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Metaphysical Causation

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Abstract: There is a systematic and suggestive analogy between grounding and causation. In my view, this analogy is no coincidence. Grounding and causation are alike because grounding is a type of causation: metaphysical causation. In this paper I defend the identification of grounding with metaphysical causation, drawing on the causation literature to explore systematic connections between grounding and metaphysical dependence counterfactuals, and I outline a non-reductive counterfactual theory of grounding along interventionist lines.

1. Introduction
2. The Causation-Grounding Analogy
3. Cases of Metaphysical Causation
4. Metaphysical Dependence Counterfactuals
5. Metaphysical Causal Models
6. Impossible Interventions and the Classification of Causation
7. Conclusion

1. Introduction

> "Grounding is something like metaphysical causation."
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> Schaffer (2012) p.122

> "Ground, if you like, stands to philosophy as cause stands to science."
>
> Fine (2012) p.40

> "I offer a treatment of grounding in the image of causation... "
>
> Schaffer (2016) p.96

In the quotes above, I think Jonathan Schaffer and Kit Fine have understated the intimacy of the connection between grounding and causation. The thesis of the present paper is that grounding *just is* a type of causation: metaphysical causation. I will refer to this claim as *G=MC*. According to G=MC, the grounding relation[1] is a special case of the causal relation: whenever A grounds B, A is a (metaphysical) cause of B and B is a (metaphysical) effect of A. Grounding is a way of causing.

[1] Perhaps neither grounding nor causation is strictly speaking relational, but is instead best expressed with something like a sentence operator; see Fine 2012. This issue is orthogonal to my argument.

Making sense of G=MC requires us to draw a contrast between metaphysical causation and non-metaphysical causation—or, to coin a term, *nomological causation*. As I conceive it, this contrast is between two different ways in which the causal sufficiency relation can hold. If an instance of the causal sufficiency relation is mediated by a law of nature, then it is an instance of nomological causation. If an instance of the causal sufficiency relation is not mediated by any law of nature, then it is an instance of metaphysical causation. *That the throwing of the stone is a sufficient cause of the breaking of the window* is mediated by the laws of nature; but *that the existence of Socrates is a sufficient cause of the existence of Singleton Socrates* is not mediated by any law of nature. I characterize the notion of mediation in §5, in terms of the structural-equations framework I will present. Beyond that notion, the proposed distinction between types of causation relies only on the notion of a law of nature, to which most metaphysicians are independently committed.[2] Assuming that we antecedently understand lawhood, we have in hand everything we need in order to demarcate cases of grounding from cases of nomological causation.

Why think that grounding is metaphysical causation?—because of the theoretical unity and simplicity that ensues. G=MC has two major theoretical benefits:

- G=MC is ideologically parsimonious. If grounding is just metaphysical causation, then we do not need a separate theory of grounding invoking new primitive notions. Instead, our theory of grounding will invoke only whatever fundamental ideology is employed by our best theory of causation in general, in addition to the notion of a law of nature.[3]
- G=MC accounts in a straightforward way for the explanatory nature of grounding claims: grounding explanations are a type of causal explanation, and they work by identifying metaphysical causes. G=MC thereby supports a compelling unified theory of explanation, undermining counterexamples to the appealingly simple view (defended *inter alia* by Railton 1981, Lewis 1986c and Skow 2014) that all explanations are causal explanations.

Contemporary metaphysicians typically adopt a Quinean methodology of comparing total theories, or 'systems of the world' as Quine (1975) puts it. Given such a methodology, the having of a theoretical benefit can count in favour of a principle of fundamental metaphysics. The theoretical benefits described above can accordingly form the basis of a *prima facie* case for G=MC.

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[2] For a closely related application of lawhood, see Hale & Leech (forthcoming).

[3] In this respect, my proposal resembles those of J. Wilson (2014) and Hofweber (2009), who argue that grounding claims can and should be accommodated using antecedently-understood ideology such as counterfactual dependence, logical consequence or conceptual inclusion. My version of their approach requires only counterfactual dependence and laws of nature.

The argument from theoretical virtue is not conclusive. To reinforce the case for G=MC, we need independent reasons to think that grounding has important features in common with more familiar forms of causation. Such reasons can be found in the systematic analogy between grounding and nomological causation, which is explored in §2-6 of this paper. Strikingly many of the important features of causal ideology apply across both nomological causation and grounding, and in comparison to the extensive commonalities between nomological causation and grounding, the residual differences between them look insignificant. The relations of grounding and of nomological causation have the same logical properties (which can be challenged in structurally analogous ways); the relations have the same connections to explanation and to counterfactuals; the same puzzle cases and theoretical issues arise when we try to give the relations a counterfactual analysis; and popular interventionist treatments of nomological causation carry smoothly over to grounding. The best explanation of these persistent parallels is that grounding and nomological causation are different ways for a generalized causal relation to obtain[4].

According to G=MC, metaphysical causation and nomological causation are different species of the same genus. This is something that my proposal has in common with a type of dualistic position defended by a number of recent authors. According to Jonathan Schaffer, the relations of grounding and causation are both species of the genus *directed determination relation*; and according to Karen Bennett, they are both species of the genus *building relation*. It is tempting to dismiss my dispute with such authors as merely terminological: for example, we could simply translate their term 'directed determination' by my term 'causation', and their term 'causation' by my term 'nomological causation'. But there is more to the dispute than choice of terminology: where I posit a single primitive, Bennett and Schaffer posit two distinct primitives neither of which is reducible to the other. Thus their view ultimately has more in common with the views of authors like Fine (2012) and Koslicki (2015) who treat ground and cause as fully distinct fundamental notions. Of course, ideological parsimony is a notoriously vexed methodological principle (see e.g. Quine 1968, Lowe 2006, Paul forthcoming); in what follows, I invite you temporarily to suspend any doubts about it and to take seriously the ideological parsimony argument for G=MC.

[4] Some of these parallels are also noted by Schaffer (2012, 2015). The conclusion of the present paper, which was written before Schaffer (2016) became available, is significantly stronger than Schaffer's: I develop the structural-equations approach to grounding in service of my main argument that grounding is a type of causation, whereas Schaffer's aim is the more modest one of providing a tractable formal model for grounding. J. Wilson (2016), which was also written subsequently to the present paper, offers a reply to the argument from the grounding-causation analogy to grounding-causation unity.

For those who remain uncomfortable with my terminological preferences, I can offer alternatives. Instead of using 'causation' for the genus-level term and 'metaphysical causation' and 'nomological causation' for the species, we could use 'objective explanation' for the genus and 'grounding' and 'causation' for the species. Then P grounds Q iff P objectively explains Q and this explanatory fact is not itself objectively explained by any law of nature; and P causes Q iff P objectively explains Q and this explanatory fact is objectively explained by some law of nature. But nothing much rests on this terminological choice. In the present paper I will continue to use 'causation' to refer to the genus, on the basis that labelling grounding as metaphysical causation emphasizes our prior conceptual familiarity with the notion.

Some signposting is in order. §2 locates the target of the analysis—the grounding relation—and sets out the systematic analogy between grounding and causation. §3 identifies some core examples on which to test G=MC. In §4, I explore the fate of key counterfactuals associated with metaphysical causal dependence, and discuss some apparent difficulties facing counterfactual accounts of grounding. I argue that these problems are familiar from the metaphysics of causation and that they can readily be handled by sophisticated counterfactual accounts of causal dependence. One interesting approach of this kind, interventionism, essentially involves the use of structural-equation models; in §5 I present a number of grounding models that are analogues of problem cases familiar from the causation literature. §6 discusses how these grounding models should be understood, and proposes a classification scheme for varieties of causation in terms of the source of the dependency. §7 concludes by summarizing the case for G=MC.

2. Grounding and Causation

First we need to get clear on exactly which notion of ground our analysis is targeting. In this paper we will be solely concerned with the notion of *strict ground*, which Fine (2012) distinguishes from *weak ground*. While that distinction will not be important in what follows, Fine's distinction between *partial ground* and *full ground* will be crucial. It is worth seeing how Fine introduces the partial/full distinction:

> A is a partial ... ground for C if A, on its own or with some other truths, is a [full] ground of C (i.e. A, $\tilde{A} <$ B, where $\tilde{A}$ is a possibly empty set of 'other truths'). Thus given that A, B is a full ground for A v B, each of A and B will be a partial ground for A v B. Each will be relevant to the grounding of A v B, even though neither may be sufficient on its own.
>
> Fine (2012)

Fine appears to intend his distinction between full and partial ground to be understood by analogy to the distinction between causal sufficiency and causal relevance. Two contributory causes may be causally relevant to some fact even though neither would be sufficient on its own, as when two people co-operate to move a heavy object. Accordingly, I will identify Fine's notion of full ground with *sufficient metaphysical cause*, and his notion of partial ground with *contributory metaphysical cause*. I will focus only on the metaphysical analogues of the locutions 'sufficient cause' and 'contributory cause' to simplify presentation, and because these locutions correspond directly with Fine's notions of ground, but the interventionist approach to grounding to be presented in §5-6 in fact generalizes to the whole of our causal discourse. We have a range of non-equivalent causal locutions—e.g. 'is a cause of', 'is the cause of', 'caused'—and the ability to account flexibly for this range is one of the main advantages claimed for the interventionist approach to causation by its proponents (e.g. Woodward 2003). I suspect that taking advantage of the distinctions enabled by this variety of locutions will also be of value to metaphysicians thinking about grounding.

Most contemporary treatments (e.g. Rosen 2010) claim to take (full) grounding as a primitive notion. It is not always entirely clear what this means, but, at least, it involves not giving any reductive analysis of the notion in independent terms. Friends of grounding instead typically use non-reductive methods to help non-initiates get a grip on their notion. As a preliminary step, grounding theorists constrain the notion of grounding by specifying its formal properties. The first question is the question of what sort of things can ground or be grounded: in our terms, what the primary relata of the metaphysical causal relation are. Following Mellor (1995), I will be working with the view that causation in general relates facts. I adopt this view for two reasons. Firstly, as Mellor argues, fact-causation handles cases of causation by absence much more nicely than event-causation does. Secondly, every instance of causation between events can be captured in terms of causation between facts: the fact that the cause-event occurred causes the fact that the effect-event occurs. The reverse does not obtain unless we appeal to a very fine-grained theory of events, according to which e.g. the event of my cactus's being thirsty goes proxy for the fact that my cactus is thirsty. My arguments below could be adapted to the context of a suitably fine-grained theory of event-causation, but I will set things up in terms of causation between facts.

Thought of as a relation between facts, both partial and full grounding are usually taken to be partial orderings: transitive, asymmetric, and irreflexive. This provides an initial plausibility check on G=MC, which it passes with no difficulty:

the relations *is a contributory cause of* and *is a sufficient cause of* are likewise generally taken to be transitive, asymmetric, and irreflexive. However, it turns out that these logical properties can be challenged, in closely analogous ways, both for grounding and for nomological causation.

Take transitivity first. The cases that seem to threaten the transitivity of nomological causation are cases of pre-emption where the cause triggers *and then cuts off* an alternative causal pathway to the effect[5]. Hall gives the example (Hall 2004) of a hiker, who sees a boulder rolling towards them and ducks; the boulder passes harmlessly overhead and they survive. Plausibly, the falling rock caused their ducking, and their ducking caused their survival, but the falling rock did not cause their survival. As Jonathan Schaffer has pointed out, we can generate structurally similar cases to challenge the transitivity of grounding. Schaffer (2012) discusses a case of a dented sphere O, arguing that the dent in O grounds O having determinate shape S*, and that O having S* grounds O being near-spherical, but that the dent does not ground O being near-spherical.[6]

Not only can analogous challenges be raised to the transitivity of both nomological causation and grounding, these challenges can be met in the same sorts of ways. Friends of transitivity for grounding and for nomological causation can bite the bullet, either by rejecting one of the intuitive causal premises (e.g. Paul 2000) or by embracing the counterintuitive causal conclusion (e.g. Lewis 2000). Schaffer (2012) proposes a contrastive treatment of grounding as a diagnosis of the transitivity failure; this treatment mirrors exactly his contrastive treatment of causation (Schaffer 2005). Interventionism, to be discussed in detail in §5-6, allows for the possibility of transitivity failures both for metaphysical causation and for nomological causation, while also letting us specify conditions under which causal relations will be transitive (Woodward 2003, p.79-81).

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[5] As far as I am aware, Nancy Cartwright was the first to draw attention to this type of example (in Cartwright 1979).

[6] A referee suggests that Schaffer's counterexample is less persuasive than Hall's, since it is less obvious that the dent does not ground the ball's being roundish than it is that the falling rock does not cause the hiker's survival. I agree with the referee on the relative strength of judgments here, but what is important for present purposes is the structural similarity of the proposed counterexamples. My own diagnosis of the relative strength of these cases turns on how strongly the supposed cause threatens the supposed effect; something's posing a threat to an event tends to undermine that thing as a candidate cause of that event. Given the setup of the cases, it's easy to imagine that the boulder posed a serious threat to the hiker's survival, but hard to imagine that the dent posed a serious threat to the near-sphericality of the dented object. There's accordingly more pressure to deny that the boulder falling is a cause of the survival than there is pressure to deny that the dent is a ground of the near-sphericality.

The asymmetry of nomological causation has likewise been challenged. One of Lewis's motivations for not building the temporal asymmetry of causation directly into his 1979 analysis (Lewis 1979/1986) was the desire to allow for the coherence of backwards nomological causation, such as might occur in cases of consistent time travel. For example, consider the case of a time-traveller who travels back in time and engineers the meeting between their parents that leads to their own eventual birth; the meeting is then a cause of the time-travelling, and the time-travelling is a cause of the meeting. In recent work, the asymmetry of grounding has been challenged in a similar manner. Naomi Thompson (Thompson 2016) and Elizabeth Barnes (Barnes forthcoming) have given several candidate examples of grounding loops, concluding that grounding is non-symmetric rather than asymmetric[7].

A first example of Thompson's (adapted from Fine 2001) is the mass, density and volume of a homogeneous body. Each pair of these parameters is sufficient to derive the third parameter, and it would seem arbitrary to privilege any two of them as fundamental with the third being derivative. In response, we might well want to treat the values of each parameter as wholly grounded in the values of the other two. This requires giving up on asymmetry for partial ground, and accordingly also requires giving up on either irreflexivity or transitivity (or both). A second example of Thompson's is the following truth-teller pair (see Cook 2011 p.474 for discussion), where the truth-value of each sentence is plausibly (via the principle that the fact that 'P' is true is grounded in the fact that P) fully grounded in the truth-value of the other sentence:[8]

P: '*Q*' is true
Q: '*P*' is true

Again, the same sorts of response to these challenges to asymmetry are available in the causation and grounding cases. Probably the most popular responses will be either both to reject all putative cases of symmetric causation and to reject all putative cases of symmetric grounding, or to endorse asymmetry for each notion only when restricted to some more specific subject-matters. Neither of these responses represents any particular threat to G=MC.

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[7] Barnes formulates her arguments in terms of ontological dependence rather than of grounding, but many grounding theorists think of cases of ontological dependence as instances of ground.

[8] The sentences are either both true or both false; it's an interesting question which truth-values they have (and why) but not one that we need to address for present purposes. As a referee points out, this case also threatens either transitivity or irreflexivity; those who think grounding is non-symmetric rather than asymmetric must choose their poison.

More radically still, some authors have recently argued that grounding is not even irreflexive (of course, if irreflexivity fails, so does asymmetry). Carrie Jenkins (Jenkins 2013) argues that a relation of grounding between physical states and mental states might obtain even in the context of a mind-brain identity theory; Jessica Wilson (J. Wilson 2014) endorses this line of thought, and also raises the prospect that identity itself—which after all is taken to be an explanatory notion within various metaphysical theories—might in fact be a grounding relation. But, once again, such revisionary hypotheses about grounding are quite compatible with G=MC, since we have no special reason to think causation really is irreflexive in these peculiar and recherché applications. Indeed, since the irreflexivity of causation has itself been questioned by appeal to the possibilities of a bootstrapping time-traveller who is responsible for their own existence, of a self-causing deity, or of a self-causing concrete universe, these arguments in fact strengthen the grounding-causation analogy.

Thinking of nomological causation and grounding as different ways for a single notion of causation to hold does have some immediate consequences for the logical relationship between grounding and nomological causation. Assuming for the moment that the genus-level notion of causation is asymmetric, G=MC requires that the holding of nomological causation in one direction excludes the holding of metaphysical causation in the other direction. If A is a nomological cause of B, then B does not ground A, and vice versa. This principle seems a plausible one—at least setting aside exotic time-travel cases, and the like, which anyway threaten asymmetry of the genus-level causal relation. So this result provides G=MC with some initial, defeasible, support; the logical relationship between nomological causation and grounding is as G=MC would lead us to expect it to be.

Logical considerations only take us so far in understanding grounding. (Divisibility is a partial order on the natural numbers, but it is not the same relation as grounding.) Our grip on grounding is supposed to come in two other main ways: through examples, and through the connection with explanation. Nomological causation and grounding stand in the same distinctive relation to our practice of explanation: nomological causal relations and relations of ground each figure in explanations, without being literally identical to those explanations. When we want to explain why the bottle broke, we cite the nomological causes of its breaking; and when we want to explain why Singleton Socrates exists, we cite the existence of Socrates. This sort of distinction between causation and causal explanation is familiar from the philosophy of science, and it carries straight over to grounding.

As Schaffer (2016) points out, nomological causation and grounding also bear similar relations to a range of metaphysical notions connected with explanation. First, to laws: we naturally think of particular cases of grounding as supported by general metaphysical principles, analogously to how particular cases of nomological causation are supported by general laws of nature. Second, to modality: Schaffer (2016, fn.5) endorses a global supervenience principle of effects/grounded facts on causes/grounding facts for both (deterministic) nomological causation and grounding. Third, to inference: under the right conditions we can be justified in inferring the effect/grounded fact from the cause/grounding fact. Putting all this together, the connection with explanation provides a striking further parallel between nomological causation and grounding.

A final—and rather more nebulous—point of analogy between grounding and nomological causation concerns their methodological status. Both notions have historically attracted suspicion from philosophers with empiricist inclinations: consider Hume's argument that causation cannot be perceived (Hume 1748), Lewis's campaign to account for everything in the scientific and manifest image in terms of his doctrine of Humean Supervenience (Lewis 1986a), Sider's affirmation that "as a Humean I'm suspicious of metaphysical pushings and pullings" (Sider 2011 p.145) and Daly's recent arguments that the notion of grounding is 'unintelligible' or 'obscure' because it cannot be characterized in independent terms (Daly 2012). Relations of cause and ground are thought to lack clear content exactly insofar as they go beyond the uncontroversial notions (constant conjunction, supervenience) that they are supposed to explain. Here is not the place to properly evaluate this line of thought, although A. Wilson (forthcoming) explores one way in which it could be developed; it will suffice for present purposes to note that it further extends the analogy between grounding and nomological causation.

Thus far we have found nothing of consequence to distinguish nomological causation from grounding: they have the same general logical features, they come in analogous flavours, and they bear the same general connections to explanation. Of course, the analogy does not go on forever: the differences in what nomological causation and grounding depend upon gives rise to some differences between nomological causation and grounding down the line. I will discuss three disanalogies between them, which arise from their different relationships with the temporal ordering of events, with the notion of causal production, and with the notion of fundamentality.

The most obvious disanalogy between grounding and nomological causation is that grounding is usually synchronic (it relates facts about some time t to further facts about t) while causation is usually diachronic (it relates facts about some earlier time t_1 to facts about some later time t_2.) However, I think that this difference does not run deep; some nomological causal relations may be synchronic and some grounding relations may be diachronic[9]. For example, if consistent time travel is possible then a time-traveller's pressing a button at t to travel back in time and present their former self with a freshly-printed set of time-machine blueprints may be a cause of another event that also occurs at t: the existence of some well-used and dog-eared blueprints. And any cases of gravitational or quantum action at a distance would (at least on some interpretations) count as synchronic causation. Conversely, my being human as opposed to being a swampman may be grounded in my past causal history, and my present ability to refer to Montana may be grounded in my past causal interaction with Montana. Still, most cases of nomological causation are diachronic while most cases of metaphysical causation are synchronic, and the current proposal can account for this fact in a satisfying way. Recall that on the present proposal, nomological causal dependencies are mediated by the laws of nature. Since the laws of nature typically relate events at one time to events at another, it is then to be expected that nomological causal dependencies should by and large be diachronic. And since metaphysical causal dependencies are not mediated by any laws of nature (instead being mediated by principles of logic or metaphysics that do not typically impose diachronic constraints) it is to be expected that metaphysical causal dependencies should by and large be synchronic.

Nomological causation and grounding also appear to differ in their relationship with concrete dynamical processes. Nomological causation is widely assumed to have a special relationship with concrete physical processes which transfer marks, or mass-energy, or some other conserved physical quantity. Sometimes this relationship is exploited to construct a full-fledged theory of causation, for example by Fair (1979), Salmon (1984) and Dowe (1992). But even defenders of alternative counterfactual or probabilistic approaches to causation are likely to agree that nomological causation stands in some special relationship to concrete physical processes, while grounding does not. This is exactly as would be predicted by my proposal for demarcating nomological causation from metaphysical causation. Since nomological causal dependencies are mediated by laws of nature while metaphysical causal dependencies do not, it is entirely unsurprising that claims about actual nomological causal dependencies have consequences for actual law-governed natural processes while claims about actual metaphysical causal dependencies have no such consequences.

[9] For discussion of more examples of these sorts, see (Wilson MS).

While some conceptions of the special relationship between causation and physical processes might be inimical to G=MC, there is a widespread and popular conception of this relationship that is fully congenial to G=MC. That is the dualistic view defended by Hall (2004), who argues that we have two basic and different notions of causation: *causal production* and *causal dependence*. Causal dependence is a matter of the right patterns of counterfactuals; causal production is a distinctively dynamical way that causal dependence might obtain. Crucially, though, there are other ways that causal dependence might obtain; dependence need not go via production. Hall motivates this distinction by appeal to cases of causation by absence and cases of double prevention (see §5); it is also a natural fit for friends of G=MC. Cases of metaphysical causation are amongst those cases in which causal dependence does not go via causal production.

Grounding is also thought to have a special connection to fundamentality: a grounding fact is supposed to be more fundamental than any facts it grounds, and something is fundamental *iff* it is ungrounded (Bennett forthcoming). Nomological causation is not usually seen as connected to fundamentality in this way (although Bennett demurs). However, this observation poses no threat to G=MC. Nomological causation is typically connected in an analogous way to an analogous ordering: the temporal ordering. (And, as already noted, there are parallel challenges to the claims that grounding partially orders events with respect to fundamentality and that nomological causation partially orders events with respect to time.) I have suggested that the difference between nomological causation and grounding should be traced to a difference between how the dependencies are mediated. Dependencies between facts about different times are typically mediated by the laws of nature, while dependencies between facts about different levels of reality are typically not mediated by the laws. This suggestion explains why nomological causal connections typically structure the world with respect to time, while metaphysical causal connections typically structure the world with respect to fundamentality.

Part of the orthodox view of ground is *grounding necessitarianism:* the principle that full grounds necessitate the facts they ground. While this is a standard principle of ground, validated within the systems of e.g. Fine and Schaffer, it has been challenged by a number of authors. Leuenberger (2014) and Skiles (2015) have argued directly against it. Parsons (1999) and Briggs (2012b) have argued that the relation of truthmaking does not entail the corresponding strict conditional; so if truthmaking is a kind of full grounding then these authors deny that full grounds always necessitate. For the purposes of this paper, I can remain neutral on grounding necessitarianism. Still, it is plausible that full grounds at least sometimes necessitate

the facts they ground, while sufficient nomological causes at least sometimes do not. Fortunately, this distinction between metaphysical causation and nomological causation is predicted by G=MC in conjunction with the demarcation criterion proposed above. Given the widespread assumption that laws of nature are metaphysically contingent, then a failure of necessitation for nomological causation is just what we should expect; if an instance of a dependency relation is mediated by a contingent fact, then there is no barrier to the possibility of the cause obtaining without the effect obtaining. Instances of metaphysical causation in contrast are not typically mediated by any contingent fact; it is then entirely to be expected that the grounding fact necessitates the grounded fact.

3. Cases of Metaphysical Causation

Further explication of grounding tends to go by way of example, and the recent literature contains a rich and diverse diet of cases. Here is a representative sample:

Singleton: The existence of Socrates grounds the existence of singleton Socrates.

Double-negation: The truth of P grounds the truth of ¬¬P.

Disjunction: The truth of P grounds the truth of P∨Q.

Conjunction: The truth of P grounds the truth of P&Q.

Truthmaking: The existence of Socrates grounds the truth of 'Socrates exists'.

Mind/body: My being in brain state B grounds my being in mental state M.

Part/whole: The existence of my head grounds my existence.

Act-Consequentialism: Act A's having the best consequences grounds A's being right.

Euthyphro: God's desiring that P grounds its being good that P.

Noether: The symmetry of the laws of nature under time-translation grounds the fact that energy is a conserved quantity.

Since these cases are so different from one another, there is plenty of scope to deny that they are all genuine instances of grounding. For example, we could follow Ramsey (1927) in thinking ¬¬P just a notational variant on P, and deny Double-negation. Identity theorists deny Mind/Body. And of course, deontologists deny Act-Consequentialism and non-theists deny Euthyphro. Accordingly, it is not necessary or even desirable that a theory of grounding should entail that each one of these examples is a genuine case of grounding. But a theory of grounding ought to underwrite these grounding claims at least in the context of the background assumptions that have typically motivated their defenders; otherwise, the theory could reasonably be accused of changing the subject.

Armed with the distinction between full ground and partial ground, understood by analogy with sufficient cause and contributory cause, we can readily see that some of our cases correspond to full ground and others to partial ground. Plausibly Singleton, Double-Negation, Disjunction, Truthmaking, Mind/Body, Act-Consequentialism, Euthyphro and Noether are cases of full grounding (sufficient metaphysical causation) and Conjunction and Part/Whole are cases of partial grounding (contributory metaphysical causation). However, a case could be made that (say) Truthmaking and Euthyphro are in fact cases of partial ground: in addition to the worldly facts, we may need to add in facts about meanings in English and facts about non-existence of other gods before they give us cases of full ground. For simplicity, I will focus on the remaining, less controversial, cases of full ground.

G=MC allows for a wide variety of kinds of fact amongst the causal relata. Our examples involve facts about concrete entities (Socrates), facts about abstract entities (Singleton Socrates), and facts about entities which are neither clearly abstract nor clearly concrete (God, laws of nature). Consequently G=MC falsifies the familiar thought that abstract objects are outside the causal order.[10] How bad is this result? It is widely (although not universally) held that abstracta do not enter into causal relations. Indeed, acausality is one of the criteria that David Lewis considers when seeking to characterize the abstract/concrete distinction (Lewis 1986b). But as I see it, the primary motivation for thinking that abstract objects are acausal is that abstract objects fail to engage in the kinds of activity which can sustain causal production (see p.11). Abstracta do not have mass or couple to quantum fields. Will we then propose new dynamical theories for abstract objects, positing metaphysical forces between them, to sustain metaphysical causation? No; a parallel physics of abstracta is a bad plan. But we can do full justice to this thought via a prohibition on abstract causal production, while still allowing for abstract causal dependence. Causal dependence need not rest on any productive connection between cause and effect: a classic example of this is causation by omission. But more generally, we can go along with Hall's denial that dependence need go via production, and interpret G=MC accordingly: we identify grounding with metaphysical causal dependence rather than with metaphysical causal production.[11] Metaphysical causation need not involve any form of causal production—no metaphysical 'biff'!—but it does need to involve characteristically causal patterns of counterfactual dependence.

[10] Versions of this argument could be run with respect to specific kinds of abstract objects (such as sets), or with respect to some characteristic feature of some abstract objects (such as lack of spatial location). My response will also apply to these variant arguments.

[11] This response could alternatively be made out by appeal to a flavour of causal pluralism other than Hall's: see, for example, Sober (1985), Hitchcock (2003), Cartwright (2004), Psillos (2009), Godfrey-Smith (2010), Strevens (2013).

It is also worth noting that causation *simpliciter* is often not seen as restricted to causation amongst concreta; for example, God's act of bringing the world into existence (and time along with it) is pretty widely taken to be a potential case of causation, even though it is not obviously a case of causation amongst concreta. Likewise, a restriction of 'causation' to refer to causation amongst concreta would render Amie Thomasson's influential defence[12] of the view that works of art are created abstract objects (as well as the Cartesian dualist view that minds are non-concrete objects with causal powers) as just conceptually or linguistically confused. However, I don't need to rest too much on the conceptual coherence of any particular cases of causation involving abstracta. What I am arguing is that the general notion of causal dependence is conceptually separable from its particular application to concrete objects, events, and states of affairs.

These various manoeuvres may seem to miss the point. Doesn't intuition tell us directly that grounding is not a type of causation? A distinguished anticipation of this objection can be found in Kim (1973), who influentially criticized Lewis's theory of causation for not adequately distinguishing counterfactual dependence in virtue of causation from counterfactual dependence in virtue of two events overlapping and hence sharing a common part. Kim took it to be intuitively obvious that counterfactual dependencies deriving from overlap should not count as causation. Other similar objections maintain that it is intuitively obvious that causation must hold between events at different times, or between events with spatial extension.

Objections from direct intuition can be resisted either by denying the evidential force of intuitions in the relevant domain, or by arguing that we do not in fact have the alleged intuitions. Examples of the former strategy include David Wallace on objective chance (Wallace 2012) and Alastair Wilson on laws of nature (A. Wilson 2013), and examples of the latter include Sydney Shoemaker on laws of nature (Shoemaker 1980, 1998) and Robert Williams on gunk (Williams 2006). Both strategies seem applicable to our intuitions concerning grounding and causation. We could maintain that the relevant issues are simply too highly theoretical and abstract for intuition to carry weight: nothing in our evolutionary history, one might argue, has adapted us to be accurate in our intuitions about fundamental ideological notions within metaphysics. Alternatively, we can offer nomological causation—the type of causal dependencies that themselves depend on the laws of nature—as the source of our problematic intuitions, saying that we mistake intuitions about nomological causation for intuitions about causation in general. Such a mistake might be unsurprising, given the prominence of nomological causation in our everyday lives.

[12] See, e.g., Thomasson (1999, 2007).

One way of pushing the challenge from intuition would be to insist that the term 'causation', as it is generally used, analytically excludes cases of grounding. If this is so, then defenders of G=MC are simply misunderstanding the terms they use. But this is a dangerous line of thought: it threatens to make taxonomic progress in science impossible. Compare: if everyone believes that all dinosaurs were in fact scaly lizard-like things, then everyone will be inclined to take the extension of 'dinosaurs' as it occurs in "birds are a type of dinosaur" to include only scaly lizard-like things. But we should not conclude that the hypothesis that birds are a type of dinosaur is confused, contradictory or analytically false. Instead, that birds are dinosaurs is a perfectly reasonable revisionary taxonomic hypothesis, one that contemporary palaeontologists take seriously. What a palaeontologist who floats this hypothesis is suggesting is that, in order to optimize our classificatory scheme, we should expand our category 'dinosaur' to include birds. I am proposing G=MC in the same spirit.

We have seen some putative cases of metaphysical causation, and addressed some initial objections to G=MC that arise from them. In the next section, we will use our cases to draw out a systematic connection between grounding and counterfactuals.

4. Metaphysical Dependence Counterfactuals

The simplest counterfactual analysis of causation is the early theory of Lewis (1973)[13]. Lewis defines causation as the ancestral of counterfactual dependence, where counterfactual dependence of P on Q requires the truth of $\neg Q \mathrel{\Box\!\!\rightarrow} \neg P$. Here are the Lewisian counterfactuals corresponding to our examples of full ground[14]:

CF-Singleton: If Socrates had not existed, nor would have Singleton Socrates.

CF-Double-negation: If P had not been true, nor would $\neg\neg P$ have been.

CF-Disjunction: If P had not been true, nor would $P \vee Q$ have been.

CF-Mind/body: If I had not been in brain state B, I would not have been in mental state M.

CF-Act-consequentialism: If act A had not had the best consequences, A would not have been right.

CF-Euthyphro: If God had not desired that P, P would not have been good.

CF-Noether: If the laws of nature had not been symmetric under time-translation, then energy would not have been a conserved quantity.

[13] Lewis's account draws directly on one of Hume's 'two definitions of cause' (Hume 1748).

[14] These examples are posed in the past tense (had not) instead of the present tense (were not to). I think this makes judgments clearer without affecting any substantive issues.

Some of these counterfactuals seem fine: for example, CF-Singleton, CF-Double-negation, and CF-Noether. This suggests we are on the right track. But it looks like there are potential problems with others of them, of two different kinds:

- Some of the antecedents may be metaphysically impossible (as in the case of CF-Euthyphro, or of CF-Double-Negation for any necessarily true P), in which case those counterfactuals are *counterpossibles*.
- Some of the counterfactuals seem to have the wrong truth-conditions. For example, CF-Disjunction looks false: if P had not been true, P∨Q might still have been true (e.g. if Q were true). And CF-Mind/Body looks false also: perhaps if I had not been in brain state B, I might have been in a very similar state B*, in which case I would still have been in mental state M.[15]

The first issue is discussed in a companion paper (A. Wilson forthcoming) and is mostly set aside here. For the purposes of this paper I will be assuming (with Brogaard & Salerno, Fine, Goodman, Kment, Nolan, Priest, *et al.*)[16] that we can ascribe non-trivial truth-conditions even to counterfactuals with metaphysically impossible antecedents. (For further defence of this assumption, see §6.) The second issue will be handled by the interventionist approach to be introduced later in this section; for more details on how this works, see the discussions of symmetric overdetermination in §5 and of causal proportionality later on in this section. In the meantime, we have a more urgent issue to confront. Even if the CF counterfactuals do hold, there might nevertheless fail to be metaphysical causal dependence as a result of the unwanted truth of some additional counterfactuals.

Since grounding is usually asymmetric, if G=MC is correct then metaphysical causal dependence must likewise usually be asymmetric. Therefore, in addition to the holding of a given CF counterfactual, a simple counterfactual account of metaphysical causation will typically require the *failure* to hold of the corresponding RCF counterfactual:

RCF-Singleton: If Singleton Socrates had not existed, Socrates would not have existed either.

RCF-Double-negation: If ¬¬P had not been true, P would not have been true either.

RCF-Disjunction: If P∨Q had not been true, P would not have been true either.

[15] See Yablo (2004) and Menzies & List (2009) for more discussion.

[16] See e.g. Brogaard & Salerno (2007), Goodman (2004), Kment (2006), Nolan (1997), Priest (2005).

RCF-Mind/body: If I had not been in mental state M, I would not have been in brain state B.

RCF-Act-consequentialism: If act A had not been right, it would not have had the best consequences.

RCF-Euthyphro: If P had not been good, God would not have desired it.

RCF-Noether: If energy had not been a conserved quantity, the laws of nature would not have been symmetric under time-translation.

Unfortunately, many of these RCF counterfactuals seem to be as plausible, or nearly as plausible, as their CF counterparts. This looks like a challenge for defenders of G=MC; if the RCF counterfactuals are true, and if their truth suffices for causal dependence, then we get pervasive two-way grounding dependence. This consequence could be used as a *reductio* of the very idea of metaphysical causation, and accordingly (at least for grounding enthusiasts) as a *reductio* of G=MC. However, such a conclusion would be much too hasty. The problem is not specific to metaphysical causation, and so it cannot form the basis of an objection to G=MC.

Similar problems with the truth of reverse counterfactuals afflict counterfactual analyses of nomological causation even in the simplest cases. Had the window not smashed, it would have been because no brick collided with it. But I am standing right by the window. So: *had the window not smashed, I would not have thrown the brick at it.* It is a familiar point that the apparent truth of this latter counterfactual should not lead us to conclude that the smashing of the window caused me to throw the brick. Any counterfactual account must deal with this problem of causal asymmetry somehow or other, and no reason has been given to think that successful solutions to the problem will not generalize to the case of metaphysical causation.

The standard way of dealing with the problem of causal asymmetry for counterfactual analyses of causation has been to restrict the analysis so as to associate causal dependence only with a certain class of counterfactuals, a class that does not include the problematic smashing-to-throwing counterfactual. Lewis dubbed the problematic counterfactuals *back-trackers*, and restricted his analysis (Lewis 1973b/1986) so that only non-back-tracking counterfactuals were sufficient for causal dependence. In combination with Lewis's proposed semantics for non-back-tracking counterfactuals in terms of 'small miracles' (Lewis 1973a), this account successfully excludes the most obvious problem cases[17].

[17] Lewis (1979/1986) tweaked his original semantics to avoid cases like Kit Fine's example of Nixon's button (Fine 1975). The specifics will not concern us here.

The word 'back-tracking' does not properly capture what is wrong with the RCF reverse metaphysical dependence counterfactuals. Unlike the smashing-to-throwing counterfactual, the RCF counterfactuals do not track back in time from the (supposed) cause and then forward again to the (supposed) effect; they instead track *down* in the 'order of being' from the (supposed) cause and then back *up* to the (supposed) effect. So we might call them *down-trackers*, using the collective term *wrong-tracker* to cover both back-trackers and down-trackers. If G=MC is on the right lines, it suggests that back-tracking and down-tracking are different ways of wrong-tracking, and that there is a unified class of non-wrong-tracking (or *right-tracking*) counterfactuals which sustain genuine relationships of causal dependence. We can test this hypothesis by considering a curious feature of back-trackers, described by Lewis as a 'syntactic peculiarity':

> Back-tracking counterfactuals, used in a context that favors their truth, are marked by a syntactic peculiarity. They are the ones in which the usual subjunctive conditional constructions are readily replaced by more complicated constructions: "If it were that... then it would have to be that ..." or the like.
>
> Lewis (1979) p.458

This feature is also had by down-tracking counterfactuals. The RCF counterfactuals listed above are indeed more idiomatically posed with the more complicated forms Lewis refers to. If Socrates's singleton had not existed, then it *would have to have been that* Socrates didn't exist; if ¬¬P hadn't been true, P *could not have been* true either; if energy had not been a conserved quantity, the laws of nature *would have had to have been* non-symmetric under time-translations. The CF counterfactuals, in contrast, are if anything less felicitous when posed in these more complicated forms and certainly do not gain in felicity to the same extent. To my ears at least, "If act A had not had the best consequences, it would have had to have not been right" seems to introduce a complication that is irrelevant to the thought being expressed.

An adequate counterfactual analysis of causation must provide a natural, informative and non-*ad-hoc* characterization of right-tracking counterfactuals. In the case of nomological causation, we could try to pick out right-trackers by reference to time variables somehow associated with the antecedent and the consequent; we simply specify that the antecedent-time must be earlier than the consequent-time. This move is already unattractive in the case of nomological causation, because it rules out causal loops, but it is transparently hopeless in the case of metaphysical causation. We (perhaps!) have a grasp on an event's temporal location that is independent of nomological causal facts about it; we lack any grasp of the level of a fact in the order of being that is independent of grounding facts about it.

Lewis hoped to avoid making the temporal asymmetry of counterfactual dependence (and hence of causal dependence) into a necessary truth about causation. Instead, he hoped to exclude back-trackers by appeal to large-scale features of worlds like ours, which he thought would infect back-trackers with widespread indeterminacy (Lewis 1979/1986). *If I had not flicked the switch, the light would not have gone on.* This counterfactual is determinately true: the closest antecedent-worlds will all be pretty similar, and in none of them the light goes on anyway. But the reverse counterfactual, Lewis argued, is not determinately true. A wide variety of alternative courses of events might well have given rise to the light not going on; my not flicking, a power cut, a blown bulb, a loose connection. The closest antecedent worlds are diverse, and there will be very little true at them all.

Will anything like this Lewisian indeterminacy-based manoeuvre work to distinguish right-tracking from wrong-tracking counterfactuals in full generality? No: even if it were successful in the case of nomological causation (and it is not[18]), the manoeuvre would not carry over to the case of metaphysical causation. The asymmetry of traces in the actual world, as we have learned from thermal physics, is intimately tied to the monotonic increase in entropy in closed macroscopic systems. But there is apparently no physical basis for any asymmetry of traces in the metaphysical order of being, no physical quantity which is determined in a lawlike way to be greater for a grounding entity than for the grounded entity. Absent any independent reason to believe reality has the relevant feature, the Lewisian indeterminacy-based manoeuvre does not get off the ground.

One possible response to the difficulties with characterizing right-tracking is to capitulate, and to give up the goal of analyzing causation in non-causal terms. We could characterize the right-tracking counterfactuals as those where the consequent is causally dependent on the antecedent. Any resulting counterfactual theory of causation would then be so uninformative that it could scarcely qualify as an analysis; but perhaps this is the best we can do. Giving up in this way on the project of the counterfactual analysis of causation, and thereby 'taking causation as primitive', would not undermine G=MC. It would not threaten the analogy between grounding and nomological causation emphasized throughout the paper, and it would not vitiate the theoretical benefits of identifying grounding with metaphysical causation set out in §1. However, in the remainder of this paper I will focus on a more ambitious approach to analyzing causation: the *interventionist* approach associated with Woodward (2003), Hitchcock (2001), and Pearl (2009).

[18] Elga (2001) has persuasively argued that the asymmetry-of-traces account is hopeless.

Unlike the Lewisian approach, interventionism does not comprise a full reduction of causation to counterfactual dependence, but it is still a form of counterfactual theory since it involves a non-trivial "systematic connection between causal claims and certain counterfactuals" (Woodward 2003, p. 70). As with Lewis's theory, the counterfactual dependencies sufficient for causation must be restricted in order to prevent wrong-trackers from giving rise to spurious causation. To encode the distinction between right-trackers and wrong-trackers, interventionists make use of *causal models* consisting of a set of *variables*, a set of *structural equations* relating values of the variables, and an *assignment* of actual values to variables. The distinction between right-tracking and wrong-tracking counterfactuals is then derived in the interventionist framework from a distinction between *appropriate* and *inappropriate* causal models. Right-tracking counterfactuals are those with antecedents specifying some combination of *interventions* on model variables in some appropriate model, and with consequents specifying some values for other model variables in that model.

Interventionists do not offer any independent characterization of appropriateness; an appropriate model is just one which correctly captures the causal structure of the situation modelled. This non-reductive approach is of course controversial; my claim is simply that such a move is no less plausible in the case of metaphysical causation than it is in the case of nomological causation. One possible deflationary interpretation of the project of non-reductive analysis reads it as offering not a single non-directed analysis but as offering a disjunction of two analyses; either appropriateness is reductively analysed in terms of causation, or causation is reductively analysed in terms of appropriateness, but the interventionist declines to commit herself to which analysis is correct and commits herself only to the disjunction. This understanding of interventionism is likewise just as applicable to the case of metaphysical causation as it is to the case of nomological causation.

The reliance on appropriate models is key to the way in which interventionists distinguish sufficient causes from contributory causes, and hence to the way in which full grounds will be distinguished from partial grounds in light of G=MC. What is a sufficient cause according to one causal model might be different from what is a sufficient cause according to a more complex causal model that incorporates additional variables. Accordingly, interventionist verdicts both about sufficient causes and about full grounds rely on a judicious choice of appropriate model. There are various attitudes one could take to this situation—one could hold that sufficiency is model-relative and that choice of models is a pragmatic business, or that verdicts of sufficiency are correct only if validated by some 'one true causal model' for the

whole of reality, or that a model is appropriate if no inclusion of additional variables undermines the model's verdicts about sufficiency. Since these problems arise just as forcefully for interventionist approaches to nomological causation as they do for interventionist approaches to metaphysical causation, I will set them aside.

The reliance on appropriate models is likewise key to the interventionist response to worries about causal proportionality. Whether CF-Mind/Body is true depends on which model is appropriate, and in particular on whether interventions on the physical state variable in the appropriate model give rise to radically different or merely slightly different physical states. While there is no standard solution to this problem—see Yablo (1992) for discussion and Woodward (2008) for an interventionist treatment of proportionality—we can again set the issue aside for present purposes since it applies with equal force to cases of nomological causation and to cases of metaphysical causation. Any adequate interventionist treatment of proportionality for nomological causation will carry over to an adequate treatment of proportionality for metaphysical causation.

The notion of an intervention does a lot of work for interventionists. It in effect plays the role allotted to small miracles in the Lewisian semantics for right-tracking counterfactuals, the role of specifying that the antecedent be realized in a way which does not 'drag along' unwanted causal history. An intervention is a 'clean' alteration of the value of a particular variable that does not affect the values of upstream causal variables: for example, an intervention on the reading of a barometer leaves unchanged both the pressure in the room and the barometer's own causal origins. It is immediately apparent that interventionism does not offer a reductive theory of causation, since the notion of an intervention is explicitly causal. Nonetheless, interventionists typically maintain that their account is still informative because it shows us how various distinct causal claims are conceptually connected to one another. Interventionism will deliver verdicts about specific causal dependencies once we have specified a causal model, even though there is no algorithm for building causal models which does not itself appeal to causal judgments. By applying the interventionist analysis to grounding construed as metaphysical causation, we might accordingly hope to derive some interesting and informative results about the relation of different grounding claims to one another.

If the non-reductive approach to explicating causation is worthwhile in the case of nomological causation, then it ought also to be worthwhile in the case of metaphysical causation. In the next section, I will show how the approach handles familiar cases of grounding, by exploring a selection of metaphysical causal models.

5. Metaphysical Causal Models

From an interventionist perspective, the counterfactual dependencies involved in metaphysical causation will be underwritten by a particular *metaphysical causal model*. This section describes causal models for four kinds of case from the causation literature, offers metaphysical causal models with the same structure, and discusses some interpretive problems that arise.

The metaphysical causal models presented below help us in at least two ways. Firstly, the models reflect a range of potential patterns of metaphysical causation; this illustrates the flexibility of an approach to grounding based on G=MC. Secondly, the models correspond to metaphysical versions of well-known puzzle cases from the causation literature; this further reinforces the analogy between grounding and nomological causation by showing that that the same theoretical pressures arise for analyses of both notions. The models include cases (omission and double prevention) that motivate Hall's distinction between causal production and causal dependence (Hall 2004), as well as cases (symmetric overdetermination and early pre-emption) that have often been raised as counterexamples to simple counterfactual theories of causation but which can be handled by the interventionist approach[19].

Each model, formally speaking, consists of a set of variables representing features of reality, a set of structural equations linking the values of the variables according to the causal structure of reality, and an assignment function specifying which values the variables actually take. We may think of each variable as a question, and of the possible values of each variable as the various possible answers to that question (Briggs 2012a). Variables may in general be either discrete (whether Socrates exists) or continuous (how tall Socrates is). The facts that ground and are grounded, in this framework for modelling metaphysical causation, are thus identified with question-answer pairs: think of them, if you like, as 'the fact that A is the correct answer to Q'. For yes/no questions we conventionally assign values of 1 for 'yes', 0 for 'no'.

The structural equations of a causal model are written in the form $A=f(B,C,D...)$. It is important to note that this '=' does not denote identity, or indeed any symmetric relation. Instead it expresses the counterfactual dependence of A on a function of some other variables. Thus, each causal model encodes a set of counterfactual dependencies: if B, C, D *were* set to specific values by an intervention,

[19] Interventionists claim significant advantages over other counterfactual theories of causation with respect to these cases. See Woodward (2003) for an interventionist treatment of pre-emption in both its early and late varieties (p.77-81), and for an interventionist treatment of symmetric overdetermination (p.83-84).

A *would* take a specific value. This central role played by counterfactual claims in the interventionist framework is what marks it out as part of the broad tradition of counterfactual approaches to causation. For the standard philosophical account of interventionist counterfactuals, see Woodward (2003 p.59-61); for detailed explorations of their semantics, see Briggs (2012a) and Santorio (MS).

Now that we have encountered the structural equations of a model, we can use them to characterize the notion of a mediating principle that was introduced in §1. Mediating principles are general facts that determine which structural equations are part of an appropriate model. In other words, they are those general facts upon which the relationship between values of variables in an appropriate model depends. Each of them is a (perhaps partial) answer to the question: why is this equation part of an appropriate model of this situation? Sometimes a full answer to such questions will require citing laws of nature, sometimes it will not: in the former case we have nomological causation, and in the latter case metaphysical causation.

I here assume that we can clearly enough identify which causal dependencies are mediated by laws of nature to draw the intended distinction between nomological and metaphysical causation, at least in paradigm cases. If the nomic/non-nomic distinction has borderline cases, then there will be borderline cases between nomological causation and metaphysical causation. And, if (as contemporary Humeans maintain) the notion of a law of nature does not run metaphysically deep, then the distinction between nomological causation and metaphysical causation will likewise fail to run deep. None of this presents any problem for G=MC.

My proposed way of distinguishing between types of causation itself makes use of the ideology of causation, by invoking the dependence of a model's structural equations on the mediating principles. However, any circularity here is benign. We are not explaining causation itself in causal terms, but merely using it to help us draw additional, finer-grained, distinctions. We can go on to apply our demarcation criterion to the envisaged dependence of structural equations on mediating principles; that further dependence will typically be classified as metaphysical causation.

If the reader remains unpersuaded by my proposed characterization of metaphysical causation in terms of the nomic status of mediating principles, there remains a less ambitious alternative compatible with G=MC. This alternative is to regard the distinction between metaphysical and nomological causation as primitive, not characterizable in independent terms. The majority of my arguments would be unaffected, although the argument from ideological parsimony of §1 would lapse.

The structural equations and assignment function of a causal model may be partially represented by a directed graph with actual variable values at nodes. (The causal modelling literature, being oriented towards practical applications, tends to ignore possible cases of causal loops by requiring the graphs also to be acyclic.) Such graphical visualizations, while heuristically useful, leave out important aspects of the structure of causal models: they do not represent the alternative values a variable could have taken, or the details of complex dependencies between variable values. Accordingly, many distinct causal models may be represented by a single directed acyclic graph, so we will also need to provide a full set of structural equations to properly characterize our metaphysical causal models. In the following examples, the structural equations and assignments (and hence the visual representations) are held fixed as we move from examples of nomological causation to examples of metaphysical causation; only the interpretation of the variables changes.

The simplest possible kind of case of causation involves one fact's obtaining because another fact obtains:

Simple: Window

Variables

C: Whether Suzy throws the rock

E: Whether the window smashes

Structural Equations

E=C

Assignment

C=1; E=1

Graphical Representation

$\boxed{\text{C=1}} \rightarrow \boxed{\text{E=1}}$

Models with this structure also describe straightforward cases of grounding:

Simple: Singleton

C: Whether Socrates exists

E: Whether Singleton Socrates exists

Simple: Colour

C: Whether the brick is red

E: Whether the brick is coloured

Our second kind of case, causation by omission, involves a dependence of the effect (here, the fact that the plant dies) on some other fact's not obtaining (here, on my failure to water the plant.) The plant dies *because* I do not water it.

Omission: Dessication

Variables

C: Whether I water the plant

E: Whether the plant dies

Structural Equations

E=1-C

Assignment

C=0; E=1

Graphical Representation

$\boxed{\text{C=0}} \rightarrow \boxed{\text{E=1}}$

Cases of causation by omission play a prominent role in the causation literature: Hall (2004) appeals to them in defending his influential distinction between dependence and production, and they drove Lewis to deny that causation is a relation at all (Lewis 2004). Examples of grounding with the same structure are easy to find. Here are two: the set of unicorns is empty *because* it is not the case that unicorns exist, and the proposition that 1+1=3 is false *because* it is not the case that 1+1=3.

Omission: Unicorns

Variables

C: Whether unicorns exist

E: Whether the set of unicorns is empty

Omission: Falsehood

Variables

C: Whether it is the case that 1+1=3

E: Whether the proposition that 1+1=3 is false

Cases of *causal overdetermination* are interesting because they challenge simple counterfactual analyses. We can distinguish symmetrically overdetermined causation (where both causes, intuitively, 'take effect') from pre-emption (where one potential cause is prevented from taking effect by the action of another). A familiar and gruesome example of symmetrical overdetermination is the firing squad:

Symmetric Overdetermination: Firing Squad

Variables

A: Whether guard A fires

B: Whether guard B fires

E: Whether the prisoner dies

Structural Equations

E=max(A, B)

Assignment

A=1; B=1; E=1

Graphical Representation

$$\begin{array}{ccc} \boxed{\text{A=1}} & \searrow & \\ & & \boxed{\text{E=1}} \\ \boxed{\text{B=1}} & \nearrow & \end{array}$$

Symmetrically overdetermined grounding is commonplace. The presence of arsenic and the presence of strychnine each suffice to make a potion poisonous, and the truth of P and the truth of Q each suffice for the truth of their disjunction:

Symmetric Overdetermination: Poison

Variables

A: Whether the potion contains 1 gram of arsenic

B: Whether the potion contains 1 gram of strychnine

E: Whether the potion is poisonous

Symmetric Overdetermination: Disjunction

Variables

A: Whether P is the case

B: Whether Q is the case

E: Whether P∨Q is the case

As well as further illustrating the commonality between nomological causation and grounding, symmetrical overdetermination cases help us to see how the interventionist framework handles the second kind of problem for counterfactual approaches to grounding raised on p.16. In cases of symmetric overdetermination, the appropriate interventionist model contains variables corresponding to both overdetermining causes. If one of these variables is left out of the model, then the interventionist apparatus will fail to deliver the correct causal verdicts.

To check for a causal dependency between two variables A and E in symmetric overdetermination cases, we look for some variable B on which we can intervene and hold fixed so as to give rise to a counterfactual dependence of E on A (see Woodward 2003, p.82 for further discussion of interventionist treatments of symmetric overdetermination). However, if one of the overdetermining causes is not represented in the model, then there will be no such variable B that can be held fixed in the antecedent of the model's interventionist counterfactuals. Consequently, no interventionist counterfactual encoded by the model will characterize E as depending on interventions on A, and we obtain the wrong causal verdict. Once again, interventionism here relies on a distinction, which is not reductively analysed, between appropriate and inappropriate causal models of a situation: an appropriate model is one that contains all the relevant causal variables. The interventionist framework is accordingly non-reductive, but (as I argued in the previous section) this feature is no more problematic for the application of interventionism to metaphysical causation than it is for the application of interventionism to nomological causation.

In causal pre-emption cases, a potential cause is prevented from taking effect by the triggering of a causal chain leading to the effect via a different route. In the

causation literature, it is common to distinguish early pre-emption, where the pre-empted cause does not occur, from late pre-emption where the pre-empted cause occurs but the causal chain it triggers does not run to completion; here we will only need to consider early pre-emption. In the following typical case of early pre-emption, Kangaroo's eating of a tasty shrub is pre-empted by Wombat's:

Early Pre-emption: Marsupials

Variables

C: Whether Wombat bites into the plant

P: Whether Wombat swallows the plant

Q: Whether Kangaroo sees the plant

R: Whether Kangaroo eats the plant

E: Whether the plant is digested

Structural Equations

P=C

R=max(Q-C, 0)

E=max(P, R)

Assignment

C=1; P=1; Q=1; R=0; E=1

Graphical Representation

$$\begin{array}{ccccc} \boxed{C=1} & \rightarrow & \boxed{P=1} & \rightarrow & \boxed{E=1} \\ & \searrow & & \nearrow & \\ \boxed{Q=1} & \rightarrow & \boxed{R=0} & & \end{array}$$

Cases of grounding early pre-emption tend to involve one metaphysical principle trumping another. In the following examples, the presence and arrangement of my particles trumps the presence and arrangement of a subset of them in constituting a person[20], and the legal circumstances according to which a crime counts as a murder trump the circumstances according to which it counts as an assault:

Early Pre-emption: Constitution

Variables

C: Whether my particles are arranged me-wise here.

P: Whether there is a person with exactly ten fingers here.

Q: Whether a subset of my particles are arranged me-without-a-little-finger-wise.

R: Whether there is a person with exactly nine fingers here.

E: Whether there is a person here.

Early Pre-emption: Crime

C: Whether the aggressor unlawfully and premeditatedly killed the victim.

[20] This, at least, is the grounding scenario apparently envisaged by defenders of solutions to the problem of the many according to which objects are maximal on any given precisification, as in the view of Lewis (1993). See also Sider (2001).

P: Whether the aggressor should be found guilty of murder.
Q: Whether the aggressor unlawfully physically attacked the victim.
R: Whether the aggressor should be found guilty of assault.
E: Whether the aggressor should be found guilty of a crime.

A final type of causal model deserves to be mentioned. The models described above each involve either nomological causation or metaphysical causation, but we can combine the two sorts of causal link to produce 'mixed' causal models that seem quite unproblematic. In the following example, the trajectory of the cricket ball and the rules of cricket conspire to cause the fact that the batsman's team is all out:

Early Pre-emption: Cricket Wicket

Variables

C: Whether the batsman catches the ball.
P: Whether the batsman should be given out handled the ball.
Q: Whether the ball approaches the wicket.
R: Whether the ball strikes the wicket.
E: Whether the batting team is all out.

These mixed cases provide additional support for G=MC. Where some causal chain includes both grounding and causal links—as when the ball is delivered, strikes the wicket, and the rules determine that the batsman is out—we are unhesitating in our judgment that the delivery of the ball caused the batsman to be out. It is of no consequence to our intuitive judgments that a grounding link is an essential component of the causal chain; and this is just what G=MC would predict.

6. Impossible Interventions and the Classification of Causation

So far, so good. But a concern has been deferred from §4: the notion of an intervention may well seem problematic in the grounding context. How can we make sense of an intervention on any variable which has its value of metaphysical necessity? Intervening on a variable like C in the Falsehood model is metaphysically impossible. And how can we make sense of an intervention on a variable which has its value metaphysically necessitated by an upstream variable? Intervening on a variable like E in the Falsehood model generates a metaphysically impossible scenario in which 1+1=3 but the proposition that 1+1=3 is false.

Interventionists have tended to apply a constraint such as the following to the variables within a causal model[21]:

[21] Weslake (forthcoming) and Woodward (2015) use constraints of this sort as part of their interventionist solutions to the causal exclusion problem. Along similar lines, Bennett (2003) argues that two causes do not causally overdetermine an effect if one cause metaphysically

> ***Independent Manipulability:*** It is metaphysically possible that every proper subset of the variables in [a causal model] be set to every combination of their possible values by independent interventions
>
> Weslake (forthcoming)

Independent Manipulability is not compatible with an interventionist treatment of metaphysical causation. No metaphysically possible intervention can give rise to a metaphysically impossible state of affairs. And on the common assumption that full grounds metaphysically necessitate their effects (see §2), interventions on variable values that leave upstream variables unchanged give rise to metaphysically impossible states of affairs. Advocates of G=MC should embrace this consequence: metaphysical causation is inextricably bound up with counterpossible dependence, as I argue in a companion paper (A. Wilson forthcoming). The appeal to metaphysically impossible interventions is a feature, not a bug, in the present account of grounding.

I am proposing that in the light of G=MC we ought to abandon Independent Manipulability in the grounding context, and accordingly we ought to deny that Independent Manipulability is a fully general requirement on causal models. Interventionists ought not restrict themselves to considering only metaphysically possible interventions. However, a principle like Independent Manipulability may still have a valuable subsidiary role to play: it might hold for the nomological causation that interventionists have aimed to model, yet fail for metaphysical causation. Such a supposition would allow us to continue to use the Independent Manipulability requirement to guard against widespread nomological causal overdetermination, without undermining the interventionist treatment of metaphysical causation.

These considerations concerning the modal status of interventions can potentially be exploited to distinguish in a more fine-grained way among sub-species of causation. On this line of thought, physical causation would be a type of nomological causation mediated by the laws of physics; accordingly, some interventions on the appropriate model will be physically impossible. Biological causation, by contrast, would be a type of nomological causation mediated by laws of biology but not by laws of physics; accordingly, intervening on the appropriate model would be physically possible but biologically impossible. Psychological causation would be a type of nomological causation mediated by psychological laws, with interventions on

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necessitates the other. Although I cannot tackle the exclusion problem here, any widespread causal overdetermination resulting from G=MC ought not to worry us. Common sense may tell us that events are not systematically overdetermined with respect to nomological causation, but it does not tell us that events are not systematically overdetermined with respect to causation in general.

the appropriate model being biologically possible but psychologically impossible; and so on. Generally, for every distinct type of law of nature L that we countenance, we can characterize a corresponding species of nomological causation—L-causation—such that L-dependencies are mediated by L-laws and the interventions involved give rise to L-impossible scenarios that are nonetheless possible in some wider sense.

A similar strategy can be used to classify different varieties of metaphysical causation. Perhaps logical grounding is a type of causation mediated by logical laws or valid rules of inference; perhaps mereological grounding is a type of causation mediated by laws of mereology; perhaps set-theoretic grounding is a type of causation mediated by axioms of set theory. I have only been able to sketch the resulting classification scheme here, but I hope that this sketch still goes some way towards illustrating the potential theoretical fruitfulness of G=MC.

7. Conclusion

We are now in a position to draw together the various strings of the grounding-physical causation analogy and to sum up the overall case for G=MC. Grounding and nomological causation are alike in the following respects:

- Grounding comes in flavours—full ground, partial ground—that are exactly analogous to the notions of sufficient cause and of contributory cause. (§2)
- Both the relations of (strict partial) grounding and nomological causation are ordinarily thought to form a partial order. (§2)
- Transitivity and asymmetry have been challenged for both grounding and nomological causation by appeal to structurally similar types of cases, and analogous responses are available. (§2)
- Both grounds and nomological causes can be informatively cited in explanations. (§2)
- Grounding and nomological causation stand in the same general relations to laws, necessity and inference. (§2)
- The projects of reducing each notion to counterfactuals face structurally similar problems with wrong-tracking counterfactuals. (§4)
- Both grounding and nomological causation are closely associated with distinctive patterns of one-way counterfactual dependence. (§5)
- Analogous puzzle cases challenge counterfactual analyses of each notion. (§5)
- A generalized interventionist approach can be applied to both notions, providing in each case an account which is non-reductive but potentially still informative and which handles the main puzzle cases. (§5)

My case for G=MC rests upon this systematic analogy, upon the benefits of G=MC (described in §1) with respect to ideological parsimony and to the grounding-explanation connection, and upon the coherence of mixed causal models (§5). G=MC makes sense of how we understand and assess grounding claims, and of the role they play in our metaphysical theorizing. When combined with an interventionist approach to causation and with a semantics for interventionist counterfactuals which allows for non-trivial counterpossible truth and falsity, G=MC delivers sensible verdicts over a wide variety of cases.[22]

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