The Deductive-Nomological Model of Explanation

In this essay I will propose the view that Hemple's Deductive-Nomological model of explanation correctly captures and explicates the role of scientific explanation. In order to do this I will begin by introducing the role of explanation in science. In my second section I will present the Deductive-Nomological model. My third section will link explanation with prediction as a consequence of the model. In my final section I will propose several potential problems with Hemple's model before proposing a slightly altered thesis that better deals with the problems encountered.

1. Science and Explanation

Science is expected to fulfil several roles. One of the most important of these is an expectation in its ability to explain phenomena. This ability to explain is closely linked to its capacity to make predictions about the future. If the U.S.A. were suddenly ravaged by a succession of unseasonable and especially destructive hurricanes its citizens may expect certain scientists (e.g. meteorologists) to tell them how long this succession of hurricanes would continue for, and how far across America the destruction would be wreaked. Certain people might also expect that science will be able to provide us with an explanation of why this unexpected and unprecedented weather occurred – perhaps certain environmental groups would ask if global warming and the associated climate change were responsible. We might be able to predict how long these storms would continue by researching the observable phenomena that caused them – pressure, temperature and suchlike. By explaining what has occurred in the past we might be able to predict what will happen in the future. If several explanations as to the origins of the unusual weather were available then we might discriminate the correct from the fallacious explanations by checking actual events against the predictions each explanation made.

Whilst the predictive power of science is, at least in part dealt with, in discussions of the problems of induction, we must be clear that the explanatory power of science is also an area of great philosophical interest. Hemple proposes that to explain a fact is to "show how that fact could be subsumed under a law or several laws together with various antecedent conditions."[1] This is known as the 'covering-law' thesis and can be broken down into two versions, the 'deductive-nomological model of explanation' and the 'probabilistic-statistical model of explanation'.[2]

2. The Deductive-Nomological Model of Explanation

This model of explanation proposes that a phenomenon is explained by deducing it from a law together with other auxiliary statements concerning the phenomenon (explanandum). Hemple uses the phenomenon observable whilst washing up as an example. If one removes glass beakers from the hot washing up water and places them upside down on a plate to drain one may see bubbles form around the tumblers' rims. These grow for a while then recede back into the tumblers and disappear. This phenomenon can be explained as follows. The tumblers are hot from the washing up water. As they are removed they trap cool air. This air is heated by the hot tumblers, causing a pressure increase inside the tumbler. A soapy film forms a seal between the tumbler and the plate and bubbles are formed from this as the hot air escapes. As the air cools again and the pressure drops the bubbles shrink and then disappear.

Hemple proposes that the above explanation may be viewed as an argument to the effect that the phenomenon was to be expected in view of several explanatory facts. These facts may be divided into two groups: particular facts

[1] Bird, *Philosophy of Science*
[2] Hemple, *Aspects of Scientific Explanation*

or antecedent conditions and general laws. Included amongst the particular facts are the facts that the tumbler had been immersed in hot soapy water and that when placed upside down upon the plate a soapy film formed between the two surfaces. The general laws include Boyle's Law of gases and various other laws of heat exchange and the properties of bubbles. Whilst not all of these laws are made explicit, they are assumed in various claims made about certain events leading to others (e.g. the bubbles expanding and retracting).

I stated above that the explanation takes the form an argument showing the observed phenomenon as to be expected. This is so because the explanandum sentence – e.g. 'Soap bubbles appear and recede.' – may be deduced from the explanans – i.e. the particular facts and general laws involved. This gives us the general formula of the deductive-nomological explanation:

C1, C2, … Cn - facts

L1, L2, … Ln - laws

E - Explanandum-sentence[3]

By showing us that given certain laws and facts the observed phenomenon was to be expected we are able to understand why the phenomenon occurred. A deductive nomological explanation presents the explanandum as a logical consequence of the explanans.

Here we must note that a deductive-nomological explanation must contain certain laws. If we are to envisage an argument devoid of such laws we may arrive at something like:

---

[3] Hemple, Ibid

The soap bubbles first expanded and then receded

The Soap bubbles first expanded

Whilst this argument is deductively valid it is clearly not an explanation of why the soap bubbles first expanded.

At this point I have been freely using the term 'law' without any precise definition. Given the essential nature of laws in the deductive-nomological model of explanation we must attempt to rigorously define this term. It seems that many lawlike sentences share the same logical form (e.g. for every x if Fx then Gx). However, it is clear that lawlike sentences cannot be characterised by their form alone. The sentence 'Every Caius philosopher has dark hair' is of the same logical form as a great sentences expressing laws, but is clearly not a law itself. Goodman points out that the difference between my sentence about Caius philosophers and a true law is that the latter can and the former cannot "sustain counterfactual and subjunctive conditional statements."[4] That is, whilst Boyle's law can make predictions about any gas in hypothetical situations, my example sentence cannot – i.e. it cannot lead to the prediction that if a Caian swapped courses to philosophy he would have dark hair.

However, Hemple disregards an explication of lawlikeness reliant upon counterfactuals and subjunctive conditionals on the basis of their "notorious philosophical difficulties". Equally, any attempt to explicate the term on the basis of lawlike sentences' explanatory power will fail because we are attempting to characterise explanatory power in terms of concepts including lawlike statements.

Perhaps a more thorough clarification of the distinction between lawlike and non-lawlike sentences is provided by Goodman, who focuses on the potential for lawlike sentences to be "projected" from examined to unexamined cases.

[4] Goodman (1955)

This "projectability" is "determined primarily by the relative "entrenchment" of their constituent predicates."[5] That is, by the extent to which the predicates have previously been used in generalisations. Thus, terms like 'Caius philosopher' are ruled out because of the lack of entrenchment. Whilst this method of distinction is not contentious, it is especially pertinent for our discussion as a lawlike sentence must be confirmable by its instances – and thus be of a general form – in order for it to function in an explanatory fashion.

3. Explanation and Prediction

I earlier linked the predictive power of science with its explanatory power. With a better grasp of the deductive-nomological model of scientific explanation we can now make the nature of this link more clearly. Galileo's laws for the motion of projectiles state that a projectile will travel furthest, at any given initial velocity, if fired at an angle of 45°. He already knew this to be the case from the testimonies of gunners firing cannons and mortars. By making deductions from his laws, Galileo was able to make the prediction that equal deviation above and below 45° will cause equal deviations in distance from the maximum. This as yet untested prediction was confirmed by further empirical study. This nice example illustrates the form of the link between explanation and prediction – both important features of the scientific endeavour rely upon the deductive-nomological model.

We may note that predictions about the future cannot be made simply using specifications about the system in question at the time that the predictions are made. The laws and auxiliary facts must also make some accurate claim about the system at the time of the predicted event. For example, one must include in the explanans a premise, implicit or explicit, that unexpected disturbing influences do not affect the system at the time when the prediction is expected to be borne out – such as a freak gust of wind when Galileo's projectile is mid-flight.

[5] Hemple, ibid

Given this proviso we can see how a deductive-nomological explanation is a potential deductive-nomological prediction – the potential being realised if we know the laws and facts of the explanans at a time suitably earlier than the event described in the explanandum. Thus the difference between a scientific explanation and a scientific prediction is a pragmatic rather than logical one. Hemple refers to this as the *thesis of the structural identity of explanation and prediction*.

4. Problems with the Thesis of Structural Identity

This thesis is not without its critics. The symmetry in structure of prediction and explanation leads to two sub-theses: That every adequate explanation is potentially a prediction and that every adequate prediction is potentially an explanation. These two theses must be separated as they are not both treated as equally immune to criticism.

In defending the first of the sub-theses Hemple states a general condition: "Any rationally acceptable answer to the question 'Why did event X occur?' must offer information which shows that X was to be expected – if not definitely, as in the case of D-N explanation, then at least with reasonable probability." [6] If X had the potential to be expected due to a deductive nomological explanation then it must also have had the potential to be predicted by this explanation.

This notion has been attacked by several critics who make the claim that there are certain adequate explanations that do not constitute potential predictions. Scriven makes just this criticism, illustrating it through the link between syphilis and paresis.[7] We may explain why an individual develops paresis by presenting the proposition 'The only cause of paresis is syphilis' in conjunction with the fact that the individual has suffered from syphilis. Scriven

[6] Hemple, ibid
[7] Scriven, 1959

maintains that this is a perfectly adequate explanation for the individual's paresis – even though only a very small proportion of syphilitic patients develop paresis. This last fact must lead us to rationally predict that any given syphilis sufferer will not develop paresis. However, if paresis does occur, we must conclude that syphilis is the cause – as no other cause of paresis is known. Scriven believes that this provides an adequate explanation that is not an adequate potential prediction.

Hemple correctly counters this claim by pointing out that the rarity of syphilitic patients developing paresis prevents syphilis forming a sufficient adequate explanation for paresis – despite its necessary presence in any explanation of paresis. Hemple likens this method of explanation to explaining a man's winning first prize in the Irish sweepstake by his buying a ticket – thought buying a ticket is a necessary condition for winning, it is far from sufficient. More radically than this, I believe Scriven's criticism to be analogous to claiming that paresis develops because the patient is breathing. Breathing is, presumably, like syphilis, a necessary, thought not sufficient property for developing paresis.

There is no doubt that the above criticism introduces a type of phenomenon that we have not so far dealt with. Hitherto we have been applying our theory to relatively simply deterministic phenomenon. Hemple points out, "the best examples of explanations conforming to the D-N [deductive-nomological] model are based on physical theories of deterministic character." Perhaps most simply, Boyle's law explains measurable and predictable changes in pressure in terms of changes in volume – given certain auxiliary facts such as constant temperature. In examples utilising such simple and easily applicable deterministic laws we can use the deductive-nomological model to show why the explanandum can be expected with certainty.

Scriven's example of paresis introduces a notion that he exploits further in another example. He suggests that in some cases we are only capable of asserting some or all of the explanans after we have attained knowledge that the explanandum event occurred. We are asked to imagine the explanation of a bridge collapsing due to metal fatigue. The collapse would only occur in the case of excessive load, external damage or metal fatigue. We are aware that the first two factors are absent at the time of collapse and that there is evidence of metal fatigue. Given our knowledge that the bridge *did* collapse we are able to assert that metal fatigue was strong enough to cause the failure.

However, all that this example succeeds in showing is that at times we are not aware that all the conditions of the explanans are realised independently of the explanandum. This means that we must introduce the notion of a counterfactual into our explanans. This allows the counterfactual clause (e.g. 'If the bridge collapses in the absence of excessive load or external damage…) to remain unsatisfied without falsifying the thesis itself. Furthermore, Scriven's case is rather superficial in that we may suppose the limitation here to be a pragmatic one – i.e. at a time prior to the collapse we were not capable of discovering the presence and extent of the metal fatigue – there is no epistemic impossibility due to laws of logic or nature here.

Cases of events that are inherently probabilistic and allow no possibility of certainty pose a rather more interesting problem. Bird invites us to imagine the example an atomic nucleus decaying. Some form of 'inductive-statistical' approach to explanation may be adopted here. This is a form of the Deductive-Nomological approach that contains a law in the explanans that makes the explanandum very likely thought not necessary (e.g. 'The probability of the bridge collapsing because of metal fatigue is very high. '). We may note here that the degree of probability involved in the explanans is not the most important factor in the explanation. Imagine two people, X and Y, commit suicide. If our best psychological theory, involving all available data – race, sex, affluence, background etc – proposes that X's suicide was far more likely than Y's we may not conclude that our explanation of X's suicide is any better than that of Y's.[8] Hemple proposes that the inductive-statistical approach is appropriate to adopt in cases where the explanans is incomplete.

[8] Greeno and Jeffrey, 1971

Thus the inductive-statistical approach provides us with some means of explanation whilst our knowledge is incomplete. However, in cases where our knowledge is not incomplete but rather that further knowledge is impossible – as in the case of a nucleus decaying – genuine scientific explanation seems somewhat problematic. Indeed, Hemple does seem to conclude that the inductive-statistical model is "completely parasitic" [9] upon his Deductive-Nomological model. If there exist indeterministic phenomena, such as the decay of a radioactive nucleus, we are faced with a complete inductive-statistical explanation. This forces a detachment of the inductive-statistical model from the Deductive-Nomological, leading to severe problems for certain aspects of Hemple's theory.

However, the case that apparently best illustrates Hemple's problems may also save him. If we are presented with two identical atomic nuclei one may decay and the other may not. This is not attributable to any difference in the nuclei or their surroundings. One nucleus simply decayed whilst the other did not. As this is the case it is difficult to see how a law of nuclear decay may be involved in the explanation of the event. Both nuclei are equally subject to the law but we observe them behaving in different ways. Bird suggests that we should conclude that "the law explains neither the occurrence of the decay nor its non-occurrence."[10] Whilst this seems rather paradoxical Bird proposes that we accept the notion of objective chance – that each individual nucleus has a certain probability of decaying within a certain time. Thus the law explains the fact that both nuclei had X chance of decaying. It does not explain the decay or non-decay - these are things that are not to be explained – they are indeterministic. This view is more satisfactory than Hemple's more simplistic view that of the "epistemic relativity of the inductive-statistical explanation"[11] and saves the bulk of his theory from critics such as Salmon.

[9] Salmon, Causality and Explanation
[10] Bird, ibid
[11] Hemple, ibid