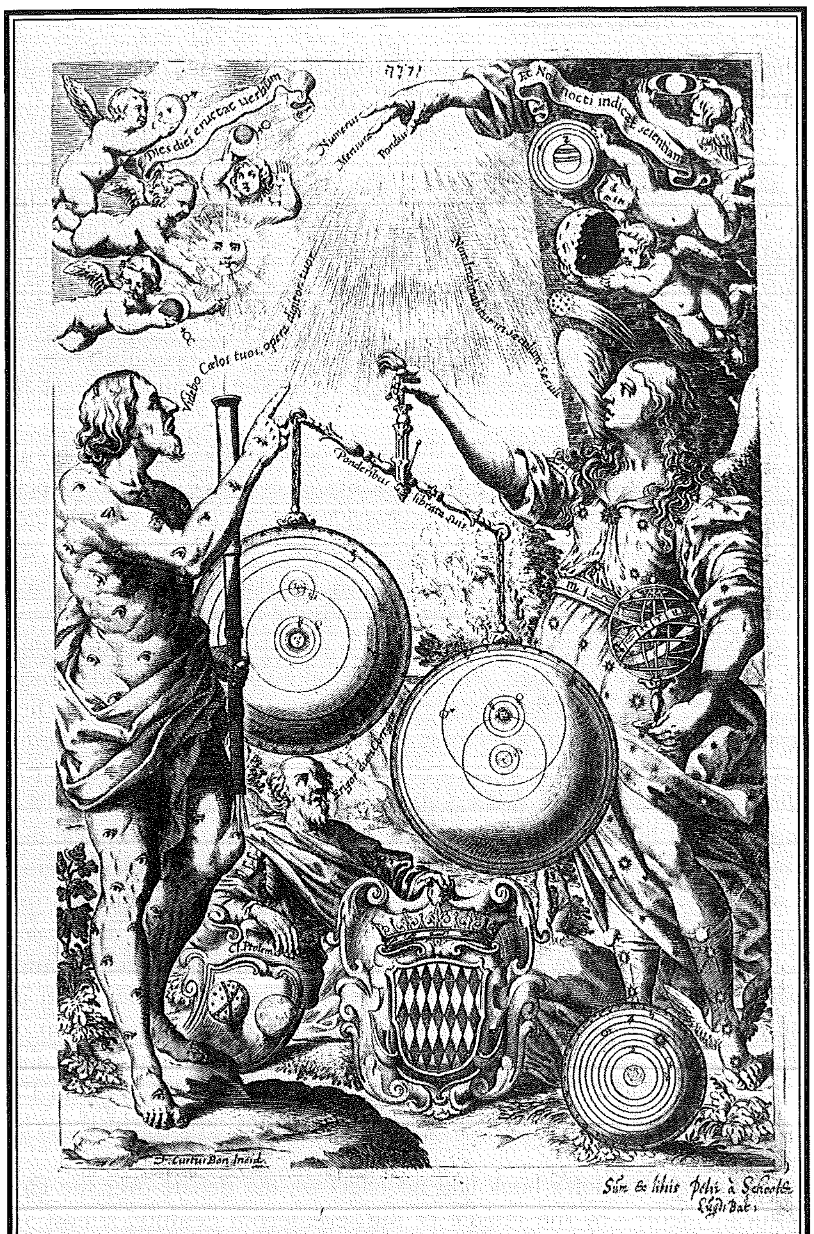

Philosophy of Science

The Central Issues

Martin Curd | J. A. Cover

W. W. Norton & Company
New York | London

A. J. AYER

What Is a Law of Nature?

There is a sense in which we know well enough what is ordinarily meant by a law of nature. We can give examples. Thus it is, or is believed to be, a law of nature that the orbit of a planet around the sun is an ellipse, or that arsenic is poisonous, or that the intensity of a sensation is proportionate to the logarithm of the stimulus, or that there are 303,000,000, 000,000,000,000,000 molecules in one gram of hydrogen. It is not a law of nature, though it is necessarily true, that the sum of the angles of a Euclidean triangle is 180 degrees, or that all the presidents of the third French Republic were male, though this is a legal fact in its way, or that all the cigarettes which I now have in my cigarette case are made of Virginian tobacco, though this again is true and, given my tastes, not wholly accidental. But while there are many such cases in which we find no difficulty in telling whether some proposition, which we take to be true, is or is not a law of nature, there are cases where we may be in doubt. For instance, I suppose that most people take the laws of nature to include the first law of thermodynamics, the proposition that in any closed physical system the sum of energy is constant: but there are those who maintain that this principle is a convention, that it is interpreted in such a way that there is no logical possibility of its being falsified, and for this reason they may deny that it is a law of nature at all. There are two questions at issue in a case of this sort: first, whether the principle under discussion is in fact a convention, and secondly whether its being a convention, if it is one, would disqualify it from being a law of nature. In the same way, there may be a dispute whether statistical generalizations are to count as laws of nature, as distinct from the dispute whether certain generalizations, which have been taken to be laws of nature, are in fact

FROM *The Concept of a Person* (New York: St. Martin's Press, 1963), 209–34. This article was first published in *Revue Internationale de Philosophie* 36 (1956), 144–65.

statistical. And even if we were always able to tell, in the case of any given proposition, whether or not it had the form of a law of nature, there would still remain the problem of making clear what this implied.

The use of the word 'law', as it occurs in the expression 'laws of nature', is now fairly sharply differentiated from its use in legal and moral contexts: we do not conceive of the laws of nature as imperatives. But this was not always so. For instance, Hobbes in his *Leviathan* lists fifteen 'laws of nature' of which two of the most important are that men 'seek peace, and follow it' and 'that men perform their covenants made': but he does not think that these laws are necessarily respected. On the contrary, he holds that the state of nature is a state of war, and that covenants will not in fact be kept unless there is some power to enforce them. His laws of nature are like civil laws except that they are not the commands of any civil authority. In one place he speaks of them as 'dictates of Reason' and adds that men improperly call them by the name of laws: 'for they are but conclusions or theorems concerning what conduceth to the conservation and defence of themselves: whereas Law, properly, is the word of him, that by right hath command over others'. 'But yet,' he continues, 'if you consider the same Theorems, as delivered in the word of God, that by right commandeth all things; then they are properly called Laws.'[1]

It might be thought that this usage of Hobbes was so far removed from our own that there was little point in mentioning it, except as a historical curiosity; but I believe that the difference is smaller than it appears to be. I think that our present use of the expression 'laws of nature' carries traces of the conception of Nature as subject to command. Whether these commands are conceived to be those of a personal deity or, as by the Greeks, of an impersonal fate, makes no difference here. The point, in either case, is that the sovereign is thought to be so powerful that its dictates are bound to be obeyed. It is not as in Hobbes's usage a question of moral duty or of prudence, where the subject has freedom to err. On the view which I am now considering, the commands which are issued to Nature are delivered with such authority that it is impossible that she should disobey them. I do not claim that this view is still prevalent; at least not that it is explicitly held. But it may well have contributed to the persistence of the feeling that there is some form of necessity attaching to the laws of nature, a necessity which, as we shall see, it is extremely difficult to pin down.

In case anyone is still inclined to think that the laws of nature can be identified with the commands of a superior being, it is worth pointing out that this analysis cannot be correct. It is already an objection to it that it burdens our science with all the uncertainty of our metaphysics, or our theology. If it should turn out that we had no good reason to believe in the existence of such a superior being, or no good reason to believe that he issued any commands, it would follow, on this analysis, that we should not be entitled to believe that there were any laws of nature. But the main argument against this view is independent of any doubt that one may have about the existence of a superior being. Even if we knew that such a one existed, and that he regulated nature, we still could not identify the laws of nature with his commands. For it is only by discovering what were the laws of nature that we could know what form these commands had taken. But this implies that we have some independent criteria for deciding what the laws of nature are. The assumption that they are imposed by a superior being is therefore idle, in the same way as the assumption of providence is idle. It is only if there are independent means of finding out what is going to happen that one is able to say what providence has in store. The same objection applies to the rather more fashionable view that moral laws are the commands of a superior being: but this does not concern us here.

There is, in any case, something strange about the notion of a command which it is impossible to disobey. We may be sure that some command will never in fact be disobeyed. But what is meant by saying that it cannot be? That the sanctions which sustain it are too strong? But might not one be so rash or so foolish as to defy them? I am inclined to say that it is in the nature of commands that it should be possible to disobey them. The necessity which is ascribed to these supposedly irresistible commands belongs in fact to something different: it belongs to the laws of logic. Not that the laws of logic cannot be disregarded; one can make mistakes in deductive reasoning, as in anything else. There is, however, a sense in which it is impossible for anything that happens to contravene the laws of logic. The restriction lies not upon the events themselves but on our method of describing them. If we break the rules according to which our method of description functions, we are not using it to describe anything. This might suggest that the events themselves really were disobeying the laws of logic, only we could not say so. But this would be an error. What is describable as an event obeys the laws of logic: and what is not describable as an event is not an event at all. The chains which logic puts upon nature are purely formal: being formal they weigh nothing, but for the same reason they are indissoluble.

From thinking of the laws of nature as the commands of a superior being, it is therefore only a short step to crediting them with the necessity that belongs to the laws of logic. And this is in fact a view which many philosophers have held. They have taken it for granted that a proposition could express a law of nature only if it stated that events, or properties, of certain kinds were necessarily connected; and they have interpreted this necessary connection as being identical with, or closely analogous to, the necessity with which the conclusion follows from the premisses of a deductive argument; as being, in short, a logical relation. And this has enabled them to reach the strange conclusion that the laws of nature can, at least in principle, be established independently of experience: for if they are purely logical truths, they must be discoverable by reason alone.

The refutation of this view is very simple. It was decisively set out by Hume. 'To convince us', he says, 'that all the laws of nature and all the operations of bodies, without exception, are known only by experience, the following reflections may, perhaps, suffice. Were any object presented to us, and were we required to pronounce concerning the effect, which will result from it, without consulting past observation: after what manner, I beseech you, must the mind proceed in this operation? It must invent or imagine some event, which it ascribes to the object as its effect: and it is plain that this invention must be entirely arbitrary. The mind can never find the effect in the supposed cause, by the most accurate scrutiny and examination. For the effect is totally different from the cause, and consequently can never be discovered in it.'[2]

Hume's argument is, indeed, so simple that its purport has often been misunderstood. He is represented as maintaining that the inherence of an effect in its cause is something which is not discoverable in nature; that as a matter of fact our observations fail to reveal the existence of any such relation: which would allow for the possibility that our observations might be at fault. But the point of Hume's argument is not that the relation of necessary connection which is supposed to conjoin distinct events is not in fact observable: it is that there could not be any such relation, not as a matter of fact but as a matter of logic. What Hume is pointing out is that if two events are distinct, they are distinct: from a statement which does no more than assert the existence of one of them it is impossible to deduce anything concerning the existence of the other. This is, indeed, a plain tautology. Its importance lies in the fact that Hume's opponents denied it. They wished to maintain both that the events which were coupled by the laws of nature were logically distinct from one another, and that they were united by a logical relation. But this is a manifest contradiction. Philosophers who hold this view are apt to express it in a form which leaves the contradiction latent: it was Hume's achievement to have brought it clearly to light.

In certain passages Hume makes his point by saying that the contradictory of any law of nature is at least conceivable; he intends thereby to show that the truth of the statement which expresses such a law is an empirical matter of fact and not an *a priori* certainty. But to this it has been objected that the fact that the contradictory of a proposition is conceivable is not a decisive proof that the proposition is not necessary. It may happen, in doing logic or pure mathematics, that one formulates a statement which one is unable either to prove or disprove. Surely in that case both the alternatives of its truth and falsehood are conceivable. Professor W. C. Kneale, who relies on this objection,[3] cites the example of Goldbach's conjecture that every even number greater than two is the sum of two primes. Though this conjecture has been confirmed so far as it has been tested, no one yet knows for certain whether it is true or false: no proof has been discovered either way. All the same, if it is true, it is necessarily true, and if it is false, it is necessarily false. Suppose that it should turn out to be false. We surely should not be prepared to say that what Goldbach had conjectured to be true was actually inconceivable. Yet we should have found it to be the contradictory of a necessary proposition. If we insist that this does prove it to be inconceivable, we find ourselves in the strange position of having to hold that one of two alternatives is inconceivable, without our knowing which.

I think that Professor Kneale makes his case: but I do not think that it is an answer to Hume. For Hume is not primarily concerned with showing that a given set of propositions, which have been taken to be necessary, are not so really. This is only a possible consequence of his fundamental point that 'there is no object which implies the existence of any other if we consider these objects in themselves, and never look beyond the idea which we form of them',[4] in short, that to say that events are distinct is incompatible with saying that they are logically related. And against this Professor Kneale's objection has no force at all. The most that it could prove is that, in the case of the particular examples that he gives, Hume might be mistaken in supposing that the events in question really were distinct: in spite of the appearances to the contrary, an expression which he interpreted as referring to only one of them might really be used in such a way that it included a reference to the other.

But is it not possible that Hume was always so mistaken; that the events, or properties, which are coupled by the laws of nature never are distinct? This question is complicated by the fact that once a generalization is accepted as a law of nature it tends to change its status. The meanings which we attach to our expressions are not completely constant: if we are firmly convinced that every object of a kind which is designated by a certain term has some property which the term does not originally cover, we tend to include the property in the designation; we extend the definition of the object, with or without altering the words which refer to it. Thus, it was an empirical discovery that loadstones attract iron and steel: for someone who uses the word 'loadstone' only to refer to an object which has a certain physical appearance and constitution, the fact that it behaves in this way is not formally deducible. But, as the word is now generally used, the proposition that loadstones attract iron and steel is analytically true: an object which did not do this would not properly be called a loadstone. In the same way, it may have become a necessary truth that water has the chemical composition H_2O. But what then of heavy water which has the composition D_2O? Is it not really water? Clearly this question is quite trivial. If it suits us to regard heavy water as a species of water, then we must not make it necessary that water consists of H_2O. Otherwise, we may. We are free to settle the matter whichever way we please.

Not all questions of this sort are so trivial as this. What, for example, is the status in Newtonian physics of the principle that the acceleration of a body is equal to the force which is acting on it divided by its mass? If we go by the text-books in which 'force' is defined as the product of mass and acceleration, we shall conclude that the principle is evidently analytic. But are there not other ways of defining force which allow this principle to be empirical? In fact there are, but as Henri Poincaré has shown,[5] we may then find ourselves obliged to treat some other Newtonian principle as a convention.* It would appear that in a system of this kind there is likely to be a conventional element, but that, within limits, we can situate it where we choose. What is put to the test of experience is the system as a whole.

This is to concede that some of the propositions which pass for laws of nature are logically necessary, while implying that it is not true of all of them. But one might go much further. It is at any rate conceivable that at a certain stage the science of physics should become so unified that it could be wholly axiomatized: it would attain the status of a geometry in which all the generalizations were regarded as necessarily true. It is harder to envisage any such development in the science of biology, let alone the social sciences, but it is not theoretically impossible that it should come about there too. It would be characteristic of such systems that no experience could falsify them, but their security might be sterile. What would take the place of their being falsified would be the discovery that they had no empirical application.

The important point to notice is that, whatever may be the practical or aesthetic advantages of turning scientific laws into logically necessary truths, it does not advance our knowledge, or in any way add to the security of our beliefs. For what we gain in one way, we lose in another. If we make it a matter of definition that there are just so many million molecules in every gram of hydrogen, then we can indeed be certain that every gram of hydrogen will contain that number of molecules: but we must become correspondingly more doubtful, in any given case, whether what we take to be a gram of hydrogen really is so. The more we put into our definitions, the more uncertain it becomes whether anything satisfies them: this is the price that we pay for diminishing the risk of our laws being falsified. And

* See chapter 6 of *La science et l'hypothèse* (Paris: E. Flammarion, 1902); *Science and Hypothesis*, trans. W. J. Greenstreet (New York: Dover, 1952). Poincaré reasons that any attempt to verify the second law, $F = ma$, by experiment—even on a single body of constant mass—requires a way of measuring forces independently of the accelerations they cause and of ascertaining when two forces are equal in magnitude. This, he argues, must presuppose the truth of the third law (that action and reaction are equal and opposite). Thus, he concludes that if the second law is empirical, then the third law must be treated as a definition. Poincaré also argues that if the second law is treated not as an empirical law but as a definition of force, then it can be applied to more than one body only if the masses of different bodies can be compared. This, too, he argues, presupposes Newton's third law, since when two bodies act on each other, the ratio of their masses is defined as the inverse ratio of their accelerations (assuming that no other bodies are acting on them).

if it ever came to the point where all the 'laws' were made completely secure by being treated as logically necessary, the whole weight of doubt would fall upon the statement that our system had application. Having deprived ourselves of the power of expressing empirical generalizations, we should have to make our existential statements do the work instead.

If such a stage were reached, I am inclined to say that we should no longer have a use for the expression 'laws of nature', as it is now understood. In a sense, the tenure of such laws would still be asserted: they would be smuggled into the existential propositions. But there would be nothing in the system that would count as a law of nature: for I take it to be characteristic of a law of nature that the proposition which expresses it is not logically true. In this respect, however, our usage is not entirely clear-cut. In a case where a sentence has originally expressed an empirical generalization, which we reckon to be a law of nature, we are inclined to say that it still expresses a law of nature, even when its meaning has been so modified that it has come to express an analytic truth. And we are encouraged in this by the fact that it is often very difficult to tell whether this modification has taken place or not. Also, in the case where some of the propositions in a scientific system play the rôle of definitions, but we have some freedom in deciding which they are to be, we tend to apply the expression 'laws of nature' to any of the constituent propositions of the system, whether or not they are analytically true. But here it is essential that the system as a whole should be empirical. If we allow the analytic propositions to count as laws of nature, it is because they are carried by the rest.

Thus to object to Hume that he may be wrong in assuming that the events between which his causal relations hold are 'distinct existences' is merely to make the point that it is possible for a science to develop in such a way that axiomatic systems take the place of natural laws. But this was not true of the propositions with which Hume was concerned, nor is it true, in the main, of the sciences of to-day. And in any case Hume is right in saying that we cannot have the best of both worlds; if we want our generalizations to have empirical content, they cannot be logically secure; if we make them logically secure, we rob them of their empirical content. The relations which hold between things, or events, or properties, cannot be both factual and logical. Hume himself spoke only of causal relations, but his argument applies to any of the relations that science establishes, indeed to any relations whatsoever.

It should perhaps be remarked that those philosophers who still wish to hold that the laws of nature are 'principles of necessitation'[6] would not agree that this came down to saying that the propositions which expressed them were analytic. They would maintain that we are dealing here with relations of objective necessity, which are not to be identified with logical entailments, though the two are in certain respects akin. But what are these relations of objective necessity supposed to be? No explanation is given except that they are just the relations that hold between events, or properties, when they are connected by some natural law. But this is simply to restate the problem; not even to attempt to solve it. It is not as if this talk of objective necessity enabled us to detect any laws of nature. On the contrary it is only *ex post facto*, when the existence of some connection has been empirically tested, that philosophers claim to see that it has this mysterious property of being necessary. And very often what they do 'see' to be necessary is shown by further observation to be false. This does not itself prove that the events which are brought together by a law of nature do not stand in some unique relation. If all attempts at its analysis fail, we may be reduced to saying that it is *sui generis* [altogether unique]. But why then describe it in a way which leads to its confusion with the relation of logical necessity?

A further attempt to link natural with logical necessity is to be found in the suggestion that two events E and I are to be regarded as necessarily connected when there is some well-established universal statement U, from which, in conjunction with the proposition *i*, affirming the existence of I, a proposition *e*, affirming the existence of E, is formally deducible.[7] This suggestion has the merit of bringing out the fact that any necessity that there may be in the connection of two distinct events comes only through a law. The proposition which describes 'the initial conditions' does not by itself entail the proposition which describes the 'effect': it does so only when it is combined with a causal law. But this does not allow us to say that the law itself is necessary. We can give a similar meaning to saying that the law is necessary by stipulating that it follows, either directly or with the help of certain further premisses, from some more general principle. But then what is the status of these more general principles? The question what constitutes a law of nature remains, on this view, without an answer.

II

Once we are rid of the confusion between logical and factual relations, what seems the obvious course is to hold that a proposition expresses a law of nature when it states what invariably happens. Thus, to say that unsupported bodies fall, assuming this to be a law of nature, is to say that there is not, never has been, and never will be a body that being unsupported does not fall. The 'necessity' of a law consists, on this view, simply in the fact that there are no exceptions to it.

It will be seen that this interpretation can also be extended to statistical laws. For they too may be represented as stating the existence of certain constancies in nature: only, in their case, what is held to be constant is the proportion of instances in which one property is conjoined with another or, to put it in a different way, the proportion of the members of one class that are also members of another. Thus it is a statistical law that when there are two genes determining a hereditary property, say the colour of a certain type of flower, the proportion of individuals in the second generation that display the dominant attribute, say the colour white as opposed to the colour red, is three quarters. There is, however, the difficulty that one does not expect the proportion to be maintained in every sample. As Professor R. B. Braithwaite has pointed out, 'when we say that the proportion (in a non-literal sense) of the male births among births is 51 per cent, we are not saying of any particular class of births that 51 per cent are births of males, for the actual proportion might differ very widely from 51 per cent in a particular class of births, or in a number of particular classes of births, without our wishing to reject the proposition that the proportion (in the nonliteral sense) is 51 per cent.'[8] All the same the 'non-literal' use of the word 'proportion' is very close to the literal use. If the law holds, the proportion must remain in the neighbourhood of 51 per cent, for any sufficiently large class of cases: and the deviations from it which are found in selected sub-classes must be such as the application of the calculus of probability would lead one to expect. Admittedly, the question what constitutes a sufficiently large class of cases is hard to answer. It would seem that the class must be finite, but the choice of any particular finite number for it would seem also to be arbitrary. I shall not, however, attempt to pursue this question here. The only point that I here wish to make is that a statistical law is no less 'lawlike' than a causal law. Indeed, if the propositions which express causal laws are simply statements of what invariably happens, they can themselves be taken as expressing statistical laws, with ratios of 100 per cent. Since a 100 per cent ratio, if it really holds, must hold in every sample, these 'limiting cases' of statistical laws escape the difficulty which we have just remarked on. If henceforth we confine our attention to them, it is because the analysis of 'normal' statistical laws brings in complications which are foreign to our purpose. They do not affect the question of what makes a proposition lawlike: and it is in this that we are mainly interested.

On the view which we have now to consider, all that is required for there to be laws in nature is the existence of *de facto* constancies. In the most straightforward case, the constancy consists in the fact that events, or properties, or processes of different types are invariably conjoined with one another. The attraction of this view lies in its simplicity: but it may be too simple. There are objections to it which are not easily met.

In the first place, we have to avoid saddling ourselves with vacuous laws. If we interpret statements of the form 'All S is P' as being equivalent, in Russell's notation, to general implications of the form '$(x)(\Phi x \supset \Psi x)$', we face the difficulty that such implications are considered to be true in

all cases in which their antecedent is false.* Thus we shall have to take it as a universal truth both that all winged horses are spirited and that all winged horses are tame; for assuming, as I think we may, that there never have been or will be any winged horses, it is true both that there never have been or will be any that are not spirited, and that there never have been or will be any that are not tame.† And the same will hold for any other property that we care to choose. But surely we do not wish to regard the ascription of any property whatsoever to winged horses as the expression of a law of nature.

The obvious way out of this difficulty is to stipulate that the class to which we are referring should not be empty. If statements of the form 'All S is P' are used to express laws of nature, they must be construed as entailing that there are S's. They are to be treated as the equivalent, in Russell's notation, of the conjunction of the propositions '$(x)(\Phi x \supset \Psi x)$ and $(\exists x)\Phi x$'. But this condition may be too strong. For there are certain cases in which we do wish to take general implications as expressing laws of nature, even though their antecedents are not satisfied. Consider, for example, the Newtonian law that a body on which no forces are acting continues at rest or in uniform motion along a straight line. It might be argued that this proposition was vacuously true, on the ground that there are in fact no bodies on which no forces are acting; but it is not for this reason that it is taken as expressing a law. It is not interpreted as being vacuous. But how then does it fit into the scheme? How can it be held to be descriptive of what actually happens?

What we want to say is that if there *were* any bodies on which no forces were acting then they *would* behave in the way that Newton's law prescribes. But we have not made any provision for such hypothetical cases: according to the view which we are now examining, statements of law cover only what is actual, not what is merely possible. There is, however, a way in which we can still fit in such 'non-instantial' laws. As Professor C. D. Broad has suggested,[9] we can treat them as referring not to hypothetical objects, or events, but only to the hypothetical consequences of instantial laws. Our Newtonian law can then be construed as implying

* Throughout this reading, we have added parentheses to Ayer's formulas. The universal generalization "$(x)(\Phi x \supset \Psi x)$" should be read as "for all x, if x has property Φ, then x has property Ψ." Because of the way that the truth-functional connective "$\supset$" is defined, any conditional formula of the form "$(p \supset q)$" is true whenever its antecedent, p, is false, regardless of whether the consequent, q, is true or false. Hence, Ayer's remark about winged horses in the next sentence.

† In predicate logic, "$(x)(\Phi x \supset \Psi x)$" is logically equivalent to "$\sim(\exists x)(\Phi x \,\&\, \sim \Psi x)$." This negation of an existential generalization says "it is not the case that there exists anything, x, such that x has property Φ and lacks property Ψ." Consequently, when nothing has property Φ—as in Ayer's example of winged horses—both statements are true, regardless of the nature of property Ψ.

that there are instantial laws, in this case laws about the behaviour of bodies on which forces are acting, which are such that when combined with the proposition that there are bodies on which no forces are acting, they entail the conclusion that these bodies continue at rest, or in uniform motion along a straight line. The proposition that there are such bodies is false, and so, if it is interpreted existentially, is the conclusion, but that does not matter. As Broad puts it, 'what we are concerned to assert is that this false conclusion is a necessary consequence of the conjunction of a certain false instantial supposition with certain true instantial laws of nature'.

This solution of the present difficulty is commendably ingenious, though I am not sure that it would always be possible to find the instantial laws which it requires. But even if we accept it, our troubles are not over. For, as Broad himself points out, there is one important class of cases in which it does not help us. These cases are those in which one measurable quantity is said to depend upon another, cases like that of the law connecting the volume and temperature of a gas under a given pressure, in which there is a mathematical function which enables one to calculate the numerical value of either quantity from the value of the other. Such laws have the form '$x = Fy$', where the range of the variable y covers all possible values of the quantity in question. But now it is not to be supposed that all these values are actually to be found in nature. Even if the number of different temperatures which specimens of gases have or will acquire is infinite, there still must be an infinite number missing. How then are we to interpret such a law? As being the compendious assertion of all its actual instances? But the formulation of the law in no way indicates which the actual instances are. It would be absurd to construe a general formula about the functional dependence of one quantity on another as committing us to the assertion that just these values of the quantity are actually realized. As asserting that for a value n of y, which is in fact not realized, the proposition that it is realized, in conjunction with the set of propositions describing all the actual cases, entails the proposition that there is a corresponding value m of x? But this is open to the same objection, with the further drawback that the entailment would not hold. As asserting with regard to any given value n of y that either n is not realized or that there is a corresponding value m of x? This is the most plausible alternative, but it makes the law trivial for all the values of y which happen not to be realized. It is hard to escape the conclusion that what we really mean to assert when we formulate such a law is that there is a corresponding value of x to every *possible* value of y.

Another reason for bringing in possibilities is that there seems to be no other way of accounting for the difference between generalizations of law and generalizations of fact. To revert to our earlier examples, it is a generalization of fact that all the Presidents of the Third French Republic are male, or that all the cigarettes that are now in my cigarette case are made of Virginian tobacco. It is a generalization of law that the planets of our solar system move in elliptical orbits, but a generalization of fact that, counting the earth as Terra, they all have Latin names. Some philosophers refer to these generalizations of fact as 'accidental generalizations', but this use of the word 'accidental' may be misleading. It is not suggested that these generalizations are true by accident, in the sense that there is no causal explanation of their truth, but only that they are not themselves the expression of natural laws.

But how is this distinction to be made? The formula '$(x)(\Phi x \supset \Psi x)$' holds equally in both cases. Whether the generalization be one of fact or of law, it will state at least that there is nothing which has the property Φ but lacks the property Ψ. In this sense, the generality is perfect in both cases, so long as the statements are true. Yet there seems to be a sense in which the generality of what we are calling generalizations of fact is less complete. They seem to be restricted in a way that generalizations of law are not. Either they involve some spatio-temporal restriction, as in the example of the cigarettes *now* in my cigarette case, or they refer to particular individuals, as in the example of the presidents of France. When I say that all the planets have Latin names, I am referring definitely to a certain set of individuals, Jupiter, Venus, Mercury, and so on, but when I say that the planets move in elliptical orbits I am referring indefinitely to anything that has the properties that constitute being a planet in this solar system. But it will not do to say that generalizations of fact are simply conjunctions of particular statements, which definitely refer to individuals; for in asserting that the planets have Latin names, I do not individually identify them: I may know that they have Latin names without being able to list them all. Neither can we mark off generalizations of law by insisting that their expression is not to include any reference to specific places or times. For with a little ingenuity, generalizations of fact can always be made to satisfy this condition. Instead of referring to the cigarettes that are now in my cigarette case, I can find out some general property which only these cigarettes happen to possess, say the property of being contained in a cigarette case with such and such markings which is owned at such and such a period of his life by a person of such and such a sort, where the descriptions are so chosen that the description of the person is in fact satisfied only by me and the description of the cigarette case, if I possess more than one of them, only by the one in question. In certain instances these descriptions might have to be rather complicated, but usually they would not: and anyhow the question of complexity is not here at issue. But this means that, with the help of these 'individuating' predicates, generalizations of fact can be expressed in just as universal a form as generalizations of law. And conversely, as Professor Nelson Goodman has pointed out, generalizations of law can themselves be expressed in such a way that they contain a reference to particular individuals, or to specific places and times. For, as he remarks, 'even the hypothesis "All grass is green" has as an equivalent "All grass in London or elsewhere is green" '.[10] Admittedly, this assimilation of the two types of statement looks like a dodge; but the fact that the dodge works shows that we cannot found the distinction on a difference in the ways in which the statement can be expressed. Again, what we want to say is that whereas generalizations of fact cover only actual instances, generalizations of law cover possible instances as well. But this notion of possible, as opposed to actual, instances has not yet been made clear.

If generalizations of law do cover possible as well as actual instances, their range must be infinite; for while the number of objects which do throughout the course of time possess a certain property may be finite, there can be no limit to the number of objects which might possibly possess it: for once we enter the realm of possibility we are not confined even to such objects as actually exist. And this shows how far removed these generalizations are from being conjunctions: not simply because their range is infinite, which might be true even if it were confined to actual instances, but because there is something absurd about trying to list all the possible instances. One can imagine an angel's undertaking the task of naming or describing all the men that there ever have been or will be, even if their number were infinite, but how would he set about naming, or describing, all the possible men? This point is developed by F. P. Ramsey who remarks that the variable hypothetical '$(x)\Phi x$' resembles a conjunction (*a*) in that it contains all lesser, *i.e.* here all finite conjunctions, and appears as a sort of infinite product. (*b*) When we ask what would make it true, we inevitably answer that it is true if and only if every x has Φ; *i.e.* when we regard it as a proposition capable of the two cases truth and falsity, we are forced to make it a conjunction which we cannot express for lack of symbolic power'.[11] But, he goes on, 'what we can't say we can't say, and we can't whistle it either', and he concludes that the variable hypothetical is not a conjunction and that 'if it is not a conjunction, it is not a proposition at all'. Similarly, Professor Ryle, without explicitly denying that generalizations of law are propositions, describes them as 'seasonal inference warrants',[12] on the analogy of season railway-tickets, which implies that they are not so much propositions as rules. Professor Schlick also held that they were rules, arguing that they could not be propositions because they were not conclusively verifiable; but this is a poor argument, since it is doubtful if any propositions are conclusively verifiable, except possibly those that describe the subject's immediate experiences.

Now to say that generalizations of law are not propositions does have the merit of bringing out their peculiarity. It is one way of emphasizing the difference between them and generalizations of fact. But I think that it emphasizes it too strongly. After all, as Ramsey himself acknowledges, we do want to say that generalizations of law are either true or false. And

they are tested in the way that other propositions are, by the examination of actual instances. A contrary instance refutes a generalization of law in the same way as it refutes a generalization of fact. A positive instance confirms them both. Admittedly, there is the difference that if all the actual instances are favourable, their conjunction entails the generalization of fact, whereas it does not entail the generalization of law: but still there is no better way of confirming a generalization of law than by finding favourable instances. To say that lawlike statements function as seasonal inference warrants is indeed illuminating, but what it comes to is that the inferences in question are warranted by the facts. There would be no point in issuing season tickets if the trains did not actually run.

To say that generalizations of law cover possible as well as actual cases is to say that they entail subjunctive conditionals. If it is a law of nature that the planets move in elliptical orbits, then it must not only be true that the actual planets move in elliptical orbits; it must also be true that if anything were a planet it would move in an elliptical orbit: and here 'being a planet' must be construed as a matter of having certain properties, not just as being identical with one of the planets that there are. It is not indeed a peculiarity of statements which one takes as expressing laws of nature that they entail subjunctive conditionals: for the same will be true of any statement that contains a dispositional predicate. To say, for example, that this rubber band is elastic is to say not merely that it will resume its normal size when it has been stretched, but that it would do so if ever it were stretched: an object may be elastic without ever in fact being stretched at all. Even the statement that this is a white piece of paper may be taken as implying not only how the piece of paper does look but also how it would look under certain conditions, which may or may not be fulfilled. Thus one cannot say that generalizations of fact do not entail subjunctive conditionals, for they may very well contain dispositional predicates: indeed they are more likely to do so than not: but they will not entail the subjunctive conditionals which are entailed by the corresponding statements of law. To say that all the planets have Latin names may be to make a dispositional statement, in the sense that it implies not so much that people do always call them by such names but that they would so call them if they were speaking correctly. It does not, however, imply with regard to anything whatsoever that if it were a planet it would be called by a Latin name. And for this reason it is not a generalization of law, but only a generalization of fact.

There are many philosophers who are content to leave the matter there. They explain the 'necessity' of natural laws as consisting in the fact that they hold for all possible, as well as actual, instances: and they distinguish generalizations of law from generalizations of fact by bringing out the differences in their entailment of subjunctive conditionals. But while this is correct so far as it goes, I doubt if it goes far enough. Neither the notion of possible, as opposed to actual, instances nor that of the subjunctive conditional is so pellucid that these references to them can be regarded as bringing all our difficulties to an end. It will be well to try to take our analysis a little further if we can.

The theory which I am going to sketch will not avoid all talk of dispositions; but it will confine it to people's attitudes. My suggestion is that the difference between our two types of generalization lies not so much on the side of the facts which make them true or false, as in the attitude of those who put them forward. The factual information which is expressed by a statement of the form 'for all x, if x has Φ then x has Ψ', is the same whichever way it is interpreted. For if the two interpretations differ only with respect to the possible, as opposed to the actual values of x, they do not differ with respect to anything that actually happens. Now I do not wish to say that a difference in regard to mere possibilities is not a genuine difference, or that it is to be equated with a difference in the attitude of those who do the interpreting. But I do think that it can best be elucidated by referring to such differences of attitude. In short I propose to explain the distinction between generalizations of law and generalizations of fact, and thereby to give some account of what a law of nature is, by the indirect method of analysing the distinction between treating a generalization as a statement of law and treating it as a statement of fact.

If someone accepts a statement of the form '$(x)(\Phi x \supset \Psi x)$' as a true generalization of fact, he will not in fact believe that anything which has the property Φ has any other property that leads to its not having Ψ. For since he believes that everything that has Φ has Ψ, he must believe that whatever other properties a given value of x may have they are not such as to prevent its having Ψ. It may be even that he knows this to be so. But now let us suppose that he believes such a generalization to be true, without knowing it for certain. In that case there will be various properties X, X_1 . . . such that if he were to learn, with respect to any value of a of x, that a had one or more of these properties as well as Φ, it would destroy, or seriously weaken his belief that a had Ψ. Thus I believe that all the cigarettes in my case are made of Virginian tobacco, but this belief would be destroyed if I were informed that I had absent-mindedly just filled my case from a box in which I keep only Turkish cigarettes. On the other hand, if I took it to be a law of nature that all the cigarettes in this case were made of Virginian tobacco, say on the ground that the case had some curious physical property which had the effect of changing any other tobacco that was put into it into Virginian, then my belief would not be weakened in this way.

Now if our laws of nature were causally independent of each other, and if, as Mill thought, the propositions which expressed them were always put forward as being unconditionally true, the analysis could proceed quite simply. We could then say that a person A was treating a statement of the form 'for all x, if Φx then Ψx' as expressing a law of nature, if and only if there was no property X which was such that the information that a value a of x had X as well as Φ would weaken his belief that a had Ψ. And here we should have to admit the proviso that X did not logically entail not-Ψ, and also, I suppose, that its presence was not regarded as a manifestation of not-Ψ; for we do not wish to make it incompatible with treating a statement as the expression of a law that one should acknowledge a negative instance if it arises. But the actual position is not so simple. For one may believe that a statement of the form 'for all x, if Φx then Ψx' expresses a law of nature while also believing, because of one's belief in other laws, that if something were to have the property X as well as Φ it would not have Ψ. Thus one's belief in the proposition that an object which one took to be a loadstone attracted iron might be weakened or destroyed by the information that the physical composition of the supposed loadstone was very different from what one had thought it to be. I think, however, that in all such cases, the information which would impair one's belief that the object in question had the property Ψ would also be such that, independently of other considerations, it would seriously weaken one's belief that the object ever had the property Φ. And if this is so, we can meet the difficulty by stipulating that the range of properties which someone who treats 'for all x, if Φx then Ψx' as a law must be willing to conjoin with Φ, without his belief in the consequent being weakened, must not include those the knowledge of whose presence would in itself seriously weaken his belief in the presence of Φ.

There remains the further difficulty that we do not normally regard the propositions which we take to express laws of nature as being unconditionally true. In stating them we imply the presence of certain conditions which we do not actually specify. Perhaps we could specify them if we chose, though we might find it difficult to make the list exhaustive. In this sense a generalization of law may be weaker than a generalization of fact, since it may admit exceptions to the generalization as it is stated. This does not mean, however, that the law allows for exceptions: if the exception is acknowledged to be genuine, the law is held to be refuted. What happens in the other cases is that the exception is regarded as having been tacitly provided for. We lay down a law about the boiling point of water, without bothering to mention that it does not hold for high altitudes. When this is pointed out to us, we say that this qualification was meant to be understood. And so in other instances. The statement that if anything has Φ it has Ψ was a loose formulation of the law: what we really meant was that if anything has Φ but not X, it has Ψ. Even in the case where the existence of the exception was not previously known, we often regard it as qualifying rather than refuting the law. We say, not that the generalization has been falsified, but that it was inexactly stated. Thus, it must be allowed that someone whose belief in the presence of Ψ, in a given instance, is destroyed by the belief that Φ is accompanied by X may still be treating '$(x)(\Phi x \supset \Psi x)$' as expressing a law of nature if he is prepared to accept '$(x)((\Phi x \cdot \sim Xx) \supset \Psi x)$' as a more exact statement of the law.

Accordingly I suggest that for someone to treat a statement of the form 'if anything has Φ it has Ψ' as expressing a law of nature, it is sufficient (i) that subject to a willingness to explain away exceptions he believes that in a non-trivial sense everything which in fact has Φ has Ψ (ii) that his belief that something which has Φ has Ψ is not liable to be weakened by the discovery that the object in question also has some other property X, provided (*a*) that X does not logically entail not-Ψ (*b*) that X is not a manifestation of not-Ψ (*c*) that the discovery that something had X would not in itself seriously weaken his belief that it had Φ (*d*) that he does not regard the statement 'if anything has Φ and not-X it has Ψ' as a more exact statement of the generalization that he was intending to express.

I do not suggest that these conditions are necessary, both because I think it possible that they could be simplified and because they do not cover the whole field. For instance, no provision has been made for functional laws, where the reference to possible instances does not at present seem to me eliminable. Neither am I offering a definition of natural law. I do not claim that to say that some proposition expresses a law of nature entails saying that someone has a certain attitude towards it; for clearly it makes sense to say that there are laws of nature which remain unknown. But this is consistent with holding that the notion is to be explained in terms of people's attitudes. My explanation is indeed sketchy, but I think that the distinctions which I have tried to bring out are relevant and important: and I hope that I have done something towards making them clear.

Notes

1. *Leviathan*, Part I, Chap. xv.
2. *An Enquiry Concerning Human Understanding*, iv, I.25.
3. *Probability and Induction*, pp. 79 ff.
4. *A Treatise of Human Nature*, i, iii, vi.
5. Cf. *La Science et l'hypothèse* [Science and hypothesis], pp. 119–29.
6. Cf. Kneale, *op. cit.*
7. Cf. K. Popper, "What Can Logic Do for Philosophy?" *Supplementary Proceedings of the Aristotelian Society*, Vol. XXII: and papers in the same volume by W. C. Kneale and myself.
8. *Scientific Explanation*, pp. 118–29.

9. "Mechanical and Teleological Causation," *Supplementary Proceedings of the Aristotelian Society*, XIV, 98 ff.
10. *Fact, Fiction and Forecast*, p. 78.
11. *Foundations of Mathematics*, p. 238.
12. " 'If,' 'So,' and 'Because'," *Philosophical Analysis* (Essays edited by Max Black), p. 332.

FRED I. DRETSKE

Laws of Nature

It is tempting to identify the laws of nature with a certain class of universal truths. Very few empiricists have succeeded in resisting this temptation. The popular way of succumbing is to equate the fundamental laws of nature with what is asserted by those universally true statements of non-limited scope that embody only qualitative predicates.[1] On this view of things a law-like statement is a statement of the form "$(x)(Fx \supset Gx)$" or "$(x)(Fx \equiv Gx)$" where "*F*" and "*G*" are purely qualitative (nonpositional). Those law-like statements that are true express laws. "All robins' eggs are greenish blue," "All metals conduct electricity," and "At constant pressure any gas expands with increasing temperature" (Hempel's examples) are law-like statements. If they are true, they express laws. The more familiar sorts of things that we are accustomed to calling laws, the formulae and equations appearing in our physics and chemistry books, can supposedly be understood in the same way by using functors in place of the propositional functions "*Fx*" and "*Gx*" in the symbolic expressions given above.*

I say that it is tempting to proceed in this way since, to put it bluntly,

FROM *Philosophy of Science* 44 (1977): 248–68.

* Although it does not affect any of the philosophical issues debated in this chapter, Dretske's remark about functors raises an interesting question, namely, whether predicate logic has the resources to represent quantitative laws adequately. It seems most unlikely that a so-called functional law written as an equation involving several variables, each of which takes real numbers as values, can be properly regarded as having the simple form $(x)(Fx \supset Gx)$, where *F* and *G* are qualitative predicates. The functors mentioned by Dretske attempt to solve this problem by converting the equation into a function that is then treated as a predicate. Consider the ideal gas law, $PV = nRT$. The functor in this case might be, "is identical with the value of nRT divided by V" and the law would read (roughly): "For all x, if x is the value of the pressure of an ideal gas, then x is identical with the value of nRT divided by V." Not only is this clumsy but, by focusing on pressure in the antecedent, it obscures the interdependence of the variables: the ideal gas law is not about pressure; it is about all the variables and their functional relation. Alternatively, we might define the predicate "obeys the equation $PV = nRT$" and then portray the ideal gas law as: "For all x, if x is an ideal gas, then x obeys the equation $PV = nRT$." But this says merely that all ideal gases obey the ideal gas law, which can hardly be regarded as a perspicuous *representation* of the law.

conceiving of a law as having a content greater than that expressed by a statement of the form $(x)(Fx \supset Gx)$ seems to put it beyond our epistemological grasp.[2] We must work with what we are given, and what we are given (the observational and experimental data) are facts of the form: this *F* is *G*, that *F* is *G*, all examined *F*'s have been *G*, and so on. If, as some philosophers have argued,[3] law-like statements express a kind of nomic necessity between events, something *more* than that *F*'s are, as a matter of fact, always and everywhere, *G*, then it is hard to see what kind of evidence might be brought in support of them. The whole point in acquiring instantial evidence (evidence of the form "This *F* is *G*") in support of a law-like hypothesis would be lost if we supposed that what the hypothesis was actually asserting was some kind of nomic connection, some kind of modal relationship, between things that were *F* and things that were *G*. We would, it seems, be in the position of someone trying to confirm the *analyticity* of "All bachelors are unmarried" by collecting evidence about the marital status of various bachelors. This kind of evidence, though relevant to the *truth* of the claim that all bachelors are unmarried, is powerless to confirm the *modality* in question. Similarly, if a hypothesis, in order to qualify as a law, must express or assert some form of necessity between *F*'s and *G*'s, then it becomes a mystery how we ever manage to confirm such attributions with the sort of instantial evidence available from observation.

Despite this argument, the fact remains that laws are *not* simply what universally true statements express, not even universally true statements that embody purely qualitative predicates (and are, as a result, unlimited in scope). This is not particularly newsworthy. It is commonly acknowledged that law-like statements have some peculiarities that prevent their straightforward assimilation to universal truths. That the concept of a law and the concept of a universal truth are different concepts can best be seen, I think, by the following consideration: assume that $(x)(Fx \supset Gx)$ is true and that the predicate expressions satisfy all the restrictions that one might wish to impose in order to convert this universal statement into a statement of law.[4] Consider a predicate expression "*K*" (eternally) coextensive with "*F*"; i.e., $(x)(Fx \equiv Kx)$ for all time. We may then infer that if $(x)(Fx \supset Gx)$ is a universal truth, so is $(x)(Kx \supset Gx)$. The class of universal truths is closed under the operation of coextensive predicate substitution. Such is *not* the case with laws. If it is a law that all *F*'s are *G*, and we substitute the term "*K*" for the term "*F*" in this law, the result is not necessarily a law. If diamonds have a refractive index of 2.419 (law) and "is a diamond" is coextensive with "is mined in kimberlite (a dark basic rock)" we cannot infer that *it is a law* that things mined in kimberlite have a refractive index of 2.419. Whether this is a law or not depends on whether the coextensiveness of "is a diamond" and "is mined in kimberlite" is *itself* law-like. The class of laws is not closed under the same operation as is the class of universal truths.

Using familiar terminology we may say that the predicate positions in a statement of law are *opaque* while the predicate positions in a universal truth of the form $(x)(Fx \supset Gx)$ are *transparent*.* I am using these terms in a slightly unorthodox way. It is not that when we have a law, "All *F*'s are G," we can alter its truth value by substituting a coextensive predicate for "*F*" or "G." For if the statement is true, it will remain true after substitution. What happens, rather, is that the expression's status *as a law* is (or may be) affected by such an exchange. The matter can be put this way: the statement

(A) All *F*'s are G (understood as $(x)(Fx \supset Gx)$)

has "*F*" and "G" occurring in transparent positions. Its truth value is unaffected by the replacement of "*F*" or "G" by a coextensive predicate. The same is true of

(B) It is universally true that *F*'s are G.

If, however, we look at

(C) It is a law that *F*'s are G.

we find that "*F*" and "G" occur in opaque positions. If we think of the two prefixes in (B) and (C), "it is universally true that . . ." and "it is a law that . . . ," as operators, we can say that the operator in (B) does not, while the operator in (C) does, confer opacity on the embedded predicate positions. To refer to something as a statement of law is to refer to it as an expression in which the descriptive terms occupy opaque positions. To refer to something as a universal truth is to refer to it as an expression in which the descriptive terms occupy transparent positions. Hence, our concept of a law differs from our concept of a universal truth.[5]

* *Transparent* and *opaque* are terms used in the theory of reference. Consider the true sentence, "Blue whales live in water." If we replace the expression "blue whales" with a phrase that designates the same class of animals—"the largest mammals on earth," for example—then the sentence must remain true. Philosophers of language say that "Blue whales live in water" is a transparent context because its truth value cannot be altered by the substitution of coreferring expressions. Contrast this with "John knows that blue whales live in water." This is an opaque context. John might be ignorant of the fact that blue whales are the largest mammals on earth. Hence, he could know that blue whales live in water without also knowing that the largest mammals on earth live in water. Thus, in this case, the substitution of a coreferring expression could change a true sentence into a false one. Modal contexts (that is, sentences involving possibility or necessity) can also create opacity. "Blue whales are necessarily whales" is true but "The largest mammals on earth are necessarily whales" is false because it is contingent, not necessary, that the world's largest mammals happen to be whales. Similarly, Dretske argues, sentences of the form "It is a law that all *F*s are *G*" are referentially opaque.

Confronted by a difference of this sort, many philosophers have argued that the distinction between a natural law and a universal truth was not, fundamentally, an *intrinsic* difference. Rather, the difference was a difference in the *role* some universal statements played within the larger theoretical enterprise. Some universal statements are more highly integrated into the constellation of accepted scientific principles, they play a more significant role in the explanation and prediction of experimental results, they are better confirmed, have survived more tests, and make a more substantial contribution to the regulation of experimental inquiry. But, divorced from this context, stripped of these *extrinsic* features, a law is nothing but a universal truth. It has the same empirical content. Laws are to universal truths what shims are to slivers of wood and metal; the latter *become* the former by being *used* in a certain way. There is a *functional* difference, nothing else.[6]

According to this reductionistic view, the peculiar opacity (described above) associated with laws is not a manifestation of some intrinsic difference between a law and a universal truth. It is merely a symptom of the special status or function that some universal statements have. The basic formula is: law = universal truth + X. The "X" is intended to indicate the special function, status or role that a universal truth must have to qualify as a law. Some popular candidates for this auxiliary idea, X, are:

1 High degree of confirmation,
2 Wide acceptance (well established in the relevant community),
3 Explanatory potential (can be used to explain its instances),
4 Deductive integration (within a larger system of statements),
5 Predictive use.

To illustrate the way these values of X are used to buttress the equation of laws with universal truths, it should be noted that each of the concepts appearing on this list generates an opacity similar to that witnessed in the case of genuine laws. For example, to say that it is a law that all *F*'s are G may possibly be no more than to say that it is well established that $(x)(Fx \supset Gx)$. The peculiar opacity of laws is then explained by pointing out that the class of expressions that are well established (or highly confirmed) is not closed under substitution of coextensive predicates: one cannot infer that $(x)(Kx \supset Gx)$ is well established just because "*Fx*" and "*Kx*" are coextensive and $(x)(Fx \supset Gx)$ is well established (for no one may know that "*Fx*" and "*Kx*" *are* coextensive). It may be supposed, therefore, that the opacity of laws is merely a manifestation of the underlying fact that a universal statement, to qualify as a law, must be well established, and the opacity is a result of this epistemic condition. Or, if this will not do, we can suppose that one of the other notions mentioned above, or a combination of them, is the source of a law's opacity.

This response to the alleged uniqueness of natural laws is more or less standard fare among empiricists in the Humean tradition. Longstanding (= venerable) epistemological and ontological commitments motivate the equation: law = universal truth + X. There is disagreement among authors about the differentia X, but there is near unanimity about the fact that laws are a *species* of universal truth.

If we set aside our scruples for the moment, however, there is a plausible explanation for the opacity of laws that has not yet been mentioned. Taking our cue from Frege, it may be argued that since the operator "it is a law that . . ." converts the otherwise transparent positions of "All *F*'s are *G*" into opaque positions, we may conclude that this occurs because within the context of this operator (either explicitly present or implicitly understood) the terms "*F*" and "*G*" do not have their usual referents. There is a shift in what we are talking about. To say that *it is a law* that *F*'s are G is to say that "All *F*'s are *G*" is to be understood (in so far as it expresses a law), not as a statement about the extensions of the predicates "*F*" and "*G*," but as a singular statement describing a relationship between the universal properties *F*-ness and *G*-ness. In other words, (C) is to be understood as having the form:

6 *F*-ness → G-ness.[7]

To conceive of (A) as a universal truth is to conceive of it as expressing a relationship between the extensions of its terms; to conceive of it as a law is to conceive of it as expressing a relationship between the properties (magnitudes, quantities, features) which these predicates express (and to which we may refer with the corresponding abstract singular term). The opacity of laws is merely a manifestation of this change in reference. If "*F*" and "*K*" are coextensive, we cannot substitute the one for the other in the *law* "All *F*'s are *G*" and expect to preserve truth; for the law asserts a connection between *F*-ness and *G*-ness and there is no guarantee that a similar connection exists between the properties *K*-ness and *G*-ness just because all *F*'s are *K* and *vice versa*.[8]

It is this view that I mean to defend in the remainder of this essay. Law-like statements are singular statements of fact describing a relationship between properties or magnitudes. Laws are the relationships that are asserted to exist by true law-like statements. According to this view, then, there is an *intrinsic* difference between laws and universal truths. Laws imply universal truths, but universal truths do not imply laws. Laws are (expressed by) *singular* statements describing the relationships that exist between universal qualities and quantities; they are not universal statements about the particular objects and situations that exemplify these qualities and quantities. Universal truths are not transformed into laws by acquiring some of the extrinsic properties of laws, by being used in explanation or prediction, by being made to support counterfactuals, or by becoming well established. For, as we shall see, universal truths *cannot* function in these ways. They *cannot* be made to perform a service they are wholly unequipped to provide.

In order to develop this thesis it will be necessary to overcome some metaphysical prejudices, and to overcome these prejudices it will prove useful to review the major deficiencies of the proposed alternative. The attractiveness of the formula: law = universal truth + X, lies, partly at least, in its ontological austerity, in its tidy portrayal of what there is, or what there must be, in order for there to be laws of nature. The antidote to this seductive doctrine is a clear realization of how utterly hopeless, epistemologically and functionally hopeless, this equation is.

If the auxiliary ideas mentioned above (explanation, prediction, confirmation, etc.) are deployed as values of X in the reductionistic equation of laws with universal truths, one can, as we have already seen, render a satisfactory account of the opacity of laws. In this particular respect the attempted equation proves adequate. In what way, then, does it fail?

(1) and (2) are what I will call "epistemic" notions; they assign to a statement a certain epistemological status or cognitive value. They are, for this reason alone, useless in understanding the nature of a law.[9] Laws do not begin to be laws only when we first become aware of them, when the relevant hypotheses become well established, when there is public endorsement by the relevant scientific community. The laws of nature are the same today as they were one thousand years ago (or so we believe); yet, some hypotheses are highly confirmed today that were not highly confirmed one thousand years ago. It is certainly true that we only begin to *call* something a law when it becomes well established, that we only recognize something as a statement of law when it is confirmed to a certain degree, but that something *is* a law, that some statement does in fact express a law, does not similarly await our appreciation of this fact. We discover laws, we do not invent them—although, of course, some invention may be involved in our manner of expressing or codifying these laws. Hence, the status of something as a statement of law does not depend on its epistemological status. What does depend on such epistemological factors is our ability to identify an otherwise qualified statement *as true* and, therefore, *as a statement of law*. It is for this reason that one cannot appeal to the epistemic operators to clarify the nature of laws; they merely confuse an epistemological with an ontological issue.

What sometimes helps to obscure this point is the tendency to conflate laws with the verbal or symbolic expression of these laws (what I have been calling "statements of law"). Clearly, though, these are different things and should not be confused. There are doubtless laws that have not yet (or will never) receive symbolic expression, and the same law may be given different verbal codifications (think of the variety of ways of expressing the laws of thermodynamics). To use the language of "propositions" for a moment, a law is the proposition expressed, not the vehicle we use to express it. The *use* of a sentence *as an expression of law* depends on epistemological considerations, but the law itself does not.

There is, furthermore, the fact that whatever auxiliary idea we select for understanding laws (as candidates for X in the equation: law = universal truth + X), if it is going to achieve what we expect of it, should help to account for the variety of other features that laws are acknowledged to have. For example, it is said that laws "support" counterfactuals of a certain sort. If laws are universal truths, this fact is a complete mystery, a mystery that is usually suppressed by using the word "support." For, of course, universal statements do not *imply* counterfactuals in any sense of the word "imply" with which I am familiar. To be told that all *F*'s are G is not to be told anything that implies that if this *x* were an *F*, it would be G. To be told that all dogs born at sea have been and will be cocker spaniels is *not* to be told that we would get cocker spaniel pups (or no pups at all) if we arranged to breed dachshunds at sea. The only reason we might *think* we were being told this is because we do not expect anyone to assert that all dogs born at sea *will be* cocker spaniels unless they know (or have good reasons for believing) that this is true; and we do not understand *how* anyone could *know* that this is true without being privy to information that insures this result—without, that is, knowing of some bizzare law or circumstance that *prevents* anything but cocker spaniels from being born at sea. Hence, *if* we accept the claim at all, we do so with a certain presumption about what our informant must know in order to be a serious claimant. We assume that our informant knows of certain laws or conditions that *insure* the continuance of a past regularity, and it is this presumed knowledge that we exploit in endorsing or accepting the counterfactual. But the simple fact remains that the statement "All dogs born at sea have been and will be cocker spaniels" does not *itself* support or imply this counterfactual; at best, *we* support the counterfactual (if we support it at all) on the basis of what the claimant is supposed to know in order to advance such a universal projection.

Given this incapacity on the part of universal truths to support counterfactuals, one would expect some assistance from the epistemic condition if laws are to be analyzed as well established universal truths. But the expectation is disappointed; we are *left* with a complete mystery. For if a statement of the form "All *F*'s are G" does not support the counterfactual, "If this (non-G) were an *F*, it would be G," it is clear that it will not support it just because it is well established or highly confirmed. The fact that all the marbles in the bag are red does not support the contention that if this (blue) marble were in the bag, it would be red; but neither does the fact that we *know* (or it is highly confirmed) that all the marbles in the bag are red support the claim that if this marble were in the bag it would be red. And making the universal truth *more universal* is not going

to repair the difficulty. The fact that all the marbles in the universe are (have been and will be) red does not imply that I *cannot* manufacture a blue marble; it implies that I *will not*, not that I cannot or that if I were to try, I would fail. To represent laws on the model of one of our epistemic operators, therefore, leaves wholly unexplained one of the most important features of laws that we are trying to understand. They are, in this respect, unsatisfactory candidates for the job.

Though laws are not merely well established general truths, there is a related point that deserves mention: laws are the *sort* of thing that can become well established prior to an exhaustive enumeration of the instances to which they apply. This, of course, is what gives laws their predictive utility. Our confidence in them increases at a much more rapid rate than does the ratio of favorable examined cases to total number of cases. Hence, we reach the point of confidently using them to project the outcome of unexamined situations while there is still a substantial number of unexamined situations to project.

This feature of laws raises new problems for the reductionistic equation. For, contrary to the argument in the second paragraph of this essay, it is hard to see how confirmation is possible for universal truths. To illustrate this difficulty, consider the (presumably easier) case of a general truth of *finite* scope. I have a coin that you have (by examination and test) convinced yourself is quite normal. I propose to flip it ten times. I conjecture (for whatever reason) that it will land heads all ten times. You express doubts. I proceed to "confirm" my hypothesis. I flip the coin once. It lands heads. Is this evidence that my hypothesis is correct? I continue flipping the coin and it turns up with nine straight heads. Given the opening assumption that we are dealing with a fair coin, the probability of getting all ten heads (the probability that my hypothesis is true) is now, after examination of 90% of the total population to which the hypothesis applies, exactly .5. If we are guided by probability considerations alone, the likelihood of all ten tosses being heads is now, after nine favorable trials, a toss-up. After nine favorable trials it is no more reasonable to believe the hypothesis than its denial. In what sense, then, can we be said to have been accumulating evidence (during the first nine trials) that all would be heads? In what sense have we been confirming the hypothesis? It would appear that the probability of my conjecture's being true never exceeds .5 until we have exhaustively examined the entire population of coin tosses and found them *all* favorable. The probability of my conjecture's being true is either: (i) too low ($\leq .5$) to invest any confidence in the hypothesis, or (ii) so high ($= 1$) that the hypothesis is useless for prediction. There does not seem to be any middle ground.

Our attempts to confirm universal generalizations of nonlimited scope is, I submit, in exactly the same impossible situation. It is true, of course, that after nine successful trials the probability that all ten tosses will be heads is greatly increased over the initial probability that all would be heads. The initial probability (assuming a fair coin) that all ten tosses would be heads was on the order of .002. After nine favorable trials it is .5. In this sense I have increased the probability that my hypothesis is true; I have raised its probability from .002 to .5. The important point to notice, however, is that this sequence of trials did not alter the probability that the *tenth* trial would be heads. The probability that the unexamined instance would be favorable remains exactly what it was before I began flipping the coin. It was originally .5 and it is now, after nine favorable trials, still .5. I am in no better position now, after extensive sampling, to predict the outcome of the tenth toss than I was before I started. To suppose otherwise is to commit the converse of the Gambler's Fallacy.

Notice, we could take the first nine trials as evidence that the tenth trial would be heads *if* we took the results of the first nine tosses as evidence that the coin was biased in some way. Then, on *this* hypothesis, the probability of getting heads on the last trial (and, hence, on all ten trials) would be greater than .5 (how much greater would depend on the conjectured degree of bias and this, in turn, would presumably depend on the extent of sampling). This new hypothesis, however, is something quite different than the original one. The original hypothesis was of the form: $(x)(Fx \supset Gx)$, all ten tosses will be heads. Our new conjecture is that there is a physical asymmetry in the coin, an asymmetry that tends to yield more heads than tails. We have succeeded in confirming the general hypothesis (all ten tosses will be heads), but we have done so via an intermediate hypothesis involving *genuine laws* relating the physical make-up of the coin to the frequency of heads in a population of tosses.

It is by such devices as this that we create for ourselves, or some philosophers create for themselves, the *illusion* that (apart from supplementary *law-like* assumptions) general truths can be confirmed by their instances and therefore qualify, in this respect, as laws of nature. The illusion is fostered in the following way. It is assumed that confirmation is a matter of *raising the probability of a hypothesis*.[10] On this assumption any general statement of finite scope can be confirmed by examining its instances and finding them favorable. The hypothesis about the results of flipping a coin ten times can be confirmed by tossing nine straight heads, and this confirmation takes place without *any* assumptions about the coin's bias. Similarly, I confirm (to some degree) the hypothesis that all the people in the hotel ballroom are over thirty years old when I enter the ballroom with my wife and realize that *we* are both over thirty. In both cases I raise the probability that the hypothesis is true over what it was originally (before flipping the coin and before entering the ballroom). But this, of course, isn't confirmation. Confirmation is not simply raising the probability that a hypothesis is true, it is raising the probability that the unexamined cases resemble (in the relevant respect) the examined cases. It is *this* probability that must be raised if genuine confirmation is to occur (and if a confirmed hypothesis to be useful in *prediction*), and it is precisely this probability that is left unaffected by the instantial "evidence" in the above examples.

In order to meet this difficulty, and to cope with hypotheses that are *not* of limited scope,[11] the reductionist usually smuggles into his confirmatory proceedings the very idea he professes to do without: *viz.*, a type of law that is not merely a universal truth. The general truth then gets confirmed but *only* through the mediation of these supplementary laws. These supplementary assumptions are usually introduced to *explain* the regularities manifested in the examined instances so as to provide a basis for projecting these regularities to the unexamined cases. The only way we can get a purchase on the unexamined cases is to introduce a hypothesis which, while *explaining* the data we already have, *implies* something about the data we do not have. To suppose that our coin is biased (first example) is to suppose something that contributes to the explanation of our extraordinary run of heads (nine straight) and simultaneously implies something about the (probable) outcome of the tenth toss. Similarly (second example) my wife and I may be attending a reunion of some kind, and I may suppose that the other people in the ballroom are old classmates. This hypothesis not only explains our presence, it implies that most, if not all, of the remaining people in the room are of comparable age (well over thirty). In both these cases the generalization can be confirmed, but only via the introduction of a law or circumstance (combined with a law or laws) that helps to explain the data already available.

One additional example should help to clarify these last remarks. In sampling from an urn with a population of colored marbles, I can confirm the hypothesis that all the marbles in the urn are red by extracting at random several dozen red marbles (and no marbles of any other color). This is a genuine example of confirmation, not because I have raised the probability of the hypothesis that all are red by reducing the number of ways it can be false (the same reduction would be achieved if you *showed* me 24 marbles from the urn, all of which were red), but because the hypothesis that all the marbles in the urn are red, together with the fact (law) that you cannot draw nonred marbles from an urn containing only red marbles, *explains* the result of my random sampling. Or, if this is too strong, the law that assures me that random sampling from an urn containing a substantial number of nonred marbles would reveal (in all likelihood) at least one nonred marble lends its support to my confirmation that the urn contains only (or mostly) red marbles. Without the assistance of such auxiliary laws a sample of 24 red marbles is powerless to confirm a hypothesis about the total population of marbles in the urn. To suppose otherwise is to suppose that the *same* degree of confirmation would be afforded the hypothesis if you, whatever your deceitful intentions, showed me a carefully selected set of 24 red marbles from the urn. This *also* raises the probability that they are all red, but the trouble is that it does not (due to your unknown motives and intentions) raise the probability that the unexamined marbles resemble the examined ones. And it does not raise this probability because we no longer have, as the best available explanation of the examined cases (all red), a hypothesis that implies that the remaining (or most of the remaining) marbles are also red. Your careful selection of 24 red marbles from an urn containing many different colored marbles is an equally good explanation of the data and it does *not* imply that the remainder are red. Hence, it is not just the fact that we have 24 red marbles in our sample class (24 positive instances and no negative instances) that confirms the general hypothesis that all the marbles in the urn are red. It is this data *together with a law* that confirms it, a law that (together with the hypothesis) explains the data in a way that the general hypothesis alone cannot do.

We have now reached a critical stage in our examination of the view that a properly qualified set of universal generalizations can serve as the fundamental laws of nature. For we have, in the past few paragraphs, introduced the notion of *explanation*, and it is this notion, perhaps more than any other, that has received the greatest attention from philosophers in their quest for the appropriate X in the formula: law = universal truth + X. R. B. Braithwaite's treatment ([3]) is typical. He begins by suggesting that it is merely deductive integration that transforms a universal truth into a law of nature. Laws are simply universally true statements of the form $(x)(Fx \supset Gx)$ that are derivable from certain higher level hypotheses. To say that $(x)(Fx \supset Gx)$ is a statement of law is to say, not only that it is true, but that it is *deducible from* a higher level hypothesis, *H*, in a well established scientific system. The fact that it must be deducible from some higher level hypothesis, *H*, confers on the statement the opacity we are seeking to understand. For we may have a hypothesis from which we can derive $(x)(Fx \supset Gx)$ but from which we cannot derive $(x)(Kx \supset Gx)$ despite the coextensionality of "*F*" and "*K*." Braithwaite also argues that such a view gives a satisfactory account of the counterfactual force of laws.

The difficulty with this approach (a difficulty that Braithwaite recognizes) is that it only postpones the problem. Something is not a statement of law simply because it is true and deducible from some well-established higher level hypothesis. For every generalization implies another of smaller scope (e.g. $(x)(Fx \supset Gx)$ implies $(x)(Fx \cdot Hx \supset Gx)$), but this fact has not the slightest tendency to transform the latter generalization into a law.* What is required is that the higher level hypothesis *itself* be law-like. You cannot give to others what you do not have yourself. But now, it seems, we are back where we started from. It is at this point that Braithwaite begins talking about the higher level hypotheses having *explanatory force* with respect to the hypotheses subsumed under them. He is forced into this maneuver to account for the fact that these higher level hypotheses—not themselves law-like on his characterization (since not themselves derivable from still higher level hypotheses)—are capable of conferring lawlikeness on their consequences. The higher level hypotheses are laws because they explain; the lower level hypotheses are laws because they are deducible from laws. This fancy twist smacks of circularity. Nevertheless, it represents a conversion to *explanation* (instead of *deducibility*) as the fundamental feature of laws, and Braithwaite concedes this: "A hypothesis to be regarded as a natural law must be a general proposition which can be thought to *explain* its instances" ([3], p. 303) and, a few lines later, "Generally speaking, however, a true scientific hypothesis will be regarded as a law of nature if it has an explanatory function with regard to lower-level hypotheses or its instances." Deducibility is set aside as an incidental (but, on a Hempelian model of explanation, an important) facet of the more ultimate idea of explanation.

* Dretske uses a dot (instead of an ampersand) to stand for *and*.

There is an added attraction to this suggestion. As argued above, it is difficult to see how instantial evidence can serve to confirm a universal generalization of the form: $(x)(Fx \supset Gx)$. If the generalization has an infinite scope, the ratio "examined favorable cases/total number of cases" never increases. If the generalization has a finite scope, or we treat its probability as something other than the above ratio, we may succeed in raising its probability by finite samples, but it is never clear how we succeed in raising the probability that the unexamined cases resemble the examined cases without invoking laws as auxiliary assumptions. And this is the very notion we are trying to analyze. To this problem the notion of explanation seems to provide an elegant rescue. If laws are those universal generalizations that explain their instances, then following the lead of a number of current authors (notably Harman ([8], [9]); also see Brody ([4])) we may suppose that universal generalizations can be confirmed because confirmation is (roughly) the converse of explanation; *E* confirms *H* if *H* explains *E*. *Some* universal generalizations can be confirmed; they are those that explain their instances. Equating laws with universal generalizations having explanatory power therefore achieves a neat economy: we account for the confirmability of laws in terms of the explanatory power of those generalizations to which laws are reduced.

To say that a law is a universal truth having explanatory power is like saying that a chair is a breath of air used to seat people. You cannot make a silk purse out of a sow's ear, not even a very good sow's ear; and you cannot *make* a generalization, not even a purely universal generalization, explain its instances. The fact that *every F* is G fails to explain why *any F* is G, and it fails to explain it, not because its explanatory efforts are too feeble to have attracted our attention, but because the explanatory attempt is never even made. The fact that all men are mortal does not explain why you and I are mortal; it *says* (in the sense of *implies*) that we are mortal, but it does not even suggest *why* this might be so. The fact that all ten tosses will turn up heads is a fact that logically guarantees a head on the tenth toss, but it is not a fact that explains the outcome of this final toss. On one view of explanation, *nothing* explains it. Subsuming an instance under a universal generalization has exactly as much explanatory power as deriving Q from $P \cdot Q$. None.*

If universal truths of the form $(x)(Fx \supset Gx)$ could be *made* to explain their instances, we might succeed in making them into natural laws. But, as far as I can tell, no one has yet revealed the secret for endowing them with this remarkable power.

This has been a hasty and, in some respects, superficial review of the doctrine that laws are universal truths. Despite its brevity, I think we have touched upon the major difficulties with sustaining the equation: law = universal truth + X (for a variety of different values of "X"). The problems center on the following features of laws:

a A statement of law has its descriptive terms occurring in opaque positions.
b The existence of laws does not await our identification of them *as* laws. In this sense they are objective and independent of epistemic considerations.
c Laws can be confirmed by their instances and the confirmation of a law raises the probability that the unexamined instances will resemble (in the respect described by the law) the examined instances. In this respect they are useful tools for prediction.
d Laws are not merely summaries of their instances; typically, they figure in the explanation of the phenomena falling within their scope.
e Laws (in some sense) "support" counterfactuals; to know a law is to know what would happen if certain conditions were realized.
f Laws tell us what (in some sense) must happen, not merely what has and will happen (given certain initial conditions).

The conception of laws suggested earlier in this essay, the view that laws are expressed by singular statements of fact describing the relationships between properties and magnitudes, proposes to account for these features of laws in a single, unified, way: (a)–(f) are all manifestations of what might be called "ontological ascent," the shift from talking about individual objects and events, or collections of them, to the quantities and qualities that these objects exemplify. Instead of talking about green and red things, we talk about the *colors* green and red. Instead of talking about gases that have a volume, we talk about the volume (temperature, pressure, entropy) that gases have. Laws eschew reference to the things that have length, charge, capacity, internal energy, momentum, spin, and velocity

* For further criticisms of deductive subsumption as sufficient for explanation, see David-Hillel Ruben, "Arguments, Laws, and Explanation" in chapter 6.

in order to talk about these quantities themselves and to describe *their* relationship to each other.

We have already seen how this conception of laws explains the peculiar opacity of law-like statements. Once we understand that a law-like statement is not a statement about the extensions of its constituent terms, but about the intensions (= the quantities and qualities to which we may refer with the abstract singular form of these terms), then the opacity of laws to *extensional* substitution is natural and expected. Once a law is understood to have the form:

6 *F*-ness → *G*-ness

the relation in question (the relation expressed by "→") is seen to be an *extensional* relation between *properties* with the terms "*F*-ness" and "*G*-ness" occupying *transparent* positions in (6). Any term referring to the same quality or quantity as "*F*-ness" can be substituted for "*F*-ness" in (6) without affecting its truth or its law-likeness. Coextensive terms (terms referring to the same *quantities* and *qualities*) can be freely exchanged for "*F*-ness" and "*G*-ness" in (6) without jeopardizing its truth value. The tendency to treat laws as some kind of intensional relation between extensions, as something of the form $(x)(Fx \boxed{N}\!\!\rightarrow Gx)$ (where the connective is some kind of modal connective), is simply a mistaken rendition of the fact that laws are extensional relations between intensions.

Once we make the ontological ascent we can also understand the modal character of laws, the feature described in (e) and (f) above. Although true statements having the form of (6) are not themselves *necessary* truths, nor do they describe a modal relationship between the respective qualities, the contingent relationship between properties that is described imposes a modal quality on the particular events falling within its scope. This *F must* be G. Why? Because *F*-ness is linked to G-ness; the one property yields or generates the other in much the way a change in the thermal conductivity of a metal yields a change in its electrical conductivity. The pattern of inference is:

I *F*-ness → G-ness
This is *F*
———
This must be G.

This, I suggest, is a valid pattern of inference. It is quite unlike the fallacy committed in (II):

II $(x)(Fx \supset Gx)$
This is *F*
———
This must be G.

The fallacy here consists in the absorption *into* the conclusion of a modality (entailment) that belongs to the relationship *between* the premises and the conclusion. There is no fallacy in (I), and this, I submit, is the source of the "physical" or "nomic" necessity generated by laws. It is this which explains the power of laws to tell us what *would* happen if we did such-and-such and what *could not* happen whatever we did.

I have no proof for the validity of (I). The best I can do is an analogy. Consider the complex set of legal relationships defining the authority, responsibilities, and powers of the three branches of government in the United States. The executive, the legislative, and the judicial branches of government have, according to these laws, different functions and powers. There is nothing *necessary* about the laws themselves; they could be changed. There is no law that prohibits scrapping all the present laws (including the constitution) and starting over again. Yet, given these laws, it follows that the President *must* consult Congress on certain matters, members of the Supreme Court *cannot* enact laws nor declare war, and members of Congress *must* periodically stand for election. The legal code lays down a set of relationships between the various *offices* of government, and this set of relationships (between the abstract offices) impose legal constraints on the individuals who occupy these offices—constraints that we express with such modal terms as "cannot" and "must." There are certain things the individuals (and collections of individuals—e.g., the Senate) can and cannot do. *Their* activities are subjected to this modal qualification whereas the framework of laws from which this modality arises is itself modality-free. The President (e.g., Ford) *must* consult the Senate on matter *M*, but the relationship between the *office* of the President and that *legislative body* we call the Senate that makes Gerald Ford's action obligatory is not *itself* obligatory. There is no law that says that this relationship between the office of President and the upper house of Congress must (legally) endure forever and remain indissoluble.

In matters pertaining to the offices, branches and agencies of government the "can" and "cannot" generated by laws are, of course, legal in character. Nevertheless, I think the analogy revealing. Natural laws may be thought of as a set of relationships that exist between the various "offices" that objects sometimes occupy. Once an object occupies such an office, its activities are constrained by the set of relations connecting that office to other offices and agencies; it *must* do some things, and it *cannot* do other things. In both the legal and the natural context the modality at level n is generated by the set of relationships existing between the entities at level $n + 1$. Without this web of higher order relationships there is nothing to support the attribution of constraints to the entities at a lower level.

To think of statements of law as expressing relationships (such as class inclusion) between the extensions of their terms is like thinking of the legal code as a set of universal imperatives directed to a set of particular individuals. A law that tells us that the United States President must consult Congress on matters pertaining to *M* is not an imperative issued to Gerald Ford, Richard Nixon, Lyndon Johnson, *et al.* The law tells us something about the duties and obligations attending the *Presidency*; only indirectly does it tell us about the obligations of the Presidents (Gerald Ford, Richard Nixon, *et al.*). It tells us about their obligations in so far as they are occupants of this office. If a law was to be interpreted as of the form: "For all x, if x is (was or will be) President of the United States, then x must (legally) consult Congress on matter *M*," it would be incomprehensible why Sally Bickle, were she to be president, would have to consult Congress on matter *M*. For since Sally Bickle never was, and never will be, President, the law, understood as an imperative applying to *actual* Presidents (past, present and future) does not apply to her. Even if there is a possible world in which she becomes President, this does not make her a member of that class of people to which the law applies; for the law, under this interpretation, is directed to that class of people who become President in *this* world, and Sally is not a member of this class. But we all know, of course, that the law does not apply to individuals, or sets of individuals, in this way; it concerns itself, in part, with the offices that people occupy and only indirectly with individuals in so far as they occupy these offices. And this is why, if Sally Bickle were to become President, if she occupied this office, she would have to consult Congress on matters pertaining to *M*.[12]

The last point is meant to illustrate the respect and manner in which natural laws "support" counterfactuals. Laws, being relationships between properties and magnitudes, *go beyond* the sets of things in *this* world that exemplify these properties and have these magnitudes. Laws tell us that quality F is linked to quality G in a certain way; hence, if object O (which has neither property) were to acquire property F, it would also acquire G in virtue of this connection between F-ness and G-ness. A statement of law asserts something that allows us to entertain the prospect of alterations in the extension of the predicate expressions contained in the statement. Since they make no reference to the extensions of their constituent terms (where the extensions are understood to be the things that are F and G in this world), we can hypothetically alter these extensions in the antecedent of our counterfactual ("if this were an F . . .") and use the connection asserted in the law to reach the consequent (". . . it would be G"). Statements of law, by talking about the relevant properties rather than the sets of things that have these properties, have a far wider scope than any true generalization about the actual world. Their scope extends to those possible worlds in which the extensions of our terms differ but the connections between properties remains invariant. This is a power that no universal generalization of the form $(x)(Fx \supset Gx)$ has; this statement says something about the actual F's and G's in *this* world. It says absolutely nothing about those possible worlds in which there are *additional* F's or *different* F's. For this reason it cannot imply a counterfactual. To do this we must ascend to a level of discourse in which what we talk about, and what we say about what we talk about, remains the *same* through alterations in extension. This can only be achieved through an ontological ascent of the type reflected in (6).

We come, finally, to the notion of explanation and confirmation. I shall have relatively little to say about these ideas, not because I think that the present conception of laws is particularly weak in this regard, but because its very real strengths have already been made evident. Laws figure in the explanation of their instances because they are not merely summaries of these instances. I can explain why this F is G by describing the relationship that exists between the properties in question. I can explain why the current increased upon an increase in the voltage by appealing to the relationship that exists between the flow of charge (current intensity) and the voltage (notice the definite articles). The period of a pendulum decreases when you shorten the length of the bob, not because all pendulums do that, but because the period and the length are related in the fashion $T = 2\pi\sqrt{L/g}$. The principles of thermodynamics tell us about the relationships that exist between such quantities as energy, entropy, temperature and pressure, and it is for this reason that we can use these principles to explain the increase in temperature of a rapidly compressed gas, explain why perpetual motion machines cannot be built, and why balloons do not spontaneously collapse without a puncture.

Furthermore, if we take seriously the connection between explanation and confirmation, take seriously the idea that to confirm a hypothesis is to bring forward data for which the hypothesis is the best (or one of the better) competing explanations, then we arrive at the mildly paradoxical result that laws can be confirmed *because* they are more than generalizations of that data. Recall, we began this essay by saying that if a statement of law asserted anything more than is asserted by a universally true statement of the form $(x)(Fx \supset Gx)$, then it asserted something that was beyond our epistemological grasp. The conclusion we have reached is that *unless* a statement of law goes beyond what is asserted by such universal truths, unless it asserts something that cannot be completely verified (even with a complete enumeration of its instances), it cannot be confirmed and used for predictive purposes. It cannot be confirmed because it cannot explain; and its inability to explain is a symptom of the fact that there is not enough "distance" between it and the facts it is called upon to explain. To get this distance we require an ontological ascent.

I expect to hear charges of Platonism. They would be premature. I have not argued that there are universal properties. I have been concerned to establish something weaker, something conditional in nature: *viz.*, universal properties exist, and there exists a definite relationship between these universal properties, *if* there are any laws of nature. If one prefers desert landscapes, prefers to keep one's ontology respectably nominalistic, I can and do sympathize. I would merely point out that in such barren terrain there are no laws, nor is there anything that can be dressed up to look like a law. These are inflationary times, and the cost of nominalism has just gone up.[13]*

Notes

1. This is the position taken by Hempel and Oppenheim ([10]).

2. When the statement is of nonlimited scope it is already beyond our epistemological grasp in the sense that we cannot *conclusively* verify it with the (necessarily) finite set of observations to which traditional theories of confirmation restrict themselves. When I say (in the text) that the statement is "beyond our epistemological grasp" I have something more serious in mind than this rather trivial limitation.

3. Most prominently, William Kneale in [12] and [13].

4. I eliminate quotes when their absence will cause no confusion. I will also, sometimes, speak of laws and statements of law indifferently. I think, however, that it is a serious mistake to conflate these two notions. Laws are what is expressed by true lawlike statements (see [1], p. 2, for a discussion of the possible senses of "law" in this regard). I will return to this point later.

5. Popper ([17]) vaguely perceives, but fails to appreciate the significance of, the same (or a similar) point. He distinguishes between the structure of terms in laws and universal generalizations, referring to their occurrence in laws as "intensional" and their occurrence in universal generalizations as "extensional." Popper fails to develop this insight, however, and continues to equate laws with a certain class of universal truths.

6. Nelson Goodman gives a succinct statement of the functionalist position: "As a first approximation then, we might say that a law is a true sentence used for making predictions. That laws are used predictively is of course a simple truism, and I am not proposing it as a novelty. I want only to emphasize the Humean idea that rather than a sentence being used for prediction because it is a law, it is called a law because it is used for prediction; and that rather than the law being used for prediction because it describes a causal connection, the meaning of the causal connection is to be interpreted in terms of predictively used laws" ([7], p. 20–21). Among functionalists of this sort I would include Ayer ([2]), Nagel ([16]), Popper ([17]), Mackie ([14]), Bromberger ([6]), Braithwaite ([3]), Hempel ([10], [11]) and many others. Achinstein is harder to classify. He says that laws express regularities that can be cited in providing analyses and explanations ([1],

* This essay was written during the 1970s, a decade of high inflation. Nominalists deny that universals have any real existence, insisting that general terms such as *red*, *giraffe*, and *electrically charged* do not refer to universal properties, abstract objects, or Platonic forms. Typically, nominalists view the meaning of general terms as deriving from particular resemblances between particular things.

p. 9), but he has a rather broad idea of regularities: "regularities might also be attributed to properties" ([1], pages 19, 22).

7. I attach no special significance to the connective "$\rightarrow$." I use it here merely as a dummy connective or relation. The kind of connection asserted to exist between the universals in question will depend on the particular law in question, and it will vary depending on whether the law involves quantitative or merely qualitative expressions. For example, Ohm's Law asserts for a certain class of situations a constant ratio (R) between the magnitudes E (potential difference) and I (current intensity), a fact that we use the "=" sign to represent: $E/I = R$. In the case of simple qualitative laws (though I doubt whether there are many genuine laws of this sort) the connective "$\rightarrow$" merely expresses a link or connection between the respective qualities and may be read as "yields." If it is a law that all men are mortal, then humanity yields mortality (humanity $\rightarrow$ mortality). Incidentally, I am not denying that we can, and do, express laws as simply "All F's are G" (sometimes this is the only convenient way to express them). All I am suggesting is that when lawlike statements are presented in this form it may not be clear what is being asserted: a law or a universal generalization. When the context makes it clear that a relation of law is being described, we can (without ambiguity) express it as "All F's are G" for it is then understood in the manner of (6).

8. On the basis of an argument concerned with the restrictions on predicate expressions that may appear in laws, Hempel reaches a similar conclusion but he interprets it differently. "Epitomizing these observations we might say that a lawlike sentence of universal nonprobabilistic character is not about these classes or extensions *under certain* descriptions" ([11], p. 128). I guess I do not know what being *about* something *under a description* means unless it amounts to being about the property or feature expressed by that description. I return to this point later.

9. Molnar ([15]) has an excellent brief critique of attempts to analyze a law by using epistemic conditions of the kind being discussed.

10. Brody argues that a qualitative confirmation function need not require that any E that raises the degree of confirmation of H thereby (qualitatively) confirms H. We need only require (perhaps this is also too much) that if E does qualitatively confirm H, then E raises the degree of confirmation of H. His arguments take their point of departure from Carnap's examples against the special consequence and converse consequence condition ([4], pages 414–418). However this may be, I think it fair to say that most writers on confirmation theory take a *confirmatory* piece of evidence to be a piece of evidence that *raises* the probability of the hypothesis for which it is confirmatory. How well it must be confirmed to be acceptable is another matter of course.

11. If the hypothesis is of nonlimited scope, then its scope is not known to be finite. Hence, we cannot know whether we are getting a numerical increase in the ratio: examined favorable cases/total number of cases. If an increase in the probability of a hypothesis is equated with a (known) increase in this ratio, then we cannot raise the probability of a hypothesis of nonlimited scope in the simple-minded way described for hypotheses of (known) finite scope.

12. If the law was interpreted as a universal imperative of the form described, the most that it would permit us to infer about Sally would be a counteridentical: If Sally were one of the Presidents (i.e. identical with either Ford, Nixon, Johnson, . . .), then she would (at the appropriate time) have to consult Congress on matters pertaining to M.

13. For their helpful comments my thanks to colleagues at Wisconsin and a number of other universities where I read earlier versions of this paper. I wish, especially, to thank Zane Parks, Robert Causey, Martin Perlmutter, Norman Gillespie, and Richard Aquilla for their critical suggestions, but they should not be blamed for the way I garbled them.

References

[1] Achinstein, P. *Law and Explanation*. Oxford: Clarendon Press, 1971.

[2] Ayer, A. J. "What Is a Law of Nature." In [5], pages 39–54.

[3] Braithwaite, R. B. *Scientific Explanation*. Cambridge, England: Cambridge University Press, 1957.

[4] Brody, B. A. "Confirmation and Explanation." *Journal of Philosophy* 65 (1968): 282–299, Reprinted in [5], pages 410–426.

[5] Brody, B. A. *Readings in the Philosophy of Science*. Englewood Cliffs, N.J.: Prentice Hall, 1970.

[6] Bromberger, S. "Why-Questions." In [5], pages 66–87.

[7] Goodman, N. *Fact, Fiction and Forecast*. London: The Athlone Press, 1954.

[8] Harman, G. "The Inference to the Best Explanation." *Philosophical Review* 74 (1965): 88–95.

[9] Harman, G. "Knowledge, Inference and Explanation." *Philosophical Quarterly* 18 (1968): 164–173.

[10] Hempel, C. G., and Oppenheim, P. "Studies in the Logic of Explanation." In [5], pages 8–27.

[11] Hempel, C. G. "Maximal Specificity and Lawlikeness in Probabilistic Explanations." *Philosophy of Science* 35 (1968): 116–133.

[12] Kneale, W. "Natural Laws and Contrary-to-Fact Conditionals." *Analysis* 10 (1950): 121–125.

[13] Kneale, W. *Probability and Induction*, Oxford: Oxford University Press, 1949.

[14] Mackie, J. L. "Counterfactuals and Causal Laws." In *Analytical Philosophy*. (First Series). Edited by R. J. Butler. Oxford: Basil Blackwell, 1966.

[15] Molnar, G. "Kneale's Argument Revisited." *Philosophical Review* 78 (1969): 79–89.

[16] Nagel, E. *The Structure of Science*. New York: Harcourt Brace, 1961.

[17] Popper, K. "A Note on Natural Laws and So-Called 'Contrary-to-Fact Conditionals.' " *Mind* 58 (1949): 62–66.