Laws, Counterfactuals, Stability, and Degrees of Lawhood*

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I identify the special sort of stability (invariance, resilience, etc.) that distinguishes laws from accidental truths. Although an accident can have a certain invariance under counterfactual suppositions, there is no continuum between laws and accidents here; a law's invariance is different in kind, not in degree, from an accident's. (In particular, a law's range of invariance is not "broader"—at least in the most straightforward sense.) The stability distinctive of the laws is used to explicate what it would mean for there to be *multiple* grades (or degrees) of physical necessity. Whether there are is for science to discover.

1. Introduction. This paper addresses the following questions:

- What, precisely, is the special relation that laws of nature bear to counterfactual conditionals, setting laws apart from merely accidental truths?
- Does a law have a broader "range of invariance" (a.k.a. stability, robustness, resilience, autonomy, permanence, constancy) than an accidental truth?
- In what sense is physical necessity "between" logical necessity and no necessity at all?
- Are there—could there be—*multiple* grades of necessity between logical necessity and no necessity at all? What would this involve? Are there different degrees of lawhood?

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- If so, then is there merely a difference in degree between natural laws and accidental generalizations? Or does there nevertheless remain a difference in kind?

Let's begin with the first of these questions.

2. Laws and Counterfactuals—What is their Special Relation? It has often been held that which subjunctive conditionals are correct is closely bound up with what the laws of nature are.[1] (I shall use "$p > q$" to abbreviate the subjunctive conditional "Were p the case, then q would be the case.") For instance, if "All copper is thermally conductive" expresses a natural law, then had the handle been made of copper, it would have been thermally conductive. In contrast, although all of the coins in my pocket are made of silver, it is not the case that had this penny been in my pocket, it would have been made of silver.

However, it is difficult to identify the precise relation that laws, but not accidental truths, bear to counterfactuals. An accidental generalization sometimes appears to behave just like a law in connection with certain counterfactuals. For example, if it is an accidental generalization that all [fifty] of the pears on this tree are now ripe, then had there been another pear on the tree, it too would now have been ripe. (After all, it is no coincidence that all of the pears on the tree ripened at the same time, considering that they all experienced roughly the same environmental conditions.) For that matter, all of the pears on the tree would still have been ripe had I worn a different shirt today. Indeed, this just goes to show that *any* accidental truth is invariant with respect to *certain* hypothetical changes. Thus, the intuitive difference between laws and accidental truths in their relations to counterfactuals cannot adequately be captured by the sort of characterization often found in the philosophical literature, such as this:

> [L]aws must not only apply to the existing physical world but must also cover physical situations which, though non-existent, are permitted by the laws of nature. . . . Mere accidental regularities, however, do not extend to physically non-existing situations. (Weinert 1995, 18–19)

It might initially be supposed that although an accidental truth would still have obtained under *some* range of counterfactual circumstances, that range is narrower than the range under which a law would

1. Among those who have advocated views along roughly these lines are Bennett (1984), Carroll (1994), Chisholm (1955), Goodman (1983), Horwich (1987), Jackson (1977), Mackie (1962), Pollock (1976), and Strawson (1952). Note that "counterfactual conditionals" are just subjunctive conditionals with false antecedents.

still have held. The proposal, in other words, is that an accidental truth's "range of invariance" is a proper subset of a law's, where the "range of invariance" of some truth q (or set of truths S) is the set of p's under which q (or every member of S) is "invariant" (i.e., is "preserved")—that is, the p's such that had p obtained, then q (or all of S's members) would [still] have obtained.[2]

However, I believe that this is incorrect: It can happen that under a given counterfactual supposition, a given accidental generalization would still have obtained, but a given law would not. For instance: Suppose that it is an accidental generalization that all of the electrical wires now on the table are made of copper. Had copper been an electrical insulator rather than conductor, then all of the wires on the table would have been useless. A certain law obviously fails to be preserved under this counterfactual antecedent, whereas a certain accidental generalization (that all of the wires now on the table are copper) would still have obtained.[3]

Here is another example. Suppose that President Clinton has a policy of putting only dimes in a certain pocket, and suppose that he never, in fact, violates this policy. So the generalization "All of the items that are ever in Clinton's pocket are dimes" is true, and it has a certain range of invariance: If you had handed Clinton a quarter and asked him to put it in this pocket, he would have refused. This case falls within the generalization's range of invariance. But its range of invariance is limited: Perhaps if you had handed Clinton a check for an extraordinarily large campaign contribution and asked him to put *that* in this pocket, he would have done so; this may fall outside of the generalization's range of invariance. Now consider what would have happened if we had taken a given quarter and asked Clinton to pocket it, *and* if a body on Jupiter last year had accelerated despite experiencing no net force.[4] Such an acceleration is inconsistent with (and so falls outside

2. This is proposed by Haavelmo (1944, 28f.).

3. Of course, what to make of a counterfactual like this (a "counterlegal") is a vexing question on which reasonable people differ. Those who regard the natural laws as conceptual necessities will take every counterlegal as trivial. Obviously, I am working here to elaborate the idea that physical necessity constitutes a grade of necessity *between* logical (or conceptual) necessity and no necessity at all. Accordingly, I do not take "counterlegals" as trivial. Bear in mind that context often influences whether a certain accident (e.g., that all of the wires now on the table are made of copper) is preserved under a given counterfactual antecedent (counterlegal or otherwise).

4. It might be thought that had a body accelerated without feeling a net force, then the natural laws would have been fundamentally different, and who knows what the universe would then have been like: maybe there would have been no human beings at all, much less Clinton, and no United States at all, much less quarter-dollar coins. I agree. But my taking this view is compatible with my holding that had a body on Jupiter last

the range of invariance of) Newton's first law of motion.[5] However, none of this would have made any difference to Clinton; the quarter would still have been worth only twenty-five cents. Had we asked Clinton to pocket it, he would have refused. My point is that the Clinton generalization would still have obtained under this counterfactual supposition, whereas Newton's first law of motion would not. A non-law's range of invariance may extend to some circumstances that fall outside of a given law's range of invariance. So it cannot be that a law's range of invariance is automatically broader than an accidental generalization's in that the latter is a proper subset of the former. (Later, I shall suggest that there is nevertheless a sense in which the laws *collectively* possess a *maximal* range of invariance.)

As I noted, each of the counterfactual suppositions in the above examples is logically inconsistent with some law. Accordingly, it might be suggested that a given law's range of invariance includes every counterfactual antecedent that is logically consistent with every law, whereas these are not all included in an accident's range of invariance. For example, although "All of the pears on this tree are now ripe" extends to *some* physically possible, non-existent situations, it does not extend to *all* of them. It is not the case that this generalization would still have obtained had the preceding spring season been cooler, or had a pear on the tree been kept under strictly controlled environmental conditions radically different from those actually experienced by the pears.

Our proposal, so far, is that some fact p is a law (i.e., it is a law that p) exactly when p is preserved under every counterfactual supposition that is logically consistent with the facts that are laws. This is almost right, I think, but it must be refined in three respects: (i) Suppose that p and q are laws, and that r is a contingent truth that follows from (p & q). Must it be a law that r? Perhaps Fodor (1981, 40) is correct in suggesting that it is not a *law* that all objects that are emeralds or pendulums are green emeralds or pendulums having a period of $2\pi(l/g)^{1/2}$. Let's leave room for this possibility.[6] But then if (as we have

year accelerated despite experiencing no net force *and* had we and Clinton still lived, quarter-dollars still existed, and we asked Clinton to pocket a quarter, *then* Clinton would have refused to pocket it. In other words, (p & r) $>$ q plainly does not entail $p > q$.

5. For the purposes of this example, we may presuppose classical physics, since our concern is the logical relation between the natural laws—whatever they are—and counterfactuals.

6. For example, many nineteenth-century chemists believed it to be a law that nitrogen's atomic weight is 14 units and a law that all noncyclic alkane hydrocarbons differ in their atomic weights by multiples of 14 units, but a coincidence that all noncyclic alkane hydrocarbons differ in their atomic weights by multiples of the atomic weight of nitro-

just proposed) there is a range of counterfactual suppositions under which all of the facts that are laws are preserved, then the laws may not be the *only* facts so preserved; any of their logical consequences is also preserved even if it is not itself a law. Furthermore, if p and q are laws but (p & q) is not a law, then ($\neg p$ or $\neg q$) may be consistent with each of the facts that are laws. In that event, our proposal cannot be correct in holding that all of the facts that are laws (e.g., p and q) are preserved under the counterfactual supposition "Had either p been false or q been false." (ii) A fact that is a law may fail to be preserved under a counterfactual antecedent that, although consistent with every fact that is a law, is inconsistent with some such fact's *lawhood*. For example, had it not been a *law* that every material object accelerating from rest remains at speeds less than 3×10^8 m/s, then perhaps it would not have been *true*; perhaps some object would have accelerated beyond that speed. Of course, if p is a law, then the supposition that p is not a law is inconsistent with the facts that are laws so long as "It is a law that p" entails "It is a law that it is a law that p." But this entailment may not hold. (iii) Likewise, a fact that is a law may fail to be preserved under a counterfactual antecedent that, although consistent with every fact that is a law, is inconsistent with the *non-lawhood* of some non-laws. For example, had Reichenbach's (1947, 368) famous accidental generalization "All gold objects are smaller than one cubic mile" instead been a law, then perhaps the law of thermal expansion would have failed (since perhaps a gold object of slightly less than one cubic mile, upon being heated, would have been barred from expanding beyond one cubic mile). Of course, if p is a non-law, then the counterfactual supposition that p is a law is inconsistent with the facts that are laws so long as "p is a non-law" entails "It is a law that p is a non-law." But this entailment may not hold.

To avoid these problems, let's define "p is physically necessary" to mean "p follows from the laws' lawhood and the non-laws' non-lawhood." In other words, p is physically necessary in world W exactly when p is true in every possible world with *exactly* the same laws as W. Let $\blacksquare p$ mean "p is a law" and $\Box p$ mean "p is physically necessary", so $\blacksquare p$ entails $\Box p$ but not vice versa; if $\Box p$ where p entails q, then $\Box q$; $\blacksquare p$ entails $\Box \blacksquare p$; $\neg\blacksquare p$ entails $\Box\neg\blacksquare p$; $\Box p$ entails p. Our proposal is now that some fact p follows from the laws exactly when p is preserved under every counterfactual supposition that is logically consistent with the facts that are physically necessary.[7]

gen. (See van Spronsen 1969, 73ff.; for more on such coincidences, see Lange 1994, 1996.)

7. In the Appendix, I briefly discuss some potential difficulties for this view.

It may be fairly easy to tell whether a given counterfactual supposition is consistent with those claims p where we believe $\blacksquare p$. But to say whether it is consistent with p's *lawhood* (not to mention with the *non-lawhood* of various putative non-laws), we must make some more substantive claims about what lawhood is.[8] I shall now do so, and thereby derive some more tractable proposals regarding the laws' special relation to counterfactuals.

Implicit in the concept of a natural law is the idea that the laws of nature *govern* the universe. For instance, a given emerald's color is *governed* by the fact that it is a law that all emeralds are green, comets *follow* the same laws of motion as the planets *obey*, and gravity was believed to act *in accordance with* (or *under*) Newton's inverse-square law. The laws governing various phenomena may themselves be governed by higher-order laws. For instance, it is a law that all laws of motion are Lorentz-invariant, and it is a law that for each kind of elementary particle, there is a law specifying its rest mass. So we have a hierarchy:

⋮
LAWS
that govern
LAWS
that govern
LAWS
⋮

At the bottom of this hierarchy are the facts about the actual world (i.e., *not* counterfactual conditionals) that are governed by laws but do not themselves govern anything (or describe what governs something). These are the "non-nomic facts"—e.g., the facts about particles in motion that are governed by laws *of motion*, as contrasted with the facts that are governed by laws *about laws*. Whereas $\blacksquare p$, $\neg\Box q$, and $(r \supset \blacksquare r)$ are (if true) nomic facts, the non-nomic facts include that all emeralds are green and that all gold objects are smaller than one cubic mile. A "non-nomic claim" (a claim that, if true, expresses a non-nomic fact)

8. For instance, it appears to be a consequence of Lewis's account of law (1973, 72ff.; 1986, 122ff.)—according to which the laws are (roughly) the general truths belonging to the deductive system having the best combination of simplicity and informativeness regarding the Humean truths—that "There exists nothing in the entire history of the universe except a single lonely electron" is inconsistent with the actual laws' lawhood and non-laws' non-lawhood. (In such an impoverished universe, "All copper objects are electrically conductive" does not belong to the best system, whereas "All material particles are electrons" presumably does.) On other accounts of law, the counterfactual supposition of a lonely electron *is* consistent with the facts that are actually physically necessary. So to apply our proposal, we must make some substantive claims about lawhood.

does not concern the laws; it is not made true or false by which counterfactual conditionals are correct, and its truth-value does not depend in any obvious way on whether or not some fact is a law (or physically necessary). (Let U be a language for science containing exactly the non-nomic claims; identify a language with the set of its sentences.)[9]

If it is a law that all emeralds are green ($\blacksquare p$), then although $\Box\Box p$ holds and entails $\Box p$, $\blacksquare p$ rather than $\Box\Box p$ is intuitively *responsible* for p's physical necessity. Or suppose that $\blacksquare(\neg\blacksquare q \supset r)$ and $\neg\blacksquare q$, where q and r are non-nomic. That r follows from $(\neg\blacksquare q \supset r)$'s lawhood and q's non-lawhood *shows* that $\Box r$—that r is no accident. But intuitively, it is not the *reason why* $\Box r$; if r is "Every emerald in my pocket is green," then r follows from a truth $\blacksquare p$ ("It is a law that all emeralds are green") where p is non-nomic. The law that $(\neg\blacksquare q \supset r)$ is not partly responsible for r's physical necessity because this law does not *govern* r; in the hierarchy, it is a law governing *laws*. To put the point generally: if some p is physically necessary, then p must follow from facts of the form $\blacksquare q$ and $\neg\blacksquare r$ where q and r are facts at or below p's level in the hierarchy of laws and what they govern. (For instance, though q is non-nomic and thus below $(\neg\blacksquare r \supset q)$ in the hierarchy, $\blacksquare q$ could be responsible for $(\neg\blacksquare r \supset q)$'s physical necessity.) So if $\Box p$ where p is non-nomic, then the responsibility for p's physical necessity must fall entirely on the lawhood and non-lawhood of various non-nomic facts; p must follow from facts of the form $\blacksquare s$ and $\neg\blacksquare t$ where s and t are non-nomic.

The intuition that there are non-nomic facts—facts that laws govern but that govern nothing themselves—has sometimes been invoked in the service of the view that p's lawhood is ultimately reducible to, or at least supervenient upon, the non-nomic facts. On this Humean view, lawhood adds nothing to the world beyond what the non-nomic facts already bring. I do not subscribe to this view; I believe that the distribution of $\blacksquare$'s and $\neg\blacksquare$'s over the non-nomic facts is not determined by these facts, any more than the rules of chess supervene on the actual moves made in a given chess game played according to the rules. The laws fail to supervene on the facts that they govern. Indeed, I think that once the non-nomic facts are fixed, the $\blacksquare$'s and $\neg\blacksquare$'s could be distributed in just about *any* way among them. In particular, once it is fixed which non-nomic claims possess $\blacksquare$ and which do not, the accidents may include any of those that are not entailed by but are consistent with those that possess $\blacksquare$.[10] If $\neg\blacksquare q$ and various facts of the form $\blacksquare p$

9. Although I presume that "Humean regularities" (e.g., that all emeralds are green) are non-nomic, I am not prepared to say whether a fact concerning causal relations, explanatory relations, or objective chances is non-nomic, since this would require analyses of these difficult concepts, which it is not my aim here to provide.

10. This leaves room for some constraints on the distribution of $\blacksquare$'s and $\neg\blacksquare$'s. For

logically entailed r (where p, q, and r are non-nomic and the facts $\blacksquare p$ alone do not suffice to logically entail r), then $\neg r$ together with those facts $\blacksquare p$ would logically entail $\blacksquare q$, contrary to the notion that once the non-nomic facts are fixed, the $\blacksquare$'s and $\neg\blacksquare$'s can be distributed among them in any fashion (e.g., p gets a $\blacksquare$ whereas q does not).[11] So my contention is that the only constraint that facts of the form $\blacksquare p$ and $\neg\blacksquare q$ (where $p,q \in$ U) impose on the facts in U (laws and accidents alike) is that the facts in U must be consistent with the p's where $\blacksquare p$.[12]

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instance, plausibly "It is a law that all F's are G" logically entails "It is a law that no F's are non-G." Likewise, perhaps "All emeralds at spatiotemporal location l are green" and "All emeralds at l are blue" cannot *both* be laws. But I see no reason why they could not both be physically necessary (when it is physically impossible for an emerald to be at l). I do want to permit $\neg\blacksquare p$ and $\blacksquare q$ when p is logically equivalent to q. For example, I believe that "All emeralds are green" is a law but "All non-green things are non-emeralds" is a physically necessary non-law. Non-green things do not constitute a natural kind any more than do the emeralds plus the pendulums (recalling Fodor's remark mentioned earlier). Our belief that "All non-green things are non-emeralds" lacks lawhood is manifested in our beliefs about how it is supported by evidence. Suppose we discover that a given non-green stone with specific gravity 2.2 is a non-emerald. Typically, we do not regard this evidence as confirming that a given non-green stone with specific gravity 4.5 is a non-emerald. Obviously, this is related to Hempel's "paradox of the ravens" and to the traditional view (held by many of those cited in fn 1) that there is a special kind of confirmation that a hypothesis can receive only if we believe that it may state a law. (See my forthcoming-a,b.)

There must be further constraints on the distribution of $\blacksquare$'s and $\neg\blacksquare$'s among the non-nomic claims *if* the non-nomic facts include facts about objective chances (see fn. 9). Plausibly, "It is a law that all F's are G" logically entails "It is a law that for any n, no F's have n% chance of being non-G." (So long as probabilities n must be standard—i.e., non-infinitesimal—numbers, even an F with 0% chance of being non-G *could* be non-G, which cannot be if it is a law that all F's are G.) Something like this is needed for the principle in the main text to apply to a world with non-nomic objective chances. For if it is a law that all F's are G, then no F possesses (say) 20% chance of being G, even though an F having 20% chance of being G can logically possibly exist in a world where all F's are G—namely, when "by chance" all F's are G. This would be an example where the distribution of $\blacksquare$'s and $\neg\blacksquare$'s among the non-nomic claims imposes a constraint on the accidental truths in U beyond that they must be consistent with the p's in U where $\blacksquare p$—it would, that is, unless "It is a law that all F's are G" logically entails that it is physically necessary that no F has 80% chance of being non-G (i.e., 20% chance of being G). Understanding the relation between laws and objective chances would require grappling with issues concerning objective chance that are not directly relevant to the topics of this essay. Accordingly, I shall not develop the considerations in this paragraph.

11. If no facts $\blacksquare p$ are involved, then in $\neg r$'s logically entailing $\blacksquare q$, we would have a respect in which the distribution of $\blacksquare$'s over the non-nomic facts is determined by those facts.

12. So for a non-nomic fact to be accidental, it suffices that it fail to follow from the non-nomic facts that are laws; there is then no possibility of its following from the lawhood of those laws, or from any laws' lawhood or non-laws' non-lawhood. This

The idea that even after it is fixed which non-nomic claims possess $\blacksquare$ and $\neg\blacksquare$, the accidental truths in U remain entirely open seems implicit in the traditional contrast between natural laws and initial conditions. Having designated which non-nomic claims state laws and which do not, God (let's say) is free to set the non-nomic initial conditions in any manner consistent with the truth of the non-nomic claims that state laws. That two possible worlds could have exactly the same non-nomic facts, but differ in which non-nomic facts state laws, should not really be surprising, considering that the laws in a given world depend not just on what *in fact* happens there, but also on what *would have* happened there had certain circumstances unrealized in that world instead come to pass there. Intuitively two worlds can be identical in the former respect but different in the latter. This is especially evident when the two worlds are highly impoverished. For example, if a given possible world's history involves nothing but a single elementary particle moving uniformly forever, then presumably its laws could be exactly the same as the actual world's, but alternatively its laws could posit a gravitational force twice as strong as the actual one. This difference would make a difference to the counterfactual conditionals holding in the given world, but either law is consistent with the non-nomic facts there.[13]

Earlier I concluded that if $\Box p$ for $p \in$ U, then there must be facts of the form $\blacksquare s$ and $\neg\blacksquare t$ from which p follows, where $s,t \in$ U. I have just held that there are such facts only if p follows from facts s where $\blacksquare s$ and $s \in$ U. Let Λ be the set of such facts s along with their logical consequences in U. So we have found that Λ contains exactly the facts p in U where $\Box p$. Thus, if a non-nomic counterfactual supposition p is consistent with Λ, then $\neg p$ (which is also non-nomic) is not in Λ, and so $\neg p$ is not physically necessary, and so p is logically consistent with the facts that are physically necessary. Recall that this very constraint figured in our earlier proposal: A fact p follows from the laws exactly when p is preserved under every counterfactual supposition that is logically consistent with the facts that are physically necessary. From this proposal, it follows in particular that for any non-nomic fact p, $p \in \Lambda$ only if p is preserved under every counterfactual supposition in U that

seems altogether intuitive: if $p \in$ U, then to know whether some p in U is physically necessary, we do not need to know what lawhood is, only what the laws in U are.

13. It seems to me a highly counterintuitive consequence of Lewis's account of law (see fn. 8) that had the universe's initial conditions been such that there existed nothing forever except a single lonely electron, then it would not have been a law that all copper objects are electrically conductive and it would have been a law that all material particles are electrons. For another argument for nomic non-supervenience, see Carroll 1994. See also the end of Section 3.

is logically consistent with the facts that are physically necessary. But we have just seen that if a counterfactual supposition in U is consistent with Λ, then it is consistent with the facts that are physically necessary. So if a non-nomic fact p belongs to Λ, then p is preserved under every counterfactual supposition in U that is consistent with Λ. We can easily make this a biconditional: Suppose p is a non-nomic fact but $\neg\Box p$ (i.e., $p \notin \Lambda$). Then the counterfactual supposition $\neg p$ is consistent with Λ, but obviously p is not preserved under this supposition.

So we have derived this principle as a candidate for capturing the special relation between the laws and counterfactuals:

(1) Λ's members would still have been true, under any $p \in$ U that is consistent with Λ.

We could go further. Recalling the hierarchy of laws and what they govern, let U^+ contain just the claims that purport to describe either non-nomic facts or the laws governing those facts. (So $U \subset U^+$, "All laws of motion are Lorentz-invariant" $\in U^+$, and $(p \supset \neg\blacksquare q) \in U^+$ if $p,q \in U$.) By an argument precisely analogous to that given above, we can derive

(2) Λ's members would still have been true, under any $p \in U^+$ that is consistent with Λ^+,

where Λ^+ contains exactly the truths of the form $\blacksquare p$ and $\neg\blacksquare q$ for $p,q \in U$, and their logical consequences in U^+. (So Λ^+ contains exactly the facts p in U^+ where $\Box p$.)

We might go even further: Perhaps if $\blacksquare p$, then under any counterfactual antecedent in the specified range, p would not only still have been *true*, but also would still have been a *law*. This suggests expansions of (1) and (2):

(3) Λ^+'s members would still have been true, under any $p \in U$ that is consistent with Λ,

(4) Λ^+'s members would still have been true, under any $p \in U^+$ that is consistent with Λ^+.[14]

Philosophers have long recognized that a counterfactual conditional's correctness is "a highly volatile matter, varying with every shift of context and interest" (Lewis 1973, 92). For example, our concerns influence which of these is correct: "Had I jumped from this window, I would have suffered serious injury," ". . . I would have arranged for a net to be in place below," ". . . the window would have to have been

14. I briefly entertain challenges to these principles in the Appendix. Ultimately, I endorse (1) and (2), but shall eventually identify a novel kind of exception to (3) and (4).

much closer to the ground" (Bennett 1984, 71). Principles like (1)–(4) are intended to hold in *any* context, since they are supposed to reflect the logical relation between laws and counterfactuals.

However, even if these principles are correct, I do not believe they would be an entirely satisfactory means of distinguishing the laws' special relation to counterfactuals.

The source of my dissatisfaction is *not* that if the physical necessities' special range of invariance is itself delimited by reference to the laws (e.g., as invariance under those counterfactual suppositions in U that are consistent with Λ), then whether some truth in U is physically necessary cannot be read off simply from which counterfactual conditionals are correct; we would first have to know which counterfactual suppositions in U are consistent with Λ, and so what the physical necessities in U are. However, why should we have expected the physical necessities to be capable of being read off from the correctness of various counterfactuals? Admittedly, we should have expected this had we thought that physical necessity just *is* invariance under a certain range of counterfactual antecedents. The physical necessities must not then be needed to designate that range, on pain of circularity. But I do not contend that a given non-nomic fact's range of invariance *makes* that fact physically necessary. Perhaps it is the other way around: various counterfactual conditionals are correct in virtue of the physical necessity of various facts.

Instead, here is the reason I am dissatisfied with elaborating the laws' special relation to counterfactuals in terms of the laws' invariance under every counterfactual supposition in a range picked out by reference to the laws: because this does not explain why the laws' relation to counterfactuals is so *special*. For *any* set of truths (except the set of all truths), even a set that includes some accidents, there is *some* range of counterfactual suppositions under which it is invariant. For the laws in U, one such range consists of those antecedents in U that are consistent with the laws in U. Perhaps another set of truths is invariant under every counterfactual antecedent consistent with "George Washington was the first President of the United States." What is so special about the first sort of invariance that it gives the laws an especially intimate relation to counterfactuals? Unless we already have some ground for regarding the laws as special—and so for privileging the range of counterfactual antecedents consistent with the laws—we cannot regard the laws' invariance under these counterfactual antecedents as giving the laws a *special* relation to counterfactuals. Of course, it gives the laws a *unique* relation to counterfactuals, but this fact has no great significance if it requires gerrymandering the relevant range of counterfactual antecedents precisely to suit the laws. That no accidental truth p in U is preserved under every non-nomic counterfactual antecedent consistent with the laws in U is a trivial, unilluminating fact, since p obviously cannot be preserved under the supposition $\neg p$. Suppose we had instead begun by considering a certain range of counterfactual antecedents that are logically consistent with p, encompassing some that are logically inconsistent with laws. Then we might have found that p is invariant under all of *these* counterfactual suppositions, whereas a given law is not.

3. Stability. How should we characterize the special sort of invariance under counterfactual suppositions that distinguishes Λ (Λ^+) from any other set S of truths in U (U^+) that is logically closed in U (U^+)?[15] We have just seen the disadvantage of using *the laws* to pick out the relevant range of counterfactual suppositions. But (1) and (4) can be expressed in a manner that allows *the set whose invariance is under discussion* to pick out the range of counterfactual suppositions where its invariance under those suppositions is at issue. Let's say that set S possesses "stability" just when

(i) $S \subset U^+$;
(ii) all of S's members are true;
(iii) if $p \in U^+$ and p follows from members of S, then $p \in S$;
(iv) for any $m \in S$, and for any $p \in U^+$ that is consistent with every member of S, $(p > m)$ is correct.[16]

Likewise, let's say that S possesses "non-nomic stability" just when

(i) $S \subset U$;
(ii) all of S's members are true;
(iii) if $p \in U$ and p follows from members of S, then $p \in S$;
(iv) for any $m \in S$, and for any $p \in U$ that is consistent with every member of S, $(p > m)$ is correct.

Then (1) says that Λ has non-nomic stability, and (4) says that Λ^+ is stable. Intuitively, S has [non-nomic] stability exactly when all of S's members are preserved whenever [non-nomically speaking] they *could all* be preserved—i.e., under any [non-nomic] supposition with which they are all logically consistent. Stability, then, is a kind of *maximal* invariance.

15. I require logical closure because it ensures that if p is consistent with each member of S, then p is consistent with each logical consequence of members of S, and so that it is logically possible that all of S's members would still have been true, had p obtained.

16. Actually, (iv) renders (ii) superfluous: Let p be a logical truth. The same applies in the definition of "non-nomic stability" below.

Let's focus on (1)—Λ's non-nomic stability.[17] Do any sets besides Λ possess non-nomic stability?

Non-nomic stability is also possessed by the set of logical truths in U and the set of all truths in U. The set of logical truths in U is non-nomically stable because *trivially* a logical truth q is logically entailed by any p, and so automatically $p > q$ holds (at least where p is consistent with the logical truths). The set of all truths in U is non-nomically stable because $p > q$ is *trivially* true if p and q are true, and no false supposition in U is consistent with each of this set's members. These two sets, then, are *trivially* stable.

Are there any other non-nomically stable sets besides these two and Λ? In particular, is there a non-trivially non-nomically stable set that includes an accidental truth, or have we found a satisfactory way to distinguish laws from accidents by their relation to counterfactuals?

To begin with, consider two non-nomically stable sets, S and T, where neither is a subset of the other. Suppose that m belongs to S but not to T, and n belongs to T but not to S. Then the counterfactual supposition ($\neg m$ or $\neg n$) is consistent with every member of S, since otherwise its negation, (m and n), must follow from members of S; and so (from (iii) in the definition of "non-nomic stability," recalling that S is non-nomically stable) n must be a member of S, contrary to our initial supposition. By the same reasoning, ($\neg m$ or $\neg n$) is consistent with every member of T. Since S has non-nomic stability, m must be preserved under this counterfactual antecedent, and so the counterfactual [($\neg m$ or $\neg n$) > $\neg n$] must be true.[18] But then n is not preserved under this counterfactual antece-

17. I set aside (4) because I shall ultimately suggest that there can be an exception to it. Also, recall (from my discussion of $\neg[\neg\blacksquare p > p]$, where p is "Every material object accelerating from rest remains at less than 3×10^8 m/s") that Λ is not stable *simpliciter*, only *non-nomically*.

18. Let's take this more slowly. On a possible-worlds account of counterfactuals (like Lewis's), $p > q$ is true (when it is not the case that p is necessarily false) if and only if there is a possible world in which $p\&q$ is true that is more like the actual world (in the special sense of "similarity" relevant here) than is any world in which $p\&\neg q$ is true. So if $(\neg m \vee \neg n) > m$ is correct (and it is not the case that $(\neg m \vee \neg n)$ is necessarily false), then there must be a world in which $(\neg m \vee \neg n)\ \&\ m$ is true that is more like the actual world than is any world in which $(\neg m \vee \neg n)\ \&\ \neg m$ is true. But any world in which $(\neg m \vee \neg n)\ \&\ m$ is true is a world in which $\neg n$ is true. So there must be a world in which $(\neg m \vee \neg n)\ \&\ \neg n$ is true that is more like the actual world than is any world in which $(\neg m \vee \neg n)\ \&\ \neg m$ is true—and so, in particular, than is any world in which $(\neg m \vee \neg n)\ \&\ \neg m\ \&\ n$, i.e., any world in which $(\neg m \vee \neg n)\ \&\ n$. It follows that $(\neg m \vee \neg n) > \neg n$. Thus, if it is not the case that $(\neg m \vee \neg n)$ is necessarily false, then $[(\neg m \vee \neg n) > m] \Rightarrow [(\neg m \vee \neg n) > \neg n]$.

On such an account of counterfactuals, $(p \vee r) > q$ if $p > q$ and there is a world in which p is true that is more like the actual world than is any world in which r is true—whether or not $r > q$. It has sometimes been suggested that $(p \vee r) > q$ requires $p > q$

dent, and so T cannot have non-nomic stability, contrary to our initial supposition. We have, then, a *reductio* of that supposition; we have shown that if there are two non-nomically stable sets, one must be a proper subset of the other. Since Λ possesses non-nomic stability, it follows that if there is any other non-nomically stable set, then either it is a proper subset of Λ or Λ is a proper subset of it.

So our question—whether any accidental truth belongs to a set that non-trivially possesses non-nomic stability—now becomes: Is there a non-nomically stable set containing all of Λ's members and some (but not all) accidental truths?

There is good reason to believe that the answer is "No." Consider a set $S \subset U$ of truths, deductively closed in U, where $\Lambda \subset S$. S contains some truth beyond those in Λ—some accidental truth *a*. (Some *p*'s that are consistent with Λ fail to be consistent with S. Intuitively, then, the range of counterfactual antecedents under which S must be preserved in order to qualify as non-nomically stable is narrower than the corresponding range for Λ. On the other hand, for S to be non-nomically stable, the relevant antecedents must direct you to a narrower range of possible worlds—namely, possible worlds in which there obtains not only Λ, but also *a*.) To see why any set S lacks non-nomic stability, consider an example: The logical closure in U of Λ's members together with Goodman's (1983) accidental generalization: "All of the matches now in this book remain forever unlit" (*a*). Suppose that all of the matches in the book are dry and well-made, oxygen is present, and so on, but it is an accidental generalization that none of them is ever struck. Now consider the counterfactual antecedent: "Had one of them been struck." That one of them is struck (*p*) is logically consistent with every logical consequence of Λ's members along with *a*, since Λ's members plus the fact that one of these matches is struck does not logically entail that one of them lights; for the match to light, oxygen must also be present, the match must be dry and well-made, and so on—which is not entailed by Λ's members together with *a*. Since *p* is consistent with every member of the set under consideration, that set has non-nomic stability only if $p > a$—only if the matches would still have been unlit. But when standard conditions prevail, then had one of these matches been struck, oxygen would still have been present, the matches would still have been dry and well-made, etc., and so the struck

and $r > q$, considering certain English sentences (e.g., "Were you to stay home or to go out, you would still complain!"). But Loewer (1976) and McKay and Van Inwagen (1977) argue persuasively that in such cases, the English "or" does not function as the logical "$\vee$".

match *would* have lit—$p > a$ is false. Hence, the logical closure of a together with Λ's members is not stable.

We could have demonstrated this result in a different way.[19] Let b be some accidental truth that is unrelated to a, such as "All gold objects are smaller than one cubic mile." The counterfactual antecedent "Had $\neg a$ or $\neg b$" ("Had either one of the matches in the book been lit or there been a gold object exceeding one cubic mile") is logically consistent with every logical consequence of Λ's members together with a. But in a great many contexts, we would be correct in denying that had $\neg a$ or $\neg b$, then $\neg b$ ("Had one of the matches in the book been lit or there been a gold object exceeding one cubic mile, then there would have been a gold object exceeding one cubic mile"), though this counterfactual is required by the non-nomic stability of the set under consideration.[20] In a great many contexts, we would be correct in denying both ($\neg a$ or $\neg b$) $> \neg a$ and ($\neg a$ or $\neg b$) $> \neg b$.

This kind of argument can be given regarding any set of truths logically closed in U and having Λ as a proper subset (except the set of all truths in U, which trivially possesses non-nomic stability). The set in question must be the logical closure in U of Λ's members and some accidental truth—call it a. Since the set does not contain all of the contingent truths, there must be accidental truths that are not entailed by a together with Λ's members. Let b be such a truth. The counterfactual antecedent ($\neg a$ or $\neg b$) is consistent with every member of the given set, since otherwise some member of the set must entail $\neg$($\neg a$ or $\neg b$), i.e., (a & b), and so (by closure) b must belong to the set, contrary to our supposition. So the set's non-nomic stability requires that ($\neg a$ or $\neg b$) $> a$, since a belongs to the set, and hence that ($\neg a$ or $\neg b$) $>$ $\neg b$—in other words, that under this counterfactual antecedent, b should always be sacrificed for the sake of preserving a. But if there are some conversational contexts in which we would be correct in doing this, there are others in which (at least for some such b) we would be correct in denying this counterfactual and instead asserting ($\neg a$ or $\neg b$) $>$ ($\neg a$ & b), because a closer possible world is reached by sacrificing a.

19. Notice, when comparing this discussion to the close of the previous section, that we cannot demonstrate this set's instability merely from the fact that a trivially fails to be preserved under the counterfactual antecedent "Had a not obtained," since $\neg a$ is inconsistent with a member (a) of S.

20. To recognize the influence that context can exert here, note that the example of context-sensitivity I gave earlier (involving the counterfactual "Had I jumped from this window, I would have suffered serious injury"—call this "$p > q$") can be recast in the form I am discussing here, since $(p > q) \Leftrightarrow [p \,\&\, (q \vee \neg q) > q] \Leftrightarrow [(p \,\&\, q) \vee (p \,\&\, \neg q) > q]$. Let $a = \neg(p \,\&\, q)$ and $b = \neg(p \,\&\, \neg q)$. Context influences whether we would be correct in asserting $[(\neg a \vee \neg b) > \neg a]$ or $[(\neg a \vee \neg b) > \neg b]$ or neither.

And there may well be contexts in which neither of these counterfactuals can be correctly asserted. Since there are contexts in which a is not preserved under a counterfactual antecedent consistent with the given set (which contains a), that set lacks non-nomic stability. In short, such a set is stable only if a's preservation is more important than b's in *every* conversational context, for *any* b that is outside the set, which is highly implausible.[21]

So here we apparently have the laws' special relation to counterfactuals: Λ is non-trivially non-nomically stable, and this property is possessed by no set containing an accidental truth—even an accidental truth that would still have obtained under a wide range of counterfactual suppositions. But hold on. Suppose that p and q are each in U, false, and consistent with Λ. By Λ's non-nomic stability, $q > m$ for every $m \in \Lambda$. But suppose that for some $m \in \Lambda$, $p > \neg(q > m)$. In other words, suppose that one of the counterfactual conditionals whose correctness is responsible for Λ's non-nomic stability would not itself still have held, had p obtained (though $p > m$, for every $m \in \Lambda$). Then it would, in a sense, be mere coincidence that Λ possesses non-nomic stability, since it is an accident (not merely logically contingent, but physically unnecessary) that $\neg p$ obtains. In other words, although Λ's members *would* all still have obtained under each counterfactual antecedent in U under which they *could* all still have obtained, Λ's non-nomic stability would not itself still have obtained under each of those counterfactual antecedents. What should we say about this scenario? While Λ's non-nomic stability does not preclude it, I suggest that intuitively, we do not countenance it as possible. On the contrary, we believe not only that had we tried to violate the natural laws (e.g., to accelerate a material particle from rest to beyond the speed of light), we would have failed, but also that if the non-nomic circumstances had been different in some physically possible way (e.g., if we now had access to twenty-third century technology), then it would still have been the case that had we tried to accelerate a material particle from rest to beyond the speed of light, we would have failed [presuming that such acceleration really

21. We could put this claim to the test by selecting as our a an accidental truth that is preserved under a tremendously broad range of counterfactual antecedents consistent with it together with the laws. For instance, let a be "Sometime in the history of the universe, there exists some matter." It is perhaps initially difficult to find any counterfactual antecedent, consistent with this claim together with the laws, under which this claim might not be preserved. But let b be "The energy of the universe is insufficient to return the universe to a Big Crunch in much less than 15 billion years [the current age of the universe]." I see no reason to say that had either $\neg a$ or $\neg b$ (i.e., had there either been no matter ever or else so much energy as to close the universe in much less than 15 billion years), then a would still have obtained.

would violate the actual laws]. Any set whose non-trivial non-nomic stability is accidental in this sense must contain an accidental truth; it does not contain exactly the physical necessities in U.

In other words, a possible world might contain a set S, having that world's Λ as a proper subset, that possesses non-trivial non-nomic stability in that world, but only in virtue of the conditions that, as a matter of physically unnecessary fact, happen to prevail there: Had that universe's non-nomic initial conditions been different in a manner consistent with S (and, therefore, with that world's Λ), then (although S's members would all still have held) S would not have possessed non-nomic stability.

According to my earlier argument, we expect there to be no such set in the actual world—no set containing an accident that non-trivially possesses non-nomic stability. Intuitively, it would take an extraordinarily unlikely coincidence for all of the counterfactuals needed to make S non-trivially non-nomically stable to be correct, although S contains an accidental truth. Nevertheless, this seems to be a logical possibility. Therefore, to identify the special relation that holds in any possible world between the laws there and the counterfactual conditionals that are correct there, we must strengthen our notion of S's "non-nomic stability" by replacing (iv) in our earlier definition with

(iv′) for any $m \in$ S, and for any $p \in$ U that is consistent with every member of S, any $q \in$ U that is consistent with every member of S, any $r \in$ U that is etc., all of the following are correct: $(p > m)$, $p > (q > m)$, $p > (q > (r > m))$, etc.

Again, the nested counterfactuals required by Λ's non-nomic stability are intuitively correct. For example, had there been an electron at this location and no proton near it, then had a proton been near it, their electrostatic attraction would have accorded with Coulomb's law.[22]

Notice one consequence of my proposal that for any $m \in$ U, $\Box m$ in some world exactly when m belongs in that world to a set that non-

22. It might be thought unnecessary to add these nested counterfactuals, on the grounds that the nested counterfactual $p > (q > r)$ is logically equivalent to the non-nested counterfactual $(p\&q) > r$. But they are not logically equivalent. In other words (hold on!) the q-world closest to the p-world closest to the actual world need not be the $(p\&q)$-world closest to the actual world; indeed, the former world need not even be a p-world. Consider this example. Suppose that you and I have just run a race, and I have won. I believe that I would always win if I really tried. Then I am willing to assert: "Suppose that you had won the race. Then I must not have been trying; had I tried, I would have won." This is $p > (q > r)$. I am not willing to assert the corresponding $(p\&q) > r$: Had you won and I really tried, I would have won. There is no logically possible world in which you and I both win the race. (However, for a more sympathetic treatment of the purported logical equivalence, see Skyrms 1980, 169ff.)

trivially possesses non-nomic stability.[23] If $(p > m)$, $p > (q > m)$, $p > (q > (r > m))$, and so on, then in the closest p-world, not only does m still obtain, but all of the following are correct: $(q > m)$, $q > (r > m)$, and so on. So if Λ has non-nomic stability in the actual world, then Λ has non-nomic stability in the closest p-world. It follows, by the above proposal, that the *physical necessity* of Λ's members is preserved under any non-nomic p that is consistent with Λ. It seems to me that this result also accords with our intuitions: Had I failed to brush my teeth this morning, or had I never been born, or had we never discovered that $E = mc^2$ is a law, or had there been no asteroid to collide with the earth and wipe out the dinosaurs, the natural laws would have been no different.[24]

4. Grades of Lawhood. That Λ is a non-nomically stable set more inclusive than the set of logical truths in U, but more exclusive than the set of all truths in U, both of which are also non-nomically stable, but trivially so, is a way of elaborating the intuition that physical necessity represents a kind of necessity "between" logical necessity and no necessity at all. Admittedly (as we saw earlier), for *any* set of non-nomic truths (except the set of all non-nomic truths), there is *some* range of counterfactual antecedents such that those truths would all still have held had any of those counterfactual antecedents obtained. But this is not enough for there to be a type of *necessity* corresponding to membership in this set. For that, I suggest, the set's members must all be preserved under the range of counterfactual suppositions *that they themselves pick out*—namely, those suppositions in U that are logically consistent with all of the set's members. (And, as I noted at the close of the previous section, their preservation under this range of counterfactual suppositions must not *itself* be accidental, but must be preserved likewise.) In other words, there is a grade of necessity corresponding to a set in U if and only if that set is non-nomically stable, i.e., is *maximally* invariant in the sense I have elaborated.

This provokes a question: Are there any other grades of necessity "between" logical necessity and no necessity at all? In other words, is

23. In my forthcoming-a,b, I draw out another consequence of this proposal, using it to elaborate a sense of "inductive confirmation" according to which we can confirm h inductively only if we believe that h may be physically necessary. I thereby vindicate intuitions expressed by Goodman (1983) and Mackie (1962) among many others.

24. As I noted earlier, not all philosophical accounts of natural law entail that the laws in U would have been no different under any counterfactual circumstance with which Λ is logically consistent. In particular, some accounts hold that the laws supervene on the non-nomic facts.

there only one grade of physical necessity, or are there many? Are there any proper subsets of Λ that non-trivially possess non-nomic stability?

I speak of "grades of necessity" here—I could perhaps just as well have referred to "degrees of lawhood"—to emphasize that there would be a natural ordering among them. As I showed above, for any two non-trivially non-nomically stable, proper subsets of Λ, one must be a proper subset of the other. In other words, if there are multiple such sets S, T, U, V . . . , then they must form a sequence: S has T as one of its proper subsets, and T has U, and U has V, and so on.

It is not obvious, however, that there is a proper subset of Λ that has non-trivial non-nomic stability. Suppose we take some law—say, the Lorentz force law—and remove it (and any other claims depending essentially upon it) from Λ, leaving a proper subset T of Λ that is logically closed in U. Now consider an argument of the same form as several that I offered earlier. Consider some law—say, that any electron's rest mass is 9.11×10^{-31} kilograms—that is a member of T. It seems highly implausible that (in every conversational context, it is correct that) had either the Lorentz force law been false or the electron-mass law been false, then the Lorentz force law would have been false, as T's non-nomic stability requires. In many contexts, it is surely neither correct that the Lorentz force law would have been false nor correct that the electron-mass law would have failed.

On the other hand, it certainly appears *logically possible* for there to be multiple grades of physical necessity.[25] We can design a possible world where this is so by stipulating some of the facts in U and some of the counterfactual conditionals holding in that world. Consider the following claims:

- *a* = All particles are X-ons or Y-ons, and are never created or destroyed,
- *b* = All X-ons have one unit of positive electric charge and one unit of mass,
- *c* = All Y-ons have one-half unit of negative electric charge and one unit of mass,
- *d* = Coulomb's law governing the force between two electric charges—broadened to cover not merely electrostatic cases but also dynamic ones (i.e., taken to describe instantaneous rather than retarded action-at-a-distance), and
- *e* = Newton's three laws of motion.

25. By the same token, it is logically possible for there to be *no* set that non-trivially possesses non-nomic stability, and hence no grade of necessity "between" logical necessity and no necessity at all. The *concept* of natural law should not suffice to guarantee that there are, in fact, natural laws. It is up to science to discover whether there are.

Suppose that these are truths in the world being constructed, and suffice (along with the initial conditions) to determine all events in that world. Now stipulate that the set containing exactly *a*, *b*, *c*, *d*, *e*, and their non-nomic logical consequences non-trivially possesses non-nomic stability. Stipulate further that the set containing exactly *a*, *d*, *e*, and their non-nomic logical consequences non-trivially possesses non-nomic stability. (So its members would all still have held had Y-ons instead possessed two-thirds of a unit negative electric charge.) And stipulate further that the set containing exactly *a*, *e*, and their non-nomic logical consequences non-trivially possesses non-nomic stability. (So Newton's "laws" would still have held had the electric force been an inverse-cubed force.) We now have a world with *three* non-trivially non-nomically stable sets, and hence three grades of physical necessity.[26]

Perhaps the existence of multiple grades of physical necessity is not a mere logical possibility, but actually obtains. Perhaps the fundamental equations of quantum mechanics span one grade of physical necessity, and these together with the laws specifying the potentials associated with various kinds of forces and the values of the fundamental physical constants span another grade. If so, then the fundamental equations of quantum mechanics would still have held had, say, the electromagnetic force been twice as strong as it actually is. It is up to further scientific investigation to tell us whether this is true—whether there are multiple grades of physical necessity.

Suppose that the closest *p*-world (where $p \in \mathrm{U}$ and *p* is consistent with the actual world's Λ) contains multiple grades of physical necessity: Not only is the actual world's Λ non-nomically stable there, but so is the deductive closure in U of Λ and *a*, where *a* is non-nomic and is not a physical necessity in the actual world. Then *a* is physically necessary in the closest *p*-world, but not in the actual world. So although the lawhood of the actual laws is preserved in the closest *p*-world, the non-lawhood of the actual non-laws is not. We have here an exception to (3), (4), and Λ^{+}'s stability.

I have explained the sense in which the laws have a broader range of invariance than the accidental truths—indeed, a *maximally* broad

26. If it is logically possible for there to be more than one grade of physical necessity, then it is worth considering how this multiplicity could be accommodated by various proposed accounts of natural law. Consider, for instance, the Armstrong-Dretske-Tooley account of laws as relations of nomic necessitation among universals. There would have to be several different kinds of nomic necessitation. I do not regard this as an argument against the account; presumably, if you are willing to countenance one such primitive relation among universals, you would not mind a multiplicity of them. But it is a complication. It is not clear to me how various grades of physical necessity would be accommodated by a Lewis-style regularity account.

range of invariance—despite the fact that an accidental truth's range of invariance need not be a proper subset of a law's, and despite the fact that any accidental truth is invariant under *some* range of counterfactual suppositions. I have also argued that although there may be multiple grades of necessity "between" logical necessity and no necessity at all, there remains a difference in kind, not merely in degree, between the laws and the accidental truths, since there is a sharp distinction between stability and instability. The laws (in the sense of Λ) are all preserved wherever (in U) they all could be, and no set containing an accidental truth can make this boast non-trivially.

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APPENDIX

Several challenges face principles like (1) according to which some *p*-world with exactly the actual laws (if there be any such world) is "closer" than any *p*-world with different laws. I cannot address these challenges adequately here. But readers might wish to know roughly how I would reply to some of them. (For more extended discussion, see my forthcoming-b.)

1. It is a law that the half-life of iodine-131 is 8.1 days. So it is physically possible for there to be many atoms of I-131 in the universe's history, and for each to decay when it turns 1000 years old. But since this is exceedingly unlikely under the actual laws, doesn't it follow that had this circumstance obtained, the laws would (contrary to the above thesis) probably have been different? I don't think so. Admittedly, were we to *discover* that each of the many I-131 atoms decays when it becomes 1000 years old, then (ceteris paribus) we would *think* it exceedingly unlikely that I-131's half-life is 8.1 days. But it does not follow that had this coincidence occurred, the laws would have been different, just as "Had Oswald not shot Kennedy, someone else would have" does not follow from "Had we *discovered* that Oswald didn't shoot Kennedy, we would have *concluded* that someone else did."

2. A world where the gravitational constant differs *very* slightly from its actual value (too slightly to make any appreciable difference) is intuitively closer to actuality than a world with the actual laws but where the quantity of matter shortly after the Big Bang sufficed to produce a Big Crunch before stars (and life) had time to form. So had one or the other of these two counterfactual possibilities obtained, then (contrary to the above thesis) the laws would have been different (in a tiny way)? No: the *intuitive* sense of "closer to actuality" is not the sense that governs counterfactual conditionals. Otherwise, as Lewis (1986, 42ff.) emphasizes, we would have to deny such intuitively correct counterfactuals as "Had Nixon pressed the button, there would have been a nuclear holocaust" because a world where such a calamity occurs is *intuitively* further from actuality than a world where Nixon presses the button but a small miracle interrupts the signal.

3. Consider a vendor of weatherglasses who knows that his product's accuracy (when assembled properly) is secured by natural law. Here is his conversation with a potential customer:

Customer (pointing to a glass): Is this weatherglass reliable?
Vendor: Yes. For instance, it read "fair" yesterday, and you can plainly see that it is fair today.
Customer: But maybe it read "fair" yesterday because it was broken so that it would always read fair. Then its "accuracy" yesterday would not confirm its accuracy when it is in proper order.

Vendor: It was in proper order yesterday.

Customer: Good. But does the fact that it read "fair" yesterday and was in proper order, and that it is fair today, confirm (to some degree) that whenever it is in proper order, its prediction is accurate? To be good evidence, it must have been *possible* for this test to have revealed that the weatherglass was incorrect yesterday.

Vendor: Yes, but had the weatherglass read "foul" yesterday and been in proper order, it would have been inaccurate, since today is fair.

With this last counterfactual, the vendor seems to regard (1) as violated, since he believes that the laws securing the glass's reliability are not all preserved under a supposition (that the glass read 'foul' yesterday and was in proper order) consistent with Λ.

We can reconcile this example with (1) by noting that the vendor utters this counterfactual while trying to convince the customer of the very laws whose preservation is at issue. The vendor presents yesterday's weatherglass reading and today's weather as evidence for these laws. Therefore, although the vendor herself already believes them, she cannot presume them when entertaining the counterfactual; from the customer's viewpoint, she would then be begging the question. After all, had the vendor been willing to invoke her knowledge of laws unknown to the customer, she could have answered the customer's initial question ("Is this weatherglass reliable?") simply by citing the relevant laws. Instead, she offers evidence for these laws.

I would account in a similar way for certain other apparent counterexamples to (1), such as "Had the esteemed physicist Smith proposed some alternative to special relativity that came to be accepted by the physics community, then special relativity would have been false." Of course, there are some contexts in which we reject this counterfactual, such as when we are discussing the objectivity of the natural laws. But in a context where we accept it, we proceed as if we do not already believe that special relativity correctly describes the laws, as if we are investigating the matter along with the counterfactual scientific community (just as the weatherglass vendor in the conversation sets aside some of his beliefs about the laws, and proceeds as if he is considering the evidence from the customer's vantage point).

4. Bennett (1984, 84ff.) entertains this challenge to principles like (1): "If I reached Jupiter within the next ten seconds, that would be a miracle [a violation of the actual laws]" because Earth is more than ten light-seconds from Jupiter. Bennett claims that these principles are not violated because the antecedent is implicitly "If I reached Jupiter within the next ten seconds from my present position, which is more than ten light-seconds from Jupiter," which is inconsistent with Λ. In my 1993, I offer a procedure for distinguishing the clauses implicit in a counterfactual antecedent from the facts retained in the closest p-world entirely by virtue of the closeness criterion. Suppose someone asserts "($p > q$) because r" where r is a truth about the actual world that the person asserting $p > q$ takes also to be true in the relevant possible world(s) and to be partly responsible there for making q obtain. Suppose, however, that when asked "$p > r$?", she replies "No." I argue that r must then have

originally been implicit in *p*, but this implication was removed by the question (since the question would otherwise be trivial). Bennett's contention is supported by this procedure. Addressing someone who asserted Bennett's counterfactual, we ask "Do you believe that if you reached Jupiter within the next ten seconds, you would now be at your actual current position, which is more than ten light-seconds from Jupiter?" She answers, "No. My point was that in order to reach Jupiter within the next ten seconds, I would have to be closer to Jupiter now than I actually am—closer than ten light-seconds."

5. If the laws are deterministic, then principles like (1) demand (in the words of Lewis 1986, 171) that "if the present were ever so slightly different, then all of the past would have been different, which is absurd." (Actually, what follows is merely that the universe would have been different in *some*, perhaps trivial, respect at every past moment.) If it strikes you as remarkable that a trivial counterfactual supposition could propagate through all past times, then I believe it should strike you as equally remarkable that it could propagate through all future times. Determinism portrays the cosmos as a remarkable place. (Here I agree with Carroll 1994, 187ff.)

I believe that some backwards-directed counterfactuals are correct in certain contexts, such as "Had Stirling Moss won, he would have had to have used wet-weather tires from the start of the race" (Jackson 1977, 11). But Lewis is correct in holding that often when we entertain a counterfactual supposition, we preserve the actual course of events prior to the moment with which the counterfactual supposition is concerned, instead of reasoning that the laws require the supposed events to have certain causal antecedents, and those antecedents to have certain antecedents, and so on. In the classic example (see Bennett 1984, 70): When Darcy and Elizabeth quarrel, and subsequently Darcy (being a proud man) refrains from asking a favor of Elizabeth, we say (in certain contexts) that had Darcy asked Elizabeth for a favor, then she (holding a grudge) would not have granted it. We proceed as if the counterfactual supposition manages to obtain without any causal antecedents at all—as if through a "miracle"—apparently in violation of the actual laws. Otherwise, we would have to "backtrack": Darcy would have made his request only if no quarrel had occurred, in which case Elizabeth would have granted it.

Various replies to this argument against (1) have been offered (e.g., Bennett 1984, 73; Carroll 1994, 187). The one I favor is that sometimes "miracles" *do* bring about *p* in the closest *p*-world, but these "violations" of the actual laws are in fact *consistent* with those laws because of a consideration that I have so far disregarded: laws need not correspond straightforwardly to exceptionless regularities. Rather, a law of a given world may merely be close enough for the relevant purposes to the truth in that world.

(This view can also be defended on grounds having nothing to do with non-backtracking counterfactuals; see my forthcoming-b. A law like "In the absence of disturbing factors, a metallic object of length L_0 heated by ΔT expands by $kL_0\Delta T$" refers in its ceteris paribus clause to a tacitly understood list of other influences that is not complete, but does manage to include all of those factors that are sometimes non-negligible – cannot always safely be ignored –

for the purposes for which the law is tacitly understood to be applicable. For more on the problems raised by such provisos, see Hempel 1988.)

A law may be good enough for certain applications because it is "approximately true," as Newton's laws are in the actual world, when relativistic deviations can be ignored. Or a law of a given world may be utterly violated, but remain good enough because the violations occur "offstage," i.e., outside our range of concern in discussing that world, as when the laws of the closest possible world (in a non-backtracking context) where Darcy asks Elizabeth for a favor are violated by the manner in which the counterfactual supposition comes to pass.

To reconcile principles like (1) with offstage violations of the laws, we must revise these principles so that they require merely that various conditionals be correct enough for the relevant purposes. In different scientific disciplines, different purposes may be relevant. This raises the possibility of elaborating the concept of a law *of a given scientific field* in terms of a set's non-nomic stability *for that field's purposes*. As I have argued elsewhere (1995), a law of physics might then be an accident of ecology, or a law of cardiology might be an accident of evolutionary biology.