

Naturalizing Grounding: How Theories of Ground Can Engage Science

Abstract: This paper surveys some of the grounding literature searching for points of contact between theories of ground and science. I find that there are some places where a would-be naturalistic grounding theorist can draw inspiration. I synthesize a list of recommendations for how science may be put to use in theories of ground. I conclude that the prospects for naturalizing the metaphysics of ground are bright.

Keywords: grounding, naturalism, naturalizing grounding, metametaphysics, epistemology of metaphysics, scientific metaphysics, metaphysics of science

Quine famously resurrected metaphysics from its death at the hands of the positivists — but he reined in its speculative character, directing us to populate our ontology by appeal to our best science. To the extent that the grounding literature has reframed the central questions of metaphysics so that the metaphysician’s proper concern is not with populating ontologies, but with limning ontological dependence relations (Schaffer 2009) arguably alien to science (Hofweber 2009), one might wonder about the prospects for preserving Quine’s naturalistic impulse in the grounding literature. In fact, one might think that the grounding literature is a rather *non-naturalistic* enterprise — a messy hotbed of unchecked metaphysical speculation and a fine example of what I have elsewhere called *free range metaphysics* (Bryant 2017), or metaphysics only nominally constrained by science. I’ll argue here that that’s not entirely the case.

This paper will survey some prominent papers in the grounding literature, searching for points of contact between theories of ground and science. I’ll find that there are some places where a would-be naturalistic grounding theorist can draw inspiration. I’ll synthesize a list of recommendations for how science may be put to use in theories of ground, including: to help identify putative grounding relata, to show correlations among them, to demonstrate their non-identity, to provide a stock of explanatory patterns, to identify candidate essential properties, to directly motivate some grounding claims and metaphysical laws, and to motivate agnosticism

about particular grounding claims where scientific evidence is lacking. I'll conclude that grounding theories can be suitably naturalistic and we have a general framework for making them so.

Preliminaries

My central concern is whether and how we can construct a naturalized metaphysics of ground. For the purposes of this paper, I'm assuming the desirability of naturalization — that is, it's not part of my aim here to motivate a naturalized metaphysics over a non-naturalized one. But let's dispense with the term 'naturalized metaphysics'. The terms *naturalize*, *naturalism*, and *naturalistic* are famously troublesome, since they're used to mean a number of significantly different things (see Papineau 2014 for some examples). I'll introduce my own term here: *scientifically responsible metaphysics*. The more a metaphysical theory engages conscientiously and painstakingly with the empirical data, theoretical insights, or practices of the current sciences, the more scientifically responsible it is. Note that this is a low bar for scientific responsibility — you just have to engage with science *somewhat*! We might say that metaphysics that engages science just a little bit is *minimally* scientifically responsible — the more engagement, the merrier. 'Engaging with science' can mean lots of different things. It can mean, *inter alia*, unifying scientific theses (Ladyman and Ross 2007), integrating scientific postulates or theses into metaphysical theories in a non-ad-hoc manner, drawing conclusions of philosophical interest on the basis of scientific evidence, drawing theoretical conclusions that track the practices of scientists (see Ereshefsky unpublished and Waters 2014), interpreting scientific data, correcting scientists' interpretation of the data where appropriate, revising metaphysical claims in light of new data or theoretical understanding, and formulating new or revising old metaphysical questions in response to new scientific understanding. What I'm looking to do here is to see whether the grounding theorist engages with science in any of these ways.

Now, what are we talking about when we talk about grounding? To say that x grounds y is to say, roughly, that y metaphysically depends on x . For something to metaphysically depend on something else is for it to obtain or exist *in virtue of* the other (Fine 2012). The thing doing the

grounding is thought to be more fundamental, ontologically or explanatorily, than the thing being grounded. Beyond that, it is difficult to say what grounding-talk is meant to track. In part, that's because the term 'grounding' is often said to be primitive (Schaffer 2009, Rosen 2010).¹ We are meant to have an intuitive grasp of it. But further, there is little agreement about the relata of the grounding relation, its formal properties, or its paradigm examples. Some hold that the relata are objects (Schaffer 2009) and some that they are facts (Audi 2012, Fine 2012). The formal properties of the relation are typically thought to be asymmetry, transitivity, and irreflexivity, but there's vacillation on this, too (Wilson 2014). As for paradigm examples, the following have been suggested:

- Socrates grounds Socrates' singleton set
- the fact that A and the fact that B ground the fact that A&B
- the Swiss cheese grounds the holes of the Swiss cheese
- natural features ground moral features
- sparse properties ground abundant properties
- truthmakers ground truths

The first and second are from Kit Fine (1994, 2012) and the rest are from Jonathan Schaffer (2009). These examples are certainly motley, and they don't impress everyone; some grounding skeptics have argued that the grounding concept does no unique conceptual work (see Wilson 2014). These skeptical worries are important and compelling, but for the purposes of this paper, I will set them aside and assume that the grounding literature is tracking some unique relation.

I. The State of the Metaphysics of Ground, Epistemology and Practice

I.1 Epistemology

I will begin by looking at some *second-order* claims of grounding theorists — that is, some of their explicitly epistemological and methodological claims — with the hope of finding potential avenues for making theories of ground scientifically responsible. I will then turn to the

¹ This linguistic point is not to be confused with the thought that the grounding facts and the grounding relation itself might be ontologically primitive (Bennett 2011 explores these possibilities).

first-order practices of grounding theorists — that is, their actual metaphysical theorizing — and assess whether the methods that emerge in practice reveal any such avenues.

I.1.1 Explanatory Fit

Let's begin with Fine. Fine (2001) helpfully makes his epistemology explicit. He assigns a role to two main sources of evidence: intuition and explanatory power. First, he says, "We appear to be in possession of a wealth of intuitions concerning what does or does not ground what" (2001, 21). For instance, intuition leads him to say that "what grounds the truth of a disjunction is the truth of those of its disjuncts that are true" and "what grounds the occurrence of a compound event at a given time is the occurrence of its component events" (2001, 21-22). Intuition guides us toward certain grounding claims and away from others, and is the basis for our stock of examples.

The second source of evidence is "explanatory in character" (2001, 22). When you provide the ground of a proposition, you explain it. Given the tight connection between grounding and explanation, Fine thinks "a system of grounds may be appraised, in much the same way as any other explanatory scheme, on the basis of such considerations as simplicity, breadth, coherence, or non-circularity" (2001, 22). The most important of these considerations, in his view, is explanatory strength, or "the capacity to explain that which stands in need of explanation and would otherwise be left unexplained" (2001, 22). Which things stand in need of explanation and which things don't depends on "a general pattern of explanation" (2001, 22). We want to know whether the grounding claim *fits* such a pattern. So our support and evaluation of grounding claims is a holistic matter (2001, 22).

One important question for our present purposes is whether Fine explicitly requires that scientific explanations be part of the general pattern of explanation against which we judge our grounding claims. He doesn't seem to require it — he says just that with each proposition of interest, there will be some associated domain of agreed-upon facts. I take it that the associated domain, which Fine calls the *extended domain*, is where we find the general pattern of explanation. He says the extended domains of morality, science, and mathematics are moral, scientific, and mathematical practice, respectively (2001, 22). What, then, is the extended

domain of a metaphysical claim? Presumably it's metaphysical practice. Does metaphysical practice hold itself accountable to a background of scientific explanations? Sometimes, sometimes not. It's doubtful that there is a single unified thing, *metaphysical practice*, that we can hold up and evaluate for scientific responsibility. Rather, there are a variety of practices. So it's not particularly clear what this extended domain does for us. But at any rate, since there's no overarching, explicit requirement on metaphysical practice that it be constrained by science, then we haven't built in any requirement that our metaphysics of ground be responsive to science. So grounding theories constructed in accordance with Fine's method could well be constructed largely independently of science.

But suppose that we *were* to require of our grounding claims that they fit the explanations offered by science. A second important question immediately arises: what does this notion of 'fit' require of us? For a proposition to fit into an explanatory pattern might be: 1) for it not to contradict any of the pattern's constituent explanations, 2) for it to resemble those constituent explanations in important respects. Fit of the first kind isn't enough for scientific responsibility. That's because requiring logical consistency with a stock of explanatory patterns doesn't ensure that the consistency was brought about in the right way. That is, it leaves open the possibility that the metaphysician speculates independently of science and achieves logical consistency with its constituent explanations by happy accident. Whatever the epistemic arguments for taking a scientifically responsible approach to metaphysics (arguments that I don't give here), they should lead us to reject this speculative approach as epistemically reckless.

On the other hand, requiring that the metaphysician countenance explanations that resemble scientific explanations in relevant respects can rule out these happy accidents. Of course, we'd have to spell out in a principled manner which kinds of resemblance we're looking for — a task that I'll bracket here. But the resemblances would have to be fairly specific. It wouldn't do for the explanations to simply be of the same general kind — causal or mechanistic, for instance. For merely mimicking the general form of scientific explanation wouldn't much constrain our metaphysical claims, wouldn't ensure consistency with science, and wouldn't rule out accidental consistency with science. A relatively more specific sort of resemblance would be for the metaphysical explanation to integrate some component parts of a scientific explanation,

such as scientific posits or data. This holistic, non-accidental explanatory fit with science would make a metaphysics of ground somewhat scientifically responsible.

I.1.2 Diagnostics

Schaffer (2009) also gives an explicit method for formulating theories of ground, which we might *prima facie* think points the way to a scientifically responsible metaphysics of ground. According to his Aristotelian conception of metaphysics, “The method of metaphysics is to deploy diagnostics for what is fundamental, together with diagnostics for grounding” (2009, 351). I’ll examine both sets of diagnostics, since I take grounding and fundamentality to be intimately related. In Schaffer’s view, there are three diagnostics for what is fundamental: 1) minimal completeness, i.e. the posited fundamentalia (i.e. fundamental things) provide a supervenience base for the actual world and include nothing superfluous; 2) metaphysical generality, i.e. the most general features of the collection of posited fundamentalia are necessary features; and 3) what Schaffer calls *empirical specifiability*, i.e. “the substances have a content informed by fundamental physics” (2009, 377).

The last is the most relevant for my purposes here. He explains: “The content of an inventory [of fundamental substances] is its most specific features, and the content is empirically specifiable iff these features fit those found in fundamental physics” (2009, 377).² I take Schaffer to mean that the specific features or properties metaphysicians ascribe to their fundamental posits (call them F_M for features posited in metaphysics) must fit the features or properties found (that is, discussed, posited, quantified over) in fundamental physics (call them F_P for features found in fundamental physics). Again, the notion of fit needs to be cashed out. Its role here might be to require 1) that F_M be logically consistent with F_P , 2) that F_M include nothing over and above the content of F_P , or 3) that F_M include all and only the items in F_P . But none of these requirements secures scientific responsibility, in that none of them requires consilience with science to be the result of a conscientious and painstaking engagement with science. That is, 1-3 may occur by

² Note that as Schaffer defines it, empirical specifiability is not merely empirical, but scientific. The distinction matters in this context because scientifically responsible metaphysics must be engaged with science in particular; being empirical is not sufficient.

happy accident. To borrow Mark Wilson's (2006) phrase, the empirical diagnostic appears to mention science without mandating its use.

One might object that the diagnostics here are likely meant only as after-the-fact checks on theoretical results, rather than as guides to the formulation and justification of the metaphysical theory. I grant the point. But then the latter aspect of the method is missing. The point stands that the method doesn't get us scientifically responsible theories, in that it contains no requirement for the metaphysical theory to be formed on the basis of science.

Schaffer's diagnostics for grounding claims include: 1) permissiveness, i.e. the grounding relations generate abundantly many entities and 2) abstraction, i.e. the relations are not additions to the world, but merely ways of specifying aspects of it that are "implicitly present from the start" (2009, 377-378). Neither of these diagnostics integrates science, so neither secures scientific responsibility. In sum: neither the diagnostics for fundamentality nor for grounding ensure that we get scientifically responsible theories.

I.1.3 Direct Empirical Support

I now turn to Paul Audi's epistemological claims, which are more promising as regards scientific responsibility. Audi suggests (following Daly 2012) that grounding claims can be backed empirically, albeit indirectly:

it is not clear that claims about grounding are insulated from empirical confirmation or disconfirmation. As Daly points out, facts about grounding might be indirectly empirically confirmable by having a place in a well-confirmed theory, a theory confirmed through its empirical consequences. (2012, 116)

So like Fine, Audi thinks that holistic considerations can figure into the justification of particular grounding claims; unlike Fine, he explicitly mentions that the theories into which the grounding claims must fit are well-confirmed empirical theories (here we may again read 'empirical' as 'scientific'). Not only that, Audi thinks that grounding claims can receive *direct* scientific support. He articulates a process for justifying grounding claims partly on the basis of scientific evidence. He takes the grounding claim *something's being an electron grounds its having negative charge* and lays out the following justificatory process for it:

1. We have contact with electrons in a way that enables us to refer to the property of *being an electron*...
2. We discover a disposition associated with being an electron, the power to repel certain things, and we call this power *negative charge*.
3. We discover that this disposition is associated with other things besides electrons, such as down quarks.
4. We may conclude from this that being an electron is not the very same thing as having negative charge.
5. We find reason to think that things' having negative charge is explained in terms of other facts about them (not the same fact in the case of electrons as in the case of down quarks).
6. These cannot be causal explanations.
7. We conclude that being an electron grounds having negative charge. (2012, 117)

While Audi does not generalize from the example, we may do so on his behalf. Here is the process in a more schematic form:

1. We have empirical reasons for positing entities of type x . So there is a property y of *being an x* .
2. Entities of type x also have some empirically discoverable property φ .
3. We discover that φ is realizable by entities of types other than x .
4. Therefore (from 1-3), we discover that φ is not y .
5. We find reason to think that in general, the members of some entity type having φ is explained in terms of facts particular to that entity type.
6. These explanations cannot be causal explanations.
7. So we conclude that in the case of some particular entity of type x , property y grounds its having property φ .

According to Audi, “this account is epistemically hybrid”, in that some of the steps are clearly empirical (read: informed by science) and some clearly *a priori* (2012, 117). The *a priori* step is the implicit assumption of Leibniz’s Law required to make the inference to step 4 valid. At any rate, Audi makes it clear that scientific evidence can help back grounding claims by allowing us

to identify putative grounding relata (i.e. negative charge in the case of electrons), by showing correlations among those relata, by demonstrating non-identity of relata, and perhaps by providing a stock of explanatory patterns. Since Audi's justificatory process involves bringing scientific evidence to bear in the justification of grounding claims, it is scientifically responsible in my sense of the term.

Nevertheless, Audi's method will not figure as a whole into my recommendations. Let me explain why. First, the schema does not apply in cases where y and φ are essentially connected — e.g. *having particular DNA* and *being Richard Nixon* — since step 3 will not be satisfied in such cases.³ Moreover, it is not clear that we will typically satisfy step 5. That is, we may not usually find that an entity's having property φ is explained by type-specific facts. We might find that having property φ can be explained by the same sort of fact across entity types — e.g. members of two different entity types might share a property other than y , and *that* property could ground token instances of φ in each case. Lastly, even when we do satisfy step 5, it does not follow that the property that grounds φ in the case of entity x is y . That is, the justificatory process is not valid. The grounder could be some other property particular to members of entity type x .^{4,5} For all those reasons, I don't recommend this justificatory process. So the grounding literature contains at least one example of a second-order view conducive to scientifically responsible grounding theories, but not one that I will recommend. Perhaps a more suitable method emerges in first-order practice.

³ The non-applicability of the schema in such cases is surprising, since Audi claims that being essentially connected is necessary for standing in a grounding relation (2012, 108).

⁴ One might think that there is an easy fix here — namely, we should add that there is reason to take y to be what explains φ (I thank an anonymous reviewer for raising this point). However, the demand for a reason to take y to be what explains φ is just the demand for an argument for taking y to be the grounds of φ . So the 'fix' is not so much a fix as a demand for an entirely different justificatory process for our conclusion.

⁵ Does the justificatory process nevertheless give us defeasible, *prima facie* justification? The process does give us some evidence for our conclusion — and we could call it '*prima facie* justification'. But we would likewise have to call a correlation '*prima facie* justification' for a causal claim. I don't see this as a particularly fruitful way of characterizing matters, because if these cases count as cases of *prima facie* justification, then being *prima facie* justified is too easily achieved to be of much real epistemic significance. The important point is that we haven't done the needed work to rule out relevant and very much live alternative hypotheses. I thank my anonymous reviewer for raising this question.

I.2 Practice

Since theory and practice sometimes diverge, and since not every philosopher ascends to the second order and makes her epistemology or methodology explicit, I'll now examine the first-order practices of some metaphysicians of ground. Here I will organize my treatment around some of the central questions of the literature: whether reality is flat or hierarchical, whether there is a fundamental level, and what grounds what. Questions that I will not discuss include, *inter alia*, whether there is a single grounding relation and what the term *grounding* means. Regarding the latter, many grounding theorists (most notably Schaffer 2009) are silent. That is because, as I mentioned above, they take *grounding* to be primitive and its meaning communicable only by providing examples, offering analogies, and “enfold[ing] the concept within a formalism” (Schaffer 2015, §1.1). There is also the question, also mentioned above, of whether various uses of the notion of grounding equivocate on or collapse into other notions of dependence, and whether the grounding concept has a unique and indispensable role (see again Wilson 2014). These are conceptual questions — questions about the role of the grounding concept in a broader framework of metaphysical concepts — and they are answerable on conceptual grounds. This conceptual work is both inevitable and crucial, partly because we need a clear conception of the metaphysical questions we're interested in before we set about answering them. This goes to show that some *a priori* work is indispensable — in scientifically responsible metaphysics, as in any inquiry.

I.2.1 Levels

Let us start with the question of whether reality is hierarchical or flat — whether there are levels of reality that stand in asymmetric dependence relations to one another. For instance, there might be a mental level that depends on a biological level that depends on a mereologically atomic physical level. If the hierarchical view obtains, the asymmetrical ordering would arguably be done by grounding relations. On this question, Karen Bennett writes:

I have no knockdown argument against the claim that the world is flat. But every fiber of my being cries out in protest... *any* version of flatworldism will be radically

revisionary... flatworldism is, to borrow a colorful word from a friend, ‘crazypants’” (2011, 28).

Here, Bennett readily admits that her intuitions on this matter, however strong, don’t constitute a *knockdown* argument. But does she think they constitute an argument? Does she think they count as evidence — defeasible evidence, but evidence nonetheless — of her favoured thesis? Bennett could simply be using intuition-talk in the way that Cian Dorr, in his response to Ladyman and Ross (2007), describes — i.e. as “a device for committing oneself to P while signaling that one is not going to provide any further arguments for this claim” (2010, np). That is, she may simply be signaling her rejection of flatworldism. This interpretation receives some support when Bennett says that her complaint against flatworldism is “a cousin of the incredulous stare” (2011, 28), given that the incredulous stare is clearly not an argument. But then, why not simply say, plainly, ‘I will assume the falsity of flatworldism’? At any rate, we do not yet have an example of a scientifically responsible approach to the question — perhaps because this does not constitute an attempt at justifying an answer to it.

By contrast, Schaffer (2003) argues by appeal to the structure of science. He says the hierarchical view of nature is “an empirical thesis based on the idea that the structure and discoveries of science reflects the structure of nature” (2003, 500). We take as evidence the fact that our best sciences paint a structured picture of the world, and we conclude that the world is so structured. He explains: “grounding is a notion that is extremely natural in the sciences, in considering the relation between levels. One need not be versed in an arcane metaphysics to think that the chemical depends on the physical” (2015, §4.4). In the picture of the world that emerges from science, the world is structured by these dependencies, and this is the metaphysician’s proper motivation for positing a hierarchical worldview structured by grounding relations. Here we have an approach to the question of whether reality is flat or hierarchical that is scientifically responsible, insofar as it looks to science and treats the scientific worldview as a source of evidence.

I.2.2 A Fundamental Level

The grounding literature is also concerned with the question of whether the hierarchical structure of the world — the various levels and the asymmetric dependence relations that organize them — bottoms out in something absolutely fundamental. That is, whether the grounding chain stops in something ungrounded. This is a question analogous to the question of whether causal chains trace back to some uncaused cause. Ross Cameron (2008) responds to the question as follows:

I have identified an intuition, that... [t]here must be a metaphysical ground, a realm of ontologically independent objects which provide the ultimate ontological basis for all the ontologically dependent entities, and a realm of basic facts which provide the ultimate metaphysical grounding for all derivative facts. (2008, 8)

He attempts to argue for the intuition, but after some difficulty, says the following:

It is proving hard to argue for the intuition. Of course, it is an *intuition*; is not that reason enough to believe it? Yes, it is; I certainly feel the force of the intuition strongly, and I think that this alone, given that I have seen no argument *against* the intuition, is sufficient to give me reason to believe that the intuition is true. We have to rest on intuition at *some* point, after all; is not here as good a place as any? Why should we even be trying to offer an argument for it? (2008, 11)

This is a much clearer case than the Bennett case above, in that Cameron clearly does see his intuitions as evidential. However, he goes on to provide an argument for fundamentality that he thinks is decisive — namely that positing a fundamental level provides “a common metaphysical explanation for every dependent entity” and therefore gives us a tidy picture of the world (2008, 12). I understand the point to be that there’s one broad type of metaphysical explanation for every dependent thing’s existence — namely that the thing exists in virtue of the fundamental level, or constituents of the fundamental level. At any rate, to the extent that Cameron doesn’t make use of science in this context, we’ll find no clues here about how to make grounding theory scientifically responsible.

In his treatment of the question of whether there is a fundamental level, Schaffer (2003) again does significantly better. Here, he does not take himself to be answering the question of whether there is anything whatsoever that is fundamental, but rather, whether there is a bottom-

most, mereologically atomic level — a level consisting of units without proper parts (2003, 500). It is common to simply assume that there is a fundamental level, so understood, but Schaffer argues that science does not support the assumption. He says that when we ask whether there is a fundamental atomic structure in nature, we must “look to the structure of science for empirical evidence” (2003, 500). He continues, “Thus I think that there is only one serious argument for atomism, which is that *science indicates atomism*—the trajectory of current physics points to a world constituted out of simple microphysical particles” (original emphasis, 2003, 500). The argument for atomism is:

- (1) There will be a complete microphysics,
- (2) The complete microphysics will postulate particles, and
- (3) These particles are the mereological atoms. (2003, 502)

In Schaffer’s view, the only serious argument here is the one that appeals to science. But he rejects it, also for scientifically-motivated reasons — namely, “the empirical evidence does not favor *any* of (1)-(3)” (2003, 503). In fact, he argues:

the history of science is a history of finding ever-deeper structure. We have gone from ‘the elements’ to ‘the atoms’... to the subatomic electrons, protons, and neutrons, to the zoo of ‘elementary particles’, to thinking that the hadrons are built out of quarks, and now we are sometimes promised that these entities are really strings, while some hypothesize that the quarks are built out of peons (in order to explain why quarks come in families). Should one not expect the future to be like the past. (2003, 503).

An induction on the trajectory of science would suggest that it will continue to posit further and further levels of physical reality. But ultimately, Schaffer concludes that regarding the question of a fundamental level, “The empirical evidence to date is neutral as to which structure science is reflecting” (2003, 505). For that reason, he says we should withhold belief (2003, 506). He considers whether or not the available scientific evidence supports the fundamentality thesis and recommends the appropriate attitude; in so doing, his treatment of the question is scientifically responsible.

I.2.3 What Grounds What

The question of what grounds what is the question of which sorts of entities or facts ground which other sorts of entities or facts, and of which token grounding relations obtain between particular entities or facts. In his treatment of the question, Audi claims:

Facts involving redness and loudness... never stand in grounding relations with one another. Nothing could be red in virtue of being loud, or loud in virtue of being red (and no range of intermediaries could ever link them together in a chain of grounding). These properties are simply too disparate. (2012, 108)

So, on his view, grounding facts are “importantly tied to the natures of properties” (2012, 108).

For instance, he says:

Compare maroonness. The fact that a thing is maroon is *bound* to ground its being red (assuming, for the moment, that a given thing’s redness is not identical with its maroonness). To label this relationship, let us say that facts are suited to stand in a relation of grounding only if their constituent properties are *essentially connected*. (2012, 108)

When an essential connection obtains between the constituent properties of the grounding relata, the type grounding relation is essential to the property type. That is, it is the nature of the one property to ground or be grounded by the other. So if we find justification for positing an essential connection between properties, we are on our way to justifying a grounding claim. But what could justify a claim about essential connection? Audi claims:

it *seems* to be of the essence of maroonness that its instances ground instances of redness (in the same particular). And likewise, it is of the essence of redness that an instance of it can be grounded in an instance of maroonness. (my emphasis, 2012, 109)

The added emphasis should signal that here, Audi appeals to intuition. So in this case, he does not follow the scientifically responsible justificatory procedure he articulated at the second order. But he could have done so! We have a wealth of scientific data pertaining to colour (see Akins and Hahn 2015 for a history of scientific development on the matter). One should appeal to it to inform the discussion of essential connection — for instance, by considering correlations between, on the one hand, spectral reflectance properties or types of spectral reflectance properties (Byrne and Hilbert 2003) or equivalence classes of spectral reflectances (Rosenthal

2001) and, on the other, color ascriptions.^{6,7} But at least in this case, Audi justifies the essence claim on intuitive grounds, without explicit consideration of science. So despite the scientific responsibility of his second-order view, Audi's first-order treatment of the what-grounds-what question isn't scientifically responsible.

One particular version of the what-grounds-what question is the question of what is fundamental, since that question is about what ultimately grounds everything. Though Schaffer (2003) claims there is no scientific basis for positing bottom-level, mereologically atomic fundamentalia, he does not rule out other sorts of fundamentalia. He considers a number of arguments in favour of the claim that the whole cosmos, *qua* all-encompassing system, is the one and only fundamental object. This view is called *monism*. One of his arguments is from common sense — “the overall pull of intuitions across cultures and ages favors the monistic view” (2010, 49). Monism, he says, “properly understood as the claim that the cosmos is an integrated whole... best fits intuitions about priority” (2010, 50). The appeal to intuitions is unfortunate, but happily Schaffer says, “I should hasten to add that I think this counts for little” (2010, 50). Instead, he focuses on articulating a scientifically-motivated argument for monism. He says “advanced physics is field theoretic physics, and field theory has a natural monistic interpretation in terms of a spacetime bearing properties” (2009, 378). For instance, “general relativistic models are $\langle M, g, T \rangle$ triples, where M is a four-dimensional continuously differentiable point manifold, g is a metric-field tensor, and t [sic] is a stress-energy tensor... The obvious ontology here is that of a spacetime manifold bearing fields” (2009, 378 fn 40). And further:

the cosmos forms one vast entangled system... Physically, one gets initial entanglement from the assumption that the world begins in one explosion (the Big Bang) in which everything interacts. This initial entanglement is then preserved thereafter on the assumption that the world evolves via Schrödinger's equation. More precisely, the initial singularity is virtually certain... to produce universal entanglement, and the Schrödinger

⁶ We would need a strong or near-perfect correlation to get the modal oomph required for an essential connection claim. Perfect correlations likely won't be forthcoming given a large enough sample of human subjects, due to human error, differences in human visual systems and processing, and cultural differences with regard to colour concepts.

⁷ I thank Jake Quilty-Dunn for his input here.

dynamics are virtually certain... to preserve it. In fact Schrödinger evolution tends to spread entanglements, so that even without initial entanglement, ‘eventually every particle in the universe must become entangled with every other’ (2010, 52)

These arguments present scientific support for monism. He concludes: “And so, given that quantum mechanics (or better, relativistic quantum field theory) represents our best current guide to the structure of reality, it seems that empirical inquiry now favors the holism of the monistic view” (2010, 55). His appeal to science is explicit. Since Schaffer takes the best current science and draws conclusions of philosophical interest from it, his argument for monism is scientifically responsible. And since, on his view, laws of metaphysics govern grounding relations (2010, 56), scientifically-motivated token grounding claims could allow us to posit, in a scientifically responsible fashion, metaphysical laws about which types of things ground which types of things.

II. Scientifically Responsible Metaphysics of Ground

On the basis of my examination of some of the first-order and second-order views espoused in the grounding literature, I’ll now synthesize some general recommendations for how to make grounding theories scientifically responsible. In the formulation of grounding theories, science can and ought to be used, *inter alia*:

- to help in the identification of putative grounding relata, by acquainting us with worldly objects, properties, states of affairs, and so on
- to show correlations among putative grounding relata
- to demonstrate the non-identity of relata
- to provide a stock of explanatory patterns with which we expect non-accidental fit
- to acquaint us with candidate essential properties and so help substantiate claims of essential connection and grounding
- to motivate particular grounding theses and accompanying metaphysical laws, e.g. that the cosmos is ungrounded
- to motivate agnosticism about particular grounding theses where scientific support is lacking, e.g. about whether grounding chains descend infinitely

Some grounding claims will be subject to these forms of scientific support and some not. Value-laden grounding claims (like *the gods' love grounds the pious*) and grounding claims involving at least one abstract relatum (like *Socrates grounds Socrates' singleton*) may not be subject to direct scientific support. In these cases, we should adhere to something analogous to Ockham's Razor: we should not, beyond necessity, make grounding claims that lack direct scientific support. This isn't for the sake of simplicity, but because this type of claim is more epistemically vulnerable than scientifically supported ones and, as a matter of principle, we should minimize epistemic risk, other things being equal.

Conclusion

I have surveyed some of the grounding literature with an eye to the prospect of making it scientifically responsible. I worked in a piecemeal fashion, starting with explicit second-order commitments and proceeding to first-order practices. I found the second-order views and first-order practices of metaphysicians of ground to be, unsurprisingly, heterogeneous. At the second order, I found that Fine's epistemology doesn't explicitly integrate science, notwithstanding its holism. On the other hand, explicitly requiring that grounding claims non-accidentally fit into a pattern of scientific explanation would make our theory scientifically responsible. With its mention of physics, Schaffer's second-order view *prima facie* points the way toward scientific responsibility, but turns out to require mere consistency with science, not conscientious engagement with it. Audi's justificatory process is promising, since it encourages the use of scientific evidence and explanation in the justification of some grounding claims, but it fails in other respects. At the first order, Schaffer demonstrates what scientifically responsible grounding theories can look like, by using scientific evidence to motivate belief in levels and monism, as well as neutrality toward mereological atomism.

Based on my examination of the literature, I compiled a list of potential contributions of science to theories of ground, including: helping identify putative grounding relata, showing correlations among them, demonstrating their non-identity, providing a stock of explanatory patterns, identifying candidate essential properties, directly motivating particular grounding claims and metaphysical laws, and motivating agnosticism about some grounding claims where

scientific evidence is lacking. So the prospects for naturalizing theories of ground are bright — such theories can be scientifically responsible and we have a general framework for making them so.

Acknowledgments

I wish to thank Michael Devitt and David Papineau for comments on this work. I also thank audiences at presentations of this work at *The Metaphysics and Epistemology of Grounding and Fundamentality* conference at the CUNY Graduate Center on December 11, 2015 and at the Canadian Philosophical Association Annual Congress at the University of Calgary on May 29, 2016. Thanks also to my commentator, Brandon Beasley.

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