intent of the given argument and of the background assumptions that may be assumed to have been tacitly taken for granted, or at least to be available, in the given context. Unequivocal decision rules cannot be set down for this purpose any more than for determining whether a given informally stated inference which is not deductively valid by reasonably strict standards is to count nevertheless as valid but enthymematically formulated, or as fallacious, or as an instance of sound inductive reasoning, or perhaps, for lack of clarity, as none of these. . . .

■ | Notes

1. See Dewey, John. *How We Think*. Boston, New York, Chicago, 1910; Chapter VI.

2. For a fuller presentation of the model and for further references, see, for example, Hempel, C. G. and P. Oppenheim, "Studies in the Logic of Explanation," *Philosophy of Science* 15: 135–175 (1948). (Secs. 1-7 of this article, which contain all the fundamentals of the presentation, are reprinted in Feigl, H. and M. Brodbeck (eds.), *Readings in the Philosophy of Science*. New York, 1953.)—The suggestive term "covering law model" is W. Dray's; cf. his *Laws and Explanation in History*. Oxford, 1957; Chapter I. Dray characterizes this type of explanation as "subsuming what is to be explained under a general law" (*loc. cit.*, p. 1), and then rightly urges, in the name of methodological realism, that "the requirement of a *single* law be dropped" (*loc. cit.*, p. 24; italics, the author's): it should be noted, however, that, like the schema (D) above, several earlier publications on the subject (among them the article mentioned at the beginning of this note) make explicit provision for the inclusion of more laws than one in the explanans.

3. The relevance of the covering-law model to causal explanation is examined more fully in sec. 4 of Hempel, C. G., "Deductive-Nomological *vs.* Statistical Explanation." In Feigl, H., et al. (eds.), *Minnesota Studies in the Philosophy of Science*, vol. III. Minneapolis, 1962.

4. The concept of probabilistic explanation, and some of the peculiar logical and methodological problems engendered by it, are examined in some detail in Part II of the essay cited in note 3.

5. Freud, S. *Psychopathology of Everyday Life*. Translated by A. A. Brill. New York (Mentor Books) 1951; p. 64.

Carl G. Hempel

The Thesis of Structural Identity

Since in a fully stated D-N explanation of a particular event the explanans logically implies the explanandum, we may say that the explanatory argument might have been used for a deductive prediction of the explanandum-event *if* the laws and the particular facts adduced in its explanans had been known and taken into account at a suitable earlier time. In this sense, a D-N explanation is a potential D-N prediction.

This point was made already in an earlier article by Oppenheim and myself,[1] where we added that scientific explanation (of the deductive-nomological kind) differs from scientific prediction not in logical structure, but in certain pragmatic respects. In one case, the event described in the conclusion is known to have occurred, and suitable statements of general law and particular fact are sought to account for it; in the other, the latter statements are given and the statement about the event in question is derived from them before the time of its presumptive occurrence. This conception, which has sometimes been referred to as the *thesis of the structural identity* (or of the symmetry) *of explanation and prediction*, has recently been questioned by several writers. A consideration of some of their arguments may help to shed further light on the issues involved.

To begin with, some writers[2] have noted that what is usually called a prediction is not an argument but a sentence. More precisely, as Scheffler has pointed out, it is a sentence-token, i.e., a concrete utterance or inscription of a sentence purporting to describe some event that is to occur after the production of the token.[3] This is certainly so. But in empirical science predictive sentences are normally established on the basis of available information by means of arguments that may be deductive or inductive in character; and the thesis under discussion should be understood, of course, to refer to explanatory and predictive *arguments*.

Thus construed, *the thesis of structural identity amounts to* the con-

junction of *two sub-theses*, namely (i) that *every adequate explanation is potentially a prediction* in the sense indicated above; (ii) that conversely *every adequate prediction is potentially an explanation*. I will now examine a number of objections that have been raised against the thesis, dealing first with those which, in effect, concern the first sub-thesis, and then with those concerning the second sub-thesis. I will argue that the first sub-thesis is sound, whereas the second one is indeed open to question. Though the following considerations are concerned principally with D-N explanation, some of them are applicable to other types of explanation as well. . . .

The first sub-thesis, as has already been noted, is an almost trivial truth in the case of D-N explanation, since here the explanans logically implies the explanandum. But it is supported also by a more general principle, which applies to other types of explanation as well, and which expresses, I would submit, a general *condition of adequacy for any rationally acceptable explanation of a particular event*. That condition is the following: Any rationally acceptable answer to the question 'Why did event X occur?' must offer information which shows that X was to be expected— if not definitely, as in the case of D-N explanation, then at least with reasonable probability. Thus, the explanatory information must provide good grounds for believing that X did in fact occur; otherwise, that information would give us no adequate reason for saying: "That explains it— that does show why X occurred." And an explanatory account that satisfies this condition constitutes, of course, a potential prediction in the sense that it could have served to predict the occurrence of X (deductively or with more or less high probability) if the information contained in the explanans had been available at a suitable earlier time.

The condition of adequacy just stated can be extended, in an obvious manner, to explanations concerned, not with individual events, but with empirical uniformities expressed by putative laws. But such explanations cannot well be spoken of as potential *predictions* since law-statements purport to express timeless uniformities and thus make no reference to any particular time, whether past, present, or future.[4]

It will hardly be necessary to emphasize that it is not, of course, the *purpose* of an explanation to provide grounds in support of the explanandum-statement; for . . . a request for an explanation normally *presupposes* that the explanandum-statement is true. The point of the preceding remarks is rather that an adequate explanation cannot help providing information which, if properly established, also provides grounds in support of the explanandum-statement. . . . We may say that an adequate answer to an explanation-seeking why-question is always also a potential answer to the corresponding epistemic why-question.

The converse, however, does not hold; the condition of adequacy is necessary but not sufficient for an acceptable explanation. For example, certain empirical findings may give excellent grounds for the belief that the orientation of the earth's magnetic field shows diurnal and secular

variations, without in the least explaining why. Similarly, a set of experimental data may strongly *support* the assumption that the electric resistance of metals increases with their temperature or that a certain chemical inhibits the growth of cancer cells, without providing any *explanation* for these presumptive empirical regularities. The predictive inferences here involved are inductive rather than deductive; but what bars them from the status of potential explanations is not their inductive character . . . , but the fact that they invoke no laws or theoretical principles, no explanatory statements that make a general claim. Reliance on general principles, while perhaps not indispensable for prediction, is required in any explanation: such principles alone can give to whatever particular circumstances may be adduced the status of explanatory factors for the event to be explained.

Some of the objections recently raised against the thesis of the structural identity of explanation and prediction concern in effect the first of its two sub-theses, which has now been presented in some detail: the claim that any adequate explanatory argument is also potentially predictive. I will consider three objections to the effect that there are certain perfectly satisfactory explanations that do not constitute potential predictions.

Scriven has argued that the occurrence of an event X is sometimes quite adequately explained by means of a "proposition of the form 'The only cause of X is A' . . . for example, 'The only cause of paresis is syphilis';" this proposition enables us to explain why a certain patient has paresis by pointing out that he previously suffered from syphilis. And this explanation holds good, according to Scriven, even though only quite a small percentage of syphilitic patients develop paresis, so that "we must, on the evidence [that a given person has syphilis], still predict that [paresis] will *not* occur."[5] But if it does occur, then the principle that the only cause of paresis is syphilis can "provide and guarantee our explanation" in terms of antecedent syphilitic infection.[6] Thus we have here a presumptive explanation which indeed is not adequate as a potential prediction. But precisely because paresis is such a rare sequel of syphilis, prior syphilitic infection surely cannot by itself provide an adequate explanation for it: A condition that is nomically necessary for the occurrence of an event does not, in general, explain it; or else we would be able to explain a man's winning the first prize in the Irish sweepstakes by pointing out that he had previously bought a ticket, and that only a person who owns a ticket can win the first prize.

A second argument which, like Scriven's, has considerable initial plausibility has been advanced by Toulmin[7] by reference to "Darwin's theory, explaining the origin of species by variation and natural selection. No scientist has ever used this theory to foretell the coming-into-existence of creatures of a novel species, still less verified his forecast. Yet many competent scientists have accepted Darwin's theory as having great explanatory power." In examining this argument, let me distinguish what

might be called the *story* of evolution from the *theory* of the underlying mechanisms of mutation and natural selection. The story of evolution, as a hypothesis about the gradual development of various types of organisms, and about the subsequent extinction of many of these, has the character of a hypothetical historical narrative *describing* the putative stages of the evolutionary process; it is the associated theory which provides what *explanatory insight* we have into this process. The story of evolution might tell us, for example, that at a certain stage in the process dinosaurs made their appearance and that, so much later, they died out. Such a narrative account does not, of course, explain why the various kinds of dinosaurs with their distinctive characteristics came into existence, nor does it explain why they became extinct. Indeed even the associated theory of mutation and natural selection does not answer the first of these questions, though it might be held to shed some light on the latter. Yet, even to account for the extinction of the dinosaurs, we need a vast array of additional hypotheses about their physical and biological environment and about the species with which they had to compete for survival. But if we have hypotheses of this kind that are specific enough to provide, in combination with the theory of natural selection, at least a probabilistic explanation for the extinction of the dinosaurs, then clearly the explanans adduced is also qualified as a basis for a potential probabilistic prediction. The undeniably great persuasiveness of Toulmin's argument would seem to derive from two sources, a widespread tendency to regard the basically descriptive story of evolution as explaining the various states of the process, and a similarly widespread tendency to overestimate the extent to which even the theory of mutation and natural selection can account for the details of the evolutionary sequence.

I now turn to a third objection to the claim that an adequate explanation is also a potential prediction. It is based on the observation that sometimes the only ground we have for asserting some essential statement in the explanans lies in the knowledge that the explanandum event did in fact occur. In such cases, the explanatory argument clearly could not have been used to predict that event. Consider one of Scriven's examples.[8] Suppose that a man has killed his wife whom he knew to have been unfaithful to him, and that his action is explained as the result of intense jealousy. The fact that the man was jealous might well have been ascertainable before the deed, but to explain the latter, we need to know that his jealousy was intense enough to drive him to murder; and this we can know only after the deed has actually been committed. Here then, the occurrence of the explanandum event provides the only grounds we have for asserting one important part of the explanans; the explanandum event could not therefore have been predicted by means of the explanatory argument. In another example,[9] Scriven considers an explanation to the effect that the collapse of a bridge was caused by metal fatigue. This account, he argues, might be supported by pointing out that the failure could

have been caused only by an excessive load, by external damage, or by metal fatigue, and that the first two factors were not present in the case at hand, whereas there is evidence of metal fatigue. *Given the information that the bridge did in fact collapse*, this would establish not only that metal fatigue was at fault but that it was strong enough to cause the failure. While Scriven's notion of "the only possible cause" of a given event surely requires further elucidation, his example does afford another illustration of an explanatory account one of whose constituent hypotheses is supported only by the occurrence of the event to be explained—so that the latter could not have been predicted by means of the explanatory argument.

However, the point thus illustrated does not affect at all the conditional thesis that an adequate explanatory argument must be such that it could have served to predict the explanandum event *if* the information included in the explanans had been known and taken into account before the occurrence of that event. What Scriven's cases show is that sometimes we do not know independently of the occurrence of the explanandum event that all the conditions listed in the explanans are realized. However, this means only that in such cases our conditional thesis is counterfactual, i.e., that its if-clause is not satisfied, but not that the thesis itself is false. Moreover, Scriven's argument does not even show that in the kind of case he mentions it is logically or nomologically impossible (impossible by reason of the laws of logic or the laws of nature) for us to know the critical explanatory factor before, or independently of, the occurrence of the explanandum-event; the impossibility appears to be rather a practical and perhaps temporary one, reflecting present limitations of knowledge or technology.

But while it thus leaves our thesis unaffected, Scriven's observation is of methodological interest in its own right: it shows that sometimes an event is explained by means of hypotheses for some of which the fact of its occurrence affords the only available evidential support. This may happen, as we saw, when one of the explanatory hypotheses states that a certain relevant factor was strong enough to bring about the event in question; but the observation applies also to other cases. Thus the explanation . . . of the appearance and initial growth of the soap bubbles, includes in its explanans the assumption that a soap film had formed between the plate and the rims of the tumblers;* and practically the only evidence available in support of this explanatory assumption is the fact that soap bubbles did emerge from under the tumblers. Or consider the explanation of the characteristic dark lines in the absorption spectrum of a particular star. The key assumption in the explanans is that the star's atmosphere

* See the first section of Hempel's "Two Basic Types of Scientific Explanation," (the preceding reading in this chapter) for more about why bubbles appear when a tumbler is taken from warm soapy water and inverted on a plate.

contains certain elements, such as hydrogen, helium, and calcium, whose atoms absorb radiation of the wave lengths corresponding to the dark lines; the explanation relies, of course, on many other assumptions, including the optical theory that forms the basis for spectroscopy, and the assumption that the apparatus used is a properly constructed spectroscope. But while these latter explanans statements are capable of independent test and corroboration, it may well be that the only evidence available in support of the key explanatory hypothesis is the occurrence of the very lines whose appearance in the spectrum the argument serves to explain. Strictly speaking, the explanandum event here provides support for the key explanatory hypothesis only by virtue of the background theory, which connects the presence of certain elements in the atmosphere of a star with the appearance of corresponding absorption lines in its spectrum. Thus, the information that the explanandum event has occurred does not by itself support the explanatory hypothesis in question, but it constitutes, as we might say, an essential part of the only evidence available in support of that hypothesis.

Explanations of the kind here considered may be schematically characterized as arguments of the form (D-N) in which the information or assumption that E is true provides an indispensable part of the only available evidential support for one of the explanans statements, say, C_1. Let us call such explanations *self-evidencing*. It might be held that the actual occurrence of the explanandum event always provides some slight additional support even for an explanans whose constituent sentences have been accepted on the basis of independent evidence, and that in this sense every D-N explanation with true explanandum is in some measure self-evidencing; but we will apply this appellation to an explanatory account only if, at the time of its presentation, the occurrence of the explanandum event provides the only evidence, or an indispensable part of the only evidence, available in support of some of the explanans-statements.

An explanatory argument of the form (D-N) which is self-evidencing is not for that reason circular or pointless. To be sure, if the same argument were adduced in support of the assertion that the explanandum-event did occur (or, that E is true), then it would be open to the charge of epistemic circularity. If the argument is to achieve its objective then all the grounds it adduces in support of E—i.e., $C_1, C_2 \ldots, C_k; L_1, L_2, \ldots, L_r$—would have to be established independently of E; and this condition is violated here since the only ground we have for believing or asserting C_1 includes the assumption that E is true. But when the same argument is used for explanatory purposes it does not claim to establish that E is true; that is *presupposed* by the question 'Why did the event described by E occur?' Nor need a self-evidencing explanation involve an explanatory circle. The information that the explanandum event has occurred is not included in the explanans (so that the occurrence of the event is not "explained by

itself"); rather it serves, quite outside the explanatory context, as evidence supporting one of the explanans statements. Thus, an acceptable self-evidencing explanation benefits, as it were, by the wisdom of hindsight derived from the information that the explanandum event has occurred, but it does not misuse that information so as to produce a circular explanation.

An explanation that is self-evidencing may for that reason rest on a poorly supported explanans and may therefore have no strong claim to empirical soundness. But even this is not inevitable. In the case of the absorption spectrum of a star, for example, the previously accepted background information, including the relevant theories, may indicate that the dark lines observed occur *only* if the specified elements are present in the star's atmosphere; and then the explanandum, in conjunction with the background information, lends very strong support to the crucial explanatory hypothesis.

The notion of a self-evidencing explanation can, I think, shed some further light on the puzzle illustrated by the explanation of paresis in terms of antecedent syphilitic infection. Consider another illustration. Some cases of skin cancer are attributed to intensive ultraviolet irradiation. But this factor very often does not lead to cancer, so that the information that a person has been exposed to such radiation does not permit the prediction of cancer. Is that information alone nevertheless sufficient to explain the development of skin cancer when it does follow intensive irradiation? No doubt, an explanation will often be formulated so as to mention only the antecedent irradiation; but the underlying rationale surely must be more complex. Leaving aside the important quantitative aspects of the problem, the crucial point in that rationale can, I suggest, be schematically stated as follows: Some, though by no means all, individuals have the disposition to develop skin cancer upon exposure to strong ultraviolet irradiation; let us call these radiation-sensitive. Now, in the case of explanation, we know that the given individual was exposed to strong radiation (C_1) and did develop cancer of the skin in the affected area (E). But jointly, these two pieces of information lend support to the assumption that the individual is radiation-sensitive (C_2)—an hypothesis that is not supported in the case of prediction, where C_1 is available, but not E. And the two statements C_1 and C_2 (in combination with the general statement that sensitive individuals will develop skin cancer when exposed to intensive radiation) do provide an adequate explanans for E. If the explanation is thus construed as invoking C_2 in addition to C_1, it is seen to be self-evidencing, but also to possess an explanans which would provide an adequate basis for prediction if C_2 could be known in advance. That is impossible, of course, as long as the only available test for radiation-sensitivity consists in checking whether an individual does develop skin cancer upon intensive irradiation. But, clearly, it is conceivable that other, independent, tests of

radiation-sensitivity might be found and then C_2 might well be established independently of, and even prior to, the occurrence of the event described by E.

In discussing the structural identity of explanation and prediction, I have so far considered only the first of the two sub-theses distinguished earlier, namely, the claim that every adequate explanation is also a potential prediction. I have argued that the objections raised against this claim fall short of their mark, and that the first sub-thesis is sound and can indeed serve as a necessary condition of adequacy for any explicitly stated, rationally acceptable explanation.

I turn now to the second sub-thesis, namely, that every adequate predictive argument also affords a potential explanation. This claim is open to question even in the case of certain predictive arguments that are of deductive-nomological character, as the following example illustrates. One of the early symptoms of measles is the appearance of small whitish spots, known as Koplik spots, on the mucous linings of the cheeks. The statement, L, that the appearance of Koplik spots is always followed by the later manifestations of the measles might therefore be taken to be a law, and it might then be used as a premise in D-N arguments with a second premise of the form 'Patient i has Koplik spots at time t', and with a conclusion stating that i subsequently shows the later manifestations of the measles. An argument of this type is adequate for predictive purposes, but its explanatory adequacy might be questioned. We would not want to say, for example, that i had developed high fever and other symptoms of the measles because he had previously had Koplik spots. Yet this case—and others similar to it—does not constitute a decisive objection against the second sub-thesis. For the reluctance to regard the appearance of Koplik spots as explanatory may well reflect doubts as to whether, as a matter of universal law, those spots are always followed by the later manifestations of measles. Perhaps a local inoculation with a small amount of measles virus would produce the spots without leading to a full-blown case of the measles. If this were so, the appearance of the spots would still afford a usually reliable basis for predicting the occurrence of further symptoms, since exceptional conditions of the kind just mentioned would be extremely rare; but the generalization that Koplik spots are always followed by later symptoms of the measles would not express a law and thus could not properly support a corresponding D-N explanation.

The objection just considered concerns the explanatory potential of predictive arguments of the form (D-N). But the second sub-thesis, in its general form, which is not limited to D-N predictions, has further been challenged, particularly by Scheffler and by Scriven,[10] on the ground that there are other kinds of predictive argument that are adequate for scientific prediction, yet not for explanation. Specifically, as Scheffler notes, a scientific prediction may be based on a finite set of data which includes no laws and which would have no explanatory force. For example, a finite

set of data obtained in an extensive test of the hypothesis that the electric resistance of metals increases with their temperature may afford good support for that hypothesis and may thus provide an acceptable basis for the prediction that in an as yet unexamined instance, a rise in temperature in a metal conductor will be accompanied by an increase in resistance. But if this event then actually occurs, the test data clearly do not provide an explanation for it. Similarly, a list of the results obtained in a long series of tossings of a given coin may provide a good basis for predicting the percentage of Heads and Tails to be expected in the next 1000 tossings of the same coin; but again, that list of data provides no explanation for the subsequent results. Cases like these raise the question of whether there are not sound modes of scientific prediction that proceed from particulars to particulars without benefit of general laws such as seem to be required for any adequate explanation. Now, the predictive arguments just considered are not deductive but probabilistic in character. . . . In regard to the second sub-thesis of the structural identity claim, let us note this much here: the predictions in our illustrations proceed from an observed sample of a population to another, as yet unobserved one; and on some current theories of probabilistic inference such arguments do not depend upon the assumption of general empirical laws. According to Carnap's theory of inductive logic,[11] for example, such inferences are possible on purely logical grounds; the information about the given sample confers a definite logical probability upon any proposed prediction concerning an as yet unobserved sample. On the other hand, certain statistical theories of probabilistic inference eschew the notion of purely logical probabilities and qualify predictions of the kind here considered as sound only on the further assumption that the selection of individual cases from the total population has the character of a random experiment with certain general statistical characteristics. But that assumption, when explicitly spelled out, has the form of a general law of statistic-probabilistic form; hence, the predictions are effected by means of covering laws after all. And though these laws do not have the strictly universal character of those invoked in D-N explanations and predictions, they can serve in an explanatory capacity as well. Thus construed, even the predictions here under discussion turn out to be (incompletely formulated) potential explanations. . . .

▪ | Notes

1. Hempel and Oppenheim (1948), section 3.

2. See Scheffler (1957), section 1 and (1963), Part I, sections 3 and 4; Scriven (1962), p. 177.

3. Cf. Scheffler (1957), section 1. . . .

4. This point is made, for example, by Scriven (1962), pp. 179ff.

5. Scriven (1959a), p. 480, italics the author's.

6. *Loc. cit.* Barker has argued analogously that "it can be correct to speak of explanation in many cases where specific prediction is not possible. Thus, for instance, if the patient shows all the symptoms of pneumonia, sickens and dies, I can then explain his death—I know what killed him—but I could not have definitely predicted in advance that he was going to die; for usually pneumonia fails to be fatal." (1961, p. 271). This argument seems to me open to questions similar to those just raised in reference to Scriven's illustration. First of all, it is not clear just what would be claimed by the assertion that pneumonia killed the patient. Surely the mere information that the patient had pneumonia does not suffice to explain his death, precisely because in most cases pneumonia is not fatal. And if the explanans is taken to state that the patient was suffering from very severe pneumonia (and perhaps that he was elderly or weak) then it may well provide a basis at least for a probabilistic explanation of the patient's death—but in this case it obviously also permits prediction of his death with the same probability. For some further observations on Barker's argument, see the comments by Feyerabend and by Rudner, and Barker's rejoinders, in Feigl and Maxwell (1961), pp. 278–85. A detailed critical discussion that sheds further light on Scriven's paresis example will be found in Grünbaum (1963) and (1963a), chapter 9; see also Scriven's rejoinder (1963).

7. Toulmin (1961), pp. 24–25. Scriven (1959a) and Barker (1961) have offered arguments in the same vein. For a critical discussion of Scriven's version, see Grünbaum (1963) and (1963a), chapter 9.

8. Scriven (1959), pp. 468–69.

9. Scriven (1962), pp. 181–87.

10. See Scheffler (1957), p. 296 and (1963), p. 42; Scriven (1959a), p. 480.

11. Carnap (1950), section 110.

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