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SYMPOSIUM

Reply to my Critics: On explanations by constraint

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My sincere thanks to Professors Saatsi, Skow, and Andersen for the care they have lavished on my book. I lack the space to reply to all of their questions, suggestions, and criticisms, but I will continue to think about them all.

The aim of *Because Without Cause* is to identify what makes various explanations in mathematics and science succeed as explanations. Skow professes to find this aim "a little obscure." I am unsure whether to take him at his word, since my aim is exactly the same as the aim of many, perhaps all, other philosophical writers on explanation since 1948. Regarding each explanation from science or math that I examine, I aim to specify which of its features give it the power to explain. I aim to use similarities and differences among these features to group explanations into "natural kinds," where the members of a given kind all derive their explanatory power in fundamentally the same way—and in a different way from the members of any other kind. For this purpose, it is obviously unhelpful to say, with Skow, that "an explanation 'P because Q' works by supplying the information that Q."

In Chapter 2, I argue that in scientific practice, it is often believed that some laws of nature are "constraints" whereas others, though likewise naturally necessary, are "coincidences." I introduce what it would be for energy conservation, for instance, to be a constraint rather than a coincidence. I do so in terms of energy conservation's possessing a stronger variety of necessity than the force laws and other such laws. I argue that energy conservation's holding as a constraint rather than coincidentally would make energy conservation explanatorily prior to the fact that gravitational and electrostatic forces, for instance, are alike in conserving energy (49–51). By contrast, if energy conservation is a coincidence, then the force laws help to explain why energy is conserved. I then cash out the constraint/coincidence distinction in terms of

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how energy conservation behaves under a particular counterfactual antecedent. Roughly, energy conservation is a constraint exactly when energy would still have been conserved even if there had been additional kinds of forces and, hence, additional force laws (72–3). I also sketch (74–86) the account of natural law that I gave in *Laws and Lawmakers* (Lange 2009) in order to demonstrate one way that an account of lawhood can leave room for the constraint/coincidence distinction. In particular, I show how an account of lawhood can entail that if energy conservation possesses stronger necessity than the force laws, then energy conservation would still have held, had there been additional kinds of forces. The truth of this counterfactual conditional is part of what gives energy conservation the special sort of invariance under counterfactual antecedents that, on my account, constitutes its lawhood.

I argue (86–95) that some notable accounts of lawhood would have great difficulty embracing the constraint/coincidence distinction. But I offer no general argument that my account of lawhood—according to which a fact's lawhood is grounded in its membership in a "non-maximal stable set"—is the only account that could incorporate the constraint/coincidence distinction in a natural way. Thus, as I emphasize on page 74, I agree with Andersen's remark that "one need not accept" my account of lawhood "in order to draw on the detailed case studies and this distinction." But I disagree with her contention that this "undermines the support" that my account of lawhood is supposed to derive from its being able to embrace the constraint/coincidence distinction. An account's capacity to do justice to an important feature of scientific practice counts to some degree in that account's favor, especially when rival accounts have difficulty accommodating that feature.

Of course, a philosopher might adopt my view that there is a nested hierarchy of stable sets of truths, with smaller stable sets associated with stronger grades of necessity, without adopting my view that the existence of a non-maximal stable set containing a given truth is *what it is* for that truth to possess the corresponding variety of necessity. Such a philosopher might seek some other facts responsible for the subjunctive facts making the set stable, where these other facts also constitute the corresponding necessity. I wish any such philosopher well in her search.

I agree with Andersen that to ascertain whether a given fact is a constraint or a coincidence, scientists must often consider that fact in combination with other facts, not in isolation (Lange 2009: 80–82). On my account, that is because a fact's lawhood and constrainthood depend on there being an entire battery of other facts joining the given fact to achieve collective stability. So a fact's lawhood, on my view, is not its individual achievement, but rather a team effort. As Andersen notes, energy conservation as a constraint is widely taken in physics to require the Hamiltonian dynamical framework. On my view, a non-maximal nomically stable set that includes the space-time symmetry meta-laws will generate a subnomically stable set that includes the conservation laws only if the latter set also includes the Hamiltonian dynamical framework. But none of this teamwork shows that whether a law possesses an especially strong necessity "comes down to what we are doing with it." Even if we purport to give many "explanations by constraint" by appealing to energy conservation, those "explanations" are not explanatory unless energy conservation is in fact a constraint.

Furthermore, if Andersen's pragmatist view applied to the constraint/coincidence distinction, then presumably by the same token, it would apply to the law/accident distinction. I have argued (Lange 2002) that a law of one scientific field, such as fundamental physics or island biogeography, can be an accident of another field. But I do not see any reason to believe that an even merely approximate truth's lawhood-in-a-field comes down to what the field does with it, rather than constituting what Andersen calls "a fact about the world." Lawhood and constrainthood, on my account, depend on subjunctive facts, but those facts, though unobservable, are capable of being confirmed empirically (186) just like facts about other unobservables—and, for that matter, just like facts about unobserved observables. That the truth of a counterfactual conditional can be confirmed empirically should be relatively uncontroversial. So I see no reason to agree with Andersen that "there is no determinate empirical fact" about constrainthood.

Of course, there is a sense in which a regularity's status as a constraint rather than a coincidence, or as a law rather than an accident, makes no difference to experience. Philosophers like me who teach students about the underdetermination of theory by evidence are fond of displaying how several curves can be drawn through all of the data points that we have already ascertained, where these curves diverge sharply in their predictions regarding the data points that we will observe next. The "grue" problem is nicely illustrated in this way. In the case of two hypotheses that disagree solely about whether a given regularity is a constraint or a coincidence, or disagree solely about whether some regularity is a law or an accident, the "two" curves will overlap perfectly! But this does not mean that scientists cannot justly adjudicate empirically between these two hypotheses. That is the role that the "theoretical virtues" play in science. The same inductive reasoning that supports our predictions about future observations also carries us to the knowledge of subjunctive facts about what would have obtained, under certain unrealized conditions (410–411). To return to my analogy (55) that Andersen cites: Even if we had no direct access to the statute books so as to verify that there exists a mandatory minimum sentencing law, we could still discover considerable evidence that such a law exists in the consistent sentences handed down by judges despite the great diversity of their cases, in their remarks from the bench upon sentencing, in legislators' election-year speeches, in lawyers' strategies inside and outside of court, and so forth.

As I mentioned, I propose in Chapter 2 that energy conservation, for example, is a constraint exactly when, roughly speaking, energy would still have been conserved even if there had been forces that are neither electromagnetic nor gravitational nor …—that is, even if there had been additional kinds of forces and, hence, additional force laws. Skow argues that although energy conservation's constrainthood—its especially strong necessity—entails the above counterfactual, the reverse entailment fails. His analogy is that even if there is no monitor constraining who enters a bookstore, it could happen coincidentally that not only everyone inside is over 21, but also everyone outside who nearly entered is over 21, so it would still have been the case that everyone inside is over 21 even if there had been additional people inside. Analogously, Skow argues, even if energy conservation is a coincidence rather than a constraint, it could be that every additional force there would have been, had there been additional forces, conserves energy.

Let us assume that Skow is correct. To repair this problem, Skow says that we need to unpack the conservation law's constrainthood partly in terms of *explanation*: we need to build into the conservation law's constrainthood that every force conserves energy *because* energy conservation is a law. However, as Skow remarks, this move would obviously be fatal to my approach. This move uses explanation to unpack constrainthood, whereas my approach is to use constrainthood to unpack a variety of explanation. I need to understand constrainthood independently of explanation in order for my account of constrainthood to reveal how explanation by constraint works.

Fortunately, it is easy to tweak my account to avoid these problems: Let energy conservation be a constraint exactly when *it is necessary that* energy would still have been conserved even if there had been additional kinds of forces. To motivate this tweak, return to Skow's analogy. Even if in fact everyone who nearly entered the bookstore is over 21, this ain't necessarily so. Since there is no monitor barring those younger than 21, there could have been, though there was not, someone younger than 21 who did not enter but nearly entered. Had there been such a person, then had additional persons entered the bookstore, it would not have been the case that everyone inside is over 21. This is a nested counterfactual conditional. In Skow's example, the fact that everyone in the store is over 21 is invariant under the counterfactual antecedent that additional people are inside. But that counterfactual conditional, in turn, is not invariant under the antecedent positing someone outside younger than 21 with the most propitious means, motive, and opportunity for entering. Analogously, even if energy would still have been conserved had there been additional forces, this counterfactual conditional's truth lacks necessity if energy conservation is not a constraint.

I can afford to use necessity to unpack constrainthood in this way because what I am unpacking is the *especially strong* necessity that constitutes constrainthood. In unpacking constrainthood as the above counterfactual conditional's *necessary* truth, I did not stipulate that the conditional's necessity is especially strong. Yet if the conditional is necessary, then its necessity must be especially strong, outrunning what the force laws and their team possess. The counterfactual's antecedent "had there been additional kinds of forces (i.e., neither gravitational nor electromagnetic nor …)" is counterlegal; among the dynamical laws alongside the force laws is the closure law that all forces are gravitational or electromagnetic or … The dynamical laws' necessity obviously cannot require their invariance under counterfactual antecedents that are logically inconsistent with the dynamical laws. The range of invariance corresponding to the dynamical laws' necessity does not include "had there been additional kinds of forces." So if energy conservation is necessarily invariant under this counterfactual antecedent, then its invariance must involve a stronger necessity than the variety possessed by the dynamical laws.

As I mentioned, in Chapter 2, I sketch the account of lawhood given in *Laws and Lawmakers* (Lange 2009) in order to demonstrate one way that an account of lawhood can entail that if energy conservation possesses stronger necessity than the force laws, then energy conservation would still have held, even if there had been additional kinds of forces. Now, we must ask the following question: Does my account of lawhood entail that if energy conservation possesses stronger necessity than the force laws, then *necessarily* energy conservation would still have held, had there been additional kinds of forces? On my account, there is a 1–1 correspondence between grades of necessity and non-maximal stable sets, and possession of a grade of necessity consists roughly in invariance under every counterfactual antecedent that is logically consistent with the corresponding stable set. On page 76 of *Because Without Cause*, I define "subnomic stability" as follows:

> Consider a non-empty set Γ of subnomic truths containing every subnomic logical consequence of its members. Γ possesses *subnomic stability* if and only if for each member m of Γ and for any p where $\Gamma \cup \{p\}$ is logically consistent (and in every conversational context), it is not the case that if p had held, then m might not have held (i.e., m's negation might have held)—that is, $\sim(p \diamond\!\!\rightarrow \sim m)$. (Note that $\sim(p \diamond\!\!\rightarrow \sim m)$ entails that had p obtained, m would have obtained.)

In the book, I noted that for simplicity's sake, I omitted from this definition some details appearing in the fuller definition in (Lange 2009) that would make no difference for my current purposes. But those details are helpful now! Here is the fuller definition:

> Consider a nonempty set Γ of sub-nomic truths containing every sub-nomic logical consequence of its members. Γ possesses *sub-nomic stability* if and only if for each member m of Γ (and in every conversational context),
>
> $$\sim(p \diamond\!\!\rightarrow \sim m),$$
> $$\sim(q \diamond\!\!\rightarrow (p \diamond\!\!\rightarrow \sim m)),$$
> $$\sim(r \diamond\!\!\rightarrow (q \diamond\!\!\rightarrow (p \diamond\!\!\rightarrow \sim m))), \ldots$$
>
> for any sub-nomic claims *p, q, r,* … where $\Gamma \cup \{p\}$ is logically consistent, $\Gamma \cup \{q\}$ is logically consistent, $\Gamma \cup \{r\}$ is logically consistent …. (Lange 2009: 29)

The nested counterfactuals required for stability, on this fuller definition, are precisely what we need. We saw nested counterfactuals manifest the fact that it is *coincidental* that everyone in the bookstore is over 21—even when it is the case that had there been additional people inside, everyone inside would still have been over 21. I unpack the fact that *necessarily* energy conservation would still have held, had there been additional kinds of forces, in terms of nested counterfactuals: that the relevant counterfactual—that energy conservation would still have held, had there been additional kinds of forces—would still have held, under every antecedent that is logically consistent with the corresponding stable set. That set contains the conservation laws but not the force laws. By the above fuller definition of "stability," the set's stability entails that the counterfactual conditional—that energy conservation would still have held, had there been additional kinds of forces—would itself still have held under any counterfactual antecedent that is logically consistent with the set. So that counterfactual conditional's truth is necessary.

I may just have indulged in exactly what Saatsi calls "adventurous" modal metaphysics! He is correct that my recognizing mathematical truths as especially strongly necessary is "relatively incontestable," whereas my distinguishing various strengths of natural necessity is "much less orthodox." Nevertheless, the idea that some laws possess stronger varieties of natural necessity than others is crucial to the idea that mathematical truths and certain natural laws could alike constitute constraints. The literature on "distinctively mathematical explanations" is dominated by the issue of whether those explanations support mathematical platonism. That issue tends to obscure the distinctively mathematical explanations' similarities to some putative explanations appealing to conservation laws, symmetry principles, and other constraints. Conversely, by suggesting that certain putative explanations appealing to conservation laws and symmetry principles belong to the same natural kind as distinctively mathematical explanations, I hope to motivate the idea that some scientists have regarded conservation laws and symmetry principles, among other laws, as like mathematical truths in having stronger necessity than force laws possess. Below I give another example of such mutual illumination by co-classification.

Saatsi asks why I do not attribute the explanatoriness of various non-causal scientific explanations to their supplying information about the explanandum's systematic counterfactual dependence on the explanans. Saatsi's perspective would unify non-causal explanations with causal explanations by characterizing them both as working by virtue of answering what-if-things-had-been-different questions ("w-questions"). One reason I resist Saatsi's proposal is that although some "explanations by constraint" are associated with such patterns of counterfactual dependence, other "explanations by constraint" are associated with no pattern of counterfactual dependence. As Saatsi acknowledges, the book gives some examples of this phenomenon. For instance, I write, "consider an explanation by constraint such as 'Every kind of force at work in this particular space-time region conserves momentum because a force that fails to conserve momentum is impossible; momentum conservation constrains the kinds of forces there could have been.' This explanation reveals nothing about the kinds of forces that would have existed in this region under various hypothetical conditions where momentum conservation is not a constraint" (88). We should expect to find some distinctively mathematical explanations that similarly correspond to no systematic pattern of counterfactual dependence, since distinctively mathematical explanations are just explanations by constraint. (This is one of the ways that co-classifying distinctively mathematical explanations with other explanations by constraint supplies mutual illumination.) This expectation is borne out. For instance, I suggest on page 7, following Colyvan, that the reason why there are always antipodal equatorial points at the same temperature is because of the Intermediate Value Theorem and that temperature is a continuous function. There is nothing interesting to be said about what would have happened, had temperature not been a continuous function or had the IVT failed.

As I argue in the book, this is a place where it helps to compare non-causal scientific explanations to explanations in mathematics, the subject of Chapters 7–9. Accounts of scientific explanation that emphasize systematic patterns of counterfactual dependence are like accounts of explanation in mathematics that characterize a proof that explains why a given theorem holds as a derivation of that theorem that answers w-questions by revealing how the theorem is modified when its derivation begins from other premises in the same family, such as premises about squares rather than equilateral triangles. Problems encountered by this approach to explanation in mathematics often carry over to the counterfactual-dependence approach to non-causal scientific explanation. These problems include examples where an explanatory proof goes nowhere when it is launched from different premises in the same family, rather than going to some modification of the theorem being explained.

Another reason for resisting Saatsi's counterfactual-dependence proposal is the converse of the previous objection. Sometimes the explanans and explanandum of explanations by constraint do figure in patterns of counterfactual dependence, but these patterns fail to track explanatory relations. Again, the book contains some examples. One involves special relativity's explanation of why the Lorentz transformations hold, which is discussed in Chapter 3. The Lorentz transformations are deducible from various space-time symmetries, such as the principle of relativity, together with the invariance of the space-time interval. (Here, I do not mean "invariance" under counterfactual antecedents; I mean "invariance" in the usual relativistic sense of not being frame-dependent, i.e., in the sense of being equal in all inertial reference frames.) The same derivation, but from the temporal interval's invariance rather than the space-time interval's, yields the Galilean transformations in place of the Lorentz transformations. Thus, the derivation supplies answers to some w-questions, such as what the space-time transformations would have been like, had the temporal interval been invariant instead of the space-time interval. However, such counterfactual dependence cannot suffice for explanation. Instead of the space-time interval's invariance, the relativity of simultaneity could be used together with the same space-time symmetries to derive the Lorentz transformations. The same derivation, but with simultaneity's invariance in place of its relativity, yields the Galilean transformations in place of the Lorentz transformations. Thus, the derivation supplies answers to some w-questions, such as what the space-time transformations would have been, had simultaneity been invariant rather than frame-dependent. So if counterfactual dependence sufficed for explanation, the Lorentz transformations would be explained by the relativity of simultaneity together with space-time symmetries. But this is not the direction of explanation that is commonly accepted. The Lorentz transformations and the relativity of simultaneity are thought to have a common explanation in the space-time symmetries and the space-time interval's invariance. By the same token, the relativistic formula for the addition of parallel velocities could be used together with the same space-time symmetries to derive the Lorentz transformations. The same derivation, but with the classical velocity-addition formula in place of the relativistic formula, yields the Galilean transformations in place of the Lorentz transformations, underwriting a counterfactual about what the transformations would then have been. But the velocity-addition law is not generally taken to explain why the Lorentz transformations hold. Rather, once again, they have common explainers.

Let me give another example where counterfactual dependence is unaccompanied by explanatory dependence. Suppose that energy conservation is in fact a constraint rather than a coincidence. Had energy conservation not been a constraint, there might well have been forces that do not conserve energy. But, likewise, had there been forces that do not conserve energy, then energy conservation would obviously not have been a constraint. The counterfactual dependence is symmetric, but the explanatory dependence is asymmetric. Note that "Had there been forces that do not conserve energy" is not the counterfactual antecedent that I discussed earlier in connection with the constraint/coincidence distinction: "Had there been additional kinds of forces." The latter antecedent specifies nothing about the additional forces—certainly not that they fail to conserve energy.

We should have expected the explanans and explanandum in many explanations by constraint to figure in patterns of counterfactual dependence that do not track explanatory dependence, since the same thing happens to the explanans and explanandum in many causal explanations. To prevent the counterfactual dependence between two effects of a common cause, or the counterfactual dependence of a cause on its effect, from counting as underwriting an explanation, counterfactual-dependence approaches to causal explanation must restrict the relevant counterfactuals somehow. For instance, they may restrict them to counterfactuals with antecedents positing what Woodward (2003) calls "interventions." But this manoeuver is unsuitable for a counterfactual-dependence account of *non-causal* explanation. The concept of an "intervention" is thoroughly causal and so inapplicable to many of the explanantia and explananda of non-causal explanations. There is no such thing as an intervention on a law of nature. But if a counterfactual-dependence account of non-causal explanation tries to do without interventions, then it must find some other way to distinguish which counterfactual-dependence relations generate explanatory relations. I am pessimistic that this can be done. But, of course, I cannot survey all possible approaches here, including Saatsi's own.

Saatsi thinks that my account of explanation by constraint permits explanations that are too insubstantial since "information about the strong degree of necessity involved risks being *too cheap*: the exalted modal aspect of the explanandum can be communicated without doing much explaining." I see this feature of my account not only as fitting scientific practice, but also as being no different from accounts of causal explanation according to which causal explanations work by supplying contextually relevant information about the explanandum's causal history. In some contexts, a very spare description of just a single event in the explanandum's long and intricate causal history is enough to constitute a causal explanation. Likewise, in some contexts, merely supplying the information that the explanandum is topologically necessary suffices to answer the why question. I can easily imagine this happening when someone who has become frustrated, after several fruitless attempts to untie a knot, is informed that he has failed because it is topologically impossible to untie a trefoil knot. Likewise, far from being cheap or uninformative, it can be very surprising and illuminating to learn simply that the existence at every moment of antipodal equatorial points of the same temperature has the same inevitability as temperature's continuity, rather than being the upshot of meteorological or geophysical facts.

But of course, while my account permits such sparse explanations, it does not require that all explanations by constraint be so meager. Explanations may supply a great deal of information about where the explanandum's necessity comes from. The book gives many examples where putatively explanatory derivations, starting from the explanatorily fundamental laws occupying the various strata of the hierarchy of stable sets, take very subtle and intricate routes, such as proposed explanations of the Lorentz transformations discussed in Chapter 3 and of the parallelogram of forces discussed in Chapter 4. Saatsi considers the question, "Why is it that given that mass is additive, if A has the mass of 1 kg, and B has the mass of 1 kg, then the union A + B has the mass of 2 kg?" Perhaps Saatsi is correct that the answer "Because 1 + 1 = 2" is "utterly shallow." But that impression may arise from everyone's knowing that 1 + 1 = 2 and that this fact suffices to necessitate the explanandum, so it is difficult to see what information someone asking Saatsi's question might want. Furthermore, "Because 1 + 1 = 2" may not explain A + B's mass at all, if A and B can chemically interact when "united."

Although some particular information about the source of the explanandum's especially strong necessity sometimes counts as an explanation, the criteria for an explanation by constraint remain severe. For instance, in Chapter 3 (136–139), I show how on my account, to explain Mother's failure to distribute her strawberries evenly among her children (without cutting any) while wearing a blue suit, we cannot appeal to the fact that Mother is wearing a blue suit. Her clothing is explanatorily irrelevant. Although it is impossible to distribute 22 strawberries evenly among three children while wearing a blue suit, to appeal to *this* impossibility would supply misinformation about the source of the necessity of Mother's failure. Perhaps this consequence of my account goes some way toward removing the impression that an explanation by constraint can be too "cheap."

In accordance with his counterfactual-dependence proposal, Saatsi suggests that "explaining why a double pendulum has a given number of equilibrium configurations" indispensably involves grasping how "the number of equilibrium configurations" would be different "if the potential energy function was different." He indicates that there is a pattern of counterfactual dependence here: had the potential energy function possessed this or that particular additional feature, the pendulum would have had at least eight equilibrium configurations or at least twelve. But this pattern does not obviously concern how the *explanandum* in my example would have been different. The explanandum is that a given double pendulum has, or that all double pendulums have, at least three equilibrium configurations. This explanandum would still have held, even if the given double pendulum's potential energy function had possessed some additional feature giving the pendulum at least eight equilibrium configurations. That the pendulum's having (say) *eight* equilibrium configurations has a causal explanation appealing to some abstract feature of the potential energy function, which answers a w-question, does not show that the pendulum having *at least three* equilibrium configurations has such an explanation.

I do not agree with Skow that the fact that three fails to divide 23 evenly is no reason why Mother failed (i.e., no first-level reason), but is merely a reason why her having three children and 23 strawberries is a reason why Mother failed (i.e., a second-level reason). Skow's approach seems to beg the question against the possibility of non-causal explanations. Skow develops his view much more systematically in his provocative (2016). But there he does not examine any explanations of laws or even of regularities. Skow would presumably have to regard laws in those explanations as first-level rather than only second-level reasons. I am reminded of the inference-ticket conception of natural laws—as Skow (2016: 85–7) apparently was, too—according to which laws do not explain, but merely mediate the inference from the explanans to the explanandum. Nothing in scientific practice makes that conception plausible (Lange 2000: 188–191). Skow's view seems to me as Procrustean as insisting that Mother's having three children and 23 strawberries is no reason why Mother failed, but is merely a reason why the fact that three fails to divide 23 evenly is a reason why Mother failed (cf. Alexander 1958). Critics of the inference-ticket conception objected that in an inference, one inference rule can be replaced by an additional premise, with another inference rule stepping in to mediate the new inference (Nagel 1954). Likewise, it seems to me a matter of context and convenience whether, in offering or reconstructing a given explanation, we portray the fact that three fails to divide 23 as explaining why the fact about the numbers of strawberries and children explains why Mother failed or whether we portray both facts as explaining Mother's failure.

It is suboptimal that all three critics chose to focus on the same part of the book—its account of "explanations by constraint" (Chapters 1–4)—instead of fanning out to critique its accounts of dimensional explanations of various kinds, "really statistical" explanations, explanations in mathematics, mathematical coincidence and unification, mathematically natural properties, or the various connections between explanations in mathematics and non-causal scientific explanations (Chapters 5–11). This unanimity of focus among the three critics is a matter of coincidence, not constraint!

References

Alexander, H.G. 1958. General statements as rules of inference? In *Minnesota Studies in the Philosophy of Science*, vol. 2, ed. H. Feigl, M. Scriven, and G. Maxwell, 309–329. Minneapolis: University of Minnesota Press.

Lange, Marc. 2000. *Natural Laws in Scientific Practice*. Oxford: Oxford University Press.

Lange, Marc. 2002. Who's afraid of ceteris-paribus laws. Or: How I learned to stop worrying and love them. *Erkenntnis* 57: 407–423.

Lange, Marc. 2009. *Laws and Lawmakers*. New York: Oxford University Press.

Nagel, Ernest. 1954. Critical Notices. *Mind* 63: 403–412.

Skow, Bradford. 2016. *Reasons Why*. Oxford: Oxford University Press.

Woodward, James. 2003. *Making Things Happen*. New York: Oxford.