ASPECTS OF SCIENTIFIC EXPLANATION

AND OTHER ESSAYS

IN THE PHILOSOPHY OF SCIENCE

ASPECTS *of*

And Other

Carl G. Hempel

SCIENTIFIC EXPLANATION

Essays in the Philosophy of Science

THE FREE PRESS, *NEW YORK*

COLLIER-MACMILLAN LIMITED, *LONDON*

TO *Diane*

A DIVISION OF THE MACMILLAN COMPANY

Printed in the United States of America

The Free Press
A DIVISION OF THE MACMILLAN COMPANY
866 Third Avenue, New York, New York 10022

Collier-Macmillan Canada Ltd., Toronto, Ontario
First Free Press Paperback Edition 1970

Library of Congress Catalog Card Number: 65-15441

PRINTING NUMBER 1 2 3 4 5 6 7 8 9 10

PREFACE

THE ESSAYS gathered in this volume address themselves to one or another of four major topics in the philosophy of science, and have accordingly been grouped under the headings "Confirmation, Induction, and Rational Belief," "Conceptions of Cognitive Significance," "Structure and Function of Scientific Concepts and Theories," and "Scientific Explanation."

All but one of the pieces are revised versions of articles that have previously appeared in print, as indicated in the footnotes on their origins. The longest of the essays, from which this collection takes its title, was specifically written for this volume. It presents a self-contained study of scientific explanation, including a reexamination of the concept of explanation by covering laws as it had been partially developed in two earlier essays, which are here reprinted as items 9 and 10. The title essay also deals in some detail with explanation by statistical laws, a subject that had received only brief consideration in those earlier articles. The analysis of statistical explanation here presented differs in important respects from a previous study of the subject, published in 1962, which is listed in the bibliography but not included in this volume.

Though articles 9 and 10 slightly overlap the title essay, they have been reprinted here because they have been widely discussed in the recent literature on explanation, so that it seemed worthwhile to make them available for reference; and because most of the substance of those articles is not included in the title essay.

While I still regard the central ideas of the reprinted essays as basically sound, I have naturally changed my views on various points of detail. Where it seemed appropriate, such changes have been indicated in footnotes marked

"Added in 1964" or in the Postscripts by which I have supplemented three of the articles. Stylistic changes, deletions of passages that did not advance the argument, and corrections of minor errors have been effected without special notice.

In the Postscripts just mentioned, I have also commented on some recent developments in the philosophical analysis of the central problems, and I have added some afterthoughts of my own. But I have not attempted to bring the bibliographies of all the reprinted articles up to date, since merely to list more recent publications without discussing their contents would have been pointless.

As I have tried to make clear at appropriate places in these essays and in the added notes and Postscripts, I have greatly benefitted from the work of others, from discussions and criticisms of my writings that have appeared in print, and from personal exchanges of ideas with friends, colleagues, and students: to all these intellectual benefactors I am grateful.

Several of these essays were written during summer months in air-conditioned seclusion at the house of my old friends Paul and Gabrielle Oppenheim in Princeton. To Paul Oppenheim, with whom I have discussed philosophical questions for many a year, I am grateful also for letting me reprint here one of the articles we wrote jointly. Work on some of the other essays was done during a year as Fulbright Research Fellow in Oxford, 1959-60. Finally, a sabbatical leave from Princeton University in conjunction with a Fellowship for 1963-64 at that scholarly haven, the Center for Advanced Study in the Behavioral Sciences, enabled me to write the title essay and to revise the earlier articles for republication.

I am much indebted to the editors and publishers who permitted me to reprint the articles and excerpts reproduced in this volume.

I gratefully dedicate this book to my wife; her sympathetic encouragement and unfaltering support would have deserved a better offering.

C. G. H.

Stanford, California,

June, 1964

CONTENTS

I.

CONFIRMATION, INDUCTION,

AND RATIONAL BELIEF

1. STUDIES IN THE LOGIC OF CONFIRMATION

1. OBJECTIVE OF THE STUDY[1]

THE DEFINING characteristic of an empirical statement is its capability of being tested by a confrontation with experiential findings, *i.e.* with the results of suitable experiments or focused observations. This feature distinguishes statements which have empirical content both from the statements of the formal sciences, logic and mathematics, which require no experiential test for their validation, and from the formulations of transempirical metaphysics, which admit of none.

The testability here referred to has to be understood in the comprehensive sense of "testability in principle" or "theoretical testability"; many empirical statements, for practical reasons, cannot actually be tested now. To call a statement of this kind testable in principle means that it is possible to state just what experiential findings, if they were actually obtained, would constitute favorable evidence

1. The present analysis of confirmation was to a large extent suggested and stimulated by a cooperative study of certain more general problems which were raised by Dr. Paul Oppenheim, and which I have been investigating with him for several years. These problems concern the form and the function of scientific laws and the comparative methodology of the different branches of empirical science.

In my study of the logical aspects of confirmation, I have benefited greatly by discussions with Professor R. Carnap, Professor A. Tarski, and particularly Dr. Nelson Goodman, to whom I am indebted for several valuable suggestions which will be indicated subsequently.

A detailed exposition of the more technical aspects of the analysis of confirmation presented in this essay is included in my article 'A Purely Syntactical Definition of Confirmation,' *The Journal of Symbolic Logic*, vol. 8 (1943).

This article is reprinted, with some changes, by kind permission of the editor of *Mind*, where it appeared in volume 54, pp. 1-26 and 97-121 (1945).

for it, and what findings or "data," as we shall say for brevity, would constitute unfavorable evidence; in other words, a statement is called testable in principle if it is possible to describe the kind of data which would confirm or disconfirm it.

The concepts of confirmation and of disconfirmation as here understood are clearly more comprehensive than those of conclusive verification and falsification. Thus, *e.g.*, no finite amount of experiential evidence can conclusively verify a hypothesis expressing a general law such as the law of gravitation, which covers an infinity of potential instances, many of which belong either to the as yet inaccessible future or to the irretrievable past; but a finite set of relevant data may well be "in accord with" the hypothesis and thus constitute confirming evidence for it. Similarly, an existential hypothesis, asserting, say, the existence of an as yet unknown chemical element with certain specified characteristics, cannot be conclusively proved false by a finite amount of evidence which fails to "bear out" the hypothesis; but such unfavorable data may, under certain conditions, be considered as weakening the hypothesis in question, or as constituting disconfirming evidence for it.[2]

While, in the practice of scientific research, judgments as to the confirming or disconfirming character of experiential data obtained in the test of a hypothesis are often made without hesitation and with a wide consensus of opinion, it can hardly be said that these judgments are based on an explicit theory providing general criteria of confirmation and of disconfirmation. In this respect, the situation is comparable to the manner in which deductive inferences are carried out in the practice of scientific research: this, too, is often done without reference to an explicitly stated system of rules of logical inference. But while criteria of valid deduction can be and have been supplied by formal logic, no satisfactory theory providing general criteria of confirmation and disconfirmation appears to be available so far.

In the present essay, an attempt will be made to provide the elements of a theory of this kind. After a brief survey of the significance and the present status of the problem, I propose to present a detailed critical analysis of some common conceptions of confirmation and disconfirmation and then to construct explicit definitions for these concepts and to formulate some basic principles of what might be called the logic of confirmation.

2. SIGNIFICANCE AND PRESENT STATUS OF THE PROBLEM

The establishment of a general theory of confirmation may well be regarded as one of the most urgent desiderata of the present methodology of empirical science. Indeed, it seems that a precise analysis of the concept of confirmation is

2. This point as well as the possibility of conclusive verification and conclusive falsification will be discussed in some detail in section 10 of the present paper.

a necessary condition for an adequate solution of various fundamental problems concerning the logical structure of scientific procedure. Let us briefly survey the most outstanding of these problems.

(*a*) In the discussion of scientific method, the concept of relevant evidence plays an important part. And while certain inductivist accounts of scientific procedure seem to assume that relevant evidence, or relevant data, can be collected in the context of an inquiry prior to the formulation of any hypothesis, it should be clear upon brief reflection that relevance is a relative concept; experiential data can be said to be relevant or irrelevant only with respect to a given hypothesis; and it is the hypothesis which determines what kind of data or evidence are relevant for it. Indeed, an empirical finding is relevant for a hypothesis if and only if it constitutes either favorable or unfavorable evidence for it; in other words, if it either confirms or disconfirms the hypothesis. Thus, a precise definition of relevance presupposes an analysis of confirmation and disconfirmation.

(*b*) A closely related concept is that of instance of a hypothesis. The so-called method of inductive inference is usually presented as proceeding from specific cases to a general hypothesis of which each of the special cases is an "instance" in the sense that it conforms to the general hypothesis in question, and thus constitutes confirming evidence for it.

Thus, any discussion of induction which refers to the establishment of general hypotheses on the strength of particular instances is fraught with all those logical difficulties—soon to be expounded—which beset the concept of confirmation. A precise analysis of this concept is, therefore, a necessary condition for a clear statement of the issues involved in the problem complex of induction and of the ideas suggested for their solution—no matter what their theoretical merits or demerits may be.

(*c*) Another issue customarily connected with the study of scientific method is the quest for "rules of induction." Generally speaking, such rules would enable us to infer, from a given set of data, that hypothesis or generalization which accounts best for all the particular data in the given set. But this construal of the problem involves a misconception: While the process of invention by which scientific discoveries are made is as a rule *psychologically guided and stimulated* by antecedent knowledge of specific facts, its results are *not logically determined* by them; the way in which scientific hypotheses or theories are discovered cannot be mirrored in a set of general rules of inductive inference.[3] One of the crucial

3. See the lucid presentation of this point in Karl Popper's *Logik der Forschung* (Wien, 1935), esp. sections 1, 2, 3, and 25, 26, 27; *cf.* also Albert Einstein's remarks in his lecture *On the Method of Theoretical Physics* (Oxford, 1933), 11, 12. Also of interest in this context is the critical discussion of induction by H. Feigl in "The Logical Character of the Principle of Induction," *Philosophy of Science*, vol. 1 (1934).

considerations which lead to this conclusion is the following: Take a scientific theory such as the atomic theory of matter. The evidence on which it rests may be described in terms referring to directly observable phenomena, namely to certain macroscopic aspects of the various experimental and observational data which are relevant to the theory. On the other hand, the theory itself contains a large number of highly abstract, nonobservational terms such as 'atom', 'electron', 'nucleus', 'dissociation', 'valence' and others, none of which figures in the description of the observational data. An adequate rule of induction would therefore have to provide, for this and for every other conceivable case, mechanically applicable criteria determining unambiguously, and without any reliance on the inventiveness or additional scientific knowledge of its user, all those new abstract concepts which need to be created for the formulation of the theory that will account for the given evidence. Clearly, this requirement cannot be satisfied by any set of rules, however ingeniously devised; there can be no general rules of induction in the above sense; the demand for them rests on a confusion of logical and psychological issues. What determines the soundness of a hypothesis is not the way it is arrived at (it may even have been suggested by a dream or a hallucination), but the way it stands up when tested, *i.e.* when confronted with relevant observational data. Accordingly, the quest for rules of induction in the original sense of canons of scientific discovery has to be replaced, in the logic of science, by the quest for general objective criteria determining (A) whether, and—if possible—even (B) to what degree, a hypothesis *H* may be said to be corroborated by a given body of evidence *E*. This approach differs essentially from the inductivist conception of the problem in that it presupposes not only *E*, but also *H* as given, and then seeks to determine a certain logical relationship between them. The two parts of this latter problem can be related in somewhat more precise terms as follows:

(A) To give precise definitions of the two nonquantitative relational concepts of confirmation and of disconfirmation; *i.e.* to define the meaning of the phrases '*E* confirms *H*' and '*E* disconfirms *H*'. (When *E* neither confirms nor disconfirms *H*, we shall say that *E* is neutral, or irrelevant, with respect to *H*.)

(B) (1) To lay down criteria defining a metrical concept "degree of confirmation of *H* with respect to *E*," whose values are real numbers; or, failing this,

(2) To lay down criteria defining two relational concepts, "more highly confirmed than "and "equally well confirmed as," which make possible a nonmetrical comparison of hypotheses (each with a body of evidence assigned to it) with respect to the extent of their confirmation.

Interestingly, problem B has received much more attention in methodological research than problem A; in particular, the various theories of the so-called probability of hypotheses may be regarded as concerning this problem complex;

we have here adopted[4] the more neutral term 'degree of confirmation' instead of 'probability' because the latter is used in science in a definite technical sense involving reference to the relative frequency of the occurrence of a given event in a sequence, and it is at least an open question whether the degree of confirmation of a hypothesis can generally be defined as a probability in this statistical sense.

The theories dealing with the probability of hypotheses fall into two main groups: the "logical" theories construe probability as a logical relation between sentences (or propositions; it is not always clear which is meant);[5] the "statistical" theories interpret the probability of a hypothesis in substance as the limit of the relative frequency of its confirming instances among all relevant cases.[6] Now it is a remarkable fact that none of the theories of the first type which have been developed so far provides an explicit general definition of the probability (or degree of confirmation) of a hypothesis H with respect to a body of evidence E; they all limit themselves essentially to the construction of an uninterpreted postulational system of logical probability.[7] For this reason, these theories fail to provide a complete solution of problem B. The statistical approach, on the other hand, would, if successful, provide an explicit numerical definition of the degree of confirmation of a hypothesis; this definition would be formulated in terms of the numbers of confirming and disconfirming instances for H which constitute the body of evidence E. Thus, a necessary condition for an adequate interpretation of degrees of confirmation as statistical probabilities is the establishment of precise criteria of confirmation and disconfirmation; in other words, the solution of problem A.

4. Following R. Carnap's use in "Testability and Meaning," *Philosophy of Science*, Vols. 3 (1936) and 4 (1937); esp. section 3 (in Vol. 3).

5. This group includes the work of such writers as Janina Hosiasson-Lindenbaum [*cf.* for instance, her article "Induction et analogie: Comparaison de leur fondement,", *Mind*, Vol. 50 (1941)], H. Jeffreys, J. M. Keynes, B.O. Koopman, J. Nicod, St. Mazurkiewicz, and F. Waismann. For a brief discussion of this conception of probability, see Ernest Nagel, *Principles of the Theory of Probability* (International Encyclopedia of United Science, Vol. I, no. 6, Chicago, 1939), esp. sections 6 and 8.

6. The chief proponent of this view is Hans Reichenbach; *cf.* especially "Ueber Induktion und Wahrscheinlichkeit," *Erkenntnis*, vol. 5 (1935), and *Experience and Prediction* (Chicago, 1938), Chap. V.

7. (Added in 1964.) Since this article was written, R. Carnap has developed a theory of inductive logic which, for formalized languages of certain types, makes it possible explicitly to define—without use of the qualitative notion of confirming instance—a quantitative concept of degree of confirmation which has the formal characteristics of a probability; Carnap refers to it as inductive, or logical, probability. For details, see especially R. Carnap, "On Inductive Logic," *Philosophy of Science*, vol. 12 (1945); *Logical Foundations of Probability* (Chicago, 1950; 2nd ed., 1962); *The Continuum of Inductive Methods* (Chicago, 1952); "The Aim of Inductive Logic" *in* E. Nagel, P. Suppes, and A. Tarski, eds., *Logic, Methodology, and Philosophy of Science. Proceedings of the 1960 International Congress* (Stanford, 1962).

However, despite their great ingenuity and suggestiveness, the attempts which have been made so far to formulate a precise statistical definition of the degree of confirmation of a hypothesis seem open to certain objections,[8] and several authors[9] have expressed doubts as to the possibility of defining the degree of confirmation of a hypothesis as a metrical magnitude, though some of them consider it as possible, under certain conditions, to solve at least the less exacting problem B (2), *i.e.* to establish standards of nonmetrical comparison between hypotheses with respect to the extent of their confirmation. An adequate comparison of this kind might have to take into account a variety of different factors;[10] but again the numbers of the confirming and of the disconfirming instances which the given evidence includes will be among the most important of those factors.

Thus, of the two problems, A and B, the former appears to be the more basic one, first, because it does not presuppose the possibility of defining numerical degrees of confirmation or of comparing different hypotheses as to the extent of their confirmation; and second because our considerations indicate that any attempt to solve problem B—unless it is to remain in the stage of an axiomatized system without interpretation—is likely to require a precise definition of the concepts of confirming and disconfirming instance of a hypothesis before it can proceed to define numerical degrees of confirmation, or to lay down nonmetrical standards of comparison.

(*d*) It is now clear that an analysis of confirmation is of fundamental importance also for the study of a central problem of epistemology, namely, the elaboration of standards of rational belief or of criteria of warranted assertibility. In the methodology of empirical science this problem is usually phrased as concerning the rules governing the test and the subsequent acceptance or rejection of empirical hypotheses on the basis of experimental or observational findings, while in its epistemological version the issue is often formulated as concerning the validation of beliefs by reference to perceptions, sense data, or the like. But no matter how the final empirical evidence is construed and in what terms it is accordingly expressed, the theoretical problem remains the same: to

8. *Cf.* Karl Popper, *Logik der Forschung* (Wien, 1935), section 80; Ernest Nagel, *l.c.*, section 8, and "Probability and the Theory of Knowledge," *Philosophy of Science*, vol. 6 (1939); C. G. Hempel, "Le problème de la vérité," *Theoria* (Göteborg), vol. 3 (1937), section 5, and "On the Logical Form of Probability Statements," *Erkenntnis*, Vol. 7 (1937-38), esp. section 5. *Cf.* also Morton White, "Probability and Confirmation," *The Journal of Philosophy*, Vol. 36 (1939).

9. See, for example, J. M. Keynes, *A Treatise on Probability* (London, 1929), esp. Chap. III; Ernest Nagel, *Principles of the Theory of Probability*, esp. p. 70; compare also the somewhat less definitely skeptical statement by Carnap, *l.c.* (note 4) section 3, p. 427.

10. See especially the survey of such factors given by Ernest Nagel in *Principles of the Theory of Probability*, pp. 66-73.

characterize, in precise and general terms, the conditions under which a body of evidence can be said to confirm, or to disconfirm, a hypothesis of empirical character; and that is again our problem A.

(*e*) The same problem arises when one attempts to give a precise statement of the empiricist and operationalist criteria for the empirical meaningfulness of a sentence; these criteria, as is well known, are formulated by reference to the theoretical testability of the sentence by means of experiential evidence,[11] and the concept of theoretical testability, as was pointed out earlier, is closely related to the concepts of confirmation and disconfirmation.[12]

Considering the great importance of the concept of confirmation, it is surprising that no systematic theory of the nonquantitative relation of confirmation seems to have been developed so far. Perhaps this fact reflects the tacit assumption that the concepts of confirmation and of disconfirmation have a sufficiently clear meaning to make explicit definitions unnecessary or at least comparatively trivial. And indeed, as will be shown below, there are certain features which are rather generally associated with the intuitive notion of confirming evidence, and which, at first, seem well suited to serve as defining characteristics of confirmation. Closer examination will reveal the definitions thus obtainable to be seriously deficient and will make it clear that an adequate definition of confirmation involves considerable difficulties.

Now the very existence of such difficulties suggests the question whether the problem we are considering does not rest on a false assumption: Perhaps there are no objective criteria of confirmation; perhaps the decision as to whether a given hypothesis is acceptable in the light of a given body of evidence is no more subject to rational, objective rules than is the process of inventing a scientific hypothesis or theory; perhaps, in the last analysis, it is a "sense of evidence," or a feeling of plausibility in view of the relevant data, which ultimately decides whether a hypothesis is scientifically acceptable.[13] This view is comparable to the opinion that the validity of a mathematical proof or of a logical argument has to be judged ultimately by reference to a feeling of soundness or convincingness; and both theses have to be rejected on analogous grounds: they involve a con-

11. *Cf.*, for example, A. J. Ayer, *Language, Truth and Logic* (London and New York, 1936), Ch. I; R. Carnap, "Testability and Meaning," sections 1, 2, 3; H. Feigl, "Logical Empiricism" (in *Twentieth Century Philosophy*, ed. by Dagobert D. Runes, New York, 1943); P.W. Bridgman, *The Logic of Modern Physics* (New York, 1928).

12. It should be noted, however, that in his essay "Testability and Meaning," R. Carnap has constructed definitions of testability and confirmability which avoid reference to the concept of confirming and of disconfirming evidence; in fact, no proposal for the definition of these latter concepts is made in that study.

13. A view of this kind has been expressed, for example, by M. Mandelbaum in "Causal Analyses in History," *Journal of the History of Ideas*, Vol. 3 (1942); *cf.* esp. pp. 46–47.

fusion of logical and psychological considerations. Clearly, the occurrence or non-occurrence of a feeling of conviction upon the presentation of grounds for an assertion is a subjective matter which varies from person to person, and with the same person in the course of time; it is often deceptive and can certainly serve neither as a necessary nor as a sufficient condition for the soundness of the given assertion.[14] A rational reconstruction of the standards of scientific validation cannot, therefore, involve reference to a sense of evidence; it has to be based on objective criteria. In fact, it seems reasonable to require that the criteria of empirical confirmation, besides being objective in character, should contain no reference to the specific subject matter of the hypothesis or of the evidence in question; it ought to be possible, one feels, to set up purely formal criteria of confirmation in a manner similar to that in which deductive logic provides purely formal criteria for the validity of deductive inference.

With this goal in mind, we now turn to a study of the nonquantitative concept of confirmation. We shall begin by examining some current conceptions of confirmation and exhibiting their logical and methodological inadequacies; in the course of this analysis, we shall develop a set of conditions for the adequacy of any proposed definition of confirmation; and finally, we shall construct a definition of confirmation which satisfies those general standards of adequacy.

3. NICOD'S CRITERION OF CONFIRMATION AND ITS SHORTCOMINGS

We consider first a conception of confirmation which underlies many recent studies of induction and of scientific method. A very explicit statement of this conception has been given by Jean Nicod in the following passage: "Consider the formula or the law: *A entails B*. How can a particular proposition, or more briefly, a fact, affect its probability? If this fact consists of the presence of B in a case of A, it is favorable to the law '*A entails B*'; on the contrary, if it consists of the absence of B in a case of A, it is unfavorable to this law. It is conceivable that we have here the only two direct modes in which a fact can influence the probability of a law. . . . Thus, the entire influence of particular truths or facts on the probability of universal propositions or laws would operate by means of these two elementary relations which we shall call *confirmation* and *invalidation*."[15] Note that the applicability of this criterion is restricted to hypotheses of the form '*A entails B*'. Any hypothesis H of this kind may be expressed in the notation

14. See Popper's statement, *l.c.*, section 8.

15. Jean Nicod, *Foundations of Geometry and Induction* (transl. by P. P. Wiener), London, 1930; 219; *cf.* also R. M. Eaton's discussion of "Confirmation and Infirmation," which is based on Nicod's views; it is included in Chap. III of his *General Logic* (New York, 1931).

of symbolic logic[16] by means of a universal conditional sentence, such as, in the simplest case,

$$(x)[P(x) \supset Q(x)]$$

i.e. 'For any object x: if x is a P, then x is a Q,' or also 'Occurrence of the quality P entails occurrence of the quality Q.' According to the above criterion this hypothesis is confirmed by an object a if a is P and Q; and the hypothesis is disconfirmed by a if a is P, but not Q.[17] In other words, an object confirms a universal conditional hypothesis if and only if it satisfies both the antecedent (here: '$P(x)$') and the consequent (here: '$Q(x)$') of the conditional; it disconfirms the hypothesis if and only if it satisfies the antecedent, but not the consequent of the conditional; and (we add this to Nicod's statement) it is neutral, or irrelevant, with respect to the hypothesis if it does not satisfy the antecedent.

This criterion can readily be extended so as to be applicable also to universal conditionals containing more than one quantifier, such as 'Twins always resemble each other', or, in symbolic notation, '$(x)(y)(\text{Twins}(x, y) \supset \text{Rsbl}(x, y))$'. In these cases, a confirming instance consists of an ordered couple, or triple, etc., of objects satisfying the antecedent and the consequent of the conditional. (In the case of the last illustration, any two persons who are twins and resemble each other would confirm the hypothesis; twins who do not resemble each other would disconfirm it; and any two persons not twins—no matter whether they resemble each other or not—would constitute irrelevant evidence.)

We shall refer to this criterion as Nicod's criterion.[18] It states explicitly what is perhaps the most common tacit interpretation of the concept of confirmation. While seemingly quite adequate, it suffers from serious shortcomings, as will now be shown.

(*a*) First, the applicability of this criterion is restricted to hypotheses of universal conditional form; it provides no standards of confirmation for existential hypotheses (such as 'There exists organic life on other stars', or 'Poliomyelitis is caused by some virus') or for hypotheses whose explicit formulation calls for the use of both universal and existential quantifiers (such as 'Every human

16. In this essay, only the most elementary devices of this notation are used; the symbolism is essentially that of *Principia Mathematica*, except that parentheses are used instead of dots, and that existential quantification is symbolized by '(E)' instead of by the inverted 'E.'

17. (Added in 1964). More precisely we would have to say, in Nicod's parlance, that the hypothesis is confirmed by the *proposition* that a is both P and Q, and is disconfirmed by the *proposition* that a is P but not Q.

18. This term is chosen for convenience, and in view of the above explicit formulation given by Nicod; it is not, of course, intended to imply that this conception of confirmation originated with Nicod.

being dies some finite number of years after his birth', or the psychological hypothesis, ' You can fool all of the people some of the time and some of the people all of the time, but you cannot fool all of the people all of the time', which may be symbolized by '$(x)(Et)\mathrm{Fl}(x, t) \cdot (Ex)(t)\mathrm{Fl}(x, t) \cdot \sim (x)(t)\mathrm{Fl}(x, t)$', (where '$\mathrm{Fl}(x, t)$' stands for 'You can fool person x at time t'). We note, therefore, the desideratum of establishing a criterion of confirmation which is applicable to hypotheses of *any* form.[19]

(*b*) We now turn to a second shortcoming of Nicod's criterion. Consider the two sentences

$$S_1: \text{`}(x)[\mathrm{Raven}(x) \supset \mathrm{Black}(x)]\text{'};$$

$$S_2: \text{`}(x)[\sim\mathrm{Black}(x) \supset \sim \mathrm{Raven}(x)]\text{'}$$

(*i.e.* 'All ravens are black' and 'Whatever is not black is not a raven'), and let a, b, c, d be four objects such that a is a raven and black, b a raven but not black, c not a raven but black, and d neither a raven nor black. Then according to Nicod's criterion, a would confirm S_1, but be neutral with respect to S_2; b would disconfirm both S_1 and S_2; c would be neutral with respect to both S_1 and S_2, and d would confirm S_2, but be neutral with respect to S_1.

But S_1 and S_2 are logically equivalent; they have the same content, they are different formulations of the same hypothesis. And yet, by Nicod's criterion, either of the objects a and d would be confirming for one of the two sentences, but neutral with respect to the other. This means that Nicod's criterion makes confirmation depend not only on the content of the hypothesis, but also on its formulation.[20]

One remarkable consequence of this situation is that every hypothesis to which the criterion is applicable—*i.e.* every universal conditional—can be stated in a form for which there cannot possibly exist any confirming instances. Thus, *e.g.* the sentence

$$(x)[(\mathrm{Raven}(x) \cdot \sim \mathrm{Black}(x)) \supset (\mathrm{Raven}(x) \cdot \sim \mathrm{Raven}(x)]$$

is readily recognized as equivalent to both S_1 and S_2 above; yet no object whatever can confirm this sentence, *i.e.* satisfy both its antecedent and its consequent;

19. For a rigorous formulation of the problem, it is necessary first to lay down assumptions as to the means of expression and the logical structure of the language in which the hypotheses are supposed to be formulated; the desideratum then calls for a definition of confirmation applicable to any hypothesis which can be expressed in the given language. Generally speaking, the problem becomes increasingly difficult with increasing richness and complexity of the assumed language of science.

20. This difficulty was pointed out, in substance, in my article "Le problème de la vérité," *Theoria* (Göteborg), vol. 3 (1937), esp. p. 222.