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Why do the Laws Explain Why?

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What exactly is this criterion, that laws must explain the phenomena? ... What makes laws so well suited to secure us this good? When laws give us 'satisfying' explanations, in what does this warm feeling of satisfaction consist? There are indeed philosophical accounts of explanation, and some mention laws very prominently; but they disagree with one another, and in any case I have not found that they go very far toward answering *these* questions.

Bas van Fraassen (1989: 31)

To tell a physicist that the laws of nature are not explanations of natural phenomena is like telling a Tiger stalking prey that all flesh is grass.

Steven Weinberg (1992: 28–9)

10.1 From where do the laws derive their explanatory power?

Long before Hempel and Oppenheim formulated their deductive-nomological model of scientific explanation in 1948, laws of nature were explicitly recognized as possessing distinctive explanatory power. For example, in his 1841 anatomy textbook, Jacob

Henle (the founder of modern histology) wrote, 'To explain a physiological fact means in a word to deduce its necessity from the physical and chemical laws of Nature.'[1] What gives the natural laws their special power to explain?

This question can be sharpened. Henle refers to deducing a phenomenon's 'necessity' from the laws. Presumably, for a phenomenon to derive necessity from the laws, the laws themselves must possess necessity. However, the laws are widely held to be contingent facts.[2] How, then, can they possess necessity? Of course, we might say that they possess 'nomic' (a.k.a. 'natural', 'physical') necessity even though they are not logically, conceptually, mathematically, or metaphysically necessary. But if '*p* possesses nomic necessity' just means that *p* follows logically from the laws, then why does 'nomic necessity' count as a variety of necessity? It must *deserve* to be so designated, or else we could just as well say that there is a variety of 'necessity' possessed by all and only the logical consequences of, for example, 'George Washington was the first President of the United States.'

To explain why the laws explain why, one might assert that all scientific explanations are causal and that laws explain by connecting causes to effects. We would then need an account of causation to understand how laws contribute to creating causal connections. However, we do not need to wait for an account of causation in order to investigate why the laws explain why, because not all scientific explanations are causal. Some laws explain others, for example, and those explanations are not causal. Indeed, that *p* is a law

[1] T. H. Huxley found this passage memorable enough to place atop his student notepad in 1845 (Morris 1997: 28).

[2] This view is disputed by scientific essentialists (such as Bird (2005b); Collier (1996); Ellis and Lierse (1994); Ellis (2001); Fales (1993); Harré and Madden (1975); T. Nagel (1979: 186); Sankey (1997); Shoemaker (1998); Q. Smith (1996–7); Swoyer (1982); and Tweedale (1984)), who ascribe metaphysical necessity to the laws. See Lange 2004b, 2005b criticizing the essentialists's account of the relation between laws and counterfactuals. Nevertheless, one motivation for essentialism is easily understood: how can the laws possess the necessity requisite for their explanatory power if they are contingent? Essentialists argue that their view can account nicely for the laws' necessity and explanatory power. My project in this paper is to see whether an account of laws as contingent truths can do so.

explains why *p* is the case, and this explanation is not causal. For instance, suppose it is a fundamental law of nature that between any two point bodies that carry Q and Q' statcoulombs (respectively) of positive electric charge and have been at rest, R centimeters apart, for at least R/c seconds, there is a mutual electrostatic repulsion of QQ'/R^2 dynes, for any values of Q, Q', and R. This law ('Coulomb's law') explains why there is in fact such a force between the bodies in every such pair, throughout the universe's entire history. It is no accident or coincidence that in every such case, there is such a force; it does not reflect some special condition that just happened to prevail in each actual case. The reason for this regularity *p* is that *p* is required by law; even if pairs had existed under different conditions, it would still have been the case that *p*. If Coulomb's law is fundamental, then the law requiring *p* is none other than that *p* is a law; there is no other explanation. And this explanation is not causal, since it would be a category mistake to regard a law of nature as a cause. (For instance, a law has no specific spatiotemporal location, unlike a cause.) A law is a 'because' but not a cause.

As I mentioned, the laws' explanatory power is puzzling. The laws explain by virtue of their necessity. For example, Coulomb's law explains why there is in fact such a force between the bodies in every such pair, throughout the universe's entire history: there *had* to be, so there was. But the laws of nature are contingent facts. How, then, can they be necessary so as to be empowered to make other facts necessary, thereby explaining them? The laws have a paradoxical-sounding status: necessary *and* contingent.

The laws' explanatory power is especially puzzling in the case of the most fundamental laws, whatever they really are. Suppose Coulomb's law to be one of them. A derivative law (such as the law concerning the electrostatic forces exerted by uniformly charged spheres) may derive its necessity from the fundamental laws (in this case, Coulomb's law). But the fundamental laws possess their necessity without inheriting it from any other law. So consider the facts in virtue of which Coulomb's law is a law—the facts that make it a law: its 'lawmakers'. If the lawmakers are necessary, then what makes *them* necessary? If their necessity is an ontological primitive, then why is it a kind of necessity? Why does it *deserve* to be so called? (If it does not merit the title, then it cannot endow the laws with their explanatory power.) If, on the other hand, the law-makers's necessity is constituted by other facts, then are those facts necessary or not? If they are necessary, then the regress continues as we turn our attention to what makes those facts necessary. But if the lawmakers are not necessary, or if their 'necessity' is constituted by facts that are not themselves necessary, then once again, the laws' 'necessity' is bogus; a law has no necessity to bestow upon what it is supposed to explain. Inevitability cannot be inherited from what isn't inevitable; what is thereby endowed would then be mere 'conditional inevitability'.[3] In order for q's obtaining to help make it the case that p had to obtain, it must be that q had to obtain.

[3] Of course, I use the word 'inevitable' advisedly, since a statistical explanation cannot make its explanandum inevitable. But I am concerned with p's lawhood explaining p, which is not a statistical explanation. (However, the laws' modal force makes itself felt in statistical explanations as well. Whether there is a single sense of scientific explanation or several senses, some vaguely derivative from others, is something that I cannot address here. Likewise, I shall not consider whether explanations that cite initial conditions are derivative from those citing none by taking the form 'p because it is a law that p'.)

Some philosophers deny that there is any modal force behind scientific explanations, and so would presumably deny that the laws have to possess a variety of necessity in order for them to possess their characteristic explanatory power. Such philosophers would presumably reject my use of 'inevitable', even as an intuition pump. Salmon (1985) famously distinguishes the modal conception of scientific explanation from the ontic and the epistemic conceptions. By rejecting the modal conception of scientific explanation, one might seem to make it easier to account for the laws' explanatory power (since the laws' modality is no longer at issue). But perhaps one makes it too easy: if the laws' modality is not responsible for their explanatory power, then why can't accidents function as laws do in scientific explanations? My goal is to see what laws would have to be like in order for them to possess explanatory power within the constraints of a roughly modal conception of scientific explanation. That such a conception would have to be stretched somehow to accommodate statistical explanations is a familiar problem. My concern is that the origin of the laws' explanatory power remains mysterious even on a modal conception of scientific explanation.

Furthermore, as I mentioned in note 2, essentialists have attacked Lewis's and Armstrong's accounts of law as failing to supply laws with the modal force required for laws to possess their explanatory power. Essentialists issue the same challenge to any account of laws as contingent truths. The essentialists' critique plainly presupposes a modal conception of scientific explanation. My aim here is to develop an alternative to essentialism about laws that accounts for the laws' explanatory power and directly takes on the essentialists' challenge rather than dodging it by arguing that significantly less modal force suffices for explanation than essentialists believe.

This is the sort of regress that ought to bother us. In epistemology, for instance, it is easy to get a regress started by pointing out that the belief that *p* cannot be justified by the belief that *q* unless the belief that *q* is justified in some manner prior to the belief that *p*. The belief that *p* cannot 'inherit' positive justificatory status from the belief that *q* unless the latter belief has 'earned' this status already. How this regress comes to an end is the question that has vexed foundationalists, coherentists, infinitists, and others who populate the epistemological menagerie. A similar regress ought to bother theorists of natural law and scientific explanation. Presumably, the fact that *q* cannot render necessary the fact that *p* unless the fact that *q* has necessity to lend; otherwise, *p*'s deriving from *q* gives *p* only a 'conditional' necessity—a condition that, in the case of the fundamental laws, is undischarged by other laws. As Blackburn (1993: 53) remarks: if *p*'s necessity is constituted by *F* and '*F* just cites that something *is* so [but *F*] does not *have to be* so, then there is strong pressure to feel that the original necessity has not been explained or identified, so much as undermined.' Van Fraassen (1980: 213), who is more concerned than Blackburn with scientific explanation, expresses the same problem thus:

> To posit a micro-structure exhibiting underlying regularities, is only to posit a new cosmic coincidence. That galvanometers and cloud chambers behave as they do, is still surprising if there are electrons, etc., for it is surprising that there should be such regularity in the behavior of electrons, etc.

If the vaunted explanatory power of the laws is merely the power to render various facts inevitable *given the laws*, then it remains unclear why the laws are more fit to explain than other facts are; for example, the fact that George Washington was the first President of the United States can render various other facts 'inevitable' given itself.

Of course, all explanations come to an end somewhere—that is to say, all explanations that we actually offer in practice. You do not have to know why it is that *q* obtains in order for *q* to answer your question 'Why *p*?' Likewise, by citing my belief that *q*, I may succeed in justifying my belief that *p* without having to go on and justify my belief that *q*; every justification that we give comes to an end somewhere. But although my belief that *q* need not ever have been the target of an *act* of justifying in order for me to use it in another such act (to answer your question 'How do you know that *p*?'), my belief that *q* must have the *status* of being justified in order for it to help contribute to another belief's having that status. Likewise, the facts constituting *p*'s lawhood must have the status of being necessary in order for them to help make *p* necessary (i.e., a law) and thereby explain why *p* obtains.[4]

That every explanation given in practice comes to an end somewhere does not entail that there is an end to the regress consisting of (*i*) the regularity involving the electrostatic forces between pairs of point charges at rest, (*ii*) the fact that this regularity is necessary (i.e., Coulomb's law, which thereby explains the regularity), (*iii*) some fact that helps to make Coulomb's law necessary, (*iv*) some fact that in turn helps to constitute the necessity of the previous fact, and so on. I shall suggest that each of these facts possesses a species of necessity *full stop*, not merely necessity *conditional* on some fact appearing later in the regress. Consequently, each fact in the regress can help to constitute the necessity of its predecessor in the regress. Thus, none of these necessities is primitive. Each fact in the regress is necessary in virtue of facts at the next step in the regress—which, being themselves necessary, are able to constitute its necessity.

In the following section, I shall examine some accounts of what laws are in virtue of which they possess their characteristic explanatory power. Perhaps one of these accounts can explain why the fact that *p* is a law deserves to count as explaining why *p* obtains. For the moment, I wish only to emphasize that we

[4] That a belief's 'justification' (or a fact's 'explanation') may refer either to the act of justifying (explaining) it or to its status of being justified (having an explanation), a status that it can possess even if it has never been the target of such an act, is a case of the 'notorious "ing–ed" ambiguity' (Sellars 1963: 154).

cannot dodge this question simply by responding that laws are appropriate 'givens' because scientific explanation just *is* derivation from the laws. Hempel (2001: 337) rightly points out that if the facts cited by *p*'s explanation must themselves have explanations in order for them to explain why *p* obtains, then an infinite regress beckons. I agree. Hempel says that the infinite regress would be unacceptable because 'we will normally require of an explanation that it be expressed in a finite number of statements'. Although finitude seems appropriate to require of *p*'s 'explanation' in the sense of some (known or unknown) description of various facts that is sufficiently complete or relevant to satisfy certain concerns, finitude does not seem mandatory for *p*'s 'explanation' in the sense of the facts in virtue of which *p* had to obtain.

The threat of a regress is no reason for denying that the facts that constitute *p*'s lawhood (that make *p* necessary) must themselves have explanations rendering them necessary in order for them to be capable of making *p* necessary—any more than (most) epistemologists are motivated by the threat of a regress to reject the view that the belief that *q* must already have the status of being justified in order for it to justify the belief that *p*. Epistemologists try to deal somehow with the threat rather than suggest that the status of being justified means merely 'given certain premises'. I shall try to deal with the analogous threat for the case of scientific explanation.

There are no further laws to make the fundamental laws necessary. Rather, the fundamental laws seem to be explanatorily self-sufficient: Coulomb's law is able to explain (to render certain regularities necessary) without in turn deriving its explanatory power (its necessity) from other laws. But if there is nothing in virtue of which it is necessary, then it seems to 'explain' merely by rendering certain facts necessary given itself. Even if a scientific explanation is precisely a derivation from the laws (and perhaps certain initial conditions), it remains unclear why we should be interested in scientific explanations—why the lawhood of Coulomb's law *deserves* to be taken as a given. Henle himself seems sensitive to this puzzle about scientific explanation. Immediately after identifying laws as powering explanations, he admits, 'It is true, even these laws offer no explanation as to the ultimate grounds.' (Nordenskiold 1936: 398) But then how *do* they explain?[5]

I shall propose a conception of natural laws that accounts for their necessity (and hence their explanatory power) while recognizing their status as contingent facts. I will explain what gives the laws their distinctive variety of necessity, being careful not merely to stipulate that the laws merit being characterized as necessary. I will suggest that the laws are laws in virtue of certain contingent facts, that each of these facts possesses a certain species of necessity, that it derives its necessity from other contingent facts that are likewise necessary, and so on endlessly, without circularity—since a fact cannot help to explain itself. All of these facts are among the facts in virtue of which the laws are laws. That is why the fundamental laws appear to be explanatorily self-sufficient: able to explain without having explanations themselves. Each of the lawmakers is necessary in virtue of other lawmakers. Throughout I will avoid any conception of what scientific explanations are that is tailored in an ad hoc manner to an antecedent metaphysical account of what laws of nature are. To better appreciate these various desiderata, I will now look briefly at whether some other proposals in the literature are able to account for the laws' explanatory power.

10.2 Some answers on the market

Let's look briefly at some answers to our title question that others have given. Here is how Hempel explains why the laws explain why:

A D-N explanation answers the question '*Why* did the explanandum-phenomenon occur?' by showing that the phenomenon resulted from

[5] Parfit (1992: 5) writes, 'We should not claim that, if an explanation rests on a brute fact, it is not an explanation.' However, he immediately concedes, 'But we might claim something less. Any such explanation may, in the end, be merely a better description.'

certain particular circumstances, specified in C_1, C_2, ..., C_k, in accordance with the laws L_1, L_2, ..., L_r. By pointing this out, the argument shows that, given the particular circumstances and the laws in question, the occurrence of the phenomenon *was to be expected*; and it is in this sense that the explanation enables us to *understand why* the phenomenon occurred.

(Hempel 1965: 337)

Here we have a characteristically positivist attempt to analyze a metaphysical notion (explanation) in epistemological terms (expectation). I take this strategy to be a non-starter.

Armstrong (1978, 1983, 1997) analyzes laws as contingent relations of nomic necessitation N holding among universals: $N(F,G)$ makes it a law that all F's are G. Although such a relation could have failed to hold, there is (at least in the case of a fundamental law) no reason why it holds. How, then, can it explain? Armstrong says that the law that p makes it the case that p. But this 'making' is merely stipulated to be a consequence of 'nomic necessitation'. Lewis is correct in criticizing Armstrong for this ad hoc device:

[H]ow can the alleged lawmaker impose a regularity? ... Don't try *defining* N in terms of there being a law and hence a regularity—we're trying to *explain* lawhood. And it's no good just giving the lawmaker a name that presupposes that somehow it does its stuff, as when Armstrong calls it 'necessitation'. If you find it hard to ask why there can't be F's that are not G's when F 'necessitates' G, you should ask instead how any N can do what it must do to deserve that name.

(Lewis 1986c: xii; cf. Lewis 1983b: 366; van Fraassen 1989: 98)

Without an account of why $N(F,G)$ qualifies as a variety of 'necessity', it remains mysterious how p is rendered necessary, and thereby explained, by the fact that it is a law that p. We could, of course, simply stipulate that scientific explanation of p involves p's derivation from nomic-necessitation relations. But this move seems just as unsatisfactory as the ordinary-language 'dissolution' of the problem of justifying induction. If 'justification' of a prediction in science simply means 'by induction' and if 'explanation' of a fact in science simply means 'by law', then although it is pointless to ask why inductive arguments justify and why laws explain, we can still ask why we should care about giving 'justifications' and 'explanations'.

However, Lewis's criticism of Armstrong's account as ad hoc may boomerang against his own account (Lewis 1973b, 1983b, 1986c, 1994a) of laws as roughly the generalizations in the deductive system of truths possessing the best combination of simplicity and strength. The question 'Granted that *p* follows from the generalizations in the best deductive system, why does *p* obtain?' remains an open question. It is unclear why *p*'s derivation from laws so understood deserves to be called a scientific explanation—a reason why *p* holds. Lewis himself seems to downplay the need to explain why the laws explain:

> If you're prepared to grant that theorems of the best system are rightly called laws, presumably you'll also want to say that they underlie causal explanations; that they support counterfactuals; that they are not mere coincidences; that they and their consequences are in some good sense necessary; and that they may be confirmed by their instances. If not, not. It's a standoff—spoils to the victor.
>
> (Lewis 1994a: 232)

Yet it seems ad hoc to say that laws are necessary (and so make their consequences necessary, thereby explaining them) in virtue of belonging to the best system. Of course, Lewis is satisfied with Humean stand-ins for genuine necessity. On Lewis's picture, events are metaphysically prior to laws, and so laws cannot genuinely explain events. Lewis suggests that we reconstrue explanation so that it does not require any such metaphysical priority.

Lewis (1986c: xv–xvi) insists that whatever entities a philosopher construes chances to be, those entities have got to deserve to be called 'chances'. They can't merely be stipulated to be chances; beliefs about them must rationally constrain our opinions in the way that beliefs about chances do (namely, in accordance with the Principal Principle). But the same principled stand Lewis takes regarding a satisfactory account of chances should also be taken regarding a satisfactory account of laws. Generalizations in the best system cannot merely be stipulated to be laws. They must deserve to be called 'laws' by (among other things) explaining.

Lewis might have thought that generalizations in the best system explain because to explain *p* is to unify *p* with other facts, and the greatest unification is achieved by integrating *p* with the deductive system of truths possessing the optimal combination of simplicity and strength. On the other hand, it seems question-begging to construe 'unification' in exactly this way, as van Fraassen (1989: 48–51) has argued, and so it remains ad hoc to say that explanatory power derives from membership in the Lewisian best system.

That explanations unify is an idea that has been developed in different ways by different philosophers: in terms of explanations reducing the number (of types) of unexplained facts, for instance, or in terms of explanations deriving many facts through arguments taking the same form (see, e.g., Kitcher 1989). Let's consider briefly what it would take for the unificationist picture to account for the laws' explanatory power.

Henle seems to have thought that although laws are contingent, their capacity to unify gives them the capacity to explain. The full passage from Henle's textbook is as follows:

> To explain a physiological fact means in a word to deduce its necessity from the physical and chemical laws of Nature. It is true, even these laws offer no explanation as to the ultimate grounds, but they make it possible to combine a mass of details under one point of view.
>
> (Nordenskiold 1936: 398)

Of course, there are many ways to 'combine' a mass of details. One might simply conjoin them, for instance. But a mere conjunction is not explanatorily prior to its conjuncts. If a 'point of view' somehow captures the mass of details in a more orderly or compact form (e.g., integrates them with the 'best system', or derives them from very few facts using very few kinds of arguments), then although such a thing may be convenient or elegant, it is not yet clear why it thereby counts as explanatory—that is, why it counts as a reason why those details hold, why it counts as *prior* to those details in some sense that is not ad hoc. A unificationist picture must include some account of why a law captures a mass of details so as to explain them. If *p*'s lawhood unifies various facts by showing how they are all inevitable given *p*'s lawhood, then once again, those facts are not thereby made inevitable unless *p*'s lawhood is inevitable.

For that matter, if *p* has many, diverse consequences, and *p* unifies and hence explains those facts, then it is not clear how *p*'s lawhood, in explaining *p*, thereby increases the unity; no additional facts are integrated by this explanation that weren't already unified by *p*. On the other hand, if the bare fact that *p* cannot explain its various consequences, but only *p*'s lawhood can explain them, then we need some account of why this is so. Merely to define 'unification' as 'under law' remains unilluminating.

I shall now look more closely at one final, recent proposal. Woodward and Hitchcock (2003a, 2003b) have suggested that an explanatory generalization 'can be used to answer a range of what-if-things-had-been-different questions' (2003a: 4) and thereby 'tells us what [the explanandum] depends on', explaining it. This approach has several advantages over some of its predecessors. First, it avoids the charge of ad-hocness because answering what-if-things-had-been-different questions seems intuitively to have something to do with explaining (and in this respect differs from a fact's deriving from nomic-necessitation relations or from generalizations in the best system). That Coulomb's law helps to explain why there is a certain force between two bodies seems plausibly bound up with the fact that Coulomb's law correctly specifies how that force would have been different, had the two bodies' charges and separation been different in various ways. Secondly, the capacity of Coulomb's law to specify correctly what would have happened under these conditions reflects a characteristic feature of laws that has long been recognized: their intimate relation to counterfactuals. In scientific practice, the natural laws are called upon to tell us what would have been the case, had things been different in some nomically possible way. For example, were Uranus's axis not so nearly aligned with its orbital plane, then conditions on Uranus would have been different, but the laws of nature would have been just the same (which is *why* conditions on Uranus would have been different). Scientific practice thereby suggests a principle that I shall call 'nomic preservation' (NP).

NP: For any counterfactual supposition *q*, it is true that had *q* been the case, the natural laws would have been no different—as long as *q* is nomically possible, i.e., logically consistent with all of the *m*'s (taken together) where it is a law that *m*[6]

where I shall henceforth reserve lower-case letters *m*, *q*, etc. for sentences purporting to state facts entirely governed by laws rather than concerning which facts are laws. (Therefore, NP does not cover counterfactual suppositions such as 'Had it been a law that ...' or 'Had it been an accident that ...'.) Although the truth-values of counterfactual conditionals are notoriously context-sensitive, NP is intended by its advocates to hold in all contexts, since it purports to capture the *logical* relation between laws and counterfactuals, and logic is not context-sensitive. Principles roughly like NP have been defended by Bennett (1984); Carroll (1994); Chisholm (1946); Goodman (1983); Horwich (1987); Jackson (1977); Mackie (1962); Pollock (1976); Strawson (1952), and many others.[7] Woodward

[6] Advocates of principles like NP must intend to include (e .g.) the logical, mathematical, conceptual, and metaphysical necessities among the natural laws. This seems reasonable; if *p* possesses a higher grade of necessity, then it possesses all lower varieties 'by courtesy'.

[7] In Lange 2000: 58–82, I examine various sorts of challenges to NP, including eccentric contexts where counterfactuals seemingly in violation of NP are properly held to be true. Notably, Lewis (1986c: 171) rejects NP (even though NP appears to reflect scientific practice). Lewis's argument is that if we insist that the laws would have been no different, had Jones missed his bus to work this morning, then apparently, we must say (if the world is deterministic) that the world's state billions of years ago would have been different, had Jones missed his bus. That sounds counterintuitive. Although I cannot discuss this issue adequately here, I am inclined to think that $q \mathrel{\Box\!\!\rightarrow} m$ ('Had *q* been the case, then *m* would have been the case') says not that *m* is true in the closest *q*-world, but rather that (roughly speaking) *m* is true in a non-maximal situation that consists just of the relevant

and Hitchcock exploit the fact (ensured by NP) that Coulomb's law would still have held, had the bodies' charges or separation been different, and so that Coulomb's law correctly specifies the forces that those bodies would have experienced under those circumstances. I shall return to NP in the next section.

However, let me mention four difficulties encountered by the Woodward–Hitchcock account of why the laws explain why. First, Woodward and Hitchcock emphasize that for a generalization to be explanatory, it suffices that there exist *a range* of what-if-things-had-been-different questions that it can correctly answer. (Roughly speaking, the broader the range, the deeper the explanations that the generalization supplies. Woodward and Hitchcock do not regard the 'laws' as uniquely explanatory; they regard any generalization for which there exists such a range as explanatory.) Consider, then, a generalization (g) that is the same as Coulomb's law except that it predicts a vastly different force for a single combination of Q, Q', and R—a combination that happens to go forever uninstantiated. So g is true, since it departs from Coulomb's law only in a circumstance that is never realized. Moreover, there exists a range of what-if-things-had-been-different questions that g correctly answers—nearly the same range as Coulomb's law does. Yet g is not nearly as explanatorily potent as Coulomb's law. In fact, I don't think that g has any explanatory power at all (at least in fundamental physics).[8] A given actual case conforms to g

fragment of the closest q-world. In a context where we should not 'backtrack' in assessing counterfactuals, the relevant fragment does not concern the events responsible for bringing q about (Lewis's 'small miracle'). Therefore, an actual law would still have been true, had q, since the miracle (which violates the actual law) is 'offstage'. The world's state billions of years ago likewise stands outside of the relevant fragment of the closest q-world. So when we occupy a non-backtracking context and consider what would have happened, had Jones missed his bus, we are not interested in whether the world's state billions of years ago would have been different. If we focus our attention upon q's past light cone (e .g., in discussing how remarkable a deterministic world would be), then we enter a (backtracking) context where it is true that the world's state billions of years ago would have been different, had Jones missed his bus. In neither context is a counterfactual of the form ($q \mathbin{\Box\!\!\rightarrow}$ a violation of the actual laws) true.

[8] Here's why I said 'at least in fundamental physics'. Some sub-field of physics might be interested only in a limited range of the conditions allowed by the fundamental laws

not because all cases have to do so, but rather because all cases have to obey Coulomb's law, and the demands of Coulomb's law happily coincide with *g*'s demands in the given case. Likewise, all actual cases conform to *g* not because *g* must be obeyed, but merely as an accidental byproduct of their complying with Coulomb's law—accidental in that *g* would not have resulted from Coulomb's law, had a certain combination of Q, Q', and R happened to be instantiated.

Here is a second, closely related difficulty. Consider the generalization that whenever the gas pedal of a certain car is depressed by x inches and the car is on a dry, flat road, then the car's acceleration is $f(x)$. According to Woodward and Hitchcock, this generalization can help to explain the car's acceleration on a given occasion because (following Haavelmo 1944: 29) had the pedal on that occasion been depressed to a greater or lesser degree, then the car's acceleration would still have been correctly specified by the above generalization. However, these counterfactuals would themselves not still have held, had the car's engine been modified in various ways. (Here we have our first example of a nested counterfactual.) It is difficult to regard the above counterfactuals as exhibiting the generalization's explanatory power considering that their holding is something of a fluke—so precariously resulting from prevailing conditions. (Those conditions, rather than the generalization, should presumably be part of the explanation.) The generalization's correctly answering various what-if-things-would-have-been-different questions seems too accidental to give the generalization explanatory power. We thus return to one of our original questions: if the truths supposedly responsible for a given generalization's explanatory power are not themselves necessary, then how can that generalization render facts necessary so as to explain them?

of physics. If the uninstantiated circumstance in which the alternative to Coulomb's law diverges from Coulomb's law involves conditions outside of the limited range of interest to the sub-field, then the alternative to Coulomb's law might have explanatory power in that field.

Here is another example where a generalization's capacity to answer a certain range of what-if-things-had-been-different questions is itself too fragile to supply the generalization with explanatory power. Suppose I am asked why all U.S. Presidents have (as of this writing) been male, and I answer that the reason is that all persons nominated for President by major U.S. parties have been male, so no matter which candidate had won the election, all Presidents would have been male. This generalization specifies that the explanandum would still have held under certain unrealized conditions (e.g., had the Republican candidate won in the election of 1912).[9] However, it is really the conditions that are responsible for this generalization about nominees that explain why all U.S. Presidents have been male. Had these conditions been different, then perhaps a woman would have been President if the Republican candidate had won in the 1912 election. (That was another nested counterfactual.)

Now for a third difficulty with the Woodward–Hitchcock proposal. The range of what-if-things-had-been-different questions that *p* answers seems to be the same as the range of what-if-things-had-been-different questions that 'It is a law that *p*' answers. However, it might be argued that 'It is a law that *p*' has explanatory power, whereas the bare fact that *p* does not. For example, there is a given force between two bodies not because Coulomb's law is true, but because it is a law. Of course, the mere fact that Coulomb's law is true suffices to entail that any two such bodies *do* feel such a force. But that they *must* feel such a force requires that the equation hold as a matter of law.

[9] I am not suggesting that this regularity is explanatory according to Woodward and Hitchcock. It is not, on their view, because it does not answer questions about what would have happened, had the quantities in the regularity taken on different values. I do not see why they privilege those sorts of counterfactual suppositions; an ecological law concerning the relation between an island's biodiversity and its area, for example, presumably derives some of its explanatory force from the fact that the same relation would still have held even if different species had evolved (and even if matter had been a continuous rigid substance rather than corpuscular), though the law's equation contains no such variables, but merely relates biodiversity to area. (See Lange 2002, 2004a.) But this is not my concern here.

There is a fourth, related difficulty. Woodward and Hitchcock purport to explain how a law explains a regularity, as when Newton's gravitational-force law (and the Earth's mass) explain the regularity that all bodies in free fall near the Earth's surface accelerate at approximately 9.8 m/s^2. According to Woodward and Hitchcock, the gravitational-force law explains the regularity concerning free fall because the law specifies correctly what alternative regularity would have obtained, had (say) the Earth's mass taken on some other value. Because the law includes variables that the regularity does not, the law specifies what the new regularity would have been, under other values of those variables. However, 'It is a law that *p*' includes no variables that are absent from *p*. So 'It is a law that *p*' cannot specify the extent to which events would have departed from *p* under other conditions. (For instance, Newton's gravitational-force law obviously does not specify by how much the gravitational force would have departed from being inversely proportional to the square of the separation, had certain nomically impossible conditions obtained—whereas Newton's gravitational-force law does specify by how much free-fall acceleration would have departed from 9.8 m/s^2 had Earth's mass been twice as great.) Hence, the Woodward–Hitchcock account cannot explain why *p* is explained by the fact that it is a law that *p*.[10]

I shall offer an account of the laws' explanatory power that also focuses on counterfactual conditionals. But unlike Woodward and Hitchcock, I shall draw a sharp distinction between laws and accidents, and I shall try to account for why 'It is a law that *p*' explains *p*. Furthermore, I shall argue that a generalization's answering *some* range or other of what-if-things-had-been-different questions is insufficient to give it explanatory power. A particular

[10] Woodward and Hitchcock regard many generalizations as explanatory despite not being traditionally considered 'laws'; Woodward and Hitchcock do not believe that there exists a sharp, important distinction between laws of nature and accidental generalizations. Therefore, I believe, they would not be bothered by the third or fourth objections I have raised. In addition, I believe that they would regard as oversimplified an 'explanation' of the form '*p* because it is a law that *p*'.

kind of range of invariance under counterfactual suppositions is required for a generalization to qualify as necessary. Furthermore, the generalization's invariance across that range of counterfactual suppositions cannot itself be precarious; its invariance must be invariant, and so forth all the way down, in order to generate explanatory power.

10.3 Laws: necessary yet contingent

NP entails that if it is a law that p, then p would still have been true, had q been the case—for any q that is 'nomically possible': logically consistent with all of the m's (taken together) where it is a law that m. Obviously, no accident would still have been true under every q that is nomically possible, since $\sim p$ is nomically possible if p is an accident. But the range of counterfactual suppositions being considered here (every nomically possible q) is designed expressly to suit the laws. What if we allowed any logically closed set of truths to pick out for itself a convenient range of counterfactual suppositions: those with which all of the members of that set (taken together) are logically consistent? Let's call the set 'stable' exactly when (whatever the conversational context) the set's members would all still have held, under every such counterfactual supposition—even under however many such suppositions are nested. (Nested counterfactuals are important. Recall that my second objection to the Woodward–Hitchcock proposal was that the relation $f(x)$ between the gas pedal and the car's acceleration seems too accidental to be explanatory. Nested counterfactuals help to cash out this thought: although there obtain various counterfactuals of the form 'Had the gas pedal been depressed by x inches with the car on a dry, flat road, then the car's acceleration would have been $f(x)$', there fail to obtain various nested counterfactuals of the form 'Had the car's engine been modified..., then had the gas pedal been depressed by x inches with the car on a dry, flat road, the car's acceleration would have been $f(x)$.')

More precisely: Consider a non-empty, logically closed set Γ of truths p. Then I define

Γ is 'stable' exactly when for any member p of Γ and any claims q, r, s… each of which is logically consistent with all of the members of Γ taken together (e.g., $\Gamma \cup \{q\}$ is logically consistent), the subjunctive conditionals (which will be counterfactuals if q, r, s… are false)

$q \mathrel{\Box\!\!\rightarrow} p$,
$r \mathrel{\Box\!\!\rightarrow} (q \mathrel{\Box\!\!\rightarrow} p)$,
$s \mathrel{\Box\!\!\rightarrow} (r \mathrel{\Box\!\!\rightarrow} (q \mathrel{\Box\!\!\rightarrow} p))$, etc.

hold in any context.[11]

The intuitions behind NP (which are manifested in scientific practice) suggest that the laws (together with the logical, mathematical, conceptual, and metaphysical necessities—and all of the logical consequences thereof) form a stable set. In contrast, the analogous closure of Reichenbach's (1954: 10) favorite accident, 'All solid gold cubes are smaller than a cubic mile', is unstable, since had Bill Gates wanted to build a gold cube exceeding a cubic mile, then I dare say there would have been such a cube. Likewise, the gas-pedal generalization that I mentioned in the previous section does not belong to a stable set unless that set also includes a description of the car's engine (since had the engine contained six cylinders instead of four, the gas-pedal generalization might have failed to hold). Having fortified the set with a description of the car's engine, we find the supposition that the engine contains six cylinders to be logically inconsistent with the set, and so the gas-pedal generalization's failure to be preserved under this counterfactual supposition is no obstacle to the set's stability. But now the set, to be stable, must also include a description of the factory that manufactured the engine (since had that factory been different, the engine might have been

[11] Strictly speaking, it is redundant to include the requirement that the members of a stable set be true. If p is false, then if q is a logical truth, $(q \mathrel{\Box\!\!\rightarrow} p)$ is false, and so no set to which p belongs is stable. (I have just asserted that if q is a logical truth, then $(q \mathrel{\Box\!\!\rightarrow} p)$ is true *only if* p is true. I have doubts about the *if* direction; see note 25.)

different). For that matter, suppose that I am not wearing an orange shirt, and consider the counterfactual 'Had either I been wearing an orange shirt or the gas-pedal generalization failed to hold.' Is '... then the gas-pedal generalization would still have held' true in all contexts? I think not. Therefore, to be stable and include the gas-pedal generalization, the set must also include the fact that I am not wearing an orange shirt. I conclude that the only stable set containing the gas-pedal generalization is the set containing all truths *p*.

Accordingly, I suggest that stability distinguishes the laws from the accidents in that no set Γ containing an accidental truth is stable (except for the set of *all* facts *p*, which is *trivially* stable since no counterfactual supposition *q* is logically consistent with all such facts).[12] The sort of argument I have just made could presumably be made regarding any logically closed set of truths *p* that includes *some* of the accidents but not *all* of them.[13]

I have suggested that the closure of the laws forms a stable set and that no set containing an accident is stable (except for the trivial case where the set contains all of the facts *m*). Are there any other stable sets? Stability possesses an interesting formal property: for any two stable sets, one must be a proper subset of the other. In other words, the stable sets come in a natural hierarchy; there is a total ordering.

[12] I have argued elsewhere (2000, 2002, 2004a) that the laws of an inexact (a.k.a. special) science need not be stable simpliciter, as long as they form a set that is stable 'for that field's purposes'. Thus I agree with Woodward and Hitchcock that the explanatory generalizations include some facts that are not laws of physics and that philosophers do not traditionally consider to be laws.

[13] Actually, I am willing to acknowledge the possibility in principle of a logically closed set Γ of truths, containing some but not all of the accidents, where each member *m* of Γ would still have held under any *q* with which every member is logically compatible. But if such a set were to exist, I claim, its invariance would be a fluke; although $q \mathrel{\Box\!\!\rightarrow} m$ holds, there is some *r* that is logically consistent with every member of Γ for which $r \mathrel{\Box\!\!\rightarrow} (q \mathrel{\Box\!\!\rightarrow} m)$ does not hold, or there is some more highly nested counterfactual under which *m* fails to be preserved. In contrast, it is the case not only that had we tried to break the laws, we would have failed, but also that had we had access to 23rd-century technology, then had we tried to break the laws, we would have failed. This is one reason why we need nested counterfactuals in the definition of 'stability'. Shortly we will see one nice consequence of including those nested counterfactuals.

Here is the proof:

Show: If Γ and Σ are distinct stable sets, then one must be a proper subset of the other.

Proof by *reductio*: Suppose that sets Γ and Σ are stable, t is a member of Γ but not of Σ, and s is a member of Σ but not of Γ.

Then ($\sim s$ or $\sim t$) is logically consistent with Γ.

Since Γ is stable, every member of Γ would still have been true, had it been the case that ($\sim s$ or $\sim t$).

In particular, then, t would still have been true, had it been the case that ($\sim s$ or $\sim t$). That is, ($\sim s$ or $\sim t$) $\Box\!\!\rightarrow t$.

Since t and ($\sim s$ or $\sim t$) would have held, had ($\sim s$ or $\sim t$), it follows that $\sim s$ would have held, had ($\sim s$ or $\sim t$). Of course, this does not mean that $\sim s$ is a member of Γ, merely that Γ's stability demands that ($\sim s$ or $\sim t$) $\Box\!\!\rightarrow \sim s$.

Now let's apply similar reasoning to Σ. Since ($\sim s$ or $\sim t$) is logically consistent with Σ, and Σ is stable, every member of Σ would still have been true, had it been the case that

($\sim s$ or $\sim t$).

In particular, then, s would still have been true, had it been the case that ($\sim s$ or $\sim t$). That is, ($\sim s$ or $\sim t$) $\Box\!\!\rightarrow s$.

But we have now reached an impossible conclusion: ($\sim s$ or $\sim t$) $\Box\!\!\rightarrow$ (s & $\sim s$)!

This last would be for something logically impossible to occur in the 'closest world' where a given logical possibility is realized. (I shall return to this idea in a moment.)

That the laws' closure is stable does not preclude certain of its proper subsets from being stable. For instance, perhaps the logical closure of the basic laws of motion qualifies as stable, since its members would still have held, even if the force laws had been different (e.g., even if electromagnetic forces had been somewhat stronger). With a hierarchy of non-trivially stable sets, there would be various grades of nomic necessity.

Since there may be a hierarchy of stable sets, I propose that *m* is a law if and only if *m* belongs to some (or, equivalently, the largest) nonmaximal stable set.[14] We have here a way to draw a sharp distinction between the laws and the accidents. On this view, what makes the laws special, as far as their range of invariance is concerned, is that they are stable: *collectively*, taken as *a set*, the laws are as resilient as they could logically possibly be. Because each law helps to delimit the range of invariance that each other law must possess, in order for the whole set of laws to be stable, the laws form a unified, integrated whole. That is, lawhood is a collective affair, not an individual achievement, since *p* is a law exactly when *p* belongs to a nontrivially stable *set*.[15]

All of the laws would together still have held under every counterfactual supposition under which they *could* logically possibly all together still have held—that is, under every supposition with which they are all together logically consistent. No set containing an accident can make that boast non-trivially. A stable set is *maximally* resilient under counterfactual perturbations; it has as much invariance under counterfactual suppositions as it could logically possibly have. In this way, the relation between lawhood and membership in a nontrivially stable set ties nicely into the laws' *necessity*. Intuitively, 'necessity' is an especially strong sort of persistence under counterfactual perturbations. But not all facts that would still have held, under even a wide range of counterfactual perturbations, qualify as 'necessary' in any sense. Being 'necessary' is supposed to be *qualitatively* different from merely being invariant under a wide range of counterfactual suppositions. The set of laws is maximally resilient—as resilient as it could logically possibly be.

[14] By this definition, the logical, mathematical, conceptual, and metaphysical necessities also qualify as laws. For some purposes, however, we might want to construe the 'laws' more narrowly as the truths belonging to some nonmaximal stable set and not possessing any of these other varieties of necessity.

[15] There is, then, a sense in which the laws' unity is bound up with their lawhood, though my take on this idea obviously differs from Lewis's as well as from the interpretation offered by those who identify the laws' explanatory power as deriving from the unification they bring.

For every set that is maximally resilient, I suggest, there is a variety of necessity that is possessed by all and only its members. No flavor of necessity is possessed by an accident, even by one that would still have held under many counterfactual suppositions (such as the gas-pedal generalization).[16]

Here is another argument that stability is associated with a variety of necessity. Suppose that *q* is possible and that *p* would have held, had *q* been the case. Then intuitively, *p* must be possible: whatever would have happened, had something possible happened, must also qualify as possible.[17] Now what must the set containing exactly the necessities of some particular variety be like in order to respect the above principle? It says that if *q* is possible—that is to say, logically consistent with the relevant set—and if *p* would have held, had *q* been the case, then *p* must be possible—that is, logically consistent with that set. That is immediately guaranteed if the set is stable. (If *q* is logically consistent with a given stable set, then under the counterfactual supposition that *q* holds, every member of that set would still have held, and so anything else that would *also* have been the case must join the members of that set and therefore must be logically consistent with them.)

On the other hand, look what happens if a logically closed but *unstable* set of truths contains exactly the necessities in some sense. Because the set is unstable, there is a counterfactual supposition *q* that is logically consistent with the set but where some member *m* of the set would not still have held under this supposition.[18] That is to say, *m*'s negation might have held. But *m*, being a

[16] Of course, the set of *all* truths *p* is stable. But I don't see its 'maximal resilience' as giving it a corresponding flavor of necessity, since its stability arises from the fact that there are *no* counterfactual suppositions with which all of its members are consistent. We could, I suppose, take the set of all truths as corresponding to the zeroth grade of necessity, the degenerate case. (We could likewise weaken the notion of 'stability' so that the null set possesses stability, though again trivially.)

[17] This is the same as the 'POSSIBILITY' principle that Williamson (2005) endorses and deems 'pretheoretically plausible'.

[18] For simplicity, I have temporarily ignored the nested counterfactuals in the definition of 'stability'. To accommodate them, we would have to add nested counterfactuals to 'whatever would have happened, had something possible happened, must also qualify as possible'. For instance, we would have to add 'had something possible happened, then

member of the set, is supposed to be necessary, so *m*'s negation is an impossibility. Therefore, if an unstable set contains exactly the necessities in some sense, then had a certain possibility (in that sense) come to pass, something impossible (in that sense) might have happened. This conflicts with an intuition slightly broader than the one we were looking at: namely, that whatever *might* have happened, had something possible happened, must also qualify as possible.

Here is still another, perhaps more picturesque way to put this: If an unstable set contains exactly the necessities in some sense, then though some *q*-world is possible (in that sense), the closest *q*-world—or, at least, one of the optimally close *q*-worlds—is impossible (in that sense). This conflicts with the intuition that *any possible q*-world is closer to the actual world than is *every impossible q*-world. Hence, if a logically closed set of truths contains exactly the necessities in some sense, then that set must be *stable*.

It seems plausible and fruitful to connect necessity to stability. What makes the set of logical truths and the set of natural laws *alike* is that they are both nontrivially stable sets. It is this commonality that makes both sorts of truths 'necessary'. Stability allows different varieties of necessity to be given a unified treatment, but without suggesting that for *every* logically closed set of truths, there is a corresponding variety of necessity. As we have seen, the stable sets are not plentiful. (The logical consequences of 'George Washington was the first President of the United States', for example, do not form a stable set.) The hierarchy of stable sets explains how the laws could be necessary and yet contingent. Interestingly, this view takes a fact's necessity not to be an individual achievement, but rather as a collective affair, since *p* possesses some flavor of necessity exactly when *p* belongs to a nontrivially stable *set*.

Notice also that 'stability' is not defined in terms of law. Whereas NP uses laws to pick out the relevant range of counterfactual

whatever would have happened, had something possible happened, must also qualify as possible'. In other words, if r is possible, q is possible, and $r \mathrel{\Box\!\!\rightarrow} (q \mathrel{\Box\!\!\rightarrow} m)$, then m must be possible.

suppositions, stability allows the set in question to do so. Thus, the notion of stability lets us break out of the notorious circle that results from specifying the *nomic necessities* as the truths that would still have held under every counterfactual supposition that is logically consistent with the *nomic necessities*. The laws' stability accounts not only for their necessity and for their sharp difference from the accidents, but also for another important feature of lawhood: that the laws would all still have been *laws*, had q been the case, for any q that expresses a nomic possibility. Suppose m is a member of Γ, a stable set, and $q, r, s\ldots$ are all logically consistent with Γ. Then $q \mathrel{\Box\!\!\rightarrow} (r \mathrel{\Box\!\!\rightarrow} m)$, $q \mathrel{\Box\!\!\rightarrow} (s \mathrel{\Box\!\!\rightarrow} m)$, $q \mathrel{\Box\!\!\rightarrow} (r \mathrel{\Box\!\!\rightarrow} (s \mathrel{\Box\!\!\rightarrow} m))$, etc. So in the closest q-world, these counterfactuals hold: $r \mathrel{\Box\!\!\rightarrow} m$, $s \mathrel{\Box\!\!\rightarrow} m$, $r \mathrel{\Box\!\!\rightarrow} (s \mathrel{\Box\!\!\rightarrow} m)$, etc., which are just the counterfactuals needed for Γ to remain stable in the closest q-world.

Therefore, if the laws (and their logical consequences) are exactly the members of a non-trivially stable set, then automatically the laws remain laws in the closest q-world, as long as q is nomically possible. We thereby save the intuition that were Uranus's axis not so nearly aligned with its orbital plane, then although conditions on Uranus would have been different, the laws of nature would have been just the same—which is *why* conditions on Uranus would have been so different.

Many features of lawhood can thus be explained by the connection between lawhood and stability. Let's now consider how this approach could account for the laws' explanatory power.

10.4 The lawmakers are explanatorily self-sufficient

Presumably, the laws' explanatory power derives from their necessity. In virtue of what do the laws possess a species of necessity? We saw in the previous section that lawhood is associated with membership in a nonmaximal stable set. What accounts for this association? Is one relatum responsible for the other, or do they have a common origin in some third fact? I propose that the laws are necessary *in virtue of* forming such a set and that their necessity is what *makes* them laws. In other words, rather than holding that the lawhood of p, q, ... is responsible for various subjunctive facts (namely, those that make stable the set spanned by p, q, ...), I suggest the opposite order of ontological priority: those subjunctive facts[19] make it a law that p, a law that q, etc.

Admittedly, this proposal reverses the standard picture of laws as 'supporting' or 'underwriting' counterfactuals. It also runs counter to the familiar view that typical subjunctive facts are not ontologically primitive, but rather have as their truthmakers the laws together with various non-subjunctive ('categorical') facts.[20] I cannot do justice here to the difficult metaphysical issues raised by this proposal. But let me mention briefly four of its attractive features.

[19] Of course, counterfactuals are notoriously context sensitive. Accordingly, the subjunctive fact that makes 'Had I jumped from the ledge, I would have hurt myself badly' true in one conversational context is distinct from the subjunctive fact that makes it false in another conversational context. The same counterfactual expresses different propositions on different occasions of use. From the context sensitivity of such counterfactuals, van Fraassen has argued that 'science by itself does not imply' them (1989: 35) since 'scientific propositions are not context-dependent in any essential way' (1980: 118). But doesn't science tell us in a given context whether some counterfactual conditional is true? (How close Jones's height must be to exactly six feet, in order for 'Jones is six feet tall' to be true, differs in different contexts, but that does not prevent the truth of the claim about Jones's height from being ascertained scientifically in a given context.) Van Fraassen's modus ponens becomes my modus tollens: since science plainly *does* reveal the truth (in a given context) of various counterfactuals, some scientific claims do express different propositions in different contexts. I think that we discover what color the emeralds in my pocket would have been, had there been any, in just the same way as we discover the colors of the actual emeralds forever unobserved deep underground.

[20] However, my proposal is compatible with our *discovering* (or justifying our belief in) a given counterfactual conditional's truth by consulting (or appealing to) what we already know about the laws (and perhaps also about various categorical facts). The order of knowing (or justifying) may differ from the order of being. It might be objected that 'Had p obtained, then q would have obtained' just means 'Had p obtained, then q would *have to* have obtained' where q's necessitation arises from law—so laws must be ontologically prior to subjunctive facts. However, even if we may be tempted to think laws partly responsible for the truth of 'Had the match been struck, it would have lit', are we equally tempted to think laws partly responsible for the truth of 'Had the match been struck, it would still have been dry'? Goodman famously revealed the difficulties involved in trying to understand a counterfactual as having truth-conditions involving only laws and non-subjunctive facts, without primitive subjunctive facts. Furthermore, '... then q would have obtained' is not equivalent to '... then q would *have to* have obtained'. For example, had I gone out to lunch, I would have eaten Chinese food, but I wouldn't *have* to have; there are plenty of other restaurants around.

1. If we take the subjunctive truths as responsible for the laws, then as we saw in the previous section, we can give a nice account of what makes the laws necessary despite being contingent. That account has no need to posit some novel, question-begging notion of 'necessity'. A stable set's members are collectively as resilient under counterfactual perturbations as they could collectively be. This fits nicely with our pretheoretic conception of what it takes to deserve to be called 'necessary':

> If there be any meaning which confessedly belongs to the term necessity, it is *unconditionalness*. That which is necessary, that which *must* be, means that which will be whatever supposition we make with regard to other things.
>
> (J. S. Mill, *A System of Logic*, Book III, ch. 5, §4)

When the question is whether the members of a certain set Γ possess a distinctive variety of necessity, then the answer is determined by whether the set's members would together all still have held 'whatever supposition we make with regard to other things', which I have interpreted as requiring that the supposition be logically consistent with Γ. Perhaps this is what Mill meant by restricting the relevant suppositions to those *with regard to other things*.

Stalnaker (1968) and Williamson (2005) omit Mill's restriction; they suggest that p is necessary exactly when $\sim p \mathrel{\Box\!\!\rightarrow} p$ (or, equivalently, exactly when $q \mathrel{\Box\!\!\rightarrow} p$ for any q). This biconditional presumes that counterfactuals with impossible antecedents are (vacuously) true. This presumption is commonly enshrined in formal logics of counterfactuals. (If there are no possible q-worlds, then trivially, p holds in every possible q-world.) However, this presumption is not motivated by scientific practice or by any ordinary counterfactual reasoning (since counterfactuals of the form 'If p hadn't been the case, then p would still have been the case' are not in ordinary or scientific use). Consequently, I am reluctant to make this presumption. Indeed, it seems to me that counterlogicals (like counterlegals) are not trivial, but are much like other counterfactuals. For example, a counterlogical such as 'Had there been a violation of the principle of double negation, then Gödel would probably have discovered it' is true in certain contexts, whereas '... then I would probably have discovered it' is false in those contexts, and neither is trivial. (The same applies to counterarithmeticals: Had Fermat's last theorem been false, then a computer program searching for exceptions to it might well have discovered one, but it is not true that had Fermat's last theorem been false, then I would have discovered an exception to it.) Furthermore, notice that the biconditional 'p is necessary exactly when $\sim p \mathbin{\Box\!\!\rightarrow} p$' depicts p's necessity as p's individual achievement rather than a collective affair bound up with p's belonging to some integrated whole (as I explained in the previous section). Likewise, even if counterlogicals are trivially true, the biconditional 'p is necessary exactly when $\sim p \mathbin{\Box\!\!\rightarrow} p$' does not generalize to any variety of necessity other than the strongest kind; unless the laws of nature are metaphysically necessary[21], the biconditional cannot account for the natural laws' necessity. All of these difficulties are avoided on the account involving stability. For example, it identifies something as common to necessities of all varieties in virtue of which they qualify as necessary, without collapsing all varieties of necessity into one.

2. Similarly, by holding that Γ's stability is what makes laws out of Γ's members, I avoid having to give some ad hoc account of why the facts that make p a law also succeed in making p invariant under precisely those counterfactual suppositions that are logically consistent with all of the m's (taken together) where it is a law that m. It is difficult to imagine how a metaphysical account of the lawmaking facts that is *not* given in terms of subjunctive truths could have as a consequence that the laws form a stable set, unless this consequence were built into the analysis artificially—inserted, as it were, 'by hand'.[22]

3. Consider instantaneous rates of change, such as a body's velocity or the strengthening of the electric field at a given location. I

[21] As some have held—see notes 2, 3, and 22.

[22] In my (2004b, 2005b) I deploy this sort of argument against Ellis's (2001) 'scientific essentialism'.

have argued (2005a) that in order for a quantity $Q(t)$'s instantaneous rate of change at time t_0 to be a cause of (and to help explain) $Q(t)$'s values at later moments, the instantaneous rate of change cannot be reduced to some mathematical function of $Q(t)$'s actual values at various moments in t_0's neighborhood (as Russell famously maintained it could). Rather, Q's instantaneous rate of change at t_0 should be understood in terms of a subjunctive fact having no 'categorical ground'. For example, what it is for a body's instantaneous velocity at t_0 to equal 5 cm/s is for the body to exist at t_0 and for it to be true at t_0 that were the body to exist after t_0, the body's trajectory would have a time-derivative from above at t_0 equal to 5 cm/s. Any motivation for this view also amounts to an argument, independent of puzzles about natural law, that some subjunctive facts supply fundamental physical magnitudes.

4. If lawhood is associated with being contingent but belonging to a nonmaximal stable set, then it appears to be metaphysically possible for a world to contain no laws at all. I see no reason why the subjunctive truths holding in a given possible world must fit together to make stable at least one of the nonmaximal sets containing contingent truths there. It could be that for each such set Γ, there is some p that is logically consistent with Γ's members (taken together) but where ($p \,\Box\!\!\rightarrow m$) is false, for some m in Γ. Nevertheless, presumably various contingent subjunctive facts hold in a possible world lacking laws.

Here is a way to imagine one such world. To begin with, it contains objects with various capacities, such as matches with the capacity to light when struck. By this, I mean merely that various contingent subjunctive facts hold there, such as ($p \,\Box\!\!\rightarrow m$): had a given match been struck, then it would (still) have been true that all struck matches light. However, every such capacity has a potential defeater so as to preclude the stability of any nonmaximal set containing contingent truths. For example, the set generated by m (that all struck matches light) is logically consistent with q (that some matches are wet when struck), but it is false that $q \,\Box\!\!\rightarrow m$, so the set generated by m is unstable. Furthermore, if we now also include $\sim q$ in the set, there is a further defeater—e.g., an r that is logically consistent with the set such that it is false that $r \Box\!\!\rightarrow m$, or perhaps false that $r \Box\!\!\rightarrow (p \Box\!\!\rightarrow m)$. In this way, no non-maximal set containing contingent truths manages to be stable. The metaphysical possibility of a world with contingent subjunctive facts but no laws sustaining them suggests that in the actual world, the subjunctive facts are ontologically prior to the laws.[23]

My claim that subjunctive facts are ontologically prior to the laws sounds roughly like claims made by Cartwright (1989, 1999) and Mumford (2004), among others, that assign ontological priority to capacities over laws. Both Cartwright and Mumford believe that (roughly speaking) properties come modally loaded because a property just is the cluster of capacities it bestows on its bearers, and these capacities do the work traditionally assigned to laws. Cartwright says that laws, as exceptionless regularities, are restricted to ideal cases or to the highly controlled conditions of 'nomological machines'; Mumford says that there are no laws because nothing needs to be added to property instantiations to 'govern' them. In contrast, I defend the ontological priority of subjunctive facts over laws without accepting an analysis of properties in terms of capacities or accepting that actual laws cover only ideal or artificial cases.[24] On my view, the metaphysical possibility of a world without laws (to which I alluded in the previous paragraph) arises neither from the existence of capacities that make laws dispensable nor from the possibility that there exists no patch of the universe

[23] Admittedly, this argument is not much more than an intuition pump, and others (e.g., Carroll 1994: 10) have invoked the opposite intuition: that without laws, there are no nontrivially true counterfactuals. However, even those who have asserted that all contingent subjunctive facts are sustained by laws and categorical facts should, I think, revise their view to allow that *some* contingent subjunctive facts in the actual world are sustained by no laws, such as the fact that had I worn a red shirt today, then Lincoln would still have been assassinated in 1865. This counterfactual may not be true in every context, since sometimes we 'backtrack'. But in those contexts where backtracking is disallowed, I see no laws that have a hand in making this counterfactual true.

[24] For discussion of what a law of an inexact science would be, and how the concept of a 'stable' set can be extended to include sets containing ceteris-paribus generalizations that are accurate enough for certain purposes, see my 2000, 2002, 2004a.

that is so ideal or isolated that only a single kind of capacity is expressed there. Rather, the metaphysical possibility of a world without laws arises from the possible failure of the subjunctive facts to fit together so as to make stable a nonmaximal set containing contingent truths.

Whereas Cartwright and Mumford place capacities (a.k.a. causal powers, 'natures') at the bottom of the world, I locate subjunctive facts there. Just as Cartwright and Mumford see little or no work for laws to do, once capacities are admitted, I see no work for capacities to do once primitive subjunctive facts are admitted. I ask Cartwright and Mumford: Are capacities supposed to be ontologically distinct from subjunctive facts? If so, then how do capacities *make* the subjunctive facts turn out a certain way? If not, then a capacity cannot scientifically explain subjunctive facts, since a capacity just is a collection of subjunctive facts. Cartwright seems to struggle with the problem of characterizing a capacity as distinct from the subjunctive facts for which it is partly responsible. She concludes that the 'nature' associated with possessing (say) one statcoulomb of positive electric charge is to make a certain 'contribution' to the resultant force—the same contribution whatever other influences are present (1999: 82). But on her view, that contribution is not a piece of the world's furniture. Rather, the contribution is specified by the difference it would make to the outcome in various circumstances. The nature of charge would seem, then, to be fully captured by a large collection of subjunctive facts.

My suggestion that subjunctive facts are ontologically primitive (and so ungrounded by laws and non-subjunctive facts) does not entail that all ontologically primitive facts are subjunctive. The latter view has sometimes been motivated by the idea that all fundamental physical properties are nothing but collections of causal powers. That view, which Whittle proposes in her contribution to this collection, encounters a familiar regress problem: A given property is individuated by the effects that its instantiation would produce in various circumstances, but those effects and circumstances are themselves individuated by their own effects in various circumstances, and so forth endlessly. Mumford is sensitive to the objection that a property's relations to other properties can individuate it only if those other properties have already been individuated. He suggests (2004: 187) that 'we can break into the circle of interdefinability' because some properties have effects on us: their 'phenomenal appearances'. But the issue is not how we *know* a given property, but what *makes* it the property that it is. That question is not addressed by turning to some other property that we are caused to possess by interacting with instances of the given property, unless that other property is itself individuated somehow other than by its relations. In contrast, Whittle responds to the regress problem by suggesting that all of the properties get individuated together as collectively forming the satisfier of a gigantic Ramsey sentence. However, I see no reason to believe that the Ramsey sentence will have a *unique* actual satisfier. When Ramsey sentences are used to implicitly define theoretical terms in the philosophy of mind and elsewhere, the Ramsey sentences contain some O-predicates ('O' for 'old' or 'original'—in the olden days, for 'observational') that are understood independently of the Ramsified theory. But if all properties are to be individuated by their causal roles, then we have no O-predicates. We are left with just bare causal nodes and branches. Nothing obliges this austere causal network to be actually realized in only one way. If having one statcoulomb of positive electric charge is supposed to be *the* property standing in a certain causal relation to *the* property standing in a certain causal relation to *the* property standing…, but this system of simultaneous equations has no unique solution, then it fails to individuate properties.

Let me return from this digression, which (ironically!) aimed to elaborate my suggestion by sketching its relations to various suggestions made by others. Having briefly looked at four attractive features of construing subjunctive facts as ontologically primitive, let's consider how this picture might allow us to make sense of the laws' explanatory power. On this view, *p* is a law in virtue of *p*'s invariance under a certain range of subjunctive suppositions—that is, in virtue of various subjunctive facts $q \,\Box\!\!\rightarrow p$, $r \,\Box\!\!\rightarrow p$, and so forth. So when p's lawhood explains the fact that p, it is these subjunctive facts that do the explaining. They explain p by entailing that p is inevitable, is no fluke, is not the result of some accidental circumstance, but rather would still have been the case no matter what, i.e., under any possible circumstances. Of course, p would not have been the case under certain logically, metaphysically, mathematically, and conceptually possible (but nomically impossible) circumstances, such as had $\sim p$ been the case. But the circumstances q, r, ...—the 'nomically possible' circumstances—do not constitute an arbitrary, gerrymandered range (as we saw suffices for explanatory power on the Woodward–Hitchcock account; recall my first objection to that proposal). This range deserves to be called 'any possible circumstances' because these circumstances are exactly those that are logically consistent with the laws, and the laws' stability (as we have just seen) invests the laws with a variety of necessity. Therefore, even though $\sim p$ is logically, mathematically, metaphysically, and conceptually possible, p would still have been the case 'no matter what'. The subjunctive truths (not merely $q \,\Box\!\!\rightarrow p$, $r \,\Box\!\!\rightarrow p$, and the others explaining p, but all of the subjunctive facts that make stable the set containing p and the other laws, thereby making them laws) carve out a genuine variety of possibility where p would still have been the case in any possible circumstance.

Since the subjunctive facts $q \,\Box\!\!\rightarrow p$, $r \,\Box\!\!\rightarrow p$, and so forth are (on this picture) ontologically primitive, they are not made true by p, and so when they explain why p is the case, p is not helping to explain itself. Having used the laws' stability to account for the laws' paradoxical-sounding status (necessary yet contingent), I now return to the key question I pressed at the start of the paper: how do p's lawmakers manage to constitute p's necessity unless they are necessary themselves? But if they are necessary, then what constitutes *their* necessity? A fundamental law's necessity cannot derive from the necessity of other laws, so it must come from its lawmakers. If they, in turn, are not necessary, then the law cannot be necessary and so cannot supply necessity to what it explains. To say that the fundamental laws explain by fiat (because a 'scientific explanation' just *is* subsumption under the laws) leaves it unclear why we should care about such 'explanation'. How does the regress of necessity come to an end?

I am now, at last, prepared to give my answer to this question. On the picture I am sketching, p is a law in virtue of various subjunctive facts. So when p's lawhood explains why p is the case, what must really be doing the explaining are various subjunctive facts $q \mathrel{\Box\!\!\rightarrow} p$, $r \mathrel{\Box\!\!\rightarrow} p$, and so forth (which make p a law). Whence do *they* derive their necessity, without which they could not make p necessary? Although they are *ontologically* primitive (rather than having various categorical facts and laws as their truthmakers[25]), these subjunctive facts are not *explanatorily* primitive. Like other contingent facts, they have explanations. Just as p is explained by $q \mathrel{\Box\!\!\rightarrow} p$, $r \mathrel{\Box\!\!\rightarrow} p$, and so forth (which ensure that p would still have obtained no matter what), so $q \mathrel{\Box\!\!\rightarrow} p$ is explained by $r \mathrel{\Box\!\!\rightarrow} (q \mathrel{\Box\!\!\rightarrow} p)$, $s \mathrel{\Box\!\!\rightarrow} (q \mathrel{\Box\!\!\rightarrow} p)$, and so forth. These nested subjunctive truths ensure that $(q \mathrel{\Box\!\!\rightarrow} p)$ would still have obtained under all possible circumstances (for the relevant flavor of possibility, which is carved out by these and

[25] So on my view, p does not help to make it the case that $q \mathrel{\Box\!\!\rightarrow} p$, even when q obtains. Indeed, I think there may well be contexts in which q and p obtain, but $q \mathrel{\Box\!\!\rightarrow} p$ does not obtain—contrary to 'Centering' in the Stalnaker–Lewis possible-worlds account of counterfactuals. (I mentioned this in passing in note 11.) For instance, suppose that a given radioactive particle that now exists has a half-life of 100 years. (I assume that its decay is an irreducibly statistical process; the half-life does not reflect our ignorance of some 'hidden variable' that determines when it will decay.) Then in the next 100 years, it may decay, but then again, it may not. Were I to wear a red shirt today, then the particle might decay in the next 100 years, but then again, it might not; it is not the case that it would decay, and it is not the case that it would not decay, in the next 100 years. (Here we have the widely accepted failure of conditional excluded middle for subjunctive conditionals.) I take it that this is the case today even if, in fact, I do wear a red shirt today. Here then (whether the particle decays or not) we have an example where q and p obtain, but (in a given context) $q \mathrel{\Box\!\!\rightarrow} p$ does not obtain. (In another context, however, we properly say that the particle would still have decayed whether or not I had worn a red shirt today.) Setting this controversial argument aside (and for a different view of counterfactuals involving events governed by statistical laws, see Edgington 2004), I have suggested that subjunctive facts are ontologically basic—that p does not help to make it the case that $q \mathrel{\Box\!\!\rightarrow} p$, even when q obtains. Hence, given my view that various subjunctive facts (such as $q \mathrel{\Box\!\!\rightarrow} p$) are responsible for p's qualifying as a law, p does not help to make it the case that p is a law. Hence p does not help to explain itself when p's lawhood explains the fact that p.

other subjunctive facts)—the very same 'all possible circumstances' under which p would still have held. In other words, these nested subjunctive truths render ($q \square\!\!\rightarrow p$) necessary just like p. Like the non-nested subjunctive facts explaining p, these nested subjunctive facts are required (according to the definition of 'stability') in order for p and its colleagues to form a stable set—that is, to be laws. Moreover, these nested subjunctive facts also have explanations, in terms of twice-nested subjunctive facts, and so forth all the way down. Each of these multiply nested subjunctive facts is likewise required (according to the definition of 'stability') in order for the laws to be laws. (Recall that my second objection to the Woodward–Hitchcock proposal arose from its not requiring that an explanatory generalization's invariance be invariant. That is ensured, on my proposal, by the multiply nested subjunctives required for stability.) Thus, the subjunctive facts that explain p are able to make p inevitable since they, in turn, are inevitable, and the subjunctive facts making *them* inevitable are inevitable, and so forth infinitely.

Our puzzle was that the fundamental laws have no explanations among the laws, making the source of their necessity (and hence their explanatory power) mysterious. How can p's lawhood involve p's inevitability if nothing makes *the lawmakers* inevitable? My answer is that the lawhood of a fundamental law is constituted by various subjunctive truths, and each of these truths is necessary in virtue of other subjunctive truths from among those that constitute the law's lawhood, and so forth infinitely. Since there are no primitive necessities ending this regress, its members do not have mere conditional inevitability. When p's lawhood explains why p is the case, each of the subjunctive facts that helps to constitute p's necessity is itself necessary, its necessity constituted by other subjunctive facts that help to constitute p's necessity. The structure is 'self-contained'; its members depend on no outside facts to constitute their necessity.

This structure (in which every fact that helps to make it a law that p is explained by other facts that help to make it a law that p)

gives a fundamental law the appearance of being explanatorily self-sufficient: able to render certain regularities necessary without in turn deriving its necessity from anywhere else. But if there is nothing in virtue of which it is necessary, then it seems to 'explain' merely by rendering certain facts necessary given itself—that is, conditionally necessary, not necessary *full stop*. Now we have seen that each of the facts that makes *p* a law has an explanation. But since the facts that make it inevitable are drawn exclusively from among the other facts that make *p* a law, the fundamental laws *are* explanatorily self-sufficient: their lawmakers depend on no outside facts to constitute their necessity.[26]

[26] For comments on previous drafts, thanks to Toby Handfield, Ram Neta, and John Roberts.