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Science

INTRODUCTION

In our time, science, philosophy, and religion have come to represent three quite distinct intellectual enterprises. Each appeals for allegiance not merely on the ground that it can answer fundamental questions, but also because of its contribution to human life and culture. In other periods, philosophy and religion competed for supremacy, though, as appears in the chapter on PHILOSOPHY, some philosophers and theologians tried to remove this conflict by arguing for the complete compatibility of reason and faith. Nevertheless, before the 19th century, the issue, if one existed, was between philosophy and religion. Science had not yet become sufficiently distinct from philosophy to complicate the picture.

When science and philosophy are not themselves sharply distinguished, men are not confronted with three separate claims upon their intellectual allegiance. Modern science as something quite distinct in method and subject matter from traditional philosophy may actually make its appearance as early as the 17th century. But not until Kant are two kinds of science plainly set apart. Not until then are they so defined that one becomes identified with what men have always called "philosophy" and the other gradually appropriates the name of "science" and regards itself as a quite separate enterprise.

Kant differentiates between the empirical and the rational sciences. This differentiation tends to correspond with the distinction by others before him of experimental and abstract philosophy. It also corresponds with a later division into the experimental or inductive and the philosophical or deductive sciences. But Kant does not seem to contemplate the possibility of conflict between science and philosophy—between the experimental study of nature and metaphysics or, what is for him the same, between empirical and rational physics.

Hume is willing to admit only mathematics to the status of a rational science, capable of demonstrating its conclusions with certainty. He insists upon experimental reasoning in the study of nature, wherein only probable conclusions can be attained. But he does not make these critical points in terms of science versus philosophy. If the traditional metaphysics is to be rejected, it is not because it is philosophy rather than science, but because it represents a failure in philosophy *or* science, resulting from the wrong method of dealing with matters of fact.

In the 19th century, however, Auguste Comte formulated a doctrine which, under the title of *Positive Philosophy*, explicitly declares that only the positive sciences—the study of natural, mental, and social phenomena by empirical methods—deserve to be called "sciences" in the eulogistic sense of that term. In contrast, philosophy is mere speculation, and religion is superstition. The word "speculation" is for the positivist only slightly less invidious than "superstition." Whereas superstition implies irrational belief, speculation represents a futile attempt by reason to go behind the phenomena in order to discover ultimate causes or substances. This cannot result in anything but guesswork or conjecture—never in knowledge or science, which are the same for the positivist. For all its show of logic and system, philosophy cannot produce conclusions which have the validity or objectivity of science, because it tries to do more than explore and describe the phen-

omena and because it tries to do whatever it does without investigation or experiment.

From many sources in addition to Comte similar views converge to form an attitude generally prevalent in the world today under the name of positivism. All its current varieties seem to have this much in common: the identification of science with knowledge of fact, and further, the restriction of such knowledge to conclusions obtained and verified empirically. Whatever does not accord with this conception of science is either, like mathematics or logic, a purely formal discipline or, like philosophy and religion, it is conjecture, opinion, or belief—personal, subjective, even wishful.

FREUD IS THE AUTHOR in this set of great books who provides us with a declaration of positivism and sets science against philosophy and religion. It is also fitting that he should be a scientist in the field of psychology, since psychology is a latecomer among the disciplines that, once branches of philosophy, now claim to be positive sciences. Not only late, but last, according to Freud, for "sociology, which deals with the behavior of man in society, can be nothing other than applied psychology. Strictly speaking, indeed, there are only two sciences—psychology, pure and applied, and natural science."

In his *New Introductory Lectures on Psycho-Analysis,* Freud concludes with a statement of what he calls the "scientific *Weltanschauung.*" In essence, he thinks, "it asserts that there is no other source of knowledge of the universe, but the intellectual manipulation of carefully verified observations, in fact, what is called *research,* and that no knowledge can be obtained from revelation, intuition, or inspiration." Freud makes the drastic implications of this statement quite explicit. "It is inadmissible to declare," he writes, "that science is one field of human intellectual activity, and that religion and philosophy are others, at least as valuable, and that science has no business to interfere with the other two, that they all have an equal claim to truth, and that everyone is free to choose whence he shall draw his convictions and in which he shall place his belief.

"Such an attitude," he goes on, "is considered particularly respectable, tolerant, broad-minded, and free from narrow prejudices. Unfortunately, it is not tenable; it shares all the pernicious qualities of an entirely unscientific *Weltanschauung* and in practice comes to much the same thing. The bare fact is that truth cannot be tolerant and cannot admit compromise or limitations, that scientific research looks on the whole field of human activity as its own, and must adopt an uncompromisingly critical attitude towards any other power that seeks to usurp any part of its province."

As a threat to the dominion of science over man and society, "religion alone is a really serious enemy." Philosophy, Freud thinks, "has no immediate influence on the great majority of mankind"; whereas "religion is a tremendous force, which exerts its power over the strongest emotions of human beings." Religion and science might be compatible if religion, offering men something "incomparably more beautiful, more comforting, and more ennobling than anything they could ever get from science," would only say: 'It is a fact that I cannot give you what men commonly call truth; to obtain that, you must go to science.' "

But religion cannot say that, Freud thinks, without losing "all influence over the mass of mankind," and science cannot, on its side, yield at all in its claim to being the *only* avenue to truth. Employing a method which "carefully examines the trustworthiness of the sense perceptions on which it bases its conclusions," which "provides itself with new perceptions . . . not obtainable by everyday means," and which "isolates the determinants of these new experiences by purposely varied experimentation," science alone can "arrive at correspondence with reality." It is "this correspondence with the real external world we call truth"; and thus when "religion claims that it can take the place of science and that, because it is beneficent and ennobling, it must therefore be true, that claim is, in fact, an encroachment, which, in the interests of everyone, should be resisted." In a little book entitled *Cosmic Religion,* Einstein appeared to have a more benign attitude toward the rela-

tion between science and religion. Elsewhere he wrote, "Science without religion is lame, religion without science is blind."

Philosophy does not seem to Freud to offer men a genuine alternative to scientific truth. Unlike religion, it is not in his view necessarily opposed to science; at times it even behaves "as if it were a science," and to some extent makes "use of the same methods." But insofar as it parts company with science by clinging "to the illusion that it can produce a complete and coherent picture of the universe," philosophy must be regarded as an impostor in the halls of knowledge.

The picture philosophy tries to construct, Freud says, "must needs fall to pieces with every new advance in our knowledge." Not itself knowledge, but mere opinion or speculation, philosophy does not, any more than religion, offer a substitute for science. Both together fall under Freud's interdict. Both together would be outcasts from human culture if what he calls "our best hope for the future," that is, "the intellect—the scientific spirit, reason—should in time establish a dictatorship over the human mind."

WILLIAM JAMES, ALMOST contemporary with Freud, also draws a sharp line between science and philosophy. Writing his *The Principles of Psychology* at a time when the experimental methods of the natural sciences, especially physiology, had just been introduced into the study of mental phenomena, he is at pains to define the scope of psychology as a natural science, and to separate the questions which can be properly considered by a scientist from those which belong to the philosopher. But, unlike Freud, James does not seem to regard the philosopher as engaged in a futile effort to solve problems which are either insoluble or better left until science finds means for solving them.

For James the distinction between science and philosophy does not seem to lie only in the methods they employ, though the empirical or experimental approach does have a bearing on the kind of problems scientists can undertake to solve and the conclusions they can reach. The problems and the conclusions are themselves characteristically different from those of the philosopher.

The scientist *describes* the phenomena, according to James, as precisely as possible and as comprehensively, but without any implication of finality or totality. He recognizes that his descriptive formulations are tentative and incomplete, always subject to the discovery of new data or a more refined presentation of the evidence. Above all, he admits that he is only describing, not *explaining*—not laying bare the ultimate reality which gives the phenomena their deepest intelligibility, or ascertaining the causes which show why, not merely how, things happen as they do.

In the Preface to his *Principles,* James says that he has "kept close to the point of view of natural science throughout the book . . . This book, assuming that thoughts and feelings exist and are vehicles of knowledge, thereupon contends that psychology, when she has ascertained the empirical correlation of the various sorts of thought or feeling with definite conditions of the brain, can go no farther—can go no farther, that is, as a natural science. If she goes farther, she becomes metaphysical. All attempts to *explain* our phenomenally given thoughts as products of deeper-lying entities . . . are metaphysical."

This scientific point of view, James admits, "is anything but ultimate . . . The data assumed by psychology, just like those assumed by physics, must sometime be overhauled. The effort to overhaul them clearly and thoroughly is metaphysics." James does not imply that metaphysics cannot "perform her task well," but he does think that "she . . . spoils two good things when she injects herself into a natural science."

Science and metaphysics should be kept quite separate, he states, even though the sciences, in accumulating "a mass of descriptive details," run "into queries which only a metaphysics alive to the weight of her task can hope successfully to deal with. That will perhaps be centuries hence; and meanwhile the best mark of health that a science can show is this unfinished-seeming front."

The variance of James's conception of metaphysics and its future from other traditional

views on that subject is discussed in the chapter on METAPHYSICS. Here it is relevant to observe that James has a conception of science broad enough to include both the empirical natural sciences and what he calls the "pure or *a priori* sciences of Classification, Logic, and Mathematics." Yet in his view metaphysics does not represent philosophy as opposed to science, because it aims at ultimate reality or underlying causes. For example, he rejects the theory of a soul, not because he knows it to be false, but because he thinks it has no place in "a psychology which contents itself with verifiable laws" and which is to "remain positivistic and non-metaphysical."

James in *Pragmatism* does not embrace the positivist view, prevalent in the 19th century and our own day. He limits science to, as well as excludes philosophy from, the domain of empirical knowledge. In discussing the possibility of free will, he says that "Psychology will be Psychology and Science, Science, as much as ever (as much and no more) in this world, whether free-will be true in it or not. Science, however, must be constantly reminded that her purposes are not the only purposes, and that the order of uniform causation which she has use for, and is therefore right in postulating, may be enveloped in a wider order, in which she has no claims at all."

The 20th-century authors included in this set deal in a variety of ways with the problem of distinguishing the spheres of science, philosophy, and religion, and also of relating them to one another: notably Whitehead in *Science and the Modern World,* Planck in his *Scientific Autobiography,* Russell in *The Problems of Philosophy,* Weber in his essay on "Science as a Vocation," and Heisenberg in *Physics and Philosophy.*

EARLIER MODERN SCIENTISTS and philosophers who do not make a sharp distinction between science and philosophy and who antedate any explicit formulation of the positivist doctrine, nevertheless do for the most part conceive natural science as experimental in its method and as having for its goal the formulation of general laws describing and correlating the phenomena. They do not all exclude causes from the consideration of the natural scientist; nor do they all, as stringently as James, rule out explanation in favor of description or correlation. Furthermore, the almost universal emphasis by modern writers upon the experimental character of the natural sciences does not mean a universal identification of science with the experimental disciplines.

Mathematics, for example, is usually regarded as a science in spite of its being non-experimental. For Locke and Hume, as well as for Descartes, it exhibits certain characteristics—the self-evidence of principles, the certainty of demonstrations—which make it more genuinely worthy of the high name of science than are the tentative hypotheses and probable conclusions of experimental physics. Other disciplines are called "sciences" by comparison with mathematics rather than physics. Descartes, for instance, seems to think that metaphysics can as surely be made a science as mathematics can be. Locke argues that demonstration from axioms is not limited to the science of quantity. As much clarity and certainty is attainable in reasoning about moral matters. Thus, ethics is no less a science than mathematics.

Hobbes appears to take a similar view of politics, though it must be noted in his case that he differs from Descartes and Locke, from Francis Bacon, Hume, and others, in not distinguishing mathematics from physics with respect to the latter's need for experimental evidence. All the sciences are for him alike in being "the demonstrations of consequences of one affirmation to another," regardless of "the diversity of the matter." The "certain and infallible" sign that a man is a scientist in any field of subject matter is that he can "demonstrate the truth thereof perspicuously to another."

Hobbes, furthermore, seems to think that what is true of geometry is true of every science, namely, that it must begin with definitions. "In geometry," he says, "men begin at settling the signification of their words; which settling of significations, they call *definitions.*" Without definitions, science is impossible. "In the right definition of names," Hobbes maintains, "lies the first use of speech, which is the

acquisition of science; and in the wrong, or no definitions, lies the first abuse, from which proceed all false or senseless tenets."

Freud expresses the opposite view, which is generally more characteristic of the attitude of the modern scientist, especially the experimentalist or empiricist in method. "The view is often defended," he writes, "that sciences should be built on clear and sharply defined basal concepts." But "in actual fact, no science, not even the most exact, begins with such definitions. The true beginning of scientific activity," Freud holds, "consists rather in describing phenomena and then proceeding to group, classify and correlate them. Even at the stage of description, it is not possible to avoid applying certain abstract ideas to the material in hand, ideas derived from various sources and certainly not the fruit of new experience only . . . They must at first necessarily possess some measure of uncertainty; there can be no question of any clear limitation of their content. So long as they remain in this condition, we come to an understanding about their meaning by repeated references to the material of observation, from which we seem to have deduced our abstract ideas, but which is in point of fact subject to them."

The basic concepts or definitions of a science are, according to Freud, "in the nature of conventions; although," he adds, "everything depends on their being chosen in no arbitrary manner, but determined by the important relations they have to the empirical material . . . It is only after more searching investigation of the field in question that we are able to formulate with increased clarity the scientific concepts underlying it . . . Then indeed, it may be time to immure them in definitions. The progress of science, however, demands a certain elasticity even in these definitions." This may not be true of mathematical concepts or definitions, but, Freud points out, the science of physics illustrates "the way in which even those 'basal concepts' that are firmly established in the form of definitions are constantly being altered in their content."

WITH THE EXCEPTION OF Hobbes, the notion that scientific conclusions can be drawn from definitions or can be established without recourse to experiment, is not usually extended by modern writers from mathematics and metaphysics to physics. As the chapter on PHYSICS shows, the basic division of the study of nature into philosophical and scientific physics becomes equivalent, in modern times, to a separation of the philosophy of nature from the experimental natural sciences. We shall return presently to that sense of "science" in which physics is associated with mathematics and metaphysics as a branch of theoretical philosophy or as one of the speculative sciences. All three disciplines are thought of as proceeding in the same way: by the demonstration of conclusions from principles obtained by induction from experience—ordinary sense-experience, that is, not the special experiences artificially contrived in a laboratory under experimental conditions. But it should be observed that, in the modern period, even those authors who use "science" in the foregoing sense when they discuss mathematics and metaphysics, treat physics differently. They hold that physics must be experimental if it is to be scientific.

In proportion as modern physics becomes more and more the model of science, the meaning of the word "science" tends to become reserved for experimental study, or at least for empirical investigation, so that non-experimental disciplines, like metaphysics or ethics, are questioned when they call themselves "sciences." Other disciplines try to establish themselves as sciences by imitating physics. Marx, for example, in presenting his own work as economic *science*, seeks to explain how it can be scientific even if it is not experimental.

"The physicist," he writes, "either observes physical phenomena where they occur in their most typical form and most free from disturbing influence, or, wherever possible, he makes experiments under conditions that assure the occurrence of the phenomenon in its normality." If experiment, in the strict sense, is impossible in economics, at least the student of economics can be scientific in his effort to observe the phenomena "in their most typical form." England, Marx thinks, offers the most

typical example of "the capitalist mode of production, and the conditions of production and exchange corresponding to that mode." Hence, for scientific purposes, he has used England "as the chief illustration in the development of [his] theoretical ideas."

THE EXPERIMENTAL CHARACTER of modern physics, whether it is called natural science or natural philosophy, is discussed in the chapter on PHYSICS. The distinction between the construction or use of experiments and the appeal to experience—apart from experiment—either as a source or as a test of scientific formulations, is discussed in the chapter on EXPERIENCE, as well as in the chapters on HYPOTHESIS and INDUCTION. Here it seems pertinent to note that neither the distinction between induction and deduction, nor the distinction between hypotheses and axioms, unequivocally marks the line which separates science from philosophy.

Aristotle and Bacon, for example, regard induction as the source of axioms in metaphysics or *philosophia prima* as well as in physics or the philosophy of nature. They may have different theories of induction, but only insofar as one conceives induction as an intuitive generalization from *ordinary sense-experience,* and the other makes induction an inference from *experiments,* does the difference between them seem to have a bearing on the distinction between philosophy and science.

Similarly, the difference between the scientist's and the philosopher's consideration of hypotheses seems to lie not in the role they play in reasoning or argument, but rather in their having or not having a special relation to experimentation, either to guide it or to submit to its test.

Experiment, then, seems to be the distinguishing mark of science on the side of method; and, by an extension of meaning, even in those subject matters where experiments in the strict sense—in laboratories, with apparatus, under controlled conditions—are impossible, the scientist differs from the philosopher in an analogous point of method. The scientist investigates, does research, makes observations which go beyond experiences which ordinary men have in the course of daily life.

It seems to be in this spirit that Newton opens the *Optics* with the statement that "my design in this book is not to explain the properties of light by hypotheses, but to propose and prove them by reason and experiments." In the same spirit Faraday says of himself: "As an experimentalist, I feel bound to let experiment guide me into any train of thought which it may justify; being satisfied that experiment, like analysis, must lead to strict truth if rightly interpreted; and believing also that it is in its nature far more suggestive of new trains of thought and new conditions of natural power."

Lavoisier imposes upon himself the rule "never to form any conclusion which is not an immediate consequence necessarily flowing from observation and experiment." Gilbert criticizes those who write about magnetism without recourse to experiments—philosophers who are not themselves investigators and have no firsthand acquaintance with things. Referring to "what has been held by the vulgar and by tradition" concerning the motion of the heart and arteries, Harvey proposes to separate true from false opinions "by dissection, multiplied experience and accurate observation."

Even a scientist like Joseph Fourier, who conceives physical theory as a kind of applied mathematics, says that "no considerable progress can hereafter be made which is not founded on experiments . . . for mathematical analysis can deduce from general and simple phenomena the expression of the laws of nature; but the special application of these laws to very complex effects demands a long series of exact observations." Like Fourier, Galileo also combines mathematics and experiment in the study of nature. But though he is willing to introduce experiments where they are necessary in order to test rival hypotheses or alternative mathematical formulations of the laws of motion, he seems to express a preference for the rigor of purely mathematical physics.

In the Fourth Day of Galileo's *Concerning Two New Sciences*, discussing the parabolic path of projectiles, one person in the dia-

logue, Sagredo, says that "the force of rigid demonstrations such as occur only in mathematics fills me with wonder and delight." The understanding thus derived, he adds, "far outweighs the mere information obtained by the testimony of others or even by repeated experiment." Agreeing with this, Salviati, another person in the dialogue, claims that "the knowledge of a single fact acquired through a discovery of its causes prepares the mind to understand and ascertain other facts without need of recourse to experiment, precisely as in the present case, where by argumentation alone the Author proves with certainty that the maximum range occurs when the elevation is 45°. He thus demonstrates what has perhaps never been observed in experience, namely, that of other shots those which exceed or fall short of 45° by equal amounts have equal ranges."

THE CONCEPTION OF SCIENCE as consisting in a rigorous demonstration of conclusions from axioms—whether in mathematics or other subject matters—seems to be modern as well as ancient. It is found in Descartes and Spinoza, in Hobbes and Locke, as well as in Plato and Aristotle. Holding that "science in its entirety is true and evident cognition," Descartes may add that "it has been mathematicians alone who have been able to succeed in making any demonstrations, that is to say, producing reasons which are evident and certain"; yet he also hopes to make metaphysics a science after the model of mathematics.

This conception of science is somewhat qualified by Descartes when he discusses the study of nature. Here he tends toward experimentalism. Here he says that "experiments . . . become so much the more necessary the more one is advanced in knowledge." Referring to particular effects which "might be deduced from the principles in many different ways," he thinks that the only way to overcome the difficulty of discovering the principles on which the effects do depend is "to try to find experiments of such a nature that their result is not the same if it has to be explained by one of the methods, as it would be if explained by the other."

On the other hand, the conception of science as knowledge founded upon experiment, or at least upon extended observation, seems to be ancient as well as modern. Aristotle criticizes those of his predecessors in physics whose "explanation of the observations is not consistent with the observations." The test of principles "in the knowledge of nature," he says, "is the unimpeachable evidence of the senses as to each fact." It is for this reason that he praises the method of Democritus as scientific.

"Lack of experience," Aristotle writes, "diminishes our power of taking a comprehensive view of the admitted facts. Hence those who dwell in intimate association with nature and its phenomena grow more and more able to formulate, as the foundations of their theories, principles such as to admit of a wide and coherent development; while those whom devotion to abstract discussions has rendered unobservant of the facts are too ready to dogmatize on the basis of a few observations. The rival treatments of the subject now before us will serve to illustrate how great is the difference between a 'scientific' and a 'dialectical' method of inquiry. For whereas the Platonists argue that there must be atomic magnitudes 'because otherwise "The Triangle" will be more than one,' Democritus would appear to have been convinced by arguments appropriate to the subject, *i.e.*, drawn from the science of nature."

There are many passages in which Aristotle rejects an astronomical hypothesis because it does not account for the observations, or favors one theory against all others because it alone seems to fit the sensible phenomena. So, too, in his biological works, he makes experience the test of theories. Speaking of the generation of bees, for example, he says that if we ever learn the truth about this matter, "credit must be given to observation rather than to theories, and to theories only if what they affirm agrees with the observed facts." And in his treatise *On the Motion of Animals*, he calls for "reference to particulars in the world of sense, for with these in view we seek general theories, and with these we believe that general theories ought to harmonize."

But Aristotle also defines science as the cer-

tain demonstration of universal and necessary conclusions from self-evident principles. "Scientific knowledge," he writes, "is judgment about things that are universal and necessary; and the conclusions of demonstration . . . follow from first principles (for scientific knowledge involves apprehension of a rational ground)." The emphasis here is on knowledge of causes, and on the certainty and necessity of conclusions which can be demonstrated from axiomatic truths.

By these criteria, metaphysics and mathematics are, in Aristotle's conception of the three philosophical sciences, perfect examples of scientific knowledge. Physics as a general philosophy of nature is also scientific knowledge in this sense; but the particular natural sciences, such as astronomy or zoology, are more empirical than philosophical in character. At least they involve admixtures of demonstration from principles with the verification of hypotheses by observation. To the extent that they are empirical, they are qualified by an uncertainty and a tentativeness in formulation which do not seem to be present in Aristotle's conception of the purely philosophical sciences.

It might even be said that the knowledge of nature which depends on empirical research is not strictly scientific at all. Locke appears to say just that. "How far soever human industry may advance useful and experimental philosophy in physical things," he writes, "scientifical will still be out of our reach." Holding that "our knowledge of bodies is to be improved only by experience," Locke adds: "I deny not but a man accustomed to rational and regular experiments, shall be able to see farther into the nature of bodies, and guess righter at their yet unknown properties, than one that is a stranger to them; but yet, as I have said, this is but judgment and opinion, not knowledge and certainty. This way of getting and improving our knowledge in substances only by experience and history . . . makes me suspect that natural philosophy is not capable of being made a science."

WHETHER THE EXPERIMENTAL study of nature is the type of all scientific knowledge (in its object, its method, and the character of its conclusions) or whether, according to another conception, the philosophical disciplines are the more perfect, perhaps even the only examples of science, there seems to be no question that different values attach to these two meanings of science—or, as it is currently expressed, to science and philosophy.

The philosophical sciences may be either theoretical or practical according as they aim at wisdom or at action, but they are seldom praised as being useful productively. The practical sciences which are also traditionally regarded as branches of moral philosophy—such as ethics, politics, and economics—may be knowledge put to use in the guidance of individual conduct or the affairs of society, but apart from poetics, which may direct production in the sphere of the fine arts, there does not seem to be any philosophical science, or branch of philosophy, that provides a mastery of matter or some control over nature. None has applications in the sphere of the useful arts.

As indicated in the chapters on ART, KNOWLEDGE, and PHILOSOPHY, Bacon appears to take a contrary view. Using the word "practical" to mean productive rather than moral or civil, he divides the philosophy of nature into speculative and practical branches. He regards mechanics as the application of physics to useful purposes, and finds a productive counterpart to metaphysics in what he calls "magic."

Nor is Bacon's point merely that "the real and legitimate goal of the sciences is the endowment of human life with new inventions and riches," in opposition to those whom he criticizes for thinking that "the contemplation of truth is more dignified and exalted than any utility or extent of effects." In addition, he thinks that the truth of science can be tested by its productive utility. "That which is most useful in practice," he writes, "is most correct in theory."

Bacon's position with regard to the productive utility of science would not be contrary to the traditional view if by "the philosophy of nature" he meant science in the experimental rather than the philosophical sense. His emphasis upon experimentation in all parts of the

study of nature suggests that that is the case. The fact that he places equal emphasis upon machinery and inventions and power over nature also suggests that technology is the other face of any science which is experimental in method.

Bacon and Descartes seem to be the first to perceive that knowledge which is experimental in origin must be by its very nature capable of technological applications. The instruments and apparatus which Bacon regards as necessary implements of science, no less than the machinery and inventions which science can be expected to produce, represent the very same techniques of operating upon nature. Experimental science is thus seen to be at once the creature and creator of technology. As Plato's *The Republic* projects a society which cannot be realized unless it is ruled by the science of the philosopher, so Bacon's *New Atlantis* prophesies a civilization which the dominance of experimentalism and technology have brought to present reality.

IT IS A STRIKING fact about the 20th-century view of science that it introduces aesthetic considerations. In contemporary physics, Einstein, as much as anyone, is responsible for emphasizing the role of aesthetic criteria—simplicity, beauty, elegance—in the formulation of theories. When, in his early work, Einstein found his theories challenged by apparent experimental results which, if true, would have required unaesthetic theoretical explanations, he rejected the experiments. It usually turned out that the experiments were wrong and the theory correct. These criteria are subjective, in the first instance, but, in due course, scientists came to agree on which theories are truly beautiful.

It appears to be a deep fact about nature, at least as we perceive it, that beautiful theories are also true; *i.e.*, fit the facts. This requirement of fitting the facts distinguishes the scientific aesthetic from that of the artist. A beautiful work of art is not, in any obvious sense, the solution to a problem. It just is. Nonetheless, the same sensibilities illuminate science, at its highest level, and the arts.

As Heisenberg writes, "the two processes, that of science and that of art, are not very different. Both science and art form in the course of the centuries a human language by which we can speak about the more remote parts of reality, and the coherent sets of concepts as well as the different styles of art are different words or groups of words in this language."