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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

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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.

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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 th 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.