

## EXPLANATORY UNDERSTANDING AND CONTRASTIVE FACTS

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### ABSTRACT

After reviewing pragmatic, inferential, and causal accounts of explanatory understanding, I develop a fourth account based on an analysis of the notion of nomic responsibility. I also give an account of the object of explanation in terms of three types of contrastive facts and show that the conditions nomically responsible for these types of facts are not too numerous to identify.

There are three widely recognized approaches — pragmatic, inferential, and causal — to analyzing scientific explanation as it pertains to singular facts or events. These three approaches essentially agree that the purpose of an explanation is to provide some kind of explanatory understanding of the explanandum phenomenon, but disagree about the nature of this understanding and how it is to be achieved. After discussing some of the shortcomings of these approaches, I will offer a fourth alternative and attempt to show that it provides a more adequate account of explanatory understanding.

### I

Let us begin by considering the pragmatic approach. The most sophisticated and thoroughly pragmatic treatment of explanation is to be found in Bas van Fraassen's important work *The Scientific Image* (1980) (cf. Achinstein 1983, and Sintonen 1984). On van Fraassen's view, an explanation is essentially an answer to a why-question, where the nature of the question as well as the evaluation of answers are determined largely

by pragmatic factors involving the particular circumstances in which the question arises.

In evaluating answers to why-questions, van Fraassen proposes that a good answer must satisfy a certain relevance relation that identifies the respect-in-which a reason is requested. This relevance relation, however, is not the same in all cases and instead varies from one context to another depending on the particular interests of the person asking the why-question. For example, the relevance relation might vary from "give me a motive strong enough to account for murder" to "give me a statistically relevant preceding event not screened off by other events" to "give me a common cause" (1980, p. 144). This leads van Fraassen to conclude that scientific explanation is properly a part of applied rather than pure science. Or as he expresses it:

So scientific explanation is not (pure) science but an application of science. It is a use of science to satisfy certain of our desires; and these desires are quite specific in a specific context .... The exact content of the desire, and the evaluation of how well it is satisfied, varies from context to context. It is not a single desire, the same in all cases, for a very special sort of thing, but rather, in each case, a different desire for something of a quite familiar sort. (1980, p. 156)

According to this view, then, explanatory understanding, rather than being confined to a single thing that applies in all cases, varies from one context to another, consisting in whatever properly satisfies the interest or desire that prompts an individual to raise a why-question.

There is something rather vacuous about this pragmatic conception of explanatory understanding. In particular, by not imposing any restrictions on the sorts of interests or desires the proper satisfaction of which yields explanatory understanding, it is not clear whether this type of understanding has anything to do with scientific explanation. For example, suppose that in asking why the stock market crashed in 1987, the person raising the question is interested in learning about some statistically irrelevant event that occurred long after the crash took place. We can easily find a factual answer that satisfies this person's curiosity, such as pointing out that there were two full moons during January 1992; but it seems absurd to regard this answer as providing explanatory understanding, in any scientific sense, regarding why the market happened to

crash. What this shows is that there is an important difference between explanatory understanding as it relates to science and simply satisfying a person's personal curiosity. So although it is perhaps not implausible to regard explanatory understanding as a function of some type of interest, at least some constraints must be placed on what type of interest this is in matters of scientific explanation so that not just anything a questioner has in mind will do.<sup>1</sup>

The inferential approach to explanation proposes a narrower conception of explanatory understanding. This approach, which has been most forcefully developed by Carl Hempel (Hempel and Oppenheim 1948), (1962), (1965), construes an explanation as a certain kind of logical argument that allows us to infer the explanandum on the basis of the explanans. Or more precisely, an explanation is taken to consist in a set of laws and statements of initial conditions from which follows, either deductively or inductively, a statement describing the event to be explained. A sound explanation, then, provides explanatory understanding by virtue of showing how the event in question was to be expected on the basis of the explanatory facts. Or as Hempel puts it, an explanation in the form of an "argument shows that, given the particular circumstances and the laws in question, the occurrence of the [explanandum] phenomenon *was to be expected*; and it is in this sense that the explanation enables us to *understand why* the phenomenon occurred" (1965, p. 337).

Standard criticisms of this inferential conception, criticisms that appeal to paresis (Scriven 1959), flagpoles (Bromberger 1966), and falling barometers, are well known. These criticisms are designed to show that inferring the explanandum from an explanans consisting in laws and statements of initial conditions is neither necessary nor sufficient for a sound scientific explanation. It seems to me, however, that there is a more basic worry with this inferential approach, at least as it is construed by Hempel. If, as Hempel suggests, what is essential to explanatory understanding is that the explanatory facts show that the event to be explained was to be expected, then there is no need for the explanatory facts to include any genuine laws — mere accidental generalizations will do. For example, if we are interested in why Mr. Beacon is bald, then citing the fact that he is on the school board together with the purely accidental generalization that all members of the school board are bald would establish that Mr. Beacon's baldness was to be expected. But these facts clearly do not yield any explanatory understanding regarding his

baldness. The problem is that accidental generalizations, as Hempel recognizes, are not explanatory.

There is an element of irony here. Hempel, in seeking to clarify his theory of explanation, spends a good deal of effort trying to separate genuine laws from mere accidental generalizations. Yet if explanatory understanding simply consists in understanding how the explanandum event was to be expected, then this effort is altogether misguided since for the purposes of this type of understanding accidental generalizations will do just as well as genuine laws. Explanatory understanding must thus consist in something else.

A different view of explanatory understanding is provided by the causal approach. This approach, which goes back at least to Aristotle, has been elaborated with great care by Wesley Salmon (1984) (cf. Brody 1972, Lewis 1986, and Humphreys 1989). According to Salmon, "to provide an explanation of a particular event is to identify the cause and, in many cases at least, to exhibit the causal relation between this cause and the event-to-be-explained" (1984, pp. 121-22). In defending the notion of probabilistic causation, Salmon allows that an event can be adequately explained on the basis of its causes even if these causes fail to render the event likely or something that was to be expected. Explanatory understanding is thus taken to consist simply in understanding how the event to be explained fits within the world's causal network. That is, "causal processes, causal interactions, and causal laws provide the mechanisms by which the world works; to understand *why* certain things happen, we need to see *how* they are produced by these mechanisms" (1984, p. 132).

Much of Salmon's theory of explanation is devoted to a detailed analysis of causation. But despite the merits of this analysis, I think it can be shown that the conception of explanatory understanding proposed by this causal approach is too narrow. The problem, as many philosophers now realize, is that there are cases where we understand why a given event occurred even though we are ignorant of any underlying causes.

Salmon himself notes that quantum mechanics seems to afford non-causal explanations of particular events. For example, for a system consisting of two spatially separated particles, once the angular momentum of one of the particles is measured, this simultaneously fixes, by virtue of conservation laws, the angular momentum of the other particle. Appealing to the quantity of angular momentum measured for one of these

particles thus seems to explain the quantity of angular momentum simultaneously possessed by the other even though, since causal signals can not proceed faster than the speed of light, there is no causal connection. Salmon is troubled by this kind of case, but he is not prepared to concede that no causal mechanism is at work. Instead he suggests that new developments in physical theory might yield causal explanations for quantum phenomena. Sticking to a causal conception of explanatory understanding might indeed be warranted if quantum mechanics were the only source for seemingly noncausal explanations. However, other sources of a less controversial nature are not too hard to find.

James Woodward (1989) points out that general relativity provides certain explanations that are grounded in geometrical rather than causal facts about the world. For example, a particle's moving along a geodesical path can be accounted for in terms of basic facts about the structure of spacetime, but these facts do not cause the particle to move as it does.

Beyond quantum mechanics and general relativity, the determination of ordinary macrophysical properties by means of underlying microphysical properties provides a whole range of cases involving noncausal explanations. For example, suppose we ask why a certain rock composed of gold is malleable. An adequate explanation can be given in terms of the underlying atomic structure of the rock, but this structure seems not to cause the rock to be malleable. After all, the malleability of the rock is simultaneous with its having the particular atomic structure and insofar as causes must precede their effects, this can not be a case of the malleability being caused by the underlying atomic structure.

Some ordinary macrophysical properties can be explained in a noncausal way on the basis of other macrophysical properties. Consider, for example, Hempel's pendulum example (1965, p. 352), an example he gives to show that explanations are best construed as arguments rather than mere lists of causes. The period of a pendulum can be explained on the basis of its having a certain length, but this length seems not to cause the period. Now some (for example Humphreys 1989) disagree with this assessment and suggest instead that the period of the pendulum is caused by its length. This suggestion, however, seems to conflate determination with causation. That is, the period of the pendulum is clearly determined in some nomological way by its length but this relation seems not to be of a causal nature, since the particular length and period obtain simul-

taneously with each other.

Finally, certain negative facts can be explained in terms of other negative facts even though there appears to be no causal connection. For example, suppose that Arney is the only person at the country club who does not suffer from paresis. Assuming that the only way to contract paresis is by having a prior case of syphilis, Arney's good fortune can be adequately explained by citing the fact that he has never had syphilis. In this case, the negative fact of Arney's not having syphilis seems not to cause the negative fact of his not having paresis, but it does explain it.

These various cases, from quantum mechanics and general relativity to ordinary macrophysical properties, pendulums, and negative facts, strongly suggest that explanatory understanding is not to be identified with understanding the factors that caused the event to be explained. This kind of causal understanding might be sufficient for explanatory understanding, but it is not necessary.

None of the three major approaches to analyzing scientific explanation yields a satisfactory account of explanatory understanding. It seems to me, however, that the causal approach is on the right track, but simply too narrow. As a first step, then, towards formulating a more adequate account, consider again the various examples of noncausal explanation.

In the case of a two particle system, noting that the angular momentum of one of the particles has been fixed helps explain why the other spatially separated particle in the system has a certain specified amount of angular momentum. And though the one event does not cause the other, it does seem to bring it about in some kind of nomological way. Indeed it appears that the explanatory relevance of the one event is grounded in its being nomically responsible for the other event. And likewise, it seems, for the other kinds of cases as well. For example, though the warped structure of spacetime does not cause a certain particle to move along a geodesical path, this structure is nevertheless nomologically responsible for the geodesic movement in a way that makes the structure explanatorily relevant. The malleability of a rock is not caused by its underlying microphysical properties, but these properties are nomically responsible for the malleability in an explanatorily relevant way. The length of a pendulum, though not causally related to its period, is nomically responsible for the period in a manner that allows the length to be explanatorily relevant. And finally, Arney's not having syphilis seems not to cause his not having paresis, but it is nomically responsible

for the absence of paresis in a way that is explanatorily relevant. Thus, based on these various cases, I wish to suggest that explanatory understanding consists not in just anything that properly satisfies a why-questioner's curiosity, nor in seeing how the explanandum event was to be expected or fits within a causal nexus, but instead in understanding the conditions nomic responsible for this event (cf. Coffa 1974). To render this more precise requires, of course, an analysis of the notion of nomic responsibility.

## II

Nomic responsibility is broader than causation in that whereas causation seems to require some kind of transfer of energy, nomic responsibility is grounded in a relation of nomological relevance. There are, however, at least two types of nomological relevance — weak and strong. For the first type,

(W) X is weakly nomologically relevant to Y iff (1) X and Y are logically independent of and consistent with each other, and (2)  $P(Y/X) \neq P(Y/\text{not-}X)$ .<sup>2</sup>

To distinguish weak nomological relevance from mere statistical relevance, the second condition is to be understood in terms of single case propensities rather than statistical frequencies. But though weak nomological relevance is stronger than statistical relevance, it turns out to be much too weak to serve as a basis for analyzing the relation of nomic responsibility.

Imagine a world W where an event A is nomic responsible for simultaneously bringing about a logically independent event B, and suppose that the laws of nature in this world are such that A is physically necessary and sufficient for B such that it is physically impossible for one of these events to occur without the other. In world W, A and B are weakly nomologically relevant to each other so that, based on this relation alone, there is no way to determine that it is A that is responsible for bringing about B instead of B bringing about A. What is needed is a relation of strong nomological relevance.

Recognizing that as a matter of physical necessity neither A nor B can occur without the other, consider the counterlegal situation that allows these events to occur *spontaneously* or entirely on their own. Since by hypothesis A brings about B but not conversely, it seems that if A were to occur spontaneously then B would occur, but if B were to occur spontaneously then it is not the case that A would occur. This notion of an event occurring spontaneously can be used for constructing a relation of strong nomological relevance. Letting an asterisk "\*" attached to an event symbol stand for the spontaneous occurrence of the event denoted,

- (S) X is strongly nomologically relevant to Y iff (1) X and Y are logically independent of and consistent with each other, and (2)  $P(Y/X^*) \neq P(Y/\text{not-}X^*)$ .

In world W, A is strongly nomologically relevant to B but not conversely since  $P(B/A^*) \neq P(B/\text{not-}A^*)$  and  $P(A/B^*) = P(A/\text{not-}B^*)$ , and this in turn provides a basis for establishing which event is nomically responsible for the other. That is, generally speaking, the conditions nomically responsible for bringing about a given event can be identified with those conditions that obtain that are strongly nomologically relevant to the event. But before setting this out more formally, an important qualification needs to be addressed.

The relation of strong nomological relevance is subject to a certain principle of weakening to the effect that if X is strongly nomologically relevant to Y, then so is the "conjunctive" condition X and X', where X' is any arbitrary condition that is logically independent of and consistent with both X and Y. For example, since striking a match is strongly nomologically relevant to the match's catching fire, so is striking the match in the dark. Intuitively, however, the condition of darkness in no way contributes to bringing about the match's catching fire. The relation of nomic responsibility thus requires that any excess baggage be eliminated, a requirement that is provided for in condition (3):

- (N) X is one of the conditions nomically responsible for bringing about Y iff (1) X and Y obtain, (2) X is strongly nomologically relevant to Y, and (3) there is no Z that is a proper consequence of X such that  $P(Y/X) = P(Y/Z)$ .



Given the analysis provided by (N) it is worth pointing out that insofar as strong nomological relevance can apply to conditions that are not causally related, nomic responsibility is thus broader than causation. Indeed, regarding the earlier examples involving quantum mechanics, general relativity, microphysical properties, pendulums, and negative facts, each example provides a case where (N) picks out a condition that is nomically but not causally responsible for some event. Causation, however, is not inconsistent with nomic responsibility and instead seems to be simply a special case of this more general nomological relation.

It might be objected that the relation of nomic responsibility, as identified by (N), is too general. In particular, since strong nomological relevance applies to conditions that merely create a change in propensity, it might seem absurd that the set of conditions nomically responsible for bringing about a given event should include conditions that actually *lower* the propensity of its occurring. Now there is, it seems to me, some merit to this objection, but rather than amending (N), let me suggest that it will be useful to recognize two distinct forms of nomic responsibility, one robust and the other lean.

Strong nomological relevance can be either positive or negative depending on whether a condition, when it is allowed to obtain spontaneously, increases or decreases the propensity of a given event. The robust form of nomic responsibility countenances both sorts of conditions, those that increase and those that decrease this propensity, and it is this form that (N) is designed to express. The lean form of nomic responsibility, on the other hand, eschews negatively relevant conditions and instead restricts itself to those conditions that increase the propensity. Now although the lean form might be more compatible with certain intuitions about one event bringing about another, both forms seem legitimate. Moreover, as I will try to show later, it is the robust form of nomic responsibility that is more suitable for dealing with the problem of scientific explanation.

Having clarified the nature of nomic responsibility, let me propose a potential objection to the view that explanatory understanding consists in understanding the conditions nomically responsible for bringing about the event to be explained.

## III

Suppose we want to explain something as simple as why a certain piece of litmus paper turned red. Allowing that the litmus paper had been dipped in battery acid, this would then be one of the conditions nomically responsible for the paper's turning red. However, according to (N) other such conditions would presumably be that the paper was not saturated with vinegar, that it was not painted black, that it was not covered with a protective coating of wax, that it was not struck by a meteor the instant it was placed in the acid, etc. Indeed there seems to be an endless number of conditions nomically responsible for the paper's turning red, conditions ranging from the rather ordinary to the extremely bizarre. The problem in this case is not only that it is virtually impossible to identify all these conditions, but that many of the more bizarre conditions seem altogether irrelevant for the purposes of understanding why the paper turned red. Moreover, the problem, rather than being unique to this particular case, seems quite general and will arise in most any situation where we try to identify all the conditions nomically responsible for a given event.

No adequate account of explanation should require that a correct explanation typically include an endless number of explanatory conditions, some of which are too bizarre to provide any genuine explanatory understanding. This type of problem, however, is quite common. For example, for van Fraassen's pragmatic approach, the problem arises from his favoring criterion (1980, pp. 146-149), a criterion that implies that the adequacy of an answer to a why-question is a function of the extent to which the answer increases the probability of what van Fraassen calls the topic of the why-question in relation to other members of its contrast class.<sup>3</sup> On Hempel's inferential account, the problem is created by the requirement that the explanans contain at least one law that is true or at least highly confirmed (1965, pp. 337-338), where any attempt to overcome the problem by appealing to some blanket *ceteris paribus* clause merely avoids the problem rather than solves it. And finally, for Salmon's causal approach, the problem occurs as a consequence of his requiring that the entire causal net surrounding the event to be explained be identified, where this causal net, according to Salmon (1984, pp. 36-37), includes all the conditions that are statistically relevant to the event. This seemingly ubiquitous problem begs for a solution.

One solution proposed by Paul Humphreys (1989) is simply to reject

the assumption that a correct explanation must include all the relevant facts. A correct or true explanation, according to Humphreys, need be neither objectively nor epistemically complete nor even approximately complete. Instead, all that is required for a true (causal) explanation is that it cite some subset of the relevant explanatory facts, a subset that includes at least one contributing, as opposed to counteracting, (causal) factor. This view, however, avoids one extreme only to embrace another. In the case of the litmus paper, for example, Humphreys' view allows that a fully correct explanation for the paper's turning red consists in noting that the paper was not struck by a meteor. Surely, however, a correct explanation must be more illuminating than this such that it is difficult to see how citing just any subset of the relevant (contributing) facts will yield a correct explanation. Consequently, the original problem remains. I wish to suggest that a better solution to this problem can be found by clarifying the nature of the explanandum event.

#### IV

In taking an explanation to be an answer to a why-question, van Fraassen (1980) argues that the underlying form of the question is not simply "Why P?" but instead "Why P in contrast to X?", where X picks out a set of alternatives to P (cf. Dretske 1973, and Garfinkel 1981). For example, when a person asks "Why does Barney have paresis?" he seems to have some kind of alternative in mind such as Barney's having paresis in contrast to Arney's having the disease. This seems to suggest that the object of explanation regarding singular events is not some particular event taken in isolation but instead a kind of contrast between events. How, then, is this contrast to be explained?

According to van Fraassen (1980), to explain why an event P occurs in contrast to another event Q, it is necessary to adduce information that increases the probability of P in relation to Q. David Lewis (1986), on the other hand, maintains that explaining the contrast requires citing a cause of P that would not have been a cause of Q if Q had occurred. And Peter Lipton (1991) suggests that what is required is identifying a cause of P that has no corresponding counterpart among the causes of not-Q. All these proposals, however, are mistaken. Suppose, for example, that Barney but not Arney has paresis yet both happen to suffer from ad-

vanced syphilis. In this case, since both individuals have syphilis it seems clear that the fact that Barney has this disease is altogether irrelevant to why he has paresis in contrast to Arney. Yet according to van Fraassen's criterion this fact about Barney would be explanatorily relevant, since Barney's having syphilis increases the probability of his having paresis in relation to Arney's having the disease. And likewise for Lewis' criterion. That is, as Lipton (1991) points out in a similar example, though Barney's having syphilis is a cause of his having paresis, his having syphilis (assuming that Arney and Barney are not sexually related) would not have been a cause of Arney's having paresis if Arney had also had paresis. Yet despite Lipton's observation here, the same objection applies to his criterion as well, for although Arney's having syphilis corresponds to one of the causes of Barney's having paresis, Arney's having syphilis is not one of the causes of his not having paresis.

The problem with these various strategies, it seems to me, is that they are all based on taking the object of explanation to be a contrast between events without identifying the *type* of contrast that is at issue. Thus, what is needed is a more fine-grained analysis.

Instead of treating the object of explanation as a contrast between events, I propose instead to construe it as a certain kind of fact, a contrastive fact if you will, that embodies a contrast between events. Adopting the view that an event consists in the exemplification of a property by an object at a certain time (Kim 1976), such as  $x$  having the property  $F$  at time  $t$ , we can identify three distinct types of contrastive facts, each reflecting a different type of contrast. One type of contrastive fact is expressed by " $x$ , rather than  $y$ , has  $F$  at  $t$ ." A fact of this type features a contrast in object and hence for convenience can be referred to as an "O-fact". The why-question "Why (currently) does Barney have paresis in contrast to Arney?" is a request for an explanation of an O-fact. A second type of contrastive fact exhibits a contrast in property. This type of fact, call it a "P-fact", is indicated by " $x$  is  $F$ , rather than  $G$ , at  $t$ ". An example of a P-fact is Barney's currently having paresis rather than AIDS. The third type of contrastive fact manifests a contrast in time and is specified by " $x$  has  $F$  at  $t$  rather than  $t'$ ". An example of this type of fact, which we can label a "T-fact", is Barney's having paresis today in contrast to yesterday.

The significance of recognizing these three types of contrastive facts is that they are not amenable to a single form of explanation. That is,

although in general a contrastive fact is to be explained by citing the conditions nomically responsible for its obtaining, the particular principle for identifying these conditions depends on the type of contrast involved. I will begin by indicating how the conditions nomically responsible for contrastive P-facts are to be identified.

The conditions nomically responsible for Barney's currently having paresis rather than AIDS are not the same as the conditions nomically responsible for his currently having paresis and his currently not having AIDS. These conditions would indicate what brought about the paresis and what prevented AIDS, but not what induced the paresis rather than AIDS. What we need instead is a proper subset of these conditions that includes only those conditions responsible for the difference between Barney's currently having paresis and his currently not having AIDS.

Each condition in the relevant subset should do more than merely create a difference in probability between Barney's currently having paresis and his currently having AIDS, for this would be satisfied by all sorts of intuitively irrelevant conditions, such as Barney's not having had a heart attack. Instead, each relevant condition *C* should create a difference in the degree to which it changes the propensity of each outcome so that  $(P(\text{Barney currently has paresis}/C) - P(\text{Barney currently has paresis}/\text{not-}C)) \neq (P(\text{Barney currently has AIDS}/C) - P(\text{Barney currently has AIDS}/\text{not-}C))$ . Under this criterion, Barney's having syphilis, but not his not having had a heart attack, would be included among the conditions nomically responsible for the contrastive fact consisting in Barney's currently having paresis rather than AIDS. So as a general principle,

- (P) *C* is one of the conditions nomically responsible for bringing about the contrastive P-fact that *x* is *F*, rather than *G*, at *t* iff (1) *C* is one of the conditions nomically responsible for bringing about *x* being *F* and not-*G* at *t*, and (2)  $(P(Fx \text{ at } t/C) - P(Fx \text{ at } t/\text{not-}C)) \neq (P(Gx \text{ at } t/C) - P(Gx \text{ at } t/\text{not-}C))$ .

Given (P), a similar principle can be formulated for T-facts:

- (T) *C* is one of the conditions nomically responsible for bringing about the contrastive T-fact that *x* is *F* at *t* rather than *t'* iff (1) *C* is one of the conditions nomically responsible for bringing about *x* being *F* at *t* and not-*F* at *t'*, and (2)  $(P(Fx \text{ at } t/C) -$

$$P(Fx \text{ at } t/\text{not-}C)) \neq (P(Fx \text{ at } t'/C) - P(Fx \text{ at } t'/\text{not-}C)).$$

Specifying the conditions nomically responsible for contrastive O-facts is a bit more complicated than the case for P-facts and T-facts. For the O-fact consisting in Barney's, rather than Arney's, currently having paresis, we need to identify those conditions responsible for the difference between Barney's currently having paresis and Arney's currently not having the disease. Each such condition C, however, must do more than create a difference in the degree to which it changes the propensity of Barney's currently having paresis in relation to the propensity of Arney's currently having paresis, for this would be satisfied by Arney's having syphilis even if both individuals happen to be syphilitics. Instead, C must be a condition that is based on properties that are not shared by both individuals, properties, that is, that represent differences between the two. So only if Arney does not have the property of being a syphilitic will Barney's having syphilis count as one of the conditions responsible for the difference between Barney's currently having paresis and Arney's currently not having the disease. And in general,

- (O) C is one of the conditions nomically responsible for bringing about the contrastive O-fact that  $x$ , rather than  $y$ , is F at  $t$  iff (1) C is one of the conditions nomically responsible for bringing about  $x$  being F at  $t$  and  $y$  not being F at  $t$ , (2)  $(P(Fx \text{ at } t/C) - P(Fx \text{ at } t/\text{not-}C)) \neq (P(Fy \text{ at } t/C) - P(Fy \text{ at } t/\text{not-}C))$ , and (3) C is constructed from properties that are not exemplified by both  $x$  and  $y$ .

If explanatory understanding consists in understanding the conditions nomically responsible for the explanandum phenomenon, then by taking the object of explanation to be a contrastive fact we can avoid the objection raised earlier regarding there being an endless number of conditions to identify, some of which are too bizarre to be genuinely relevant. For example, in asking why the litmus paper turned red, it first needs to be clarified what the proper object of explanation is in this case. Is the focus of our concern a contrastive P-fact (such as that the paper turned red rather than blue) or perhaps some contrastive O-fact (such as that the paper, rather than my fingers, turned red)? Once the appropriate contrastive fact is identified, the conditions nomically responsible for this fact,

as determined by (P), (T), or (O), will form a manageable set that does not include bizarre conditions such as the paper's not being struck by a meteor. The bizarre conditions, though involved in bringing about the simple event consisting in the paper's turning red, are not among the conditions nomically responsible for the contrastive fact identified since, contrary to (P), (T), and (O), these bizarre conditions fail to create a difference in the degree to which they change the propensities of the two outcomes associated with the contrastive fact.

Although the conditions nomically responsible for a contrastive fact will form a manageable set, it seems that not all these conditions need be identified for the purposes of explanation. One reason for this is that each macrophysical condition in the set will have some microphysical counterpart that is also in the set, where it would then be redundant to cite both conditions. Another reason is that in any deterministic context, many of the conditions nomically responsible for a given contrastive fact will simply be successive links in the same deterministic chain leading up to the fact such that it seems unnecessary to identify an entire chain of such conditions. So rather than citing all the conditions nomically responsible for a given contrastive fact, it seems that it will suffice to identify any subset of these conditions where the propensity of the contrastive fact based on this subset is the same as the propensity based on the more inclusive set.<sup>4</sup> With this principle in mind, we can now formulate a general analysis of scientific explanation:

- (E) An explanation for a contrastive fact E (which is either a P-fact, O-fact, or T-fact) consists in identifying (1) a set S of conditions such that S is a subset of the set S' consisting in all the conditions nomically responsible for E where  $P(E/\&S) = P(E/\&S')$ , and (2) the value  $n$  such that  $n = P(E/\&S) - P(E/\&-S)$ .<sup>5</sup>

There are two aspects of this account of explanation that are worth clarifying. First, some (such as Humphreys 1989) have challenged whether it is essential that an explanation cite the probability of the explanandum in relation to the explanans. I have argued elsewhere (Grimes 1988) that explanation admits of degree such that some facts are objectively more explainable than others. Consequently, what seems essential to cite is not the mere probability of the explanandum phenomenon in relation to the explanatory facts, but the difference in propensity created by these

facts. The second condition of (E) thus affords a measure of the degree to which the contrastive fact E is explainable.

The second aspect worth clarifying is that insofar as (E) is based on a robust form of nomic responsibility as expressed by (N), counteracting conditions that lower the propensity of the fact to be explained turn out to be explanatorily relevant. This result, however, should not be viewed with contempt. Instead, allowing that explanation admits of degree, it is essential that any counteracting conditions not be omitted from the set of explanatory facts, for otherwise the degree to which the explanandum fact is objectively explainable, as measured by the second condition of (E), becomes overinflated.

## V

As a summary, explanatory understanding on the view I am proposing consists in understanding the conditions (or a certain subset of such conditions) nomically responsible for the explanandum phenomenon, where this phenomenon is not a single event taken in isolation, nor a contrast between two events, but instead a contrastive fact that features a contrast in object, property, or time. There is, however, no single principle for identifying the conditions nomically responsible for this type of fact. Instead, the correct principle to be used depends on the type of contrast exhibited by the fact, where typically the relevant conditions picked out will not be so numerous as to be impossible to cite.

The account of explanation offered here is not entirely complete. In particular, more needs to be said about the notion of spontaneity that plays such a crucial role in the analysis of strong nomological relevance. Moreover, the concept of a condition being constructed from certain properties, a concept utilized in formulating principle (O), deserves further clarification as well. But despite these shortcomings, the view I have proposed represents a fourth approach to analyzing scientific explanation, an approach which, though a bit sketchy in places, seems to provide at least a more adequate account of the nature of explanatory understanding and of how this type of understanding is to be attained.



## NOTES

1. In Grimes (1987) I argue that by not restricting the type of interest that determines the relation of explanatory relevance, van Fraassen in effect avoids giving an account of this crucial relation as it applies to scientific explanation. Cf. Kitcher and Salmon (1987).
2. Taking X and Y to be events, facts, or conditions, X and Y are logically independent of (consistent with) each other if and only if it is logically possible for each to occur without (with) the other. The negation occurring in "not-X" is to be treated as an internal negation.
3. This result is explained in more detail in Grimes (1987).
4. To make this notion clearer, the propensity of a contrastive P-fact, such as that  $x$  is F, rather than G, at  $t$ , based on some condition C can be understood in terms of the propensity of its conjunctive counterpart, i.e.,  $P(x \text{ is F and not-G at } t/C)$ . Similar considerations apply to understanding the propensity of contrastive T-facts and O-facts.
5. For purposes of notation, the ampersand "&" stands for a conjunction forming operation that conjoins the members of the set on which it operates. "&-" stands for a similar operation that conjoins the negations of the members of the set.

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