science is based on cause-and-effect reasoning. Inevitably, therefore, as one assimilates effects to their immediate cause and those causes to *their* causes, one eventually confronts the question of a First Cause.

According to Sullivan (1952, 13):

> Real science, which is the reasoned explanation of all things in the light of their causes, is concerned with the study of universals or characteristics common to many entities.

According to Kitcher (1983, 33):

> Science offers us laws that are supposed to hold universally, and it advances claims about things that are beyond our power to observe.

According to d'Abro (1939; reprinted 1952, 15):

> Practically the whole of physical science is thus one mass of inference based ultimately, but not immediately, on direct knowledge.

According to Drake (see Galileo, 226 in a footnote):

> Modern scientific method is characterized by an inseparable linkage of theory to experiment, in such a way that no theory may properly be called scientific unless it implies experiments or observations capable of supporting or destroying it, while no experiment is scientifically significant except in its relation to some definitely formulated theory.

According to Toulmin (1953; reprinted 1960, 81):

> Certainly, every statement in a science should conceivably be *capable* of being called in question, and of being shown empirically to be unjustified; for only so can the science be saved from dogmatism.

According to Bacon (1620, 498):

> Meanwhile let no man look for much progress in the sciences–especially in the practical part of them—unless natural philosophy be carried on and applied to particular sciences, and particular sciences be carried back to natural philosophy.

According to Russell (1961, 623-4):

> Science has always prided itself on being empirical and believing only what could be verified.

According to Schneer (1960, 1):

> The primary importance of science and the characteristic that distinguished it from other philosophies and arts is its usefulness.... The remarkable thing about science is the extent to which nature and the world appear to adhere to the rules and constructions of science.

According to Gould (1986, 152):

> Science, above all, is a methodology for acquiring testable knowledge about the natural world....

According to Bergman (1983, 41):

> Science, then, is a method, a tool, used to learn about reality, and only this. It is a way of finding out what 'is', what exists; and how parts of reality interact.

According to Simpson (1962, 9):

> The important distinction between science and those other systematizations [i.e., art, philosophy, and theology] is that science is self-testing and self-correcting.

> Here the essential point of science is respect for objective fact. What is correctly observed *must* be believed.... the competent scientist does quite the opposite of the popular stereotype of setting out to prove a theory; he seeks to disprove it.

And on pages 11–12:

> As for the scope of science, it includes everything known to exist or to happen in the material universe. Since the arts, philosophy, and theology do exist in the material universe, they too are within the scope of science and can properly be studied as psychological, anthropological, and biological phenomena.

According to Bremer (1962, 37–8):

> What, then, is science according to common opinion?
>
> Science is what scientists do.
>
> Science is knowledge, a body of information about the external world.
>
> Science is the ability to predict.
>
> Science is power, it is engineering.
>
> Science explains, or gives causes and reasons.

According to the National Academy of Sciences (1984, 5):

> Scientists must be fact-seekers, open-minded, and "willing to accept changes indicated by the signposts of evidence."

On page 8:

> Scientific investigators seek to understand natural phenomena by direct observation and experimentation. Scientific interpretation of facts are always provisional and must be testable.
>
> In broadest terms, scientists seek a systematic organization of knowledge about the universe and its parts. This knowledge is based on explanatory principles . . .

On page 26:

> . . . the goal of science is to seek naturalistic explanations of phenomena—and the origins of life, the earth, and the universe are, to scientists, such phenomena—within the framework of natural laws and principles and the operational rule of testability.

According to American Institute of Biological Sciences (1963, 3):

> What is science? Is it a body of factual information? Is it a set of theories? Is it an activity or set of procedures for finding facts and developing theories? Science is really a combination of all three of these.

According to Einstein (1951, 123–4):

> As soon as science has emerged from its initial stages, theoretical advances are no longer achieved merely by a process of arrangement. Guided by empirical data, the investigator rather develops a system of thought which, in general, is built up logically from a small number of fundamental assumptions, the so-called axioms. We call such a system of thought a *theory*.

> The theory finds the justification for its existence in the fact that it correlates a large number of single observations, and it is just here that the "truth" of the theory lies..

According to Pirsig (1974, 42):

> The problem, the contradiction the scientists are stuck with is *mind*. Mind has no matter or energy but they can't escape its predominance over everything they do. Logic exists in the mind. Numbers exists only in the mind. I don't get upset when scientists say that ghosts exists in the mind. It's that *only* that gets me. Science is *only* in your mind too, it's just that that doesn't make it bad. Or ghosts either.
>
> ... Laws of nature are human *inventions*, like ghosts. Laws of logic, of mathematics are also human inventions, like ghosts. The whole blessed thing is a human invention, including the idea that it $isn\varphi t$ a human invention. The world has no existence whatsoever outside the human imagination. It's all a ghost, and in antiquity it was so recognized as a ghost, the whole blessed world we live in. It's run by ghosts. We see what we see because these ghosts *show* it to us, ghosts of Moses and Christ and the Buddha, and Plato, and Descartes, and Rouseau and Jefferson and Lincoln, and on and on. Issac Newton is a very good ghost. One of the best. Your common sense is nothing more than the voices of thousands and thousands of these ghosts from the past. Ghosts and more ghosts. Ghosts trying to find their place among the living.

According to Pirsig (1992, 121):

> If science is a study of substances and their relationships, then the field of cultural anthropology is a scientific absurdity. In terms of substance there is no such thing as culture. In terms of substance there is no such thing as culture. It has no mass, no energy. No scientific laboratory instrument has ever been devised that can distinguish a culture from a nonculture.... But if science is a study of stable patterns of value, then cultural anthropology becomes a supremely scientific field. A culture can be defined as a network of social patterns of value.

According to Pagels (1982, 81):

> Science does not deny the reality of our immediate experience of the world; it begins there. But it does not remain there, because the basis for comprehending our experience is not given with sensual experience. Science shows us that supporting the world of sensual experience there is a conceptual order, a cosmic order which can be discovered by experiment and known by the human mind. The unity of our experience, like the unity of science, is conceptual, not sensual. That is the difference between Newton

> and Goethe—Newton sought universal concepts in the form of physical laws, while Goethe looked for the unity of nature in immediate experience.
>
> Science is a response to the demand that our experience places upon us, and what we are given in return by science is a new human experience—seeing with the mind the internal logic of the cosmos. The discovery of the indeterminate universe by the quantum physicists is an example. The end of determinism meant not the end of physics but the beginning of a new vision of reality. Here in the atomic core of matter, physicists found randomness.

According to Bohm and Peat (1987, 16):

> Science is an attempt to understand the universe and humanity's relationship to nature.

And on page 56:

> The essential activity of science consists of thought, which arises in creative perception and is expressed through play. This gives rise to a process in which thought unfolds into provisional knowledge which then moves outward into action and returns as fresh perception and knowledge. This process leads to a continuous adaption of knowledge which undergoes constant growth, transformation, and extension. Knowledge is therefore not something rigid and fixed that accumulates indefinitely in a steady way but is a continual process of change. Its growth is closer to that of an organism than a data bank. When serious contradictions in knowledge is encountered, it is necessary to return to creative perception and free play, which act to transform existing knowledge. Knowledge apart from this cycle of activity, has no meaning.

And on page 67:

> Science is essentially a public and social activity.

And on page 241–2:

> Science is, however, at least in principle, dedicated to seeing any fact as it is, and to being open to free communication with regard not only to the fact itself, but also to the point of view from which it is interpreted.

And on page 260:

> Although *science* literally means "knowledge," the scientific attitude is concerned much more with rational perception through the mind and with testing such perceptions against actual fact, in the form of experiments and observations.

According to Paul Davies (1989, 1):

> Physics is the most pretentious of all the sciences, for it purports to address all of physical reality. The physicist may confess ignorance about a particular system—a snowflake, a living organism, a weather pattern—but he will never concede that it lies outside the domain of physics in principle. The physicist believes that the laws of physics, plus knowledge of the relevant boundary conditions, are sufficient to explain, in principle, every phenomenon in the universe. Thus the entire universe, from the smallest fragment of matter to the largest assemblage of galaxies, becomes the physicist's domain—a vast natural laboratory for the interplay of lawful forces.

According to William J. Kaufmann, III (1980, 1):

> From the moment of birth, our daily experiences strongly enforce the notion that reality is comprehensible. The fact that a rock released from your hand always falls down or that the moon goes through its phases every $29\frac{1}{2}$ days implies order rather than chaos to the rational human mind. To discover this order, to understand the basic and underlying qualities of all physical objects, to comprehend the fundamental principles that dictate the behavior of reality: this is the business of science.

According to Prigogine and Stengers (1984, 97) a summary of Mach's view is:

> Science is part of the Darwinian struggle for life. It helps us to organize our experience. It leads us to economy of thought. Mathematical laws are nothing more than conventions useful for summarizing the results of possible experiments. [This doctrine is known as *scientific positivism*]

According to the Vienna School of Positivism:

> Science is granted jurisdiction over all positive knowledge and philosophy needed to keep this knowledge in order. This meant a radical submission of all knowledge and questions to science.

According to Kofahl (1986, 112):

> Science is human experience systematically extended (by intent, methodology and instrumentation) for the purpose of learning more about the natural world and for the critical empirical testing and possible falsification of all ideas about the natural world.
>
> Scientific hypotheses may incorporate only elements of the natural empirical world, and thus may contain no element of the supernatural.

According to Sisler et al. (1961, 3–4):

> The inquiring scientist approaches each problem with an open mind and with the highest type of intellectual integrity, willing and eager to follow wherever the facts may lead. Whenever possible, he analyzes a complex problem into its simplest components and devices carefully controlled experiments which clearly reveal cause and effect relationships. He is critical of the validity of his own data and subjects his hypotheses to exhaustive experimental tests before arriving at even tentative conclusions. In all his work, he relies upon a faith that natural phenomena are reproducible and that the universe is orderly.

According to Broad and Wade (1983, 18):

> Science is a community of scholars engaged in the production of certifiable knowledge.

We turn now to a deeper review of Broad and Wade's book *Betrayers of the Truth* (1983). From page 7 of the preface we find:

> This is a book about how science really works. It is an attempt to understand better a system of knowledge that is regarded in Western societies as the ultimate arbiter of truth. We have written it in the belief that the real nature of science is widely misunderstood by both scientists and the public.

According to P.W. Atkins (1984, Preface page 1):

> No other part of science has contributed as much to the liberation of the human spirit as the Second Law of thermodynamics. Yet, at the same time, few other parts of science are held to be so recondite. Mention of the Second Law raises visions of lumbering steam engines, intricate mathematics, and infinitely incomprehensible entropy. Not many would pass C. P. Snow's test of general literacy, in which not knowing the Second Law is equivalent to not having read a work of Shakespeare.

According to Sean Carroll (2016, page 17):

> As knowledge generally, and science in particular, have progressed over the centuries, our corresponding ontologies have evolved from quite rich to relatively sparce. To the ancients, it was reasonable to believe that there were all kinds of fundamentally different things in the world; in modern thought, we try to do more with less.

According to Atkins and Jones (2005, page F13):

> Science is a quest for simplicity.

According to David Lindley (2008, page 8):

> Certainty, in science, has always been a fraught issue, and although quantum theory and Heisenberg's uncertainty are unquestionably products of the twentieth century, their earliest glimmerings appeared almost one hundred years earlier.

3 Conclusion

Broad and Wade, working as metascientists, analyze the relative success of science to fulfil its own criteria of being logical, repeatable, peer-reviewed, and objective. They conclude that (pp. 8–9):

> Our conclusion, in brief, is that science bears little resemblance to its conventional portrait. We believe that the logical structure discernible in scientific knowledge says nothing about the process by which the structure was built or the mentality of the builders. In the acquisition of new knowledge, scientists are not guided by logic and objectivity alone, but also by such nonrational factors as rhetoric, propaganda, and personal prejudice. Scientists do not depend solely upon rational thought, and have no monopoly it. Science should not be considered the guardian of rationality in society, but merely one major form of its cultural expression.

I found *Betrayers of the Truth* to be a fascinating and well-documented work. Unfortunately, space does not permit me to pursuit it further.

When I began the research on this paper, I had no idea just how unclear the nature of science is, even to scientists, not to mention to the philosophers of science. The public does not see this because, with the exception of a few skirmishes over the creation-evolution debate [I'll return to this in a moment], all they see of science is its practical sides. The reality of science to the philosopher is much different. As Russell put it (1958, 67–68):

> The great scandals in the philosophy of science ever since the time of Hume have been causality and induction.... If we emphasize that fact that our belief in causality and induction is irrational, we must infer that we do not know science to be true, and that it may at any moment cease to give us the control over the environment for the sake of which we like it.

Considering the widely varying definitions of science just presented, I must agree with Broad and Wade. For my own part, I am sure that I do not really understand *today's* 'science'. Science is what we humans define it to be, but there is no consensus on a common definition. And, of course, there are today some very vocal promoters of what science "really" is. It's as if some scientists believe that if they talk confidently enough about the 'truth of science' and ignore its weaknesses, that the foundational problems and controversies that still inhabiting science will just fade away. Out of sight — out of mind.

Among certain scientists, science has become a closed system of thought with no outside criticism allowed. Scientists were in, philosophers (and the public) were out. When, in 1939, Eddington called for a rebirth of natural philosophy in order that science would benefit from investigating the nature of scientific knowledge, he was politely ignored. Science remains a closed system of thought, completely outside the check-and-balances of the rest of humanity's philosophical pursuits. But natural philosophy must be reborn for it to fill the gap between science and philosophy.

I said I'd return to the issue of the creation-evolution debate, so here it is. We can add a few more common debates and controversies to the list than when I first published this article: The vaccine conspiracy theories, moon-landing conspriacy theories, the debate over cosmologies and cosmogonies, and the debate over the shape of the earth. However one might wish to define the scope of science, it must be admitted that there is a profound difference between those events that are recent in time and proximal in space compared to those events that are putatively distant in time and/or distant in space.

The following is my simplistic definition of Science:

> The general purpose of science is to reduce as much as possible the observable processes of the proximal spacetime realm to experimentally observed, numerically recorded, and mathematically codified invariable relations (physical laws) between objects and events, explaining these relationships in the contexts of a system of formal, human-invented rules, referred to as a "theory," and founded on formal mental and mathematical models whose ultimate connections to so-called "reality" which underlies physicality (the set of all possible humanly measurable relations between spacetime events) lie outside the domain of science proper but lie within the domain of Natural Philosophy.

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