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A NOTE ON SCIENTIFIC ESSENTIALISM, LAWS OF NATURE, AND COUNTERFACTUAL CONDITIONALS

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Scientific essentialism aims to account for the natural laws' special capacity to support counterfactuals. I argue that scientific essentialism can do so only by resorting to devices that are just as ad hoc as those that essentialists accuse Humean regularity theories of employing. I conclude by offering an account of the laws' distinctive relation to counterfactuals that portrays laws as contingent but nevertheless distinct from accidents by virtue of possessing a genuine variety of necessity.

I

'Scientific essentialism' is the name that Ellis [1999a; 2002] gives to the view that various causal powers constitute the real essence of a natural kind, and that these causal powers, in turn, are constituted by their causal roles. For example, to be an electron (a natural kind of elementary particle) is to possess certain quantities of electric charge, mass, and so forth (causal powers), and it is essential to electric charge that like charges repel each other, that the repulsion declines with the square of the charges' separation, and so forth. The truth of various subjunctive conditionals is constitutive of a given causal power's essence. For example, electric charge must, by its very nature, figure in such truths as 'Were there a point body with charge q moving with velocity $\boldsymbol{v}$ in magnetic field $\boldsymbol{B}$, then the magnetic force $\boldsymbol{F_m}$ on the body would be $(q/c)\ \boldsymbol{v} \times \boldsymbol{B}$' (where c is the speed of light). These truths, in turn, reflects various laws of nature, such as $\boldsymbol{F_m} = (q/c)\boldsymbol{v} \times \boldsymbol{B}$ (the Lorentz-force law). Other laws, such as 'All electrons have negative electric charge', describe the causal powers essential to membership in a given natural kind. All natural laws are thus metaphysically (*de re*) necessary; the laws in which a causal power or natural kind figures must be laws in any world in which that causal power or natural kind exists. In a world with different causal powers or natural kinds, the law is again true—vacuously—but it is not a law in that world.

Advocates of scientific essentialism—such as Bird [forthcoming], Collier [1996], Ellis and Lierse [1994], Fales [1993], Harré and Madden [1975], Nagel [1979: 186], Sankey [1997], Shoemaker [1998], Smith [1996–7], Swoyer [1982], and Tweedale [1984]—see it as fitting nicely with Kripke-style accounts of the semantics of natural-kind terms and within a provocative ontology of primitive causal powers. They appeal to the intuition that the properties of mass and electric charge, for example, could not retain their identities if they swapped their causal roles [Ellis 1999a: 26; Lierse 1999: 86]. They argue that essentialism is better than Humean regularity theories of natural law at accounting for the laws' special power to support counterfactuals. This last argument forms the subject of this paper.

According to Humean regularity theorists, the truth 'All F's are G' expresses a law rather than an accident in virtue of possessing certain epistemic, pragmatic, or systematic features. Essentialists object that these features do not contribute anything toward making it the case that all F's would still have been G under various counterfactual perturbations. For example, according to Lewis's regularity theory [Lewis 1973: 72], the laws are the theorems of every true deductive system with the best combination of simplicity and strength. But essentialists regard this theoremhood property as being metaphysically too flimsy to account for the laws' special significance in the world. For example, this theoremhood property cannot explain why laws possess markedly greater invariance under counterfactual suppositions than accidents do. In positing that this theoremhood property gives the laws their greater invariance under counterfactual suppositions, Lewis is making a move that essentialists see as ultimately ad hoc, unprincipled, nothing but a naked stipulation. In this paper, I shall argue that these problems afflict the essentialists' own account.

My arguments, even if they go through, cannot foreclose the possibility that essentialism is superior to other accounts of natural law on grounds having nothing to do with accounting for the laws' relation to counterfactuals. Indeed, perhaps laws play different roles in different scientific fields (even none at all in some), and perhaps counterfactuals likewise play diverse roles, so that no general relation holds between laws and counterfactuals. I am not in a position here to address this general concern. (See Lange [2000] for an attempt to do so.) However, many essentialists, at least, accept the view (originating with Goodman and Chisholm, and held by Horwich, Jackson, Mackie, and Strawson among many others) that laws are distinguished from accidents by standing in an especially intimate relation to counterfactuals. Many essentialists rest their case to a substantial degree on how well essentialism is supposed to account for the laws' special relation to counterfactuals. In sections II–IV, I shall argue that essentialism fails to deliver the goods. In section V, I shall offer a positive proposal that avoids at least some of the ad hoc elements by which the essentialist account is encumbered.

II

Take the law that electrons have negative electric charge, and take a counterfactual that this law 'supports': Had an electron been present at spatiotemporal location L, then a negatively charged body would have been present at L. Essentialism says that this counterfactual is true because its antecedent posits an electron at L, and for something to be a genuine electron, it must be negatively charged. The law that all electrons have negative charge, in being a law, specifies part of what it is to be an electron.

How does essentialism account for the fact that had there been an electron at L, then every proton would still have possessed a mass of 1.673×10^{-24} grams? A proton, of metaphysical necessity, must possess this mass. How, then, does essentialism account for the further fact that had there been an electron at L, atomic nuclei would still have contained protons—rather than schprotons, which (I stipulate) are like actual protons except for having half their mass?

As far as I can see, no specifically essentialist understanding of natural law is needed to sustain the thought that out of every possible world having an electron at L, the closest one is like the actual one in its history *prior to* L. The essentialist could thus explain why it is the case that had there been an electron at L, then all atoms at moments *prior to* L would still have contained protons and not schprotons. But this does not explain why atoms *after* L's time would still have contained protons rather than schprotons.

The essentialist's explanation takes the familiar form: in virtue of being atoms, all atoms are composed of protons, electrons, etc.—but not schprotons. However, this response merely invites the further question: how does essentialism account for the fact that had there been an electron at L, there would (after L's time) still have been atoms—instead of schpatoms, which are like atoms except for being composed of schprotons in place of protons? How can the essentialist prevent this sort of question from arising in connection with every essence to which she appeals?

An essentialist might say that the schproton is not one of the natural kinds in the actual universe, whereas the proton is, and that the roster of natural kinds would have been no different, had there been an electron at location L. I agree with all of that. But on what grounds can an essentialist assert it? That the *links* between various natural kinds (such as the electron) and various causal powers (such as negative electric charge) are metaphysically necessary does not underwrite the counterfactual that there would have been exactly the same natural kinds, had there been an electron at L. Alternatively, an essentialist might say that it is a law that all particles of matter are protons or electrons or . . ., where 'schprotons' does not appear on the list. This law would still have held, had there been an electron at L. Essentialism must regard this law as expressing part of matter's essence or identity.[1] However, once again, that schprotons would have been schmatter and not matter, had they existed, does not suffice to entail that there would have been no schprotons, had there been an electron at L. The essentialist also needs to explain why there would still have been matter and not schmatter, had there been an electron at L.

[1] This might be disputed on the grounds that 'matter' designates no kind of thing with an essence; see van Fraassen [2002: 50–61]. (He makes similar remarks concerning 'world'.)

Alternatively, the essentialist might say that it is a law that there are no schprotons. But this law must reflect the real essence of *something*, or else essentialism can offer no reason why it must still hold, had there been an electron at L. Some essentialists [Bigelow, Ellis, and Lierse 1992; Ellis 2001: 205] have maintained that the world's spatiotemporal structure, global symmetries, and laws such as the basic principles of relativity and quantum mechanics are bound up with the *world's* essence. Likewise, Ellis has maintained, our world's essence determines what natural kinds exist. A world of the same natural kind as ours

> must also have the same basic ontology of kinds of objects, properties, and processes. It must, for example, be a physical world made up of particles and fields of the same fundamental natural kinds as those that are fundamental in this world. If electrons and protons are such fundamental natural kinds in this world, then they must also exist in every similar world.
>
> [Ellis 2001: 275]

It is a metaphysical necessity that any world of the same kind as ours lacks schprotons.

> Could there be fundamental natural kinds of objects, properties, or processes existing in worlds similar to ours that do not exist in our world? In other words, could a world of the same natural kind as ours have a richer basic ontology? I think not. A world with an ontology otherwise like ours, which included some extra ingredients, could . . . not be a world of the same specific natural kind as ours. . . . Worlds with different basic ontologies cannot be essentially the same.
>
> [Ibid.: 276]

Therefore, since the counterfactual supposition 'Had there been an electron at L' supposes a world of the same kind as ours, there would still have been no schprotons had an electron been at L. The properties that our world possesses essentially, in virtue of the kind of world that it is, prohibit the existence of schprotons and other such unheard-of kinds of things:

> If the world in which we live is a member of a natural kind, then its essential properties and structures will be those that any member of this kind must have, by virtue of its being a member of this kind . . . Certainly if John Barrow, Frank Tipler, John Leslie and other writers on cosmology are right, then the global properties of worlds of the kind in which we live are at least highly restrictive of the kinds of things that can exist in worlds like ours.
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> [Ellis 2002: 119–20]

I don't find this move very appealing. To associate the law that there are no schprotons with our *world's* essence seems like a desperate attempt to find *something* the essence of which could be responsible for this law. Even if we put this point aside and presume that our world has such an essence, a problem remains. It was evident that the counterfactual antecedent 'Had there been an electron at

L' posits a genuine electron, with an electron's real essence, because this antecedent explicitly mentioned an electron. Therefore, if we go along with essentialism in holding that electrons essentially bear negative charges, then we have explained why it is that had there been an electron at L, there would have been a negatively charged body at L. Can a parallel argument, involving our world's essence, explain why it is that had there been an electron at L, there would still have been protons and not schprotons? For the arguments to run in parallel, the antecedent must posit a world like ours. But although the antecedent explicitly posits an *electron*, it makes no mention of a *world*, much less of a world *like ours*. It seems unprincipled, ad hoc, to suppose that the antecedent is implicitly 'Had the world been *like ours* and there been an electron at L' in the philosophically loaded sense of 'like ours'. I suspect that this is the reason why Ellis does *not* contend that the antecedent implicitly demands 'a world like ours'.

I can make my point in another way. When, in an ordinary context, I grasp a dry match and say, 'Had I struck this match, it would have lit', I do not implicitly mean 'Had I struck this match and kept it dry'. Rather, had I struck this match, it would have remained dry, and that is part of the reason why it would have lit.[2] Likewise, when I say 'Had an electron been at L', I do not implicitly mean 'Had an electron been at L and the world been like ours' in Ellis's sense of 'like'. Rather, had an electron been at L, the world would still have been like the actual world (in Ellis's sense of 'like') and so there would still have been protons and not schprotons. The challenge is to explain why the match would still have been dry and the world would still have had exactly the same natural kinds. To build these features expressly into the respective counterfactual antecedents is to evade that challenge. It would be just as much of a cop out to say that 'Had there been an electron at L' implicitly includes 'and there still existed protons and no schprotons' or for Humeans to say that it implicitly includes 'and the natural laws been as they actually are'.

Rather than suppose that the antecedent implicitly demands 'a world like ours', Ellis proposes a theory of counterfactuals along these lines:

> To evaluate a conditional, on such a theory, we should have to consider what would happen, or be likely to happen, in a world of the same natural kind as ours in which the antecedent condition is satisfied, other things being as near as possible to the way they actually are. The proposition 'if A were the case, then B would be the case' will be true on such a theory if and only if in any world of the same natural kind as ours in which 'A' is true, in circumstances as near as possible to those that actually obtain, 'B' must also be true.
>
> [Ellis 2001: 278]

But this amounts to making the naked stipulation that when evaluating counterfactuals, the antecedent should direct us to a world 'like ours'—that worlds

[2] See Lange [1993; 2000: 60–2] on how to distinguish what is implicit in a counterfactual antecedent *p* from what is not implicit in *p* but would have been the case, had *p* been the case.

'like ours' are all closer than worlds 'unlike ours.' Though this sounds empty, it is decidedly not when 'like ours' is understood in Ellis's particular sense. For essentialism just to stipulate that a world 'like ours', in the philosophically loaded sense, is the 'closest' possible world having an electron at L would be no better than for a Humean to stipulate nakedly that we should allow theorems of the simplest, strongest deductive system to exert special influence in determining the 'closest' possible world with an electron at L.

III

Essentialism is able to explain why, had there been an electron at L, then electric charges would still have accorded with Coulomb's law, since Coulomb's law expresses part of the essence of electric charge. However, I have just argued that essentialism is unable to explain, in a non-ad hoc manner, why there would still have been protons and not schprotons, had there been an electron at L. This counterfactual antecedent is, of course, logically consistent with the actual laws. But counterlegals are also standardly employed in scientific practice—sometimes in relatively trivial ways ('Had copper not been electrically conductive, then all of the wires on the table would have been useless'), sometimes in theoretically sophisticated contexts ('Had the fundamental constants of the universe been slightly different, then nucleosynthesis in stars would not have proceeded beyond carbon, and so life as we know it would not have evolved'). Ellis [1999a: 29–30; 1999b: 72–3] seems to believe that counterlegals are produced primarily by overheated philosophical imaginations operating without scientific constraint. He can thus afford to set counterlegals aside as all vacuously true. I believe that counterlegals have long been offered in sober scientific contexts. Airy [1830], for instance, investigated what the world would have been like had certain unnatural kinds of forces existed, and argued that energy conservation would then have been violated. Putnam [1975: 296] and I [2000: 264; 2002; forthcoming] have argued that the irreducibility of certain macro-level scientific explanations arises from the truth of certain counterfactuals with antecedents that logically contradict the fundamental laws of physics. I shall now argue that essentialism has difficulty in dealing with counterlegals in a non-ad hoc manner.

Consider the counterlegal 'Had there been an electron at L and, two nanometers away, a proton charged to $+(1/2)e$' (where e is the actual fundamental unit of charge: 1.602×10^{-19} coulombs). Though inconsistent with the law that all protons possess charge $+e$, this counterlegal is logically consistent with every law specifying the electron's causal powers (charge, mass, spin, etc.). Should the essentialist say that this counterlegal posits (along with a schproton) an electron or a schmelectron?

That it posits a schmelectron, along with schmelectric charge, may seem like a reasonable view to ascribe to essentialists. As we saw in the previous section, some essentialists emphasize that a possible world's essence greatly restricts its natural kinds, and so to accommodate schprotons, a possible world's essence presumably must be different from the actual world's; plausibly, then, all of the natural kinds populating that possible world (all elementary-particle kinds, at least) are different. But intuitively, had an electron with charge $-e$ been at rest for a long time at distance r from a proton with charge $+(1/2)e$, they would have attracted each other with a force of $(1/2)e^2/r^2$, just as Coulomb's law ('Schmoulomb's law'?) dictates. This is the sort of counterfactual that students are asked to entertain in physics courses. ('Exercise 11: Had protons possessed a positive charge half the size of the electron's negative charge, would an atom of one proton and one electron have been stable?') If a counterlegal automatically posits an entirely new population of natural kinds, then essentialism cannot readily account for the preservation of certain laws (or their schmanalogues) under that counterlegal supposition.

Here is another example (mentioned by Earman [1986: 98]). One of Maxwell's four basic equations of electromagnetism says, in effect, that there are no magnetic monopoles—that a north magnetic pole cannot exist without being paired with a south pole (unlike electric charges, where an isolated positive charge can exist). Physicists have often considered what things would have been like had there been magnetic monopoles. (For example, had there been magnetic monopoles, then such and so apparatus would have detected them by behaving in such and so manner.) Although 'Had there been magnetic monopoles' is a counterlegal, Maxwell's other three equations (and many other natural laws) would still have held, had there been magnetic monopoles. (Or so physicists apparently assert when they reason about what magnetic monopoles would have been like.) Essentialists must say that although physicists use words like 'electric and magnetic fields' (and '*magnetic* monopoles'!) when reasoning about what things would have been like, had magnetic monopoles existed, there would then in fact have been no genuine electric or magnetic fields. Fair enough. But now it becomes difficult to understand why the entirely different sorts of fields there would then have been would have been governed by direct analogues of Maxwell's equations.

On the other hand, perhaps the essentialist should somehow allow that although a possible world with schprotons is essentially different from the actual world, the counterlegal 'Had there been an electron at L and, two nanometers away, a proton charged to $+(1/2)e$' posits a genuine electron, with genuine electric charge. From this premise, essentialism can explain why Coulomb's law would still have governed the force between that electron and the schproton nearby. But how can essentialism explain why this premise holds? The essentialist might point out that this counterlegal is logically consistent with 'All electrons are negatively charged' and all of the other regularities that follow logically from the laws specifying the electron's causal powers (and electric charge's causal role). Therefore, the essentialist might say, this counterlegal posits a genuine electron (with electric charge).

However, the principle to which the essentialist is now appealing may be incorrect. The counterlegal 'Had an electron been accelerated beyond the speed of light' is logically consistent with all of the regularities following logically from the laws expressing the magnetic field's real essence, such as the Lorentz-force law $\boldsymbol{F_m} = (q/c)\ \boldsymbol{v} \times \boldsymbol{B}$. The counterlegal, in other words, is logically consistent with all of the regularities following from laws in which $\boldsymbol{B}$ figures. But it is doubtful that had an electron been travelling faster than c, it would have felt a magnetic force given by $(q/c)\ \boldsymbol{v} \times \boldsymbol{B}$. On the contrary, under this counterlegal supposition, the Lorentz-force law presumably breaks down.

Of course, the essentialist could respond by amending the principle I handed her: that a given natural kind would still have existed, under a certain counterlegal, if that counterlegal is logically consistent with all of the regularities following logically from the laws specifying that kind's essence. But whatever the correct principle is, essentialism was supposed to explain why it holds—else essentialism cannot account for the laws' support of counterfactuals. It is difficult to see how essentialism could account for the correct principle for counterlegals in a non-ad hoc manner. I see no way for the basic essentialist ideas to tell us what the correct principle for counterlegals is.

I suspect that the reference of natural-kind terms in counterlegals is a complex matter and that context plays an important role. (That is not to say that a counterlegal's truth is *entirely* determined by context; Airy apparently believed he was describing something about the world in holding that Newton's laws of motion would still have been laws, had certain unnatural kinds of forces existed.) The counterlegals' context-sensitivity should not lead us to join Ellis in dismissing all counterlegals as vacuously true, since (as is well known) context plays a significant role even in connection with counterfactuals that are not counterlegals. Indeed, essentialism seems explanatorily deficient regarding non-counterlegals for the same reason as it is unable to deal with counterlegals in a non-ad hoc manner. As we have seen, essentialism must recognize that under a counterlegal, some natural-kind terms may cease to function as rigid designators. Could this happen under any *non*-counterlegals? An essentialist might deny that it could, holding that under any non-counterlegal, the actual natural kinds would still have existed. But as we have seen, for an essentialist to make this stipulation would be no less ad hoc than for a Humean to stipulate that under any non-counterlegal, the actual laws would still have held. Essentialism was supposed to *explain why* the laws and natural kinds would have been no different under various counterfactual perturbations. In the next section, I will approach this issue from a different direction.

IV

According to essentialism, a law's metaphysical necessity is supposed to account for the fact that it would still have held under various counterfactual suppositions. Of course, there are plenty of accidental truths that would still have held under plenty of counterfactual suppositions. For example, all of the pears on my tree would still have been ripe, had there been another pear on the third branch, or had I worn a red shirt this morning. What is it about the specifics of the laws' relation to counterfactuals that suggests that laws possess metaphysical necessity? What aspect of the laws' relation to counterfactuals cannot be explained unless the laws are metaphysically necessary? After all, no metaphysical necessity corresponds to 'All of the fruit on my tree is ripe', and yet this fact would still have obtained under a broad range of counterfactual suppositions. What is the key difference between a law's and an accident's invariance under counterfactual suppositions in virtue of which they demand such entirely different explanations? This is the most serious challenge facing the essentialist's account of the laws' relation to counterfactuals.

The key difference, the essentialist might say, is that a law is invariant under every counterfactual supposition that is metaphysically possible, whereas no accident has this sort of invariance. Hence a law is metaphysically necessary. But this reply obviously cannot persuade someone who has not already bought into the essentialist's picture. Accordingly, the essentialist might shift her ground and say that the key difference is that a law is invariant under every counterfactual supposition that is logically consistent with every fact about what the natural laws are, whereas no accident is invariant under every such counterfactual supposition. (The facts about the laws include that it is a law that all electrons are negatively charged, that it is not a law that all schmelectrons are negatively charged (because the schmelectron is not a natural kind), and that it is not a law that all electrons are outside spatiotemporal location L (because it is an accident that no electron is at L).)

The essentialist might argue that no accident A is invariant under every counterfactual supposition that is logically consistent with all of the facts about the laws: A is obviously not invariant under the counterfactual 'Had $\sim$A been the case', yet $\sim$A must be logically consistent with every fact about the laws (since if the laws entailed A, then A would not be accidental). On the other hand, the principle that every law would still have been a law, under every counterfactual supposition that is logically consistent with every fact about the laws, needs to be defended carefully against various prima facie counterexamples and counterarguments.[3] Nevertheless, this principle is intuitively very plausible and fits well with scientific practice. (Something along these lines has been defended by a host of philosophers, including Goodman, Chisholm, Horwich, Jackson, Mackie, and Strawson; see Lange [2000].) Yet even if the essentialist is granted this principle, she still faces the crucial question: *why* does the fact that only the laws possess this particular pattern of invariance under counterfactual suppositions require (or, at least, suggest) that the laws are set apart by virtue of

[3] For discussion, see Lange [2000: 58–89]. Notable among these counterarguments is Lewis's argument that if the laws are deterministic, then for any ordinary counterfactual antecedent *p*, the closest *p*-world includes a 'miracle' (a violation of the actual laws) since a miracle is needed to make room for *p* to obtain in this world, considering that the events there have all been the same as the actual events up until a given moment. I cannot address Lewis's argument properly here; see Lange [2000: 73–7, 178–80].

being metaphysically necessary? What is it about essences that is supposed to suggest that the truths about the essences of things, and only those truths, would still have been true under any counterfactual supposition that is logically consistent with the truths about the essences of things? Consider a counterfactual supposition *p*. Suppose that *p* is logically consistent with all of the actual facts about the essences of things. Therefore, no contradiction would be involved in all of those facts still holding under the supposition that *p* had been the case. But this logical consistency does not explain why all of those facts *would* still have held, had *p* been the case.

Let's put this point more perspicuously. Call a logically closed set of truths 'stable' if and only if every member of the set is invariant under every counterfactual supposition that is logically consistent with every member of the set. Any logically closed set of truths that includes an accident is unstable: the fact that *p* is logically consistent with every member of the set fails to ensure that had *p* held, then every member of the set would still have held. (The only exception is the set of *all* truths, since trivially, *no* counterfactual *p* is logically consistent with every member of that set.) For example, take a logically closed set of truths that includes the accident that all of the wires on the table are made of copper but omits the accident that all of the pears on my tree are ripe. Here is a counterfactual supposition that is consistent with every member of this set: had either some wire on the table *not* been made of copper or some pear on the tree *not* been ripe. What would the world then have been like? It is not the case (in many conversational contexts) that the generalization about the wires would still have held. (Indeed, in many contexts, it is the case for neither generalization that it would still have held.) The same sort of argument could presumably be made regarding any logically closed set of truths that includes *some* accidents but not *all* of them. So any logically closed set of truths that includes an accident (but not every truth) is unstable, whereas the set containing exactly the logical closure of all of the facts about the laws is stable. How is this supposed to be explained by the idea that the truths about the laws express the essences of various kinds of things? I'll return to 'stability' in the concluding section.

A related argument can be made concerning the laws that specify the causal roles of various causal powers. According to essentialism, a causal power's identity depends on the conditionals describing how the power would be displayed. In the case of electric charge, we might suppose these conditionals to include 'Were there two point bodies, possessing charges q and Q, which have long been at rest at distance r apart, then they would exert a force of magnitude qQ/r^2 upon each other' (Coulomb's law) and 'Were there a point body with charge q moving with velocity $\boldsymbol{v}$ in magnetic field $\boldsymbol{B}$, then the body would feel a force of $(q/c)\ \boldsymbol{v} \times \boldsymbol{B}$' (the Lorentz-force law). It might be objected that these conditionals refer to the force on a body, but the body may well be feeling other forces as well (such as gravitational forces). So these conditionals are false unless they include in their antecedents some sort of open-ended *ceteris paribus* clause, which threatens to empty the conditionals of content. (Bigelow [1999: 50] expresses this worry.) The essentialist should reply that these conditionals describe component forces, not total forces, and that other laws govern how component forces add and how the net force on a body relates to the body's motion. No *ceteris paribus* qualifiers need be added to the counterfactual antecedents.

However, imagine a strange but possible world where the laws would make bodies in spatiotemporal region R violate Coulomb's 'law,' but everywhere and everywhen outside R, the laws would make bodies obey Coulomb's 'law.' Suppose that as a matter of fact, physicists in this world create a perfect vacuum throughout R, and they would still have done so even if there had existed, somewhere sometime in this universe's history, two point bodies with charges q and Q at separation r. In other words, had there been such a pair of bodies, then as a matter of fact, no such pair would have inhabited R. Now consider the counterfactual 'Had there been two point bodies, with charges q and Q, which have long been at rest at a separation r, then they would have exerted a force of magnitude qQ/r^2 upon each other'. This counterfactual conditional is true in the possible world I have described, even though Coulomb's 'law' is not a law there. Therefore, this conditional's truth in a possible world (such as the actual world) does not suffice to capture the fact that Coulomb's law is a law there. Instead, the conditional (corresponding to Coulomb's law) that helps to constitute electric charge as a causal power must be something more like 'Were there two point bodies, possessing charges q and Q, which have long been at rest at a separation r, then they would exert a force of magnitude qQ/r^2 upon each other, *no matter what the other circumstances were* (e.g., even if the bodies were in region R)'. However, this particular conditional, while closer to what we need, is not true if the 'other circumstances' can include counterlegal ones. The 'other circumstances' must be restricted to 'physical possibilities', i.e., circumstances that are logically consistent with the natural laws.

Each causal power would then have its identity fixed by its own collection of subjunctive conditionals, their antecedents being 'Had it been the case that... and A', 'Had it been the case that... and B', 'Had it been the case that... and C', and so forth, where A, B, C, etc. constitute every physically possible circumstance that is logically consistent with the rest of the antecedent. (In the case of electric charge, one antecedent would be 'Had there been a pair of point charges (etc.) *in region R*.) This scheme ensures that the range of counterfactual circumstances covered by each causal power's essential conditionals consists of the *entire range* of physical possibilities in which that power could be triggered. Each causal power's essence, according to this scheme, invokes *all* of the laws of nature, since every law helps to limit the range of physically possible circumstances. But this remarkable interconnection among the various causal powers must be inserted into essentialism 'by hand'. Although we can in this fashion rig essentialism so that it dictates that the natural laws are invariant under every physical possibility, as the laws' collective stability demands, this sort of fine-tuning is ad hoc—no better than the sort of ad hoc elements that essentialists find in Humean regularity theories.

V

I conclude by sketching a constructive proposal that hearkens back to the previous section's discussion of 'stability'. Recall that roughly speaking, a set of truths is 'stable' exactly when each of its members is invariant under every counterfactual supposition with which they are all logically consistent. Now to account for the laws' distinctive relation to counterfactuals, we could say that 'It is a natural law that *p*' means that *p* is not a logical truth and *p* belongs to a logically closed set *S* of truths that non-trivially possesses 'non-nomic stability', where *S* is non-nomically stable if and only if

> for any $m \in S$ and any *q, r,*... such that each is logically consistent with every member of *S*:
> (i) had *q* been the case, then *m* would still have been the case
> (ii) had *r* been the case, then had *q* been the case, then *m* would still have been the case,
> and so forth for multiply nested counterfactuals.

Lower-case letters here stand for 'non-nomic' claims, i.e., claims that do not involve terms like 'law', 'accident', 'necessary', and so forth. (For example, *p* might be 'All electrons are negatively charged' but not 'It is a law that all electrons are negatively charged'. In the above definition of 'non-nomic stability', it is presumed that S is a set of non-nomic claims.) As we discussed in the previous section, no set containing an accidental truth is non-nomically stable—except for the set of *all* non-nomic truths, which is *trivially* so (since *no* counterfactual supposition *q* is logically consistent with every member of that set). Hence, the above proposal regarding natural law demands that the laws' non-nomic stability be non-trivial.

Notice that the laws are not used to delimit the range of counterfactual suppositions under which a set *S* must be invariant in order to qualify as non-nomically stable. This makes it interesting to define lawhood in terms of non-nomic stability. The nested counterfactuals are included in the definition to cover examples such as 'Had there been two point charges that have long been at relative rest at a separation *r*, then had their separation instead been 2*r*, the force between them would have been one-quarter as great'. But the nested counterfactuals offer an additional benefit: they make it the case that if *S* is non-nomically stable, then *S* is still non-nomically stable in the closest *q*-world, for any *q* that is logically consistent with every member of *S*. Hence, it follows from the above proposal that the actual laws would still have been *laws*, had *q* been the case. This is (as I discussed in the previous section) one of the intuitions that a satisfactory account must capture.

Although this account, unlike essentialism, does not define the laws in terms of some sort of necessity, it follows from this account that the laws possess a certain distinctive kind of necessity that accidents lack. What is it for the members of a certain set *S* of truths to possess some kind of *necessity*, and not merely to be invariant under some or another broad range of counterfactual suppositions (in the manner of 'All of the pears on my tree are ripe')? Intuitively, some kind of necessity is involved exactly when *S*'s members would all still have been true 'no matter what' in the broadest possible sense—in other words, when *S* has a kind of *maximal* invariance under counterfactual suppositions. For *S* to possess non-nomic stability is precisely for *S*'s members *collectively* to be maximally invariant, in that they would all still have held under every counterfactual supposition under which they *could logically possibly* all still have held—namely, under every counterfactual supposition with which they are all logically consistent. In this way, we can explain what makes it *necessary* that L (where L is a law) without having to join the essentialist in portraying L as holding in *every* 'possible world' and without diminishing the sharp modal distinction between laws and other truths (i.e., accidents) that obtain in some, but not all, 'possible worlds'. Non-nomic stability, I contend, elaborates the sense in which the laws are contingent yet necessary—that is, the sense in which the laws possess a genuine grade of necessity weaker than logical necessity.

The set of logical necessities, the set of natural laws (and their logical consequences), and the set of all non-nomic truths are all non-nomically stable (the last trivially so). Each is a proper subset of the next.[4] Hence, the range of invariance that the set of laws possesses, in connection with its stability, is narrower than the logical truths' range and broader than the (vanishing) range for the set of all non-nomic truths. That is the sense in which the laws' variety of necessity (often called 'natural necessity' or 'physical necessity') is intermediate between logical necessity and mere contingency (the zeroth grade of necessity). (Cf. Bigelow, Ellis, and Lierse [1992: 373].)

Here is another argument for this analysis 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. Now suppose that the necessities, of some particular flavour (the logical necessities, or instead the physical necessities, or whatever), are exactly the members of some particular logically closed set of truths. What must that set be like in order to respect the above principle? It says that if *q* is possible (that is to say, logically consistent with every member of the relevant set) and if *p* would have held, had *q* been the case, then *p* must be possible (that is, logically consistent with every member of that set). This is immediately guaranteed if the set is non-nomically stable. (If *q* is logically consistent with every member of a given non-nomically 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 be logically consistent with the members of the set.)

[4] In Lange [2000], while elaborating various formal features of non-nomic stability, I demonstrate that if two sets are non-nomically stable, then one must be a subset of the other.

On the other hand, look what happens if a logically closed set of truths that *lacks* non-nomic stability contains exactly the necessities of some flavour. Because the set is unstable, there is a counterfactual supposition q that is logically consistent with every member of the set, but there is some member p of the set that would not still have held under this supposition. That is to say, p's negation might have held. But p, being a member of the set, is supposed to be necessary, so p's negation is an impossibility. Therefore, if a set lacking non-nomic stability contains exactly the necessities in some sense, then had a certain possibility come to pass, something impossible might have happened. This conflicts with another plausible intuition, slightly broader than the one with which we began: namely, that whatever *might* have happened, had something possible happened, must also qualify as possible.

Here is another, perhaps more picturesque way to put this: If a set lacking non-nomic stability contains exactly the necessities of some variety, then though some q-world is possible, the closest q-world (or, at least, one of the optimally close q-worlds) is impossible. 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 of some variety, then that set must be non-nomically *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', though in different senses. Stability allows different varieties of necessity to be given a unified treatment, but without suggesting that *every* logically closed set of truths corresponds to a variety of necessity. For as we have seen, the stable sets are not plentiful.

This stripped-down approach requires nothing ad hoc to bring it into line with the special relation to counterfactuals that sets laws apart from accidents. Whereas essentialism takes the truth of certain counterfactuals to be grounded in the essential properties of the world, the approach I have sketched simply takes the truth of those counterfactuals as primitive matters of fact (like the truth of certain actuals). Rather than taking the laws to be determined by the essences of the properties figuring in them, this approach takes the laws as determined by various non-nomic actual and counterfactual truths. These counterfactuals are ontologically prior to the facts about what the laws are. Whether this direction of ontological priority encounters greater problems than it avoids is a question for further research to address.[5]

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