THE SCIENTIFIC APPROACH

Basic Principles of the Scientific Method

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A. Definition

I.1 In spite of the tremendous influence of science upon modern civilization, there exists as yet no standardized definition of science. Laymen, scholars, and scientists themselves define the

term in varying ways and employ it in a variety of contexts. To some, science simply denotes a generalized prestige (e.g., Christian Science, the science of boxing, scientific history, a scientific analysis of modern art). To others, it denotes a body of verified knowledge (e.g., biology, astronomy, physics, chemistry). To still others it connotes an objective analysis of phenomena. According to a standard dictionary, the word "science" is derived from the Latin word *scientia* (*sciens,* the present participle of *scire,* to "know"); and is defined in a variety of ways: (1) originally, state or fact of knowing; knowledge, often as opposed to *intuition, belief,* etc. (2) systematized knowledge derived from observation, study, and experimentation carried on in order to determine the nature or principles of what is being studied. (3) a branch of knowledge or study, especially one concerned with establishing and systematizing facts, principles, and methods, as by experiments and hypotheses: as the *science* of music. (4) *a.* the systematized knowledge of nature and the physical world. *b.* any branch of this. (5) skill, technique, or ability based upon training, discipline, and experience: often somewhat humorous, as the *science* of boxing.

I.2 Checking the definition of the adjective "scientific" does not help very much to determine its essential features. According to a standard source, the word "scientific" is derived from the Latin word *scientia,* meaning knowledge, plus the term *facere,* meaning to make; both terms were originally employed as a translation from the Greek term *episthemonikos,* or making knowledge (from which the modern term *epistemology* is derived, meaning the study or theory of the origin, essence, methods, and limits of knowledge). In German, for example, the term for science, *Wissenschaft,* denotes these same two qualities: *wissen,* to know, and *schaft,* to do, make, or work. This term, like the Greek form, connotes a special feature of this type of knowledge: namely, applied knowledge or applied logic (from the Greek term *logos,* meaning to know). In short, the word "science" connotes reasoned knowledge and applied logic.

I.3 The difficulty encountered in attempting to define the term "science" arises mainly from the tendency to confuse the

content of science with its method. Much of the content of science is constantly changing; so what may be scientific (i.e., accepted as true) today may become unscientific (i.e., regarded as untrue) tomorrow. (A common illustration of this point is the case of *phlogiston,* which reputable physicists once thought was the necessary agent for combustion to occur. Now everyone knows that oxygen is the necessary agent in combustion, and *phlogiston* does not exist in modern scientific thinking.) Furthermore, the demarcation between science and nonscience is not clear-cut; it actually is not a line but an area both shifting and subject to debate—depending upon the authorities one accepts. For purposes of precision, clarification and usefulness, therefore, it seems appropriate to define the term "science" in a combination of three ways: (a) analytically—i.e., in terms of its essential and distinctive component attributes, (b) functionally—i.e., in terms of the services it performs, and (c) operationally—i.e., in terms of the processes or operations performed when practicing it.

I.4 An examination of scores of standard books about science fails to elicit a clear and comprehensive definition; but such an examination does rather clearly suggest a consensus among authoritative writers with regard to the essential attributes or processes of science. According to such a consensus, *science may be defined* quite accurately and functionally as: *an objective, logical, and systematic method of analysis of phenomena, devised to permit the accumulation of reliable knowledge.* The following discussion will be devoted to an explication of the key terms of this definition, while this book as a whole attempts to serve as an operational definition of the scientific method.

I.5 *Objective:* Science is an intersubjective method; it is available to any interested and competent person; it is not the special province of a favored few. Objectivity in science refers to attitudes devoid of personal whim, bias or prejudice, and to methods centered around ascertainment of the publicly demonstrable qualities of a phenomenon. Evidence in science is factual, not conjectural; and truth is achieved by the demonstration of evidential proof. Though science is a subjective enterprise insofar

as it is practiced by individuals, scientific method encourages a rigorous, impersonal mode of procedure dictated by the demands of logic and objective procedures. Authority in science is achieved by the accumulation of publicly ascertainable evidence supporting one's argument; it is not a consequence of mere opinion (no matter how strongly held), nor of faith alone, nor of assumed verity. To be devoted to the ideal of objectivity in science is, in effect, to be devoted to the ideal of public verifiability according to the consensus of trained observers.

I.6 Objectivity also connotes an attitude devoid of subjective value judgments. The attitude of the scientist toward *normative* (i.e., value-endowed, expressing a desirable norm or standard) phenomena is treated later; but suffice it to say at this point that objectivity in science denotes an impartial viewpoint which refrains from inferring or implying that any phenomenon is "good" or "bad" *per se.* Whether or not absolute objectivity is ever possible for human beings to achieve is a question best left to philosophers; but certainly the scientist attempts constantly—both by training and particularly by the use of objectifying instruments—to look at his data with as little bias as possible.

I.7 The objective attribute of science specifies that the ultimate court of resort in any speculative argument is the objective event: an observation or any experience that can be publicly verified by trained observers. Pending a detailed discussion later of how data in science are derived, it should suffice to point out at this time that the impressive growth of modern science as a reliable method of achieving knowledge is based largely upon its foundation of verified objective facts. To the extent that a particular field of study employs non-objective data or refers to subjective phenomena, then to that extent is it regarded as "less scientific" (i.e., less reliable) than are the more advanced sciences.

I.8 To say that science is objective also connotes that it is *descriptive* and *analytical.* In practice scientific method simply answers the question of "What is the fact?" or "What is the relationship?" When scientists sometimes advocate or prescribe, they do so only to answer a legitimate scientific question, and are saying in effect *"If* this, . . . *then* this." Although scientific

method raises many questions of its own, they are always of a logical, of a methodological, or of a meta-ethical (i.e., universally ethical) order; they are never of a parochially ethical order. That function belongs to religion, politics, or other normative systems of belief; it can never be imposed upon, delegated to, or assumed by science.

I.9 To anticipate somewhat a more detailed discussion of this point, it might be said here that this attribute probably occasions more misunderstanding among laymen than does any other attribute of science. True, scientists offer many answers to normative questions, but such questions are generally not in themselves of scientific origin. A scientist might say, for example, "You should fly above twenty-thousand feet, *provided* you want to conserve fuel"; or "You should take insulin, *provided* you want to avoid death from diabetic shock." He likewise might say "We should adopt a city-manager plan, *provided* it has been demonstrated to be a more efficient type of government, and *assuming* that efficiency in government is desirable." In short, the scientist is never prescriptive or advocatory except (a) when he is functioning simply as a layman and not as a scientist as such, or (b) when he has been addressed with a value question concerning which he possesses objective knowledge.

I.10 The foregoing remarks should not be interpreted to imply that a scientist, as a scientist, does not advocate any values. He does, and he holds such values highly. He values, for example, the pursuit of knowledge for its own sake (i.e., simply for the satisfaction of knowing); he values the attributes of science herein being discussed as desirable qualities in relation to his work; and he values the opportunities to pioneer on the frontiers of research. In other words he values highly what may be referred to as the spirit of inquiry and the ideal of objectivity (or "truth"). These values underlie all his efforts as a scientist, but they may be and often are quite distinct from the popular values of his culture as such. As a scientist, about the only way that he is influenced by cultural values would be in his choice of problems for research, and of course in the impetus which led him to become a seeker of knowledge in the first place. In this sense of the

term "value," it is undoubtedly true that every person, including the scientist, is a product of his time and culture, and therefore cannot escape the influences of its value system.

I.11 A final note on the subject of objectivity concerns the question of the so-called normative sciences. During its present evolution modern science has developed largely in the areas of physical phenomena. But there is no inherent reason why the scientific approach cannot be applied to areas involving human attitudes, beliefs and values. In fact modern scientific psychology shows exactly this tendency. At the present time the objective approach to the analysis and understanding of subjective or mental phenomena has been beset with staggering methodological difficulties; but there is no inherent reason to assume that both the theoretical and technical problems involved in studying subjective behavior cannot be solved in the future. In time, when the social and psychological sciences have achieved greater knowledge, rigor and skill, a true science of subjective phenomena (e.g., ethical, moral, artistic feelings) is certainly forseeable.

I.12 *Logical:* To say that science is a logical method is simply (yet very significantly) to say that the scientist is constantly guided by the accepted rules of reasoning standardized by reputable logicians. Competence in science demands competence in logical analysis—a large field in itself, and some crucial aspects of which are noted throughout this book. Rules of definition, forms of deductive inference, theories of probability, systems of calculi, etc., are fundamental in any mature and reputable science. Science is not a "cook book" of facts, rules or formula. Rather, it is a *systematic* arrangement of facts, theories, instruments and processes —all interrelated by principles of reasoned thought. Although one may function in applied fields (e.g., dentistry, plumbing, auto repairing, bridge building) by learning and applying formulas, to function as a scientist demands both a thorough grounding in logical analysis as well as skill and knowledge of a specific factual sort.

I.13 Since science is a logical system, it is also self-critical—i.e., it contains within its methods the tools for its own analysis. Somewhat like a physician checking his own health, the scientist

in practice constantly employs skepticism toward current as well as new ideas, constantly retests accepted facts, constantly suggests doubt when answers appear too obvious, and constantly demands that all new ideas be subjected to the merciless demonstration of objective verification. As a safeguard against intellectual smugness or dogmatism, this attitude on the part of the scientist bespeaks a fundamental awareness of the fact that the desire to believe can be intellectually seductive even for the best minds. So in order to avoid the all-too-human tendency to be satisfied with the *status quo,* the scientist guards himself by a cloak of critical doubt. In this sense, science can never offer the comfortable surety of omniscient systems of belief. The true scientist is constantly searching, never satisfied, and always doubtful of everything he knows, for he has learned early in his career the singular lesson of science: what is thought to be true today might be proved to be false by tomorrow.

I.14 *Systematic:* Science proceeds in an orderly manner both in its organization of a problem and in its methods of operation. It does not proceed randomly or haphazardly. Here is one of the qualitative differences between scientific and popular thinking. Unscientific analyses tend to marshall sundry and often unrelated facts in order to support an argument; violating, at the same time, the accepted principles of logical inference in support of their proofs. The systematic procedures inherent in the scientific approach assume the form of a closely interwoven, logically arranged sequence of steps which permit little deviation. Verification in science, as a matter of fact, is substantially a systematic process of logical inference which demands that the premises, facts and conclusions be arranged in an orderly manner.

I.15 The systematic feature of science also implies internal consistency. In a well-developed science, the various theories and laws are interrelated and corroborative. They support each other, or at least do not contradict each other. Immaturity of a science is characterized by serious internal disagreements relating to theories, laws, propositions, principles and sometimes even of method. It should be pointed out, however, that complete and final internal consistency is never achieved even in the most ad-

vanced sciences. New discoveries suggest new laws, principles or theories, which in turn demand the modification of established notions of reality. It is in this way that science grows. This dynamic quality, however, (except in a beginning science) should not be construed to permit glaring contradictions in the internal interrelation and interdependence of the theoretical foundations of that science.

I.16 *Method:* Science is a systematized form of analysis; it is not any particular (or even general) body of knowledge. But a dispute often arises as to whether there is only one scientific method or several. Pending a detailed discussion of this point in Chapter V, it may be said at this time that this problem is largely a semantic one, not a conceptual one (i.e., it arises mainly from the various meanings attached to the word "method"). This writer takes the position that there is basically *only one* scientific method, however broad its borders may be; and that the various so-called "methods" are essentially techniques of research or exemplifications of the basic general method of description and analysis as defined in the previous discussion and as developed throughout this text.

I.17 Though the various fields of science differ both in content and in techniques, an examination of all the highly developed sciences reveals a common foundation of procedures of inquiry. It is in this sense—of possessing common essential features—that the singular term "method" is here preferred to the plural term "methods." To contend that different fields of study utilizing basically different methods of inquiry are all equally valid (hence, "scientific"), is to suggest that method is not significantly related to validity. Yet all reputable scientists follow the same basic rules of evidence and reasoning in order to validate their conclusions. It is difficult, therefore, to accept the notion that basically different methods of inquiry—not simply different techniques—are all equally valid, therefore equally scientific. It is hoped that this volume will help not only to demonstrate the essential features which give scientific method its unity, but also will help to provide a functional and meaningful description of scientific method at its best.

I.18 *Phenomena:* Scientific method is applicable to any kind of behavior or event that has objectively demonstrable attributes or consequences. If an event is presumed to be inherently subjective (e.g., an idea, a feeling, an inspiration, a dream), then it is not amenable to scientific analysis— unless, of course, its presence can be demonstrated by virtue of some related objective attributes or consequences. Thus, for example, a presumably subjective behavior (say, a dream) cannot be studied scientifically until and unless it can be shown to exhibit objective attributes or consequences. Though the phenomena studied by science are publicly verifiable, it should not be assumed that such objects or events of study are the only interest of science. Scientific method is built upon a foundation of ideational abstractions (i.e., notions, ideas, theories, laws, principles, etc.) devised to relate and explain observable objects and events. Much of the content of science, therefore, consists of intellectual notions about things or events. But the object of all such thought is the particular phenomenon being studied; and that particular phenomenon is the experience or perceived event.

I.19 A discussion of the legitimate object of scientific study (i.e., the observed object or event) often raises the question of assumedly spiritual (i.e., extra-natural) or supernatural phenomena. Put another way, it is often asserted that science cannot study—and therefore cannot legitimately answer questions about —supernatural events. The scientific answer to such an assertion is quite simple. Philosophically, science is neither theistic (i.e., a belief in a god or gods) nor atheistic; but it is objective insofar as it studies phenomena having behavioral attributes or consequences. If something exists or occurs having such attributes that it can be objectively ascertained and confirmed, then it can be studied scientifically. Whether it has been "caused" by a "natural" or a "supernatural" force or agent is a separate and wholly different kind of question (which will be considered later in some detail).

I.20 *Devised:* It is often remarked that science is a "synthetic" system insofar as it is an artificially created synthesis of various elements into an interrelated and logical whole. In short, it is an invention, a creation of human ingenuity. The only remark that

need be made about the term "devised" is that scientific method is a creation to serve a particular purpose—viz., the orderly arrangement of factual knowledge and ideas about reality in that form which seems most fruitful in terms of the end to be served. Since it is created to serve a particular purpose, it can—and in fact in some ways, does—change as new ideas suggest modifications. But the only essential point that needs to be made here is that man arranges his thinking about his world according to various preferences; and the scientific method is the one such arrangement which has so far appeared to be the most fruitful for the explanation of objective phenomena.

I.21 *Accumulate:* Science is cumulative; it is an integrated system built up in an orderly manner wherein each fact, principle, theory, law, etc., supports other facts, theories, laws, etc. But science is not a mere accumulation. A cook book, a telephone directory, a stock-market report, an engineer's manual, are all assemblages of accumulated facts—but they are not science. The accumulated knowledge making up a systematic science is dynamic, not static. Science always seeks additional knowledge in the belief (borne out by history) that knowledge is never complete. "Truth" in science is always relative and temporal, never absolute or final. In contrast to many closed philosophical or ideological "systems" (e.g., political, aesthetic, moral, religious, and other theories with which we are familiar), science may properly be defined as an "open" rather than as a "closed" system of ideas. Therefore, it grows constantly by discarding erroneous or useless notions and by substituting more correct or useful ones in the light of new evidence. As a matter of fact, this very dynamic quality is one of the intrinsic features of science; and primarily because of this, science has grown continually from its primitive beginnings to its present awe-inspiring eminence.

I.22 This attribute of cumulativeness certainly should not be construed to mean that science grows by simple accretion. Scientific theorists employ a related *principle of parsimony* (often referred to as Occam's razor) which decrees that complex explanations or methods should be replaced by simpler formulations wherever possible. In fact, the tendency of scientists to designate some phenomena by "big words" actually is a consequence of

this principle; for the history of science demonstrates that previously complex explanations or designations are constantly being replaced by scientifically simpler and more precise terminology. (This principle in action is illustrated in several different sections throughout this book.) This principle suggests, for example, that when there seems to be equal probability of truth, utility or fruitfulness among various techniques or theories, the simplest one should be preferred. Simplicity, however, does not necessarily connote ease of comprehension. As employed in this principle, simplicity refers to a preference for the smallest necessary number of independent elements to be embodied in a theory or a procedure.

I.23 More important, the principle of parsimony decrees that one should strive constantly to explain as much as possible by the employment of as few terms, symbols, concepts or formulae as possible. In a broad sense, then, a major function of science is to explain all its phenomena as parsimoniously (i.e., as economically) as possible. An outstanding virtue of Newton's laws of motion, for example, was the fact that not only did they explain many formerly unexplained phenomena, but that they also explained the laws of falling bodies, "discovered" by Galileo earlier, as well as the movements of heavenly bodies, described by Kepler earlier. Thus the attribute of cumulativeness and the principle of parsimony are so closely interrelated that science strives constantly to predict the behavior of as yet unobserved phenomena in terms of the common and known qualities which they possess as members of a class of phenomena. Cumulativeness, orderliness and parsimony, therefore, work together to permit the largest possible number of specific predictions to be made from as few basic and general "laws" as possible.

I.24 The term "reductionism" is often employed in discussions of this broad principle of parsimony. Essentially, reductionism refers to the general practice of striving to encompass as many sub-theories as possible into broader, more-inclusive categories of "grand theories." Though much scientific knowledge at any given time is temporarily unrelated or uncoordinated (e.g., discrete facts or "laws"), the scientist strives constantly to interrelate such discrete facts into meaningful wholes or patterns.

Eventually—as verified by the history of science—such patterns become integrated into larger systems of facts and ideas ("theories") which permit a wider range of explanation than would have been possible had the segmented facts been viewed in isolation.

I.25 *Reliable* (knowledge): This term has several and somewhat different specific meanings, but in the present context it refers to that kind of knowledge which one can depend upon in terms of predictability. In this sense, then, reliable knowledge is synonymous with exact or correct knowledge. Science strives constantly for exactness; it is not satisfied with half-truths and is intolerant of careless procedures. Probably the outstanding quality both in popular thinking and in the professional attitudes of scientists is this feature of precision and exactness. In fact it is almost axiomatic that science progresses to the extent that its measurements and calculations become more refined. It should be borne in mind, however, that accuracy or precision is not an end in itself but relative only to the purposes which it is to serve: viz., to promote more specific description, and hence to promote reliable prediction or control. Many exact measurements are meaningless in terms of the purpose at hand. There is at present no useful purpose served, for example, in refining the distance between the earth and the sun in terms of millimeters (if such could in fact be done). The gross measure in terms of thousands of miles is accurate enough for present scientific purposes.

I.26 Furthermore, many significant scientific principles are not supported by precise facts. The genetic principles involved in Mendel's laws of heredity, for example, do not yet permit a highly specific determination of the results of cross-breeding among large and heterogeneous populations. Nevertheless, increasing exactness usually generates increased understanding. Therefore, the highest degree of exactness commensurate with the demands made by the problem is an outstanding attribute of scientific method. As will be noted many times throughout this volume, a common stumbling block to the further development of a scientific approach is often the very inexactness of much present knowledge.

I.27 The problem of achieving reliability is a highly complex one, and will be examined in its various aspects throughout much of this book. At the present, however, reliable knowledge generally refers to knowledge which permits better predictions than could be made by chance or guesswork alone. Admittedly much popular ("folk") knowledge is reliable insofar as much common behavior is highly predictable by virtue of habit, custom, familiar experiences, etc. But much popular prediction, when accurate, is so simply by virtue of chance alone. The function of scientific method, therefore, is to understand phenomena to such an extent that the ratio and scope of accurate predictions can be consistently increased. It is presumably only through a valid, organized system of knowledge such as science that prediction can be effectively raised beyond the limited experience of a particular and unsophisticated group of individuals. Illustrations of this fact can, of course, easily be drawn from any common field where the knowledge and skill of the scientist is pitted against that of the layman.

I.28 The preceding discussion explicating the definition of science has left unanswered a basic question: Is scientific method the only reliable method—or is it simply one of many equally valid methods—for answering queries about objective phenomena? This question can be answered only in relative terms in light of one's faith in various knowledge systems. Among scientists, of course—and presumably among most laymen too—it is safe to aver that scientific method is regarded as the most reliable method so far devised for understanding objective phenomena. Such a statement implies, in effect, that in the competitive arena of opposing logical and methodological systems, all presumably devoted to the discovery of truth, scientific method has become the strongest intellectual tool that man has devised for furnishing verifiable and practicable answers to questions of demonstrable fact. Stated otherwise, this conviction avers that man has tried many different systems for answering the factual problems posed by himself and by nature; and that of all such systems, scientific method has unquestionably achieved the highest reliability of all.

I.29 The imposing growth of the layman's faith in scientific method has been derived from the ability of science to answer questions of a physical and biological nature. But the remarks in the previous paragraph should not be construed to be limited to nonhuman (and particularly to nonsocial) phenomena. This conviction of the efficacy of scientific method also implies that human problems of fact—as distinct from problems of faith and morals (i.e., of purely subjective value judgments or entirely normative questions)—can be solved better by the employment of a scientific approach than they can by other methods. This implies, for example, that many psychological and social problems which have perplexed man for centuries can eventually be solved satisfactorily provided (a) that they are submitted to a scientific approach, and (b) that they are phrased in objective terms. This problem will be dealt with more thoroughly in the following chapters.

I.30 A final remark relevant to the definition of science should be made concerning the proper scope of scientific inquiry. According to some views, scientific method can profitably be applied to any field of human endeavor; others argue that it is inherently limited to purely physical and biological phenomena of a nonsocial sort. In fact in some fields (particularly history and the humanities) there is still a wide range of opinion as to the feasibility of utilizing the scientific method at all. Perhaps this volume will help to clarify if not resolve this issue; for throughout various chapters it should become quite evident that it is *not the field* of study but the *type of problem* posed that determines whether or not a scientific approach can be profitably employed. At this point, therefore, the *scope* of scientific method will be viewed as the *whole range* of human interest.

B. *Science* versus *Pseudo-science*

I.31 Science as herein defined refers to a method of analysis involving (a) certain basic procedural attributes (objectivity, exactness, etc.), as well as (b) certain basic assumptions about reality (viz., the "postulates" of science to be explained in the following

chapter). Pseudo-science, therefore, refers to modes of analysis which *pretend* or *profess* to meet the requirements of scientific method but which in fact violate one or more of its essential attributes. Flagrant examples of pseudo-science are easy to identify; but the more subtle—and therefore more insidious and convincing—cases require a rather precise delineation of the attributes involved.

I.32 Before examining pseudo-science, however, it is important to realize that knowledge is advancing rapidly. What may have been regarded as legitimate science at one time or place may later be viewed as pseudo-science. Phrenology, for example (i.e., "reading character" by interpreting the structure of the skull), was at one time regarded as a legitimate type of psychology. Today it has become simply a device for duping ignorant laymen. Astrology (i.e., predicting the future by the stars), palmistry (i.e., predicting a person's future by "reading the life lines" on his palm), or numerology (i.e., predicting one's future by interpreting the order of numbers in his birth date, or the numbered-order of the letters in his name, etc.), were all at one time regarded as reputable sciences. Today they are clearly defined as quackery.

I.33 A second aspect of this problem of identifying pseudo-science is a consequence of the fact that some methodological approaches are partly scientific and partly pseudo-scientific. That is, they combine legitimate with illegitimate methods, inferences or assumptions. Two cases in point might be cited: (a) religious "science"—which rests partly on objectively verified psychological principles of suggestibility (i.e., "mind over matter"), and partly on scientifically unconfirmed notions of bodily processes (i.e., all illness is "mental"); and (b) naturopathy—which rests partly on verified physiological principles (viz., the relation of diet to health), and partly on scientifically unconfirmed notions of bodily processes (viz., that all diseases can be cured without resort to medicines or surgery).

I.34 The essential features of a pseudo-scientific approach to phenomena, therefore, are those which ignore, deny or violate the essential attributes of valid science. Among the outstanding qualities of a pseudo-science are the following: (a) It is usually subjective rather than objective—i.e., it relies upon the unique personal interpretations of phenomena made by a particular practitioner. Therefore, it varies with the particular "authority" (e.g., a dogma, a bible or its equivalent, a semi-god, some type of oracle, or a charismatic leader—i.e., one perceived by his or her followers as having god-like qualities). (b) It is illogical insofar as it violates one or more basic rules of inference, of definition, of argument, of proof, etc. (c) It is unsystematic in the respect that its various parts do not necessarily relate to and support each other by virtue of internal consistency. (d) It is "fixed" or "closed" rather than accumulative insofar as its "facts" are unimpeachable in terms of new evidence. (e) Just as important is the fact that it exhibits very low reliability—i.e., its predictions are no better than those one could make by chance. Since an ultimate criterion of the validity of any purported science is its predictive power (a subject to be discussed at some length later), it is particularly in this respect that pseudo-science—when subjected to valid and objective measures of prediction—performs no better than does random guesswork alone.

I.35 Since the layman is untrained in the intellectual aspects of modern science, he often finds himself in a quandary when trying to distinguish between legitimate scientists and their imitators. All around him, every day, he hears or sees apparent authorities (often dressed in white laboratory coats) who exhort him to believe their assertions. The resolution of this quandary is an overwhelming task for the layman; for who and what is reputable and therefore reliable in science is a question demanding knowledge both of science in general and of the field involved in particular. It is for this reason that the nonspecialist is so often confused, and even duped, by conflicting claims all made in the name of science. This quandary, incidentally, faces the scientist himself at times when he is faced with cogent arguments outside his field of special knowledge.

I.36 Of course, many purported scientists are simply flagrant charlatans; but an additional difficulty facing the layman is that of differentiating the scientist when he is functioning as such from the scientist in his role as an ordinary citizen. Many reputable scientists speak or write publicly on many topics outside their established fields of accomplishment. A scientist—at least in

a so-called free society—has the same right as has any other citizen to speak on any topic he wishes. But when a reputable scientist purports to speak authoritatively *outside* his field of knowledge, he is then exploiting the "halo prestige" of his scientific role (i.e., he is exploiting the tendency of individuals to extend a person's prestige from one field to another but unrelated field of accomplishment). The physicist who speaks authoritatively in the field of politics, the psychologist who speaks authoritatively in the field of child-rearing—all are as pseudo-scientific at that time as is the opera star who endorses deodorants, or as is the famous athlete who pontificates on the effects of smoking. In these cases, such persons are functioning pseudo-scientifically; and their established prestige in one field does not qualify them to speak authoritatively in any field other than the one of their established competence.

I.37 One particular facet of this science *versus* pseudo-science problem which often seems to interest the layman is the role of the amateur in relation to scientific discovery. The notion is commonly held that great discoveries are often the product of amateur minds, and therefore that the authority of the scientist is sometimes to be critically suspected. This popular notion contains both a philosophical implication and an intellectual imputation. The philosophical implication is that discovery is solely a matter of accident; and therefore that discovery in science is essentially no different than, say, the discovery of a cache of gold buried under the sands of a beach. With most great scientific discoveries, however, the reverse is often true.

I.38 The intellectual imputation of this popular notion, however, is more complex. It appears obviously demonstrable that the scientist is highly regarded by most laymen, sharing as he does the generalized prestige of all intellectuals and professionally trained persons—especially those whose efforts so often result in positive contributions to mankind's material welfare. In some respects, in fact—especially since the significance of scientific achievement both in the medical and in the astrophysical fields has become highly magnified—one might safely generalize that the scientist has become somewhat of a "hero type."

I.39 Yet at the same time, many people of limited knowledge seem to suspect or resent the superior abilities of prestiged individuals—especially so in the United States, where the doctrine of political equality is often extended to imply both social and intellectual equality. In this sense, then, the scientist—like the college professor, to whom he is professionally very closely related—is often regarded at best as a somewhat impractical and ineffectual person who spends most of his time on inconsequential matters. (This is the "absent-minded professor" of cartoon fame.) At worst, however, he is sometimes viewed by laymen as a sinister or even malevolent individual whose "cold-blooded" devotion to scientific discovery knows no bounds of humanistic or ethical values. (This is the "mad scientist" of horror-movie fame.) The social significance of this dualistic attitude of laymen toward the scientist invites serious speculation, but is beyond the scope of this volume.

I.40 Regardless of its philosophical implications or its intellectual imputations, this popular notion in regard to discovery is simply erroneous in fact. True, a few "great" discoveries that later were scientifically encompassed or explained have been made by poorly trained workers or laymen. But in all such cases the discoveries represented either an isolated fact or a single sequential relationship. (Well-known cases in point would be the discovery of the paralyzing power of curare, long used by the Amazonian natives; of the heart-stimulating power of digitalis, long recognized by the Plains Indians of the U.S.; and of the unrecognized discovery of Newton's laws of motion by the ancient Chinese who developed the principle underlying rocket propulsion.)

I.41 The great masses of verified knowledge underlying modern science—particularly its fundamental theories—have resulted from the cumulative efforts of well-trained and long-laboring men of superior intelligence who employed the methods treated in this volume. The inventions or discoveries sometimes made, even spectacularly, by laymen generally have very little meaning in and of themsleves. They must be fitted into an organized and coherent system of knowledge before they can attain significance

or applicability. It is the laboriously constructed network of theories, principles, laws, facts and techniques, created by generations of scientists, which gives meaning to such discoveries or inventions occasionally made by laymen. Especially today, when the storehouse of scientific knowledge in the physical and biological fields is so voluminous and the theoretical structure so complex, it is highly improbable that an untrained person—no matter how innately intelligent—could make a significant contribution to modern sicence.

I.42 A final point of peripheral relevance and interest to the layman—in this discussion of the differences between science and pseudo-science—is the problem of choosing between conflicting claims made by reputable scientists. Scientists do not always agree; in fact, in some fields they even disagree strongly. The layman often wonders "Who's right?" This problem is inherent in the dynamic character of science, and is particularly acute in the less developed (particularly the social) sciences. New ideas, new theories, new findings, new interpretations of old findings—all these create honest and legitimate differences of opinion, even among objectively-oriented, well-trained investigators. Particularly in the applied fields of science (medicine or psychology, for example), where knowledge is far from complete, legitimate speculation ("hypotheses") or tentative theories may have to be substituted for reliable knowledge.

I.43 In such instances the layman has no way of solving his dilemma; in the language of metaphor, "You pays your money and you takes your choice." To the uninitiated who often thinks of science as a citadel of agreement ("Science says . . !"), it is well to remember that some of the greatest scientists of all time (e.g., Harvey, Semmelweis, Pasteur, Einstein) were at one time in their careers in sharp disagreement with the majority of their colleagues—let alone accepted by laymen. To the extent that a science is relatively undeveloped (sociology or linguistics, for example, in contrast to physics), then to that extent are its spokesmen less able to speak authoritatively in the language of reliable predictions; and therefore to that extent more imposters are apt to be found operating pseudo-scientifically in such a field. (A

partial resolution of this layman's dilemma is the establishment of systems of public accreditation as has occurred in the field of medicine. Psychologists, for example, are moving to legitimatize through state licensing agencies the specification of who is and who is not qualified to practice psychotherapy.)

C. *The Relation Between Science and Nonscience*

I.44 Not all human behavior is guided by scientific knowledge. Most of an individual's acts are motivated by ideas unsupported by scientific evidence. In fact, the areas of greatest ideological involvement (politics, religion, morality, art, etc.,) are those wherein people function according to tenaciously held beliefs alone. Cogent arguments often are convincing in themselves, even without objective confirmation; and to many persons mere verisimilitude (i.e, the appearance of being true or real) is an adequate foundation for belief.

I.45 Everyday life consists largely of mental and physical habits based simply upon supposed certainty. "Common sense," for example, is regarded as an adequate guide for much daily behavior. Even the primitive person knows that water runs only down hill, that night follows day, and that all living organisms grow, reproduce and eventually die. The fact that much common knowledge is actually unconfirmed by scientific evidence is of little concern to the believer in the virtue of so-called common sense. If such a person believes that the stars determine human events (astrology), that probability in a card game is simply a matter of random behavior ("chance, luck"), that physical or facial features determine personality (physionogmic "psychology"), or that prayer causes rain—then such beliefs will often be accepted as personally and socially adequate guides to daily behavior.

I.46 Nonscientific knowledge, therefore, is essentially of three kinds: (a) that which is based mainly upon sheer habit alone (e.g., how to eat properly, how to ride a bicycle, how to drive a car, how to dance); (b) that which is accepted as factually true by one's reference group (e.g., certain "foods" are tasty, others

inedible; sex, race, nationality, class or occupational roles should be sharply distinguished; there is a proper time and place for such acts as eating, sleeping, etc.); and (c) that which is assumed to be true by reason of particular ideological premises (e.g., religion is a "good thing"; democracy is the best form of government; *our* wars are always only defensive ones; monogamy is the only morally defensible and naturally "logical" form of heterosexual arrangement).

I.47 The often purported "conflict" between science and nonscience, therefore, assumes complex dimensions. The essential element of credulity is *faith* ("I believe") or *certitude* ("I know"). To the believer, ghosts *do* exist, "a leopard *cannot* change its spots" (i.e., personality *cannot* be altered), virtue *will* be rewarded, and "luck" *will* change. And the faith or certitude of the believer in science is essentially no different—i.e., is no more or less credulous—than is that of the nonscientist. *Only the referent is different.* The scientifically oriented person *believes* that the bridge (built according to scientific "laws") *will* hold, that the airplane *will* fly, that the drug *will* cure, and that the dead *cannot* arise. The referent in one case is faith in tradition, custom, the consensus of one's peers, or in one's own powers of observation and reasoning. The referent in the other case is faith in a method (viz., the scientific method) and its authorities. In cases of dispute between the two explanatory systems, the deciding factor for any given individual will be the certitude that either system offers him.

I.48 For most modern individuals the problem of choosing among different explanatory systems assumes confusing proportions. By the time one has reached a reasoning age, his knowledge is an undifferentiated mass of habits, objectively verified facts, and simple beliefs. Unable to distinguish clearly among the various types of knowledge he possesses, the layman often finds himself confused between opposing claims—of religion *versus* science (e.g., Christ was born of a virgin *versus* parthenogenesis in animals can result only in female offspring), of custom *versus* fact (e.g., wives should be younger than husbands *versus* women on the average live longer than men), of science *versus* pseudo-science

(e.g., this illness can be cured only by drugs or surgery *versus* it can be cured by a magical panacea), or of ideological claims *versus* other ideological claims (e.g., private profit-motivated capitalism is the best form of economy *versus* socialism is the best form).

I.49 Aided and abetted by social training and indoctrination, this confusion is compounded by several factors. One such factor is expediency, or the need to "get things done." People cannot always wait for the scientifically verified answer to come in. Time may be "awasting," and the desire to act may be compelling. The common saying that "Something is better than nothing," often expresses such an impatience with the careful working out of a scientifically-planned analysis of a problem. ("Something is better than nothing," is not only specious logic but can also be fatal reasoning. If the "something" is a poisonous mushroom and the "nothing" is continued hunger pangs, it is doubtful that sure death is "better" than possible starvation.)

I.50 Another such factor is one's choice of faith-reference groups. A given person at any given time may believe in various —and possibly conflicting—authority figures (e.g., the pastor, the parent, the teacher, the public official, the editor of a newspaper, the leader of a gang); and often even such authority figures may all be woefully ignorant of the true facts of a given problem. Obviously the person who does not have the facts at his command is unable to judge objectively among conflicting claims to the truth. But when an argument is cogently presented from an approved reference group—as, for example, it so often is in nationalistic histories, in jingoistic newspapers, or in product advertising—then the layman is easily convinced that the knowledge so obtained is true because it is both credible and authoritative.

I.51 This state of confusion can easily be dispelled by the person trained in scientific method. Such a person learns, first, to distinguish and separate arguments of opinion from those of fact, and to realize that only the latter are resolvable according to scientific evidence. Secondly, he learns how to formulate a problem according to the demands of the scientific approach.

And thirdly, he learns how to assess conflicting authorities and how to sift and evaluate evidence. It is these three major abilities that distinguish the scientifically-oriented person from the layman. And it is essentially these three major processes that will concern us in the chapters to follow.