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Michael A. Day

University of Nebraska-Lincoln

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THE PRAGMATICS OF SCIENTIFIC LAWS

MICHAEL A. DAY

Department of Philosophy, University of Nebraska-Lincoln 68588

What it is for a statement to be a scientific law has been widely discussed and debated in the philosophy of science. Not only is the question interesting in itself, but it is essential that this question be answered if a complete analysis of such things as scientific explanation and prediction are to be given. The purpose of this paper will be to put forward an analysis of the phrase "X is reasonably classified as a scientific law at time t" in such a way as to highlight certain pragmatical aspects of scientific laws while doing justice to the syntactical and semantical aspects of scientific laws. One important insight this analysis will bring out is that the concept of reduction (in the sense of theory reduction) has an essential role in what is reasonably classified as a scientific law.

My strategy will be to put forward and discuss an analysis which attempts to formulate, in some sense, the syntactical and semantical aspects of scientific laws, and then to use this analysis (with a slight modification) to put forward an analysis of the phrase "X is reasonably classified as a scientific law at time t". But before considering this first analysis, a few preliminary remarks must be made.

First of all, I do not want to concern myself with the question whether scientific laws are sentences or whether they are propositions (i.e., what can be expressed by a declarative sentence). But for the sake of this paper, I am going to construe scientific laws as sentences. Now if one is convinced that scientific laws are propositions, he must at least admit that if we could determine what conditions must be satisfied for a sentence to express a scientific law, then we have come a long way in determining the nature of scientific laws; hence we can justify an investigation of sentences as relevant to the nature of scientific laws, even if scientific laws are propositions. Also, treating scientific laws as sentences will require the relativizing of our discussion to particular languages. For example, if we claim that sentence X is confirmed with respect to sentence Y, then the truth value of this claim will depend upon the language which X and Y are members. Now this relativizing to particular languages will not be explicitly stated in the following account, hence one must keep this implicitly in mind.

Now before putting forth the first analysis, an explanation must be given of what will be meant by a framework. Consider the following:

An ordered pair $\langle A, B \rangle$ is a framework *if and only if* A and B are each consistent sets of sentences closed under entailment (i.e., if a subset of

sentences from either set entails a sentence S, then S is a member of that set).

With this in mind, let us put forth the first analysis.

X is a scientific law of framework F (where $F = \langle A, B \rangle$) IFF

- (1) X is a member of A,
- (2) X is an unrestricted general sentence,
- (3) X is empirical,
- (4) X is confirmed with respect to B,
- (5) X is not a compound sentence, and
- (6) there is no sentence Y which satisfies conditions (1) - (5) and is an F-generalization of X.

Now this is explicitly an analysis (or definition) of a binary relation which can hold between a sentence and an ordered pair whose members are sets of sentences. Implicitly, it is an analysis of a three-placed relation which can hold between a sentence, an ordered pair whose members are sets of sentences, and a language. Also, it must be realized that if there exists a sentence X which is a scientific law of some framework, this does not imply that X is a scientific law or that X is even *reasonably classified* as a scientific law. For example, let A only consist of the sentence "All planets move around the sun in rectangular orbits" (which we will call "Z") and all sentences entailed by the sentence Z, and let B be identical to A. Now a case (and a good case at that) can be made that sentence Z is a scientific law of $\langle A, B \rangle$, but this should not be viewed as committing us to the claim that sentence Z is a scientific law or that sentence Z is now or ever was or will be reasonably classified as a scientific law. Perhaps if certain conditions were satisfied by the framework $\langle A, B \rangle$, then we might be committed to such claims.

Let us now turn to a discussion of conditions (1)-(6) of the above analysis. First of all, the motivation behind condition (1) will become obvious as the paper develops, and there should be no problem in understanding what it requires.

The second condition is included so that only sentences which are (in some sense) universal will be reasonably classified as scientific laws. I will not say what should actually be included in this condition since my main concern is not with the syntactical and semantical characteristics of scientific laws. But let me say something about what might be included in condition (2). Firstly, this condition could be construed, in part, as requiring that the scientific laws of a framework are to be syntactically universal [Hempel, 1965, p. 266]. For example, if the sentences under consideration are sentences of English, condition (2) might require the scientific laws of a

framework to be sentences that begin with such words as “all” or “every” followed by a subject expression (or that they could be so formulated without change of meaning). Or if the sentences are sentences of first-order predicate calculus, condition (2) might require an “essential” occurrence of a universal quantifier. H. A. Lauter in his discussion of Reichenbach’s views on scientific laws sets forth a plausible requirement: “every reduced prenex equivalent of ϕ has at least one occurrence of a universal quantifier” [Lauter, 1970, p. 134]. Condition (2) might also be interpreted as requiring that the scientific laws of a framework cannot mention particular objects, places, or times. Further, it could even require that the predicates of the scientific laws be purely qualitative (i.e., it is possible to give the meanings of the predicates without reference to particular objects, places, or times) [Hempel, 1965, p. 268]. Also, condition (2) could require that a scientific law of a framework is such that the evidence for the law does not exhaust the “scope of predication” of the law [Nagel, 1961, p. 63]. (In this case, the evidence relating to a law of framework $F=\langle A,B \rangle$ would be the sentences of B.) Finally, condition (2) might be interpreted as also requiring that the scientific laws of a framework are not restricted to descriptions of actual cases but extend to the realm of hypothetical cases, in other words, that they support relevant counterfactuals [Rescher, 1970, p. 102].

Condition (3) is included in the analysis so as not to allow sentences which are truths or falsehoods of mathematics and logic as being scientific laws of a framework. Further, the condition can be interpreted as ruling out sentences which are analytically true or false as being possible candidates for the scientific laws of a framework.

The motivation behind condition (4) is based upon the fact that we will want to hold that a sentence is reasonably classified as a scientific law at a particular time only if it is confirmed at that particular time; hence we require the scientific laws of a framework to satisfy condition (4). Now since confirmation is usually construed as a relation between sentences (provided one is working with sentences), condition (2) has relativized the confirmation of a scientific law of framework $\langle A,B \rangle$ to the set of sentences B. Further, condition (4) might be interpreted as requiring not only “direct” confirmation of a scientific law of a framework but also “indirect” or “systematic” confirmation [Nagel, 1961, p. 64-66].

Condition (5) is included in this analysis because we do not want to hold that a sentence (which satisfies certain conditions) is reasonably classified as a scientific law when the sentence is actually a conjunction one of whose conjuncts is a scientific law. For example, consider a sentence formed by the conjunction of Newton’s second law and the first law of thermodynamics. Now provided certain conditions are met, we would be committed to the position that this conjunction is reasonably classified as a scientific law if we

did not include condition (5) in this analysis. Note that the natural thing to say concerning this sentence is that it is not *a* scientific law but a conjunction consisting of scientific laws.

Now to determine whether a sentence is a non-compound sentence will usually require (unless we have a strong correlation between syntax and semantics) an inspection of what is expressed by the sentence. Consider the following sentence:

All heavenly objects are god-beloved and all terrestrial objects are god-beloved.

Now this sentence may appear to be a compound sentence if we only observed its syntax, but actually it is a non-compound sentence since what it expresses with respect to English is that all objects are god-beloved.

To understand condition (6), an explanation of what is meant by an F-generalization must be given. Consider the following:

Y is an F-generalization of X *if and only if* (1) Y entails X but X does not entail Y, or (2) Y can be established as a generalization of X on the basis of the facts expressed by the sentences of A and B and a competent knowledge of the language of which the sentences A and B are members (where $F = \langle A, B \rangle$).

The motivation behind condition (6) is that we want only the most general sentences of A to be the scientific laws of framework F. This will eventually allow us to incorporate in the final analysis Peter Achinstein's insight (with certain qualifications) as given in the following quotation.

“(5)’ If it is reasonable at time *t* to classify L as a law then either: (a) there is not known at *t* any proposition L’ which is known or believed to be a generalization of L in any of its equivalent formulations and which is believed is or might be true; or (b) at some previous time *t** when L was known and was classified as a law there was not known any proposition L’ of the sort described in (a).” [Achinstein, 1971, p. 33-34]. (Note: Achinstein uses the term “proposition” to mean a declarative sentence.)

Now to fully understand condition (6) and the above quotation, an analysis of what is meant by “Y is a generalization of X” should be given. But this would be a difficult undertaking and is certainly beyond the scope of this paper. Actually, Achinstein has put forward such an analysis [Achinstein, 1971, Ch. II], but not only are there counterexamples to his analysis involving ordinary usage but if his analysis of a generalization is adopted then criterion (5)’ in the above quotation is false. Therefore, since criterion (5)’ of the above quotation appears to be true, we will leave the analysis of

“Y is a generalization of X” on the intuitive level. But one comment must be made. Whether a sentence Y is a generalization of a sentence X can sometimes, but not always, be established on basis of an understanding of the language of which the sentences X and Y are members. For example, consider the following two pairs of sentences.

- (1)' All men are good cooks.
 All bachelors are good cooks.
- (2)' All people with chromozone Z are susceptible to cancer.
 All John's children are susceptible to cancer.

The first member of (1)' can be established as a generalization of the second member of (1)' if one has an adequate understanding of English, but such is not the case for the second pair of sentences. Now if one knows that all John's children have chromozone Z, one could establish that the first member of (2)' is a generalization of the second member of (2)' (provided one had an adequate understanding of English.)

Looking critically at the above analysis of “X is a scientific law of framework F,” it must be admitted that the analysis is not free from problems. First of all, the analysis presupposes an understanding of such problematic issues as involved in the distinction between empirical and nonempirical sentences, the distinction between compound and non-compound sentences, and the theory of confirmation (just to mention a few). But in defense of the analysis, it must be contended that such problems are not unique to this analysis since analogous problems confront all analyses. Secondly, one might object to this analysis since it is not clear what the conditions of the analysis are to include. For example, a definite position has not been taken with respect to what is included in condition (2) of the analysis. Does it require or does it not require that the scientific laws of a framework must support relevant counterfactuals? In response to this objection, I can only say that I have attempted to leave the analysis somewhat open, in this respect, so as to remain as neutral as possible with respect to positions which might be taken concerning the syntactical and semantical aspects of scientific laws, since my main concern is with certain pragmatic aspects of scientific laws. Thirdly, one may feel uneasy about this analysis since traditionally analyses of scientific laws have not made references to so-called frameworks, where this analysis does; and this analysis appears to relativize our talk of scientific laws to frameworks, which appears not to be the case. To dispel this uneasiness, I can only conjecture that past analyses have not made references to frameworks since they have mainly been concerned with the syntactical and semantical aspects of scientific laws over the pragmatcal aspects. Further, it must be remembered that even if it is true that a sentence X is a scientific law of a certain framework, this does not

commit us to the claim that X is a scientific law or *reasonably classified* as a scientific law. Also, it does seem to be the case that our talk of scientific laws is in one important sense relativized to a framework, namely to the framework which represents what is currently accepted by the scientific community.

Let us now attempt to formulate certain pragmatic aspects of scientific laws by giving an analysis of the phrase "X is reasonably classified as a scientific law at time t." This analysis will be based upon the fact that certain sentences which were reasonably classified in the past as scientific laws are still so classified even though it is now known that there are counter-instances to these laws, or that these laws are incomplete in their descriptions, or that these laws are in some sense mistaken. For example, Newton's laws of motion and the second law of thermodynamics are still reasonably classified as scientific laws even though there are known counter-instances to these laws. But it is not simply the fact that what was reasonably classified in the past as a scientific law is still so classified; for example, the laws of phlogiston theory are not reasonably classified as scientific laws today. It appears that if these past scientific laws are still to be reasonably classified as scientific laws, they must satisfy the additional requirement of being reducible to (or, roughly speaking, explainable by) what is currently accepted by the scientific community.

The formulation of these pragmatic factors will involve a slight modification in the notion of a framework (and an appropriate use of the concept of theory reduction). We will allow a temporal index to be associated with each framework so that a framework can represent what is accepted by the scientific community at a particular time; hence we can speak of the accepted scientific framework at a particular time. For the sake of brevity and clarity, the analysis to be put forth will make use of the previous analysis:

X is reasonably classified as a scientific law at time t *IFF* (1) X is a scientific law of F_t , where F_t is the accepted scientific framework at time t, or (2) X is a scientific law of $F_{t'}$, where $F_{t'}$ is a past ($t' < t$) accepted scientific framework, and X is reducible to F_t .

It must be realized that the accepted scientific framework at a particular time t will ultimately have to be abstracted from what was accepted by the scientific community at time t. But this should not be taken to mean that what is to be construed as the accepted scientific framework at time t is arbitrarily selected or that it will not meet certain formal, epistemic, and empirical requirements. For example, if $F_t = \langle A, B \rangle$ is the accepted scientific framework at time t, the sentences of B would consist of all and only all observation sentences which were accepted as true by the scientific

community at time t . Further, we could require that the sentences of B were accepted as true at time t on the basis of certain observations that had been made by time t , and that it is reasonable to accept these sentences as true on the basis of these observations. Also, we would require that the sentences of A are sentences that were accepted by the scientific community at time t . Further, we could require that the sentences of A were accepted, to a substantial degree, on the basis of the acceptance of the truth of the observation sentences of B , and that it is reasonable to accept the sentences of A provided that the sentences of B are accepted as true. But a complete discussion of the requirements that an accepted scientific framework must satisfy, though necessary, is beyond the scope of this paper.

For the rest of the paper, let us assume that the above analysis is adequate and determine some of the more interesting results which follow from this analysis. First of all, the analysis allows it to be reasonable to simultaneously classify a sentence and a generalization of it as scientific laws, if the sentence and its generalization are members of appropriate accepted scientific frameworks. Further, it even allows it to be reasonable to simultaneously classify a sentence as a scientific law but not one of its generalizations even when the generalization is a member of an accepted scientific framework and confirmed within that framework. This can happen because the accepted scientific framework of which the generalization is a member may at the time of its acceptance contain a higher generalization, and hence rule out this lower generalization as being a scientific law of the framework. For example, we want it to be reasonable to classify Kepler's second law of planetary motion (i.e., any radius from the sun to a planet sweeps out equal areas in equal times) as a scientific law, but not arbitrary generalizations of Kepler's second law whose subjects would consist in arbitrarily specified planetary systems. The above analysis will allow for such discriminating classifications since the analysis has incorporated Achinstein's insight as given in the earlier quotation. We can also explain such a discriminating classification with respect to Kepler's second law because of the pragmatic fact that at the time of the acceptance of Kepler's second law, there was not known any generalization of it which was confirmed with respect to the accepted scientific framework of that time; whereas no such fact holds for these arbitrary generalizations of Kepler's second law. Moreover, since this analysis has included the spirit of Achinstein's insight, we must mention what Achinstein says about how this settles the dispute between those philosophers who hold that scientific laws cannot mention particular objects, places, or times, and those philosophers who hold that it is permissible for scientific laws to mention particular objects, places, or times. He says, using slightly different wording, that both disputants are partially correct from a pragmatistical point of view, in the sense that, a sentence

mentioning particular objects, places, or times can be reasonably classified as a scientific law but only if there is no generalization of the law which was known and confirmed at the time when the law was originally accepted [Achinstein p. 31-32].

According to the above analysis, a sentence can be reasonably classified as a scientific law if it bears an appropriate reduction relation as well as satisfying certain other conditions. Reduction is generally construed as a relation which can exist between theories, and therefore the condition which requires a sentence to be reducible to an appropriate scientific framework should be taken as requiring the reducibility of the theory, which the sentence is a member, to a theory of the appropriate scientific framework. Just what it means to say that one theory is reducible to another theory is a difficult question to answer; but it has been informally characterized as one theory explaining or accounting for another theory. One thing that is clear is that reduction cannot simply be construed as the derivability of one theory from another. Because if it was, then the theory which is reduced could in no way be incompatible with the reducing theory; but in many cases of reduction, the two theories are not mutually compatible.

With this brief discussion of reduction in mind, we see that the above analysis allows for the possibility that two (or more) sentences which are in contradiction or lead to contradictory results can at the same time be reasonably classified as scientific laws, as long as these sentences are members of accepted scientific frameworks and bear the appropriate reduction relations. For example, the above analysis allows for the possibility that the second law of thermodynamics and the laws of statistical mechanics can be reasonably and simultaneously classified as scientific laws, which seems to be a desirable result of the analysis.

Also, the above analysis puts a new twist to some of the problems surrounding the truth of scientific laws. For example, a question could arise as to whether it is reasonable to classify a sentence which is known to be false as a scientific law. Many philosophers would say that it is not since scientific laws are simply true nomological sentences. Other philosophers would agree, but for the different reason that since scientific laws are analogous to rules of inference, they are not capable of being false since they are not capable of any truth value at all. But in view of the above analysis of "X is reasonably classified as a scientific law at time t," the possibility certainly exists that it may be reasonable to classify a sentence which is known to be false as a scientific law if the sentence is reducible to the appropriate scientific framework. This is because reduction, as earlier pointed out, is not simply a deductive relation, and hence even allows for the possibility that a sentence may be false (and therefore known to be false) and still be reducible to a set of true sentences.

As a concluding comment, I would like to say something about the identity conditions for scientific laws. In this paper, it has been assumed for the sake of discussion that scientific laws are sentences. Now if one does construe scientific laws as sentences, then one would construe the identity conditions for scientific laws as being the identity conditions for individual sentences. Perhaps one might construe scientific laws not as individual sentences but as sentence-types, and hence would individuate laws with respect to the identity conditions for sentence-types. Also, one might construe scientific laws as propositions, and hence would individuate laws with respect to the identity conditions for propositions. No matter which position is taken on the identity conditions for scientific laws, each position would then attempt to explain our talk about scientific laws in terms of the proposed identity conditions of that position.

Now suppose we had two sentences of different sentence-types, and said of each sentence that it was the same scientific law (for example, we might say of each sentence that it is Newton's second law of motion). If we construed laws as being sentences or sentence-types, we might explain this by saying that each sentence is called Newton's second law because each sentence or each instance of each sentence-type has the same meaning. If we construed scientific laws as propositions, we might explain this by saying that each sentence expresses the same proposition. But such explanations will not always work. Consider the following sentences [Zemansky, 1957, Ch. 7]:

(1) "No process is possible whose sole result is the absorption of heat from a reservoir and the conversion of this heat into work.

(2) "No process is possible whose sole result is the transfer of heat from a cooler to a hotter body.

Now each sentence can be referred to as the second law of thermodynamics. The first sentence is referred to as the Kelvin-Planck formulation of the second law; the second sentence is referred to as the Clausius formulation of the second law. But how do we explain this, since neither sentence means the same thing or expresses the same proposition? It appears that to explain this we are going to have to say something about how each of these sentences is related to other sentences. For example, given a certain set of sentences (representing the background of thermodynamics), both of the above sentences can be used to construct a proof for the existence of a certain thermodynamic function of state, called the entropy. And one can construe that the main contribution of the second law of thermodynamics (to thermodynamics) is that the second law guarantees the existence of the entropy function; hence we can explain why both of the above sentences can be referred to as the second law of thermodynamics, even though they do not have the same meaning or express the same proposition.

HISTORY AND PHILOSOPHY OF SCIENCE

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