

Fundamentality and Ontological Minimality

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ABSTRACT

In this chapter, a generic definition of fundamentality as an ontological minimality thesis is sought and its applicability examined. Most discussions of fundamentality are focused on a mereological understanding of the hierarchical structure of reality, which may be combined with an atomistic, object-oriented metaphysics. But recent work in structuralism, for instance, calls for an alternative understanding and it is not immediately clear that the conception of fundamentality at work in structuralism is commensurable with the mereological conception. However, it is proposed that once we understand fundamentality as an ontological minimality thesis, these two as well as further conceptions of fundamentality can all be treated on a par, including metaphysical infinitism of the ‘boring’ type, where the same structure repeats infinitely.

1. Introduction¹

This chapter deals with the idea that reality comes with a hierarchical structure of ‘levels’. The idea has a long history and it remains popular, despite some recent challenges. Our everyday experiences as well as scientific practice seem to, *prima facie*, strongly support such a view, since the sciences are naturally interpreted as operating at different levels, different *scales*.² Usually, the reference to scale becomes apparent when talking about parts and wholes, which are studied in *mereology*: we talk about subatomic particles constituting atoms, atoms constituting molecules, and molecules constituting everything we see around us. A typical view is that composite objects *depend for their existence* on their parts – at least in the sense of having *some* parts. Fundamentality comes in when we ask whether there is an end or a beginning to this hierarchical structure, the relevant chain of dependence. That is, is there a fundamental level or does the hierarchical structure of reality continue *ad infinitum*?

The received view has long been that there indeed is a fundamental level. The fundamental level is usually thought to be at the *smaller* end of the spectrum: *mereological atomism* suggests that certain indivisible ‘atoms’, such as subatomic particles, are fundamental. But this does not mean that the fundamental level must necessarily be at the bottom of the scale – the fundamental end could also be at the top, i.e., the universe as a whole could be considered fundamental. Moreover, this conception of fundamentality associates it very closely with some sort of *ontological independence* – the mereological atoms are fundamental in the sense that everything else depends on them, is *grounded* in them, or even *reducible* to them. But there is another traditional way of understanding fundamentality, or the intuition that drives it: it’s the world’s *intrinsic structure* that is fundamental (see Fine 2001, 26). Now, it may not be immediately clear what this is supposed to amount to, but here’s another way of putting the idea (albeit one that I am

¹ Some of the material presented here is based on the discussion in Tahko 2015a, Ch. 6.

² I do not wish to put much weight on the notion of a ‘level’, the idea is that the ‘levels’ reflect an order of priority.

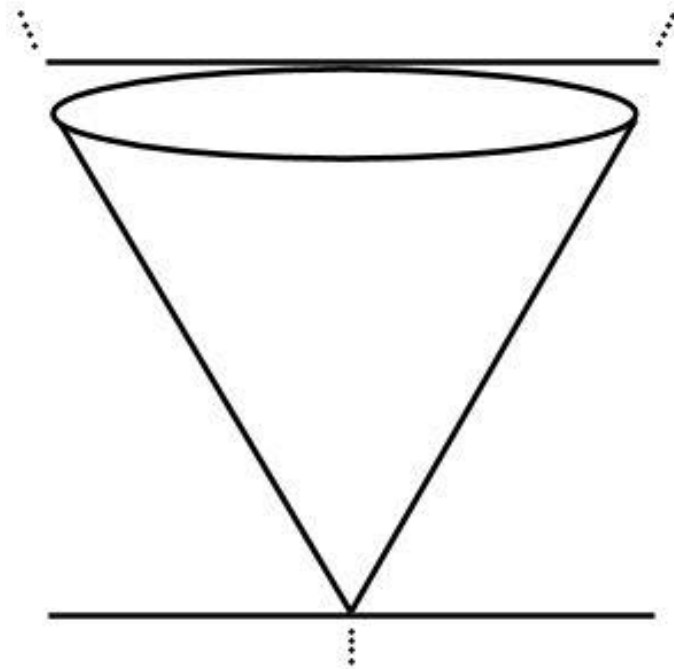
not a big fan of): whatever God had to bring about to make the world is what counts as fundamental; the fundamental entities are the basic building blocks of reality, like axioms in a theory (see Wilson 2014, 560 and Wilson 2016). It is this conception of fundamentality – attributable at least to Kit Fine and Jessica Wilson – which I find worth exploring in more detail, and indeed to hold much more promise when attempting to develop a general theory of fundamentality.³ On this view, fundamentality itself is primitive and not something that is fixed by the relevant chain of dependence. That is, we must first fix the fundamental level and only then do we know what the correct direction of priority is. But before we examine this view of fundamentality in more detail, we will first have to wade through the complexities of the more mereologically inclined approach, which is perhaps more familiar.

Recent work by scientifically-minded philosophers, taking heed of contemporary physics, has gone some way towards refuting the idea of levels altogether (e.g., Ladyman and Ross 2007, 4, 53–7, 178–80). Without the hierarchical view introduced by the levels metaphor, talk about a fundamental level does not seem possible. So, before we can get started, we must clarify several issues, such as the idea of a hierarchical structure itself. Further complications are introduced when we try to make sense of the possibility that there could be a hierarchy and no fundamental level. An important question here is whether it is possible that the levels not only go on *ad infinitum*, but are also infinitely *complex*.

Consider the following illustration (which represents a mereological hierarchy):

³ For further discussion, see Bennett Forthcoming, Ch. 5, where different senses of absolute fundamentality are discussed. I got my hands on the book too late to discuss it here in detail, but the view that I support takes fundamentality as a primitive. Bennett as well associates this view with Fine and Wilson.

JUNK?



GUNK?

Figure 1

The cone in *Figure 1* represents the hierarchical structure of reality, with the smallest thing(s) at the bottom and the universe as a whole at the top. Why a *cone*? Because it reflects the idea that there is a scale to the structure of reality. Another reason: it seems natural to think that there are fewer different *kinds* of things at the smaller end of the spectrum. The Standard Model of particle physics postulates that there are 61 elementary or fundamental particles (if we count particles and their corresponding antiparticles as well as the various colour states of quarks and gluons) – everything else is composed of these fundamental things. In contrast, the larger end of the spectrum may be considered to encompass *all* the different kinds of things there are in reality – perhaps even infinitely many different kinds. It should be noted though that putting this in terms of kinds is entirely optional and the resulting picture will of course depend on one’s views regarding kinds; one

option might even be to consider the cosmos as a whole as just one *kind*, in which case the previous description of fewer kinds at the smaller end would not be accurate. Leaving that aside, the lines at each end of the cone represent the *hypothetical* bottom and top levels. The dotted sections represent the possibility of infinite descent (gunk) and infinite ascent (junk), beyond the hypothetical bottom and top levels.

Four options immediately arise regarding the hierarchical structure of reality:

- (1) Closed (i.e., the chain of dependence terminates) at both ends of the cone.
- (2) Open at the top, but not at the bottom.
- (3) Open at the bottom, but not at the top.
- (4) Open at both ends.

If both ends of the cone are closed, then we might consider either one of them as fundamental, fixing the direction of the relevant dependence relation accordingly. If only one end is closed, then it seems, *prima facie*, more plausible that the closed end is fundamental, whether it is the top or the bottom. The first three options enable different varieties of *metaphysical foundationalism*, which, in its broadest sense, states simply that there is a fundamental level. The fourth option, however, cannot support metaphysical foundationalism, as there is neither a top nor a bottom level. In this case, only some sort of *metaphysical infinitism* would seem to be available, regardless of the direction of the relevant dependence relation. To give names to the different types of metaphysical infinitism at play, let's start with (3) (assuming that the order of priority is from top to bottom), which is best known: an ontology embracing (3) is typically called 'gunky', where 'gunk' is a term

familiar from mereology, referring to the idea that all wholes have further proper parts, *ad infinitum* (Lewis 1991, 20). Similarly, an ontology embracing (2) is ‘junky’, where ‘junk’ is the converse of gunk, i.e., everything is a proper part of something (Schaffer 2010, 64). Note though that, strictly speaking, gunk does not rule out junk, nor does junk rule out gunk, contrary to (2) and (3). This brings us to (4), which indeed combines gunk and junk, resulting in what has been labelled a ‘hunky’ ontology (Bohn 2009, 193).

These are the basic options, but this description is somewhat simplified, as we have not yet said anything about what ‘fundamentality’ amounts to. In particular, we should clarify the role of mereology in discussions of fundamentality, which we’ll do in the second section. The third section outlines a common objection to the possibility of metaphysical infinitism, with some critical remarks. In the fourth section, a more general sense of fundamentality will be explicated with the help of the idea of *ontological minimality* – this more general approach to fundamentality considers it as an *ontological minimality thesis*. The fifth section examines the tension between the mereological, object-oriented ontology and *structuralism*. It is suggested that fundamentality understood as an ontological minimality thesis can accommodate both. Finally, in the sixth section we will briefly consider whether fundamentality understood as an ontological minimality thesis rules out metaphysical infinitism.

2. Mereological Fundamentality

The options outlined above were presented in mereological terms: the cone in *Figure 1* is taken to represent a mereological hierarchy, where mereological complexes are at the top and (supposed) mereological atoms at the bottom. The ‘levels’ of reality according to this picture are thus mereological levels. This brings us to Mereological Fundamentality, which may be described as a combination of the following two theses:

Mereological Hierarchy (M): The world is organized into mereological levels, resulting in a hierarchical structure governed by mereological dependence relations.⁴

Fundamentality Thesis (F): There is a fundamental ‘level’ at one end of the hierarchical structure of reality, that is, the relevant chain of dependence is closed at least at one end.

Together, (M) and (F) entail (simplified) Mereological Fundamentality:

Mereological Fundamentality (MF): The world is organized into mereological levels and there is a fundamental, mereologically independent level which is at one end of the mereological scale.

The idea, according to (MF), is that fundamentality is a thesis about mereological dependence, or to put it another way: (absolute) fundamentality is *mereological independence*. On this view, the type of dependence that we track with the notion of (relative) fundamentality is mereological dependence. On the face of it, (MF) is compatible with three of the options listed in the previous section: (1), (2), and (3). So, the only option ruled out is (4), where both ends of the hierarchical structure are open. (MF) comes in two primary forms, depending on which end of the mereological

⁴ I take the notion of ‘mereological dependence’ from Kim, which he prefers to the term ‘mereological supervenience’ and contrasts with causal dependence: ‘the properties of a whole, or the fact that a whole instantiates a certain property, may depend on the properties and relations had by its parts’ (2010, 183).

scale is considered fundamental. An additional commitment that those who support (MF) may have is that the entities at the fundamental level have the highest degree of ‘reality’, i.e., they are the most fundamental. But we need not dwell on the idea of degrees of reality or fundamentality here.⁵ Metaphors abound, but to put it in terms of grounding, x is fundamental or *ontologically independent* in the relevant sense if and only if nothing grounds x (Schaffer 2009, 373). Note that this is of course a much more general thesis than (MF), which ties fundamentality specifically with mereological dependence; grounding may involve other types of dependence or it can be considered primitive.⁶ But again, the view I favour is that fundamentality itself is primitive and should not be defined in terms of grounding or any other dependence relation. In what follows I will avoid the grounding terminology and will attempt to find a somewhat more neutral way to explicate (but not define!) fundamentality.

Given (M), (MF) is naturally combined with the idea that the mereological dependence relation is *asymmetric*. The direction of the asymmetric dependence is fixed by which end of the hierarchy is considered fundamental. But this is a question that must be settled separately. What determines the direction of the dependence relation is the distinction between *pluralism* and *monism*.⁷ The pluralists hold that the direction of the dependence is from the larger to the smaller, resulting in mereological atomism – this is, perhaps, the standard view.⁸ The monists hold that the parts are dependent on the whole and hence that there is only one fundamental entity, namely, the universe. However, pluralism and monism are independent of (MF), which does not by

⁵ The idea can be understood in many ways. For discussion, see, e.g., McDaniel 2013.

⁶ For an introduction to grounding, see for instance Bliss and Trogon 2014. Moreover, another possible view here is that fundamentality tracks (and can be defined in terms of) what Bennett (Forthcoming) calls ‘building’, which also encompasses several dependence relations, including grounding.

⁷ For further discussion on the monism/pluralism issue as well as an alternative account of fundamentality, see Trogon 2009.

⁸ Cotnoir (2013) labels this as the ‘default’ view in a recent note.

itself fix the direction of priority. So, different combinations of these views may be possible. One proponent of the monistic view, Schaffer, considers only *substances* to be fundamental, and further, that there is exactly one substance, namely the cosmos. On this understanding, a substance is a basic or fundamental, ontologically independent entity. This is roughly how Aristotle might characterize the notion of ‘substance’. So, for Schaffer, it is the cosmos, conceived as a substance, which is prior to its (arbitrary) parts. Schaffer’s Spinoza-inspired *priority monism*, however, does not assume mereological atomism, even though he operates in mereological terms. In fact, one of Schaffer’s arguments in favour of priority monism draws on its compatibility with the possibility of gunk (2010, 61ff.).⁹ The question of gunk is of some importance here, as those committed to (MF) and the idea that the dependence relation goes from the larger to the smaller (pluralism) will struggle to accommodate the infinite divisibility of matter entailed by a gunky ontology – we will return to this shortly.

(MF) combined with mereological atomism is may once have been the default view when it comes to fundamentality, but its popularity has dwindled. For instance, Ladyman and Ross (2007) strongly oppose the view; so does Markosian (2005). Most opponents of (MF) are worried about the (additional but common) commitment to mereological atomism. The worry that Ladyman and Ross have regarding this picture is that none of the various atomistic conceptions can stand the test of contemporary physics – but note that this is strictly speaking a case against (M) rather than (MF).¹⁰ The core of the critique by Ladyman and Ross is that there is nothing in fundamental physics that corresponds with the atomistic idea of ‘simples’. Note, however, that even if their

⁹ This might be a good place to note that Schaffer may have changed his views after the 2003 paper, where fundamentality is discussed in mereological terms – he may now prefer to define fundamentality in terms of grounding.

¹⁰ The phenomenon they appeal to is famous: ‘quantum entanglement’. However, it is not at all clear that the quantum entanglement objection is successful. For discussion of this issue, see Dorato and Morganti 2013, and O’Conaill 2014.

critique is correct, it only applies to (MF) combined with pluralism, which together entail a commitment to mereological atomism. Even though it won't get around the problems associated with the idea of mereological hierarchy, one could be tempted to defend (MF) but adopt (priority) monism when faced with the line of criticism from Ladyman and Ross, hence taking the fundamental level to be at the top end of the cone in *Figure 1*. This way one could endorse the possibility of a gunky ontology without losing (MF). In any case, pluralism still enjoys wider support, at least partly because it seems to be a promising way to articulate (MF). Yet, there is a wide agreement about the incompatibility of (MF) + pluralism + gunk. This has, naturally enough, resulted in some hostility towards gunk, given the popularity of both (MF) and pluralism. But if we are happy to leave the door open to some form of metaphysical infinitism (and hence gunk) then we could instead drop (MF) while keeping pluralism. The question that remains is: how strong is the case against gunk/metaphysical infinitism and in favour of (MF)?

3. The Problem with Metaphysical Infinitism

There is a well-known paper by Cameron (2008), which summarizes the basic argument in favour of (MF) – or against metaphysical infinitism.¹¹ Cameron resists the idea that there could be infinite chains of ontological dependence because of the unintuitive implications that such chains would entail. Applying the idea to the case of composition, Cameron notes that in a gunky world, composition would never 'get off the ground'. In other words, if complex objects are ontologically dependent on their mereological parts, then composition never bottoms out in gunky worlds. The intuitive result, according to Cameron, is that complex objects are not possible in gunky worlds – and this is a strong result! It rules out the possibility that we live in a gunky world, at least if we accept the plausible idea that complex objects are ontologically dependent on their parts. But how

¹¹ See also Paseau 2010.

strong is the intuitive appeal that this argument rests on? This question is pressing, given that Cameron and many others writing about fundamentality and the idea that composition couldn't 'get off the ground' without a fundamental level typically acknowledge that this appeal to intuition hardly constitutes a proper argument in favour of fundamentality.

One complication concerns the way in which we think about the structure of space-time. If space-time itself is made up of zero-dimensional space-time points and hence has no internal structure, no smaller parts, then this 'pointy' space-time would seem to rule out a certain type of infinite regress by its very nature: surely those space-time points themselves do not depend for their existence on anything and hence are, in one sense, fundamental. It's standard to think that any given collection of space-time points composes a space-time region. These regions are identified in terms of their composite space-time points. Yet, there are two different ways to conceive of the relationship between the points and the regions: we can either think of points as derivative and facts about extended objects as more fundamental or we can hold that the space-time points and facts about their arrangement are more fundamental than space-time regions (see Hawthorne 2008, 264). The latter is of course the typical way of looking at things nowadays, but this question regarding the relative fundamentality of the regions and the points would seem to precede Cameron's case. The relevant intuition that Cameron appeals to would thus seem to presuppose the view that points are more fundamental.

If I may, I'd also like to make an anecdotal point. Having presented versions of this paper and the related arguments to various audiences around the world, the most common reaction seems to be that people do not find themselves drawn towards the foundationalist intuition that Cameron and various others have attempted to defend. Now, this may be because I have not done justice to the idea or presented the argument clearly enough. But the challenge here is that no systematic argument has been put forward in the first place – I take it that Cameron is mainly just reporting the fundamentality intuition that he thinks many metaphysicians share. My impression is,

however, that the intuition is currently not that widely shared. There are good reasons for this. One of the most important of them is the worry pushed by Ladyman and Ross, namely the strong association with mereological atomism, which does not fare so well in the light of contemporary physics. Yet, personally I thought that I *do* have at least something very much like the fundamentality intuition. But I am now less certain that it's the *same* fundamentality intuition that Cameron has in mind. It may be closer to what Wilson (2014, 560) has in mind when she compares entities in the fundamental base to the axioms of a theory. Importantly, the understanding of fundamentality that I find appealing is not accurately captured by (MF), because I wish to drop the mereological connotations. It is, however, captured by the Fundamentality Thesis (F). It's crucial to recognize that (F) does not specify which type of dependence is at issue when it comes to the hierarchical structure. All it requires is that there is a hierarchical structure governed by (presumably) an asymmetric dependence relation that terminates at least at one end. This is still a thesis that would require an argument in its support, but it is not immediately subject to the same counterarguments that (MF) is. However, on its own, (F) is really not fine-grained enough to constitute an interesting metaphysical thesis at all. The question that we now face is whether anything more can be said about (F) without a commitment to (M), hence leading back to (MF)?

4. Fundamentality and Ontological Minimality

I think we should resist the idea that the appeal of metaphysical foundationalism rests solely on (MF), since the problems associated with mereological atomism have been known for some time. Moreover, even though I have not discussed the grounding-based approach to fundamentality here, I don't think that it does much better (see Wilson 2014 for criticism). However, it's clear that (F) on its own is not going to do the trick either.¹² Let's see if something more can be said about it. Rather

¹² Some recent notable discussions which introduce further complications (being favourable to metaphysical infinitism)

than attempting to list all the possible ways to understand levels and the relevant chains of dependence that structure them, I will here try to explicate (but not define) a more general sense of fundamentality, which could capture (MF) but also many, if not all, other conceptions of fundamentality. To do so, recall that we distinguished the Fundamentality Thesis (F) from the idea of Mereological Hierarchy (M). The first is neutral about the sense of ontological dependence that does the structuring. But if (M) is already too restrictive about the relevant sense of dependence, then we better adopt the broadest possible sense of ontological dependence at the outset.¹³ Even this is not enough though: it must be recognized that what is fundamental and hence what fixes the direction of priority is independent of (M) and (F). If one accepts (M) + pluralism, the fundamental level consists of mereological atoms, but if we drop (M), the nature of the *fundamental*ia – the elements that are fundamental – is unrestricted. This is where the notion of *ontological minimality* finally comes in. With the help of ontological minimality, we can explicate a general conception of fundamentality which is neutral regarding the nature of the *fundamental*ia:

Generic Ontological Fundamentality (GOF) The world is organized into ‘levels’ of ontological elements and the fundamental ‘level’ consists of ontologically minimal elements.

This definition is only provisional and it is obviously in need of further explication, as nothing has yet been said about ‘ontological elements’ in general and ‘ontologically minimal elements’ in

are Bliss 2013, 2014 and Morganti 2014, 2015. The alternative formulation that I am sketching has its origins at least in Fine 2001 and Wilson 2014 – although I don’t mean to suggest that there are no differences between these conceptions. New work on metaphysical foundationalism is also constantly in the pipeline, see for instance Bennett Forthcoming, Dixon 2016 and Raven 2016.

¹³ For an introduction to the various senses of ontological dependence, see Tahko and Lowe 2015.

particular. Moreover, I don't wish to put too much weight on the notion of 'level' used here – it could be regarded merely as a placeholder for whatever notion one wishes to use to parse the hierarchical structure of reality. In fact, even the idea of a hierarchy could be dropped here, as there could be just one 'level', a flat world. But I will continue to speak as if there are several levels. Since (GOF) is supposed to be able to express (MF) as well, we can already identify at least one thing that could take the place of 'ontological elements' in (GOF), namely, mereological elements. In that case we would get the familiar hierarchy of mereological levels and the ontologically minimal elements would be mereological atoms – if (MF) is combined with pluralism. But what else could the ontological elements be? That would seem to depend on three things. Firstly, what kind of hierarchy are we interested in? Secondly, what kind of dependence structures that hierarchy? Third, how is the hierarchy manifested in the world, i.e., what is the relevant science? These are difficult questions, especially the last one. If the critical remarks by Ladyman and Ross that we discussed above are correct, then much of the relevant work in determining the correct answers to these three questions will come from science. It may also be worth noting that (GOF) is neutral between pluralism and monism. It can certainly be combined with pluralism, for there could be multiple ontologically minimal elements (e.g., mereological atomism). But it could feasibly also be combined with monism, for it could turn out that there is only one ontologically minimal element (e.g., the universe as a whole, like in Schaffer's priority monism).

However, even if we will eventually need input from science, this does not mean that we can't say anything more at the moment. Further specification of ontologically *minimal* elements – the theoretical background of 'ontological minimality' – is possible.¹⁴ To get the idea started,

¹⁴ Compare the idea also with one of Schaffer's (2004) criteria for sparsity, namely 'minimality', according to which sparse properties serve as the minimal ontological base, i.e., the fundamental properties that macro-properties supervene on (assuming that they do supervene!) form the minimal ontological base. Schaffer himself argues against this criterion with appeal to the possibility of gunk, but as we will see, gunk may not be a similar problem for the

ontologically minimal elements could be compared to ‘minimal truthmakers’, familiar from Armstrong (see also Tahko and O’Conaill 2016):

If T is a minimal truthmaker for p , then you cannot subtract anything from T and the remainder still be a truthmaker for p . (Armstrong 2004, 19–20.)

A minimal truthmaker for a given proposition can be understood as the smallest or least encompassing portion of reality that fully grounds the truth of that proposition. This analogy between minimal truthmakers and ontologically minimal elements suggests that the fundamental level consists of the least encompassing portion of reality. In usual accounts of minimal truthmakers, the least encompassing portion of reality is understood in terms of parthood, which would naturally take us back towards (MF) rather than (GOF). However, it may be possible to avoid the mereological connotations by invoking the more general notions of *composition* and of *being integral* as intended by Kit Fine:

When one object is a part of another, there is a sense in which it is *in* the other—not in the sense of being *enclosed by* the other, as when a marble is in an urn, but more in the sense of being *integral to* the other. When parts are in question, it is also appropriate to talk of a given object being *composed of* or *built up from* the objects that it contains. (Fine 2010, 560)

This more general notion of ‘part’ may allow one to avoid the unintuitive consequences of infinite chaining of parts more narrowly understood, i.e., construed according to classical mereology. On this view, all manner of things, from sentences to symphonies to sets, can

notion of ontological minimality introduced here.

be composed of other things. It seems plausible that the components of a composite object one level down are typically *integral* to the object in the sense suggested by Fine. But it is less clear that this has to be the case when we proceed further down. Fine suggests that a person would somehow *change* if her kidney was replaced with a new one, and perhaps it's plausible that a kidney changes when some of its cells die and are replaced by new ones – it certainly does if some of these cells become cancerous. But given that our cells die and are replaced by new ones all the time, it doesn't seem that any individual cell is really integral to us. I think that this is the case regardless of the fact that the cells may be integral to whatever organ they are a part of or whatever biological function they participate in. But if it is possible that the components several levels down are *not* integral to the object at the higher level, then the infinite regress causing the typical unintuitive consequences of infinite chaining (transitivity) wouldn't follow.

The more general line of thought here is that the liberal sense of parthood is not obviously transitive – this may have further consequences regarding what counts as a minimal truthmaker on one hand and an ontologically minimal element on the other. So there could, perhaps, be an understanding of ontological minimality whereby we should only be concerned with the parts that are *integral* to an object, even if these parts are composed of further parts. This would be in clear violation of (MF), of course, for the fundamental level might not be the *mereologically* fundamental level. But note that arguments from gunk (or junk) would no longer apply, since infinite mereological descent would not necessarily violate ontological minimality. Moreover, on the face of it this would seem to imply that not everything is grounded in the fundamental, because there could be cases where we do not need to follow the grounding chain beyond the *immediate* ground, to use Fine's (2012, 50) terminology. The discussion surrounding the transitivity of grounding more generally is beyond the scope of this paper though.¹⁵ The same goes for an analysis

¹⁵ For critical discussion regarding grounding and transitivity, see Schaffer 2012 and Tahko 2013.

of the possible compatibility between gunk and ontological minimality (although we will return to this in the final section). But let's consider Fine's discussion of transitivity briefly.

Consider sets and their members. On a traditional conception of parthood, suggesting that the members of sets are *parts* of sets is problematic: since the parthood relation is traditionally conceived as transitive, but the relation of member to set is *not* transitive, the members of a set cannot be its parts. But according to Fine, this confuses two claims: that the relation a member of a set bears to the set is the *parthood* relation, and that the members of a set are its *components*. We can consistently deny the first of these and accept the second. This suggests that the transitivity of parthood, when parthood is understood in the more liberal sense that Fine suggests, is a question that must be settled separately, i.e., it is not built in to the notion itself:

[I]f part is understood as component, it will be a substantive question whether or not the relation is transitive. In the case of sums, for example, it will be transitive, since components of components are components, while in the case of sets, it will fail to be transitive, since components of components (that is, members of members) will sometimes fail to be components (members). (Fine 2010, 569.)

Of course, even if Fine is correct about the case of sets and their members, this does not yet show that the relevant dependence relation at work in the hierarchical structure of reality is not transitive. It merely shows that there is at least one conception of parthood which may not be transitive. In any event, this opens the possibility of interpreting ontologically minimal elements quite liberally indeed: the smallest, minimal 'parts' of reality do not need to be mereological elements at all, they can be anything that count as *components*, such as structures, relations, objects, or whatever. This may enable us to overcome at least some of the complications regarding the tension between a classic, object-oriented metaphysics such as mereological atomism and the type of view defended for instance by Ladyman and Ross, according to which reality is fundamentally *relational* or

structural. We turn to this topic in the next section.

5. Fundamentality, Structuralism, and Ontological Minimality

Perhaps the primary reason to search for a general notion of fundamentality such as (GOF) is exactly because *ontic structural realism* (OSR) familiar from the work of Ladyman and Ross (see also French 2014, Esfeld and Lam 2010, and others) consider (MF) to be based on a completely skewed sense of priority: it's not *objects* that are fundamental, but *structure* or *relations*. The question is, could these two camps nevertheless agree on the relevant notion of *fundamentality*? Kerry McKenzie (2014a) has done some important work in order to clarify the issue; she distinguishes the extreme version of (OSR) defended, e.g., by Ladyman and French, and a more moderate version defended, e.g., by Esfeld and Lam. The first takes structure as prior to objects, whereas the latter eschews talk about priority between structure and objects altogether (because they are on a par, ontologically speaking) (McKenzie 2014a, 355–6). McKenzie spends some time arguing that instead of supervenience, we should focus on ontological dependence in articulating the relevant sense of priority. I do not consider this particularly helpful, as supervenience as well is very naturally considered as a species of ontological dependence. That said, McKenzie is right about the importance of finding the relevant sense of dependence and it's clear that, given that we're looking for a conception of fundamentality compatible with (OSR), this can't be *mereological dependence*, which is naturally associated with Mereological Fundamentality (MF). According to McKenzie's analysis, we would do well to adopt Fine's (1995) essentialist notion of dependence and clarify (OSR)'s understanding of priority in these terms. McKenzie focuses on what we may call *generic essential existential dependence* (GEDE), defined as follows:

(GEDE) x depends essentially for its existence upon F s =_{df} It is part of the essence of x that x exists only if something is an F .¹⁶

Applying (GEDE) to (OSR), McKenzie observes that the extreme version of (OSR) as developed by Ladyman and French turns out to be in trouble because although the dependence of objects on structure can be derived, so can the dependence of structure on objects. Hence, McKenzie takes the analysis to favour the moderate version of (OSR) as developed by Esfeld and Lam instead. But it should be noted that all this rides on the relevant understanding of what is considered essential. The relevant essentialist content on McKenzie's analysis concerns the nature of relations – whether we conceive of them extensionally or intensionally, and it is on the extensional conception that the dependence between objects and structure emerges as symmetric, whereas the intensional conception is considered inferior for this purpose. The further details of McKenzie's account are not crucial for our purposes, but what is important is that (GEDE) is indeed able to produce the relevant dependence structure. Note though on this view what is fundamental is not strictly speaking primitive, but it is rather determined by what is considered essential – (GEDE) does not presuppose an object-oriented metaphysics nor the extreme or the moderate version of (OSR). So, here we have a sense of dependence that fairly is neutral, albeit there are no doubt those who would take issue with the fact that (GEDE) relies on the notion of essence.¹⁷

¹⁶ Compare with Tahko and Lowe 2015, section 4.3. McKenzie uses a formal definition due to Fine and Correia rather than (GEDE), but the content is the same.

¹⁷ However, this may not be a huge problem, since (GEDE) entails the modal-existential notion of generic existential dependence, which could perhaps be adopted as well: (EDG) x depends generically for its existence upon F s =_{df} Necessarily, x exists only if some F exists (Tahko and Lowe 2015, section 2). In fact, (EDG) is more straightforwardly compatible with symmetric dependence anyway, since there is no requirement of building the existential dependence into the essences of the involved entities. All we need here is a way to model the symmetric dependence between objects and structure. Note also that if one wishes to hold fundamentality as primitive rather than fixed by

We clearly need our notion of ontological minimality to be quite flexible indeed, as evidenced by the need to apply it to (OSR) as well. It might be useful to introduce another example, one without the complications of contemporary physics. One reason for this is that I'd like to better demonstrate the idea that there can be several ontologically minimal descriptions and it may not always be quite straight-forward to compare them – the choice between mereological atomism and (OSR) is plausibly decided based on other criteria than considerations having to do with ontological minimality. But here's a case where the choice is less clear: consider two different ways to describe the colour space: RGB vs. YUV.¹⁸ The RGB (red, green, blue) system is perhaps the more familiar system, but YUV is useful in some cases, as it takes into account human perception of colour, which depends on lighting conditions. Hence, the Y stands for luminance (brightness) and U and V are the chrominance (colour) components; there are also other luminance/chrominance systems. Although there are differences between the systems, both RGB and YUV can give a complete description of a given colour value and it's also possible to convert an RGB value to a YUV value. But what's the connection to ontological minimality? Well, since both systems can completely describe a given colour *C* and may be considered to consist of three minimal elements (at least if we simplify a little), then each description is a minimal description of *C*. This should make clear that, just as with minimal truthmakers, there could be several mutually consistent ontologically minimal descriptions of reality. Of course, colour is unlikely to feature in the ontologically minimal description of reality, so we should not be misled by this example. But there is a clear need to illustrate the idea of ontological minimality with examples such as this, because it seems quite likely that *any* description of reality we might give based on current science will be incomplete and hence not genuinely

what is essential, an even more neutral sense of dependence may be needed. I will leave this issue aside here, since the potential connection between essentiality and fundamentality is a topic that deserves a paper of its own.

¹⁸ I owe this example to Tim Button and Hugh Mellor. Note that I do not mean to suggest that colour is a fundamental feature of reality, or indeed to put much weight on the example – the example is primarily heuristic, to get a better grasp on the abstract idea of ontological minimality.

ontologically minimal. The point is that we must resort to other criteria to assess two competing physical theories if they both give a complete, ontologically minimal description of reality. However, unless the theories differ with regard to some further theoretical virtues that we consider important, the choice appears to be arbitrary. There may, of course, be practical or contextual reasons to prefer one system over the other, quite like in the case of RGB vs. YUV. This is just to say that there could be several ontologically minimal descriptions of reality, based on different sets of ontologically minimal elements. But if one description needs to postulate *more* ontologically minimal elements than the other one to reach a complete description, then the first is clearly not an ontologically minimal description at all.¹⁹

Finally, recall that on one interpretation the cone in *Figure 1*, in the beginning of this paper, could be considered to represent different *kinds* of things, where ‘kinds’ are considered as *natural* kinds. If we apply the idea of ontological minimality here, what we get is something like the following: an ontologically minimal description identifies all and only the most fundamental natural kinds. These natural kinds could be kinds of fundamental particle, like those listed in the Standard Model, or they could be the structures identified by (OSR). Moreover, they could perhaps even be *symmetries*, as the idea that symmetries are fundamental is now emerging as a candidate view supposedly supported by physics (cf., McKenzie 2014b). The association with fundamental natural kinds is in fact quite an interesting understanding of the ontological minimality thesis, but since specifying this option would require much more detail about the nature of natural kinds, I will not be relying on this reading here (but see Tahko 2015b).

Summarizing, it appears that much remains to be done in order to specify the range of options with regard to fundamentality. The generic notion (GOF) sketched here is designed to be as

¹⁹ Note that other considerations could even trump the minimality constraint, which is a purely qualitative notion. Balancing between different theoretical virtues is notoriously difficult, see e.g., Nolan 1997 for discussion about qualitative vs. quantitative parsimony.

liberal as possible, for the various possible conceptions of fundamentality to be captured with one general notion. For this purpose, one possible sense of dependence that could do the trick (but see footnote 17) has been identified as (GEDE), which McKenzie has already applied to (OSR). The upshot is that understanding fundamentality as an *ontological minimality thesis* does seem to hold at least some promise.

6. Ontological Minimality and Metaphysical Infinitism

We will end with a more radical note, for I propose that even some versions of metaphysical infinitism may satisfy the ontological minimality thesis and hence Generic Ontological Fundamentality (GOF).²⁰ I have in mind what Schaffer (2003, 510) calls ‘infinitely boring descent’, whereby the same structure (pattern, description) repeats infinitely. To distinguish this from metaphysical infinitism *proper*, consider a scenario where reality is structured mereologically and each time we split a supposedly fundamental particle, a set of different kinds of particle emerge. This would constitute infinite *complexity*, which would not appear to be reconcilable with (GOF). In contrast, a ‘boring’ or repetitive descent may allow for an ontologically minimal description in the sense that a description of the repetitive part only needs to be supplemented with an instruction to continue as before, e.g., ‘the world stands on four elephants, the four elephants stand on a turtle, the turtle stands on two camels, the camels stand on four elephants, the four elephants stand on a turtle ... and repeat *ad infinitum*’. No other terms than these four elephants, a turtle, and two camels can be introduced that would describe reality more minimally – they carve perfectly at the joints and hence constitute the fundamental level in the sense of (GOF).²¹

²⁰ I have previously discussed this possibility in Tahko 2014.

²¹ Cf. also Raven’s (2016) recent paper, where he distinguishes between the fundamental, the foundational, and the *eliminable*. Eliminability implies a lower bound to the grounding chain – this is a version of the idea typically

In this toy example, the elephants, turtles, and camels may be considered as three different fundamental natural kinds, for instance. But a repetitive structure can be pictured otherwise too. Perhaps more in line with the structuralist conception, we could picture the world as a fractal and zoom into that fractal to find further structure. We can keep doing this indefinitely and always find further structure, more and more elaborate, stunning patterns. But all these patterns, all the structure, is already contained in the initial fractal. The function that produced the initial fractal *contains* (recall the idea of fundamental entities as axioms, as suggested by Wilson), as it were, all the further iterations that emerge when we zoom in (or indeed if we zoom out!). To use Fine's notion of *component* introduced in the previous section, we could perhaps conceive of the iterations of the function to be components of the fractal, and in this sense the fractal picture would have at least the appearance of minimality.

Admittedly, such abstract toy examples will do little to convince anyone of the possibility of *actual* boring infinite descent, even though the idea itself shouldn't be all that alien, given the now familiar case of structuralism (think of relations all the way down). Much of the real work would have to come from science, of course, and one example that has received some attention is Hans Dehmelt's (1989) Nobel lecture, where he speculates about the possibility of a quark/lepton substructure based on the model of the triton – the nucleus of hydrogen's radioactive isotope tritium. This tripartite substructure could, in Dehmelt's view, be infinitely repeated, and

expressed in terms of *well-foundedness* (e.g., Bennett 2011, 30; see also Dixon 2016) – but Raven proposes that it's possible to reject *foundationalism*, the claim that necessarily, something is fundamental if and only if it is foundational. On Raven's terms, infinitely boring descent would seem to be a case of *unbounded ineliminables*, which 'persist', i.e., infinitely repeat. On my reading, I take it that boring infinite descent would still be a case of foundationalism, while on Raven's proposal it would qualify as *fundamentality without foundations*, although more work needs to be done in order to properly compare our accounts. Finally, see Wilson 2016 and especially the idea that there could be a 'convergence' to a fundamental level at a limit. This idea could perhaps be understood as another type of 'boring' infinite descent.

since it is the *same* structure that repeats, Dehmelt's model is a *prima facie* candidate for boring infinite descent – a gunky ontology. However, as far as I'm aware, the idea has not been picked up by physicists and one might think that quantum field theory would be a more promising line of research in this regard.²² In any case, here I only wish to indicate the possibility of 'boring infinite descent' being compatible with ontological minimality. The upshot is that the idea of ontological minimality, rather than (MF), may be a promising way to capture what I take to be the core of the fundamentality intuition.²³

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²² But for a philosophical study of Dehmelt's model, see Tahko 2014.

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