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WHAT MAKES AN EXPLANATION*

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Newtonian theory has usually been accepted as a paradigm example of an explanation. There are two widely known analyses of what makes it so. According to one analysis, the deductive and predictive nature of the theory is what counts. The second analysis emphasizes the ability of the theory to connect widely different events and laws. The present paper proposes a third analysis stressing three characteristics. (1) The explanation includes a description which is in part of something unobserved. (2) The description is true in the sense of corresponding to the facts. (3) Through the description, the explanation confers "naturalness" upon the thing explained.

There has been a great deal of recent discussion about the notion of an explanation, especially scientific explanation. Most of it consists of a dialogue between those who support the deductive-predictive analysis of explanation (e.g. Hempel, Nagel, Brodbeck) and the multitudes who criticize that pattern (e.g. Hanson, Scriven, Toulmin, John Wisdom, Barker, Feyerabend, Scheffler). The discussion is a philosophical outgrowth of the long and fruitful hegemony of Newtonian mechanics in physics. The Newtonian equations are useful in two main ways. First, with suitable initial conditions added the equations allow the prediction of many and remarkably diverse types of events. Foresights into the actions of billiard balls and planets are generally cited as examples of such predictions. Second, the Newtonian equations, again with suitable special assumptions, allow the logical derivation of other physical laws. The derivations usually talked about are of Kepler's laws and the gas laws. Prediction and derivation are closely associated in Newtonian physics. Events can be predicted because they can be derived logically; laws which can be derived could have been and often are predicted by scientists with enough insight to see what special assumptions are required.

Scientists, philosophers, and other people have for a long time thought of Newtonian theory as an explanation of the events which the equations predict and of the laws which the equations imply. Proponents of the deductive-predictive analysis of explanation accept Newtonian mechanics as the ideal of an explanation, and they take the predictive-implicative aspect of the theory as what makes it a model explanation. Hempel has been engaged in a careful and valuable attempt to extract and refine the deductive-predictive relation so that it can be used as a pattern of explanation outside of physics. Because of his work, the deductive-predictive pattern is sometimes referred to as the Hempelian thesis or as an H-explanation.

Critics of the Hempelian thesis either point out overlooked difficulties in the notion of deduction; or they cite examples of what are generally considered explanations in which the thing explained either cannot be deduced from the explanation, or cannot be predicted on the basis of the explanation, or both. Sometimes the critics offer a certain alternative analysis of an explanation. Perhaps better, they offer an alternative analysis of what makes Newtonian theory the paradigm of an explanation. The alternative can be called the relational analysis.[1] Since it is less well known than the

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[1] It might also be called the colligational analysis, to use a term borrowed from John Yolton who borrowed it from Watkins. Cf. John Yolton's *Thinking and Perceiving*; Open Court, Lasalle, Illinois, 1962; pp. 133, 134.

deductive-predictive doctrine, there will be some use in describing it in a little detail for future reference.

The relational analysis arises from noticing that Newtonian theory relates a large number of different kinds of events to one another. The various occurrences can all be deduced from the Newtonian equations with suitable assumptions. It is not the deducibility which counts, however, according to the relational analysis, but rather the connection of one event with another through Newtonian mechanics. Thus, the essence of an explanation is its providing a network of connections.

Once having extracted the relational analysis of explanation, the proponents refine it, most significantly by allowing other kinds of relationships between events besides simple deducibility of statements describing them from a common set of equations. Thus, Scriven, for example, says the following:

> What is a scientific explanation? It is a topically unified communication, the content of which imparts understanding of some scientific phenomenon. . . . What is understanding? Understanding is, roughly, organized knowledge, i.e., knowledge of the relations between various facts and/or laws. These relations are of many kinds—deductive, inductive, analogical, etc. (Understanding is deeper, more thorough, the greater the span of this relational knowledge.)[2]

Similarly, in lectures delivered at the University of Virginia, John Wisdom said:

> In explaining the thing I must compare it with other actual things; and the explanation is the better, the more the word that is applied carries me over the whole face of space and time.
>
> Whether we present an explanation in terms of laws or by directly venturing a comparison, we equally offer explanation. Description is placing the thing described with respect to the conceivable; explanation is placing the thing explained with respect to the actual. But it is with respect to conceivable *cases* or with respect to actual *cases*, in the end. The law gives us the advantage of being a key for deriving many instances.[3]

In other words, explaining something consists of relating it in various ways to other things. Scriven feels that explaining a law consists of relating the law to other laws and to phenomena. Wisdom thinks a law has content only in terms of the events to which it is related; hence, explaining laws is subsidiary to explaining individual occurrences. The relational theory certainly comes close to analyzing what many people mean by an explanation. It appears for instance in the history of philosophy where an explanation of why, say, Leibniz held some particular view is often given by relating the view to doctrines of Leibniz' contemporaries and predecessors.

The common type of explanation which consists of subsuming the particular under the general can be thought of as a subcase of the relational analysis. That is particularly true in an Aristotelian system of genus and species categories, where a particular is related to everything else in the universe when it is subsumed under the correct species. Subsumption of a particular physical event under a physical law is less clearly a relational type of explanation. Such a subsumption fits the relational pattern if, with Wisdom, a law is envisaged as a tool for thinking. Ryle expresses Wisdom's view and

[2] Michael Scriven, "Explanations, Predictions, and Laws", *Minnesota Studies in the Philosophy of Science*, Vol. III *Scientific Explanation, Space and Time*, ed. by Herbert Feigl and Grover Maxwell; University of Minnesota Press, Minneapolis, 1962; pp. 224-225.

[3] John Wisdom, *Proof and Explanation*, Unpublished Lectures Delivered in the University of Virginia, Spring, 1957; pp. 81, 82.

brings out its relational nature when he calls a law an inference ticket which allows one to travel in thought from one particular instance to another.

Subsumption of the particular under the general is not always a subcase of the relational analysis, however. It depends upon what sort of metaphorical picture is given of a law. If the law is thought of a calculating machine for grinding out particular cases, then subsumption of an event under a law come to be a subcase of the deductive-predictive explication of explanations.

Besides the deductive-predictive and relational analyses of what makes Newtonian mechanics a paradigm explanation, there is another possible explication. To describe it is the main purpose of this paper. It will be convenient to start with a quotation embodying the deductive-predictive theory. It appeared in the *Scientific American.* "The curious properties of liquid helium are explained by regarding it as a gas of hypothetical particles in a similarly hypothetical background fluid."[4]

To the author of the quotation, 'hypothetical' implies that the particles and the fluid which he talks about do not really exist. Rather, he is employing a model (his own term) or an imaginary picture and its associated mathematical equations. The experimentally observed properties of liquid helium are deducible from and predictable by means of equations formally like those appropriate to a mixture of fluid and particles. Hence the properties of helium are explained by the equations.

Admittedly, the quotation is not a completely clear cut use of the deductive-predictive pattern of explanation since the author speaks in terms of an imaginative picture. The rest of the article from which the quotation comes, however, makes it clear that the picture is useful only for suggesting appropriate equations; and it is the equations with their implicative power which furnish the explanation.

Discussion of the third analysis of what makes an explanation can begin by noting two words in the quotation. One, already mentioned, is 'hypothetical'; the other is 'curious'. Regarding the first: because the fluid plus particle picture is explicitly hypothetical, there is a sense of 'explain' in which neither the equations alone nor the equations plus the picture explain why helium acts the way it does at low temperatures. The model would be explanatory only if it were true. 'True' here means 'corresponds to the facts', a phrase which is vague and philosophically suspect, but nevertheless philosophically indispensable.

The point can be put another way. Granted that liquid helium behaves as particles in a background fluid would, what is still unexplained is why helium acts in accord with the model. And that is just another way of asking, why does liquid helium have the properties it does. All that the hypothetical picture does is make possible a rephrasing of the request for an explanation; it does not provide an answer.

That suggests that one characteristic of a theory that is appropriately called an explanation, in the sense of 'explanation' being explicated, is that the theory correspond to the facts or be true. In making such an assertion, one must be careful about just what is meant. There is a sense in which the particle-fluid theory does describe liquid helium or does correspond to the facts. That is the fictional or 'as if' sense. Helium does act as if it were composed of particles in a fluid. Hence, if a person wants to describe what is observed, he can say that you observe what you would see if you mixed particles in a fluid and subjected them to the experimental conditions.

For clarification, one must distinguish between two distinct descriptions or alleged descriptions contained in the helium theory. There is the picture of the unobserved

[4] *Scientific American,* November, 1960; p. 139.

internal structure of helium. And there is the picture of the laboratory experiments and their results. The first picture is stated in words. The second picture is stated only by implication.

The situation is actually more complex than that, for the two descriptions are really contained in the one explicit picture. Perhaps the best way to make the point clear is by saying the fluid plus particle picture can be stated in either the indicative or subjunctive mood. The difference between the two is very common. The actions of a person can be described in the indicative mood by saying, he is trying to get a splinter out of his finger. Or the same actions can be described by saying, he is acting as if he were trying to remove a splinter. The subjunctive description leaves open the possibility that the person in fact is not taking out a splinter. The indicative description does not leave the possibility open.

When the fluid-particle picture is stated in the subjunctive mood, it is really describing the observable laboratory experiments, not the unobservable internal structure of helium. When the picture is put in the indicative mood, it is describing the internal structure of helium.

Corresponding to the two moods of speech, there are two senses of correspondence to the facts. The indicative mood description is true if the picture corresponds to the internal structure of helium. The subjunctive mood description is true if the experimental results it summarizes actually occur. Let me call the first type of truth indicative correspondence to the facts; and the second, subjunctive correspondence to the facts. In the new terminology, the helium theory is an explanation only if it has indicative correspondence to the facts. And, more generally, the first criterion of an explanation is that it contain a description that has indicative correspondence to the facts.

The second word in the helium quotation to which attention was called was the word 'curious'. It is the curious properties of helium which require an explanation. Similarly, it is the peculiar or curious bounce of the tennis ball which people wonder about. Tennis players rarely if ever want to know why a ball that bounces in the expected way does bounce just that way. On a decent court, most bounces are normal or natural and demand no explanation. That calls attention to the fact that the opposite of a curious occurrence is a natural or normal one. The purpose of an explanation is to make a curious happening seem natural or normal. The second characteristic of an explanation is that it confers naturalness upon the thing to be explained.

There are several senses of the word 'natural'. In one, every occurrence in the universe is natural since the universe and nature are the same thing. In another sense, any occurrence not resulting from man's volition is called natural. In the present discussion, a third already indicated sense is being used in which only those occurrences are natural which are accepted without wonder, without any need seen for explanation or further explanation. Thus to say that the purpose of an explanation is to make something seem natural is to say that the purpose is to make that thing seem not to need an explanation. The definition of 'natural' is thus connotatively circular. Fortunately, the term can be loosely defined denotatively.

The denotative definition must be loose partly because what appears curious or unnatural depends somewhat upon the individual person's background, education, and imagination. Once in a while somebody does want to know why all the bounces of tennis balls go the way they do. Often the great scientific advances and major conceptual changes occur when someone of unusual imagination or naivete wonders why an event occurs that other people take for granted.

In spite of differences in expectation between people, there are certain rather generally accepted ways in which naturalness can be conferred upon something. One way to make a particular thing seem natural, or at least more natural, is to show that it is one of a similar class of things. If a child attacks his new born brother, one sort of explanation for the behavior is that all young children act that way toward new born siblings. 'All children do it' is not likely to be accepted as much of an explanation in our psychologically orientated age. But the phrase is not devoid of explanatory value because it indicates that the particular child's behavior is not unique. It is not out of line with what usually happens with children. And what usually happens is generally looked upon as more normal and less in need of explanation than a unique event. In fact, oftentimes, especially in sociological and psychological contexts, the natural or normal state of affairs turns out to be by definition the state of affairs that occurs on the average.

One way then of conferring naturalness on something is to show that it is one of a group of similar things. Once in a while, especially in times of conceptual revolution, the opposite occurs. A comparatively unique state of affairs is suddenly accepted as natural. There follows an attempt somehow to surround that state of affairs with a class of similar things. Some of the current philosophical discussion stemming from quantum theory is an attempt to build up a class of similar occurrences around the comparatively unique quantum events. When electrons are envisioned as billiard ball particles, it is impossible to tell what any single electron will do exactly; but the behavior of the group can be predicted quite well. Some philosophers think that such a situation is unnatural and puzzling. But there are other philosophers who hold it to be quite natural and not in need of an explanation. The latter group has undergone a conceptual revolution from Newtonian habits of thought. But some of them seem to feel that they cannot leave electron behavior as a unique natural event. It must be surrounded by a class of similar occurrences. The class is usually built up out of all other movements in the universe by alleging random variations in those movements which have hitherto been disguised as experimental errors. In others words, all actions in the universe come in quantum-like groups; and the case of electrons is not all unique. Here then is a situation in which one peculiar sort of event is taken as natural which gives rise to the belief that the other events in the universe *must* be like it in some overlooked way if they too are to be natural and not in need of explanation. More commonly, the effect is reversed; a peculiar event to take on naturalness must have some overlooked characteristic that makes it like the usual run of things.

A second way that things come to seem natural is through familiarity. That is largely what has happened to those philosophers who hold that quantum movements are natural. A conceptual change such as the quantum revolution usually occurs because of growing familiarity with ideas previously introduced for scientific or other reasons.

The natural and the familiar are not universally identical, though they are more nearly equivalent than is often supposed. An example frequently cited to show that familiarity is *not* the same as naturalness is the explanation of the familiar Newtonian movements of planets in terms of the unfamiliar ideas of relativity theory. Here the familiar is explained in terms of the unfamiliar. The example loses a lot of weight when one realizes that relativity theory is accepted as an explanation most readily by scientists and philosophers who are most familiar with it. On the other hand, there is a great demand among laymen for a popular explanation of relativity theory in terms of more familiar concepts. One of the hardest points to get across to non-physicists is that relativity theory is not simply some abstruse subcase of Newtonian mechanics. A feeling is widespread among laymen that what is unfamiliar to them cannot be left without explanation. That feeling, however, tends to give way under protest to the authority exercised by scientists in our society. If the experts say that relativity explains familiar movements rather than vice versa, then most people will go along.[5]

That is not to say, of course, that physicists themselves come to look upon relative motions as natural because of familiarity or authority. It was rather fruitfulness of prediction and elegence of deduction that helped relativity supplant Newtonian mechanics as an ultimate explanation. Like quantum theory, relativity first became an explanation in the deductive-predictive sense for physicists. Then, with growing familiarity, the conceptual revolution took place which transformed the two theories into a different sort of explanation, the kind in which the movements described by the equations of the two theories come to be looked upon as natural.

So far, four ways have been suggested in which naturalness can be conferred upon things to be explained. They are: subsumption of a thing into a class of similar things, familiarity, authority, and a conceptual transformation induced by the deductive-predictive power of a theory. There are at least two other ways in which naturalness is conferred. One is through conforming to what can be called an ideal of natural order.[6] The other is through transfer of naturalness from something already accepted as natural.

An ideal of natural order is a concept, or linguistically a statement, of what sorts of occurrences are natural or normal. To the extent that 'natural' can be denotatively defined, it is through listing ideals of natural order.

I have elsewhere described how the principle of induction functions as an ideal of natural order.[7] Ordinary arithmetic and algebra are ideals of natural order; Euclidean geometry used to be. Like all such ideals, those of mathematics function in a negative way, marking what does not need an explanation. An occurrence that is natural by arithmetical standards is the existence of two stones in a box into which one stone and then another have been dropped. An occurrence that does need an explanation because it does not conform to the arithmetical ideal of natural order is the existence of less than two cups of liquid when one cup of alcohol has been added to one cup of water. If we lived in a world in which a larger number of everyday objects combined as do alcohol and water than as stones, we might have a different arithmetical ideal of natural order. Then the alcohol-water case would not need an explanation, but some reason would be sought for the abnormal appearance of two stones after the addition of one to one.

The so-called reduction of gravity to geometry is general relativity theory is just such a shift in geometrical ideals of natural order. Certain motions of heavenly bodies are not mathematical consequences of Euclidean geometry. Hence, in Newtonian theory, they were not natural and needed the explanation provided by gravitational

[5] A much better counterexample from physics to the identification of naturalness with familiarity is the Coriolus acceleration which explains the westerly movement of the tradewinds and the easterly drift of the Gulf Stream. The Coriolus force is an abstruse consequence of Newtonian mechanics. Hence it is more readily accepted than relativity as natural by non-physicists even though most people have never heard of it.

[6] The name is Stephen Toulmin's. See his *Forecast and Understanding*; Indiana University Press, Bloomington, 1962. I may be extending the term somewhat beyond Toulmin's usage.

[7] "Two Non-Logical Uses of the Principle of Induction", *Philosophical Studies*, XIII (Jan-Feb, 1962), pp. 27-32.

forces. The same motions are mathematical consequences of non-Euclidean geometry; therefore they are natural and do not require a special explanation in general relativity theory.

Perhaps the most important system of ideals of natural order for modern philosophy is Newtonian theory itself. The theory contains several standards of what is natural. There is for instance the idea that it is natural or normal for a body to move at a constant speed in a straight line. Any deviations in speed or direction are not normal and need an explanation. One of the great conceptual shifts in western thought was from the Aristotelian notion that a body naturally stops moving if left to itself to the Newtonian concept that a body keeps going when left to itself. For a more detailed treatment of this point, see the book by Toulmin just cited.

A particular event of situation takes on naturalness when it conforms to an ideal of natural order. 'Conforms' here means that the event is pretty directly described by the ideal. That happens in the example of the stones, which conforms to the arithmetical statement that $1 + 1 = 2$. But things which conform to ideals of natural order are not thereby explained. They are things which do not need explaining. In explanations, naturalness is transferred from ideals to things explained by more complicated connections. The relation used in the paradigm Newtonian explanations is deduction. It is rather remarkable that, when an event or law can be deduced mathematically from the Newtonian equations (plus other assumptions), the event or law takes on the quality of being expectable or natural. That is perhaps what leads philosophers to the deductive-predictive analysis of explanations. It is not deducibility per se, however, that makes an event explained by Newtonian theory. It is rather the transfer of naturalness to the event by the deduction. The naturalness originates in the ideals of natural order which constitute the Newtonian equations. Part of the reason deduction is accepted as a means of transferring naturalness is probably related to the use of mathematical principles as ideals of natural order. What conforms to arithmetic is natural; and, since algebra is closely akin to arithmethic, then algebraic manipulation of mathematical standards of naturalness (the Newtonian equations) preserves naturalness.

Those philosophers who are still searching for an explanation of quantum motions have been set upon their quest because there is no known way to transfer Newtonian normality by mathematical deduction to the quantum movements.

How did the Newtonian equations become ideals of natural order? One way no doubt is through a 17th century conceptual revolution initiated by the deductive-predictive fruitfulness of Newtonian theory. Another and related reason is familiarity. The billiard ball type of motion is so familiar that it can easily become standard, natural motion. By graphing certain derived equations, Newtonian theory gives an iconic picture of billiard ball movements. Thus, the Newtonian equations became ideals of natural order because, in a sense, they merely summarize mathematically motions that are already accepted as natural or on the verge of being so.

There is another possible reason why billiard ball movements under the influence of forces are so readily accepted as natural. Anthropomorphizing and empathizing probably play more of a role than philosophers care to admit. A person can easily think of or empathically feel himself bouncing around off other objects, pushing and being pushed, just as billiard balls appear to do. Much of the naturalness of billiard ball motion may come from the idea that the balls are moving just as a person would under the same circumstances. Naturalness is thus transferred through empathizing or through an anthropomorphic analogy.

Another example which suggests the efficacy of anthropomorphic analogy for making the transfer is the following. As mentioned before, to a layman, rather queer allegations are made in relativity theory which popular writers try to make appear natural. Relativists, for instance, talk about clocks slowing down with increase in relative velocity. Suppose a popular writer suggested the following. Imagine yourself running along the street waving a flag. The faster you ran, the more of your strength you would have to devote to running and the less you could give to the flag. Consequently, the slower you could wave it. That is just the sort of thing that happens to moving clocks.

The absurdity of the proposed analogy is unimportant here. The point of interest is that the comparison would, I think, make many people feel more comfortable about clocks in relativity theory. The anthropomorphic analogy, if presented seriously, would make people feel that perhaps the way that clocks operate is natural after all, or at least not so incomprehensibly odd as thitherto seemed. The analogy would transfer naturalness from one of its main sources, familiar personal experience, to inanimate objects.

Transfer of naturalness by analogy is often associated with Freudian theory. It partly accounts for the scepticism of psychoanalysis by physically orientated philosophers. If it be granted that there is a psychical entity called the libido, how can one explain the multifarious overt actions which emanate from it, or the way that the libido never seems to rest, etc. One kind of explanation sometimes given amounts to a hydrodynamic analogy. The libido can be thought of as like a dammed up body of water, always seeking an outlet; if one channel is closed, another is forced open; etc. A dammed stream is a familiar object, so familiar that the way the water acts can be taken for granted, i.e., taken as natural. By likening the libido to a stream, the naturalness of the way the water flows is analogically transferred to the libido and the actions that 'flow' from it. Many philosophers would probably be happier with Freudian theory if the naturalness of the hydrodynamic picture could be transferred deductively to the libido. That would mean in effect that the relationships between the libido and overt action could be deduced from a body-of-water-like description. It would be better still if the relationships could be deduced from hydrodynamic mathematical equations. But such deductions are impossible now and probably always will be. Hence, Freudian theory cannot get away from transfer of naturalness by analogy instead of deduction. Of course, no analogical transfer is necessary for those thinkers who have accepted the Freudian conceptual revolution. To them unconscious psychical processes such as those of the libido are natural already. They conform to Freudian ideals of natural order.

Freudian theory also uses analogy to construct the concepts of unconscious physical entities. That use of analogy should not be confused with the transfer of naturalness by analogy. A notion of the libido may be formed by saying it is like a constricted body of water. That is construction of a concept by analogy. Making certain actions of the libido seem natural because something similar would be natural in the case of water is transfer by analogy. In this case, it is the same analogy that serves both purposes. But transfer by analogy falls into the discussion of the second characteristic of explanations. Construction of concepts by analogy is part of the third characteristic to be considered directly.

Before turning to that, it is worthwhile noting one case in which naturalness almost gets transferred by analogy but in which the transfer is ultimately completed by deduction. It is the case of a planet revolving around the sun. One explanation for the planet's going round the sun instead of taking the natural straight line course into space is that the sun attracts it. It is as if you had a ball on the end of a string and were whirling it around above your head. Gravity holds the planet to the sun just as the string holds the ball to your hand. The explanation transfers naturalness by analogy from a common, familiar occurrence. But, if the force of gravity holds like the tension of a string, why do the planets move in ellipses instead of circles? The circle would be the expected motion suggested by the comparison. Hence the analogy leaves the planetary orbits not quite right. The explanation is completed by deduction from the Newtonian equations. With the given gravitational force, the equations entail the formula of an ellipse, not (very often) a circle. Since the deduction has been made to an ellipse, that type of path now seems natural.

Collingwood recently said:

> Since mathematics, when used by physics, is only a method and not an explanation, it can be dispensed with to some extent when a true explanation is achieved. For example, if force did exist as the cause of the orbits of the solar planets, their orbital motions would be understood in terms of it. Kepler's laws would add nothing to this basic understanding. They would add something to the knowledge of *how* the planets follow their orbital motions, but would add nothing to the why.[8]

The discussion of the planetary orbits preceding the quotation implies that Collingwood is wrong on two points. First the explanation of the motion does require some ideal of natural order, whether Newton's equations or Kepler's. And, second, the explanation still needs mathematics even though the notion of gravitational forces is also employed; the mathematics transfers naturalness from the ideal of natural order to the actual planetary paths.

Summarizing the second characteristic of an explanation, an explanation confers naturalness upon the thing to be explained. Several ways in which an explanation confers naturalness have been suggested. The most important kind of conferring is through transfer from either an ideal of natural order or from something familiar, such as personal everyday experience. Ideals of natural order can be listed, but the list is only loosely accurate. Sometimes ideals of natural order change, primarily through a conceptual revolution usually induced by the deductive-predictive fruitfulness of a theory. The various kinds of relations recognized by proponents of the relational analysis of explanations can be thought of as so many ways by which naturalness can be transferred.

A third characteristic of an explanation is directly connected to the first aspect, which was that an explanation must involve a description which has indicative correspondence to the facts. The third characteristic is that the description included in an explanation must partly at least be of an unobserved state of affairs or object. The state or thing need not be unobservable, merely unobserved. For example, in kinetic theory, the primary case of the explanation of a set of laws by Newtonian mechanics, one of the assumptions is that a gas is made up of unseen billiard ball-like molecules. Thus, something unobserved is part of the explanation, though the molecules are not objects which are necessarily unobservable.

More crucial support for the contention that the third characteristic is a necessary part of explanations comes from the Newtonian explanation of the movements of

[8] Frank J. Collingwood, "Is 'Physical Knowledge' Limited by Its Quantitative Approach to Reality?"; *The Nature of Physical Reality*, L. W. Friedrich, ed.; Indiana University Press, Bloomington, 1960; p. 43.

billiard balls. Two attitudes can be taken toward such movements. In the one, the motions are thought of as natural; they do not themselves need explanation though they can be used as part of the explanation of something else (as in kinetic theory). The other attitude is that billiard ball movements do need explanation and that Newtonian theory explains them.

The two attitudes are outgrowths of two different descriptions which may accompany the Newtonian equations. One descriptive picture is that of billiard ball particles moving about as billiard balls do. The other adds to the first picture the exertion of forces by one ball upon another, by the cue upon the ball, etc. Philosophers who deny reality to forces and adopt the first description are also inclined to hold that Newtonian theory is not an explanation, but merely a compendious description of billiard ball motions. Or else they support the deductive-predictive analysis of explanations. That is because, by denying forces, they remove from Newtonian theory all unobserved descriptive elements. They are thus left with something indistinguishable from a summary description which they are correctly reluctant to call an explanation. On the other hand, when unobserved forces are admitted as part of the descriptive content of Newtonian theory, that content is more than a compendium of what is observed. Then the theory itself is more than a mere description of what is seen and can be an explanation.

The general theoretical point behind the necessity for an unobserved element embodies a connection between the second and third characteristics of an explanation. An explanation must confer naturalness upon the thing explained. Hence an explanation must differ from a description of what is observed. Repeating the description of a seen curious phenomenon cannot remove the peculiarity, no matter how elegantly the description is rephrased. The description must be augmented by some unobserved state of affairs from which naturalness can be transferred to what is observed.

Explanations of overt human behavior in terms of emotions and desires involve unobserved entities. So do explanations of conscious emotions and desires in terms of unconscious drives. But saying that raises three trickly philosophical issues. One concerns the meanings of the term 'unobserved'; a second is the question of the reality of unobserved entities; and the third, the nature of such real, unobserved entities.

The first issue, though vexing, is mainly preliminary. Unobserved objects such as men behind the throne, forces, or unconscious desires are unobserved in different senses. It is useful to know how the senses compare and contrast with one another so that the appropriate criteria are employed for deciding whether one of the entities is in fact under observation. But, as far as the acceptability of explanations goes, the semantic issue has its greatest importance when it bears on the ontological ones through some empiricist criterion of meaning. Fortunately, the many ramifications of the use of such criteria can be dodged for the present in this analysis of explanations.

Leaving aside semantics then and turning directly to ontology, are there such things as forces, unconscious desires, and billiard ball electrons? And, if so, how are they properly described or thought of? Those questions bring the discussion back again to the first criterion of an explanation, namely that it correspond to the facts. Part of the description included in an explanation must be of an unobserved object or state of affairs. If that object is something like a force or an unconscious drive, then the ontological questions are automatically raised by the demand that the description of the force or unconscious drive correspond to the facts.

Again, fortunately, this analysis does not require that the ontological problems be solved. One point can be made, however. Explanations involve an inescapable use of analogy. That is partly because the unobserved part of the description in an explanation, being unobserved, cannot be directly described. It must be verbalized and conceptualized in terms of other experience or combined bits of other experiences. The unobserved element of an explanation must be described as being like such and such other objects or states of affairs.

The analogy may be quite straightforward or so complex as to be a metaphor. The explanation, 'He's removing a splinter from his finger'' is a simple comparison of the motives of one situation with those of other remembered situations. The classical explanation of the gas laws by the Newtonian based kinetic theory involves a less simple analogy. There one is supposed to think of gas molecules as like billiard balls, except that the molecules differ from billiard balls in certain characteristics such as size and color. The fact that the comparison is specifically assumed to break down in some respects makes the analogy of kinetic theory more complicated than that of the splinter case. In one interpretation of quantum theory, the analogy begins to pass over into metaphor. Electrons, in that interpretation, are like billiard balls except that they have no secondary qualities, they possess primary qualities only in a suspect sort of way, and even the mass is relativistically variable in noticeable ways. An out and out metaphor is reached with the hydrodynamic picture of libidinal energy.

There are two ways of forming a concept of something unobserved. They might be called the method of subtraction and the method of addition. In the latter, a concept of, say, an electromagnetic field or an unconscious psychical process, is built up by piece. One characteristic after another is added until the idea is completed. That is not the method of concept formation embodied by analogies. Analogy employs subtraction. The analogy first gives a package of characteristics to a concept and then one by one they are subtracted. For instance, when electrons are said to be like billiard balls, they are immediately given all of the ordinary qualities of billiard balls. Then selected properties such as visible size, color, etc. are subracted from the picture. That is why the usual locution for the analogy is: '*x* is like *y* except for . . .'.

Another part of the reason that analogy is necessary to explanations is tied in with the fact that the explanation must make the thing explained seem natural through ascribing an appropriate constitution to something unobserved in the situation. A concept of the unobserved element formed by addition cannot take on naturalness without a conceptual change. That is, again, why, when the quantum concept of an electron is built by addition from properties discovered in the laboratory, the behavior of such electrons lacks naturalness except to those philosophers who have gone through a conceptual revolution. But when the concept of an electron is formed by saying an electron is just like a billiard ball except for this and that characteristic, then any billiard ball-like behavior of an electron automatically becomes natural and explained.

The more characteristics one has to subtract from the analogical comparison, the less successful is the attempted explanation. Billiard balls with odd sizes and no color are close enough to ordinary billiard balls to make kinetic theory explanatory. But when the concept of an electron is formed by subtraction from an analogy, quantum mechanics forces the elimination of too many properties. If electrons are like billiard balls except for shape, color, size, constant mass, possession of exact positions and velocities, etc., the exceptions turn the phrase 'electrons are like billiard balls' into something resembling nonsense. The last traces of naturalness are lost and with them the last bit of explanatory value in quantum theory. The same thing happens with all explanations in which the exceptions to the description by analogy become too numerous.

Or at least it usually happens. Sometimes it seems that saying 'Electrons are like billiard balls' transfers an aura of naturalness to electrons which no number of exceptions can erase. What appears to happen is that the analogy is taken to state a similarity between the substance (as opposed to the properties) of an electron and the substance of a billiard ball; and naturalness is conferred by similarity of substance alone. Hence no differences in specifiable properties are important.

The naturalness criterion of an explanation is not the only one with which description by analogy is closely connected. The analogy and subtraction process is also related to the correspondence truth criterion of an explanation. That follows from a point made by Lewis White Beck. Beck says,

> A distinctive trait of real in contrast to systemic existence (the mode of existence of a construct) is the possession by the former of accidental properties. If all the properties of an entity are essential, all that we can legitimately conclude is that is has systemic existence as defined in a set of postulates and definitions internally consistent but claiming no independent status.[9]

Applying Beck's point, in order that the description in an explanation correspond to the facts, the thing described must be real (have real existence). In order that the thing be real, it must have accidental properties. Describing, say, a gas molecule by saying it is like a billiard ball ascribes to the molecule the accidental in addition to the experimentally essential properties of billiard balls. Thus, by Beck's criterion, the molecule can be a real object. Whether it is, is another question, of course.

The exceptions made in analogical comparisons usually begin by removing accidental properties from the unobserved object. The larger the number of explicit exceptions, the less possible it is that the molecule or other unobserved object has real existence. Much philosophical discussion turns on where the borderline should be drawn between entities that are only systematic and entities which might also be real. How many exceptions, in other words, are tolerable from a description by analogy of an unobserved state of affairs before that state of affairs can no longer be thought of as real.

It was earlier pointed out that the method of addition for forming concepts is of little or no use in explanations because of difficulties in achieving naturalness. That method also runs afoul of Beck's criterion. If one is adding one property to another to get the concept of an electron, it seems gratuitous and rather suspect to add in a lot of accidental properties which are not called for by experimental results. But, unless adding accidental properties is allowed, the electron has only a tenuous claim to reality. That is the third part of the reason that analogy is necessary to explanations. Description by analogy automatically provides accidental properties.

The inescapable connection between explanations and analogies has a philosophically interesting consequence. Giving an explanation sometimes involves a type of analogizing which is illegitimate so far as pure describing is concerned. The use of Newtonian theory to explain the movements of billiard balls is a good example. That explanation, as pointed out earlier, involves the notion of contact forces. Conceptually, a force is basically a push or a pull, something that a human being experiences and exerts. If a person bumps into a chair, he gives it a push, making it move away from him. If one billiard ball bumps into another, the second begins to move. The easiest explanation of the movement of the second ball is that the first gave it a push; or, more technically, the first ball exerted a force upon the second. The explanation

[9] Lewis White Beck, "Constructions and Inferred Entities", *Philosophy of Science*, Vol. 17 (1950), p. 82.

has made an analogy between the person-chair case and the two billiard ball case, thus introducing forces from the former case into the latter.

The analogy would be quite illegitimate if one were merely describing his encounter with a chair and the encounter of one billiard ball with another. There is a clearly experienced feeling of pushing and overcoming resistence with the chair. No such feeling is experienced or observed in the billiard ball case. In fact, the collision of two billiard balls can be taken as a paradigm of the absence of pushes and pulls or forces, and the chair situation as a paradigm of the presence of a push or force.

Many philosophers want to exclude the word 'force' from talk about billiard balls, or they redefine the term in some way so as to cleanse it of its push-pull connotations. From a descriptive point of view, such philosophers are quite right in their desire. But that does not imply that they are right from an explanatory point of view. To put the point in another way, push-pull forces are logically inappropriate to descriptions but not to explanations of the billiard ball occurrence.

Admittedly, the force explanation may be unacceptable. But the unacceptability cannot be based upon the allegation that an illegitimate way of talking has been introduced through analogy. One reason why the explanation may be unacceptable has already been cited, namely that the billiard ball movements are themselves natural and need no explanation. Or the explanation may be unacceptable because the forces do not have real existence. That is an ontological matter, not a semantic one however.

Leibniz rejected such forces because he did not believe that billiard balls ever come into direct contact and he could not accept action at a distance. Leibniz offered another explanation which again is an attempt to make the billiard ball collision seem natural by means of an analogical description of something not observed. The source of Leibniz' analogy is anthropomorphic just as is the origin of the force analogy. With great injustice to the subtlety and rationality of his philosophy, Leibniz' view can be put as follows. A person out walking may see someone approaching whom he dislikes and turn down a side street to avoid speaking. His movement is caused by what he sees and what he wants, by his perceptions and desires. Leibniz explained the billiard ball movement by saying the ball has certain perceptions and desires related to the other ball. As an explanation, Leibniz' theory is not logically suspect because of the analogy or because of the new way of talking about billiard balls. As a description, what he says would be not only suspect but absurd.

The extreme case of analogizing by explanation would be a theory which explained every event in the world. For a long time, it was thought that Newtonian theory was just that kind of theory. Had it been, then every process in the world would have been looked upon as being the movement of billiard ball particles. Descriptively, that is patently false and patently a misuse of ordinary descriptive language. But it would have been true and legitimate use of words in explanation.

Ordinary language analysts usually believe that traditional philosophers are too monistic. The traditional thinkers are charged with developing ontologies in which too many diverse aspects of the world are lumped together under one linguistic expression. The charge would be damaging if traditional ontologies were formulated as attempts at concise descriptions of the world. But such thinkers as Descartes, Leibniz, and even Plato were trying to explain what is observed, not to describe it. Hence, when applied to them, the ordinary language criticism is almost irrelevant.

That completes the present discussion. The question treated was, what makes Newtonian mechanics a paradigm explanation. Three characteristics do the job, according to the analysis outlined. They are: (1) The explanation includes a description which is in part of something unobserved. (2) The description is true in the sense of corresponding indicatively to the facts. And (3) through use of the true, unobserved element, the explanation confers naturalness upon the thing to be explained. In philosophical literature, two other analyses of the essence of an explanation are current, the deductive-predictive and the relational patterns. That all three analyses can be drawn from the same paradigm explanation show how rich Newtonian theory is as a mine of concepts.