rectly determined by the formulas of the calculus, either definitions or laws, connecting them with the elementary terms. If we demand from the modern physicist an answer to the question what he means by the symbol Ψ of his calculus, and are astonished that he cannot give an answer, we ought to realize that the situation was already the same in classical physics. There the physicist could not tell us what he meant by the symbol *E* in Maxwell's equations. Perhaps, in order not to refuse an answer, he would tell us that *E* designates the electric field vector. To be sure, this statement has the form of a semantical rule, but it would not help us a bit to understand the theory. It simply refers from a symbol in a symbolic calculus to a corresponding word expression in a calculus of words. We are right in demanding an interpretation for *E* but that will be given indirectly by semantical rules referring to elementary signs together with the formulas connecting them with *E*. This interpretation enables us to use the laws containing *E* for the derivation of predictions. Thus we understand *E*, if "understanding" of an expression, a sentence, or a theory means capability of its use for the description of known facts or the prediction of new facts. An "intuitive understanding" or a direct translation of *E* into terms referring to observable properties is neither necessary nor possible. The situation of the modern physicist is not essentially different. He knows how to use the symbol Ψ in the calculus in order to derive predictions which we can test by observations. (If they have the form of probability statements, they are tested by statistical results of observations.) Thus the physicist, although he cannot give us a translation into everyday language, understands the symbol Ψ and the laws of quantum mechanics. He possesses that kind of understanding which alone is essential in the field of knowledge and science.

Carl G. Hempel

A LOGICAL APPRAISAL OF OPERATIONISM

Operationism, in its fundamental tenets, is closely akin to logical empiricism. Both schools of thought have put much emphasis on definite experiential meaning or import as a necessary condition of objectively significant discourse, and both have made strong efforts to establish explicit criterions of experiential significance. But logical empiricism has treated experiential import as a characteristic of statements—namely, as their susceptibility to test by experiment or observation—whereas operationism has tended to construe experiential meaning as a characteristic of concepts or of the terms representing them—namely, as their susceptibility to operational definition.

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BASIC IDEAS OF OPERATIONAL ANALYSIS

An operational definition of a term is conceived as a rule to the effect that the term is to apply to a particular case if the performance of specified operations in that case yields a certain characteristic result. For

example, the term *harder than* might be operationally defined by the rule that a piece of mineral *x*, is to be called harder than another piece of mineral, *y*, if the operation of drawing a sharp point of *x* across the surface of *y* results in a scratch mark on the latter. Similarly, the different numerical values of a quantity such as length are thought of as operationally definable by reference to the outcomes of specified measuring operations. To safeguard the objectivity of science, all operations invoked in this kind of definition are required to be intersubjective in the sense that different observers must be able to perform "the same operation" with reasonable agreement in their results.[1]

P.W. Bridgman, the originator of operational analysis, distinguishes several kinds of operation that may be invoked in specifying the meanings of scientific terms.[2] The principal ones are (1) what he calls *instrumental operations*—these consist in the use of various devices of observation and measurement—and (2) paper-and-pencil operations, verbal operations, mental experiments, and the like—this group is meant to include, among other things, the techniques of mathematical and logical inference as well as the use of experiments in imagination. For brevity, but also by way of suggesting a fundamental similarity among the procedures of the second kind, I shall refer to them as *symbolic operations*.

The concepts of operation and of operational definition serve to state the basic principles of operational analysis, of which the following are of special importance:

(1) "Meanings are operational." To understand the meaning of a term, we must know the operational criterions of its application,[3] and every meaningful scientific term must therefore permit of an operational definition. Such definition may refer to certain symbolic operations and it always must ultimately make reference to some instrumental operation.[4]

(2) To avoid ambiguity, every scientific term should be defined by means of one unique operational criterion. Even when two different operational procedures (for instance, the optical and the tactual ways of measuring length) have been found to yield the same results, they must still be considered as defining different concepts (for example, optical and tactual length), and these should be distinguished terminologically because the presumed coincidence of the results is inferred from experimental evidence, and it is "not safe" to forget that the presumption may be shown to be spurious by new, and perhaps more precise, experimental data.[5]

(3) The insistence that scientific terms should have unambiguously specifiable operational meanings serves to insure the possibility of an objective test for the hypotheses formulated by means of those terms.[6] Hypotheses incapable of operational test or, rather, questions involving untestable formulations, are rejected as meaningless: "If a specific question has meaning, it must be possible to find operations by which an answer may be given to it. It will be found in many cases that the operations cannot exist, and the question therefore has no meaning."[7]

The emphasis on "operational meaning" in scientifically significant discourse has unquestionably afforded a salutary critique of certain types of procedure in philosophy and in empirical science and has provided a strong stimulus for methodological thinking. Yet, the central ideas of operational analysis as stated by their proponents are so vague that they constitute not a theory concerning the nature of scientific concepts but rather a program for the development of such a theory. They share this characteristic with the insistence of logical empiricism that all significant scientific statements must have experiential import, that the latter consists in testability by suitable data of direct observation, and that sentences which are entirely incapable of any test must be ruled out as meaningless "pseudo hypotheses." These ideas, too, constitute not so much a thesis or a theory as a program for a theory that needs to be formulated and amplified in precise terms.

An attempt to develop an operationist theory of scientific concepts will have to deal with a least two major issues: The problem of giving a more precise explication of the concept of operational definition; and the question whether operational definition in the explicated sense is indeed necessary for, and adequate to, the introduction of all nonobservational terms in empirical science.

I wish to present here in brief outline some considerations that bear on these problems. The discussion will be limited to the descriptive, or extralogical, vocabulary of empirical science and will not deal, therefore, with Bridgman's ideas on the status of logic and mathematics.

A BROADENED CONCEPTION OF OPERATIONAL DEFINITION AND OF THE PROGRAM OF OPERATIONAL ANALYSIS

The terms "operational meaning" and "operational definition," as well as many of the pronouncements made in operationist writings, convey the suggestion that the criterions of application of any scientific term must ultimately refer to the outcome of some specified type of manipulation of the subject matter under investigation. Such emphasis would evidently be overly restrictive. An operational definition gives experiential meaning to the term it introduces because it enables us to decide on the applicability of that term to a given case by observing the response the case shows under specifiable test conditions. Whether these conditions can be brought about at will by "instrumental operations" or whether we have to wait for their occurrence is of great interest for the practice of scientific research, but it is inessential in securing experiental import for the defined term; what matters for this latter purpose is simply that the relevant test conditions and the requisite response be of such kind that different investigators can ascertain, by direct observation and with reasonably good agreement, whether, in a given case, the test conditions are realized and whether the characteristic response does occur.

Thus, an operational definition of the simplest kind—one that, roughly speaking, refers to instrumental operations only will have to be construed more broadly as introducing a term by the stipulation that it is to apply to all and only those cases which, under specified observable conditions S, show a characteristic observable response R.

However, an operational definition cannot be conceived as specifying that the term in question is to apply to a given case only if S and R actually occur in that case. Physical bodies, for example, are asserted to have masses, temperatures, charges, and so on, even at times when these magnitudes are not being measured. Hence, an operational definition of a concept—such as a property or a relationship, for example—will have to be understood as ascribing the concept to all those cases that *would* exhibit the characteristic response if the test conditions *should* be realized. A concept thus characterized is clearly not "synonymous with the corresponding set of operations."[8] It constitutes not a manifest but a potential character, namely, a disposition to exhibit a certain characteristic response under specified test conditions.

But to attribute a disposition of this kind to a case in which the specified test condition is not realized (for example, to attribute solubility-in-water to a lump of sugar that is not actually put into water) is to make a generalization, and this involves an inductive risk. Thus, the application of an operationally defined term to an instance of the kind here considered would have to be adjudged "not safe" in precisely the same sense in which Bridgman insists it is "not safe" to assume that two procedures of measurement that have yielded the same results in the past will continue to do so in the future. It is now clear that if we were to reject any procedure that involves an inductive risk, we would be prevented not only from using more than one operational criterion in introducing a given term but also from ever applying a disposition term to any case in which the characteristic manifest conditions of application are not realized; thus, the use of dispositional concepts would, in effect be prohibited.

A few remarks might be added here concerning the non-instrumental operations countenanced for the introduction especially of theoretical terms. In operationist writings, those symbolic procedures have been characterized so vaguely as to permit the introduction, by a suitable choice of "verbal" or "mental" operations, of virtually all those ideas that operational analysis was to prohibit as devoid of meaning. To meet this difficulty, Bridgman has suggested a distinction between "good" and "bad" operations;[9] but he has not provided a clear criterion for this distinction. Consequently, this idea fails to plug the hole in the operationist dike.

If the principles of operationism are to admit the theoretical constructs of science but to rule out certain other kinds of terms as lacking experiential, or operational, meaning, then the vague requirement of definability by reference to instrumental and "good" symbolic operations must be replaced by a precise characterization of the kinds of sentences that may be used to introduce, or specify the meanings of, "meaningful" nonobservational terms on the basis of the observational vocabulary of science. Such a characterization would eliminate the psychologistic notion of mental operations in favor of a specification of the logicomathematical concepts and procedures to be permitted in the context of operational definition.

The reference just made to the observational vocabulary of science is essential to the idea of operational definition; for it is in terms of this vocabulary that the test conditions and the characteristic response specified in an operational definition are described and by means of which, therefore, the meanings of operationally defined terms are ultimately characterized. Hence, the intent of the original operationist insistence on intersubjective repeatability of the defining operations will be respected if we require that the terms included in the observational vocabulary must refer to attributes (properties and relationships) that are directly and publicly observable—that is, whose presence or absence can be ascertained, under suitable conditions, by direct observation, and with good agreement among different observers.[10]

In sum, then, a precise statement and elaboration of the basic tenets of operationism require an explication of the logical relationships between theoretical and observational terms, just as a precise statement and elaboration of the basic tenets of empiricism require an explication of the logical relationships connecting theoretical sentences with observation sentences describing potential data of direct observation.

SPECIFICATION OF MEANING BY EXPLICIT DEFINITION AND BY REDUCTION

Initially, it may appear plausible to assume that all theoetical terms used in science can be fully defined by means of the observational vocabulary. There are various reasons, however, to doubt this assumption.

First of all, there exists a difficulty concerning the definition of the scientific terms that refer to dispositions—and, as is noted in a foregoing paragraph, all the terms introduced by operational definition have to be viewed as dispositional in character. Recent logical studies strongly suggest that dispositions can be defined by reference to manifest characteristics, such as those presented by the observational vocabulary, only with the help of some "nomological modality" such as the concept of nomological truth, that is, truth by virtue of general laws of nature.[11] But a concept of this kind is presumably inadmissible under operationist standards, since it is neither a directly observable characteristic nor definable in terms of such characteristics.

Another difficulty arises when we attempt to give full definitions, in terms of observables, for quantitative terms such as "length in centimeters," "duration in seconds," "temperature in degrees Celsius." Within scientific theory, each of these is allowed to assume any real-number value within a certain interval; and the question therefore arises whether each of the infinitely many permissible values, say of length, is capable of an operational specification of meaning. It can be shown that it is impossible to characterize every one of the permissible numerical values by some truth-functional combination of observable characteristics, since the existence of a threshold of discrimination in all areas of observation allows for only a finite number of nonequivalent combinations of this kind.[12]

Difficulties such as these suggest the question whether it is not possible to conceive of methods more general and more flexible than definition for the introduction of scientific terms on the basis of the observational vocabulary. One such method has been developed in considerable detail by Carnap. It makes use of so-called reduction sentences, which constitute a considerably generalized version of definition sentences and are especially well suited for a precise reformulation of the intent of operational definitions. As we noted earlier, an operational definition of the simplest kind stipulates that the concept it introduces, say C, is to apply to those and only those cases which, under specified test conditions S, show a certain characteristic response R. In Carnap's treatment, this stipulation is replaced by the sentence

$$Sx \rightarrow (Cx \equiv Rx) \qquad (1)$$

or, in words: If a case x satisfies the test condition S, then x is an instance of C if and only if x shows the response R. Formula (1), called a bilateral reduction sentence, is not a full definition (which would have to be of the form $Cx \equiv \ldots$, with Cx constituting the definiendum); it specifies the meaning of Cx, not for all cases, but only for those that satisfy the condition S. In this sense, it constitutes only a partial, or conditional, definition for C[13]. If S and R belong to the observational vocabulary of science, formula (1) schematizes the simplest type of operational definition, which invokes (almost) exclusively instrumental operations or, better, experiential findings. Operational definitions that also utilize symbolic operations would be represented by chains of reduction sentences containing logical or mathematical symbols. Some such symbols occur even in formula (1), however; and clearly, there can be no operational definition that makes use of no logical concepts at all.

INTERPRETATIVE SYSTEMS

Once the idea of a partial specification of meaning is granted, it appears unnecessarily restrictive, however, to limit the sentences effecting such partial interpretation to reduction sentences in Carnap's sense. A partial specification of the meanings of a set of nonobservational terms might be expressed, more generally, by one or more sentences that connect those terms with the observational vocabularly but do not have the form of reduction sentences. And it seems well to countenance, for the same purpose, even stipulations expressed by sentences containing only nonobservational terms; for example, the stipulation that two theoretical terms are to be mutually exclusive may be regarded as a limitation and, in this sense, a partial specification of their meanings.

Generally, then, a set of one or more theoretical terms, $t_1, t_2, \ldots, t_n$, might be introduced by any set M of sentences such that (i) M contains no extra logical terms other than $t_1, t_2, \ldots, t_n$, and observation terms, (ii) M is logically consistent, and (iii) M is not equivalent to a truth of formal logic. The last two of these conditions serve merely to exclude trivial extreme cases. A set M of this kind will be referred to briefly as an *interpretative system,* its elements as *interpretative sentences.*

Explicit definitions and reduction sentences are special types of interpretative sentences, and so are the meaning postulates recently suggested by Kemeny and Carnap.[14]

The interpretative sentences used in a given theory may be viewed simply as postulates of that theory,[15] with all the observation terms, as well as the terms introduced by the interpretative system, being treated as primitives. Thus construed, the specification of the meanings of nonobservational terms in science resembles what has sometimes been called the implicit definition of the primitives of an axiomatized theory by its postulates. In this latter procedure, the primitives are all uninterpreted, and the postulates then impose restrictions on any interpretation of the primitives that is to turn the postulates into true sentences. Such restrictions may be viewed as partial specifications of meaning. The use of interpretative systems as here envisaged has this distinctive peculiarity, however: The primitives include a set of terms—the observation terms—which are antecedently understood and thus not in need of any interpretation, and by reference to which the postulates effect a partial specification of meaning for the remaining, nonobservational, primitives. This partial specification again consists in limiting those interpretations of the nonobservational terms that will render the postulates true.

IMPLICATIONS FOR THE IDEA OF EXPERIENTIAL MEANING AND FOR THE DISTINCTION OF ANALYTIC AND SYNTHETIC SENTENCES IN SCIENCE

If the introduction of nonobservational terms is conceived in this broader fashion, which appears to accord with the needs of a formal reconstruction of the language of empirical science, then it becomes pointless to ask for the operational definition or the experiential import of any one theoretical term. Explicit definition by means of observables is no longer generally available, and experiential—or operational—meaning can be attributed only to the set of all the nonobservational terms functioning in a given theory.

Furthermore, there remains no satisfactory general way of dividing all conceivable systems of theoretical terms into two classes: Those that are scientifically significant and those that are not; those that have experiential import and those that lack it. Rather, experiential, or operational, significance appears as capable of gradations. To begin with one extreme possibility: The interpretative system M introducing the given terms may simply be a set of sentences in the form of explicit definitions that provide an observational equivalent for each of those terms. In this case, the terms introduced by M have maximal experiential significance, as it were. In another case, M might consist of reduction sentences for the theoretical terms; these will enable us to formulate, in terms of observables, a necessary and a (different) sufficient condition of application for each of the introduced terms. Again M might contain sentences in the form of definitions or reduction sentences for only some of the nonobservational terms it introduces. And finally, none of the sentences in M might have the form of a definition or of a reduction sentence; and yet, a theory whose terms are introduced by an interpretative system of this kind may well permit of test by observational findings, and in this sense, the system of its nonobservational terms may possess experiential import.[16]

Thus, experiential significance presents itself as capable of degrees, and any attempt to set up a dichotomy allowing only experientially meaningful and experientially meaningless concept systems appears as too crude to be adequate for a logical analysis of scientific concepts and theories.

The use of interpretative systems is a more inclusive method of introducing theoretical terms than the method of meaning postulates developed by Carnap and Kemeny. For although meaning postulates are conceived as analytic and, hence, as implying only analytic consequences, an interpretative system may imply certain sentences that contain observation terms but no theoretical terms and are neither formal truths of logic nor analytic in the customary sense. Consider, for example, the following two interpretative sentences, which form what Carnap calls a reduction pair, and which interpret *C* by means of observation predicates, R_1, S_1, R_2, S_2:

$$S_1x \rightarrow (R_1x \rightarrow Cx) \qquad (2.1)$$
$$S_2x \rightarrow (R_2x \rightarrow -Cx). \qquad (2.2)$$

Since in no case the sufficient conditions for *C* and for $-C$ (non-*C*) can be satisfied jointly, the two sentences imply the consequence[17] for every case *x*,

$$-(S_1x \bullet R_1x \bullet S_2x \bullet R_2x), \qquad (3)$$

that is, no case x exhibits the attributes S_1, R_1, S_2, R_2 jointly. Now, an assertion of this kind is not a truth of formal logic, nor can it generally be viewed as true solely by virtue of the meanings of its constituent terms. Carnap therefore treats this consequence of formulas (2.1) and (2.2) as empirical and as expressing the factual content of the reduction pair from which it was derived. Occurrences of this kind are by no means limited to reduction sentences, and we see that in the use of interpretative systems, specification of meaning and statement of empirical fact—two functions of language often considered as completely distinct—become so intimately bound up with each other as to raise serious doubt about the advisability or even the possibility of preserving that distinction in a logical reconstruction of science. This consideration suggests that we dispense with the distinction, so far maintained for expository purposes, between the interpretative sentences, included in M, and the balance of the sentences constituting a scientific theory: We may simply conceive of the two sets of sentences as constituting one "intepreted theory."

The results obtained in this brief analysis of the operationist view of significant scientific concepts are closely analogous to those obtainable by a similar study of the logical empiricist view of significant scientific statements, or hypotheses.[18] In the latter case, the original requirement of full verifiability or full falsifiability by experiential data has to give way to the more liberal demand for confirmability—that is, partial verifiability. This demand can be shown to be properly applicable to entire theoretical systems rather than to individual hypotheses—a point emphasized, in effect, already by Pierre Duhem. Experiential significance is then seen to be a matter of degree, so that the originally intended sharp distinction between cognitively meaningful and cognitively meaningless hypotheses (or systems of such) has to be abandoned; and it even appears doubtful whether the distinction between analytic and synthetic sentences can be effectively maintained in a formal model of the language of empirical science.

NOTES

1. P.W. Bridgman, "Some general principles of operational analysis" and "Rejoinders and second thoughts," *Psychol. Rev.*, LII (1945), 246; "The nature of some of our physical concepts," *Brit. J. Phil, Sci.*, I (1951), 258.

2. ______ "Operational analysis," *Phil, Sci.*, V (1938), 123; *Brit. J. Phil. Sci.*, I, (1951), 258.

3. ______ *Phil, Sci.*, V (1938), 116.

4. ______ *Brit. J. Phil. Sci.*, I (1951), 260.

5. ______ *The Logic of Modern Physics* (New York: Macmillan, 1927), pp. 6, 23-24; *Phil. Sci.*, V (1938), 121; *Psychol. Rev.*, LII (1945), 247; "The operational aspect of meaning," *Synthése*, VIII (1950-51), 255.

6. ______ *Psychol. Rev.*, LII (1945), 246.

7. ______ *The Logic of Modern Physics*, p. 28.

8. ______ *ibid.*, p. 5; qualified by Bridgman's reply [*Phil, Sci.*, V (1938), 117] to R.B. Lindsay, "A critique of operationalism in physics," *Phil. Sci.*, IV (1937), a qualification that was essentially on the ground, quite different from that given in the present paper, that operational meaning is only a necessary, but presumably not a sufficient characteristic of scientific concepts.

9. ______ *Phil. Sci.*, V (1938), 126; "Some implications of recent points of view in physics," *Rev. intern. phil.*, III (1949), 484. The intended distinction between good and bad operations is further obscured by the fact that in Bridgman's discussion the meaning of "good operation" shifts from what might be described as "operation whose use in operational definition insures experimental meaning and testability" to "scientific procedure—in some very broad sense—which leads us to correct predictions."

10. The condition thus imposed upon the observational vocabulary of science is of a pragmatic character; it demands that each term included in that vocabulary be of such a kind that under suitable conditions, different observers can, by means of direct observation, arrive at a high degree of whether the term applies to a given situation. The expression *coincides with* as applicable to instrument needles and marks on scales of instruments is an example of a term meeting this condition. That human beings are capable of developing observational vocabularies that satisfy the given requirement is a fortunate circumstance: without it, science as an intersubjective enterprise would be impossible.

11. To illustrate briefly, it seems reasonable, prima facie, to define "x is soluble in water" by "if x is put in water then x dissolves." But if the phrase *if . . . then . . .* is here construed as the truth-functional, or "material," conditional, then the objects qualified as soluble by the definition include, among others, all those things that are never put in water—no matter whether or not they are actually soluble in water. This consequence—one aspect of the "paradoxes of material implication"—can be avoided only if the aforementioned definiens is construed in a more restrictive fashion. The idea suggests itself to construe "x is soluble in water" as short for "by virtue of some general laws of nature, x dissolves if x is put in water," or briefly, "it is nomologically true that if x is put in water then x dissolves," The phrase if . . . then . . . may now be understood in the truth-functional sense again. However, the acceptability of this analysis depends, of course, upon whether nomological truth can be considered as a sufficiently clear concept. For a fuller discussion of this problem complex, see especially R. Carnap, "Testability and meaning," *Phil. Sci.*, III (1936) and IV (1937) and N. Goodman, "The problem of counterfactual conditionals," *J. Phil.*, XLIV (1947).

12. In other words, it is not possible to provide, for every theoretically permissible value r of the length *l(x)* of a rod *x*, a definition of the form

$$[l(x) = r] = {}_{df}C(P_1x, P_2x, \ldots\ldots, P_nx),$$

where P_1, P_2 . . . . P_n are observable characteristics, and the definiens is an expression formed from P_1x, P_2x, ... P_nx with help of the connective words *and*, *or*, and *not* alone.

It is worth noting, however, that if the logical constants allowed in the definiens include, in addition to truth-functional connectives, also quantifiers and the identity sign, then a finite observational vocabulary may permit the explicit definition of a denumerable infinity of further terms. For instance, if "*x* spatially contains *y*" and "*y* is an apple" are included in the observational vocabulary, then it is possible to define the expressions "*x* contains 0 apples," "*x* contains exactly 1 apple," "*x* contains exactly 2 apples," and so forth, in a matter familiar from the Frege-Russel construction of arithmetic out of logic. Yet even if definitions of this type are countenanced—and no doubt they are in accord with the intent of operationist analysis—there remain serious obstacles for an operationist account of the totality of real numbers which are permitted as theoretical values of length, mass, and so forth. On this point, see C.G. Hempel, *Fundamentals of Concept Formation in Empirical Science* (Univ. of Chicago Press, Chicago, 1952), Sec. 7 Gustav Bergman, in his contribution to the present symposium, deplores this argument—although he agrees with its point—on the ground that it focuses attention on a characteristic shared by all quantitative concepts instead of bringing out the differences between, say, length and the psi-function. He thinks this regrettable because, after all, as he puts it, "the real numbers are merely a part of the logical apparatus; concept formation is a matter of the descriptive vocabulary." I cannot accept the suggestion conveyed by this statement. To be sure, the theory of real numbers can be developed as a branch (or as an extension) of logic; however, my argument concerns not the definability of real numbers in logical terms, but the possibility of formulating an observational equivalent for each of the infinitely many permissible real-number values of length, temperature, and so forth. And this is clearly a question concerning the descriptive vocabulary rather than merely the logical apparatus of empirical science. I quite agree with Bergmann, however, that it would be of considerable interest to explicate whatever logical differences may obtain between quantitative concepts which, intuitively speaking, exhibit different degrees of theoretical abstractness, such as length on the one hand and the psi-function on the other.

13. The use of reduction sentences circumvents one of the difficulties encountered in the the attempt to give explicit and, thus, complete definitions of disposition terms: The conditional and biconditional signs occuring in formula (1) may be construed truth-functionally without giving rise to undesirable consequences of the kind characterized in n. 11. For details, see R. Carnap, "Testability and meaning," *Phil. Sci.* (1936-37), Part II; also C. G. Hempel, *Fundamentals of Concept Formation in Empirical Science*, Secs. 6 and 8. Incidentally, the use of nomological concepts is not entirely avoided in Carnap's procedure; the reduction sentences that are permitted for the introduction of new terms are required to satisfy certain conditions of logical or of nomological validity. See R. Carnap. *Phil. Sci.*, III and IV (1936-37), 442-43.

14. J. G. Kemeny, "Extension of the methods of inductive logic," *Philosophical Studies*, III (1952); R. Carnap, "Meaning postulates," *ibid*, III (1952).

15. For the case of Carnap's reduction sentences, the postulational interpretation was suggested to me by N. Goodman and by A. Church.

16. This is illustrated by the following simple model case: The theory T consists of the sentence $(x)((C_1x \cdot C_2x) \rightarrow C_3x)$ and its logical consequences; the three "theoretical" terms occuring in it are introduced by the interpretative set M consisting of the sentences $O_1x \rightarrow (C_1x \cdot C_2x)$ and $(C_1x \cdot C_3x) \rightarrow (O_2x v O_3x)$, where O_1, O_2, O_3, belong to the observational vocabulary. As is readily seen, T permits, by virtue of M, the "prediction" that if an object has the observable property O_1 but lacks the observable property O_2, then it will have the observable property O_3. Thus T is susceptible to experiential test, although M provides for none of its consitutent terms both a necessary and a sufficient observational, or operational criterion of application.

17. Carnap calls it the representative sentence of the pair of formulas (2.1) and (2.2). See R. Carnap, *Phil. Sci.*, III and IV (1936-37), pp. 444 and 451. Generally, when a term is introduced by several reduction sentences representing different operational criterions of application, then the agreement among the results of the corresponding procedures, which must be presupposed if the reduction sentences are all to be compatible with one another, is expressed by the representative sentence associated with the given set of reduction sentences. The representative sentence reflects, therefore, the inductive risk which, as Bridgman has stressed, is incurred by using more than one operational criterion for a given term.

18. C.G. Hempel, "Problems and changes in the empiricist criterion of meaning," *Rev. intern. phil.*, IV (1951), and the "The concept of cognitive significance: a reconsideration," *Proc. Am. Acad. Arts Sci.*, LXXX (1951); W. V. Quine, "Two dogmas of empiricism," *Phil. Rev.* XL (1951).

The Observational–Theoretical Distinction

Grover Maxwell

THE ONTOLOGICAL STATUS OF THEORETICAL ENTITIES

That anyone today should seriously contend that the entities referred to by scientific theories are only convenient fictions, or that talk about such entities is translatable without remainder into talk about sense contents or everyday physical objects, or that such talk should be regarded as belonging to a mere calculating device and, thus, without cognitive content—such contentions strike me as so incongruous with the scientific and rational attitude and practice that I feel this paper *should* turn out to be a demolition of straw men. But the instrumentalist views of outstanding physicists such as Bohr and Heisenberg are too well known to be cited, and in a recent book of great competence, Professor Ernest Nagel concludes that "the opposition between [the realist and the instrumentalist] views [of theories] is a conflict over preferred modes of speech" and "the question as to which of them is the 'correct position' has only terminological interest."[1] The phoenix, it seems, will not be laid to rest.

The literature on the subject is, of course, voluminous, and a comprehensive treatment of the problem is far beyond the scope of one essay. I shall limit myself to a small number of constructive arguments (for a radically realistic interpretation of theories) and to a critical examination of some of the more crucial assumptions (sometimes tacit, sometimes explicit) that seem to have generated most of the problems in this area.[2]

THE PROBLEM

Although this essay is not comprehensive, it aspires to be fairly self-contained. Let me, therefore, give a pseudohistorical introduction to the problem with a piece of science fiction (or fictional science).

In the days before the advent of microscopes, there lived a Pasteur-like scientist whom, following the usual custom, I shall call Jones. Reflecting on the fact that certain diseases seemed to be transmitted from one person to another by means of bodily contact or by contact with articles handled previously by an afflicted person, Jones began to speculate about the mechanism of the transmission. As a "heuristic crutch," he recalled that there is an obvious *observable* mechanism for transmission of certain afflictions (such as body lice), and he postulated that all, or most, infectious diseases were spread in a similar manner but that in most cases the corresponding "bugs" were too small to be seen and, possibly, that some of them lived inside the bodies of their hosts. Jones proceeded to develop his theory and to examine its testable consequences. Some of these seemed to be of

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