

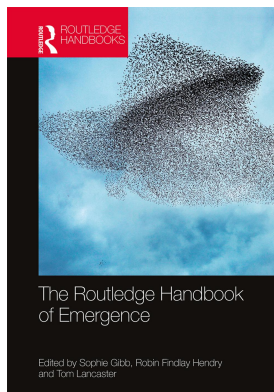
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## **The Routledge Handbook of Emergence**

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### **Fundamentality**

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# 3

## FUNDAMENTALITY

*Kerry McKenzie*

### 1. Introduction

The concept of metaphysical emergence is intimately tied up with our concept of fundamentality. Whether it is unpredictability, irreducibility, or metaphysical or dynamical autonomy that are taken as its hallmarks, it seems that that which characterizes the metaphysically emergent could equally characterize the fundamental. But the idea of the emergent as something arising out of complexity suggests that the concept involves the non-fundamental just as essentially. In order to understand emergence, then, it seems we need to get a grip on what we mean by fundamentality and how it is that we should understand the relation between the fundamental and that with which it is contrasted.

Fortunately, however, by now there exists an extensive literature on how to conceptualize fundamentality. For if anything characterizes the last decade in metaphysics, it is surely the explosion of interest metaphysicians have shown in precisely this question. Although the reasons for this foregrounding of fundamentality issues are not easy to determine, in the last few years a number of philosophers in the *a priori* tradition have gone as far as to claim that metaphysics just is the study of the fundamental and its relation to the non-fundamental – some even more restrictively that it is that of the fundamental alone.<sup>1</sup> While the idea that there is something novel about taking fundamentality to be of prime metaphysical significance has at times been over-stated, and while the idea that metaphysics is about the fundamental exclusively can be criticized on a number of grounds, it can hardly be denied that fundamentality considerations do indeed do a huge amount of work in canonical metaphysical projects.<sup>2</sup> As has been pressed by Schaffer, a swathe of the paradigm questions of metaphysics – such as the questions of Platonism vs. nominalism, idealism vs. realism, and substratum vs. bundle theories of objects – are arguably best construed not so much as questions concerning *what there is*, but rather of *what is more fundamental than what* – in other words, of what is *ontologically prior*.<sup>3</sup> Thus, it seems anyone interested in metaphysical issues – not just that of emergence – needs to think about what we are talking about when we talk about ontological priority. But just as fundamentality considerations feature centrally in *a priori* metaphysics, the same can largely be said for many projects in the philosophy of science. The debates over ontic structural realism, for example, or those between relationalists and substantialists about general relativistic spacetime, are likewise naturally viewed as primarily debates over what we should take as fundamental. And what gives many questions concerning the special sciences their

point is precisely the fact that their structurally complex subject matter seems to have non-fundamental status. Whatever team we play for in metaphysics, then, it seems we need to think carefully about conceptual questions concerning fundamentality; about ontological questions concerning what, if anything, we should take its extension to be; about ‘metametaphysical’ questions such as what it is about metaphysics that makes fundamentality so central to it; and – in the metaphysics of science especially – about methodological questions such as how the sciences themselves can assist us in answering the others.

This brief chapter will have something to say about all of these questions, and the labour will be divided as follows. In Section 2, we will introduce some of the idioms pertaining to *ontological priority* that are intended to help us get a grip on the notion of fundamentality. In Section 3, we will discuss whether priority ought to be conceptualized in terms of some kind of determination relation or rather in a form ontological dependence – a matter over which there seems to be a surprising amount of confusion in the literature. In Section 4, we will consider some issues pertaining to the level of ‘grain’ at which relations of priority ought to be conceptualized. In Section 5, we will consider the issue of whether we should believe that anything fundamental exists at all.

## 2. The ‘levels hierarchy’: science and metaphysics

Talk of the fundamental connotes a domain of entities somehow distinguished – and ‘distinguished’ in the sense of *privileged* – with respect to everything else. One says that the fundamental is *ontologically prior* to those less distinguished entities. Some take the fundamental to be defined in terms of the relation of priority it bears to non-fundamental stuff, with ontological priority regarded as the analysing primitive; others take fundamentality to be an absolute notion that must ultimately resist analysis.<sup>4</sup> But even if one adopts the latter relational conception, it would be hard to deny that part of the job description we at least associate with the fundamental involves its bearing of a special relation to the remainder of what exists.<sup>5</sup> Indeed, discussions of fundamentality typically get off the ground through the depiction of reality as equipped with a ‘layered structure’, in which the fundamental occupies a unique and especially exalted position at the root of it. As Schaffer puts it, the basic world-view that often motivates fundamentality talk is of

a *hierarchical view of reality* ordered by *priority in nature*. The primary entities form the sparse structure of being, while the grounding relations generate an abundant superstructure of posterior entities. The primary is (as it were) all God would need to create. The posterior is grounded in, dependent on, and derivative from it. The task of metaphysics is to limn this structure.<sup>6</sup>

Such a hierarchically ordered vision of reality is often said to be fractioned into ‘levels’. When confronted with this picture, philosophers of science will be apt to recall some descendent of the ‘system of reductive levels’ laid out in Oppenheim and Putnam’s vision of ‘unified science’ over half a century ago.<sup>7</sup> The purpose of this work was to arrange the diverse sciences into one connected explanatory picture, and what was supposed to effect these explanatory connections was that idea that the subject matters of less fundamental sciences were *mereologically composed* of those of the more fundamental. Thus, subatomic particles were conceived of as sitting at the bottom of the hierarchy; from there we progress through atomic physics through molecular chemistry and cell biology, all the way up to wherever in the social sciences we are willing to stop. Whatever its status in philosophy of science, Schaffer refers to this mereological conception as still the ‘central connotation’ of the levels metaphor as it is understood in fundamentality metaphysics.<sup>8</sup>

This pyramidal, monolithic, building-block picture of the sciences is surely, at best, a heuristic and a metaphor. (Where, for example, do we place the subject matter of cosmology, and how could the Higgs field – a field pervading all of space and time – be classed as fundamental on this view?) The ‘levels hierarchy’ surely has to be articulated in less crude – and likely more piecemeal and contextual – terms than this.<sup>9</sup> Nevertheless, for all that we may only have a murky idea of how the relations of priority between any two domains of science ought to be understood, it remains that almost everyone – notable exceptions aside – seems to accept that such ontologies generally do stand in relations of priority of some sort.<sup>10</sup> We will have more to say about the structure of these relations momentarily. But for now, note that if one takes the ontology of the different sciences to (by and large) stand in priority relations (however they are best articulated) and that it is the resultant ordering that defines the ‘levels hierarchy’, then it seems that this latter hierarchy *cannot* be identified with the ordered structure that Schaffer takes metaphysics to be tasked with limning. The reason is that questions of how the ontologies of the sciences relate to each other seem to be distinct from those questions Schaffer takes to be paradigmatic of metaphysics. Consider, for example, the debate in philosophy of physics over relationalism vs. substantivalism about spacetime. Surely no one is proposing that spacetime points and the relations between them stand on different ‘levels’ of the hierarchy, where different levels are conceived of (by and large) as populated by the ontology of different sciences. Rather, both the points and the relations exist *wherever in the levels hierarchy spacetime is*. (To put it another way, it is not as if the relationalist takes the spacetime points to be located somewhere ‘north’ of fundamental physics, assuming that spacetime physics indeed qualifies as fundamental physics.<sup>11</sup>) Or to take another example, suppose we are considering whether the laws of fundamental physics are primitive constituents of nature or rather, as (for example) Humeans will hold, a derived construction from fundamental properties. Then it seems that the laws of fundamental physics belong in, and *only* in, those domains *where fundamental properties are found*. For at macroscopic scales where colour charge and weak isospin, etc., are no longer predicates of objects, it seems the laws of the standard model will not just be impractical in application, but simply undefined. Rather, a different set of laws will be definable at that level. As such, it seems those who regard laws as non-fundamental entities are not committing to the idea that laws inhabit a higher ‘level’ than that inhabited by the fundamental stuff: their fundamentality is not about where they are on the hierarchy.

For these reasons, it seems that while many questions about how the ontologies of the different sciences relate are focused on their relative priority, and while many canonical questions in metaphysics are also centrally concerned with matters of priority, we cannot take it that the priority relations involved in each case align on a single hierarchical structure. On the contrary, it seems that the layered structure that (those who identify as) metaphysicians are primarily concerned with is a structure that is oriented in some sense ‘orthogonally’ from that relating the ontologies of the different sciences. What seems ultimately responsible for this two-dimensional priority structure is the fact that the paradigmatically metaphysical debates seem primarily to be over the priority of metaphysical *categories*: for example, over which of the category of objects or that of relations is the ontologically prior category (as in debates over structuralism), or whether the category of objects is ontologically prior to the category of properties (as in debates over nominalism). Questions about the structure of the scientific levels hierarchy, by contrast, seem primarily *intra*-categorical, consisting of considerations over whether the laws of the biological sciences are less fundamental than the laws of physics, or whether the properties of the cell are less fundamental than those of its constituents (and so on). Given that it seems there are two distinct, though connected, levels structures involved in each case, it should be clear that one cannot blithely assume that the priority relations defining

each axis are identical. Whether there is a one-size-fits-all relation of priority that may be usefully deployed in any area of fundamentality metaphysics is a matter to which we will return. But for now, let us remain at an abstract level and consider what features, if any, of logical form are shared by relations of priority in general.

### 3. Characterizing the fundamental

Largely responsible for the recent explosion of literature on fundamentality is the idea that supervenience and other purely modal concepts are insufficiently discriminating to do the work of characterizing the relations of priority defining the layered structure (or structures) of reality. This in itself is not a new observation, and why it has only recently taken on axiomatic status is a matter over which I can only speculate.<sup>12</sup> But regardless of whether it is new or what the reasons for its recent uptake are, I take the basic idea that mere modal correlations are too coarse to capture priority structure to be fundamentally correct.<sup>13</sup> In *a priori* metaphysics at least, the relation of ‘grounding’ has become the heir of supervenience in characterizing priority structure, with the result that the lion’s share of the contemporary discussion seems to concern arguments around the correct analysis and logical form of this putative relation.

Of course, as the ‘distinctive structuring relation of metaphysics’, grounding needs to be understood more determinately than simply as the hyperintensional relation that relates more to less fundamental stuff.<sup>14</sup> Looking at the literature, however, one is struck by considerable divergence on even the most basic aspects of how grounding is understood. For example, grounding is often identified with a hyperintensional relation of *ontological dependence*, such as that which has historically been taken to exist between attribute and that in which it inheres. In this view, the fundamental would be characterized as that without which the non-fundamental could not exist. Other times, however, grounding is presented as a relation of *ontological determination*, with the non-fundamental being thought of as that somehow *brought about, entailed by, or derivative of* the more fundamental stuff.<sup>15</sup> But even before we get into the details of how these relations are to be defined, it would seem that these two relations differ both intensionally and in terms of their logical form, with the former intuitively presenting the fundamental as a *necessary*, and the latter a *sufficient*, condition on the non-fundamental. Moreover, it is obvious that these relations are not just conceptually quite different, but extensionally distinct as well. Thus, to take some examples, entangled states in quantum mechanics seem to give us a case of dependence without a corresponding determination: for while (most would argue that) such relations cannot exist without their relata, the intrinsic properties of those relata famously do not allow for the reconstruction of the overall state. Conversely, a multiply realized but non-fundamental entity plausibly provides us with an example of determination without a corresponding dependence. For since a multiply realized special-science feature could, by definition, be brought about by any number of more fundamental goings-on, it seems right to say that it is determined by any such realizer and yet wrong to say that it is ontologically dependent on any one of them, in the sense of being unable to exist without it.<sup>16</sup> Thus, whether we regard grounding as a relation of dependence or one of determination could drastically change what we are apt to regard as fundamental.

What, then, are we to do, given that the literature is as we find it? One option is to adopt a pluralism about priority and say that both relations track facts about priority. Were we to take this approach, consistency will demand that there are no facts about what is prior to what *simpliciter*, but only with respect to one or other relation. Such a move finds an analogy in the philosophy of biology and the dispute over the species concept.<sup>17</sup> However, given that species pluralism has largely given way to *eliminativism* about the species concept – leaving only facts

about what is descended from what, what can reproduce with what, and what is morphologically similar to what in its wake – one might take the fact that non-coextensive relations between things have all been thought to track priority has similarly eliminativist morals. Now, of course, in one sense this could be taken to be an entirely unproblematic consequence. After all, knowing what determines what and what depends on what helps us to develop an intelligible picture of the world and of the way that the different sciences fit together; what, one might ask, is the value added in going further and saying what is ‘fundamental’? Indeed, those of a more cynical persuasion might even go as far as to say that the recent explosion of fundamentality talk expresses only metaphysicians’ proclivity to pepper their work with a term that has the effect of demanding that it be regarded as significant – look up the word ‘fundamental’, after all, and you will find that it has synonyms like ‘important’. Such a view recalls certain episodes in the history of physics in which fundamentality rhetoric surfaced somewhat in synch with perceived threats on funding.<sup>18</sup> If this is your stance, then banishing the word might help us view metaphysics in a more sober light.

On the other hand, however, we might view all this as much too cynical, holding that fundamentality is a distinction that the world admits whatever one’s take on the value of metaphysics (or the insecurities of metaphysicians).<sup>19</sup> Therefore, let us think more carefully about which of determination or dependence has a better claim on characterizing the fundamental. To do so, consider again the intuition pumps that Schaffer (and others) use to help us get a handle on the notion – in particular, the ‘all God had to do’ metaphor alluded to in the quote earlier. Plausibly, if we are to understand the fundamental in terms of this metaphor, then we understand it via a relation of *determination*; for what it connotes is that, by making the fundamental, everything else was settled, taken care of – or, in other words, *determined*. But it seems the same cannot be said about dependence: for knowing what everything depends on will not suffice to establish what else there is, should there be dependent entities not fully determined by that on which they depend.

It follows from all this that only if the fundamental is conceptualized in determination terms would knowledge of the fundamental suffice, at least in principle, for knowing everything else about the world. Thus, it seems that determination not only captures our initial motivating intuitions but furthermore accounts for the centre-stage role played by the fundamental in metaphysics. For at the heart of metaphysics is ontology, and ontology concerns what there is: if the fundamental is that which *determines everything whatsoever*, then it determines everything we are interested in, and so of course there is ample justification for focusing on it. Moreover, conceptualizing fundamentality in this way would mean that non-determined but ontologically dependent entities would qualify as fundamental, but occupy a sort of half-way house conceptually insofar as dependence has been taken, perhaps erroneously, to capture something relevant to fundamentality. Indeed, Barnes (2013) takes being non-determined but dependent to be the hallmark of emergence, holding that this half-way house character is precisely what emergentist intuitions have been struggling to capture all along (emergence seemingly involving, as mentioned at the outset, both the fundamental and the non-fundamental simultaneously). By contrast, multiply realized entities – that is, entities that are determined by but not dependent on their realizer in a given instance – may continue to pose problems for theses of reductionism in science consistently with saying they are not metaphysically fundamental. For the inevitably disjunctive nature of that upon which they arguably do depend makes it difficult to *identify* them, for all the usual reasons, with whatever realizes them in a given instance; similarly, it will problematize the idea that the details of any given realizer provide the *best explanation* of any token instance of the realized property. Thus, it seems that, on the determination-based conception, debates over (certain versions of)

reductionism can flourish even though we should all be able to agree that the property we are supposing to be non-reduced is metaphysically non-fundamental.

#### 4. Getting specific

So far, so *a priori*. What we wanted to understand was the levels hierarchy, and what we've done so far is identify something about the logical form of the relations the fundamental stands in to the non-fundamental – namely, that it is their job to entail its existence – and waded at the idea that it transcends that form (insofar as the relation is more fine-grained than such mere entailment). What more can we say? One question we should think about is whether a single relation – sometimes referred to as the 'big-G' relation of grounding – suffices for expressing the work that the fundamental does in determining the remainder of ontology. The fact that so much effort in the *a priori* metaphysics literature has gone into characterizing this relation suggests that many take this question to be answered in the affirmative, even if they do not all explicitly say so.

Others have argued, however, that all this is deeply misguided. They hold that if we want to develop a metaphysics of priority more contentful and illuminating than we have managed so far, then we need to go about the project piecewise, focusing on the *sui generis* relations that pertain to entities of different types.<sup>20</sup> A principal reason stated in favour of this is that establishing the mere fact that an entity is grounded leaves open many critical metaphysical questions about that entity – supposedly including even that of whether the grounded entity should be taken to exist.<sup>21</sup> Now, one might of course question how this could possibly be, for surely to say that an entity stands in any real relation or that it has a place in reality (layered or otherwise) is *ipso facto* to commit to the existence of that thing.<sup>22</sup> Nevertheless, given that we can agree that non-fundamental scientific theories exist, that their subject matter is whatever it is, and be very much uncertain as to whether that subject matter really *exists*, it seems that one can make at least an analogous point about the priorities between scientific ontologies. There at least it seems clear that merely stating that an entity may be 'derived' from a more fundamental one does indeed leave open many crucial metaphysical questions about it and that it will do so until we provide much more detail about how it is that the derivation goes.

To see this, let us retreat from *a priori* metaphysics and consider more highly specified, scientific ontologies: that is, ontologies that we understand in the context of particular, well-developed scientific theories. In particular, consider how it is that the ontology of relativistic quantum theory – the most fundamental theory produced to date, at least that we know how to submit to empirical test – determines that of non-relativistic quantum theory and of how that in turn determines the ontology of the still less fundamental theory of classical physics. Taking the latter transition first, the process by which classical ontology may be recovered from that non-relativistic quantum theory is by now well understood, due to the development of the theory of *environmentally induced decoherence* over about the last quarter-century. In a nutshell, one can show – and utilizing only *quantum theory itself* – that the effect of the environmental interactions on a physical system is to suppress, over extremely short timescales, the phenomena most characteristic of quantum regimes. In particular, suppose that one takes as a target system a tiny dust mote and considers it in an environment consisting of the microwave background, solar photons and neutrinos, and air molecules at standard atmospheric pressure. Then one can show that the quantum interference associated with the mote becomes negligible virtually instantaneously; that in any world in which such a mote occurs, it occurs approximately localized in both position and momentum, achieving the smallest spread consistent with Heisenberg uncertainty; that in any world the trajectory followed by the peak of its probability distribution will closely approximate, compared with other physically relevant scales, Newtonian trajectories; and that the probability distributions appropriate to these

systems may be interpreted as they would be classically. In other words, though we start with a quantum system in an environment (which is likewise modelled quantum-mechanically), what we get back in short order is a system that we can with every justification regard as *approximately classical*. Now to be sure, because (it turns out) one is left at the end of this ‘decoherence’ analysis with (what is most naturally interpreted as) a *multitude* of worlds, each containing a classical-like dust mote – not simply the one mote that we took ourselves to start out with – decoherence does not in itself solve the ‘measurement problem’ lying at the heart of the interpretational difficulties of quantum theory. As such, one still needs an interpretation of quantum mechanics – Bohmian, many-worlds, or whatever one prefers – in order to tell a story about why only one tranche of the resulting approximately classical ontology appears to us to be observed. But it is widely agreed that through decoherence the problem of *emergent classicality* has been solved dynamically and that it need not be solved afresh for each interpretation.<sup>23</sup> The problem, by contrast, is that there is something of an ‘embarrassment of riches’ when it comes to deriving classical stuff!

Consider now how it is that the ontology of non-relativistic (and hence non-fundamental) quantum theory is determined from that of its relativistic successor, namely quantum field theory. Recent work by Myrvold (2015) has shown in detail how wavefunctions – that is, solutions of the (non-relativistic) Schrödinger equation featuring a definite number of particle quanta – may be derived, in some circumstances, from an underlying ontology of quantum fields in the non-relativistic limit. This is the limit in which the effects of the relativity of simultaneity may be taken to be negligible. Such effects will be negligible so long as ‘we are not dealing with processes that are spread out too far in space’ – a spread which will, of course, be frame-relative – and so long as we are happy to record the properties of fields to a truncated temporal resolution.<sup>24</sup> As such, the ontology of non-relativistic quantum theory may be shown to emerge from that of more fundamental theory in a limit defined by a restriction on the accuracy with which we measure the properties of the underlying field systems, and in the circumstance that our interest is limited to regions that are spatially sufficiently small.

It seems, then, that we can by now tell intricate stories about how it is that the ontology of non-relativistic quantum theory is derived from that of its more fundamental relativistic counterpart and how classical ontology may in turn be derived from that. But it seems that the stories involved in each case raise different issues from a metaphysical perspective. For the story in the quantum-classical transition is exclusively *dynamical*: in order to produce classical systems, one need only take quantum systems (embedded – as they always will be in practice – in an ambient environment) and let them run forward in time. By contrast, the derivation of non-relativistic from relativistic systems can crucially involve frame-dependent assumptions, which we may of course expect to raise questions about the objectivity of the derived non-relativistic entities. While not wishing to prejudge the outcome of a pursuit of those questions here, the point for present purposes is simply that the manner in which the ontology of non-fundamental theories is derived can have significant implications for whether or not we will feel justified in regarding the derived entity as genuinely existent or real.

These developments in the understanding of inter-theory relations make salient the following morals. It reminds us, first of all, that showing how the ontology of non-fundamental scientific theories correspond to those of more fundamental theories represents a scientific achievement, the details of which insipid claims that the former is ‘grounded’ in the latter might easily obscure. It also reminds us that there is no one prescription on the sort of limiting relations that take us from more to less fundamental theories.<sup>25</sup> But it also reminds us that establishing that the ontology of a given non-fundamental scientific theory may be regarded as real in the first place is going to be a function of the nature of the derivation relations in which that ontology partakes. Assuming that a minimum condition on an entity’s having a place in the layered structure of



reality is that the entity concerned has some measure of objective existence, it seems clear that we are going to have to attend carefully to the nature of these derivations before we can start thinking about whether it is ‘grounded’ or not. But by that point, however, it becomes difficult to see what work the ‘grounded’ predication is doing in enhancing our understanding of the hierarchy of scientific ontologies beyond that which has already been achieved through attending to the details of the derivations themselves.

As such, it is unclear to me at least how much of the discussion in *a priori* metaphysics over ‘big-G grounding’ has to offer apropos the task of understanding the world as it is described in our best scientific theories. Rather, it seems to me that we need to do a great deal of work in order to even get to the point at which we can begin to talk about grounding, but also that by that same point it is unclear what still remains to be said. Less sceptically, however, it was noted earlier that the distinctively metaphysical applications of priority talk seem to pertain to a structure in some sense ‘orthogonal’ to that most naturally taken to relate the ontologies of scientific theories. Perhaps it is in that context that metaphysicians’ discussions over grounding in the abstract will prove their usefulness – at the very least, by providing useful tools and resources that can be adapted for a more *sui generis* treatment.<sup>26</sup>

## 5. The existence of the fundamental

It was just argued that oftentimes, before we can begin to think about matters of grounding, we have to work to establish that a given candidate for being grounded even exists in the first place. For presumably only if an entity exists can it be said to be grounded and hence non-fundamental. It is, however, a surprisingly popular view among metaphysicians that no non-fundamental entity could ever have the status of *existent*. After all, arguments based on causal exclusion and a variety of principles of parsimony are intended to militate against the view that there is anything non-fundamental at all.<sup>27</sup> But given that clearly *something* exists, the view that the non-fundamental is non-existent is plausible only to the extent that we are confident that reality bottoms out in a realm of fundamental entities. This, of course, seems to place us in a rather dangerous predicament, given that the more fundamental an entity is, the more remote from our experience it is likely to be and – the history of science counsels us – the less confident we should correspondingly be about its existence and nature. To be sure, many have asserted that the existence of the fundamental is *a priori* necessary for there to exist anything whatsoever – usually by expressing some variant of the view that without the fundamental ‘reality would be infinitely deferred, never achieved’.<sup>28</sup> But this intuition, for all that it seems to be widely shared, has proven remarkably resistant to further defence.

For example, an argument often given for the intuition is that if there were no fundamental entities, then the world would fall victim to a vicious existential regress – a regress taken to be somehow more problematic than the cosmological argument’s causal analogue. But as Bliss (2013) argues, the only compelling interpretation of what makes a regress ‘vicious’ seems to result in the regresses envisioned in many infinite-descent worlds being more appropriately classified as benign. Cameron (2008) argues similarly that the best reason to believe in fundamentalia is a virtue-based argument to the effect that worlds with fundamentalia are more ‘unified’ than those without – an argument which he claims makes their existence a contingent feature.<sup>29</sup> And not only is it the case that arguments for the necessity of fundamentalia have been called into question, but arguments outright denying the existence of a fundamental level have been marshaled as well. For example, Schaffer (2003) argues that we have good inductive grounds for denying that there is anything fundamental, since the particles we have previously regarded as fundamental have often been found to not be so after all. And while Callender (2001) is probably

right to regard this as ‘an inductive leap of the wildest sort’, McKenzie (2011) argues that it is at least conceivable that scientific theories could have anti-fundamentalist consequences. Indeed, the S-matrix theory – the theory which, through its application to strong interactions, played a crucial role in the emergence of string theory – may here be said to represent a prototype, since it enjoyed at least a modicum of success and had a natural anti-fundamentalist interpretation.

Given the failures suffered by *a priori* justifications for the necessity of fundamentalia, perhaps the right way to approach the issue is in broadly empirical terms. Taking this route commits us to believing in fundamental entities if and only if our best scientific theories imply that there are such things. As noted, this need not commit us to the existence of fundamental particles (or perhaps even fundamental laws), since it is conceivable that real physical theories could furnish us with positive reasons to deny that there in fact are any (just as, arguably, did the S-matrix theory). But if we go this way, it seems that we will inevitably be committed to another sort of ‘half-way house’ fundamentality. The reason is that if we take this naturalistic approach, certain theoretical principles must be at least *treated* as axiomatic in order to deduce any anti-fundamentalist conclusions. In this sense, it seems we can never get around a commitment to fundamental *principles*, even if we can use those same principles to deny the existence of fundamental *particles*. While philosopher-scientists such as Bohm and Popper have harboured more radical anti-fundamentalist visions, it is entirely unclear from a naturalistic perspective how we could compellingly argue for them.<sup>30</sup> Still, what does seem clear is that the world could admit more *recherché* possibilities than those insisted on by the *a priori* fundamentalist.

## Notes

- 1 See e.g. Schaffer (2009), Dorr (2008), and Paul (2012) for statements of the former view; Sider (2011, p. 1) for a statement of the latter.
- 2 For example, Stebbing 1932 lays out a conception of analytic metaphysics closely analogous to that of Paul and Schaffer.
- 3 Schaffer (2009, Sec. 2.2).
- 4 Schaffer (2009), Rosen (2010), and Bennett (2017) take a relational approach. Wilson (2014), Sider (2011), and Fine (2015) take fundamentality to be primitive.
- 5 Or, if one denies that there exists anything non-fundamental at all, one should hold that the fundamental has an essential role to play in determining the correctness or incorrectness of statements that putatively refer to non-fundamental stuff, even if they are not taken to be defined by any such role. (Note that there is room for comparison here with the notion of perfectly natural properties: while it seems these resist analysis, we get a grip on what they are through appreciating the work that they do in canonical metaphysical projects.)
- 6 Schaffer (2009), p. 351.
- 7 Oppenheim and Putnam (1958).
- 8 Schaffer (2003), p. 500.
- 9 See Craver (2015) for a defence of the levels hierarchy conceived of in a more piecemeal context of enquiry-dependent terms.
- 10 See Cartwright (1999) for a notable such exception.
- 11 For discussion of the possibility that spacetime is non-fundamental, see Huggett and Wüthrich (2013).
- 12 The basic observation is in Kim’s criticisms of supervenience (see eg. Kim 1993).
- 13 For example, approaches to priority based purely on supervenience render all necessary features of the world, such as whether the continuum hypothesis is true, non-fundamental features; nor – perhaps more importantly – can they adjudicate on relations of priority between necessary co-existents.
- 14 To say that grounding is hyperintensional is to commit to it being a relation stronger than necessitation: the grounded and its grounds could co-exist in all the same possible worlds and yet the grounding relations between them not thereby be settled.
- 15 For example, Rosen (2010), Trogon (2013), Cameron (2008), and Bliss (2013) all present dependence as synonymous with grounding. For examples of work in which grounding is taken to be a relation of determination, see Fine (2015) and Dasgupta (2015).

- 16 These cases can be a little tricky to construct, but the easiest cases are where the realizers cannot co-exist in the same world. Since laws are global entities, different fundamental laws presumably cannot co-exist at the same world; thus, if special-science laws can be multiply realized, as many believe, this would constitute just such a case of determination without dependence.
- 17 Ereshefsky (1998) is the classic reference here.
- 18 See Martin (2015) for an illuminating discussion.
- 19 As Craver (*op cit.*, p. 2) puts it, 'The suggestion that we might be better off abandoning the levels metaphor is about as likely to win converts as the suggestion that we should abandon metaphors involving weight or spatial inclusion. These metaphors are too basic to how we organize the world to seriously recommend that they could or should be stricken from thought and expression'.
- 20 Jessica Wilson stands at the forefront of this debate (see eg Wilson *op cit.*). Of course, this point is consonant with that made in Section 2 about intra-vs. – inter-categorical notions of priority, and at the end of the last section.
- 21 See Wilson *op cit.*, Section II.i.
- 22 See *ibid*, footnote 33.
- 23 See Rosaler (2015) for the defence of this claim and a much more careful discussion of decoherence and the quantum-classical relation.
- 24 Myrvold (2015, p. 3246).
- 25 To recall a point made in Section 2, note that rather than one pyramidal 'levels hierarchy' of physical ontology, the 'cGh cube' depicts the three dimensions of limiting relations that we expect to extend out from a fundamental theory of quantum gravity.
- 26 See French and McKenzie (2015) for a general defence of the value of *a priori* metaphysics along these lines.
- 27 See Thomasson (2007) for a survey of many of these arguments and extended defence against them.
- 28 Schaffer (2003).
- 29 Note that Orilia (2009) argues that Cameron's argument for contingent fundamentality on the basis of unity considerations does not succeed (independently of the perennial problem of associating 'likeliness' with 'lovely' features such as unity).
- 30 See Bohm (1957), Chapter 5; Popper (1972, pp. 194–196).

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