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Laws of Nature

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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 nonlimited 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, 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 hypoth-

esis would be lost if we supposed that what the hypothesis was actually as-
serting was some kind of nomic connection, some kind of modal relation-
ship, 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 straight-
forward 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 uni-
versal 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]

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 differ-

ence 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 (insofar 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. Lawlike 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 bizarre 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 ev-
idence (during the first nine trials) that all would be heads? In what sense
have we been confirming the hypothesis? It would appear that the prob-
ability of my conjecture's being true never exceeds .5 until we have exhaus-
tively 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
(≤ .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 mid-
dle 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 out-
come 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 de-
gree 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 physi-
cal 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 fre-
quency 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 $(x)(Fx \& Hx \supset Gx)$), 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. 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 law-likeness 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.

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* & *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 blue. 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 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 state-ment 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 *ex-tensional* relation between *properties* with the terms "*F*-ness" and "*G*-ness" occupying *transparent* positions in (6). Any term referring to the same qual-ity or quantity as "*F*-ness" can be substituted for "*F*-ness" in (6) without af-fecting 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 some-thing of the form $(x)(Fx \boxed{n} \to Gx)$ (where the connective is some kind of mo-dal connective), is simply a mistaken rendition of the fact that laws are ex-tensional 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 in-ference 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) imposes 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 indisoluble.

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 is 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 insofar 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 alternations 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.

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 law-like 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. 26). 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], p. 9), but he has a rather broad idea of regularities: "regularities might also be attributed to properties" ([1]), pp. 19, 22).

7. I attach no special significance to the connective " →." 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 "→" 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 → 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 law-like 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 expres-

sions that may appear in laws, Hempel reaches a similar conclusion but he interprets it differently. "Epitomizing these observations we might say that a law-like sentence of universal nonprobabilistic character is not about classes or about the extensions of the predicate expressions it contains, but 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], pp. 414–18). 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*.

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