The Value of Laws:
Explanation and Prediction

In the nineteenth century, certain Germanic physicists, such as Gustav Kirchhoff and Ernst Mach, said that science should not ask "Why?" but "How?" They meant that science should not look for unknown metaphysical agents that are responsible for certain events, but should only describe such events in terms of laws. This prohibition against asking "Why?" must be understood in its historical setting. The background was the German philosophical atmosphere of the time, which was dominated by idealism in the tradition of Fichte, Schelling, and Hegel. These men felt that a description of the world was not enough. They wanted a fuller understanding, which they believed could be obtained only by finding metaphysical causes that were behind phenomena and not accessible to scientific method. Physicists reacted to this point of view by saying: "Leave us alone with your why-questions. There is no answer beyond that given by the empirical laws." They objected to why-questions because they were usually metaphysical questions.

Today the philosophical atmosphere has changed. In Germany there are a few philosophers still working in the idealist tradition, but in England and the United States it has practically disappeared. As a result, we are no longer worried by why-questions. We do not have to say, "Don't ask why", because now, when someone asks why, we assume that he means it in a scientific, nonmetaphysical sense. He is simply asking us to explain something by placing it in a framework of empirical laws.

When I was young and part of the Vienna Circle, some of my early publications were written as a reaction to the philosophical climate of German idealism. As a consequence, these publications and those by others in the Vienna Circle were filled with prohibitory statements similar to the one I have just discussed. These prohibitions must be understood in reference to the historical situation in which we found ourselves. Today, especially in the United States, we seldom make such prohibitions. The kind of opponents we have here are of a different nature, and the nature of one's opponents often determines the way in which one's views are expressed.

When we say that, for the explanation of a given fact, the use of a scientific law is indispensable, what we wish to exclude especially is the view that metaphysical agents must be found before a fact can be adequately explained. In prescientific ages, this was, of course, the kind of explanation usually given. At one time, the world was thought to be inhabited by spirits or demons who are not directly observable but who act to cause the rain to fall, the river to flow, the lightning to flash. In whatever one saw happening, there was something—or, rather, somebody—responsible for the event. This is psychologically understandable. If a man does something to me that I do not like, it is natural for me to make him responsible for it and to get angry and hit back at him. If a cloud pours water over me, I cannot hit back at the cloud, but I can find an outlet for my anger if I make the cloud, or some invisible demon behind the cloud, responsible for the rainfall. I can shout curses at this demon, shake my fist at him. My anger is relieved. I feel better. It is easy to understand how members of prescientific societies found psychological satisfaction in imagining agents behind the phenomena of nature.

In time, as we know, societies abandoned their mythologies, but sometimes scientists replace the spirits with agents that are really not much different. The German philosopher Hans Driesch, who died in 1941, wrote many books on the philosophy of science. He was originally a prominent biologist, famed for his work on certain organismic responses, including regeneration in sea urchins. He cut off parts of their bodies and observed in which stages of their growth and under what conditions they were able to grow new parts. His scientific work was important and excellent. But Driesch was also interested in philosophical questions, especially those dealing with the foundations of biology, so eventually he became a professor of philosophy. In philosophy also he did some excellent work, but there was one aspect of his philosophy that I and my friends in the Vienna Circle did not regard so highly. It was his way of explaining such biological processes as regeneration and reproduction.

At the time Driesch did his biological work, it was thought that many characteristics of living things could not be found elsewhere. (Today it is seen more clearly that there is a continuum connecting the organic and inorganic worlds.) He wanted to explain these unique organismic features, so he postulated what he called an "entelechy". This term had been introduced by Aristotle, who had his own meaning for it, but we need not
discuss that meaning here. Driesch said, in effect: "The entelechy is a certain specific force that causes living things to behave in the way they do. But you must not think of it as a physical force such as gravity or magnetism. Oh, no, nothing like that."

The entelechies of organisms, Driesch maintained, are of various kinds, depending on the organism's stage of evolution. In primitive, single-celled organisms, the entelechy is rather simple. As we go up the evolutionary scale, through plants, lower animals, higher animals, and finally to man, the entelechy becomes more and more complex. This is revealed by the greater degree to which phenomena are integrated in the higher forms of life. What we call the "mind" of a human body is actually nothing more than a portion of the person's entelechy. The entelechy is much more than the mind, or, at least, more than the conscious mind, because it is responsible for everything that every cell in the body does. If I cut my finger, the cells of the finger form new tissue and bring substances to the cut to kill incoming bacteria. These events are not consciously directed by the mind. They occur in the finger of a one-month-old baby, who has never heard of the laws of physiology. All this, Driesch insisted, is due to the organism's entelechy, of which mind is one manifestation. In addition, then, to scientific explanation, Driesch had an elaborate theory of entelechy, which he offered as a philosophical explanation of such scientifically unexplained phenomena as the regeneration of parts of sea urchins.

Is this an explanation? I and my friends had some discussions with Driesch about it. I remember one at the International Congress for Philosophy, at Prague, in 1934. Hans Reichenbach and I criticized Driesch's theory, while he and others defended it. In our publications we did not give much space to this criticism because we admired the work Driesch had done in both biology and philosophy. He was quite different from most philosophers in Germany in that he really wanted to develop a scientific philosophy. His entelechy theory, however, seemed to us to lack something.

What it lacked was this: the insight that you cannot give an explanation without also giving a law.

We said to him: "Your entelechy—we do not know what you mean by it. You say it is not a physical force. What is it then?"

"Well", he would reply (I am paraphrasing his words, of course), "you should not be so narrow-minded. When you ask a physicist for an explanation of why this nail suddenly moves toward that bar of iron, he will tell you that the bar of iron is a magnet and that the nail is drawn to it by the force of magnetism. No one has ever seen magnetism. You see only the movement of a little nail toward a bar of iron."

We agreed. "Yes, you are right. Nobody has seen magnetism."

"You see", he continued, "the physicist introduces forces that no one can observe—forces like magnetism and electricity—in order to explain certain phenomena. I wish to do the same. Physical forces are not adequate to explain certain organic phenomena, so I introduce something that is force-like but is not a physical force because it does not act the way physical forces act. For instance, it is not spatially located. True, it acts on a physical organism, but it acts in respect to the entire organism, not just to certain parts of it. Therefore, you cannot say where it is located. There is no location. It is not a physical force, but it is just as legitimate for me to introduce it as it is for a physicist to introduce the invisible force of magnetism."

Our answer was that a physicist does not explain the movement of the nail toward the bar simply by introducing the word "magnetism". Of course, if you ask him why the nail moves, he may answer first by saying that it is due to magnetism; but if you press him for a fuller explanation, he will give you laws. The laws may not be expressed in quantitative terms, like the Maxwell equations that describe magnetic fields; they may be simple, qualitative laws with no numbers occurring in them. The physicist may say: "All nails containing iron are attracted to the ends of bars that have been magnetized." He may go on to explain the state of being magnetized by giving other nonquantitative laws. He may tell you that iron ore from the town of Magnesia (you may recall that the word "magnetic" derives from the Greek town of Magnesia, where iron ore of this type was first found) possesses this property. He may explain that iron bars become magnetized if they are stroked a certain way by naturally magnetic ores. He may give you other laws about conditions under which certain substances can become magnetized and laws about phenomena associated with magnetism. He may tell you that if you magnetize a needle and suspend it by the middle so that it swings freely, one end will point north. If you have another magnetic needle, you can bring the two north-pointing ends together and observe that they do not attract but repel each other. He may explain that if you heat a magnetized bar of iron, or hammer it, it will lose magnetic strength. All these are qualitative laws that can be expressed in the logical form, "if... then...". The point I wish to emphasize here is this: it is not sufficient, for purposes of explanation, simply to introduce a new agent by giving it a new name. You must also give laws.

Driesch did not give laws. He did not specify how the entelechy of an oak tree differs from the entelechy of a goat or giraffe. He did not classify his entelechies. He merely classified organisms and said that each organism had its own entelechy. He did not formulate laws that state under what conditions an entelechy is strengthened or weakened. Of course he described all sorts of organic phenomena and gave general rules for such phenomena. He said that if you cut a limb from a sea urchin in a certain way, the organism will not survive; if you cut it another way, the organism will survive, but only a fragmentary limb will grow back. Cut in still
another way and at a certain stage in the sea urchin's growth, it will reовать a new and complete limb. These statements are all perfectly respectable zoological laws.

“What do you add to these empirical laws”, we asked Driesch, “if after giving them you proceed to tell us that all the phenomena covered by those laws are due to the sea urchin's entelechy?”

We believed that nothing was added. Since the notion of an entelechy does not give us new laws, it does not explain more than the general laws already available. It does not help us in the least in making new predictions. For these reasons we cannot say that our scientific knowledge has increased. The concept of entelechy may at first seem to add something to our explanations; but when we examine it more deeply, we see its emptiness. It is a pseudoeplanation.

It can be argued that the concept of entelechy is not useless if it provides biologists with a new orientation, a new method of ordering biological laws. Our answer is that it would indeed be useful if by means of it we could formulate more general laws than could be formulated before. In physics, for example, the concept of energy played such a role. Nineteenth-century physicists theorized that perhaps certain phenomena, such as kinetic and potential energy in mechanics, heat (this was before the discovery that heat is simply the kinetic energy of molecules), the energy of magnetic fields, and so on, might be manifestations of one basic kind of energy. This led to experiments showing that mechanical energy can be transformed into heat and heat into mechanical energy but that the amount of energy remains constant. Thus, energy was a fruitful concept because it led to more general laws, such as the law of the conservation of energy. But Driesch's entelechy was not a fruitful concept in this sense. It did not lead to the discovery of more general biological laws.

In addition to providing explanations for observed facts, the laws of science also provide a means for predicting new facts not yet observed. The logical schema involved here is exactly the same as the schema underlying explanation. . . . Expressed symbolically:

1. (x) (Px ⊃ Qx)
2. Pa
3. Qa

First we have a universal law; for any object x, if it has the property P, then it also has the property Q. Second, we have a statement saying that object a has the property P. Third, we deduce by elementary logic that object a has the property Q. This schema underlies both explanation and prediction; only the knowledge situation is different. In explanation, the fact Qa is already known. We explain Qa by showing how it can be deduced from statements 1 and 2. In prediction, Qa is a fact not yet known. We have a law, and we have the fact Pa. We conclude that Qa must also be a fact, even though it has not yet been observed. For example, I know the law of thermal expansion. I also know that I have heated a certain rod. By applying logic in the way shown in the schema, I infer that if I now measure the rod, I will find that it is longer than it was before.

In most cases, the unknown fact is actually a future event (for example, an astronomer predicts the time of the next eclipse of the sun); that is why I use the term "prediction" for this second use of laws. It need not, however, be prediction in the literal sense. In many cases the unknown fact is simultaneous with the known fact, as is the case in the example of the heated rod. The expansion of the rod occurs simultaneously with the heating. It is only our observation of the expansion that takes place after our observation of the heating.

In other cases, the unknown fact may even be in the past. On the basis of psychological laws, together with certain facts derived from historical documents, a historian infers certain unknown facts of history. An astronomer may infer that an eclipse of the moon must have taken place at a certain date in the past. A geologist may infer from stratifications on boulders that at one time in the past a region must have been covered by a glacier. I use the term "prediction" for all these examples because in every case we have the same logical schema and the same knowledge situation—a known fact and a known law from which an unknown fact is derived.

In many cases, the law involved may be statistical rather than universal. The prediction will then be only probable. A meteorologist, for instance, deals with a mixture of exact physical laws and various statistical laws. He cannot say that it will rain tomorrow; he can only say that rain is very likely.

This uncertainty is also characteristic of prediction about human behavior. On the basis of knowing certain psychological laws of a statistical nature and certain facts about a person, we can predict with varying degrees of probability how he will behave. Perhaps we ask a psychologist to tell us what effect a certain event will have on our child. He replies: "As I see the situation, your child will probably react in this way. Of course, the laws of psychology are not very exact. It is a young science, and as yet we know very little about its laws. But on the basis of what is known, I think it advisable that you plan to . . ." And so he gives us advice based on the best prediction he can make, with his probabilistic laws, about the future behavior of our child.

When the law is universal, then elementary deductive logic is involved in inferring unknown facts. If the law is statistical, we must use a different logic—the logic of probability. To give a simple example: a law states that 90 per cent of the residents of a certain region have black hair. I know that an individual is a resident of that region, but I do not know the color of his hair. I can infer, however, on the basis of the statistical law, that the probability his hair is black is 2/10.
Prediction is, of course, as essential to everyday life as it is to science. Even the most trivial acts we perform during the day are based on predictions. You turn a doorknob. You do so because past observations of facts, together with universal laws, lead you to believe that turning the knob will open the door. You may not be conscious of the logical schema involved—no doubt you are thinking about other things—but all such deliberate actions presuppose the schema. There is a knowledge of specific facts, a knowledge of certain observed regularities that can be expressed as universal or statistical laws and provide a basis for the prediction of unknown facts. Prediction is involved in every act of human behavior that involves deliberate choice. Without it, both science and everyday life would be impossible.

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**Carl G. Hempel**

**Two Basic Types of Scientific Explanation**

1 **Deductive-Nomological Explanation**

In his book, *How We Think*, John Dewey describes an observation he made one day when, washing dishes, he took some glass tumblers out of the hot soap suds and put them upside down on a plate: he noticed that soap bubbles emerged from under the tumblers' rims, grew for a while, came to a standstill, and finally receded inside the tumblers. Why did this happen? The explanation Dewey outlines comes to this: In transferring a tumbler to the plate, cool air is caught in it; this air is gradually warmed by the glass, which initially has the temperature of the hot suds. The warming of the air is accompanied by an increase in its pressure, which in turn produces an expansion of the soap film between the plate and the rim. Gradually, the glass cools off, and so does the air inside, with the result that the soap bubbles recede.

This explanatory account may be regarded as an argument to the effect that the event to be explained (let me call it the explanandum-event) was to be expected by reason of certain explanatory facts. These may be divided into two groups: (i) particular facts and (ii) uniformities expressed by general laws. The first group includes facts such as these: the tumblers had been immersed, for some time, in soap suds of a temperature considerably higher than that of the surrounding air; they were put, upside down, on a plate on which a puddle of soapy water had formed, providing a connecting soap film, etc. The second group of items presupposed in the argument includes the gas laws and various other laws that have not been explicitly suggested concerning the exchange of heat between bodies of different temperature, the elastic behavior of soap bubbles, etc. If we imag--

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ine these various presuppositions explicitly spelled out, the idea suggests itself of construing the explanation as a deductive argument of this form:

\[
\begin{align*}
(D) \quad & C_1, C_2, \ldots, C_i \\
& L_1, L_2, \ldots, L_n \\
& E
\end{align*}
\]

Here, \( C_1, C_2, \ldots, C_i \) are statements describing the particular facts invoked; \( L_1, L_2, \ldots, L_n \) are general laws; jointly, these statements will be said to form the explanans. The conclusion \( E \) is a statement describing the explanandum-event; let me call it the explanandum-statement, and let me use the word "explanandum" to refer to either \( E \) or to the event described by it.

The kind of explanation thus characterized I will call deductive-nomological explanation: for it amounts to a deductive subsumption of the explanandum under principles which have the character of general laws: it answers the question "Why did the explanandum event occur?" by showing that the event resulted from the particular circumstances specified in \( C_1, C_2, \ldots, C_i \) in accordance with the laws \( L_1, L_2, \ldots, L_n \). This conception of explanation, as exhibited in schema (D), has therefore been referred to as the covering law model, or as the deductive model, of explanation.2

A very many scientific explanations can be regarded as deductive-nomological in character. Consider, for example, the explanation of mirror-images, of rainbows, or of the appearance that a spoon handle is bent at the point where it emerges from a glass of water: in all these cases, the explanandum is deductively subsumed under the laws of reflection and refraction. Similarly, certain aspects of free fall and of planetary motion can be accounted for by deductive subsumption under Galileo's or Kepler's laws.

In the illustrations given so far the explanatory laws had, by and large, the character of empirical generalizations connecting different observable aspects of the phenomena under scrutiny: angle of incidence with angle of reflection or refraction, distance covered with falling time, etc. But science raises the question "why?" also with respect to the uniformities expressed by such laws, and often answers it in basically the same manner, namely, by subsuming the uniformities under more inclusive laws, and eventually under comprehensive theories. For example, the question, "Why do Galileo's and Kepler's laws hold?" is answered by showing that these laws are but special consequences of the Newtonian laws of motion and of gravitation; and these, in turn, may be explained by subsumption under the more comprehensive general theory of relativity. Such subsumption under broader laws or theories usually increases both the breadth and the depth of our scientific understanding. There is an increase in breadth, or scope, because the new explanatory principles cover a broader range of phenomena; for example, Newton's principles govern free fall on the earth and on other celestial bodies, as well as the motions of planets, comets, and artificial satellites, the movements of pendulums, tidal changes, and various other phenomena. And the increase thus effected in the depth of our understanding is strikingly reflected in the fact that, in the light of more advanced explanatory principles, the original empirical laws are usually seen to hold only approximately, or within certain limits. For example, Newton's theory implies that the factor \( g \) in Galileo's law, \( s = \frac{1}{2} gt^2 \), is not strictly a constant for free fall near the surface of the earth; and that, since every planet undergoes gravitational attraction not only from the sun, but also from the other planets, the planetary orbits are not strictly ellipses, as stated in Kepler's laws.

One further point deserves brief mention here. An explanation of a particular event is often conceived as specifying its cause, or causes. Thus, the account outlined in our first illustration might be held to explain the growth and the recession of the soap bubbles by showing that the phenomenon was caused by a rise and a subsequent drop of the temperature of the air trapped in the tumblers. Clearly, however, these temperature changes provide the requisite explanation only in conjunction with certain other conditions, such as the presence of a soap film, practically constant pressure of the air surrounding the glasses, etc. Accordingly, in the context of explanation, a cause must be allowed to consist in a more or less complex set of particular circumstances; these might be described by a set of sentences: \( C_1, C_2, \ldots, C_i \). And, as suggested by the principle "same cause, same effect," the assertion that those circumstances jointly caused a given event—described, let us say, by a sentence \( E \)—implies that whenever and however circumstances of the kind in question occur, an event of the kind to be explained comes about. Hence, the given causal explanation implicitly claims that there are general laws—such as \( L_1, L_2, \ldots, L_n \) in schema (D)—by virtue of which the occurrence of the causal antecedents mentioned in \( C_1, C_2, \ldots, C_i \) is a sufficient condition for the occurrence of the event to be explained. Thus, the relation between causal factors and effect is reflected in schema (D): causal explanation is deductive-nomological in character. (However, the customary formulations of causal and other explanations often do not explicitly specify all the relevant laws and particular facts: to this point, we will return later.)

The converse does not hold: there are deductive-nomological explanations which would not normally be counted as causal. For one thing, the subsumption of laws, such as Galileo's or Kepler's laws, under more comprehensive principles is clearly not causal in character: we need of...
causes only in reference to particular facts or events, and not in reference to universal facts as expressed by general laws. But not even all deductive-nomological explanations of particular facts or events will qualify as causal; for in a causal explanation some of the explanatory circumstances will temporally precede the effect to be explained; and there are explanations of type (D) which lack this characteristic. For example, the pressure which a gas of specified mass possesses at a given time might be explained by reference to its temperature and its volume at the same time, in conjunction with the gas law which connects simultaneous values of the three parameters.1

In conclusion, let me stress once more the important role of laws in deductive-nomological explanation: the laws connect the explanandum event with the particular conditions cited in the explanans, and this is what confers upon the latter the status of explanatory (and, in some cases, causal) factors in regard to the phenomenon to be explained.

2 Probabilistic Explanation

In deductive-nomological explanation as schematized in (D), the laws and theoretical principles involved are of strictly universal form: they assert that in all cases in which certain specified conditions are realized an occurrence of such and such a kind will result; the law that any metal, when heated under constant pressure, will increase in volume, is a typical example; Galileo's, Kepler's, Newton's, Boyle's, and Snell's laws, and many others, are of the same character.

Now let me turn next to a second basic type of scientific explanation. This kind of explanation, too, is nomological, i.e., it accounts for a given phenomenon by reference to general laws or theoretical principles; but some or all of these are of probabilistic-statistical form, i.e., they are, generally speaking, assertions to the effect that if certain specified conditions are realized, then an occurrence of such and such a kind will come about with such and such a statistical probability.

For example, the subsiding of a violent attack of hay fever in a given case might well be attributed to, and thus explained by reference to, the administration of 8 milligrams of chlor-trimenol. But if we wish to connect this antecedent event with the explanandum, and thus to establish its explanatory significance for the latter, we cannot invoke a universal law to the effect that the administration of 8 milligrams of that antihistamine will invariably terminate a hay fever attack; this simply is not so. What can be asserted is only a generalization to the effect that administration of the drug will be followed by relief with high statistical probability, i.e., roughly speaking, with a high relative frequency in the long run. The resulting explanans will thus be of the following type:

John Doe had a hay fever attack and took 8 milligrams of chlor-trimenol.

The probability for subsidence of a hay fever attack upon administration of 8 milligrams of chlor-trimenol is high.

Clearly, this explanans does not deductively imply the explanandum, "John Doe's hay fever attack subsided"; the truth of the explanans makes the truth of the explanandum not certain (as it does in a deductive-nomological explanation) but only more or less likely or, perhaps "practically" certain.

Reduced to its simplest essentials, a probabilistic explanation thus takes the following form:

\[
\text{Fi} \quad \text{P(O,F) is very high} \quad \text{makes very likely} \quad \text{Oi}
\]

The explanandum, expressed by the statement "Oi," consists in the fact that in the particular instance under consideration, here called i (e.g., John Doe's allergic attack), an outcome of kind O (subside) occurred. This is explained by means of two explanans-statements. The first of these, "Fi," corresponds to \(C_1, C_2, \ldots, C_n\) in (D); it states that in case i, the factors F (which may be more or less complex) were realized. The second expresses a law of probabilistic form, to the effect that the statistical probability for outcome O to occur in cases where F is realized is very high (close to 1). The double line separating explanandum from explanans is to indicate that, in contrast to the case of deductive-nomological explanation, the explanans does not logically imply the explanandum, but only confers a high likelihood upon it. The concept of likelihood here referred to must be clearly distinguished from that of statistical probability, symbolized by "p" in our schema. A statistical probability is, roughly speaking, the long-run relative frequency with which an occurrence of a given kind (say, F) is accompanied by an "outcome" of a specified kind (say, O). Our likelihood, on the other hand, is a relation (capable of gradations) not between kinds of occurrences, but between statements. The likelihood referred to in (P) may be characterized as the strength of the inductive support, or the degree of rational credibility, which the explanans confers upon the explanandum; or, in Carnap's terminology, as the logical, or inductive, (in contrast to statistical) probability which the explanandum possesses relative to the explanans.

Thus, probabilistic explanation, just like explanation in the manner of schema (D), is nomological in that it presupposes general laws; but because these laws are of statistical rather than of strictly universal form, the resulting explanatory arguments are inductive rather than deductive.
in character. An inductive argument of this kind explains a given phenomenon by showing that, in view of certain particular events and certain statistical laws, its occurrence was to be expected with high logical, or inductive, probability.

By reason of its inductive character, probabilistic explanation differs from its deductive-nomological counterpart in several other important respects: for example, its explanans may confer upon the explanandum a more or less high degree of inductive support; in this sense, probabilistic explanation admits of degrees, whereas deductive-nomological explanation appears as an either-or affair: a given set of universal laws and particular statements either does or does not imply a given explanandum statement. A fuller examination of these differences, however, would lead us far afield and is not required for the purposes of this paper.

One final point: the distinction here suggested between deductive-nomological and probabilistic explanation might be questioned on the ground that, after all, the universal laws invoked in a deductive explanation can have been established only on the basis of a finite body of evidence, which surely affords no exhaustive verification, but only more or less strong probability for it; and that, therefore, all scientific laws have to be regarded as probabilistic. This argument, however, confounds a logical issue with an epistemological one: it fails to distinguish properly between the claim made by a given law-statement and the degree of confirmation, or probability, which it possesses on the available evidence. It is quite true that statements expressing laws of either kind can be only incompletely confirmed by any given finite set—however large—of data about particular facts; but law-statements of the two different types make claims of different kind, which are reflected in their logical forms: roughly, a universal law-statement of the simplest kind asserts that all elements of an indefinitely large reference class (e.g., copper objects) have a certain characteristic (e.g., that of being good conductors of electricity); while statistical law-statements assert that in the long run, a specified proportion of the members of the reference class have specified property. And our distinction of two types of law and, concomitantly, of two types of scientific explanation, is based on this difference in claim as reflected in the difference of form.

The great scientific importance of probabilistic explanation is eloquently attested to by the extensive and highly successful explanatory use that has been made of fundamental laws of statistical form in genetics, statistical mechanics, and quantum theory.

3 Elliptic and Partial Explanations: Explanation Sketches

As I mentioned earlier, the conception of deductive-nomological explanation reflected in our schema (D) is often referred to as the covering law model, or the deductive model, of explanation; similarly, the conception underlying schema (P) might be called the probabilistic or the inductive-statistical, model of explanation. The term "model" can serve as a useful reminder that the two types of explanation as characterized above constitute ideal types or theoretical idealizations and are not intended to reflect the manner in which working scientists actually formulate their explanatory accounts. Rather, they are meant to provide explications, or rational reconstructions, or theoretical models, of certain modes of scientific explanation.

In this respect our models might be compared to the concept of mathematical proof (within a given theory) as construed in meta-mathematics. This concept, too, may be regarded as a theoretical model: it is not intended to provide a descriptive account of how proofs are formulated in the writings of mathematicians: most of these actual formulations fall short of rigorous and, as it were, ideal, meta-mathematical standards. But the theoretical model has certain other functions: it exhibits the rationale of mathematical proofs by revealing the logical connections underlying the successive steps; it provides standards for a critical appraisal of any proposed proof constructed within the mathematical system to which the model refers; and it affords a basis for a precise and far-reaching theory of proof, provability, decidability, and related concepts. I think the two models of explanation can fulfill the same functions, if only on a much more modest scale. For example, the arguments presented in constructing the models give an indication of the sense in which the models exhibit the rationale and the logical structure of the explanations they are intended to represent.

I now want to add a few words concerning the second of the functions just mentioned; but I will have to forgo a discussion of the third.

When a mathematician proves a theorem, he will often omit mention of certain propositions which he presupposes in his argument and which he is in fact entitled to presuppose because, for example, they follow readily from the postulates of his system or from previously established theorems or perhaps from the hypothesis of his theorem, if the latter is in hypothetical form; he then simply assumes that his readers or listeners will be able to supply the missing items if they so desire. If judged by ideal standards, the given formulation of the proof is elliptic or incomplete; but the departure from the ideal is harmless: the gaps can readily be filled in. Similarly, explanations put forward in everyday discourse and also in scientific contexts are often elliptically formulated. When we explain, for
example, that a lump of butter melted because it was put into a hot frying pan, or that a small rainbow appeared in the spray of the lawn sprinkler because the sunlight was reflected and refracted by the water droplets, we may be said to offer elliptic formulations of deductive-nomological explanations; an account of this kind omits mention of certain laws or particular facts which it tacitly takes for granted, and whose explicit citation would yield a complete deductive-nomological argument.

In addition to elliptic formulation, there is another, quite important, respect in which many explanatory arguments deviate from the theoretical model. It often happens that the statement actually included in the explanans, together with those which may reasonably be assumed to have been taken for granted in the context at hand, explain the given explanandum only partially, in a sense which I will try to indicate by an example. In his Psychopathology of Everyday Life, Freud offers the following explanation of a slip of the pen that occurred to him: “On a sheet of paper containing principally short daily notes of business interest, I found, to my surprise, the incorrect date, ‘Thursday, October 20th,’ bracketed under the correct date of the month of September. It was not difficult to explain this anticipation as the expression of a wish. A few days before I had returned fresh from my vacation and felt ready for any amount of professional work, but as yet there were few patients. On my arrival I had found a letter from a patient announcing her arrival on the 20th of October. As I wrote the same date in September I may certainly have thought ‘Ought to be here already; what a pity about that whole month!’ and with this thought I pushed the current date a month ahead.”

Clearly, the formulation of the intended explanation is at least incomplete in the sense considered a moment ago. In particular, it fails to mention any laws or theoretical principles in virtue of which the subconscious wish, and the other antecedent circumstances referred to, could be held to explain Freud’s slip of the pen. However, the general theoretical considerations Freud presents here and elsewhere in his writings suggests strongly that his explanatory account relies on a hypothesis to the effect that when a person has a strong, though perhaps unconscious, desire, then if he commits a slip of pen, tongue, memory, or the like, the slip will take a form in which it expresses, and perhaps symbolically fulfills, the given desire.

Even this rather vague hypothesis is probably more definite than what Freud would have been willing to assert. But for the sake of the argument let us accept it and include it in the explanans, together with the particular statements that Freud did have the subconscious wish he mentions, and that he was going to commit a slip of the pen. Even then, the resulting explanans permits us to deduce only that the slip made by Freud would, in some way or other, express and perhaps symbolically fulfill Freud’s subconscious wish. But clearly, such expression and fulfillment might have been achieved by many other kinds of slip of the pen than the one actually committed.

In other words, the explanans does not imply, and thus fully explain, that the particular slip, say s, which Freud committed on this occasion, would fall within the narrow class, say W, of acts which consist in writing the words “Thursday, October 20th”; rather, the explanans implies only that s would fall into a wider class, say F, which includes W as a proper subclass, and which consists of all acts which would express and symbolically fulfill Freud’s subconscious wish in some way or other.

The argument under consideration might be called a partial explanation: it provides complete, or conclusive, grounds for expecting s to be a member of F, and since W is a subclass of F, it thus shows that the explanandum, i.e., s falling within W, accords with, or bears out, what is to be expected in consideration of the explanans. By contrast, a deductive-nomological explanation of the form (D) might then be called complete since the explanans here does imply the explanandum.

Clearly, the question whether a given explanatory argument is complete or partial can be significantly raised only if the explanandum sentence is fully specified; only then can we ask whether the explanandum does or does not follow from the explanans. Completeness of explanation, in this sense, is relative to our explanandum sentence. Now, it might seem much more important and interesting to consider instead the notion of a complete explanation of some concrete event, such as the destruction of Pompeii, or the death of Adolf Hitler, or the launching of the first artificial satellite: we might want to regard a particular event as completely explained only if an explanatory account of deductive or of inductive form had been provided for all of its aspects. This notion, however, is self-defeating; for any particular event may be regarded as having infinitely many different aspects or characteristics, which cannot all be accounted for by a finite set, however large, of explanatory statements.

In some cases, what is intended as an explanatory account will depart even further from the standards reflected in the model schemata (D) and (P) above. An explanatory account, for example, which is not explicit and specific enough to be reasonably qualified as an elliptically formulated explanation or as a partial one, can often be viewed as an explanation sketch; it may suggest, perhaps quite vividly and persuasively, the general outlines of what, it is hoped, can eventually be supplemented so as to yield a more closely reasoned argument based on explanatory hypotheses which are indicated more fully, and which more readily permit of critical appraisal by reference to empirical evidence.

The decision whether a proposed explanatory account is to be qualified as an elliptically formulated deductive or probabilistic explanation, as a partial explanation, as an explanation sketch, or perhaps as none of these is a matter of judicious interpretation; it calls for an appraisal of the
The 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 "submitting 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.


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, where we added that scientific explanation (of the deductivenomological 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 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. 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-