Laws of Metaphysics for Essentialists

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Abstract

A recent methodological approach at the interface of metaphysics and philosophy of science suggests that just like causal laws govern causation, there needs to be something in metaphysics that governs metaphysical relations. Such *laws of metaphysics* would be counterfactual-supporting general principles that account for the explanatory force of metaphysical explanations. There are various suggestions about how such principles could be understood. They could be based on what Kelly Trogdon calls *grounding-mechanical explanations*, where the role that grounding mechanisms play in certain metaphysical explanations mirrors the role that causal mechanisms play in certain scientific explanations. Another approach, by Gideon Rosen, takes it that there are *essentialist* principles or laws that tell us about what grounds what. Finally, Jonathan Schaffer defends an approach that he considers to be neutral regarding grounding or essences. In this paper I will assess these suggestions and argue that for those willing to invoke a non-modal notion of essence, there is a more promising route available: metaphysical and scientific explanations may be unified in terms of general essences. Accordingly, essentialists may be better viewed as *outlaws* when it comes to laws of metaphysics.

Keywords: Grounding, Essence, Metaphysical Explanation, Scientific Explanation, Dependence, Metaphysical Laws.

1. Unifying Scientific and Metaphysical Explanation

This paper discusses two interesting, related questions at the interface of metaphysics and philosophy of science. They are both linked to the idea that there is an important analogy—or more than just an analogy—between scientific explanations that involve causal laws or laws of nature (I use these notions synonymously), and metaphysical explanations that involve laws of metaphysics. Laws of metaphysics could be understood as counterfactual-supporting general principles that are responsible for the explanatory force of non-causal, metaphysical explanations. Here is a simple example, which assumes that set membership captures a distinctly metaphysical relation: 'if Socrates exists (or existed), then the singleton set of Socrates, {Socrates}, exists' (cf. Fine 1994, Schaffer 2018). And here is an analogous example of a counterfactual-supporting principle in the realm

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of laws of nature: 'If a positively charged particle were to come in the vicinity of a negatively charged particle, these particles would attract each other'. The two questions to be discussed are:

(1) Is the proposed analogy between scientific and metaphysical explanation substantive and helpful?[1]

(2) Can we unify scientific and metaphysical explanation?

If the answer to the first question is affirmative, then this could provide a route towards a positive answer to the second question.

Metaphysical explanation itself is now commonly discussed under the label *grounding*. There are several suggestions in the literature as to what the relationship between scientific explanations involving causation and metaphysical explanations involving grounding is supposed to be. A strong motivation to develop theories about this connection is related to the *unity of explanation*, the thought that our explanatory endeavours in the sciences and in philosophy are importantly similar, if not identical. Here are a few representative quotations from recent work in this area:[2]

> [T]here is a far-reaching structural analogy between causation and grounding. Just as earlier states of the universe typically give rise to later ones by causing them, metaphysically more fundamental facts give rise to less fundamental ones by grounding them. Certain general metaphysical principles, which I will call 'laws of metaphysics', play essentially the same role in grounding as natural laws do in causation (Kment 2014: 5).

> The unificatory role of explanation clearly calls for explanations to involve generalizations, which serve to subsume a given case under a more general pattern. But it is also worth noting that the generalizations involved cannot merely happen to hold in our world, but must also be *non-accidental* generalizations which are counterfactually robust. And so the unificatory role of explanation requires the presence of counterfactual-supporting general principles, to serve as stable patterns (Schaffer 2018: 7).

> […] just as there is a type of scientific explanation that appeals to causal mechanisms—causal-mechanical explanation—there is a type of metaphysical explanation that appeals to grounding mechanisms—grounding-mechanical explanation (Trogdon 2018: 1290).

Each of these approaches is different and I cannot discuss all the details here, but I take it that they share an important hope, namely, the hope to unify (at least a subset of) scientific and metaphysical explanations. In each case, this hope is strongly supported by an analogy between certain aspects of metaphysical and scientific explanation, specifically, an analogy between grounding and causation. This suggests an affirmative answer to question (1).

There has also been a significant critical reaction to this claim of unity between scientific/causal and metaphysical explanation, and especially to the

[1] Thanks to an anonymous reviewer for suggesting this formulation of the question.

[2] Other important work discussing the relationship between scientific and metaphysical explanation, as well as grounding and causation, includes Bennett 2017, Bernstein 2016, Fine 2012, Glazier 2016, Koslicki 2016, Kovacs 2017, 2020, Rosen 2017, Schaffer 2016, Wilsch 2015, J. Wilson 2014, 2016, and A. Wilson 2018.

analogy between grounding and causation (e.g., Bernstein 2016, Koslicki 2016, and J. Wilson 2014, 2016). One motivation behind this reaction is scepticism about grounding more generally. I am sympathetic to the arguments suggesting that we ought to go more fine-grained and distinguish between different metaphysical dependence relations, or 'small-g grounding relations', such as composition, functional realization, and set membership, instead of trying to account for all of these in terms of a unified notion of grounding (Wilson 2014: 539). This would appear to suggest a negative answer to question (1), although it's not clear whether this is the direct intention of all those who have criticised the grounding-causation link.

However, even if one favours a variety of metaphysical dependence relations instead of a singular 'big-G grounding relation', this does not necessarily entail a negative answer to question (2). I suggest that we can unify scientific and metaphysical explanation despite the challenges posed by a more fine-grained approach to metaphysical dependence relations. Accordingly, I wish to defend a positive answer to question (2), albeit motivated differently from the one developed on the basis of a positive answer to (1). Instead of a direct analogy between grounding and causation, I will seek a unified account of scientific and metaphysical explanation via *essentialist explanation*—the notion is familiar from Martin Glazier (2017) with this very title. While Glazier argues that some metaphysical explanations that involve essences cannot be understood in terms of ground (without any dedicated attention to scientific explanation), I will argue that at least some scientific explanations are best understood as involving essences (while remaining neutral about whether or not they can also be understood in terms of ground).[3]

2. Explanation Tracks Dependence

A key assumption of the framework that I wish to adopt is the idea that *any* kind of explanation must be linked to dependence relations. Specifically, what gives explanations their explanatory power is some relation or relations of dependence that obtain between the *explanandum* and the *explanans*. Roughly, this allows us to distinguish between 'worldly' or metaphysical, and representational or epistemic content. This is a rather traditional view, which can be found, for instance, in Jaegwon Kim's account of metaphysical explanation:

> My main proposal, then, is this: *explanations track dependence relations*. The relation that "grounds" the relation between explanans, *G*, and its explanatory conclusion, *E*, is that of dependence; namely, *G* is an explanans of *E* just in case *e*, the event being explained, depends on *g*, the event invoked as explaining it (Kim 1994: 68).

Kim is not using 'grounds' in the technical sense invoked in the contemporary grounding literature (because this use had not yet been introduced), but the view he entertains seems to be straight-forwardly compatible with the 'tracking' or 'backing' view of metaphysical explanation that is receiving attention in the grounding literature (e.g., Audi 2012: 119–120, Schaffer 2012: 124, Trogdon 2013: 103–104, Thompson 2016: 44, Maurin 2019, Sjölin Wirling 2020, and Skiles and Trogdon 2021).

[3] I am sympathetic to the thought that we can give a reductive account of ground in terms of essence, but I will not pursue this line here.

The tracking view of metaphysical explanation enjoys relatively wide support, but the notion of 'ground' can be used to express both metaphysical and epistemic content. Sometimes the issue is put in terms of *unionism* and *separatism* (e.g., Raven 2015: 326). Unionism is the view that grounding is a type of metaphysical explanation and hence explanatory in its own right, whereas separatism distinguishes grounding and (metaphysical) explanation. On the latter view, ground and metaphysical explanation may be separated in such a way that ground is the metaphysical part and metaphysical explanation is the epistemic part, as it were. But the two aspects are linked via the idea that grounding relations back metaphysical explanation. The reason why this issue is particularly relevant in the present context is that this is thought to be analogous to the case of causation, i.e., causal explanations are backed by the causal relations in the world.

My own sympathies are primarily with separatism, broadly speaking: it provides a natural distinction between the metaphysical content, i.e., a worldly relation or relations of grounding or dependence, and the epistemic content, i.e., metaphysical explanation as a form of mind-dependent understanding. We can make a similar distinction in the case of scientific explanation and the causal (or similar) relations that back those explanations. In fact, this is one sense in which these explanations could be considered analogous.

The key upshot is that since 'laws of metaphysics' involve metaphysical explanations and all explanations track dependencies, there must be some dependencies underlying these 'laws' or whatever does the relevant explanatory work.

3. Laws of Metaphysics?

In this section I will first consider Jonathan Schaffer's (2018) take on the laws of metaphysics, before suggesting an alternative understanding of them in terms of essence, with reference to Gideon Rosen's account.

Schaffer attempts to put forward an understanding of laws of metaphysics which is neutral with regard to grounding or essences (although he does appear to also commit to the idea that metaphysical explanation is backed by grounding relations). To be a 'law' is here understood minimally, a law is a counterfactual-supporting general principle. Schaffer's case for the laws of metaphysics is simple: if there are metaphysical explanations, they require laws of metaphysics—counterfactual-supporting general principles—in order to have explanatory force. One argument that Schaffer considers in favour of this idea is that there is a unificatory role of explanation and this role calls for explanations to involve counterfactually robust generalizations, i.e., laws of metaphysics. He also puts forward an argument from causal explanation and from paradigm cases, but all three of his arguments are interconnected. I will frame my discussion of Schaffer's proposal in terms of the following three issues:

(1) If the account is neutral with regard to grounding and essence, then what makes metaphysical explanations *metaphysical*? In other words, what is supposed to be distinctively metaphysical about the laws of metaphysics?

(2) Even if the unificatory role of metaphysical explanation is important, why should we need laws of metaphysics to uphold this role? For those of us willing to invoke essences, there is a straightforward route to unification, or so I will argue, via the involvement of (robust, genuine, counterfactually stable) *general* or *natural kind essences*.

(3) The suggested distinctly metaphysical principles involved in 'paradigm cases' of laws of metaphysics, such as *set formation*, can be equally well (or better) accounted for in terms of general essences, which Schaffer eschews.

The suggested upshot of my analysis is that laws of metaphysics collapse to general essentialist principles. Let us look at each of these three issues in a little more detail.

3.1. What Makes Metaphysical Explanations *Metaphysical*?

Schaffer's challenge is to demonstrate that there are metaphysical explanations without resorting to any distinctively 'metaphysical' machinery such as grounding or essences. I resist this challenge and propose an explicit commitment to essentialist 'machinery'. But why should we attempt to be neutral about this machinery in the first place? Schaffer's motivation for offering a minimal or neutral account is presumably to avoid the complications that more specific proposals face and to show the general applicability of the notion of a law of metaphysics. Schaffer (2018: 2) lists some candidate cases of the relevant *non-causal explanatory connections*, which are not particularly surprising: they rely on specific metaphysical principles concerning things like truthmaking, the determinate/determinable distinction, the truth-conditions of disjunctions, set membership, and so on. By now, most readers are surely familiar with such paradigm cases of 'because' that are typically discussed in the grounding literature, so I will not spend time in presenting these cases. The important point is that any explanations of this type have what Schaffer calls a 'metaphysical flavor', and he specifies: these cases 'have the feel of concerning the constitutive generation of a dependent outcome' (2018: 3).

This an important point and it is related to the discussion in the previous section: what is responsible for the 'metaphysical flavour' is some dependence relation that 'backs' the relevant metaphysical explanation. Schaffer (2018: 12) would seem to agree on this point, as he also cites Kim's famous account of explanation. Now, as Schaffer acknowledges, this much is compatible with a type of *grounding pluralism*, such as Jessica Wilson's (2014) 'small-g' grounding relations (e.g., composition and set membership) and presumably also Kathrin Koslicki's (2015) approach. Schaffer thinks that the grounding pluralist as well can accept his entire argument for laws of metaphysics, which suggests that there must be something that unifies the 'small-g' grounding relations as well. But if that's the case, then the whole point about laws of metaphysics seems to be entirely *terminological*: if the existence of worldly, non-causal dependence relations that back explanation is postulated, then laws of metaphysics do not do any additional work here, much like Wilson's original case against 'big-G' 'Grounding' suggests in the case of grounding. In Wilson's case, the point is that we do not need to postulate a novel 'Grounding' relation that is operative in the various cases of metaphysical dependence, because we already have the 'small-g' grounding relations, i.e., the specific metaphysical dependence relations. In the present context, connecting these specific dependence relations with laws of metaphysics does not tell us anything about how to understand the relevant dependence relations themselves or what, if anything, unifies these dependence relations as the ones that back metaphysical explanations. So, I really don't think that this is going to be enough for any serious proponent of laws of metaphysics who hopes to unify

explanation—recall that this was supposed to be one of the key motivations for postulating laws of metaphysics.

Schaffer's account is supposed to be neutral with regard to grounding or essences, but he does think of laws of metaphysics in terms of grounding, and he would say that: 'a law of metaphysics is a counterfactual-supporting general principle about what grounds what' (2018: 6). So, he can perhaps salvage the account from this objection, but then it won't be neutral anymore. This is not a problem in its own right, but does mean that one of Schaffer's original motivations for postulating metaphysical laws seems to be undermined. The problem is that there are competing accounts of what, in general, supports counterfactual generalisations, which brings us to (2).

3.2. Unification via General Essences

I agree with Schaffer that the unificatory role of metaphysical explanation is important, just like it is important to unify scientific explanation. The thought here is simple: we should strive to find the lowest common denominator, since our explanatory endeavours can be simplified if two distinct phenomena share the same or similar basis. But why should we need laws of metaphysics to do this? My own view is that *general essences*, such as natural kind essences (as opposed to *individual essences*), can do the job here.[4] It is worth mentioning that there are also essence-based accounts of laws of metaphysics, such as Rosen's, where it lies in the *nature* (or essence) of the grounded fact to be grounded in a certain way (2017: 285). So, on Rosen's account, it is something about the nature of the grounding relation that does the unifying:

> The plausible claim is that just as it lies in the nature of [$p \vee q$] to require either [p] or [q] as a ground, so it lies in the nature of [[p] grounds [$p \vee q$]]—and in particular, in the nature of the grounding relation itself—that facts of *this* sort need to be grounded in [p] together with an essentialist principle saying what grounds what. In a resonant slogan: It lies in the nature of metaphysical ground that particular grounding facts are always grounded in the grounds plus grounding laws (Rosen 2017: 285).

Contra Schaffer, Rosen contends that the relevant counterfactual-supporting general principle about what grounds what is an *essentialist* principle. But one might nevertheless think that Schaffer's grounding-based approach and Rosen's essentialist approach toward laws of metaphysics are on a par since they both rely on some further ontological elements to determine 'what grounds what' (despite Schaffer's attempts to remain neutral). However, I think that there is a type of category mistake looming in both suggestions. In fact, Rosen (2017: 284) even responds to such an accusation of a category mistake, concerning the idea that a law (of metaphysics) could figure along with [p] as part of the ground for [$p \vee q$]. Rosen insists that a general grounding law, say, about the nature of disjunction, can indeed be part of the grounds.

[4] A general essence explains why an entity is of this rather than that kind, but does not distinguish entities of the same kind, that is, all members of a given natural kind would share the same natural kind essence. Abstract objects like sets can also have general essences.

My worry is slightly different though, which is why it applies to both Schaffer and Rosen: why should we require any further principle—a law of metaphysics regarding 'what grounds what'—to secure the dependence between the *explanandum* and the *explanans*? One reason to be wary is that introducing a further fact about 'what grounds what' into this equation would itself seem to require an explanation, threatening infinite regress. But if we follow the simple idea that explanation tracks dependence, we have already given the whole story by the time we have identified what the relevant dependence relation and its relata are. In the example at hand, this appears to be relatively simple: the relata are [p] and [$p \vee q$] and the relation is presumably logical consequence (or logical dependence): if [p] is true then [$p \vee q$] is true. It is true that we can say of this relation that it holds in virtue of the nature of disjunction and in this sense that nature or essence contributes to the overall explanation. But there is no reason to think that the full explanation requires any additional 'grounding law' or law of metaphysics over and above the laws of logic or logical necessities which are true in virtue of the natures of all logical entities (cf. Fine 1994: 9–10).[5] So, on this view, the *modal force* and counterfactual robustness of generalisations involving logical constants like disjunction can be traced to the essences of these entities. More precisely, these *kinds* of entities, namely logical constants, have a *general essence* which gives rise to logical necessities.

Admittedly, Rosen's view need not differ very radically from the account I am proposing here. He does hold, like I do, that the answer to the question of why [p] grounds [$p \vee q$] must be that: 'it lies in the nature of disjunction that disjunctions are grounded in their true disjuncts' (Rosen 2017: 291). Moreover, he thinks that this explanation is an ultimate explanation in the sense that Glazier (2017: 2878) specifies, namely, that's where the explanation ends.[6] But consider Rosen's concluding passage:

> In many cases, if you want to know what grounds some particular fact [Fa], the answer is that [Fa] obtains in virtue of prior particular facts [$\varphi(a)$] together with a general law to the effect that whatever φs is thereby F (Rosen 2017: 289).

Now, the question that we need raise here is: what grounds that general law that whatever φs is thereby F—or better: what gives this general law its modal force (thereby making it a law)? In my view, the answer must be given in terms of the essences of the participating entities, e.g., it is part of the essence of entities of a given natural kind that they behave in a certain way. But once we have established this, we have no need to refer to a general, metaphysical law. Accordingly, it might be best to describe the essentialist approach that I favour as an *outlaw*, or a 'lawless' position (cf. also Mumford 2005).

So, I do think that it is a mistake to succumb to talk about 'laws of metaphysics', 'grounding laws' or 'general laws' in this connection or indeed to talk about the nature of metaphysical ground itself. For all we need here is the relatively

[5] There are further questions about the nature of logical consequence. For an interesting take on logical consequence and ground, see Schnieder 2018.

[6] Compare this to the debate about whether there are any laws of nature in the dispositional essentialist and powers literature: Stephen Mumford (e.g., 2005) argues in favour of 'lawlessness', i.e., the idea that powers do all the work that laws are usually postulated for, whereas Alexander Bird (e.g., 2007) defends the idea that once we have all the powers, we get the laws for 'free'. (Thanks to Toby Friend for suggesting this.)

familiar picture about essence as a basis of modal truths (as specified, e.g., in Fine 1994, Lowe 2008, and Tahko 2023a), applied to the case of metaphysical explanation understood as tracking dependence relations. This leads us to (3), which concerns other 'paradigm cases' of laws of metaphysics.

3.3. Paradigm Cases of Metaphysical Laws

Let's consider the case of *set formation*, which is indeed a very paradigmatic case. Set formation is, for Schaffer, one of the clearest cases of a law of metaphysics:

> [I]n order to explain the existence of {Socrates} from the existence of Socrates, the principle of set formation is needed to give the connection. Without set formation, the existence of Socrates and the existence of {Socrates} are just two facts with no special connection, much less the kind of asymmetric dependence that backs explanation (Schaffer 2018: 13).

Well, this is true as far as it goes, but set formation (which Schaffer limits to the context of a hierarchical conception of sets, such as the one embedded in Zermelo–Fraenkel set theory) is a very specific operation and I struggle to see what it has in common, say, with the case of disjunction discussed above, or the case of determinable/determinates. Yet, if laws of metaphysics are supposed to unify explanation, then one might think that they should together form a unified basis—similarly, many accounts of the metaphysics of laws of nature seek to find a unified basis for laws, e.g., based on powers or dispositional properties. The grounding pluralist would here point out that there are several distinct dependence relations in effect in these cases, so trying to find a single relation that unifies the cases is doomed. With some reservations, I am inclined to agree. However, building on the previous discussion regarding disjunction, we have a rather easy solution available. The solution is that just like logical constants can be regarded to have a general essence, so can sets. Indeed, any entity, be it abstract or concrete, has a general essence, which expresses the identity and existence conditions of the type of entity in question (see Tahko 2018, 2023a for further discussion). This line of thought follows an essentialist picture that is familiar, e.g., from E.J. Lowe's:

> Consider the following thing, for instance: the set of planets whose orbits lie within that of Jupiter. What kind of thing is that? Well, of course, it is a set, and as such an abstract entity that depends essentially for its existence and identity on the things that are its members—namely, Mercury, Venus, Earth, and Mars. Part of what it is to be a set is to be something that depends in these ways upon certain other things—the things that are its members. Someone who did not grasp that fact would not understand what a set is (Lowe 2008: 37).

More specifically, as I have argued elsewhere (Tahko 2018: sec 2.2.2), it is plausible that on the type of hierarchical conception of sets that we are here operating with, the set-theoretical hierarchy has an implicit modal character which is expressed by the general essence of sets. This modal character is in fact already present in the above quote from Lowe, as he specifies that sets *essentially depend* for their existence and identity on their members. Now, if this conception captures the general essence of sets, then in order to explain the existence of {Socrates} from the existence of Socrates we only need to understand that {Socrates} *is a set* and hence it essentially depends on Socrates for its existence and identity. In other

words, the general essence of sets imposes modal constraints and determines the relevant asymmetric dependence that backs explanation in cases involving sets.

Here we have the makings for a unified account of metaphysical explanation without any extra laws about 'what ground what': we simply need to recognize the role of general essences in establishing the relevant modal elements that secure the dependence and hence counterfactual robustness between the *explanandum* and the *explanans*. I suppose that one may call these essentialist truths 'laws of metaphysics' (or 'essentialist laws', as Rosen 2017: 291 seems to do). But I do not think that this is ideal since they do not have the structure of laws as we usually understand them. Admittedly, sometimes it is suggested that statements like 'all electrons have unit negative charge' express laws, but my reaction to this is very similar: these are truths about the general essences of entities and their modal implications.[7]

At the outset, I promised a unified account of metaphysical and scientific explanation, and we are not there yet. So, let us now move to some more scientifically-motivated cases and see if the same picture can be applied in that context.

4. Grounding Mechanisms and Scientific Explanation

Even if the reader is happy to follow me to the realm of essentialist explanation, it may appear that it must come with the cost of abandoning any hope of unity between scientific and metaphysical explanation. After all, the helpful analogy between these types of explanation was supposed to be based precisely on laws of metaphysics that correspond to causal laws and I have suggested that we do not need to appeal to laws of metaphysics to secure metaphysical explanation. I would now like to take a closer look at this analogy between scientific and metaphysical explanation in order to see if we can make some progress.

One promising route for laying out the analogy (or more than just an analogy) between scientific and metaphysical explanation is to consider cases of scientific explanation that appeal to causal mechanisms, as suggested by Trogdon (2018). The idea is that there are grounding explanations that are analogous to causal-mechanical explanations in science. These would be metaphysical explanations that appeal to *grounding mechanisms* or as Trogon calls them, *grounding-mechanical explanations*. So, the role that grounding mechanisms play in certain metaphysical explanations mirrors the role that causal mechanisms play in certain scientific explanations. Trogdon (2018: 1290) pitches this approach as different from Schaffer's and Alastair Wilson's, who both suggest that just like causal relationships, grounding relationships as well can be represented by directed graphs.

Trogdon also discusses cases such as set formation and the determinate-determinable relation and takes it that these are metaphysical determination relations, and that it is an essential truth about these relations that they stand in the relevant grounding relationships (e.g., it is part of what it is to be set formation that the existence of the members of a set ground the existence of the set). But we have already discussed cases of this type, so let us focus on the more original part of Trogdon's proposal. This concerns cases where 'the corresponding grounding facts aren't enough on their own to ground what they ground—they're mere

[7] I am uncertain about how exactly this lines up with Kit Fine's (2015) views about the unified foundations for essence and ground, but it seems to me that what I propose is not too far apart from the Finean picture. (Thanks to Sam Kimpton-Nye for highlighting this potential connection.)

partial grounds' (Trogdon 2018: 1291). Trogdon gives three candidate relations that involve grounding-mechanical explanation: constitution, functional realization, and mereological realization. I will focus on the last of these, partly because of Trogdon's choice of example, which makes for some interesting discussion.

Here is Trogdon's example in more detail:

> Mereological realization: part of what it is to be mereological realization is that if the Ps (e.g. certain molecular properties) stand in this relation to Q (e.g. the property of being hard) on an occasion such that the xs have the Ps, y has Q, and the xs compose y, then the fact that the xs compose y and have the Ps is among some plurality of facts that grounds the fact that y has Q (e.g. the fact that the xs compose y and have thus-and-so molecular properties is among some plurality of facts that grounds the fact that y is hard) (Trogdon 2018: 1292).

A little later, Trogdon (*ibid.*, 1297) applies this case to a cut diamond's hardness and proposes that the fact that a diamond is hard is partially grounded in the fact that its constituent carbon atoms are bonded and spatially arranged in a specific way. This grounding connection can then be modelled in terms of a grounding mechanism involving mereological realization (as in Gillett 2007) and the idea that causal powers (such as the diamond's hardness) are constituted by other causal powers. The resulting model of the relevant grounding relations is simple enough (Trogdon 2018: 1298). The diamond is composed of carbon atoms, which have certain properties, such as being bonded and spatially arranged in a specific way. These properties constitute the grounding fact and bestow causal powers to the diamond's constituent carbon atoms. The two crucial assumptions here are the following:

(1) The property of being hard is a constituent of the grounded fact (that the diamond is hard), and it is individuated by the causal powers that it bestows to the diamond.

(2) The causal powers of the carbon atoms consist of the causal powers bestowed to the diamond.

In purely philosophical terms, it is perhaps a controversial assumption that we can individuate properties like being hard in terms of the causal powers that they bestow to the thing that they are properties of (a view going back at least to Shoemaker 1980). But we can set this philosophical concern aside, because there is a more interesting issue underlying this example. This issue concerns the property of *being hard* more generally.

4.1. The Case of Hardness

Hardness is an interesting property. It can be measured by a scratching test, so a material's hardness can literally be measured in terms of its resistance to scratching by another material. Hence, in this case the property of hardness is effectively individuated in terms of the causal power to *resist* scratching. However, it also seems that this is not what hardness really *is*, i.e., it is not just the power to resist scratching—hardness can manifest in other ways as well, such as by resisting compression (or indeed not manifest at all), so it is at least multiply realizable in this sense. This may lead one to think that, say, the hardness of a diamond should really be conceived of in terms of its carbon microstructure, i.e., whatever realizes its hardness. Why should we think that hardness is anything over and above the

causal powers of the carbon microstructure? In other words, to what extent, if at all, should hardness be conceived of as a *real property* with causal powers, distinct from the powers that the carbon atoms in a specific configuration possess? This is an issue that the mereological realization model as presented above does not seem to directly address. Accordingly, the case calls for further analysis. I will suggest that it fits the pattern of a typical essentialist explanation, which does not require any further laws or a general principle in addition to the relevant general essences. But before we get there, we need to consider some further scientific detail.

As it happens, Carl Gillett (2016: 65–9) has also discussed the case of diamonds and carbon atoms as an example of compositional explanation. The case is precisely that of the diamond's hardness causing a scratch in a medium, which is glass in Gillett's example. Gillett's framework is very rich and complicated, and I cannot discuss it here in detail, but he does have something interesting to say about the question I have just raised, namely, the individuation of the relevant property of hardness and the causal powers that are bestowed to the diamond. Here is what Gillett (2016: 69) proposes: '[H]ardness and diamonds, and carbon atoms and their properties/relations, are each partially individuated by the processes that result from them.' I take it that Gillett here means 'ontologically individuated', rather than just epistemically individuated.[8] So, on Gillett's line of thought, it would seem that hardness is partially individuated by the diamond's ability to scratch glass. But in order to give a full account of what hardness really is, we will presumably have to see what other work it can do as well, and what other processes it can be involved in. However, it would clearly be hopeless to try to give a comprehensive list. Instead, I would like to borrow Mark Wilson's (2006: Ch. 6) detailed analysis of hardness and its history. He also provides a splendid diagram (Wilson 2006: 338; I will not attempt a reconstruction here) of the vast variety of different tests for hardness, of which the scratch test as applied to diamonds is merely one of many examples. This poses a further challenge for the analysis of hardness: given that it comes in a variety of very different guises, is there any plausible way to unify the phenomenon?

Even without discussing the various examples of hardness tests in any detail, we can quickly see that if we wish to (partially) individuate the property of hardness in terms of the processes that it is involved in, we will be at it for a very long time. Worse, it is not at all clear that the resulting property of hardness can be sensibly thought to be a singular property or power at all. This suggests that we would seem to need a very long list of general principles or laws of metaphysics to account for hardness, which may be taken to speak against their generality in the first place. To take one example, when we talk about the 'hardness' of certain types of plastic, it turns out that a Brinell-type 'squeeze and release' test often applied to metals will not be very useful, since plastics also have viscoelastic properties that cause the size of the indentation resulting from the test to decrease over time. These issues can have rather extreme results: 'If we followed the usual standards for the hardness of a steel, ordinary tire rubber would prove to be rather "harder" than cold-worked steel' (Wilson 2006: 339). The upshot is that we may not be able to individuate hardness, even partly, in terms of the processes that it

[8] Gillett is careful to distinguish between 'internal' and 'ultimate' ontology: 'Work in ultimate ontology seeks to articulate what entities there are in the world, including the relations between them. In contrast, internal ontology simply seeks to articulate the ontological posits of certain scientific products (Gillett 2020: 33).

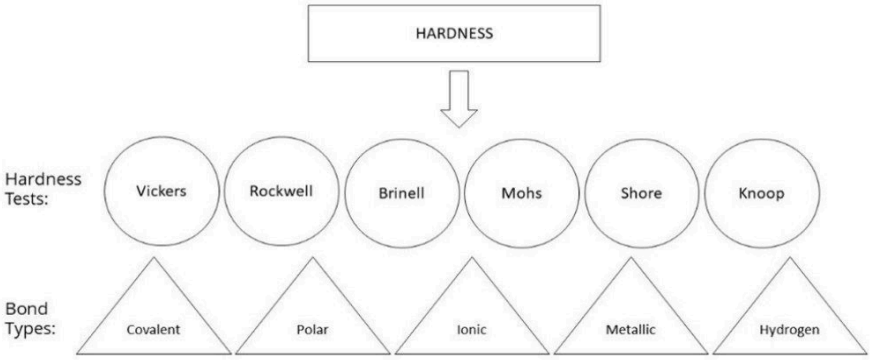
is involved in; there are just too many, and too varied, processes. So, what is *hardness*? This passage from Sidney Avner's *Introduction to Physical Metallurgy*, (also quoted in Wilson 2006: 341–2) is telling:

> The property of "hardness" is difficult to define except in relation to the particular test used to determine its value. It should be observed that a hardness number or value cannot be utilized directly in design, as can [yield value], since hardness numbers have no intrinsic significance. Hardness is not a fundamental property of a material but is related to the elastic and plastic properties. The hardness value obtained in a particular test serves only as a comparison between materials or treatments (Avner 1974: 24).

The message is clear: hardness is not a fundamental property if it is a *property* at all. This by itself does not undermine the attempt to give a grounding-mechanical explanation of, say, the diamond's hardness, since it was suggested that the diamond's hardness is grounded in the properties of carbon atoms arranged in a specific way. But if we now say that, correspondingly, the hardness of a plastic or a metal will be grounded in the properties of their constituent atoms arranged in a certain way and propose that this is a unified grounding-mechanical explanation of the property of hardness, then I think that we have gone astray. For one thing, the constituent atoms of these other materials are arranged in very *different* ways and have different bonds that underlie the relevant properties of the material. Moreover, the tests that we use to measure their hardness are also different. I do not believe that there is a useful analogy between metaphysical explanation and causal explanation on offer here; certainly not on the basis of this example. In other words, we have not yet found anything sufficiently *general* in order to put forward an analysis of hardness that would be in line with typical examples of metaphysical explanation.

However, I do think that Gillett and Trogdon are both onto something important. Even if the property of hardness turns out to be multiply based in a very messy way or indeed 'wildly disjunctive' (cf. Kim 1992: 10), it does not of course mean that the relevant causal powers would not be grounded in *something*. In other words, even if the reductive base of hardness is disjunctive, there may still be a unified account of hardness available. Yet, we are certainly not going to find a unified account of hardness at the level of carbon (or other) microstructure. We should be looking deeper. What I have in mind is that just like in the case of the earlier examples drawn from more abstract contexts, such as the case of sets, we are going to need to find the relevant existence and identity conditions—the general essence—of the kind of entity in question. So, once again it turns out that the story about the underlying general principles cannot be given without reference to some further metaphysical machinery, i.e., general essences. But since hardness appears to be shared by a vast range of different macrophysical objects, the only hope for a unifying the phenomenon would have to be something that is shared by the different realizations of this macrophysical property. What could this possibly be, and can we really find an essentialist explanation here?

Fortunately, we have learned quite a bit more about the chemistry and physics of hardness since Avner's 1974 book (see, e.g., Gilman 2009). One thing seems clear: hardness is a property that is only associated with collectives of atoms and molecules. Just like properties such as transparency or diffraction are properties that only collectives of, say, water molecules have (see Tahko 2021: 62). We already noted that different varieties of hardness are also realized by a variety of different chemical bonding mechanisms: covalent bonds, ionic bonds, polar bonds, metallic bonds, hydrogen bonds. So, we need to go even deeper to find anything in common. This is exactly what the research from the last few decades has accomplished (see, e.g., Gao et al. 2003, and Šimůnek and Vackář 2006). Fortunately, it is not in fact very difficult to find something in common for all these different cases of bonding, for they all involve the *electromagnetic force*, which can be conceived as the manifestation of the property of *electric charge*. Ultimately, it is the electromagnetic force that holds atoms and molecules together, so in this sense it is also responsible for any 'repulsion' that a macrophysical material manifests in the case of a Brinell test, a scratching test, or indeed any manipulation of a material that we might employ as a test for hardness. We can describe electromagnetic interaction via Coulomb's Law and The Lorentz Force Law, which summarises the effect of the electric force and the magnetic force. The technical details are beyond the scope of the present paper, but a simple illustration might help:



$$(1)\quad H(\mathrm{GPa}) = 350[(N_e)^{2/3} e^{-1.191 f_i}]/d^{2.5}$$

$$(2)\quad H = \frac{C}{\Omega} n \left[\prod_{i,j=1}^{n} N_{ij} S_{ij} \right]^{1/n} e^{-\sigma f_e},$$

$$f_e = 1 - \left[k \left(\prod_{i=1}^{k} e_i \right)^{1/k} \Big/ \sum_{i=1}^{k} e_i \right]^2$$

Figure 1: Hardness tests, bond types, and first principles calculations.

Figure 1 outlines six different hardness tests and five different chemical bond types. I make no attempt to match all of these, but to illustrate, the Vickers and Knoop hardness tests use a diamond indenter in the shape of a pyramid; the Vickers test can be used for all metals whereas the Knoop test is often used for brittle materials.

Depending on the material, different bond types come into play. In *Figure 1*, equation (1) is a calculation representing the hardness of an overly covalent crystal, originating in Gao et al. 2003 and picked up by Šimůnek and Vackář (2006), where N_e is the electron density expressed in the number of valence electrons per cubic angstrom, d is the bond length in angstroms, and f_i is the ionicity of the chemical bond in a specific crystal. Equation (2), from Šimůnek and Vackář 2006, is a generalised equation to calculate the hardness of more complex crystals than binary compounds. In (2), we see a system with n different binary systems described by bond strengths S_{ij} derived from the energies e_i, e_j, where N_{ij} is the number of the binary system ij, and k corresponds to the number of different atoms in the system. These recent developments are important because the experimental hardness tests are in fact fairly inaccurate:

> In principle, hardness should be related to crystal orientation. However, during the indentation, the force of the diamond wedge is diverted sideways, so the sample is subjected to a combination of stresses—compression, shear, and tension in various directions. Consequently, the anisotropic effects are reduced. Additionally, the strength of shear or tension of a sample is highly dependent on the presence of defects in the sample. As a result, experimental values of hardness can vary by more than 10% for the same sample (Šimůnek and Vackář 2006: 1).

We do not need to go into more technical detail than this. What is important is that the *first principle calculations* that equations (1) and (2) are based on represent a method to calculate physical properties directly from basic physical quantities such as mass and charge, Coulomb force of an electron, and so on. So, hardness is indeed not a fundamental property of materials. But it is, ultimately, based on bond strengths and other measurable properties (and the laws that govern them), of which electric charge is the most obvious candidate for a fundamental property.

While this explanation doesn't necessarily undermine a grounding-mechanistic account, it's clear that the source of the explanation is not available just 'one level down' from hardness. Rather, all we have here—all we need—is the fundamental property of electric charge possessed by (presumably) fundamental natural kinds such as fermions. This is precisely what we should expect on the essentialist line: we have successfully reduced the various dis-unified higher-level explanations to fundamental natural kinds whose general essences ultimately constrain all the phenomena that we typically capture under the label of 'hardness'. Let us now take a step back and look at the broader picture and its applicability.

4.2. Reductionist-Essentialist Explanation

The plausibility of the grounding-mechanistic account depends on whether or not it is compatible with the account that is now starting to emerge, call it 'reductionist-essentialist' explanation. Much more work remains to be done for us to be able to calculate a given type of hardness for a given material, but there is already ample evidence that this can be done, and the first principles calculations mentioned above also appear to be more accurate than any of the mechanical hardness tests developed. There are several ways that all this can be spelled out and of course the jury is still out there regarding some aspects of the fundamental forces that are involved in this story. But one, albeit crudely simplified, way to go would be to say that it is the dispositional essence of charge that is ultimately responsible

for the disposition of hard materials to resist scratching or whatever test we might invent for hardness.

The upshot of this type of account is that we can indeed unify scientific and metaphysical explanation because laws of nature and 'laws of metaphysics' may both be analysed in the same way (since the dispositional essentialist explains laws of nature in terms of essential properties). There are many proponents of the traditional dispositional essentialist view (e.g., Bird 2007), but in contemporary literature on dispositional essentialism some further variations have emerged. In particular, there are those who argue that (natural) properties like *charge* ground various dispositions, which may also open the door to versions of dispositionalism that do not rely on essences (Coates 2020, Tugby 2021, 2022, and Kimpton-Nye 2021).

However, my preferred strategy obviously relies on general essences, so let me attempt to formulate reductionist-essentialist explanation in more general terms, where we are interested in the behaviour of a given concrete entity *a* of kind *K*:

(I) Target of explanation: entity *a* of kind *K* has defining feature (or property/behaviour) *F*.

(II) Observation (empirical): having *F* is dependent on sub-feature (e.g., structure, another property or set of properties) *G*.

(III) General explanation: it is part of the *general essence* of entities of kind *K* that they depend on *G* for their existence.

(IV) Particular explanation: *G* necessitates *F*, so *a* has *F* because it is of kind *K*, i.e., has the particular general essence that members of *K* have.

The case of hardness can be made to fit this picture fairly easily: a given diamond is hard because its constituent carbon atoms are bonded and spatially arranged in a specific way and (let us assume) it is part of the general essence of diamonds that their constituent carbon atoms are thus bonded. So, this particular diamond is hard because the structure of its constituent carbon atoms necessitates the hardness of all diamonds. All the explanatory work is done by the kind membership (i.e., general essence of the kind) and the relevant dependence relation. It is worth noting that this dependence relation is plausibly 'internal', i.e., it holds necessarily given the existence of its relata—so it is not an additional 'element of being' or indeed a law of metaphysics.[9]

Can we find other good examples besides the case of hardness? Yes, but as with other cases of purportedly *reductive* explanation, like reductionist-essentialist explanation clearly aims to be, it can be laborious to provide sufficient scientific detail—this is stage (ii) of the general pattern presented above. Elsewhere Tahko 2023b), I have examined another case from physics, concerning the predicted stability of superheavy elements, i.e., elements with an atomic number greater than 103. The case of the yet to be synthesised element with atomic number 126, *unbihexium* is of particular interest. However, the fact that no samples of the element exist pose an interesting challenge: where does the empirical information required for stage (ii) come from?

The answer involves taking a close look at what Eugene Wigner coined the 'magic numbers': 2, 8, 20, 28, 50, 82, and 126. The numbers are based on

[9] For further discussion on relevant ontological dependence relations of this type, see Tahko and Lowe 2020.

combinations of protons and neutrons which appear to produce higher stability of the atomic nucleus (these are combinations of protons or neutrons arranged into complete shells within the nucleus). Now, fitting it into the above pattern, we might say that if the target of explanation is the predicted stability of element 126, then the relevant observation is that certain combinations of protons and neutrons produce a higher stability and we can predict this in the case of element 126 because it shares this structural feature with the already observed cases, e.g., calcium (Z = 20), which has two 'magical' isotopes, with neutron numbers 20 and 28. This gives us the general explanation: it is part of the general essence of atomic nuclei that their stability depends on a structure of binding energies and energy levels, giving rise to further dependencies involving the shell model of the nucleus. Accordingly, the structure of the shells influences the energy levels and ultimately determines the stability of the nucleus. There is obviously plenty more scientific detail that can be given about this case as well (see, e.g., Chapman 2020), but this brief overview should suffice to show that other candidate examples that fit the general pattern proposed above can be found.

5. Conclusion

The overall upshot of the paper is that we need not resort to talk of laws of metaphysics, even though metaphysical explanation can be regarded as a genuine form of explanation. Moreover, we can unify this metaphysical form of explanation and scientific explanation because they share the same ultimate basis, which on my preferred view are the general essences of the entities that these explanations concern. Alas, it is not my goal here to pursue these details. Instead, I conclude here, having provided what I promised at the outset: a (sketch of a) unified account of scientific and metaphysical explanation in terms of general (natural kind) essences (for further details, see Tahko 2021).[10]

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