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Falling under a physical law

FIVE NECESSARY CONDITIONS FOR PHYSICAL LAWFULNESS

Physical laws comprise a proper subset of the class of general propositions.[1] More specifically, physical laws occur among only two classes of general propositions: universal propositions and statistical propositions.

Some writers (e.g., Kemeny 1959, p. 37) have considered physical laws to be found only among those propositions that are mathematical formulas. But I shall regard those physical laws that are mathematical in form to be but a special case, albeit an exceptionally remarkable special case, of universal and statistical generalizations. For example, the mathematical formula that states the connection between the force impressed on a mass and its acceleration, $f = ma$, may be read in an explicit, universal form: "For any f, m, and a: If the magnitude of the mass of an object is m, and the magnitude of its acceleration is a, then the magnitude of the impressed force, f, is m times a." Similarly, the mathematical formulas (too complex and lengthy to be reproduced here) that describe the 'allowable' (better, most probable) electron orbits of an atom may be regarded as statistical propositions.

Although a physical law may in fact apply to no or few items or events in the world, physical laws are not to be thought of as descriptions of specific items or events. Such generality is

[1] Physical laws, however, are not empirical generalizations, i.e., propositions inductively generated from empirical data (although, of course, some few of them might come to be entertained by such means). "Generalization" here is to be understood in its *logical* sense, in which it contrasts with "singular"; and not in its epistemic sense, in which it often contrasts with "hypothesis," "conjecture," etc.

Generalizations are propositions about *classes* of things. They are *quantified* propositions, propositions beginning, e.g., with such *quantifiers* as: "for all...", "there is some...", "most...", "many...", "22 percent of all ...", etc.

secured by requiring that the only terms (other than logical and mathematical ones) that may properly figure in a physical law are ones that are purely descriptive.

The concept of *being a purely descriptive term* bears careful examination. For it turns out that being purely descriptive is not the same thing as being ‘unrestricted’; and that certain ‘restricted’ predicates may be regarded – for our purposes – as being purely descriptive and suitable for inclusion within physical laws.

There are two ways that a descriptive term, or predicate, may be restricted: in being analytically restricted to applying to a certain number of things; or in making reference, implicitly or explicitly, to some particular item or event.

The class of predicates that are analytically restricted in their range of application includes such members as: “is the last commercial whaling ship”; “is the largest supernova”; and “is the third longest war.” Although such predicates may fail to apply altogether, they cannot apply to an unrestrictedly large number of things. They may be contrasted with such unrestricted predicates as “is blue,” “is square,” and “conducts electricity,” all of which may – theoretically – apply to any finite or infinite number of various things.

Quinton calls the properties referred to by these former terms “ordinal properties” (1973, pp. 15–16), and the name is apt. I will adopt his nomenclature here, speaking of ‘ordinal properties’ and of the terms that refer to them as ‘ordinal predicates.’

The class of ordinal predicates, however, does not exhaust the class of analytically restricted predicates. The predicate “is the only barred spiral galaxy,” unlike “is the largest barred spiral galaxy,” does not place its subject at any particular position in an ordering. But “only” does share with “largest” the feature of applying to a restricted number of things. Thus “is the only barred spiral galaxy,” and others such as “occurred in the second quarter of the nineteenth century,” must obviously also count as being analytically restricted. Ordinal predicates, then, are but one, but perhaps the most populated, species of the genus “restricted predicate.” For convenience, we will examine ordinal predicates as representative of the latter class.

Do any physical laws include ordinal predicates? Probably the most common use of ordinal predicates is found in statements whose subjects refer to particulars, for example, “Truman was the thirty-third U.S. president” and “Jupiter is the largest planet in the solar system.” Nonetheless, ordinal predicates do often figure in statements not about particular things but about classes of things, for example, "The element with atomic number 35 is the third heaviest of the Halogen group."[2] Or, again, "In a sealed container that is a perfect heat insulator, the final temperature of several things that are initially at different temperatures will eventually stabilize between that of the hottest and that of the coldest."

There seems to be no good reason, then, to regard ordinal predicates as essentially inappropriate for inclusion in physical laws. Indeed, some of the paradigm examples of physical laws are often cast in a form that explicitly invokes ordinal properties: "The coldest temperature any physical state can attain is –273.15° C"; "The greatest velocity to which any object having mass can be accelerated is less than 299,792 km/sec."

Quinton has argued (1973, p. 16) that ordinal predicates can apply only in finite universes. If he were right about this, then there would be a powerful incentive to regard ordinal predicates as excluded from figuring within physical laws. For clearly the question of whether or not a given proposition is a *candidate* for lawfulness ought not to depend on the contingent fact of whether the universe is finite or infinite. Or, to put this a slightly different way: What sorts of propositions are candidates for lawfulness (as opposed to which of these are in fact laws) ought to be a conceptual matter, not an empirical one. If, then, ordinal predicates could apply only in finite universes, we should want to disallow their use in physical laws, for to allow them would require that we had antecedently and empirically determined that the universe is finite.

But I am quite sure that Quinton is mistaken in his contention. Ordinal predicates are as much applicable in infinite universes as in finite ones. Even if there were an infinite number, let's say, of stars, it might still be true that there is some one of them that is the largest, some one that is the smallest, and some one that is the 10,457th largest. After all, there are an infinite number of ordinals, just as there are an infinite number of cardinals. And our use of cardinals is not restricted to finite universes. Of course, though, if there were a very great number of stars, there would be the practical problem of our being incapable of *identifying* the 10,457th largest

[2] It may be to the point to remark that the proposition under examination is contingent inasmuch as being the *third* heaviest member of the Halogen group is not an analytic property of Bromine. It takes a very considerable amount of contingent theory to link these two conceptually distinct properties ("having atomic number 35" and "being a member of the Halogen group").

star. But this practical inability to identify the particular star that bears the ordinal property in question would have nothing whatever to do with there *being* such a star.

I conclude, then, that ordinal predicates – and indeed other members as well of the larger class of which they are merely the most conspicuous members, namely, the class of analytically restricted predicates – need not be disallowed from figuring within physical laws. Analytic restrictedness per se is not an insuperable impediment to physical lawfulness.

However, some analytically restricted predicates offend conceptually in ways having nothing to do with their being limited in application. For example, we should not want to allow Strawson's predicate, "is the first dog to be born at sea" (1964, p. 26), if by "sea" we understand a term tacitly restricted to a watery expanse on one named planet, namely, the Earth. It is only on the proviso that an analytically restricted predicate does not violate any other strictures on acceptability that it may be regarded as sanctioned for use.

The second class of problematic predicates, however – those that make tacit or explicit reference to particular items, places, or times (a class that includes, of course, certain analytically restricted predicates, e.g., the just-mentioned narrow construal of "is the first dog to be born at sea") – cannot so easily be accommodated.

"Copper has a greater specific gravity than aluminum" is perfectly general or, to be more precise, all its nonlogical and nonmathematical terms apply in principle to any number of things in the world. "Copper has a greater specific gravity than the specific gravity of this coin in my hand" is not perfectly general. "This coin in my hand" refers not to a *kind* of thing or to a property but to a specific particular. (And the predicate "the specific gravity of this coin in my hand" may be thought to refer to a property-token rather than to a property-type.)

We should want to lay it down as a requirement that the terms in a physical law should not refer to specific items in the world. Proper names of individuals, for example, "Truman," would be barred; and likewise would "is Truman" or (from Quine's class of neologisms) "Trumanizes," when this latter is used as a predicate necessarily applicable only to Truman. ("Trumanizes" is perfectly alright if taken to be equivalent to some set of properties that in fact, but not of necessity, uniquely applies to Truman, e.g., "completed his predecessor's fourth term in office and approved the expenditures of vast sums of money in aid to his country's vanquished enemy at the end of a global war.") More generally, no physical law may include a term such as

"= *a*" where *a* is the name of any particular item. But a predicate can fail to be purely descriptive without explicitly referring to specific particulars.

Spatial and temporal *coordinates,* singly, as opposed to spatial and temporal *relations*, are not purely descriptive terms. The predicate "is at 46° W longitude and 19° S latitude" clearly makes a tacit reference to the planet Earth.

Insofar as we regard physical laws as holding for all places and times, it would be contrary to our notion of lawfulness to allow that a law should make explicit or tacit reference to some particular place or time. (Kepler's laws seemingly present a historical counterexample. We will examine them in just a moment.) Our conception of physical law doesn't allow that one law should apply to the Northern Hemisphere of the Earth and another to the Southern Hemisphere of Venus; that one law should apply to the eighteenth century and another to the nineteenth.

Differences between spatial coordinates and *differences* between temporal events *do* figure in physical (and scientific) laws. But differences between spatial coordinates, as opposed to the coordinates themselves, are purely descriptive predicates. There are no physical laws pertaining to 46° W longitude and 19° S latitude, although there well may be to things separated from one another by the distance *between* 46° W longitude and 19° S latitude and 50° W longitude and 28° N latitude. Cities *A*, *B*, *C*, and *D*, all of which have different spatial coordinates, may pairwise stand in identical spatial relations free of any reference to any particular place (e.g., to the location of 0° longitude, i.e., Greenwich, England): *A* may be 103.5 km from *B*; and *C*, 103.5 km from *D.* Physical laws may invoke mathematical functions – differences (e.g., lengths, "is 50.552 m"), products (e.g., areas, "is 2.3 km^2"), quotients (e.g., "is 1,045 km/hr."), etc. – of pairs, triples, etc., of spatial and temporal coordinates, but never spatial or temporal coordinates *neat.*

Until recently, the predicate "is 50 m long" could not have been regarded as purely descriptive, for it tacitly referred to the standard meter bar maintained in Paris. But in 1960, the International Bureau of Weights and Measures changed the standard from that of the distance between the two lines drawn on the platinum-iridium bar to 1,650,763.73 wavelengths of the orange-red line from the isotope krypton-86, measured in a vacuum. With this change, the predicate "is *x* meters in length" became purely descriptive. Similarly, the unit of time is not defined by the pulsing of any particular clock, but by the oscillation of *any* atom of cesium (1 sec. = 9,192,631,770 oscillations of a cesium atom).

Clearly, then, I am rejecting Pap's contention that laws *can* make tacit reference to specific items (1962, pp. 292–5, 301–5). Pap cited the case of Kepler's laws, which do, certainly, refer to a specific item, the sun. Given the choice between saying that Kepler's laws are genuine laws and saying that laws cannot refer to specific items, he chose the former.

There is a way, though, to avoid having Pap's choice forced on us. By adopting the distinction made in Chapter 1, between physical laws and scientific laws, we can capture the intuitions of scores of philosophers who have argued that laws should be regarded as having only purely descriptive terms. We accommodate these intuitions by insisting that the descriptive terms of *physical laws* are always purely general; the descriptive terms of *scientific laws* may refer – implicitly or explicitly – to specific times, places, things, events, etc. It would follow, then, that Kepler's laws are scientific laws, not physical ones. Kepler's laws may be derived as a special case of Newton's Laws;[3] but Newton's laws *do not* make reference to any particular items in the world.

Goodman's notorious hypothesis "All emeralds are grue" poses certain problems parallel to those of Kepler's laws. Where Kepler's predicates made reference to a certain position in space (the center of the sun), Goodman's "grue," it would seem, makes reference to a specific time.

> The predicate ''grue''... applies to all things examined before *t* just in case they are green but to other things just in case they are blue. (1965, p. 74)

In reconstructing Goodman's definition, other philosophers have departed from his original version in at least two ways. For example, Kyburg drops the qualification "examined," so that "grue" applies to all things that are green before *t* (whether or not they are examined) and that are blue after *t*. This sort of revision makes no difference for our purposes. The predicates "is green" and "is examined and found to be green" are both purely descriptive, and both may properly

[3] "Special case" in this instance, as in so many others, means "using certain *false*, simplifying assumptions", e.g., that the planets do not affect one another's orbits, i.e., that the 'three-body problem' can be solved by two applications of the 'two-body' solution. Indeed, Newton's laws themselves are false (i.e., not quite true) as learned from developments in twentieth-century physics.

figure in a physical law. Far more troubling, however, is the term *t*. How is this to be understood? As a constant, that is, as some particular time? Or as a variable, that is, as merely some time or other? Goodman's own discussion is somewhat vague on this matter, but perhaps favors the former reading, for he does begin his preceding paragraph by writing "Suppose that all emeralds examined before a certain time *t* are green" (p. 73). Kyburg takes *t* to be a constant; indeed, he lets *t* be the year 2000 (1970, p. 132). Scheffler, however, allows that *t* should take on a successive series of values and thus treats *t* like a variable (1966, p. 455).

In any event, we can define two senses of "grue," a stronger and a weaker. The stronger sense mentions a specific time, the weaker only an indefinite time.

> A thing is (strongly) grue if there is some specific time *t* [e.g., the year 2000] before which it is green and after which it is blue.
>
> A thing is weakly grue if there is some time (or other) *t* before which it is green and after which it is blue.

The predicate "is grue" (i.e., "is strongly grue") refers to a specific time. It cannot, then, figure in a physical law. But "weakly grue" is purely descriptive. To say of something that it is weakly grue is formally analogous to saying, for example, that in the history of a certain sample of polymer resin there is a time (or some interval) before which it is a liquid and after which it is a solid. Such changes do occur and must be reckoned to fall under physical laws.

Certain items in the world *are* weakly grue, for example, the water in a vase in which a watercolor artist dips her brushes as she paints. But even if certain specific *items* in the world are weakly grue (some may even be strongly grue for that matter), are there any *kinds* of things which are weakly grue? More specifically, are there any physical laws in which "is weakly grue" figures? Might emeralds, for example, fall under a law of the sort, "All emeralds are weakly grue"?

This latter proposition clearly meets all the criteria for lawfulness so far laid down, but for one. We are unsure whether "All emeralds are weakly grue" satisfies the condition of being true. To date, it seems not to be true. What should our expectations (predictions, projections) be? Should we bet on this proposition being true? Like Goodman, I am confident that we should not. It is reasonable to believe that emeralds are neither weakly grue nor strongly grue, but are green.

Goodman's problem remains to try to find a rational basis for selecting one of two inconsistent *scientific* hypotheses ["Emeralds are green" vs. "Emeralds are grue" (we will read "weakly grue")], each of which is (allegedly) consistent with the same body of available evidence. His is far removed from our problem. "Emeralds are green" and "Emeralds are weakly grue" on the present account are equal candidates for being a physical law. Since these two propositions are logically inconsistent with one another, at most one can be a physical law, because at most one can be *true*. Finding out which is true, even elucidating conditions under which it would be reasonable to believe that one rather than the other is a safer hypothesis, is no part of the job of elucidating what the concept of a *physical* law is. Whether something is to be reckoned a *scientific* law does intimately concern the evidential basis for belief in that proposition and may well concern such matters as the history (or projectability) of the predicates figuring in that proposition. But such epistemological and historico-linguistic considerations are totally irrelevant in the conditions for being a physical law. After all, there is a logical possibility that emeralds *are* weakly grue. We should hardly, then, want to lay it down that there could be no physical law to that effect. In the end, it must be a contingent matter, and possibly an empirical one, but not a conceptual one, whether emeralds are weakly grue. Although "is grue" itself (i.e., "is green prior to the year 2000 and blue thereafter") must be excluded from physical laws, "is weakly grue" (i.e., "is green at some time or other and blue thereafter") is purely descriptive and must be permitted.[4]

By disallowing that unique spatial positions (e.g., "focused on the sun") and unique temporal positions (e.g., "is grue") should figure in physical laws, we thereby avoid the question of whether a jointly held position in space *and* time allows for several instances (occupants) or at most one. Quinton has argued for the latter thesis (1973, pp. 17-20), saying that, although any number of things can successively occupy one and the same location, and although any number of things can (and typically enormous numbers do) all exist at different places at any given moment of time, no more than one thing can occupy a joint position in space *and* time, for example, "is at P_1 at T_1" admits of no more than one instantiation. In this latter regard, "is at P_1 at T_1" is to be likened to the ordinal predicate "is the tallest man." On the other side, Waismann, for one, presupposed the logical possibility of there being multiple occupants of unique spatiotemporal positions (1965, pp. 201-2). He produced a counterfactual example of two

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[4] In a passing remark, Goodman expressed some worries about the very concept of a proposition being purely general, being free of reference to particular times and places. He cites the example "All grass is green," which he points out is logically equivalent to "All grass in London or elsewhere is green" (1965, p. 78). Does this pose a problem for our analysis? I am inclined to think not. "All grass in London or elsewhere is green" is merely an idiomatic paraphrase of "All grass in London or not in London is green." In this proposition, the predicate "in London" refers to a specific place; however, the expression occurs vacuously, or inessentially, inasmuch as *any other* spatial predicate whatever could be substituted for both occurrences and the resulting proposition would retain its original truth-value. In short, "in London or not in London" is not playing an informative role; it does nothing to change the extension of the term to which it is conjoined and may be thought to be a logical curiosity but no special problem.

physical chairs, which, on a collision course, merge into the same place. For Waismann, joint positions in space and time – in principle, if not in actual fact – clearly permit multiple instances. Even though I think Waismann is certainly right in this dispute, we need not become entangled in the controversy. For we have already rejected individual positions in space, as well as individual positions in time, as suitable properties for inclusion within a physical law. A fortiori, individual positions in space *and* time are also rejected. If there are no physical laws referring to the geographical center of Vancouver, and if there are no physical laws pertaining exclusively to December 11, 1968, then there are no physical laws restricted to the center of Vancouver on December 11, 1968.

In proscribing predicates that make tacit references to individual items and to specific places and times, we disbar from use in physical laws more than just (i) spatial and temporal coordinates, (ii) identity predicates that refer explicitly to individuals, for example, "is Truman" (" = *a*"), and (iii) the neologistic equivalents of the latter, such as "Trumanizes." We also disbar (iv) all indexicals, such terms as "here," "now," "his," "hers," and "yesterday"; and (v) demonstratives such as "over there," "in this immediate vicinity," "there, where I'm pointing," "this" (accompanied by a gesture), and the like. In short, we also exclude all those predicates whose referents are determined, in part, by the circumstances or context of their use. What remains from this winnowing is the class of predicates that may be regarded as purely descriptive and hence that may be regarded as suitable for inclusion within physical laws.

What exactly does it mean for something to 'fall under' a physical law? What *sorts* of 'things' fall under physical laws?

For a start, neither individual properties, nor a bundle of properties, nor single events, etc. (see next section of this chapter), fall under physical laws. Although they do fall under necessary universal conditionals of the sort "if any thing (/event) has the property *P*, then that thing (/event) has the property *P*," necessary truths are not to be reckoned among the class of physical laws.

Only contingently connected properties, contingently connected events, etc., fall under physical laws. That some given object is blue is not the right *sort* of thing (/fact) to fall under a physical law. Nor for that matter is the *conjunctive* property of being blue, cubical, weighing 2.1 kg, and having a temperature of 4.5° C. Similarly, the single event of a child dropping her toy is not the right sort of thing to fall under a physical law. Nor is the conjunctive event that consists of Able, Baker, and Charlie all falling ill together with food poisoning.

Single properties and conjunctions of properties do not fall under physical laws. But *pairs* of properties and states, where the members of these pairs are either single properties and states, or conjunctions of properties and states, may well fall under a physical law. The opacity (tout court) of the steel object on my desk falls under no contingent generalization. Neither does its being steel. And neither does its being both steel and opaque (where "being steel and opaque" is construed as a conjunctive property). But the ordered pair that consists of being steel and being opaque *does* fall under a contingent generalization: "Steel things are opaque" or "If anything is steel, then it is opaque." We will have to, then, distinguish between, on the one hand, properties and conjunctions of properties; and on the other hand, pairs of properties, and pairs of conjunctive properties. Only the latter among these things distinguished may fall under a physical law.

Ordinary speech is not especially sensitive to the distinction between conjunctive (or conjoined) properties and paired (or connected) properties. We are likely to say that a metal's *conducting heat and conducting electricity* falls under a physical law. And this manner of speaking might – uncritically – be taken as evidence that conjunctive properties *can* fall under a physical law. But the grammatical form is misleading. It is rather the *pair* of properties – (i) conducting heat; and (ii) conducting electricity – that falls under a physical law. In exactly parallel fashion, it is only *sequences* of events (e.g., exposure to the measles virus and the subsequent developing of the disease), but not single events (e.g., either the exposure itself, or the outbreak of the disease itself), that may fall under physical law.[5]

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5 *Sequences* of events are of course events ordered in time. Why is science so little concerned with events ordered in space? If the concepts of space and time have the kind of formal parallelism often claimed for them (see, e.g., Taylor 1964 and Swartz 1973, 1975), it is surprising that there are few if any scientific laws concerning events separated by space and not time. Is this because of some contingent fact about this particular world, or does it have to do with some essential feature of the very concept of causal relation itself? Many philosophers have tried to describe hypothetical situations in which we would want to say that causal relations worked backward, from later to earlier. The verdict on these attempts is not yet in. But few philosophers have been equally concerned to see whether they could describe situations (possible worlds) in which spatial differences played the analogous role to that of temporal differences in the actual world. I have no a priori grounds for excluding the possibility of there being such worlds. And thus I do not want to make it a requirement of falling under a physical law that the events connected must be at different times. What connections there are, and whether in time, space, or time and space, seems to me (pending a good argument to the contrary) to be an empirical question; hence, I leave it as open whether the lawful connections that obtain between events might be other than temporal, e.g., whether there might be lawful connections between contemporaneous (i.e., simultaneous) events that are spatially noncontiguous. Newton thought there were, in his belief that gravity propagated instantaneously across space.

Physical laws state connections. Formally, this means that physical laws must be conditional propositions, not categorical ones.[6] Physical laws do not state that the world *is* thus and so; only that *if* it is thus, *then* it is so.[7] In ordinary speech, the conditional form of physical laws is, more often than not, masked. Physical laws often tend to be presented in categorical form: "Aluminum

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[6] Throughout this book. "$\supset$" will be used to symbolize the truth-functional relation of material conditionality; and "$\rightarrow$" to symbolize the stronger, modal relation of entailment or logical implication.

[7] We may want to allow for a few exceptions. The late N. R. Hanson was fond of invoking in his lectures the case of the centaurs, arguing that their existence was a 'biological impossibility'. A centaur would have to have two sets of lungs, an esophagus passing through its upper bowels, etc. If C is the predicate "is a centaur," is it a physical law that nothing is a centaur, i.e., $(x)(\sim Cx)$? Such a proposition, note, is categorical, not conditional. My inclination is to refine the example, taking "is a centaur" as a defined predicate, which in fact abbreviates "is half-human and is half-horse." If so, then that there are no centaurs may be thought to be a consequence of (because equivalent to) the *conditional* universal truth that, if anything is half-human, then it is not half-horse. Alternatively, if we want to allow that categorical universals of the sort "nothing is a centaur" [i.e. $(x)(\sim Cx)$] can be physical laws, then we can incorporate these peculiar cases by a minor logical sleight-of-hand, by regarding them as 'degenerate' conditionals of this sort: $(x)(Cx \supset \sim Cx)$. (This latter conditional is, of course, logically equivalent to the preceding categorical proposition.) I will continue, then, to regard physical laws as conditional propositions, but will allow for the possibility that some of these conditionals may be 'degenerate'.

melts at 660.37° C"; "The half-life of lead-214 (Pb^{214}) is 26.8 min."; and "$E = mc^2$." But each of these apparently categorical propositions properly ought to be understood as fundamentally conditional: "If anything is aluminum, then its melting point is 660.37° C" (a universal conditional); "If anything is a 'large sample' of lead-214, then (just about) one-half of the total number of lead-214 atoms will spontaneously decay in any period of 26.8 min." (a statistical conditional); and "If the magnitude of the mass of an item is *m*, then the magnitude of the energy 'contained in' it is equal to *m* times the constant *c* squared" (a numerical conditional).

For there to be connections of the kinds just spoken of, there must be at least two items to be connected. Connectedness, in the sense required for physical laws to apply, is a nonreflexive relation. The relation "has the same electrical conductivity as" is a relation that holds contingently between any two pieces of copper and necessarily between any one piece of copper and itself. If *x* denotes a piece of copper, and if *y* denotes a piece of copper, then *x*'s having the same electrical conductivity as *y* 'falls under' a contingent conditional if $x \neq y$*; but under a necessarily true conditional if* $x = y$.[8] To fall under a physical law requires, at a minimum, that the relevant conditional proposition be contingent and that the things 'connected' be at least two.[9]

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8 If we let *C* stand for "is copper" and *S* stand for "has the same electrical conductivity as," then the true universal conditional

$$(x)(y)(Cx \,\&\, Cy \supset Sxy)$$

has a specialization that is always contingent, viz.:

$$(x)(y)(Cx \,\&\, Cy \,\&\, [x \neq y] \supset Sxy)$$

and a specialization that is logically necessary, viz.:

$$(x)(y)(Cx \,\&\, Cy \,\&\, [x = y] \supset Sxy)$$

The latter is, of course, equivalent to:

$$(x)(Cx \supset Sxx)$$

9 Putnam (1975) has argued that on one theory, "Water is H_2O" (or, as I would rephrase this statement to make the parallel explicit with our form for lawfulness, "Whatever is water is H_2O") turns out to be contingent, and on another theory to be necessarily true. Putnam opts for the latter theory. He argues that if it is true that water is H_2O (and this he says can be learned only a *posteriori*, i.e., empirically), then it is a necessary truth that water is H_2O. That a necessary truth should be knowable only a posteriori causes me no particular worry. (See Bradley and Swartz 1979, pp. 168-9). Nor need I pause for fear that his conclusion jeopardizes my insistence that physical laws are contingent. For, if Putnam is right, if "Water is H_2O" can best be understood to be a necessary truth, *[footnote 9 continued on page 26]*

'Falling under' may be conceived in either of two equivalent ways. Consider the physical law $(x)(Px \supset Qx)$. Then, Pa and Qa may be said to fall under this law because either

Pa and $(x)(Px \supset Qx)$ together entail Qa,

or, equivalently,

$(Pa \supset Qa)$ is a substitution-instance of $(x)(Px \supset Qx)$.

This notion of 'falling under' bears further examination. We focus on the case of universal generalizations.

Clearly, the overwhelming majority – but not quite all – of the sequences of events, and the pairs of properties, states, etc., in the world do **not** fall under universally true, contingent conditionals. The whiteness of the sheet of paper on which this chapter began and the rectangularity of that sheet do not fall under such a true universal conditional. For there are countless things that are white and not rectangular. Similarly, my driving to work and later that day receiving an unwanted solicitation in the mail to buy a lottery ticket do not fall under a true universal conditional. Driving to work is not always followed by the receipt of unwelcome mail. (Of course, these cases do fall under some statistical generalizations.)

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9 *[cont.]* then, according to the account given here of physical lawfulness, this statement simply is not a physical law, no more so than the statement that all triangles have three sides. (This is not to say that there are not, in other regards, profound disanalogies between these two statements.) Provided other conditional, general statements with purely descriptive terms remain logically contingent – and I see nothing in Putnam's analysis to deny this – then one can proceed to ask of these latter statements which ones are physical laws.

Putnam argues, in effect, that the statement "*A* is *MNO*" – where *A* is a natural kind term and *MNO* a description of its 'hidden' (or micro) structure – is necessarily true. Putnam offers little, except by example, of what a 'hidden' structure might be, e.g., H_2O in the case of water. I am presuming that in Putnam's account, such statements as "Water has a vapor pressure of 41.8 Torr at 35° C and a vapor pressure of 233.3 Torr at 70° C" do not turn out to be necessarily true, that having a vapor pressure of 41.8 Torr at 35° C is not part of the 'hidden structure' of water. Clearly, in the example above, concerning the electrical conductivity of copper, I am assuming that, at the most, Putnam's theory – if true – would have it that the necessary truth about copper that corresponds to that about water would be something of this sort: "Copper is that element (/stuff) that has an atomic nucleus of 29 protons" and would not imply that copper's having some *one* specific value of electrical conductivity at some particular temperature was likewise a necessary truth. If these presumptions are not correct, then it would seem that Putnam's account would render every physical law a necessary truth, and the dream of the seventeenth-century Rationalists would have been realized. Were this conclusion to be warranted by Putnam's theory, I would regard this as a *reductio* of that theory.

But, as we continue our examples, we begin to feel a bit uneasy. What about my turning up the thermostat and the subsequent start of the furnace? Isn't there concealed in this sequence a pair of events that do fall under a universal conditional, even if not *all* settings of thermostats higher are succeeded by furnaces starting? Surely – we'd be inclined to say – there is some more detailed description of what I did such that, given *that* description, the starting of the furnace does logically follow from it, taken in conjunction with some true, purely general universal proposition.

This objection must be granted; indeed, the presupposition involved in it must be made explicit and underscored. The essential point is that which generalizations, if any, a sequence of events falls under will depend on the description of those events. My setting the thermostat higher – that is, my performing action *A* – is an occasion on which *B, C, D, E* ... *J* are also all true. (Some of these latter may include various facts about the thermostat, its manner of being wired to the furnace, the condition of the furnace itself, the quantity and flow of fuel, etc.) Describe my action not simply as *A,* but as *A* and *B* and *C* in circumstances *D* and ... and *J*, and it may well be true, indeed certainly will be true, that this more specifically described event does fall under – not a statistical but – a universal conditional whose consequent describes the starting of a furnace.[10]

Clearly, our familiar, unreconstructed ontology presupposes events. But we must take care to recognize that there is no empirical science of events *as such.* Empirical science can deal only with *kinds* of events. Only events under descriptions fall under physical laws. Hempel made this point in a classic paper when he wrote:

> The object of description and explanation in every branch of empirical science is always the occurrence of an event of a certain *kind*.... (1949, p. 460)

Although Hempel was theorizing about how we explain events, the point is equally valid as regards the strictly logical relation of an event's falling under a generalization. Only inasmuch as an event is *characterized* is it even meaningful to conceive of it as falling under a physical law.

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[10] There may well be superfluity in these additional conditions. But remember, if "$(L \,\&\, M) \supset Q$" is true, then so too is "$(L \,\&\, M \,\&\, N) \supset Q$." I.e., once a sufficient number of conditions has been specified so as to make the description fall under a true universal generalization, then to specify further conditions also obtaining will result in a description that also falls under a true universal generalization.

And just as there is no science of events per se, there is, equally, no science of 'individual events.' This follows, of course, from my insisting a moment ago that physical laws must be purely descriptive in their terms. Mount Saint Helens's eruption on May 18, 1980, falls under physical law inasmuch as it was an eruption (of a certain kind *Q*), occurring under circumstances (of a certain kind *R*) of a volcano (of a kind *S*), etc. But there is no physical law pertaining analytically to Mount Saint Helens exclusively. This is not to say, however, that there might not be one or more physical laws such that the circumstances leading up to the eruption and the eruption itself were those generalizations' *only* instance. Generality does not require that there be more than one instance; nor does it require, even, that there be at least one instance. But generality does require that the proposition not be analytically restricted to specific individuals (or events).

One must be careful, then, when speaking of some particular event *E* as falling under a physical law. Descriptions that are often sufficient to *individuate* an event ("the first eruption of Mount Saint Helens in the twentieth century," "Ford's pardoning of Richard Nixon," etc.) are often very meager, often contain proper names and other restricted terms, and often fail to specify – as is required for 'falling under' a law – a sequence of events. Thus Ford's pardoning Nixon is an event that falls under a physical law only to the extent that it has some general description and is identified as a member of a pair (or sequence) of similarly generally described events.

A somewhat odd consequence of this analysis is that 'one' sequence of events might be either physically possible or physically impossible, depending upon what description one gives of the events involved. (In saying this, I am, of course, talking about nonactual events, since any and every actual happening in the world, under *any* true description, must be physically possible. My point here concerns failed attempts, imagined or counterfactual circumstances, etc.) We will see (in Chapter 4) that a proposition (and derivatively the circumstances of states of affairs it describes) is physically possible if and only if it is not inconsistent with a physical law. Let us assume that it is a physical law that no mass is accelerated to a speed in excess of 299,792 km/sec. If, then, we were to describe some attempt to propel electrons in an accelerator as an attempt to accelerate them to a speed in excess of 200,000 km/sec., we should want to say that this kind of sequence – introducing the electrons into the machine; pumping energy into the machine; and the electrons' eventually attaining a velocity in excess of 200,000 km/sec. – is physically possible. But suppose our attempt to propel the electrons to this high speed admits of a more precise description, for example, it was in fact an attempt to propel the electrons to a speed of 410,000 km/sec. Under this latter description, the realization of the sequence is physically impossible.

Shall we regard (i) the attempt to propel the electrons to a speed of at least 200,000 km/sec. and (ii) the attempt to propel the electrons to a speed of 410,000 km/sec. as one event or two? We tried to achieve the latter, higher velocity, and in so doing (logically) had to try the former as well.

Ordinary speech favors the analysis that would say there was *one* attempt – one that admits of different descriptions. We typically individuate events by means of very meager descriptions indeed, and we then go on to elaborate these descriptions – filling in the details, as it were – all the time thinking ourselves to be describing one and the same event. So long as we persist with the (probably well-taken) resolve to allow that 'one' action may admit of different descriptions, we will have the result that a (nonactual) sequence of actions (or events) may be physically possible under one description and physically impossible under another. (We will return to this point in the section "Singular propositions and physical possibility" in Chapter 5.)

This much constitutes the common core of various theories of physical laws. Physical laws are true; contingent; purely descriptive in their terms; and conditional. They are also general; that is, a physical law is either a universal or a statistical proposition. But, from this point on, the major theories of the nature of physical laws diverge considerably in their respective claims. The question will be whether these various properties constitute merely a set of necessary conditions for physical lawfulness, or whether they might constitute a sufficient set.

FACTS, EVENTS, STATES OF AFFAIRS, ETC.

I have said in the previous section that only pairs of states and sequences of events may fall under physical laws. The intended contrast was with single states and single events. But the question properly arises whether any other sorts of pairs, besides states and events, may also fall under physical laws.

To the extent that scientific laws are surrogates for physical laws, one may assume that they presuppose the same ontology, that is, that the sorts of 'things' that fall under the former fall under the latter. But when one looks for guidance in the answer to this question to the class of *scientific* laws, one is presented with a truly bewildering array. There seems to be virtually no limit to the sorts of things regarded as falling under scientific laws. Events are alleged to be lawfully connected; so are the states of objects, their properties and relations, both qualitative and quantitative; so are dispositions, traits, classes of objects, states of affairs, and facts. Even this list is scarcely complete.

Some authors have argued that physical lawfulness holds between spatiotemporal items; others that it holds between universals (i.e., between properties and relations). Others argue that events are the subject matter of physical laws. Others that numerical magnitudes are. And so on.

Sorting out all of this is quite properly a role for metaphysics. And yet, no attempt will be made to do so here. One cannot solve every problem, and some must be put aside for another day. I think this is one of those problems. To answer the kinds of questions I posed in Chapter 1, namely, having to do with the modality, number, and the truth-conditions for physical laws, one need not have settled views about the subject matter of physical laws.

Now this claim must seem strange. How could the subject matter of physical laws *not* have a bearing on the question of, for example, the modality and truth-conditions of physical laws? To answer this, I must explain more precisely just what it is about the modality and truth-conditions of physical laws that concerns me.

The questions that occupy me in this book are *independent* of those having to do with, for example, questions as to the truth of realism or nominalism. Although realism and nominalism might give (or allow) different verdicts as to the sorts of things lawfully connected by physical law (e.g., nominalists may be expected to eschew universals), neither theory assigns a determinate modal status to physical laws. Thus, suppose it is true that every case of having a lung is also a case of having a heart; and suppose that one were intent to formulate a covering law. What is it exactly that would be lawfully connected? According to one's preferred theory as to the subject matter of physical laws, one might argue that it is two *classes*, the class of those things having lungs and the class of those things having hearts, that are lawfully connected. Alternatively, one might opt for the theory that it is the *properties*, of having a lung and of having a heart respectively, that are lawfully connected.[11] And still others might prefer to argue,

[11] E.g., Dretske (1977) argues for this latter theory against the preceding one.

for example, that it is the *event* of one's having a lung that is lawfully connected with the event of one's having a heart. Etc.

As important as these differing views may be, they do not bear on the question I am intent to pursue, namely, what sense are we to make of the notion of 'lawful connectedness,' If *A* is a lawfully sufficient condition for *B*, then whatever sorts of things *A* and *B* might be, we will still want to inquire: Is this relationship of *A*'s being sufficient for *B* (taking the case where the connection is universal, for example) a case of logical sufficiency, nomological sufficiency, or mere universal – but contingent – sufficiency? One's realism or nominalism will not answer these latter questions; indeed, those theories seem not to bear on the matter at all.

Similarly, the specific question I am intent to pursue about the truth-conditions of physical laws seems to me to be independent of whether one takes the subject matter of physical laws to be events, properties, classes, facts, states of affairs, or whatever. My concerns are of a much more global nature. I want to know whether the truth of physical laws comes about because of the events, properties, classes, facts, states of affairs, or whatever else their subject matter might be; or whether these laws might derive their truth from some other source in such a way as to 'make' these events, properties, classes, facts, etc., have the connectedness they in fact instance.

I am happy, then, to be quite liberal in what sorts of pairs might properly be thought to fall under a physical law. I herein usually talk of events and states (and late in the book of classes and quantitative properties) as falling under physical laws. But this is only because I think these categories fit well the standard examples.[12] I am hardly insistent on these specific categories, however.[13] Those who prefer facts, or states of affairs, or something else, can – I think – substitute their own preferences for mine and still leave intact the thrust and tenor of the discussion that follows.

THE PRINCIPLE OF DETERMINISM

When an ordered pair falls under (or equivalently, is subsumed by or covered by) a *universal* physical law, it is customary to speak of its second member as being *determined* by the first

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[12] On occasion, I will speak, too, of projects, actions, undertakings, etc. But these I regard as cases of events.

[13] I am not even sure that states and events ultimately are different categories. I must confess to a certain attraction to the theory that would make states long-lasting, semipermanent, enduring, or 'stagnant' events.

member and that law. Thus, for example, we may speak of the event of some particular instance of an ice cube melting as having been determined by the antecedent condition of its having been heated to 40° C and the universal physical law that ice melts above 0° C. Similarly, the state of some particular sample of table salt being cubical may be said to be determined by the electronic configurations of its sodium and chlorine constituents and the relevant universal physical law that states the relationship between such configurations and a cubical crystalline structure.

Several different propositions have variously been called the "Principle of Determinism." But in light of the distinctions just given, I propose to adopt the following as the official version for the purposes of this book.

> Every event (/state) is a second member of a sequence (/pair) that falls under a universal (i.e., deterministic) physical law

Two of the most familiar supposed implications, or perhaps alternative formulations, of the Principle of Determinism bear the names (1) the "Principle of the Uniformity of Nature" (alternatively, the "Principle of Repeatability"); and (2) the (Laplacean) "Principle of Predictability in Principle" (alternatively, the "Principle of the Possibility of Forecastability"). In Chapter 11, I will turn to these latter two principles. But for the present, I wish to examine only the official version.

We must take care not to confuse the Principle of Determinism for physical laws with the corresponding version for scientific laws. The two principles are quite distinct. Scientific laws, as I argued in Chapter 1, satisfy a different set of necessary conditions than do physical laws. Scientific laws must, for example, be confirmed, and must bear intratheoretical liaisons with other scientific laws, hypotheses, etc. A Principle of Determinism for scientific laws, modeled after the official version for physical laws, would be unequivocally contingent. (Provided, that is, it were asserted as a truth-valued claim, and not as a methodological precept, e.g., as a precept to the effect "Never abandon the search for covering scientific laws.") It is certainly a contingent matter whether every event (/state) is a second member of a sequence (/pair) that can be brought under some proposition that bears a certain number of epistemic and systemic features. And the truth of any claim to the effect that such is always possible, if knowable at all, can be knowable only a posteriori.

But when a Principle of Determinism is advanced, as it is here, for *physical* laws, its modal status is considerably more problematic. The *epistemic* and *systemic* criteria that figure in the analysis of the concept of scientific law are not features of *physical* laws. Physical laws need no confirmation, no acceptance, no systemic inductive warrant, etc. Physical laws may occasionally be, but hardly need to be, part of a scientific *theory*. The criteria for being a physical law are quite different from those for being a scientific law.

I have, to this point, stated five necessary conditions for any proposition's being a physical law. A proposition is a physical law only if it is a contingently true conditional, of universal or statistical form, all of whose nonlogical and nonmathematical terms are purely descriptive predicates. Shortly, we will see that according to one theory of physical lawfulness, the Regularity Theory, these various necessary conditions are held to be sufficient for physical lawfulness. Now it might occur to some that these various conditions are easily satisfiable, so easily and readily satisfiable, in fact, that were they alone to guarantee physical lawfulness, no event (or state) whatever could possibly fail to be determined. If this suspicion were to turn out to be true, then, according to the Regularity Theory, the Principle of Determinism would have to be reckoned a necessary truth.

It is hardly a sine qua non of a satisfactory theory that the Principle of Determinism turn out to be contingent. Indeed, some Regularists (e.g., Kemeny) have thought the Principle to be necessarily true and have been quite unperturbed at the prospect.[14] Still, we shall want to see for ourselves just what modal status the Principle of Determinism would have were there to be no further conditions required for physical lawfulness than those just remarked.

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14 Kemeny (1959, pp. 39-41), argues that all events must fall under 'Laws of Nature': "We can prove that any given phase of the world is covered by some mathematical law correctly interpreted" (p. 39). His subsequent example centers on mathematical laws, showing how, in effect, the temperature of New York City satisfies a mathematical law that is itself just the function that maps the times of occurrence onto the changing temperatures of that city. In being a numerical formula, Kemeny's 'law' poses no particular difficulty whatever. But there is a feature of his formula that does prevent his argument from providing a definitive answer to the question concerning the modal status, within the Regularity Theory, of the Principle of Determinism. For the formula Kemeny constructs does not satisfy all five conditions for lawfulness elicited above; specifically, not all its predicate terms are purely descriptive. It tacitly makes reference to a particular place, viz., New York City. Kemeny makes no claim, and it would seem that he cannot, on behalf of his formula being universally applicable. Thus his argument does not clinch the matter for us, who are operating under a more restrictive set of criteria for lawfulness.

For the Principle of Determinism to be contingent, there must be both possible worlds in which it is true and possible worlds in which it is false. The possible worlds in which it is true pose no problem. It is relatively easy to describe some. This world, for example, was for several centuries believed by many scientists and philosophers to be one in which the Principle is true. Any possible world that is as this world was believed to be is one in which the Principle is true. But finding possible worlds in which the Principle of Determinism is false, particularly when the Principle is taken as asserting no more than that events are determined by contingently true universal conditionals having purely descriptive terms, is rather more difficult. As a matter of fact, it takes some ingenuity to construct such a world. Nonetheless, I think it can be done.

Before we try, let's see why it is difficult. Suppose, for example, there were a series of coin flippings in this world and that the outcomes were truly random, that is, fit no specific pattern. The trouble is that, although no formula could be given for the *entire* series, each *member* of the series could be brought under a universal conditional. Suppose each member of the series has a uniquely individuating description in purely descriptive terms. This is entirely plausible insofar as each member can uniquely be identified by its own spatiotemporal position. Then, for each item, we can construct a proprietary universal generalization of the sort, "Whenever a coin is flipped at *m* seconds after the eruption of a volcano that kills exactly *n* persons (we assume that for some value of *n* this latter is a unique event in the history of the world), and is at a distance of *p* meters from the center of that volcano, then the coin turns up heads (or tails, as the case may be)." (Each coin flipping throughout history will have associated with it a unique ordered pair of constants, $\langle m, p \rangle$.)

Against this background, let's try to construct a possible world in which some event occurs that is not the second member of a pair of falling under *some* universal generalization. Consider a possible world, *W#*, in which the entire history of the world, save for one series of coin flippings, is cyclical. (I doubt that the inhabitants of the world would know that theirs was such a world; but that would not count against its being such a world.) I hope such a notion is coherent. Many philosophers have speculated that cyclical worlds are logically possible, and I will similarly assume so. The sequence of coin flippings, unlike the other events in *W#,* does not repeat: It is truly random. We must suppose, further, that the tosses are neither taken account of, nor recorded, for these latter events – were they to occur – would have to recycle endlessly. We suppose, that is, that the outcomes of the various tossings have *no* causal consequents. (I must confess to being worried about the intelligibility of the very notion of "some particular toss of the coin" under the circumstances described; but again I will assume that the notion is coherent. If not, then perhaps the Principle of Determinism as currently construed is logically necessary after all.) Under the circumstances described, no toss of the coin is 'determined'; for there is no universal generalization connecting that toss to any previous toss or to any previous run of tosses; neither is there any universal generalization connecting that toss to anything else in its world, for every feature whatever of that world is in some cycles followed by heads and in other cycles followed by tails. Thus – with some bullying perhaps – the Principle of Determinism, even when construed as the claim that events are determined by no more than 'mere' universal generalizations, remains contingent.[15] It would seem, then, that it remains an open question – but one to be answered empirically only with great difficulty – whether and to what extent this world is determined.

Now it is supposed by many that quantum mechanics has already answered this question. Quantum mechanics, many believe, has provided ample empirical and theoretical warrant for our believing that the Principle of Determinism is false in this world, that is, that not everything that happens falls under universal physical laws. A few observations are in order. First and foremost is that the truth or falsity of this claim depends on one's analysis of 'physical law.' If, for example, it is a requirement for an event's falling under a physical law that that proposition be such as to allow the predicting (forecasting) of the event, then – on that analysis – it very much does seem that aspects of this world are undetermined. But, if one adopts some *other* analysis of physical lawfulness, then it may well turn out that a quite unpredictable event was determined (more on this in Chapter 11). Suppose for the sake of argument that individual atoms can be individuated (metaphysically, if not always or even usually in practice) by their unique positions in space in time. (Even this is contentious according to some interpretations of quantum mechanics.) *If* atoms can be so individuated, then, although the moment of decay of a given,

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15 It may be that it is easier to make the Principle false in less robust worlds; e.g., worlds that lack either spatial or temporal relations. If such worlds are countenanced, then one might simply postulate an eternal series of random occurrences of noises or an infinite random splash of colored patches, etc. See, e.g., Strawson's *Individuals* 1964, ch. 2.

let's say, radium atom may be absolutely unpredictable, that event may still be fully determined insofar as it falls under a proprietary universal generalization of the sort, "Any atom of radium that is at a spatiotemporal distance of 69.46 sec. and 1952.765 cm from the site of the occurrence of an event of sort *XYZ*, decays." Of course, the trouble here is that this latter proposition will not be recognized as true *prior* to the decay of the atom in question; *and* moreover, different atoms will have their moments of decay 'determined' by quite different universal generalizations from those of their comrades. There may even be as many physical laws as there are instances of nuclear decay.

It is hardly my intent to attempt to pursue such matters as the individuability of atomic and smaller entities. There is no need for such inquiries here. The actual truth-value of the Principle of Determinism seems to me to be a matter of as little concern as its modality.

Whether the Principle of Determinism is contingently true or false, and whether it turns out to be true according to the Regularity Theory and false according to some other, leaves quite untouched the fact that a very great deal of what happens in this world *is* determined, that is, falls under universal physical laws. The entire universe does not have to be determined in order that we should have profound puzzles about certain parts that are determined. For example, even if not everything that happens is determined, we still tend to regard our actions as determined, and we must address the problem whether the fact of our actions being determined is incompatible with our being morally responsible for what we do. When we turn in Chapters 10 through 12 to such matters, we will find that whether everything is determined, or some atomic events are not, scarcely matters in our trying to understand what is entailed by something's being determined.