The Significance of Physical Theory

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I

THE present century has witnessed exceptional activity in the construction of theories for various fields of physical science. Theories of relativity and of the structure of atoms constitute impressive monuments to man's creative activity in his quest for rational knowledge of the natural world. Philosophic reflection concerning the character of physical theory has run parallel to scientific creation. Among classics of the philosophy of theoretical physics is the book of Pierre Duhem, *La Théorie Physique; Son Object, Sa Structure,* the first edition of which was published in 1906, and the second in 1914. The present occasion for discussion of Duhem's conception of physical theory is the publication, by the Princeton University Press, of an English translation of the just-cited work by Phillip P. Wiener. The American edition bears the title THE AIM AND STRUCTURE OF PHYSICAL THEORY and includes an informative foreword, "Pierre Duhem's Life and Work," by Louis de Broglie, Nobel laureate and discoverer of the wave properties of matter (*1*).

A physical theory is a rational construction that expresses in systematic form man's knowledge of the physical world. Albert Einstein once introduced an exposition of the theory of relativity by a discussion of the nature of physical theories (*2*). As foundation for his analysis, he distinguished between constructive theories and theories of principle.

A *constructive theory* expresses the attempt to build a picture of complex phenomena out of relatively simple constituents. The kinetic theory of gases, for example, reduces mechanical, thermal, and diffusional properties of gases to molecular motions. Einstein declared that when we say that we understand a group of natural phenomena, we mean that we have found a constructive theory which embraces them.

A *theory of principle,* or *abstractive theory,* requires not the synthetic but the analytic method. Procedure for theories of principle begins with abstraction from experience instead of construction of hypothetical elements. Thermodynamics, for example, is based upon abstract principles which express the generalization that perpetual motion never occurs in ordinary experience.

According to Einstein, the merit of constructive theories is their comprehensiveness, adaptability, and clarity; that of theories of principle is their logical perfection and security of foundations.

In the present era of physical science, constructive theories of molecules, atoms, and nuclei command the universal interest of physicists and chemists. But it has not always been so. At the beginning of the 20th century, the doctrine of energetics found in thermodynamics the ideal form of physical theory. Among the proponents of energetics was the eminent French theoretical physicist, Pierre Duhem. According to the latter, constructive theories, designed to explain physical phenomena, are to be rejected as metaphysics. He summarized his doctrine of physical theory in the statement:

> A physical theory is not an explanation; it is a system of mathematical propositions whose aim is to represent as simply, as completely, and as exactly as possible a whole group of experimental laws.

In other words, Duhem held that only theories of principle, or abstractive theories, should be accepted for physical theory.

In the preface to the second edition of *La Théorie Physique,* Duhem held that his conception of theoretical physics had been confirmed by developments. This claim was supported by the creation of the theory of relativity which Einstein characterized in the aforementioned discussion as a theory of principle. But atomism, which Duhem vigorously opposed, had already begun the extraordinary developments that have made constructive theories of atom and nucleus the focus of contemporary physical interest. Thus, the course of physical theory has not been limited by the aims described by Duhem. Nevertheless, philosophers and historians of science will welcome the appearance of the excellent English translation of his significant book. Contemporary philosophy of science has emphasized the role of theoretical construction in physical theory, and Duhem's work provides an excellent introduction to this point of view.

The theory of Duhem was in its essentials an important contribution to a critical attitude on the part of physicists toward their subject. The best-known of these critical physicists was perhaps Ernst Mach, physicist, historian and philosopher of science, whose activities extended from the second half of the 19th century into the early decades of the 20th century. The aim of Mach was to eliminate metaphysics from science; to that end he described science as the economical description of the facts of experience (*3*). Since molecules and atoms were conceived to lie beyond the possibility of direct perception, Mach banned them from physical theory as fictions. Mach exerted a profound influence and his antimetaphysical doctrine was continued by the Vienna Circle, the ideas of which have been expounded in the United States by Philipp Frank (*4*). The Central European successors of Mach did diverge from him in that they accepted atoms as useful constructs. On this issue, however, Duhem's conception of physical theory conformed to that of Mach. Referring to the great development of molecular theories and mechanical models, Duhem said:

> Toward the end of the nineteenth century, hypothetical theories which were offered as more or less probable explanations of phenomena were extraordinarily multiplied. The noise of their battles and the fracas of their collapse have wearied physicists and led them gradually back to the sound doctrines Newton had expressed so forcefully. Renewing the interrupted tradition, Ernst Mach has defined theoretical physics as an abstract and condensed representation of natural phenomena.

While Duhem adhered to Mach's view that physical theory is an autonomous, abstract, and economical representation of physical phenomena, he did not share the expressed antimetaphysical attitude of Mach. Duhem left a place for an independent metaphysics of reality. For Mach and his followers, objects of perception are constructs that correlate the data of sense; Duhem had a less critical idea of the perceived object and accepted its reality from common sense. Whereas Mach denied the significance of the concept of transcendent reality, Duhem spoke of reality behind appearance. He thus retained the traditional dualism between reality and appearance, between metaphysics and physics. Thus he said:

> What is this metaphysical affirmation that the physicist will make, despite the nearly forced restraint imposed on the method he customarily uses? He will affirm that underneath the observable data, the only data accessible to his methods of study, are hidden realities whose essence cannot be grasped by these same methods, and that these realities are arranged in a certain order which physical science cannot directly contemplate. But he will note that physical theory through its successive advances tends to arrange experimental laws in an order more and more analogous to the transcendent order according to which the realities are classified, that as a result physical theory advances gradually toward its limiting form, namely, that of a *natural classification,* and finally that logical unity is a characteristic without which physical theory cannot claim this rank of a natural classification.

II

In order to set forth the historical significance of Duhem's work, I shall sketch the philosophic background of his ideas concerning the object of physical theory. A characteristic attitude was his rejection of atomism for the explanation of physical phenomena. Now atomism was especially developed by the ancient Greek philosopher Democritus, who taught that reality is constituted of atoms in the void. He held that properties of atoms, such as figure and motion, alone are real and that sensible qualities, such as color, hotness, and sweetness, are appearances which are to be explained by the action of atoms upon the organs of sense. Thus originated the doctrine that spatial and mechanical properties of matter are fundamental and constitute the object of physical theory. In modern terminology, the basic properties of matter are primary and real; sensible qualities are secondary qualities with an inferior status in reality.

The ancients accepted earth, air, fire, and water as fundamental elements, and Plato in the *Timaeus* expounded a theory that constituted the elements out of geometric figures. This Platonic reduction of quality to quantity was the initiation of a mathematical physics, but it was thrust aside by the Aristotelian physics which recognized the qualities of hotness and coldness, of wetness and dryness as fundamental. It was the historic function of Galileo to renounce the Aristotelian program of a qualitative physics and to found a quantitative science based upon the primacy of spatial and inertial properties of physical reality to the secondary qualities of sensation. Whether matter was interpreted as continuous space by Descartes, or as atoms in empty space by the atomists, primary properties were sharply distinguished from secondary qualities and made the object of physical theory.

The distinction between primary qualities and secondary qualities was adopted in the 17th century by the founders of modern physics such as Galileo, Descartes, and Newton. The distinction is exemplified by the contrast between the sensation of light and the physical action of external bodies upon the sense organs of an observer. This distinction between sensible appearance and physical cause was generally accepted by natural scientists and found philosophic acceptance in Locke's *Essay Concerning Human Understanding* (1690). The history of modern philosophy is largely an attempt to overcome this dualistic realism of the physicists. The philosopher Berkeley found that primary qualities, as well as secondary ones, are infected by relativity to the observer. Hume's skeptical analysis yielded the result that physical objects are complexes of sensory impressions. The philosopher Kant held that space and time are forms of intuition and that physical objects are constructions of thought out of data given in intuition. But, in the last analysis, Kant adhered to the original dualistic realism, for he attributed the manifold given in intuition to the action of a thing-in-itself.

Against a background of dualistic realism presupposed by natural scientists, there appeared the analysis of scientific knowledge by Ernst Mach. In order to eliminate metaphysics from science, he analyzed reality into elements of sensation which are neither physical nor mental by themselves. The things given in perception are complexes of sensible elements and are viewed as real. Insofar as properties of things are determined by other things, they are physical; but insofar as properties are related to an observing organism, they are mental. Thus, all sciences refer to the same content; in our time, this doctrine has furnished the basis of the movement for the Unity of Science (*5*).

The neutral character ascribed by Mach to the elements of sensation stimulated the creation of a Neorealism during the early decades of the 20th century, a movement that was part of what Lovejoy has called the revolt against dualism (*6*). In Europe, the Vienna Circle, under the leadership of Moritz Schlick and Rudolf Carnap, developed the doctrine of Mach that was transplanted to America under the name *logical positivism*. The program of positivism was to give an interpretation of science that is neutral with respect to metaphysical issues. As set forth by Philipp Frank, Mach's doctrine is that scientific knowledge refers only to the contents of perception. Science consists in the symbolic representation of perceptions. In departure from Mach, however, contemporary positivists accept molecules and atoms as constructs that play a valuable role in the symbolic representation of physical reality.

The neutralist interpretation of Mach's doctrine has manifested instability. The usual philosophic opinion ascribes transient reality to contents of perception. Hence, if reality consists of elements of sensation, it is dependent upon intermittent acts of perception. In view of this apparent logical consequence of positivist criticism, the doctrine of dualistic realism has retained adherents. Thus Max Planck, who wrote frequently on philosophic problems of physics, reported that in his early period he had adhered to the doctrine of Mach, but that he finally accepted the realistic point of view (*7*).

Bertrand Russell began as dualist; then in *Scientific Method in Philosophy* he described physical objects as logical constructions out of aspects given in perception (*8*); but later in the *Analysis of Matter* he expounded a causal theory of perception, a form of dualistic realism (*9*). The history of the theory of perceptible things, thus, narrates a vacillation between the characterization of a thing as constituted of transient sense data and as a persistent reality that gives rise to the momentary content of perception.

Duhem's theory was anomalous within a modern context. Central to this conception of physical theory was the rejection of the program to reduce quality to quantity. He stood with Aristotle against atomists and Cartesians by assigning a fundamental role to quality as a direct object of physical investigation. Duhem has been classified as an adherent of the school of Mach, but he did not adhere to the latter's apparent restriction of reality to the data of experience. Duhem proclaimed the autonomy of physical theory with respect to metaphysics but declared that there are realities which transcend experience. Thus he said:

> Concerning the very nature of things, or the realities hidden under the phenomena we are studying, a theory conceived on the plan we have just drawn teaches us absolutely nothing.

III

According to Duhem, the aim of physical theory is not explanation but the representation and natural classification of experimental laws. The sequence of procedures is as follows: Physical properties of things are represented by symbols, hypotheses are set up to express relationships between symbols, consequences are deduced mathematically from hypotheses, and the consequences are then tested by experimental facts. For Duhem, the abstract character of theories of principle expresses the nature of physical theory. But such abstractive theories are formulated in terms of abstract symbols which substitute for the concrete data of experiments. The laws of physics are symbolic relationships, each of which is approximate and provisional.

Duhem's conception of physical theory rests upon a distinction between practical fact and theoretical fact. Propositions about the properties of things given to observation express practical facts. Though vague and indefinite, such propositions based upon direct experience are either true or false. Theory, however, applies to a schematic construction. Through measurement, an observable property is correlated to a property of the symbolic schema. Propositions of a physical theory express theoretical facts about the schema. Though clear and definite, theoretical propositions are neither true nor false. In view of the lack of precision of measurement, an infinity of theoretical facts may be consistent with the results of experiment. A physical theory is approximate and provisional.

"An experiment in physics is the precise observation of phenomena accompanied by an interpretation of these phenomena; this interpretation substitutes for the concrete data really gathered by observation abstract and symbolic representations which correspond to them by virtue of the theories admitted by the observer." It is the theoretical interpretation of experiments through abstract and symbolic judgments that makes possible the use of instruments. Whereas the contemporary exponent of operationism interprets theory in terms of experiment, Duhem interpreted experiment in terms of theory. Duhem, thus, in effect continued the Kantian view that thought is constitutive of science. For illustration he offered the following example:

> Go into this laboratory; draw near this table crowded with so much apparatus: an electric battery, copper wire wrapped in silk, vessels filled with mercury, coils, a small iron bar carrying a mirror. An observer plunges the metallic stem of a rod, mounted with rubber, into small holes; the iron oscillates and, by means of the mirror tied to it, sends a beam of light over a celluloid ruler, and the observer follows the movement of the light beam on it. There, no doubt, you have an experiment; by means of the vibration of this spot of light, this physicist minutely observes the oscillations of the piece of iron. Ask him now what he is doing. Is he going to answer: "I am studying the oscillations of the piece of iron carrying this mirror?" No, he will tell you that he is measuring the electrical resistance of a coil. If you are astonished and ask him what meaning these words have, and what relation they have to the phenomena he has perceived and which you have at the same time perceived, he will reply that your question would require some very long explanations, and he will recommend that you take a course in electricity.

Duhem summarized his discussion by the statement:

> The result of the operations in which an experimental physicist is engaged is by no means the perception

of a group of concrete facts; it is the formulation of a judgment interrelating certain abstract and symbolic ideas which theories alone correlate to the facts really observed.

An interpretation of Duhem's conception of physical theory requires careful consideration of the reference of symbols. The physical properties of things are represented by numerical measures, but the basic question concerns the properties that the numbers represent. What are the abstract and symbolic ideas which theories alone correlate to the facts really observed? The adherents of Ernst Mach would declare that the symbols designate concrete experiences of spaces, times, colors, pressures, sounds, and so forth. The exponents of contemporary operationism would assert that the symbols designate operations by which the results of measurements are obtained (*10*). According to the well-developed views of Henry Margenau, the symbols designate constructs (*11*). An interpretation of Duhem may be determined from the following:

> When, in the course of an optical theory, we talk about luminous vibration, we no longer think of a real to-and-fro motion of a real body; we imagine only an abstract magnitude, *i.e.*, a pure, geometrical expression. It is a periodically variable length which helps us state the hypotheses of optics, and to regain by regular calculations the experimental laws governing light. This vibration is to our mind a *representation*, and not an *explanation*.

From this example, one may conclude that for Duhem the symbols of physical theory designate constructs in the contemporary sense of the term. Duhem, however, declined to accept molecules, atoms, and electrons as legitimate constructs. Thus, his point of view appears more limited than contemporary theories of physical constructs.

Duhem rejected all mechanical explanations of physical phenomena. Thus, he criticized the Cartesian theory of vortices and pressures in extended matter and especially disapproved of the contemporary development of atomic theories. Thus, he wrote:

> Consider someone, for instance, who would take physical theory just as we have it, in the year of grace 1905, presented by the majority of those who teach it. Anyone who would listen closely to the talk of classes and to the gossip of the laboratories without looking back or caring for what used to be taught, would hear physicists constantly employing in their theories molecules, atoms, and electrons, counting these small bodies and determining their size, their mass, their charge. . . . each time the fortunate daring of an experimenter will have discovered a new set of experimental laws, he will see the atomists, with feverish haste, take possession of this scarcely explored domain and construct a mechanism approximately representing these new findings. Then, as the experimenter's discoveries become more numerous and detailed, he will see the atomist's combinations get complicated, disturbed, overburdened with arbitrary complications without succeeding, however, in rendering a precise account of the new laws or in connecting them solidly in the old laws. . . . It will appear clearly to him that the physics of atomism, condemned to perpetual fresh starts, does not tend by continued progress to the ideal form of physical theory; whereas he will surmise the gradually complete realization of this ideal when he contemplates the development which abstract theory has undergone from Scholasticism to Galileo and Descartes; from Huygens, Leibniz and Newton to D'Alembert, Euler, Laplace, and Lagrange; from Sadi Carnot and Clausius to Gibbs and Helmholtz.

Duhem denied that the nature of ultimate reality is the object of physical theory. But he committed himself to a reality beyond experience more explicitly than positivists with whom he has been classified. Thus,

> Physical theory never gives us the explanation of experimental laws; it never reveals realities hiding under the sensible appearances; but the more complete it becomes, the more we apprehend that the logical order in which theory orders experimental laws is the reflection of an ontological order, the more we suspect that the relations it establishes among the data of observation correspond to real relations among things, and the more we feel that theory tends to be a natural classification.

IV

It is evident from Duhem's symbolic conception of physical theory that hypotheses are not directly derivable from experience. Accordingly, he expressed disagreement with Newton's doctrine that the principles of a physical theory should be derived by induction from experience. Newton's theory of scientific method was expounded in the "General Scholium" of his *Principia,* but it was also stated in Query XXXI at the end of the second edition of the *Optics.* In the passage quoted by Duhem, Newton stated:

> To tell us that every species of things is endowed with an occult specific quality by which it acts and produces manifest effects, is to tell us nothing; but to derive two or three general principles of motion from phenomena, and afterwards to tell us how the properties and actions of all corporeal things follow from those manifest principles, would be a very great step in philosophy.

Duhem remarked:

> It was this sort of physical theory that Newton had in mind when, in the "General Scholium" which crowns his *Principia,* he [Newton] rejected so vigorously as outside of natural philosophy any hypothesis that induction did not extract from experiment; when he asserted that in a sound physics every proposition should be drawn from phenomena and generalized by induction.

It has been held that Newton derived his theory of gravitation from the laws which were revealed to Kepler by observation. Duhem declared, however,

> The principle of universal gravity, very far from being derivable by generalization and induction from the observational laws of Kepler, formally contradicts these laws. If Newton's theory is correct, Kepler's laws are necessarily false.

The fact is that the law of gravitation determines the force acting on a planet to be the resultant of the attractive forces exerted by the sun and the other planets. In consequence, the actual orbit arises as a perturbation of the Keplerian orbit, which perturbation can be determined from refined observations. And Duhem further declared:

> Such a comparison will not only bear on this or that part of the Newtonian principle, but will involve all its parts at the same time; with those it will also involve the principles of dynamics; besides, it will call in the aid of all the propositions of optics, the statics of gases, and the theory of heat, which are necessary to justify the properties of telescopes in their construction, regulation, and correction, and in the elimination of the errors caused by diurnal or annual aberration and by atmospheric refraction. It is no longer a matter of taking, one by one, laws justified by observation, and raising each of them by induction and generalization to the rank of a principle; it is a matter of comparing the corollaries of a whole group of hypotheses to a whole group of facts.

Duhem further criticized the Newtonian method in a discussion of Ampere's claim that he deduced his mathematical theory of electrodynamic phenomena only from experiment. Duhem concluded:

> Two rocky reefs make the purely inductive course inpracticable for the physicist. In the first place, no experimental law can serve the theorist before it has undergone an interpretation transforming it into a symbolic law; and this interpretation implies adherence to a whole set of theories. In the second place, no experimental law is exact but only approximate, and is therefore susceptible to an infinity of distinct symbolic translations; and among all these translations the physicist has to choose one which will provide him with a fruitful hypothesis without his choice being guided by experiment at all.

It follows from Duhem's doctrine that an individual hypothesis cannot be tested experimentally and that crucial experiments are not possible. Regarding the latter point, he gave a profound criticism of the generally held view that Foucault's experiment on the velocity of light in liquids demonstrated the wave theory.

V

Duhem was a practicing theoretical physicist, but he was also a historian of science of the first rank. His works on the history of mechanics, on Leonardo da Vinci, and on systems of the world from Plato to Copernicus are monuments of learning. Hence, one of the merits of Duhem's work that especially justifies this American edition is the wealth of historical material that bears on physics. In order to illustrate his distinction between explanatory and abstract theories, he borrowed from Pascal a contrast between two types of mind. The broad but weak mind finds explanatory theories congenial to it; the narrow but strong mind delights in abstract theories. In French thought, Gassendi, the atomist, represents the first type, and Descartes, who sought to found physics on rational principles, represents the second type. But Duhem offered Continental physicists generally as examples of the narrow but strong mind. Newton was conceded to exemplify the narrow and strong type among the English, but Duhem found English physicists of the 19th century mainly to have broad and weak minds concerned with all kinds of mechanical models. Although Duhem supported his thesis with a wealth of historical material, nationalistic differences are hardly discernible in the contemporary international development of constructive hypotheses concerning atoms and nuclei. The French physicist Louis de Broglie quite rightly calls attention to the British physicist Dirac, whose work on the foundations of quantum mechanics has been conducted on the highest level of abstraction.

It was a thesis of Duhem that "hypotheses are not the product of sudden creation, but the result of progressive evolution." Thus, one cannot understand a hypothesis unless one knows its history. A valuable part of the book is the history of the concept of universal attraction from Aristotle to Newton. Duhem sums this up in the following:

> The most diverse considerations and the most disparate doctrines arose in turn to make their bid for the construction of celestial mechanics; common experience revealing gravity, as well as the scientific measurements of Tyco Brahe and of Picard; the observational laws formulated by Kepler, the vortices of the Cartesians and atomists, as well as the rational dynamics of Huygens; the metaphysical doctrines of the Aristotelians, as well as the systems of the physicians and the dreams of astrologers; comparisons of weight with magnetic action, as well as the affinities between the light and the mutual actions of heavenly bodies. In the course of this long and laborious birth, we can follow the slow and gradual transformations through which the theoretical system evolved; but at no time can we see a sudden and arbitrary creation of new hypotheses.

Duhem's historical point of view led him to novel evaluations of ancient doctrines. Although he proclaimed the autonomy of physical theory, and distinguished physical theory from a metaphysical cosmology, he asserted that the ideal form toward which physical theory tends is analogous to cosmology. As we have seen, for Duhem, general thermodynamics most adequately exemplified the ideal form of physical theory. He held that general thermodynamics is analogous to the cosmology of Aristotelian physics. Aristotelian physics recognized the categories of quantity and quality, as does the thermodynamics with its symbols for extensive and intensive properties. Aristotle recognized qualitative change as well as motion, as does thermodynamics. One of the essential theories of Aristotle's cosmology is that of the natural place of the elements. Duhem found the essence of this theory to be that a perfect state of the universe would be one of stable equilibrium, to which the world would return by natural motions if disturbed. But thermodynamics analogously conceives that isolated systems tend to a state of equilibrium in which entropy is a maximum. Duhem arrived at the remarkable conclusion:

If we rid the physics of Aristotle and of Scholasticism of the outworn and demoded scientific clothing covering it, and if we bring out in its vigorous and harmonious nakedness the living flesh of this cosmology, we would be struck by its resemblance to our modern physical theory.

At the close of the final article, "The Value of Physical Theory." Duhem summarized his qualified positivism. He said:

the physicist is compelled to recognize that *it would be unreasonable to work for the progress of physical theory if this theory were not the increasingly better defined and more precise reflection of a metaphysics; the belief in an order transcending physics is the sole justification of physical theory.*

Duhem expressed the previously cited vacillations of the physicist with respect to the foregoing affirmation by a quotation from Pascal, whose philosophic spirit permeates Duhem's book, and who may be permitted to speak in his native tongue:

Nous avons une impuissance de prouver invincible à tout le Dogmatisme; nous avons une idée de la verité invincible à toute le Pyrrhonisme.

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Recommended Diet for Padded Writing

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FROM a close examination of the writing in many scientific publications (including, if you do not mind, *The Scientific Monthly*), one would never guess that as a nation we are renowned for efficiency. Sentences bulge like overfed matrons with unnecessary words that obscure a writer's ideas and weaken his emphasis, much as the matronly fat obscures the streamlined glory of the past. For both matrons and sentences, a major solution is diet: for writing, a diet of efficient verbs.

The following sentences from *The Scientific Monthly* illustrate the point:

Whereas [Cannon's] studies have been primarily concerned with the physiological regulations of the internal environment, much of the work of Richter has dealt with the maintenance of the constancy of the internal environment through the operation of behavior regulators.

It is noted by Harrow that pancreatectomy is fatal to the dog, with the death of the animal occurring in one to two weeks and that the length of survival of cats after removal of the pancreas is about five to six days.

Still more unusual is the fact that these surrounding industrial regions give relatively little employment to ''Mainliners.''

Shorter, clearer, and more forceful versions of these:

. . . Richter has chiefly studied how behavior regulators maintain the constancy of the internal environment.

Harrow notes that pancreatectomy is fatal to dogs in one to two weeks and fatal to cats in about five to six days.

Still more unusual, these surrounding industrial regions employ relatively few ''Mainliners.''

Since readers may object, with some justification, to criticism of sentences removed from context, here is a complete—and representative—paragraph, again from *The Scientific Monthly*:

The decision to stay on a job or leave it, as well as where to work, generally lay with the scientists themselves. Only 18 of the 155 scientists who had remained on their jobs for at least 8 years reported that they had had no other offer or none worth considering during this period. Only 67 of the 574 job exits were due to factors over which the scientists had no control, and 28 of these resulted from the termination of war projects. Furthermore, the scientists were rarely forced to accept a job for lack of another offer; this was the case for only 75 of the 670 job entrances covered by the study. Very likely, the fact that the scientists were able to choose between job offers was at least in part due to their practice of continuing in a position while shopping for a new one: they rarely left a job without having another one lined up.