THE SCOPE AND LIMITATIONS OF SCIENCE

by H. Stanley Bennett, M.D.

Science can be defined as the study of nature and of its properties. It places chief reliance on the direct study of natural phenomena. It has the aim of giving us *understanding* of nature, by which one means the capacity to relate and to group observed properties and phenomena in logically consistent ways, permitting the formulation of generalizations and of predictions, which can then be tested by further observations and extensions of logical treatment. One can think of mathematics as the study of the properties of logical systems. From mathematics come many of the basic, logical rules we use in describing and relating the properties of nature. Biology can be defined as that part of science which deals with those portions of nature which we call "life."

Man is living, and man is part of nature. Hence the study of man is properly within the bounds of biology and of science. By convention, when studying man, we think of biology, or of science, as embracing only those aspects of man which are shared rather broadly with other living things, or which are represented generally in the properties of matter throughout nature. Those aspects of man which are unique to man—those which depend on his intellect and powers of language and creation—are usually thought of as outside the realm of science. Examples are studies of philosophy, of law, of religion, and splendid creative peaks in poetry, music, prose and art, which reached lofty levels of achievement before systematic studies of nature developed very much. But these activities reflect the properties of man, who is in turn part of nature. Hence, studies of intellectual activities of man can be regarded as parts of science. This viewpoint, which looks at the humanities as a subdivision of science, rather than as a set of disciplines separate from science, is not gladly received by many scholars in humane letters but has a logic which commends it for serious dis-

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cussion. The concept is a sort of inversion of familiar classifications of knowledge fields and merits a short scrutiny.

The Decline of Religious Cosmologies

Theologians and philosophers have not hesitated in the past to formulate and to publish their own cosmologies and celestial chronologies, and thus to inject themselves into scientific fields. These cosmological concepts, representative examples of which are recorded in the Book of Genesis, in some of the Indian Sutras, in components of the Tripitaka, or Sacred Buddhist Canon, and in the Kojiki and Nihongi of Japan, were unchecked by systematic observations logically interpreted, and can now be recognized as conceits pleasing to the authors and their audiences, serving purposes unrelated to the veracity of the concepts recorded. These primitive excursions into cosmology were really naïve attempts to create satisfying conceptual frameworks for a people's place in nature. The biblical concepts of cosmology and creation have no superiority in scientific truth over alternative attempts of Buddhists, Hindus, Japanese, or Egyptians. The Old Testament ideas are distinguished from others mainly by their special historical importance in Western culture.

We see, then, how early humanists, theologians, and scholars made intellectual excursions into scientific fields in order to create satisfying concepts relating to man's place in nature. To Jews and Christians of earlier days, the idea of an all-powerful and all-knowing God, a ruler of all nature, seemed to be a compelling necessity. In this system, man assigned to himself a prominent place, conceiving that God had created man in God's own image, and placing man's habitat, namely the earth, centrally in the universe, deeming it dishonorable to God and unflattering to man to have God's image located any otherwise. Thus, science was entangled inextricably with religion, philosophy, law, and human studies, and was a part of them. In this framework, the ultimate realities were to be perceived through thought, or through the writings or teachings of revered authorities—which means the thoughts of others. The idea that thought, speculation, even mysticism, could provide reliable guides to understanding of the realities of man and of nature is particularly prominent in Indian philosophies, including Buddhism, and clearly operated dominantly in the formulations of biblical and Aristotelian frameworks. It is often recognized that the "Wisdom of the East" assumed that meditation provided the most esteemed way to achieve knowledge and insight. The medieval reverence for established authority simply translated this reliance on thought to thinkers of the past.

A basic premise of scientific approaches is that the most reliable way to learn about something is to study it—to examine its properties directly. Of course, it is good to think about it and to read about it, but the most reliable authority resides in the phenomenon itself. Thales of Miletos is usually credited with the first explicit statement of the merits of studying directly the matter in question. Thales, the father of science, seems obscure in some ways beside his great contemporaries, Confucius, Zoroaster, Gautama Buddha, and Lao-Tze, all of the sixth century B.C., whose thoughts, more than those of Thales, had immediate impact on the lives of men for over a millennium. But like the tortoise overtaking the hare, the solid merits of the system of Thales, its capacity for self-correction, and its enormous practical value to goals of mankind have given it an astonishing ascendancy over older systems of thought, which have had great vogue, which have done much to enrich human life, and which have given vast hope and comfort to a suffering humanity.

The last few centuries have seen steady erosion of fixed systems of thought before the flexible, self-correcting, tentative, uncertain, and powerful development of science. Precisely because systematic study of nature failed to sustain the self-flattering central image of man in a universe created in six days for man by an anthropomorphic God, the rear-guard defense of Christian orthodoxy was vigorous and often bitter, cruel, and ridiculous. Every church is now ashamed of the burning of Servetus, the trial of Galileo, and of Bishop Wilberforce's assaults on Darwin. But more important, every battle so joined was lost by the church, which has been in steady retreat in influence with every advance in science. Today no churchman dares to open his lips when scientists propose that man, far from being central, seems to occupy an obscure peripheral place in the universe, finding himself on a second-rate planet revolving around a third-rate star, which is one of many millions in a galaxy, which is, in turn, only a minute fraction of discernible space and only one of many millions of its kind. And life, far from being uniquely created on a central earth, now appears to be a very probable issue wherever carbon, hydrogen, nitrogen, oxygen, sulphur, and phosphorus are found within a certain temperature range, and in the presence of energy sources, such as electrical discharges and electromagnetic radiation. It now seems reasonable to recognize the high likelihood of life in many millions of planets throughout the numerous galaxies. Bearing in mind the vast probabilities for evolution existing in many parts of the universe, it is prudent to sober our self-esteem with the realization that man may not be the loftiest expression of living matter. If the highest type of life in the universe is

to be given the flattering recognition of assigning its own form to God, then God may not be anthropomorphic.

Looking back on the hold which religion had on art, science, literature, philosophy, law, and government in the Middle Ages in western Europe, its retreat is most impressive. Of course, its declining influence has been occasioned by the secularization of learning in general, of which science may be only a part, but the logic and persuasion of the impact of science could not be withstood by any fixed system of ideas.

Let us look at this retreat in more detail. Great churchmen—William of Wykeham, Cardinals Wolsey, Richelieu, and Mazarin—served as first ministers of the greatest realms of the day. How long is it since a major power has been governed by a churchman? Once, in Europe, all the greatest philosophers were clerics: Augustine, Abelard, Aquinas. They have been replaced by laymen: Descartes, Bacon, Hume, Kant. Today what churchman-philosopher is respected beside Russell, Wittgenstein, Whitehead, or Freud? Francis Bacon, a devout Christian, in foretelling the age of science, never dreamed that some of the greatest philosophers of the scientific age would take positions which gave no consideration to God or to religion, except for the historical role these concepts have had in men's minds. Theologians today busy themselves extensively in formulating accommodations to the concepts of science. Religion has lost its command of philosophy, its leadership in thought, and even its position as chief formulator and justifier of morals and ethics. For, if the church, claiming to be infallible in doctrine, was wrong about the earth, the sun and the origin of life, including man, can one place great reliance on the church's arguments for ethics and theology? Pope Urban VIII may have been foolish in bringing Galileo to trial before the Inquisition, but he was correct in recognizing the threat which science posed to the leadership of the church. Today we see his fears well materialized. Young people appear to be tending to reject more and more of traditional church teachings and of religious arguments for moral precepts and ethics.

Erwin Schrödinger wrote of these trends as follows:

> Rising to their feet after centuries of shameful servitude imposed by the Church, conscious of their sacred rights and their divine mission, the natural sciences turned against their ancient tormentors with blows of rage and hatred; heedless that, with all her inadequacies and derelictions of duty, she was still the one and only appointed guardian of our most sacred ancestral heritage. Slowly, almost unobserved, that spark of ancient Indian wisdom, which the marvelous Rabbi had kindled to new flame beside the Jordan, flickered out: the light faded from the re-born sun of Greece, whose rays had ripened the fruits we now enjoy. The people no longer know anything of these things. Most

of them have nothing to hold on to and no one to follow. They believe neither in God nor gods; to them the church is now only a political party, and morality nothing but a burdensome restriction which, without the support of those no longer credible bugbears on which it leant for so long, is now without any basis whatever. A sort of general atavism has set in; western man is in danger of relapsing to an earlier level of development which he has never properly overcome; crass, unfettered egoism is raising its grinning head, and its fist, drawing irresistible strength from primitive habits, is reaching for the abandoned helm of our ship.[1]

These words of Schrödinger were penned nearly four decades ago. The secularization of Western culture continues rapidly. Many thoughtful persons, sensing the weakening power of religious arguments for ethical and moral behavior, see a need for easily understood secular formulations of ethics and morals which will be effective with persons who feel they cannot rely on religious guidance.

Does Science Include All Knowledge—Including Religion?

Having glanced briefly at the results of four centuries of interaction between science and religion, let us look at other aspects of the expanding realm of science. Let us remind ourselves again that we are here defining science broadly, as the study of nature and of its properties, with special reliance placed on the direct examination and observation of phenomena of interest. Man is part of nature, and his activities reflect his properties. By this argument, to repeat, study of all of man's activities, including his intellectual ones, becomes a part of science. Hence, the inversion alluded to in an earlier part of this presentation. Before, centuries ago, science was part of religion, or of philosophy. Today, according to the viewpoint considered here, religion becomes a part of science, as does literature, art, philosophy, music, and all other activities of the human intellect and human society. The expanding realm of science, then, would come to embrace all knowledge of any kind.

To what extent is this a useful concept of science; and to what extent is it to be dismissed as unsound, or as a conceit of grasping, domineering scientists? If one is to utilize widespread acceptance as a guide, one can find much to justify the view that science is expanding so as to embrace increasingly aspects of human intellect and society. The term "social sciences" lends dignity to this expansion. But can these properly be called sciences? As science is defined here, they can indeed. Psychologists attempt to study and to understand the properties of the human mind. Historians examine, report on, and analyze aspects of human activities in the past, working by tradition largely from written records and leaving to anthropologists and paleontologists the study of

past human activities as revealed otherwise. Sociologists attempt to delineate the properties of human societies, and geographers study the resources on which societies depend. Economists construct huge, over-all budgets which record and permit analysis of the flow of commodities, of labor, of money, and of articles of commerce for the world, for nations, and for other human communities. Concise records of such studies can be summarized in the form of input-output tables which provide close analogies to heat budgets of the earth, for example, of interest to geophysicists. Objective study of language is highly developed, presenting itself in the field of linguistics. In these areas, we find wide acceptance, but not universal approval, of the idea that such fields of study can be called "sciences."

But what of art, music, literature, religion, and philosophy? Can these be regarded as sciences? Objective studies of these aspects of man's intellectual activities as representative of the properties of man, in turn part of nature, can be classified as parts of science by the same logic which assigns economics, history, and linguistics to the domain of science. Thus musicology, the objective study of music with the aim of understanding music as an aspect of human achievement, is just as much a science as is history or anthropology. Similarly, studies of art, of religion, of literature, and of philosophical systems can be regarded as branches of science. Perhaps we should speak of natural sciences, of social sciences, and of intellectual sciences.

But what of creative acts themselves? Is the creation of a great painting or the composing of Handel's "Messiah" a part of science? Arguments that they are parts of science can be made on the basis of the revelations of human character, thought, and emotions embodied in such creative masterpieces. But the arguments will probably seem weak to many, who may prefer to regard these creative acts as human phenomena, as phenomena of nature, worthy of scientific study, and not scientific acts in themselves. By analogy, the emission of light with a wavelength of 546 nanometers by mercury atoms is not science, but the study of the properties of that emitted light and of the atom emitting it is part of science. By the same token, the formulation of religious, philosophical, and metaphysical concepts would be natural manifestations of the properties of man, but not science in themselves. However, objective study of the ideas so formulated would be part of science.

But what of creative acts embodied in the formulation of important scientific generalizations? Is the act itself of conceiving of quantum theory, or of evolution, or of the force of gravity—is such a creative

act in itself a part of science? If so, why is the creation of the "Messiah" not science? One answer would be no. Creative acts in themselves, of whatever kind, are phenomena of nature and are hence not part of science, though they can be studied by man, in which case the study of the properties of the ideas so created can be a part of science. Thus, Einstein, in conceiving the relationship, $e = mc^2$, proposed an idea which can be tested against reality by experiment and observation and examined for logical consistency with other relationships we regard as real. Similarly, Handel's "Messiah" can be studied as a lofty and moving expression within a Christian and musical idiom. This masterpiece summarizes much of general importance, epitomizing a vast sweep of Christian and Judaic concepts which, alas, are fading in memory with each generation.

Some Limitations of Science

So far, we have spoken optimistically of science, assigning to it broad tasks, hailing its triumphs over religion and its extending influences into man's intellectual and social activities. Is science, then, to sweep on to triumph after triumph, and is it capable, in principle, of providing us with profound understanding of all the phenomena of nature, including those involving man, his properties, his intellectual, social, and creative activities? Can we come to understand man in the same terms we use for descriptions of phenomena in physics and chemistry?

Further achievements can, indeed, reasonably be expected, since the momentum of science is far from spent. But many doubt if, in principle, man will be able to gain full understanding of nature or of the workings of man's mind. Such doubts have been expressed by many natural scientists, who, recognizing that men, for example, are made of the same matter as is the rest of the universe, nevertheless despair of gaining complete understanding, either because of the complexity of the phenomena in question or because of limitations of the human brain or for other profound reasons. Let us look at the views of some natural scientists.

Erwin Schrödinger, in his essay entitled "Seek for the Road"[2] expresses himself as follows:

> . . . if we cut out all metaphysics it will be found to be vastly more difficult, indeed, probably quite impossible to give any intelligible account of even the most circumscribed area of specialization within any specialized science you please. Metaphysics includes, amongst other things—to take just one crude example—the unquestioning acceptance of a more-than-physical—that is, tran-

scendental—significance in a large number of thin sheets of wood-pulp covered with black marks such as are now before you. . . . A real elimination of metaphysics means taking the soul out of *both* art *and* science, turning them into skeletons incapable of any further development. . . . Speaking as a scientist, it seems to me, that it is our uncommonly difficult task as post-Kantians, on the one hand, step by step to erect barriers which will restrain the influence of metaphysics on the presentation of facts seen as true within our individual fields—while on the other hand preserving it as the indispensable basis of our knowledge, both general and particular. It is the apparent contradiction which is our problem. We might say, to use an image, that as we go forward on the road to knowledge we have *got* to let ourselves be guided by the invisible hand of metaphysics reaching out to us from the mist, but that we must always be on our guard lest its soft, seductive pull should draw us from the road into an abyss. Or, to look at it another way: among the advancing hosts of the forces of knowledge, metaphysics is the vanguard, establishing the forward outposts in an unknown, hostile territory; we cannot do without such outposts, but we all know that they are exposed to the most extreme danger. Or again: metaphysics does not form part of the house of knowledge but is the scaffolding, without which further construction is impossible. Perhaps we may even be permitted to say: metaphysics turns into physics in the course of its development—but not, of course, in the sense in which it might have seemed to do so before Kant. *Never,* that is, by a gradual establishing of initially uncertain opinions, but always through a clarification of, and change in, the philosophical point of view.

In asking ourselves how far science can carry us into understanding of the properties of man and of nature, we may wish to note the view of another eminent natural scientist, Michael Polanyi. In a recent private communication, Polanyi holds that "no mechanism—be it a machine or a machine-like feature of an organism—can be represented in terms of physics and chemistry." He points out that machines are designed and shaped by men for specific purposes and that the over-all working of the machine cannot be predicted from consideration of the properties of its parts. Perhaps Polanyi is suggesting here that an electronic amplifier cannot be fully understood without taking into account the informational content of the electrical signals it amplifies. Polanyi, like Schrödinger, refers to books as beyond physico-chemical description, saying, "Nothing is said about the content of a book by its physical-chemical topography. All objects conveying information are irreducible to the terms of physics and chemistry." Turning to biology, Polanyi writes, "If DNA is to be regarded as bearing a pattern that forms part of an organism and as transmitting information through this pattern, then such a pattern is to be classed likewise as a morphological feature of the organism, and hence to be irreducible to terms of physics and chemistry. By the same token, any chemical compound bearing a complex structure and transmitting thereby substantial information to

its neighborhood, must be irreducible to physics and chemistry in respect to this particular feature."

Deeming it absurd "to speak of life as something to be explained by the laws of physics and chemistry," he points out that "Biological principles are seen to control the boundary conditions within which the forces of physics and chemistry carry on the business of life."

In indicating that "no given material system can be wholly determined by the laws of physics and chemistry," Polanyi does not say that they are beyond the realm of science. He simply calls attention to limitations to the degree of understanding he believes we can expect to achieve.

Some further reflections on the limitations of science are provided by a mathematician, J. Bronowski. In his lectures on *The Identity of Man*[3] and "The Logic of the Mind,"[4] Bronowski discusses the logical limitations inherent in efforts to understand a system from observations made from within that system. He reminds us that some of these were stated by Einstein in his theories of relativity. As Bronowski summarizes the impact of Einstein's insights,

> We get a false picture of the world if we regard it as a set of events that have their own absolute sequence, and that we merely watch. . . .
>
> If we write the laws of nature as if we ourselves had no part in them, we get the wrong answers to quite elementary questions, for example, about the orbit of the planet Mercury. . . . Nature is a network of happenings that . . . are intertwined between every part of the world; and we are among those parts. In this nexus, we cannot reach certainty because it is not there to be reached; it goes with the wrong model, and the certain answers ironically are the wrong answers. Certainty is a demand that is made by philosophers who contemplate the world from outside; and scientific knowledge is knowledge for action, not contemplation. . . . It is not possible for the brain to arrive at *certain* knowledge. All those formal systems, in mathematics and physics and the philosophy of science, which claim to give foundations for certain truth are surely mistaken.

In support of his view that the brain cannot arrive at certainty, Bronowski cites theorems of Gödel and Turing as telling us that "No machine that uses strict logic can examine its own instructions and prove them consistent." In more detail, Bronowski considers that Kurt Gödel in 1931

> proved two remarkable and remarkably unwelcome theorems. The first theorem says that any logical system which is not excessively simple (that is, which at least includes ordinary arithmetic) can express true assertions which, nevertheless, cannot be deduced from its axioms. And the second theorem says that the axioms in such a system, with or without additional truths, cannot be shown in advance to be free of hidden contradictions. In short, a logical system which has any richness can never be complete, yet cannot be guaranteed to be consistent.

Bronowski continues,

That was in 1931. In the next few years, other unpleasant theorems were established. A. M. Turing in England and Alonzo Church in America showed that no mechanical procedure can be devised which could test every assertion in a logical system and in a finite number of steps, demonstrate it to be either true or false. . . . Alfred Tarski in Poland proved . . . that there can be no precise language which is universal; every formal language which is at least as rich as arithmetic contains meaningful sentences that cannot be asserted to be either true or false.

Bronowski, accepting these theorems and their implications, deems it hopeless to

attempt to uncover an ultimate and comprehensive set of axioms (including mathematical rules) from which all the phenomena of the world could be shown to follow by deductive steps. . . . An axiomatic system cannot be made to generate a description of the world which matches it fully, point for point; at some point there will be holes which cannot be filled in by deduction, and at other points two opposite deductions may turn up. . . . It follows that the unwritten aim that the physical sciences have set themselves since Isaac Newton's time cannot be attained. The laws of nature cannot be formulated as an axiomatic, deductive, formal and unambiguous system which is also complete.

Bronowski speaks of science as knowledge of the physical workings of the world, which we seek to express in unambiguous language of logical consistency. He speaks of this matter as follows:

Plainly it matters in the most practical way that we rightly understand how we ourselves are embedded in the system of science that we in part discover and in part create. Such a system describes the activity of nature and ourselves in it; it is not a blueprint of the machinery of nature. We are an active and intimate part of our descriptions of her. Science then is not so much a model of nature as a living language for describing her.

He points out how the theorems cited a moment ago tell us the language of science cannot be complete and unambiguous. At one point, Bronowski states, "The structure of science is no more exact, in any final sense, than that of poetry."

Bronowski indicates that the logical limitations outlined above become more and more compelling as the phenomenon examined embraces more and more of the examining instrument, which is, of course, the human brain. Thus the problems become very large when man seeks to examine the workings and products of the human mind. There may, then, be very profound reasons why descriptions of human behavior, of creativity, have not been formulated in terms of logical consistency as impressive as those which have been attempted for more general, external manifestations of nature. If we are to include humani-

ties as a part of science, one must allow for rather different methods of description of human thought as compared with descriptions of atomic orbitals. Attempts to deal with aspects of human behavior in quantitative terms, using formal rules of mathematical logic, seem restricted to trivial and unimportant aspects of behavior. These currently popular approaches characterize and describe, but do not lead to understanding. Bronowski summarizes by saying, "The difference in mode between science and literature reflects the different extent to which self-reference enters their languages."

So we see that, though the realm of science is expanding, it is not infinite, it is not all-encompassing, it is not catholic. We have no basis to hope through science, or through any other means, to gain complete understanding of man or of nature. These limits may be defined as much by the abstract properties of logical systems as by the shortcomings of the human brain, or the complexities of the subjects of study. Science is very powerful nevertheless, and, though tentative and uncertain, it is self-correcting, self-expanding, and self-improving. Through science, man seeks to group and relate phenomena of nature in consistent ways and, through this process, to gain a measure of understanding and a means of influence and control over nature. We have no better way.

NOTES

1. Erwin Schrödinger, *My View of the World* (New York: Cambridge University Press, 1964), p. 6.
2. *Ibid.*
3. J. Bronowski, *The Identity of Man* (Garden City, N.Y.: Doubleday & Co., 1965).
4. J. Bronowski, "The Logic of the Mind," *American Scholar,* XXXV (1966), 233–42.