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EXPLANATORY UNIFICATION*

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The official model of explanation proposed by the logical empiricists, the covering law model, is subject to familiar objections. The goal of the present paper is to explore an unofficial view of explanation which logical empiricists have sometimes suggested, the view of explanation as unification. I try to show that this view can be developed so as to provide insight into major episodes in the history of science, and that it can overcome some of the most serious difficulties besetting the covering law model.

1. The Decline and Fall of the Covering Law Model. One of the great apparent triumphs of logical empiricism was its official theory of explanation. In a series of lucid studies (Hempel 1965, Chapters 9, 10, 12; Hempel 1962; Hempel 1966), C. G. Hempel showed how to articulate precisely an idea which had received a hazy formulation from traditional empiricists such as Hume and Mill. The picture of explanation which Hempel presented, the *covering law model*, begins with the idea that explanation is derivation. When a scientist explains a phenomenon, he derives (deductively or inductively) a sentence describing that phenomenon (the *explanandum* sentence) from a set of sentences (the *explanans*) which must contain at least one general law.

Today the model has fallen on hard times. Yet it was never the empiricists' whole story about explanation. Behind the official model stood an unofficial model, a view of explanation which was not treated precisely, but which sometimes emerged in discussions of theoretical explanation. In contrasting scientific explanation with the idea of reducing unfamiliar phenomena to familiar phenomena, Hempel suggests this unofficial view: "What scientific explanation, especially theoretical explanation, aims at is not [an] intuitive and highly subjective kind of understanding, but an objective kind of insight that is achieved by a systematic unification, by exhibiting the phenomena as manifestations of common, underlying structures and processes that conform to specific, testable, basic principles" (Hempel 1966, p. 83; see also Hempel 1965, pp. 345, 444). Herbert Feigl makes a similar point: "The aim of scientific explanation throughout the ages has been *unification,* i.e., the comprehending of a maximum of facts and regularities in terms of a minimum of theoretical concepts and assumptions" (Feigl 1970, p. 12).

This unofficial view, which regards explanation as unification, is, I think, more promising than the official view. My aim in this paper is to develop the view and to present its virtues. Since the picture of explanation which results is rather complex, my exposition will be programmatic, but I shall try to show that the unofficial view can avoid some prominent shortcomings of the covering law model.

Why should we want an account of scientific explanation? Two reasons present themselves. Firstly, we would like to understand and to evaluate the popular claim that the natural sciences do not merely pile up unrelated items of knowledge of more or less practical significance, but that they increase our understanding of the world. A theory of explanation should show us *how* scientific explanation advances our understanding. (Michael Friedman cogently presents this demand in his (1974)). Secondly, an account of explanation ought to enable us to comprehend and to arbitrate disputes in past and present science. Embryonic theories are often defended by appeal to their explanatory power. A theory of explanation should enable us to judge the adequacy of the defense.

The covering law model satisfies neither of these *desiderata.* Its difficulties stem from the fact that, when it is viewed as providing a set of necessary *and sufficient* conditions for explanation, it is far too liberal. Many derivations which are intuitively nonexplanatory meet the conditions of the model. Unable to make relatively gross distinctions, the model is quite powerless to adjudicate the more subtle considerations about explanatory adequacy which are the focus of scientific debate. Moreover, our ability to derive a description of a phenomenon from a set of premises *containing a law* seems quite tangential to our understanding

of the phenomenon. Why should it be that exactly those derivations which employ laws advance our understanding?

The unofficial theory appears to do better. As Friedman points out, we can easily connect the notion of unification with that of understanding. (However, as I have argued in my (1976), Friedman's analysis of unification is faulty; the account of unification offered below is indirectly defended by my diagnosis of the problems for his approach.) Furthermore, as we shall see below, the acceptance of some major programs of scientific research—such as, the Newtonian program of eighteenth century physics and chemistry, and the Darwinian program of nineteenth century biology—depended on recognizing promises for unifying, and thereby explaining, the phenomena. Reasonable skepticism may protest at this point that the attractions of the unofficial view stem from its unclarity. Let us see.

2. Explanation: Some Pragmatic Issues. Our first task is to formulate the problem of scientific explanation clearly, filtering out a host of issues which need not concern us here. The most obvious way in which to categorize explanation is to view it as an activity. In this activity we answer the actual or anticipated questions of an actual or anticipated audience. We do so by presenting reasons. We draw on the beliefs we hold, frequently using or adapting arguments furnished to us by the sciences.

Recognizing the connection between explanations and arguments, proponents of the covering law model (and other writers on explanation) have identified explanations as special types of arguments. But although I shall follow the covering law model in employing the notion of argument to characterize that of explanation, I shall not adopt the ontological thesis that explanations are arguments. Following Peter Achinstein's thorough discussion of ontological issues concerning explanation in his (1977), I shall suppose that an explanation is an ordered pair consisting of a proposition and an act type.[1] The relevance of arguments to explanation resides in the fact that what makes an ordered pair (p, explaining q) an explanation is that a sentence expressing p bears an appropriate relation to a particular argument. (Achinstein shows how the central idea of the covering law model can be viewed in this way.) So I am supposing that there are acts of explanation which draw on arguments supplied by science, reformulating the traditional problem of explanation as the ques-

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[1] Strictly speaking, this is one of two views which emerge from Achinstein's discussion and which he regards as equally satisfactory. As Achinstein goes on to point out, either of these ontological theses can be developed to capture the central idea of the covering law model.

tion: What features should a scientific argument have if it is to serve as the basis for an act of explanation?[2]

The complex relation between scientific explanation and scientific argument may be illuminated by a simple example. Imagine a mythical Galileo confronted by a mythical fusilier who wants to know why his gun attains maximum range when it is mounted on a flat plain, if the barrel is elevated at 45° to the horizontal. Galileo reformulates this question as the question of why an ideal projectile, projected with fixed velocity from a perfectly smooth horizontal plane and subject only to gravitational acceleration, attains maximum range when the angle of elevation of the projection is 45°. He defends this reformulation by arguing that the effects of air resistance in the case of the actual projectile, the cannonball, are insignificant, and that the curvature of the earth and the unevenness of the ground can be neglected. He then selects a kinematical argument which shows that, for fixed velocity, an ideal projectile attains maximum range when the angle of elevation is 45°. He adapts this argument by explaining to the fusilier some unfamiliar terms ('uniform acceleration', let us say), motivating some problematic principles (such as the law of composition of velocities), and by omitting some obvious computational steps. Both Galileo and the fusilier depart satisfied.

The most general problem of scientific explanation is to determine the conditions which must be met if science is to be used in answering an explanation-seeking question Q. I shall restrict my attention to explanation-seeking why-questions, and I shall attempt to determine the conditions under which an argument whose conclusion is S can be used to answer the question "Why is it the case that S?". More colloquially, my project will be that of deciding when an argument explains why its conclusion is true.[3]

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[2]To pose the problem in this way we may still invite the charge that *arguments* should not be viewed as the bases for acts of explanation. Many of the criticisms levelled against the covering law model by Wesley Salmon in his seminal paper on statistical explanation (Salmon 1970) can be reformulated to support this charge. My discussion in section 7 will show how some of the difficulties raised by Salmon for the covering law model do not bedevil my account. However, I shall not respond directly to the points about statistical explanation and statistical inference advanced by Salmon and by Richard Jeffrey in his (1970). I believe that Peter Railton has shown how these specific difficulties concerning statistical explanation can be accommodated by an approach which takes explanations to be (or be based on) arguments (see Railton 1978), and that the account offered in section 4 of his paper can be adapted to complement my own.

[3]Of course, in restricting my attention to why-questions I am following the tradition of philosophical discussion of scientific explanation: as Bromberger notes in section IV of his (1966) not all explanations are directed at why-questions, but attempts to characterize explanatory responses to why-questions have a special interest for the philosophy of science because of the connection to a range of methodological issues. I believe that the account of explanation offered in the present paper could be extended to cover explanatory answers to some other kinds of questions (such as how-questions). But I do want to disavow the

We leave on one side a number of interesting, and difficult issues. So, for example, I shall not discuss the general relation between explanation-seeking questions and the arguments which can be used to answer them, nor the pragmatic conditions governing the idealization of questions and the adaptation of scientific arguments to the needs of the audience. (For illuminating discussions of some of these issues, see Bromberger 1962.) Given that so much is dismissed, does anything remain?

In a provocative article, (van Fraassen 1977) Bas van Fraassen denies, in effect, that there are any issues about scientific explanation other than the pragmatic questions I have just banished. After a survey of attempts to provide a theory of explanation he appears to conclude that the idea that explanatory power is a special virtue of theories is a myth. We accept scientific theories on the basis of their empirical adequacy and simplicity, and, having done so, we use the arguments with which they supply us to give explanations. This activity of applying scientific arguments in explanation accords with extra-scientific, "pragmatic", conditions. Moreover, our views about these extra-scientific factors are revised in the light of our acceptance of new theories: ". . . science schools our imagination so as to revise just those prior judgments of what satisfies and eliminates wonder" (van Fraassen 1977, p. 150). Thus there are no context-independent conditions, beyond those of simplicity and empirical adequacy which distinguish arguments for use in explanation.

van Fraassen's approach does not fit well with some examples from the history of science—such as the acceptance of Newtonian theory of matter and Darwin's theory of evolution—examples in which the ex-planatory promise of a theory was appreciated in advance of the articu-lation of a theory with predictive power. (See below pp. 512–14.) More-over, the account I shall offer provides an answer to skepticism that no "global constraints" (van Fraassen 1977, p. 146) on explanation can avoid the familiar problems of asymmetry and irrelevance, problems which bedevil the covering law model. I shall try to respond to van Fraas-sen's challenge by showing that there are certain context-independent fea-

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claim that unification is relevant to all types of explanation. If one believes that expla-nations are sometimes offered in response to what-questions (for example), so that it is correct to talk of someone explaining what a gene is, then one should allow that some types of explanation can be characterized independently of the notions of unification or of argument. I ignore these kinds of explanation in part because they lack the methodo-logical significance of explanations directed at why-questions and in part because the prob-lem of characterizing explanatory answers to what-questions seems so much less recalci-trant than that of characterizing explanatory answers to why-questions (for a similar assessment, see Belnap and Steel 1976, pp. 86–7). Thus I would regard a full account of explanation as a heterogeneous affair, because the conditions required of adequate answers to different types of questions are rather different, and I intend the present essay to make a proposal about how *part* of this account (the most interesting part) should be developed.

tures of arguments which distinguish them for application in response to explanation-seeking why-questions, and that we can assess theories (including embryonic theories) by their ability to provide us with such arguments. Hence I think that it is possible to defend the thesis that historical appeals to the explanatory power of theories involve recognition of a virtue over and beyond considerations of simplicity and predictive power.

Resuming our main theme, we can use the example of Galileo and the fusilier to achieve a further refinement of our problem. Galileo selects and adapts an argument from his new kinematics—that is, he draws an argument from a set of arguments available for explanatory purposes, a set which I shall call the *explanatory store*. We may think of the sciences not as providing us with many unrelated individual arguments which can be used in individual acts of explanation, but as offering a reserve of explanatory arguments, which we may tap as need arises. Approaching the issue in this way, we shall be led to present our problem as that of specifying the conditions which must be met by the explanatory store.

The set of arguments which science supplies for adaptation in acts of explanation will change with our changing beliefs. Therefore the appropriate *analysandum* is the notion of the store of arguments relative to a set of accepted sentences. Suppose that, at the point in the history of inquiry which interests us, the set of accepted sentences is K. (I shall assume, for simplicity's sake, that K is consistent. Should our beliefs be inconsistent then it is more appropriate to regard K as some tidied version of our beliefs.) The general problem I have set is that of specifying $E(K)$, the *explanatory store over K,* which is the set of arguments acceptable as the basis for acts of explanation by those whose beliefs are exactly the members of K. (For the purposes of this paper I shall assume that, for each K there is exactly one $E(K)$.)

The unofficial view answers the problem: for each K, $E(K)$ is the set of arguments which best unifies K. My task is to articulate the answer. I begin by looking at two historical episodes in which the desire for unification played a crucial role. In both cases, we find three important features: (i) prior to the articulation of a theory with high predictive power, certain proposals for theory construction are favored on grounds of their explanatory promise; (ii) the explanatory power of embryonic theories is explicitly tied to the notion of unification; (iii) particular features of the theories are taken to support their claims to unification. Recognition of (i) and (ii) will illustrate points that have already been made, while (iii) will point towards an analysis of the concept of unification.

3. A Newtonian Program. Newton's achievements in dynamics, astronomy and optics inspired some of his successors to undertake an am-

bitious program which I shall call "dynamic corpuscularianism".[4] *Principia* had shown how to obtain the motions of bodies from a knowledge of the forces acting on them, and had also demonstrated the possibility of dealing with gravitational systems in a unified way. The next step would be to isolate a few basic force laws, akin to the law of universal gravitation, so that, applying the basic laws to specifications of the dispositions of the ultimate parts of bodies, all of the phenomena of nature could be derived. Chemical reactions, for example, might be understood in terms of the rearrangement of ultimate parts under the action of cohesive and repulsive forces. The phenomena of reflection, refraction and diffraction of light might be viewed as resulting from a special force of attraction between light corpuscles and ordinary matter. These speculations encouraged eighteenth century Newtonians to construct very general hypotheses about inter-atomic forces—even in the absence of any confirming evidence for the existence of such forces.

In the preface to *Principia,* Newton had already indicated that he took dynamic corpuscularianism to be a program deserving the attention of the scientific community:

> I wish we could derive the rest of the phenomena of Nature by the same kind of reasoning from mechanical principles, for I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards one another, and cohere in regular figures, or are repelled and recede from one another (Newton 1962, p. xviii. See also Newton 1952, pp. 401-2).

This, and other influential passages, inspired Newton's successors to try to complete the unification of science by finding further force laws analogous to the law of universal gravitation. Dynamic corpuscularianism remained popular so long as there was promise of significant unification. Its appeal began to fade only when repeated attempts to specify force laws were found to invoke so many different (apparently incompatible) attractive and repulsive forces that the goal of unification appeared unlikely. Yet that goal could still motivate renewed efforts to implement the program. In the second half of the eighteenth century Boscovich revived dynamic corpuscularian hopes by claiming that the whole of natural

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[4]For illuminating accounts of Newton's influence on eighteenth century research see Cohen (1956) and Schofield (1969). I have simplified the discussion by considering only *one* of the programs which eighteenth century scientists derived from Newton's work. A more extended treatment would reveal the existence of several different approaches aimed at unifying science, and I believe that the theory of explanation proposed in this paper may help in the historical task of understanding the diverse aspirations of different Newtonians. (For the problems involved in this enterprise, see Heimann and McGuire 1971.)

philosophy can be reduced to "one law of forces existing in nature."[5]

The passage I have quoted from Newton suggests the nature of the unification that was being sought. *Principia* had exhibited how one style of argument, one "kind of reasoning from mechanical principles", could be used in the derivation of descriptions of many, diverse, phenomena. The unifying power of Newton's work consisted in its demonstration that one *pattern* of argument could be used again and again in the derivation of a wide range of accepted sentences. (I shall give a representation of the Newtonian pattern in Section 5.) In searching for force laws analogous to the law of universal gravitation, Newton's successors were trying to generalize the pattern of argument presented in *Principia,* so that one "kind of reasoning" would suffice to derive all phenomena of motion. If, furthermore, the facts studied by chemistry, optics, physiology and so forth, could be related to facts about particle motion, then one general pattern of argument would be used in the derivation of all phenomena. I suggest that this is the ideal of unification at which Newton's immediate successors aimed, which came to seem less likely to be attained as the eighteenth century wore on, and which Boscovich's work endeavored, with some success, to reinstate.

4. The Reception of Darwin's Evolutionary Theory. The picture of unification which emerges from the last section may be summarized quite simply: a theory unifies our beliefs when it provides one (or more generally, a few) pattern(s) of argument which can be used in the derivation of a large number of sentences which we accept. I shall try to develop this idea more precisely in later sections. But first I want to show how a different example suggests the same view of unification.

In several places, Darwin claims that his conclusion that species evolve through natural selection should be accepted because of its explanatory power, that ". . . the doctrine must sink or swim according as it groups and explains phenomena" (F. Darwin 1887; Vol. 2, p. 155, quoted in Hull 1974, p. 292). Yet, as he often laments, he is unable to provide any complete derivation of any biological phenomenon—our ignorance of the appropriate facts and regularities is "profound". How, then, can he contend that the primary virtue of the new theory is its explanatory power?

The answer lies in the fact that Darwin's evolutionary theory promises to unify a host of biological phenomena (C. Darwin 1964, pp. 243-4). The eventual unification would consist in derivations of descriptions of

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[5]See Boscovich (1966) Part III, especially p. 134. For an introduction to Boscovich's work, see the essays by L. L. Whyte and Z. Markovic in Whyte (1961). For the influence of Boscovich on British science, see the essays of Pearce Williams and Schofield in the same volume, and Schofield (1969).

these phenomena which would instantiate a common pattern. When Darwin expounds his doctrine what he offers us is the pattern. Instead of detailed explanations of the presence of some particular trait in some particular species, Darwin presents two "imaginary examples" (C. Darwin 1964, pp. 90-96) and a diagram, which shows, in a general way, the evolution of species *represented by schematic letters* (1964, pp. 116-126). In doing so, he exhibits a pattern of argument, which, he maintains, can be instantiated, *in principle,* by a complete and rigorous derivation of descriptions of the characteristics of any current species. The derivation would employ the principle of natural selection—as well as premises describing ancestral forms and the nature of their environment and the (unknown) laws of variation and inheritance. In place of detailed evolutionary stories, Darwin offers *explanation-sketches*. By showing how a particular characteristic would be advantageous to a particular species, he indicates an explanation of the emergence of that characteristic in the species, suggesting the outline of an argument instantiating the general pattern.

From this perspective, much of Darwin's argumentation in the *Origin* (and in other works) becomes readily comprehensible. Darwin attempts to show how his pattern can be applied to a host of biological phenomena. He claims that, by using arguments which instantiate the pattern, we can account for analogous variations in kindred species, for the greater variability of specific (as opposed to generic) characteristics, for the facts about geographical distribution, and so forth. But he is also required to resist challenges that the pattern cannot be applied in some cases, that premises for arguments instantiating the pattern will not be forthcoming. So, for example, Darwin must show how evolutionary stories, fashioned after his pattern, can be told to account for the emergence of complex organs. In both aspects of his argument, whether he is responding to those who would limit the application of his pattern or whether he is campaigning for its use within a realm of biological phenomena, Darwin has the same goal. He aims to show that his theory should be accepted because it unifies and explains.

5. Argument Patterns. Our two historical examples[6] have led us to the conclusion that the notion of an argument pattern is central to that of explanatory unification. Quite different considerations could easily have pointed us in the same direction. If someone were to distinguish between the explanatory worth of two arguments instantiating a common pattern,

[6]The examples could easily be multiplied. I think it is possible to understand the structure and explanatory power of such theories as modern evolutionary theory, transmission genetics, plate tectonics, and sociobiology in the terms I develop here.

then we would regard that person as an explanatory deviant. To grasp the concept of explanation is to see that if one accepts an argument as explanatory, one is thereby committed to accepting as explanatory other arguments which instantiate the same pattern.

To say that members of a set of arguments instantiate a common pattern is to recognize that the arguments in the set are similar in some interesting way. With different interests, people may fasten on different similarities, and may arrive at different notions of argument pattern. Our enterprise is to characterize the concept of argument pattern which plays a role in the explanatory activity of scientists.

Formal logic, ancient and modern, is concerned in one obvious sense with patterns of argument. The logician proceeds by isolating a small set of expressions (the logical vocabulary), considers the schemata formed from sentences by replacing with dummy letters all expressions which do not belong to this set, and tries to specify which sequences of these schemata are valid patterns of argument. The pattern of argument which is taught to students of Newtonian dynamics is not a pattern of the kind which interests logicians. It has instantiations with different logical structures. (A rigorous derivation of the equations of motion of different dynamical systems would have a logical structure depending on the number of bodies involved and the mathematical details of the integration.) Moreover, an argument can only instantiate the Newtonian pattern if particular *non*logical terms, 'force', 'mass' and 'acceleration', occur in it in particular ways. However, the logician's approach can help us to isolate the notion of argument pattern which we require.

Let us say that a *schematic sentence* is an expression obtained by replacing some, but not necessarily all, the nonlogical expressions occurring in a sentence with dummy letters. A set of *filling instructions* for a schematic sentence is a set of directions for replacing the dummy letters of the schematic sentence, such that, for each dummy letter, there is a direction which tells us how it should be replaced. A *schematic argument* is a sequence of schematic sentences. A *classification* for a schematic argument is a set of sentences which describe the inferential characteristics of the schematic argument: its function is to tell us which terms in the sequence are to be regarded as premises, which are to be inferred from which, what rules of inference are to be used, and so forth.

We can use these ideas to define the concept of a *general argument pattern*. A general argument pattern is a triple consisting of a schematic argument, a set of sets of filling instructions containing one set of filling instructions for each term of the schematic argument, and a classification for the schematic argument. A sequence of sentences instantiates the general argument pattern just in case it meets the following conditions:

(i) The sequence has the same number of terms as the schematic argument of the general argument pattern.

(ii) Each sentence in the sequence is obtained from the corresponding schematic sentence in accordance with the appropriate set of filling instructions.

(iii) It is possible to construct a chain of reasoning which assigns to each sentence the status accorded to the corresponding schematic sentence by the classification.

We can make these definitions more intuitive by considering the way in which they apply to the Newtonian example. Restricting ourselves to the basic pattern used in treating systems which contain one body (such as the pendulum and the projectile) we may represent the schematic argument as follows:

(1) The force on α is β.
(2) The acceleration of α is γ.
(3) Force = mass·acceleration.
(4) (Mass of α)·(γ) = β
(5) $\delta = \theta$

The filling instructions tell us that all occurrences of 'α' are to be replaced by an expression referring to the body under investigation; occurrences of 'β' are to be replaced by an algebraic expression referring to a function of the variable coordinates and of time; 'γ' is to be replaced by an expression which gives the acceleration of the body as a function of its coordinates and their time-derivatives (thus, in the case of a one-dimensional motion along the x-axis of a Cartesian coordinate system, 'γ' would be replaced by the expression 'd^2x/dt^2'); 'δ' is to be replaced by an expression referring to the variable coordinates of the body, and 'θ' is to be replaced by an explicit function of time, (thus the sentences which instantiate (5) reveal the dependence of the variable coordinates on time, and so provide specifications of the positions of the body in question throughout the motion). The classification of the argument tells us that (1)-(3) have the status of premises, that (4) is obtained from them by substituting identicals, and that (5) follows from (4) using algebraic manipulation and the techniques of the calculus.

Although the argument patterns which interest logicians are general argument patterns in the sense just defined, our example exhibits clearly the features which distinguish the kinds of patterns which scientists are trained to use. Whereas logicians are concerned to display all the schematic premises which are employed and to specify exactly which rules of inference are used, our example allows for the use of premises (math-

ematical assumptions) which do not occur as terms of the schematic ar-
gument and it does not give a complete description of the way in which
the route from (4) to (5) is to go. Moreover, our pattern does not replace
all nonlogical expressions by dummy letters. Because some nonlogical
expressions remain, the pattern imposes special demands on arguments
which instantiate it. In a different way, restrictions are set by the instruc-
tions for replacing dummy letters. The patterns of logicians are very lib-
eral in both these latter respects. The conditions for replacing dummy
letters in Aristotelian syllogisms, or first-order schemata, require only
that some letters be replaced with predicates, others with names.

Arguments may be similar either in terms of their logical structure or
in terms of the nonlogical vocabulary they employ at corresponding
places. I think that the notion of similarity (and the corresponding notion
of pattern) which is central to the explanatory activity of scientists results
from a compromise in demanding these two kinds of similarity. I propose
that scientists are interested in *stringent* patterns of argument, patterns
which contain some nonlogical expressions and which are fairly similar
in terms of logical structure. The Newtonian pattern cited above furnishes
a good example. Although arguments instantiating this pattern do not
have exactly the same logical structure, the classification imposes con-
ditions which ensure that there will be similarities in logical structure
among such arguments. Moreover, the presence of the nonlogical terms
sets strict requirements on the instantiations and so ensures a different
type of kinship among them. Thus, without trying to provide an exact
analysis of the notion of stringency, we may suppose that the stringency
of a pattern is determined by two different constraints: (1) the conditions
on the substitution of expressions for dummy letters, jointly imposed by
the presence of nonlogical expressions in the pattern and by the filling
instructions; and, (2) the conditions on the logical structure, imposed by
the classification. If both conditions are relaxed completely then the no-
tion of pattern degenerates so as to admit *any* argument. If both conditions
are simultaneously made as strict as possible, then we obtain another
degenerate case, a ''pattern'' which is its own unique instantiation. If
condition (2) is tightened at the total expense of (1), we produce the
logician's notion of pattern. The use of condition (1) requires that ar-
guments instantiating a common pattern draw on a common nonlogical
vocabulary. We can glimpse here that ideal of unification through the use
of a few theoretical concepts which the remarks of Hempel and Feigl
suggest.

Ideally, we should develop a precise account of how these two kinds
of similarity are weighted against one another. The best strategy for ob-
taining such an account is to see how claims about stringency occur in
scientific discussions. But scientists do not make explicit assessments of

the stringency of argument patterns. Instead they evaluate the ability of a theory to explain and to unify. The way to a refined account of stringency lies through the notions of explanation and unification.

6. Explanation as Unification. As I have posed it, the problem of explanation is to specify which set of arguments we ought to accept for explanatory purposes given that we hold certain sentences to be true. Obviously this formulation can encourage confusion: we must not think of a scientific community as *first* deciding what sentences it will accept and *then* adopting the appropriate set of arguments. The Newtonian and Darwinian examples should convince us that the promise of explanatory power enters into the modification of our beliefs. So, in proposing that $E(K)$ is a function of K, I do not mean to suggest that the acceptance of K must be temporally prior to the adoption of $E(K)$.
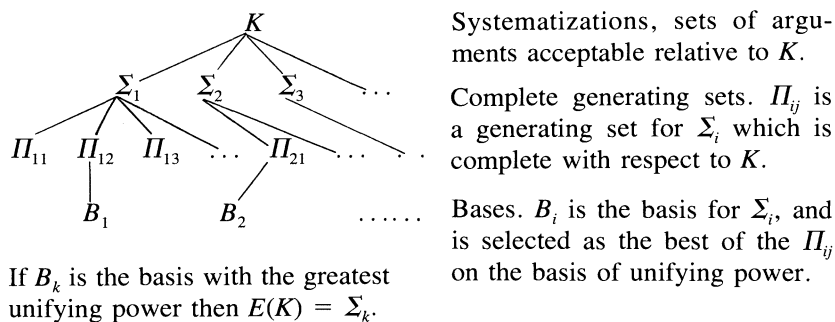
$E(K)$ is to be that set of arguments which best unifies K. There are, of course, usually many ways of deriving some sentences in K from others. Let us call a set of arguments which derives some members of K from other members of K a *systematization* of K. We may then think of $E(K)$ as the best systematization of K.

Let us begin by making explicit an idealization which I have just made tacitly. A set of arguments will be said to be *acceptable relative to K* just in case every argument in the set consists of a sequence of steps which accord with elementary valid rules of inference (deductive or inductive) and if every premise of every argument in the set belongs to K. When we are considering ways of systematizing K we restrict our attention to those sets of arguments which are acceptable relative to K. This is an idealization because we sometimes use as the basis of acts of explanation arguments furnished by theories whose principles we no longer believe. I shall not investigate this practice nor the considerations which justify us in engaging in it. The most obvious way to extend my idealized picture to accommodate it is to regard the explanatory store over K, as I characterize it here, as being supplemented with an extra class of arguments meeting the following conditions: (a) from the perspective of K, the premises of these arguments are approximately true; (b) these arguments can be viewed as approximating the structure of (parts of) arguments in $E(K)$; (c) the arguments are simpler than the corresponding arguments in $E(K)$. Plainly, to spell out these conditions precisely would lead into issues which are tangential to my main goal in this paper.

The moral of the Newtonian and Darwinian examples is that unification is achieved by using similar arguments in the derivation of many accepted sentences. When we confront the set of possible systematizations of K we should therefore attend to the *patterns* of argument which are employed in each systematization. Let us introduce the notion of a *gener-*

ating set: if Σ is a set of arguments then a generating set for Σ is a set of argument patterns Π such that each argument in Σ is an instantiation of some pattern in Π. A generating set for Σ will be said to be *complete with respect to K* if and only if every argument which is acceptable relative to K and which instantiates a pattern in Π belongs to Σ. In determining the explanatory store $E(K)$ we first narrow our choice to those sets of arguments which are acceptable relative to K, the systematizations of K. Then we consider, for each such set of arguments, the various generating sets of argument patterns which are complete with respect to K. (The importance of the requirement of completeness is to debar explanatory deviants who use patterns selectively.) Among these latter sets we select that set with the greatest unifying power (according to criteria shortly to be indicated) and we call the selected set the *basis* of the set of arguments in question. The explanatory store over K is that systematization whose basis does best by the criteria of unifying power.

This complicated picture can be made clearer, perhaps, with the help of a diagram.

Systematizations, sets of arguments acceptable relative to K.

Complete generating sets. Π_{ij} is a generating set for Σ_i which is complete with respect to K.

Bases. B_i is the basis for Σ_i, and is selected as the best of the Π_{ij} on the basis of unifying power.

If B_k is the basis with the greatest unifying power then $E(K) = \Sigma_k$.

The task which confronts us is now formulated as that of specifying the factors which determine the unifying power of a set of argument patterns. Our Newtonian and Darwinian examples inspire an obvious suggestion: unifying power is achieved by generating a large number of accepted sentences as the conclusions of acceptable arguments which instantiate a few, stringent patterns. With this in mind, we define the *conclusion set* of a set of arguments Σ, $C(\Sigma)$, to be the set of sentences which occur as conclusions of some argument in Σ. So we might propose that the unifying power of a basis B_i with respect to K varies directly with the size of $C(\Sigma_i)$, varies directly with the stringency of the patterns which belong to B_i, and varies inversely with the number of members of B_i. This proposal is along the right lines, but it is, unfortunately, too simple.

The pattern of argument which derives a specification of the positions of bodies as explicit functions of time from a specification of the forces

acting on those bodies is, indeed, central to Newtonian explanations. But not every argument used in Newtonian explanations instantiates this pattern. Some Newtonian derivations consist of an argument instantiating the pattern followed by further derivations from the conclusion. Thus, for example, when we explain why a pendulum has the period it does we may draw on an argument which *first* derives the equation of motion of the pendulum and *then* continues by deriving the period. Similarly, in explaining why projectiles projected with fixed velocity obtain maximum range when projected at 45° to the horizontal, we first show how the values of the horizontal and vertical coordinates can be found as functions of time and the angle of elevation, use our results to compute the horizontal distance travelled by the time the projectile returns to the horizontal, and then show how this distance is a maximum when the angle of elevation of projection is 45°. In both cases we take further steps beyond the computation of the explicit equations of motion—and the further steps in each case are different.

If we consider the entire range of arguments which Newtonian dynamics supplies for explanatory purposes, we find that these arguments instantiate a number of different patterns. Yet these patterns are not entirely distinct, for all of them proceed by using the computation of explicit equations of motion as a prelude to further derivation. It is natural to suggest that the pattern of computing equations of motion is the *core* pattern provided by Newtonian theory, and that the theory also shows how conclusions generated by arguments instantiating the core pattern can be used to derive further conclusions. In some Newtonian explanations, the core pattern is supplemented by a *problem-reducing pattern*, a pattern of argument which shows how to obtain a further type of conclusion from explicit equations of motion.

This suggests that our conditions on unifying power should be modified, so that, instead of merely counting the number of different patterns in a basis, we pay attention to similarities among them. All the patterns in the basis may contain a common core pattern, that is, each of them may contain some pattern as a subpattern. The unifying power of a basis is obviously increased if some (or all) of the patterns it contains share a common core pattern.

As I mentioned at the beginning of this paper, the account of explanation as unification is complicated. The explanatory store is determined on the basis of criteria which pull in different directions, and I shall make no attempt here to specify precisely the ways in which these criteria are to be balanced against one another. Instead, I shall show that some traditional problems of scientific explanation can be solved without more detailed specification of the conditions on unifying power. For the account I have indicated has two important corollaries.

(A) Let Σ, Σ' be sets of arguments which are acceptable relative to
    K and which meet the following conditions:
      (i) the basis of Σ' is as good as the basis of Σ in terms of the
          criteria of stringency of patterns, paucity of patterns, pres-
          ence of core patterns, and so forth.
      (ii) $C(\Sigma)$ is a proper subset of $C(\Sigma')$.
      Then $\Sigma \neq E(K)$.
(B) Let Σ, Σ' be sets of arguments which are acceptable relative to
    K and which meet the following conditions:
      (i) $C(\Sigma) = C(\Sigma')$
      (ii) the basis of Σ' is a proper subset of the basis of Σ.
      Then $\Sigma \neq E(K)$

(A) and (B) tell us that sets of arguments which do equally well in terms
of some of our conditions are to be ranked according to their relative
ability to satisfy the rest. I shall try to show that (A) and (B) have in-
teresting consequences.

7. Asymmetry, Irrelevance and Accidental Generalization. Some fa-
miliar difficulties beset the covering law model. The *asymmetry problem*
arises because some scientific laws have the logical form of equivalences.
Such laws can be used "in either direction". Thus a law asserting that
the satisfaction of a condition C_1 is equivalent to the satisfaction of a
condition C_2 can be used in two different kinds of argument. From a
premise asserting that an object meets C_1, we can use the law to infer
that it meets C_2; conversely, from a premise asserting that an object meets
C_2, we can use the law to infer that it meets C_1. The asymmetry problem
is generated by noting that in many such cases one of these derivations
can be used in giving explanations while the other cannot.

Consider a hoary example. (For further examples, see Bromberger
1966.) We can explain why a simple pendulum has the period it does by
deriving a specification of the period from a specification of the length
and the law which relates length and period. But we cannot explain the
length of the pendulum by deriving a specification of the length from a
specification of the period and the same law. What accounts for our dif-
ferent assessment of these two arguments? Why does it seem that one is
explanatory while the other "gets things backwards"? The covering law
model fails to distinguish the two, and thus fails to provide answers.

The *irrelevance problem* is equally vexing. The problem arises because
we can sometimes find a lawlike connection between an accidental and
irrelevant occurrence and an event or state which would have come about
independently of that occurrence. Imagine that Milo the magician waves
his hands over a sample of table salt, thereby "hexing" it. It is true (and

I shall suppose, lawlike) that all hexed samples of table salt dissolve when placed in water. Hence we can construct a derivation of the dissolving of Milo's hexed sample of salt by citing the circumstances of the hexing. Although this derivation fits the covering law model, it is, by our ordinary lights, nonexplanatory. (This example is given by Wesley Salmon in his (1970); Salmon attributes it to Henry Kyburg. For more examples, see Achinstein 1971.)

The covering law model explicitly debars a further type of derivation which any account of explanation ought to exclude. Arguments whose premises contain no laws, but which make essential use of accidental generalizations are intuitively nonexplanatory. Thus, if we derive the conclusion that Horace is bald from premises stating that Horace is a member of the Greenbury School Board and that all members of the Greenbury School Board are bald we do not thereby explain why Horace is bald. (See Hempel 1965, p. 339.) We shall have to show that our account does not admit as explanatory derivations of this kind.

I want to show that the account of explanation I have sketched contains sufficient resources to solve these problems.[7] In each case we shall pursue a common strategy. Faced with an argument we want to exclude from the explanatory store we endeavor to show that any set of arguments containing the unwanted argument could not provide the best unification of our beliefs. Specifically, we shall try to show either that any such set of arguments will be more limited than some other set with an equally satisfactory basis, or that the basis of the set must fare worse according to the criterion of using the smallest number of most stringent patterns. That is, we shall appeal to the corollaries (A) and (B) given above. In actual practice, this strategy for exclusion is less complicated than one might fear, and, as we shall see, its applications to the examples just discussed brings out what is intuitively wrong with the derivations we reject.

Consider first the irrelevance problem. Suppose that we were to accept as explanatory the argument which derives a description of the dissolving of the salt from a description of Milo's act of hexing. What will be our policy for explaining the dissolving of samples of salt which have not been hexed? If we offer the usual chemical arguments in these latter cases then we shall commit ourselves to an inflated basis for the set of arguments we accept as explanatory. For, unlike the person who explains *all* cases of dissolving of samples of salt by using the standard chemical

[7]More exactly, I shall try to show that my account can solve some of the principal versions of these difficulties which have been used to discredit the covering law model. I believe that it can also overcome more refined versions of the problems than I consider here, but to demonstrate that would require a more lengthy exposition.

pattern of argument, we shall be committed to the use of two different patterns of argument in covering such cases. Nor is the use of the extra pattern of argument offset by its applicability in explaining other phenomena. Our policy employs one extra pattern of argument without extending the range of things we can derive from our favored set of arguments. Conversely, if we eschew the standard chemical pattern of argument (just using the pattern which appeals to the hexing) we shall find ourselves unable to apply our favored pattern to cases in which the sample of salt dissolved has not been hexed. Moreover, the pattern we use will not fall under the more general patterns we employ to explain chemical phenomena such as solution, precipitation and so forth. Hence the unifying power of the basis for our preferred set of arguments will be less than that of the basis for the set of arguments we normally accept as explanatory.[8]

If we explain the dissolving of the sample of salt which Milo has hexed by appealing to the hexing then we are faced with the problems of explaining the dissolving of unhexed samples of salt. We have two options: (a) to adopt two patterns of argument corresponding to the two kinds of case; (b) to adopt one pattern of argument whose instantiations apply just to the cases of hexed salt. If we choose (a) then we shall be in conflict with [B], whereas choice of (b) will be ruled out by [A]. The general moral is that appeals to hexing fasten on a local and accidental feature of the cases of solution. By contrast our standard arguments instantiate a pattern which can be generally applied.[9]

[8]There is an objection to this line of reasoning. Can't we view the arguments $<(x)((Sx$ & $Hx) \rightarrow Dx)$, Sa & Ha, $Da>$, $<(x)((Sx$ & $\sim Hx) \rightarrow Dx)$, Sb & $\sim Hb$, $Db>$ as instantiating a common pattern? I reply that, insofar as we can view these arguments as instantiating a common pattern, the standard pair of comparable (low-level) derivations—$<(x)(Sx \rightarrow Dx)$, $Sa,Da>$, $<(x)(Sx \rightarrow Dx)$, Sb, $Db>$—share a more stringent common pattern. Hence, incorporating the deviant derivations in the explanatory store would give us an inferior basis. We can justify the claim that the pattern instantiated by the standard pair of derivations is more stringent than that shared by the deviant derivations, by noting that representation of the deviant pattern would compel us to broaden our conception of schematic sentence, and, even were we to do so, the deviant pattern would contain a "degree of freedom" which the standard pattern lacks. For a representation of the deviant "pattern" would take the form $<(x)((Sx$ & $\alpha Hx) \rightarrow Dx)$, Sa & αHa, $Da>$, where 'α' is to be replaced uniformly either with the null symbol or with '$\sim$'. Even if we waive my requirement that, in schematic sentences, we substitute for *non*logical vocabulary, it is evident that this "pattern" is more accommodating than the standard pattern.

[9]However, the strategy I have recommended will not avail with a different type of case. Suppose that a deviant wants to explain the dissolving of the salt by appealing to some property which holds universally. That is, the "explanatory" arguments are to begin from some premise such as "$(x)((x$ is a sample of salt & x does not violate conservation of energy) $\rightarrow x$ dissolves in water)" or "$(x)((x$ is a sample of salt & $x = x) \rightarrow x$ dissolves in water)." I would handle these cases somewhat differently. If the deviant's explanatory store were to be as unified as our own, then it would contain arguments corresponding to ours in which a redundant conjunct systematically occurred, and I think it would be plausible to invoke a criterion of simplicity to advocate dropping that conjunct.

A similar strategy succeeds with the asymmetry problem. We have general ways of explaining why bodies have the dimensions they do. Our practice is to describe the circumstances leading to the formation of the object in question and then to show how it has since been modified. Let us call explanations of this kind "origin and development derivations". (In some cases, the details of the original formation of the object are more important; with other objects, features of its subsequent modification are crucial.) Suppose now that we admit as explanatory a derivation of the length of a simple pendulum from a specification of the period. Then we shall either have to explain the lengths of *non*swinging bodies by employing quite a different style of explanation (an origin and development derivation) or we shall have to forego explaining the lengths of such bodies. The situation is exactly parallel to that of the irrelevance problem. Admitting the argument which is intuitively nonexplanatory saddles us with a set of arguments which is less good at unifying our beliefs than the set we normally choose for explanatory purposes.

Our approach also solves a more refined version of the pendulum problem (given by Paul Teller in his (1974)). Many bodies which are not currently executing pendulum motion *could* be making small oscillations, and, were they to do so, the period of their motion would be functionally related to their dimensions. For such bodies we can specify the *dispositional period* as the period which the body would have if it were to execute small oscillations. Someone may now suggest that we can construct derivations of the dimensions of bodies from specifications of their dispositional periods, thereby generating an argument pattern which can be applied as generally as that instantiated in origin and development explanations. This suggestion is mistaken. There are some objects—such as the Earth and the Crab Nebula—which *could not* be pendulums, and for which the notion of a dispositional period makes no sense. Hence, the argument pattern proposed cannot entirely supplant our origin and development derivations, and, in consequence, acceptance of it would fail to achieve the best unification of our beliefs.

The problem posed by accidental generalizations can be handled in parallel fashion. We have a general pattern of argument, using principles of physiology, which we apply to explain cases of baldness. This pattern is generally applicable, whereas that which derives ascriptions of baldness using the principle that all members of the Greenbury School Board are bald is not. Hence, as in the other cases, sets which contain the unwanted derivation will be ruled out by one of the conditions (A), (B).

Of course, this does not show that an account of explanation along the lines I have suggested would sanction only derivations which satisfy the conditions imposed by the covering law model. For I have not argued that an explanatory derivation need contain *any* sentence of universal

form. What *does* seem to follow from the account of explanation as unification is that explanatory arguments must not use accidental generalization, and, in this respect, the new account appears to underscore and generalize an important insight of the covering law model. Moreover, our success with the problems of asymmetry and irrelevance indicates that, even in the absence of a detailed account of the notion of stringency and of the way in which generality of the consequence set is weighed against paucity and stringency of the patterns in the basis, the view of explanation as unification has the resources to solve some traditional difficulties for theories of explanation.

8. Spurious Unification. Unfortunately there is a fly in the ointment. One of the most aggravating problems for the covering law model has been its failure to exclude certain types of self-explanation. (For a classic source of difficulties see Eberle, Kaplan and Montague 1961.) As it stands, the account of explanation as unification seems to be even more vulnerable on this score. The problem derives from a phenomenon which I shall call *spurious unification*.

Consider, first, a difficulty which Hempel and Oppenheim noted in a seminal article (Hempel 1965, Chapter 10). Suppose that we conjoin two laws. Then we can derive one of the laws from the conjunction, and the derivation conforms to the covering law model (unless, of course, the model is restricted to cover only the explanation of singular sentences; Hempel and Oppenheim do, in fact, make this restriction). To quote Hempel and Oppenheim:

> The core of the difficulty can be indicated briefly by reference to an example: Kepler's laws, K, may be conjoined with Boyle's law, B, to a stronger law $K \cdot B$; but derivation of K from the latter would not be considered as an explanation of the regularities stated in Kepler's laws; rather it would be viewed as representing, in effect, a pointless "explanation" of Kepler's laws by themselves. (Hempel 1965, p. 273 fn. 33.)

This problem is magnified for our account. For, why may we not unify our beliefs *completely* by deriving all of them using arguments which instantiate the one pattern?

$$\frac{\alpha \ \& \ B}{\alpha} \qquad [`\alpha' \text{ is to be replaced by any sentence we accept.}]$$

Or, to make matters even more simple, why should we not unify our beliefs by using the most trivial pattern of self-derivation?

$$\alpha \qquad [`\alpha' \text{ is to be replaced by any sentence we accept.}]$$

There is an obvious reply. The patterns just cited may succeed admirably in satisfying our criteria of using a few patterns of argument to generate many beliefs, but they fail dismally when judged by the criterion of stringency. Recall that the stringency of a pattern is assessed by adopting a compromise between two constraints: stringent patterns are not only to have instantiations with similar logical structures; their instantiations are also to contain similar nonlogical vocabulary at similar places. Now both of the above argument patterns are very lax in allowing any vocabulary whatever to appear in the place of 'α'. Hence we can argue that, according to our intuitive concept of stringency, they should be excluded as non-stringent.

Although this reply is promising, it does not entirely quash the objection. A defender of the unwanted argument patterns may *artificially* introduce restrictions on the pattern to make it more stringent. So, for example, if we suppose that one of *our* favorite patterns (such as the Newtonian pattern displayed above) is applied to generate conclusions meeting a particular condition C, the defender of the patterns just cited may propose that 'α' is to be replaced, not by any sentence, but by a sentence which meets C. He may then legitimately point out that his newly contrived pattern is as stringent as our favored pattern. Inspired by this partial success, he may adopt a general strategy. Wherever we use an argument pattern to generate a particular type of conclusion, he may use some argument pattern which involves self-derivation, placing an appropriate restriction on the sentences to be substituted for the dummy letters. In this way, he will mimic whatever unification we achieve. His "unification" is obviously spurious. How do we debar it?

The answer comes from recognizing the way in which the stringency of the unwanted patterns was produced. Any condition on the substitution of sentences for dummy letters would have done equally well, provided only that it imposed constraints comparable to those imposed by acceptable patterns. Thus the stringency of the restricted pattern seems accidental to it. This accidental quality is exposed when we notice that we can vary the filling instructions, while retaining the same syntactic structure, to obtain a host of other argument patterns with equally many instantiations. By contrast, the constraints imposed on the substitution of nonlogical vocabulary in the Newtonian pattern (for example) cannot be amended without destroying the stringency of the pattern or without depriving it of its ability to furnish us with many instantiations. Thus the constraints imposed in the Newtonian pattern are essential to its functioning; those imposed in the unwanted pattern are not.

Let us formulate this idea as an explicit requirement. If the filling instructions associated with a pattern P could be replaced by different filling instructions, allowing for the substitution of a class of expressions of the

same syntactic category, to yield a pattern P' and if P' would allow the derivation of *any* sentence, then the unification achieved by P is spurious. Consider, in this light, any of the patterns which we have been trying to debar. In each case, we can vary the filling instructions to produce an even more "successful" pattern. So, for example, given the pattern:

α ['α' is to be replaced by a sentence meeting condition C]

we can generalize the filling instructions to obtain

α ['α' is to be replaced by any sentence].

Thus, under our new requirement, the unification achieved by the original pattern is spurious.

In a moment I shall try to show how this requirement can be motivated, both by appealing to the intuition which underlies the view of explanation as unification and by recognizing the role that something like my requirement has played in the history of science. Before I do so, I want to examine a slightly different kind of example which initially appears to threaten my account. Imagine that a group of religious fanatics decides to argue for the explanatory power of some theological doctrines by claiming that these doctrines unify their beliefs about the world. They suggest that their beliefs can be systematized by using the following pattern:

God wants it to be the case that α.   ['α' is to be replaced by any
What God wants to be the case is   accepted sentence describing
the case.   the physical world]
_____
α

The new requirement will also identify as spurious the pattern just presented, and will thus block the claim that the theological doctrines that God exists and has the power to actualize his wishes have explanatory power. For it is easy to see that we can modify the filling instructions to obtain a pattern that will yield any sentence whatsoever.

Why should patterns whose filling instructions can be modified to accommodate any sentence be suspect? The answer is that, in such patterns, the nonlogical vocabulary which remains is idling. The presence of that nonlogical vocabulary imposes no constraints on the expressions we can substitute for the dummy symbols, so that, beyond the specification that a place be filled by expressions of a particular syntactic category, the structure we impose by means of filling instructions is quite incidental. Thus the patterns in question do not genuinely reflect the contents of our beliefs. The explanatory store should present the order of natural phenomena which is exposed by what we think we know. To do so, it must exhibit connections among our beliefs beyond those which could be found

among any beliefs. Patterns of self-derivation and the type of pattern exemplified in the example of the theological community merely provide trivial, omnipresent connections, and, in consequence, the unification they offer is spurious.

My requirement obviously has some kinship with the requirement that the principles put forward in giving explanations be testable. As previous writers have insisted that genuine explanatory theories should not be able to cater to all possible evidence, I am demanding that genuinely unifying patterns should not be able to accommodate all conclusions. The requirement that I have proposed accords well with some of the issues which scientists have addressed in discussing the explanatory merits of particular theories. Thus several of Darwin's opponents complain that the explanatory benefits claimed for the embryonic theory of evolution are illusory, on the grounds that the style of reasoning suggested could be adapted to any conclusion. (For a particularly acute statement of the complaint, see the review by Fleeming Jenkin, printed in Hull 1974, especially p. 342.) Similarly, Lavoisier denied that the explanatory power of the phlogiston theory was genuine, accusing that theory of using a type of reasoning which could adapt itself to any conclusion (Lavoisier 1862, Volume II p. 233). Hence I suggest that some problems of spurious unification can be solved in the way I have indicated, and that the solution conforms both to our intuitions about explanatory unification and to the considerations which are used in scientific debate.

However, I do not wish to claim that my requirement will debar all types of spurious unification. It may be possible to find other unwanted patterns which circumvent my requirement. A full characterization of the notion of a stringent argument pattern should provide a criterion for excluding the unwanted patterns. My claim in this section is that it will do so by counting as spurious the unification achieved by patterns which adapt themselves to any conclusion and by patterns which accidentally restrict such universally hospitable patterns. I have also tried to show how this claim can be developed to block the most obvious cases of spurious unification.

9. Conclusions. I have sketched an account of explanation as unification, attempting to show that such an account has the resources to provide insight into episodes in the history of science and to overcome some traditional problems for the covering law model. In conclusion, let me indicate very briefly how my view of explanation as unification suggests how scientific explanation yields understanding. By using a few patterns of argument in the derivation of many beliefs we minimize the number of *types* of premises we must take as underived. That is, we reduce, in so far as possible, the number of types of facts we must accept as brute.

Hence we can endorse something close to Friedman's view of the merits of explanatory unification (Friedman 1974, pp. 18-19).

Quite evidently, I have only *sketched* an account of explanation. To provide precise analyses of the notions I have introduced, the basic approach to explanation offered here must be refined against concrete examples of scientific practice. What needs to be done is to look closely at the argument patterns favored by scientists and attempt to understand what characteristics they share. If I am right, the scientific search for explanation is governed by a maxim, once formulated succinctly by E. M. Forster. Only connect.

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