

Laws of Nature

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Distinguish between two questions about laws of nature. On the one hand we might wonder: what are the laws of nature? On the other hand we might wonder: what are laws of nature?

That one little ‘the’ makes a big difference. While the first question usually falls within the purview of science, the second is squarely within the realm of metaphysics. Scientists collect data, analyze it, and try to determine what the laws of nature are. (Consider Schrödinger’s equation. Does that equation describe a law? Does it describe the only law? If not, what other laws are there?)¹ Metaphysicians, meanwhile, consider the range of possible laws of nature and attempt to discern what they have in common—what laws of nature are. (Suppose physicists reach a consensus that Schrödinger’s Equation does in fact describe a law of nature. What does that mean? What sort of thing is it that that equation describes?)

In answering the second question—the question of what laws of nature are—the notion of *metaphysical grounding* (hereafter just *grounding*) has proved increasingly important. This is true both when it comes to understanding the possible positions that one might take in response to the question ‘what are laws?’ and in giving rise to novel argumentative strategies in defense of one position or another. This application of the notion of metaphysical grounding should be of interest in its own right, but it will perhaps be of particular note to those who are otherwise skeptical of the notion of grounding and of the sorts of debates in contemporary metaphysics where grounding plays an obvious role. For if grounding also plays a role in helping us understand what laws of nature are, that is an important indication that investigations into grounding cannot be purely speculative or wholly esoteric. They make contact with our best science in interesting and important ways.

¹ When there is substantive empirical equivalence, the question of what the laws of nature are might be left to philosophers of science. This is plausibly what has happened in non-relativistic quantum theory.

Here is a plan for what follows. In section 1, I will set out some groundwork with respect to the notion of laws of nature. I will then turn to two central questions in the metaphysics of laws: what (if anything) grounds the laws (section 2) and what (if anything) the laws ground (section 3). To keep things (relatively) simple, I will focus on these questions as they apply to deterministic laws that show up in fundamental physics. In section 4, I say a bit about how the discussion might extend to laws that are not deterministic.

The reader will note that I plan to say little here by way of introduction to the notion of grounding. For those who are interested, I recommend the introduction to this volume and the earlier entries. There is, however, one important clarification regarding the notion of grounding that is worth discussing at the outset. As will be familiar to those who have read the introduction to this volume, grounding theorists are divided on the question of what sorts of entities are the relata of grounding relations. Perhaps the most standard view is what we might call *factualism*—the view that grounding relations only hold between facts. But at least some prominent philosophers endorse *ecumenicism*—the view that grounding relations can hold between many types of entities. According to the ecumenicist, grounding relations can hold between Socrates and {Socrates} for instance, or between two hydrogen atoms and an oxygen atom, on the one hand, and a water molecule, on the other.²

The discussion below will appear to endorse ecumenicism: it will focus on the viability of claims like "the Humean mosaic grounds the laws", or "laws ground causal relations", in which the relata of the grounding relations are not facts. But this appearance is misleading. As far as I can tell, all of the substantive claims under discussion below can easily be reinterpreted in language that is acceptable to the factualist. When some Humeans claim that the Humean mosaic grounds the laws, for instance, that claim can be reinterpreted as the claim that certain facts about the Humean mosaic ground certain facts about the laws. So although the discussion below appears to endorse ecumenicism, this appearance is misleading. A factualist about grounding can and should engage with the debates taken up here, albeit in slightly different terms than those in which they are presented.

Finally, let me note that there has been important work expressing skepticism about both

² Schaffer 2009 is an example of an ecumenicist. Rosen 2010 and Audi 2012 are factualists.

the notion of laws of nature and the notion of metaphysical grounding.³ I will not engage with any of that work below. Instead I will assume that there are such things as laws of nature and there is such a relation as metaphysical grounding and focus on how work on the latter might inform work on the former.

1 Laws of nature

What are laws of nature? A particularly simple account starts from observing how scientists go about discovering the laws: they pay attention to patterns, or *regularities*, in the data that they collect. They pay attention, for instance, to the fact that, in their observations, net force is always equal to mass times acceleration. (Let's assume that this *is* a fact, for the time being.) Under certain circumstances, scientists then conclude that the observed regularity corresponds to a law. They conclude, for instance, that it is a law that net force is equal to mass times acceleration.

This suggests the following account:

The simple regularity account. It is a law that all Fs are Gs if and only if all Fs are Gs.

Unfortunately, the simple regularity account faces serious issues. For one, being a regularity is not sufficient for being a law. Every road in Rhode Island has potholes. But it is surely not a law that every road in Rhode Island has potholes. Or consider the following pair of propositions:

(G) All spheres of gold are less than 1 mile in diameter.

(U) All spheres of uranium are less than 1 mile in diameter.⁴

Both (G) and (U) are regularities. Indeed they seem to be regularities of precisely the same sort. But only the latter corresponds to a law. The former, while true, is merely an accident.

³ Prominent skeptics about laws include Cartwright 1983 and van Fraassen 1989. Prominent skeptics about grounding include Hofweber 2009 and Wilson 2014.

⁴ This example is from van Fraassen 1989, p. 27.

In addition, it does not seem as though regularities are capable of fully playing the role that laws play in scientific inquiry. Scientists use the regularities they observe as a guide to discovering the laws. But they also use laws to *explain* those regularities. Why is it that net force is always equal to mass times acceleration? Because it is a law that net force is equal to mass times acceleration. But if law L just is regularity R, and we use law L to explain regularity R, then we have used something to explain itself. And nothing can explain itself.

So the simply regularity account of laws fails. Several other potential accounts have been suggested in its place. Among these there is an important distinction between accounts that are *Humean* and those that are *non-Humean*.

Humeanism about laws of nature. Laws of nature are, in some important sense, nothing over and above the actual distribution of non-modal entities throughout spacetime.⁵

Non-Humeanism about laws of nature. Laws of nature are, in some important sense, something over and above the actual distribution of non-modal entities throughout spacetime.⁶

Humeanism about laws of nature is a part of a broader Humean program according to which, in some sense, all there is is the *Humean mosaic*—the actual distribution of non-modal entities throughout spacetime.⁷ For the Humean, it isn't just laws that are nothing over and above the mosaic; causal facts and modal facts and dispositional facts and chancy facts—indeed all of those facts that you might have naively thought of as at least in some sense modal—are all nothing over and above the mosaic.

Why be a Humean? Think again of the regularity account. One significant advantage of that view, had it been viable, would have been that it identified laws with patterns of events, and in so doing made laws entirely prosaic features of our metaphysics. In particular, it would have removed any concern that laws are, in some sense, modal entities. Whereas it is natural to describe laws using modal language—laws determine what *can* happen or what *would* have

⁵ Prominent Humeans include Lewis 1986, Loewer 1996, Beebe 2000, and Albert 2000.

⁶ Prominent non-Humeans include Tooley 1977, Armstrong 1983, Carroll 1994, Maudlin 2007 and Lange 2009.

⁷ As Lewis famously put it, the mosaic is just “one little thing after another” (1986, ix).

happened or what *must* happen—the simple regularity analysis said that this language does not have any deep modal implications. For laws are just certain kinds of patterns in the distribution of actual events. Even as metaphysicians have largely given up on the simple regularity analysis, many of them have tried to preserve this aspect of that view. Perhaps we cannot give quite such a prosaic account of laws as the simple regularity account promised, these metaphysicians think, but let's try to at least avoid any commitment to the sort of necessary connections in nature about which Hume was so famously concerned.

Of course, in order for the Humean/non-Humean distinction to be made precise, one needs to be more specific about the relevant sense in which the laws might or might not be *something over and above* the Humean mosaic. Following David Lewis (1986), the traditional way to spell out this distinction is in terms of supervenience.

Supervenience-based Humeanism about laws. The laws of nature supervene on the Humean mosaic.

Supervenience-based Non-Humeanism about laws. The laws of nature do not supervene on the Humean mosaic.

As will be familiar to many, if the Fs *supervene* on the Gs, then any two worlds that are identical with respect to the Gs must also be identical with respect to the Fs. So according to supervenience-based Humeanism about laws, any two worlds that are identical with respect to the Humean mosaic are identical with respect to the laws. According to supervenience-based non-Humeanism, two worlds may be identical with respect to the Humean mosaic and still differ with respect to the laws.

Humeans about laws also need to say something more about what sort of entities laws are, beyond just that they are entities that supervene on the Humean mosaic. Currently, the most prominent Humean account of laws, which was the account endorsed by Lewis, is the *Best Systems Analysis*, according to which laws of nature are the true statements that, when taken together as a set, convey as much information as possible about the Humean mosaic without sacrificing too much by way of simplicity. In slogan form: according to the BSA, laws are the axioms of the

deductive system that best balances simplicity and strength.⁸

Advocates of the BSA tout two main advantages of their theory.⁹ First, they think that their theory effectively encodes the criteria that practicing scientists use when determining what the laws are: scientists look for true propositions that will allow them to convey large amounts of information about actual events in a relatively simple way. Second, advocates of the BSA think that in making sure that laws are nothing over and above the Humean mosaic, they avoid allowing suspect entities into their metaphysics.

At the same time, many philosophers reject the BSA and Humeanism about laws in general, and instead endorse various kinds of non-Humean analyses. Some non-Humeans, like Carroll (1994) and Maudlin (2007), are primitivists about laws of nature. They think laws admit of no further analysis. Others attempt to give an analysis of laws, but not one that has laws supervening on the Humean mosaic. According to Armstrong (1983), for instance, laws are necessitation relations between universals. Some of these non-Humeans are motivated by concerns about the supervenience claim to which Humeans are committed—is it really true, they wonder, that any two worlds that are the same with respect to the mosaic will have the same laws?¹⁰ Others are motivated by the same sort of explanatory concern that was leveled against the simple regularity account above.¹¹ What all these non-Humeans have in common is that laws, on their accounts, are something over and above the Humean mosaic.

The Humean/non-Humean distinction remains one of the most divisive debates in the metaphysics of science.¹² And as we will see over the course of the next sections, the notion of metaphysical ground may help make clear what exactly the Humean/non-Humean distinction amounts to, as well as opening new avenues of argument for and against views on either side of the distinction.

2 What grounds the laws?

⁸ See Lewis 1983, p. 41-42 and 1986 ix-x. Lewis himself cites Mill and Ramsey as inspiration. For a non-Humean version of the Best Systems Analysis see Demarest 2015.

⁹ See, for instance, Loewer 2007: 1, for a pithy summary of both of these advantages.

¹⁰ See Tooley 1977, Menzies 1993, Carroll 1994, and Beebe 2000 for discussion.

¹¹ See especially Armstrong 1983, p. 40, and Maudlin 2007, p. 172.

¹² According to Hall ms, p. 1 it is, “by far the most central and important question about laws of nature”.

Let's focus first on the question, "what (if anything) grounds the laws?" And let's restrict our focus specifically to the laws of physics, and even more specifically to deterministic laws of physics. To have a particular example to hand, suppose that we live in a Newtonian world. So it is in fact a law that net force is equal to mass times acceleration. It is a law that $f=ma$.

Perhaps the most significant application of the question "what (if anything) grounds the laws?" is in providing a novel way of understanding the Humean/non-Humean distinction set out in section 1. According to many contemporary metaphysicians, the correct way to understand that distinction is not, in fact in terms of supervenience as Lewis proposed. Instead the distinction should be understood as follows.

Grounding-based Humeanism. The laws of nature are fully grounded by the Humean mosaic.

Grounding-based Non-Humeanism. The laws of nature are not fully grounded by the Humean mosaic.

So, for instance, Beebe (2000 p. 572) writes that the difference between the Humeans and the Non-Humeans is that Non-Humeans want to "ground the distinction between laws and accidentally true generalizations in some metaphysically substantive feature of the world—something irreducibly nomic." And Schaffer (2008 p. 82) says that the view that laws of nature "are nothing over and above the pattern of events, just like a movie is nothing over and above the sequence of frames," can be expressed in slogan-form as "what must be is grounded in what is." And Loewer (2012 p. 116) says that the key feature of Humean accounts is that they "eschew fundamental nomological modalities."¹³

Whether Lewis himself would have been amenable to putting the Humean/non-Humean distinction in terms of grounding is a tricky question.¹⁴ But in any case this way of interpreting

¹³ See also Bhogal 2016. Note that even though this analysis is becoming mainstream it is far from consensus. Just as an example, Carroll's Stanford Encyclopedia of Philosophy article on philosophy of time, revised in 2016, treats Humeanism solely in terms of the supervenience account. See Miller 2015 and Kovacs ms for further discussion of why it might be a mistake to think of the Humean/non-Humean distinction in terms of grounding.

¹⁴ On the one, hand Lewis occasionally used language suggesting that the Humean was committed to some kind of reduction. On the other, he may have thought that in some cases asymmetric supervenience—such as the

the Humean/non-Humean distinction is at least a somewhat natural development. After all, it seems plausible to think that what Humeans were hoping to capture all along was the idea that the laws depend in some important way on the mosaic. But as has often been noted in the literature on grounding, supervenience doesn't seem to be the right sort of relation to capture any substantive notion of dependence.¹⁵

Of course, whether one finds this way of formulating the Humean/non-Humean distinction helpful will depend at least in part on whether finds the introduction of grounding relations helpful in other areas of metaphysics. One can imagine, for instance, a version of Wilson's 2016 argument against understanding the physicalist/non-physicalist distinction in terms of grounding,¹⁶ adapted as an argument against understanding the Humean/non-Humean distinction in terms of grounding. But it is worth emphasizing that, in addition to being potentially useful in understanding the distinction between Humeanism and non-Humeanism about laws, the notion of metaphysical grounding has helped defend Humeanism against an important challenge. Indeed the notion has proved so promising in this light that, at least anecdotally, it seems that Humeans who are otherwise skeptical of the notion of grounding are tempted to set their skepticism aside.

In order to understand the challenge that is relevant here, think back to the explanatory challenge for the simple regularity account of laws as described in section 1. On the one hand, the simple regularity account says that laws are regularities. On the other hand, scientists seem to use laws to explain regularities. But nothing can explain itself.

This challenge is a specific version of a more general *explanatory challenge* for Humeanism about laws. This general version of the challenge starts by noting that, according to the Humean, the laws are nothing over and above the mosaic. It seems plausible, then, to think that the mosaic, in some sense, explains the laws. Why are the laws what they are? Surely, for the Humean the answer to this question must be: because the mosaic is the way it is. But again, one of the key roles of laws in science, is to explain both particular features of and patterns across the mosaic. So it seems that the Humean is committed to an explanatory circle: the laws explain features of

asymmetric supervenience of Humean laws on the Humean mosaic—was itself sufficient for reduction. The discussion in Miller 2015, especially footnote 8 is helpful here.

¹⁵ For more on this, see Kovacs, 'Modality', in this volume.

¹⁶ For more, see Bryant, 'Physicalism' in this volume.

the mosaic and the mosaic explains the laws. As Maudlin (2007, p. 172) puts it: “If the laws are nothing but generic features of the Humean Mosaic, then there is a sense in which one cannot appeal to those very laws to explain the particular features of the Mosaic itself: the laws are what they are in virtue of the Mosaic rather than vice versa.”¹⁷

One way for the Humean to avoid this sort of explanatory challenge would be to give up on the idea that laws play any robust explanatory role. But that seems scientifically revisionary in a problematic way. So recently it has become increasingly standard for Humeans to instead endorse a strategy put forward by Loewer 2012, according to which the explanatory challenge can be avoided by disambiguating two different notions of explanation. Start with a grounding-based formulation of the Humean/non-Humean distinction. This formulation commits us to a very specific sense in which the laws are nothing over and above the mosaic: the laws are grounded in the mosaic. In so doing, it commits us to a very specific sense in which the mosaic explains the laws.¹⁸ The mosaic *metaphysically explains* the laws. And, according to Loewer at least, metaphysical explanation is something importantly distinct from the kind of explanatory relation that scientists have in mind when they use laws to explain particular events in and patterns across the mosaic. Calling the latter sort of explanatory relation a *scientific explanation*, we get the following result: the mosaic metaphysically explains the laws, while the laws play a role in scientifically explaining the mosaic. And it is perfectly fine, so says Loewer, at least, for A to metaphysically explain B while B plays a role in scientifically explaining A.

There’s no clear consensus as to whether this move on behalf of the Humean is successful.¹⁹ What is clear is that the notion of metaphysical grounding has opened up a response to the explanatory challenge to Humeanism about laws that was previously unappreciated. Moreover, further work on metaphysical grounding could have important further implications for this debate. In particular, Loewer’s maneuver makes one want to know more about the similarities and differences between metaphysical explanation and the grounding relations that back such explanations, on the one hand, and scientific explanation and the dependence relations—like causal relations—that back those explanations, on the other. Take for instance the claim

¹⁷ See also Armstrong 1983, p. 40 and Bird 2007, p. 86.

¹⁸ See Glazier, ‘Explanation’ in this volume for more on the connection between grounding and explanation.

¹⁹ See Lange 2013, Hicks and van Elswyck 2014, Marshall 2015, Miller 2015, Roski 2017, and Emery 2018, for further discussion.

found in Kment 2015 that metaphysical explanation is “exactly analogous” to scientific explanation, or the contention in Schaffer 2016 and Wilson 2018 that there are few, if any, important differences between grounding and causation.²⁰ Presumably these sorts of views make Loewer’s maneuver more difficult to get off of the ground.²¹

In this section I have been focused on the question, “what grounds the laws”. I have suggested that understanding Humeanism as the claim that the laws are grounded in the mosaic, has already been, and promises to continue to be, philosophically fruitful. Is the question of what grounds the laws also helpful for the non-Humean? Although there is less explicit work to date on this topic, it certainly seems as though it might be. In particular, the question “what grounds the laws?” seems as though it might be helpful in allowing us to differentiate among varieties of non-Humeanism. Non-Humeans don’t think that the laws are fully grounded in the mosaic. Do they think that the laws are fully grounded in anything at all? Some say yes. A natural way to understand Bird’s (2007) view, for instance, is that laws are grounded in the nature of the fundamental, dispositional properties. And according to Lange (2009), laws are grounded in counterfactuals.²² Others say no. According to Carroll (1994) and Maudlin (2007), laws are primitives, admitting of not further analysis. Plausibly this means that they think laws are not even partially grounded in anything at all. Still others may say that laws are partially, but not wholly grounded.²³

Getting clear on whether and how non-Humean laws might be grounded will surely be helpful in assessing the costs and benefits of non-Humeanism. We might, for instance, wish to extend Hildebrand’s (2013) argument against “unanalyzable” non-Humean laws as an argument against ungrounded non-Humean laws, and thus conclude that non-Humeanism is plausible only insofar as non-Humean laws are at least partially grounded in something (though not, of course,

²⁰ See Wang, ‘Cause’ in this volume.

²¹ In a different sort of response on behalf of the Humean to the explanatory challenge, Marshall 2015 distinguishes between a law *L* and the metanomological fact that *L* is a law, and suggests that Humeans should think that the mosaic grounds the metanomological fact that *L* is a law, but does not ground *L* itself.

²² Carroll 2008 puts forward a view according to which laws are those universal generalizations that are not coincidences; they are what they are because of “nature itself” as opposed being what they are because of something in nature—like some series of unlikely events or some very specific set of initial conditions. This view too can be understood in terms of grounding: laws are those universals that are grounded in nature itself.

²³ Note that other, especially older non-Humean views may be somewhat more difficult to classify in terms of the extent to which they say that laws are grounded. For instance, Armstrong (1983) says that laws are necessitation relations between universals. Once the notion of metaphysical grounding is in play, it seems at least in principle possible to distinguish between two versions of this view: on the one, laws just are certain kinds of necessitation relations. On the other, laws are grounded in certain kinds of necessitation relations.

in the Humean mosaic). Or suppose we follow Schaffer (2015) in thinking that Occam's razor only requires us to be concerned with minimizing those entities that we posit at the fundamental level. Then Occam's razor will not cut against non-Humean laws as long as those laws are fully grounded. Of course, there may be other reasons to be suspicious of non-Humean laws, or to take such accounts as costly, but mere concerns about simplicity would not be relevant.

3 What, if anything, do the laws ground?

So much for a discussion of the various ways in which laws might be grounded. Can laws also be grounds?

One reason for thinking that laws are grounds is that many philosophers have a strong intuition that laws in some sense govern (or guide) features of the world and it may be that the best way to understand this notion of governance is in terms of grounding.²⁴ But the notion of governance has been subject to significant scrutiny,²⁵ and there is no need to start from such a controversial starting place.

Instead, let's start from the (relatively) uncontroversial claim that laws play an important explanatory role in standard scientific practice. As we saw in section 2, even many Humeans are eager to find a way to accommodate this claim.

In fact, closer attention to scientific practice suggests that laws play two distinct sorts of explanatory role. First, laws are the reason why a certain set of initial conditions causally explains a certain set of final conditions.²⁶ So, for instance, the reason why dropping a rock of a certain mass and from a certain height causes it to hit the ground traveling a certain speed is that it is a law that $f=ma$. Second, laws explain events in the world directly. Sometimes the explanandum for which laws serve directly as explanans are individual events. For instance, a plausible answer to the question, "why is that meteor traveling slower than the speed of light?" is that it is law that

²⁴ Beebe 2000, 257, characterizes the governing conception of laws as one on which, "It isn't just that the laws plus current facts entail future facts; rather the laws 'make' the future facts the way they will be: the laws are the ontological ground of the future facts." Rosen 2010 and Bhogal 2016 also suggest that governance is best understood in terms of grounding.

²⁵ See especially Beebe 2000.

²⁶ This claim is defended in detail in Skow 2016. Note that Skow himself shys away from talk of explanation, and thus would disagree with my characterization of the relation here as explanatory.

nothing travels faster than the speed of light.²⁷ But, as pointed out in section 2, laws also are used to explain patterns of events. If you ask a scientist “why it is the case that net force always equal mass times acceleration?”, a natural response would be “because it is a law that $f=ma$.” This, recall was one of the main reasons why we didn’t want to endorse the simple regularity account of laws. Laws can’t be regularities because laws are supposed to explain regularities.

So laws seem to play two important explanatory roles—they explain causal relations between events and they explain events—both individual events and patterns of events—directly. Now notice that explanatory relations are paradigmatically backed by dependence relations. In particular, most uncontroversial cases of explanation are either backed by a causal relation or by a grounding relation. Zeke's throwing the rock explains the window breaking, for instance, because Zeke's throwing the rock causes the window to break. Or the physical properties of water ground the chemical properties of water, to take another example, because the physical properties of water ground the chemical properties of water. A natural thing to think, therefore, is that *all* explanations are backed by either a causal relation or a grounding relation. It is natural, in other words, to adopt the following assumption:

The simple backing assumption. If A explains B then either A causes B or A grounds B.

Finally, note that laws do not seem like the right sorts of things to themselves stand in causal relations. Paradigmatic cases of causation involve causal relations holding between events. And laws are not events.²⁸ Taken together, this leads to the conclusion that laws are grounds. Specifically, laws both ground causal relations between events and ground events in the world directly.

One thing that is interesting about the idea that laws ground particular events in the world is that it threatens to undercut Loewer's maneuver in response to the explanatory challenge discussed in Section 2. Loewer's maneuver, remember was to say that it was not a problem for Humeans to claim that the mosaic explains the laws while the laws also explain features of the mosaic, because there are two different types of explanation involved. The mosaic

²⁷ See Woodward 2003, p. 209 and Skow 2014 for discussion of this example.

²⁸ See Emery 2018 for further discussion of a version of this argument.

metaphysically explains the laws, while the laws scientifically explain the mosaic. But what are metaphysical and scientific explanation? Loewer is explicit that metaphysical explanations are those explanations that are backed by grounding relations. But if the argument above is correct, then at least some cases in which the laws explain the mosaic are also backed by grounding relations. So there is, in at least some cases, a genuine circle of metaphysical explanation after all. This suggests that Humeans about laws who like Loewer's maneuver will need to reject some component of the foregoing argument. Either they need to (i) allow that laws can be causes, (ii) reject the simple backing assumption, or (iii) reject the claim that laws do in fact explain events—either individual events or patterns of events—directly.

But note that even those Humeans who take route (iii), may still remain committed to the view that laws explain causal relations between events in the way described above. And insofar as they are so committed, and they find the simple backing assumption plausible, they will still be committed to the view that laws are grounds—laws ground causal relations.²⁹

4 What if the world is indeterministic?

Let's broaden our scope to consider the possibility that we live in an indeterministic world. That is, let's broaden our scope to consider the possibility that the complete state of the world at one time, plus the laws of nature, does not determine the complete state of the world at every other time. Some indeterministic worlds plausibly have no laws at all—events happen at random. But other indeterministic worlds surely do have laws. These laws do not entail that one state follows another. Instead they assign objective probabilities to one state following another.

It is an open possibility, given our best science, that our world is indeterministic. Some interpretations of quantum mechanical phenomena say that it is, while others do not. So presumably we should have a metaphysics of laws of nature that is compatible with both scenarios. And taking into account indeterministic laws alongside deterministic laws has the potential to significantly impact the role that grounding plays in the metaphysics of laws.

First, consider the question of what grounds the laws. The shift to indeterministic laws

²⁹ The emphasis on causation here may sound distinctly non-Humean but it need not be. See Hicks ms for details.

gives rise to difficulties for many accounts of the metaphysics of laws. Perhaps most famously, indeterministic laws gives rise to a serious problem for the Best Systems Analysis. This problem, which David Lewis famously dubbed the *Big Bad Bug*, is due to the fact that on the most obvious way of extending the Best Systems Analysis to indeterministic laws, the laws will sometimes assign a non-zero chance (at some time) to a series of events (after that time) that would result in the laws being different than what they in fact were. This is surprising. The laws shouldn't say that it is physically possible that the laws be different.³⁰

The literature on the Big Bad Bug is too large to survey here; the key point is just that the BSA—which is by far the most prominent Humean account—faces serious issues with indeterministic laws. Once one shifts one's focus to indeterministic laws, the claim that the laws are grounded in the mosaic is significantly more difficult to establish. But some non-Humean accounts—especially those that are not primitivist—may also face issues here. As an example, consider, Armstrong's account of laws, according to which laws are necessitation relations between universals. Clearly this account is inadequate if the laws are indeterministic—if the laws are indeterministic, then in at least some cases the instantiation of one universal leads in a lawlike way to the instantiation of another universal without the one necessitating the other. Perhaps we can endorse a straightforward extension of the Armstrong line according to which indeterministic laws are probabilifying relations between universals. But what is a probabilifying relation? Or perhaps we can say that indeterministic laws are necessitation relations between the instantiation of a certain set-up and the instantiation of a certain chance. But then what account will we give of chance?³¹ This is not to say that something like Armstrong's account cannot be extended to indeterministic laws, but only that there is work yet to be done here.

Perhaps the most interesting consequence of leaving open the possibility of indeterministic laws arises when one shifts from thinking about what grounds the laws to thinking about what the laws ground. In particular, think back to the argument, presented in section 3, that laws ground events (either individual events or patterns of events) in the world. If the laws are indeterministic and the laws ground events, then grounding may turn out to be indeterministic as well. That is, there are at least some grounding relations where the grounds do

³⁰ For discussion of the Big Bad Bug see Lewis 1994a, 478ff.

³¹ This question is especially pressing in the current context because philosophers tend to give an account of chance that is of a kind with their account of laws.

not metaphysically necessitate the things that they ground—indeed they don't even physically necessitate those things.³² This is a surprising result, given that the standard view is that grounding relations are metaphysically necessary, and even those who dissent from the standard view usually still allow that grounding relations are at least physically necessary. Indeed this result is surprising enough that many of those with previous commitments regarding the nature of grounding will probably take it as a reason to reject the argument in section 3 that laws ground events. But it is worth noting that insofar as one approaches the notion of grounding with fewer antecedent commitments—perhaps, say, because one is hopeful that the notion of grounding will help them understand the notion of governing as it has played an important but somewhat mysterious role in the metaphysics of laws—one ends up with these sort of surprising consequences.

Conclusion

The notion of metaphysical grounding has important applications to the metaphysics of laws of nature. It provides new ways of understanding important distinctions within the literature on laws and novel arguments for and against the views that arise on each side of those distinctions. And as the metaphysics of laws of nature is generally assumed to be a fairly naturalized area of metaphysics, these applications seem especially important. Insofar as the notion of metaphysical ground has applications to the metaphysics of laws of nature, that notion cannot be dismissed as entirely abstract or esoteric or uninteresting.

That is a promising result for the fan of metaphysical grounding. But here is a note of caution. Several philosophers, including, Wilsch (2015), Schaffer (2018), and Kment (2015), have suggested that we give a nomological account of metaphysical explanation, according to which, just as scientific explanation is mediated by laws of nature, metaphysical explanation is mediated by laws of metaphysics.³³ For those who might otherwise have been skeptical of the notion of

³² See Skiles, 'Necessity', in this volume and the discussion in Emery 2018.

³³ See Wilsch, 'Laws of Metaphysics', in this volume.

metaphysical explanation, this sounds encouraging. After all, laws of nature, though by no means unproblematic, are at least relatively familiar, and presumably the extant analyses of laws of nature can prove helpful in understanding laws of metaphysics. But the above discussion shows that the notion of grounding itself plays an important role in understanding what laws of nature are. There is no theoretical standpoint here that is independent of considerations of metaphysical grounding that we can use as a neutral starting point from which to try to understand that notion. As in so many areas of philosophy we instead find ourselves working with a group of interrelated concepts and tools, each of which depends in important ways on the others.

In closing let me mention one aspect of the relationship between laws and grounding that, due to considerations of space, has been overlooked above. The foregoing discussion has focused entirely on fundamental laws. Although it is controversial, many philosophers also think that there are non-fundamental laws.³⁴ If so, these laws are presumably grounded in the fundamental laws, or perhaps in other fundamental entities. Little of what has been written to date about non-fundamental laws has explicitly engaged with and made use of recent work on metaphysical grounding.³⁵ I leave it to the reader to explore these issues further.³⁶

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³⁴ Insofar as there are special science laws they are, presumably, non-fundamental laws. Such laws—if they are laws—are usually considered *ceteris paribus* laws, since they only hold under certain conditions. See Earman and Roberts 1999 and Lange 2002 for discussion.

³⁵ Prominent work on non-fundamental laws includes Albert and Loewer’s work on the *mentaculus* (see Albert 2000, and Loewer 2004 and 2009), which attempts to reduce many higher-level patterns, e.g. the second law of thermodynamics, to certain facts about the initial conditions of the universe, and Cohen and Callender’s (2009) *Better Best Systems Analysis*, which provides a recipe for identifying laws at multiple scientific levels.

³⁶ Thanks to Tobias Wilsch and Mike Raven for helpful comments.

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