

## Structuralism in the Idiom of Determination

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### Introduction

Ontic structural realism (OSR) is at its core a thesis of fundamentality metaphysics: the thesis that *structure*, not *objects*, is endowed with fundamental status.<sup>1</sup> Claimed both as the metaphysic most befitting of modern physics and radically at odds with more mainstream views, OSR first emerged as an entreaty to *eliminate* objects from our scheme of fundamental metaphysics. Such elimination was urged by Steven French and James Ladyman on the grounds that nothing less could address the ‘underdetermination of metaphysics by physics’ they claimed afflicted the status of quantum particles *qua* their being individuals or non-individuals – an affliction which they took to reduce any putative objectual commitment to a merely ‘*ersatz*’ form of realism.<sup>2</sup> Few, however, seem to have joined French and Ladyman either in acknowledging that such underdetermination exists or in attributing to it such drastic consequences. But an alternative view that physics *does* sanction objects, albeit merely as *ontologically secondary* entities, represents a different and seemingly less extreme route to the same conclusion regarding the fundamentality of structure. Indeed, what we can call the

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<sup>1</sup> E.g. French 2012, p. 122: ‘as far as the ontic structural realist is concerned, [objecthood] is to be understood as derivative at best, with structure as the fundamental ontological category.’

<sup>2</sup> Ladyman 1998, pp. 419-20.

‘priority-based’ approach to structuralism now seems widely regarded as the more plausible of the two. But since what it means to be ‘ontologically prior’ is itself a vexed philosophical question, a stance must be taken as to how we are to understand priority before its prospects can be properly evaluated. In an earlier paper, I outlined how Fine’s notion of *ontological dependence* might be utilized to articulate and defend the priority-based approach to structuralism.<sup>3</sup> Since then, however, new considerations have emerged suggesting that ontological dependence is not a relation of priority after all. As a result, the arguments outlined in that paper stand in need of reassessment.

In this work, I consider the prospects for priority-based structuralism when expressed in the idiom of *determination*, with the aim of producing a more definitive statement of the current standing of OSR. My conclusion will be that priority-based structuralism has yet to be vindicated by our best physical theories, owing to the failure of symmetry structures to determine the world’s inventory of fundamental kinds. Nevertheless, the same symmetry considerations point toward there being renewed prospects for an eliminativist structuralism – an eliminativism, moreover, of more naturalistic appeal than that associated with OSR hitherto.

The strategy that will be taken throughout will be much like that adopted before. The question of the relation between objects and structures will be examined through the lens of the most fundamental empirical theory produced to date – namely, *quantum field theory* (QFT). As such, many of the physical considerations that fuel the arguments of the previous paper will reappear here largely unchanged. But since the motivation for the present paper stems more from developments in our conception of fundamentality than any changes in the relevant physics, as great a portion of the paper (Sections 2 and 3) will consist of the groundwork needed to understand the claims as will be concerned with their evaluation (Sections 4 and 5). The present paper will moreover be more limited in its scope, in that it will not consider the claim that ‘structure is fundamental’ in its full generality, but focus rather on the more restricted and controversial thesis that structure *alone* has that status. The reason I focus exclusively on what is known as ‘strong’ (or ‘radical’) OSR over its ‘moderate’

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<sup>3</sup> McKenzie 2014.

counterpart is that it now strikes me that few metaphysicians of any stripe would take issue with the claim that *both* objects and structures have fundamental status – making it hard to square moderate structuralism with OSR’s claim to represent a departure from metaphysical orthodoxy.<sup>4</sup> But in any case, if the conclusion that eliminativism represents the only feasible form of structuralism is indeed the correct one to draw, then a moderate interpretation is ruled out *tout court* and we need not discuss it further. In what follows, then, by ‘OSR’ we will mean it as understood on its radical rendering only.

Before we get started, a couple of points should be noted about the limitations of the present methodology and its focus on QFT. First of all, since QFT is not a framework that incorporates gravity, no interpretation will be given here of the standing of spacetime points, despite the fact that they are routinely presented in the literature as objects amenable to structuralist treatment. However, since those discussions have typically focused on issues of *identity*, the morals of the discussion of particle identity at Section 4i may be expected to transfer to them. But what that lacuna in QFT also means is that, while it represents the most fundamental physical framework that has been developed to date – indeed, is arguably the ‘most powerful, beautiful and effective theoretical edifice ever constructed in the physical sciences’ – QFT is almost certainly not a framework that correctly describes the truly ontologically fundamental.<sup>5</sup> As such, while our conclusion may be right concerning what our *best current science* has to tell us about the fundamental *as that science presents it*, what significance that conclusion has for the fundamental *simpliciter* must remain an open question. Now of course, in one sense we are here in exactly the same boat as anyone working in 2017 on naturalistic fundamentality metaphysics, such as those arguing about what the world’s ‘fundamental space’ is or whether reality is fundamentally holistic.<sup>6</sup> However, given that the roots of modern structuralism lie in the question of which, if any, of our theoretical commitments can be expected to persist as science progresses, it seems more incumbent upon structuralists to defend the value of debating fundamentality questions in advance of

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<sup>4</sup> See for example Sider 2011, *passim*. Esfeld and Lam (2008) is the classic exposition of ‘moderate’ OSR.

<sup>5</sup> Duncan 2012, p. iv.

<sup>6</sup> See e.g. North 2013; Schaffer 2010.

our possession of a truly fundamental theory. But while I regard this as a sorely neglected methodological question, it is too involved, and perhaps also too disheartening, to engage with here. Thus for now, we revert to type by focusing on our best current science, by assuming that that science has implications for what is truly fundamental, and by beginning to think about whether or not it recommends to us the thesis of ontic structuralism.

## 2. Arguments for structuralism.

Under investigation is a proposition concerning the ontological fundamental: that it is structure, and only structure, to which that accolade belongs. When considering this view, it is helpful to invoke the heuristic of the world stratified into more and less fundamental ‘levels’, with OSR having something to say about the very lowest level in particular. And since OSR contests received views regarding the status of metaphysical categories, it is useful to conceive of the hierarchy of levels in a way that makes no mention of such categories – such as one based on energetic or spatial scales. Given that we are taking QFT as our physical framework, and hence Minkowski spacetime our arena, in thinking about the fundamental level we are to think about the metaphysics that emerges in the limit that spatial scales get *arbitrarily small* – or, equivalently, in which energies grow *arbitrarily large*.<sup>7</sup> With this picture in mind, we can now introduce the strategies structuralists have used to argue for the fundamentality of structure: the *priority-based* and *eliminative* strategies.

**Priority-based strategies.** These strategies aim to show that, while there are objects inhabiting the fundamental level, the accolade of ‘ontologically fundamental’ belongs to structure alone. Lest this seem paradoxical, consider that Humeans, for example, will be happy to agree that the *fundamental laws* are those describing physical goings-on among entities inhabiting the very lowest level, and that class nominalists will agree that the *fundamental properties* are those located at that level too. As such, they will identify fundamental laws and fundamental properties as fundamental instances of the categories of laws and properties respectively. But each also holds that that *category itself* is less fundamental than some other category – the distribution of fundamental properties in the first case and

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<sup>7</sup> See Castellani 2002 for a justification of this approach.

collections of fundamental objects in the second. Thus in saying that the objects in the fundamental level are not ontologically fundamental, priority-based structuralists are making essentially the same kind of move. Structuralists in this sense are finding priority structure *within* the lowest level and between the categories that can be applied there, not postulating an additional ‘underlying’ level in which objects fail to be found.

**Eliminative strategies.** Eliminative strategies, by contrast, aim to show that there *are* no objects in the fundamental level. Rather, the fundamental level is inhabited by structure and structure alone. Thus given the seeming fact that there are *objects all around us*, the eliminative structuralist must make the case that there is nevertheless a point in the hierarchy of levels at which the language of ‘objects’ ceases to apply. Thus whether it is an unambiguous individuality profile, as French and Ladyman have insisted, or some other feature deemed necessary for an entity to qualify as an ‘object’, the eliminativist holds that there is *nothing in the fundamental level* that in fact possesses it.

These, then, are the two strategies that could be used to support the fundamentality of structure. Clearly, before either of these strategies can have any real content, the criteria for qualifying as an ‘object’ or a ‘structure’ must be specified. Unfortunately, given how things have played out in the literature we should expect any such definition to be somewhat contentious. But since we must say *something*, let us attempt to confect a characterization of each category that all parties to the debate can agree on. Beginning with objects, let us first take it as a datum that the objects of physics come sorted into *kinds*, as characterized by a set of *determinate values of determinable physical properties*, such as determinate mass, charge, and spin. For brevity, let us refer to these determinate properties collectively definitive of kinds as the *determinate kind properties*. And since it is presumably part of the concept of an object that it is a *particular* – that is, something essentially distinct from a *universal* – then it should, at least in principle, be possible for there to co-exist *numerically distinct tokens* of the same kind.<sup>8</sup> Since this seems rather uncontroversial, let our first stab at a definition of objects be the following:

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<sup>8</sup> One may argue that fields are *bona fide* objects yet fail to satisfy this criterion. However, the fact that particles are presumably the paradigms of what we mean by ‘object’ in physics it seems appropriate to include this criterion. In any case, however, it is not the plurality requirement that causes the problems for structuralism, but rather the requirement of intrinsic kind properties. Since the kind

**O1: The *category of objects* consists of *pluralities of entities* defined in terms of a shared set of *determinate kind properties*.**

Going forward, we will take it as a given that such entities exist, even at the fundamental level. That is, we will take it as a given that there are many electrons, many photons, many positrons, and so on (assuming for argument's sake that these are fundamental kinds): to do otherwise seems wholly too revisionary for a naturalistic thesis. Of course, doing so immediately prompts the worry that we are *eo ipso* precluding eliminativism. Such worries will be unfounded, however, so long as we are justified in placing further requirements on what may be classed as an 'object' for the purposes of metaphysics of physics. What these further requirements should be taken to be is of course also something we can expect to be disputed. For example, as already noted French and Ladyman's insistence that the status of putative objects *qua* individuals or non-individuals must be unambiguously determined has been widely regarded as an unduly demanding condition on ontological commitment.<sup>9</sup> But what *is* clear is that unless we are to make eliminativism too easy to achieve, we must try to be as undemanding as we reasonably can be in imposing conditions on objecthood. And it furthermore seems *wholly uncontroversial* that if these pluralities of entities that have kind properties in fact turn out to be pluralities of *structures* (in some sense to be determined), then eliminativism about objects in favour of structures will be the only viable position.<sup>10</sup> Thus an uncontroversial concept of object, one begging questions neither against naturalism nor eliminativism, is the following:

**O2: The *category of objects* consists of *pluralities of entities* defined in terms of a shared set of *determinate kind properties*, where these entities are *not structures*.**

What it means to be a 'structure' must of course now be specified if O2 is to have meaning.

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properties of fields are defined in the same way as that of their quanta, the basic conclusion will remain whether we include the plurality requirement or not.

<sup>9</sup> See e.g. Brading and Skiles 2012; Chakravartty (2003).

<sup>10</sup> I take it that this is close to what French and Ladyman were getting at in their 2003, p. 37.

Given the difficulties that even structuralists concede have plagued attempts to define this notion cleanly, let us lower our ambitions and settle for characterizing what we mean by ‘structure’ in structuralism *extensionally*, via a list of its paradigm cases.<sup>11</sup> As I hope anyone familiar with the core literature will agree, these we may take to be *extrinsic properties, relations, and symmetry groups*.<sup>12</sup> Now, assuming that it is in structuralists’ dialectical interests to at least start out by being as non-revisionary with respect to the grammar of science as they can be, we should begin by assuming that the determinate kind properties are indeed *properties*. As such, we begin by assuming they are not *relations*, nor *symmetry groups*.<sup>13</sup> Going by the list above, this means that entities defined by kind properties will fail to be identifiable with structures should any of those properties turn out to be *intrinsic* properties. By ‘intrinsic properties’, we will mean properties ‘which things have in virtue of the ways they themselves are’, as opposed to those ‘which they have in virtue of their relations or lack of relations to other things’; in so doing, we follow Lewis.<sup>14</sup>

There is much more that could be said to develop this idea that it is the intrinsicity of the kind properties – of *any* of the kind properties – on which the fate of structuralism hangs. However, so as not to get too stuck in the weeds, let us settle for pointing out that this approach comports with those taken by both structuralists and their critics. In particular, it comports with the fact that Ladyman and Ross’ eliminative structuralism consists, in part, in their rejection of entities with even ‘*some* properties that are intrinsic to it’, and with Chakravartty’s insistence that OSR must establish that ‘not just some, but all properties of the particles described by quantum theory are extrinsic’.<sup>15</sup> We arrive, then, at the concept of object with which we shall proceed.

### **O3: The *category of objects* consists of *pluralities of entities* defined in terms of**

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<sup>11</sup> Cf. French and Ladyman 2011, p. 25.

<sup>12</sup> For a representative sample, see respectively Maxwell 1970, p. 188; Poincaré, 1905, p. 161; Roberts 2011.

<sup>13</sup> See Sections 5 and 6 for further validation of these claims.

<sup>14</sup> Lewis 1986, p. 61. (See McKenzie 2016 for reasons to be satisfied with this informal analysis in this context.)

<sup>15</sup> Ladyman and Ross 2007, p. 151 (*italics added*); Chakravartty 2012, p. 204. (See again also Maxwell *op cit.*)

a shared set of *determinate kind properties*, where at least some of these properties are *intrinsic properties*.<sup>16</sup>

Thus objects will be said to be supplanted by structures in any case in which what were *thought* to be characterized, even partly, in terms of intrinsic properties in fact turn out to be wholly structural. Priority-based structuralism, on the other hand, will be vindicated if there remains a place in the fundamental level for the category of objects, so long as both the *plurality* of them and their *intrinsic kind properties* may be shown to be ontologically secondary to *extrinsics, relations, and / or dynamical symmetries*.

With these clarifications of the two strategies now in place, let us turn to assessing the standing of structuralism, beginning with its priority-based version. First on the agenda, then, is defining what is meant by *ontological priority* itself.

### **3.i: Defining priority I: dependence or determination?**

In philosophy at large, the fundamental has habitually been identified with that which is *ontologically independent*. Aristotle's equation of the 'primary beings' with those that are

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<sup>16</sup> It should be noted that Esfeld and Lam, writing initially in the context of spacetime theory, adopt a more generous notion of an object: for them, an entity qualifies as an object if it (a) has intrinsic properties *or* (b) can be construed as a mere 'bearer of relations' (2008, pp. 31-2 *et passim*). Given that French and Ladyman also recognize mere 'points of intersection' between relations and yet regard their view as a form of eliminativism, we can of course ask how object-like such 'thin' objects are (cf. French and Ladyman 2010, p. 30). But in any case, in their more recent work making contact with particle physics, Esfeld and Lam note that fundamental kind properties such as charge seemingly *cannot* be analyzed in terms of relations between objects (2010, 8.4) – a result consonant with my own analysis concurs (see footnote 66 below). As a result, they do not take (b) to be an option when it comes to fundamental particles. It follows that *even if* one prefers to adopt their definition of object over mine, our results regarding the feasibility of the various options within structuralism will nevertheless all agree with each other: if the fundamental kind properties cannot be regarded as intrinsic, we cannot regard the fundamental entities as objects. (Thanks to an anonymous referee for pressing me on the relation between our two views.)



depended upon but that themselves depend upon nothing suggests this identification has roots that trace into antiquity, and much leading contemporary work continues to allude to the same view.<sup>17</sup> For example, in her monograph dedicated to ‘world-building’, Bennett states that she ‘do[es] not think there is any question that independence is a – the – central aspect of our notion of fundamentality’.<sup>18</sup> Similarly, Schaffer takes priority to constitute ‘the metaphysical notion on which one entity depends on another for its nature and existence’.<sup>19</sup> Given this precedent, it is little wonder that structuralists have principally considered the relative standing of objects and structures from this perspective. As their titles suggest, both Wolff’s ‘*Do Objects Depend on Structures?*’ and French’s ‘*The interdependence of object, structure and dependence*’ place ontological dependence centre-stage in analyzing priority-based structuralism.<sup>20</sup> Likewise, Chakravartty’s most recent set of criticisms are crafted around the assumption that ‘the standard metaphysical test for determining how fundamental something is, relative to something else, is to think about relations of dependence that may exist between them’.<sup>21</sup> Indeed, my own recent work was in the same vein, utilizing Kit Fine’s essentialist account of ontological dependence to assess the standing of structuralism. As such, the stance taken was that if objects can be shown to *necessitate* structures, given what objects essentially are, then a relation of priority running from structure to objects may be inferred to exist.

Such careful attention to how priority is understood in OSR surely constitutes a welcome development, addressing as it does earlier criticisms that the notion had been shrouded in obscurity.<sup>22</sup> And this increased focus on priority concepts in structuralism mirrors developments in metaphysics more broadly. These developments have their origin in criticisms, waged by Kim and others, of the role assigned to *supervenience*, with there now being wide agreement that purely modal concepts such as this are too course-grained to do

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<sup>17</sup> See Schaffer 2009, p. 351.

<sup>18</sup> Bennett (forthcoming), quoted in Wilson 2014, footnote 24.

<sup>19</sup> Schaffer 2010, p. 345.

<sup>20</sup> Wolff 2012; French 2010.

<sup>21</sup> Chakravartty 2012.

<sup>22</sup> Cf. Hawley 2010; Roberts 2011, p. 49.

the work of limning priority structure. As such, the way has been cleared for the development of a more fine-grained or ‘hyperintensional’ relation, generically referred to as ‘grounding’, conceived of as that which succeeds in the work at which supervenience was doomed to fail.<sup>23</sup> By this point, of course, the literature on grounding forms a wide and dense thicket. Largely responsible for this is the fact that the ‘extra ingredient’ that would augment mere modal correlation, transforming it in the process into genuine grounding, has proved very difficult to articulate in a satisfactory way. But given that both grounding *and* ontological dependence have been taken to stake out priority, it is wholly unsurprising that grounding has often been *identified* with ontological dependence in this literature. Rosen, for example, takes it that ‘we say that one class of facts *depends on* or is *grounded in* another’ as if the two notions amounted to the same thing; Schaffer too – at least in places – writes as though these were interchangeable notions.<sup>24</sup> Bliss, Cameron, and Trogdon similarly treat ‘grounding’ as a synonym of ‘dependence’.<sup>25</sup>

What is noteworthy, however, is that while Fine’s work on both ontological dependence and grounding ranks among the most influential and respected, Fine himself never expresses grounding in terms of ontological dependence at all. Rather, he consistently describes grounding as ‘a constitutive form of *determination*’ or ‘a constitutive form of *sufficient condition*’.<sup>26</sup> Indeed, other careful works in the grounding canon are also careful to describe grounding as a relation of non-causal and specifically ‘metaphysical determination’, roughly connoted by ‘fixing’, ‘making so’, and ‘bringing about’ that is stronger than mere supervenience.<sup>27</sup> But just as we can distinguish *causal determination* from *causal dependence* – for example, in cases of causal over-determination – *prima facie* we should be able to keep these notions apart too.<sup>28</sup> Indeed, it is not hard to argue that the two relations are not only conceptually quite distinct but also non-coextensive, so that failing to distinguish between

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<sup>23</sup> A relation is hyperintensional iff its truth-value can change under substitution of necessary co-existents.

<sup>24</sup> Rosen 2012, p. 109; Schaffer 2009, p. 373.

<sup>25</sup> Bliss 2014; Cameron 2008; Trogdon 2013.

<sup>26</sup> Fine 2012, p. 37; Fine 2015, p. 306.

<sup>27</sup> See e.g. Audi 2012, p. 688; Dasgupta 2012.

<sup>28</sup> Audi *op cit.*; Hall 2004.

the two has real consequences for what can regard as fundamental.<sup>29</sup>

To see this, consider some examples canonical to philosophy of science of both *ontological dependence* and *metaphysical determination*, taking the former to denote a metaphysically necessary condition and the latter a metaphysically sufficient one. Starting first with an example of ontological dependence without an accompanying metaphysical determination, we can cite *relations of entanglement* (or indeed any other ‘external’ relation). For if we assume – as is standard – that relations in general are ontologically dependent on their relata, relations such as that picked out by the singlet state of two electrons cannot be instantiated absent the electrons themselves. However, as is by now well-known, that relation is under-determined by the features intrinsic to those electrons, since the same suite of properties is possessed by the particles in (e.g.) the distinct triplet state.<sup>30</sup> As such, those properties do not fix the relation between them even from a modal point of view, hence not in any more discriminating sense either. Now admittedly, some OSRists are likely to take issue with that example, since they often hold that relations do *not* depend on their particle relata, at least not in the suitably ‘thick’, hyperintensional sense that is taken to be relevant to metaphysics. Nevertheless – as we will have cause to revisit below – they *do* agree that the particles we find in the world are not determined by spacetime symmetries, even though they hold that the very existence of particles is ontologically dependent on such symmetry.<sup>31</sup> Hence both structuralists *and* object-oriented realists ought to be able to agree that there can be ontological dependence in the absence of any corresponding metaphysical determination.

Focusing now on the converse, *multiply realized properties* seem to constitute examples of entities that are non-causally or metaphysically determined by their realizing properties and yet not ontologically dependent on them. The reason, of course, is that any instance of a realizer is ‘metaphysically sufficient’ for an instance of the higher-level property, but for any such instance there is by definition another that could similarly bring it about.<sup>32</sup> Hence it

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<sup>29</sup> This point is made in the previous paper, but I refresh it here. (It is also made in Barnes 2012, but the examples provided here strike me as more naturalistically compelling.)

<sup>30</sup> See e.g. Butterfield 1993.

<sup>31</sup> See French 2014, Chapter 10.

<sup>32</sup> See e.g. Shoemaker 2007, p. 6.

seems that this constitutes an example of metaphysical determination without a corresponding dependence. Now to be sure, there has been plenty of debate over whether multiply realized entities exist, for all that it has been taken as a truism about the ontology of the special sciences. This is not a debate I can get into any detail on here.<sup>33</sup> Let me simply state that, for all that individual cases, particularly in the sciences of the mind, have been called into question, authors such as Aizawa and Gillett make a compelling case that not only is multiple realizability a feature that higher-level properties can exhibit in principle, but moreover one that is utterly prosaic.<sup>34</sup> To quote one of their own examples, it seems undeniable that there are substances (such as certain alloys) that *are explicitly constructed* in engineering and the special sciences so as to realize paradigmatically higher-level properties (such as a certain Knoop hardness), *precisely because* those properties are realized by distinct but less readily available substances (such as tooth enamel). As such, it seems that *very many* paradigmatically high-level properties will admit a multiplicity of distinct realizers. But all that is required for present purposes is that there is one such instance, and I will take that to be uncontroversial here.

It seems, then, in that in talking of grounding *qua* ontological dependence, and of grounding *qua* metaphysical determination, we have unwittingly been utilizing different, indeed non-coextensive relations to do the same metaphysical job. Since this hardly seems, on the fact of it at least, to be an ideal state of affairs, we must consider the best way to respond. One option is to regard *both* relations to be relations of priority, and so to embrace what we might call a ‘priority pluralism’. Of course, to avoid outright inconsistencies in our priority talk, we will have to index our priority claims to the type of priority involved, and we will also have to admit that priority relations ‘cross-cut’ the world instead of arranging it into something that could with any justification be regarded as a ‘hierarchy’. But for all the appealing connotations of tolerance and inclusiveness that talk of pluralism invokes, there is a legitimate worry that doing this risks the outright *elimination* of ontological priority from our metaphysical scheme. After all, eliminativism about *species* has been taken by many to be the only reasonable inference from the phenomenon of species pluralism – a phenomenon that consists in the cross-cutting of different species concepts in a way closely analogous to how

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<sup>33</sup> For a survey, see Bickle 2016.

<sup>34</sup> Aizawa and Gillett 2009.

different putative priority relations have been shown to cross-cut here.<sup>35</sup> But while there might be *something* to say in favour of eliminating priority from our metaphysical lexicon, such a move seems highly revisionary given that metaphysicians, not least structuralists, clearly *spend a great deal of their time* talking about such questions as *what is fundamental* and *what is prior to what*. Indeed, some metaphysicians have been explicit in their statements that it is questions of priority and fundamentality that constitute *the single most important* among metaphysicians' concerns.<sup>36</sup> Thus were we to take this route, it seems much of our practice as metaphysicians would have to change rather dramatically.

But perhaps there is something in that observation that points the way toward a solution. For it seems that if we were to understand the prior in terms of that which *determines* that which is secondary, then the centrality of priority to our concerns in metaphysics could be *accounted* for in a way that it could not were it understood in terms of ontological dependence. The reason is that, were we to identify the fundamental as that which is a sufficient condition on everything else, then a full understanding of the fundamental would, at least in principle, be enough to generate an understanding of the world in its entirety. There is thus some hope on this conception that with world enough and time we could reconstruct the *whole world* – the *whole domain of metaphysics* – on the back of our enquiry into the fundamental. That, however, is unlikely if not impossible to be so on a dependence-based rendering. For while anything the non-fundamental depends upon will be a part of whatever determines it (a 'partial ground'), there is no reason to think that those necessary conditions will suffice to determine the full inventory of secondary entities. Indeed, such a predicament seems wholly implausible given multiple realizability. Thus by taking priority to be a relation of determination, we have an account of *why we care so much* about priority in the first place. Additionally (though relatedly), we can cite the fact that determination comports much more naturally with our *pre-theoretic idioms* of fundamentality. For if, as many do, we get the concept of the fundamental on the dartboard in the first place with the well-worn metaphor of it being '*all God had to do*' to bring the world into being, then it seems we

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<sup>35</sup> The classic reference here is Ereshefsky 1992. Thanks to Alison McConwell for suggesting this analogy to me.

<sup>36</sup> See e.g. Schaffer 2009, p. 347; Sider 2011, p. 1; Paul 2012a, p. 239.

make appeal to a *sufficiency*-based conception to convey our meaning.<sup>37</sup> The fundamental is, on that account, the least that God could get away with to bring the world into being; in other words, the least that *sufficed*.

In sum, then, it seems that analyzing priority as determination, *not* dependence, both vindicates our practices and is more faithful to the pre-theoretic understanding the analysis was intended to capture. As such, the *method of reflective equilibrium* would seem to counsel us to accept determination as the better way to analyze priority, even if we may have to relinquish some of our extant priority claims as a consequence.<sup>38</sup> (Indeed, as we will see, this is precisely what the structuralist must do.) But if that is right, then it appears that in my previous paper – a paper analyzing the prospects of priority-based structuralism through the lens of ontological dependence – I must be judged to have backed the wrong horse.<sup>39</sup> Indeed, since the brunt of the work exploring priority in structuralism has utilized dependence relations of some sort, it seems structuralists in general have made the wrong choice in picking their relation of priority. It therefore seems incumbent upon structuralists to return to the physics, confront it with a more appropriate set of metaphysical tools, and investigate whether priority-based structuralism translates into the *idiom of determination*.

#### 4. Structuralism in the Idiom of Determination

To recap, priority-based structuralism commits to the idea that while objects exist, even at the fundamental level, they are ontologically secondary to structure. Putting what has been said up to this point together, it commits to the idea that *pluralities* of entities bearing *fundamental kind properties*, construed as *intrinsic* properties, are *metaphysically determined* by structure. Our business now is to see if this is so. A challenge we will face in the process is the fact that, as already noted, a satisfactory specification of the ‘extra ingredient’ transforming mere supervenience into genuine metaphysical determination seems so far to

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<sup>37</sup> See e.g. Wilson 2014; Dasgupta *op cit*; Schaffer *op cit*, p. 341.

<sup>38</sup> Cf. Goodman 1955.

<sup>39</sup> The reason was that I simply failed to see that there could be a relation of metaphysical determination more closely allied to the natures of its relata than supervenience (see McKenzie *op cit*, p. 6).

have eluded us. As such, going forward, our strategy will be to *exploit as far as possible* the (almost) wholly uncontroversial fact that metaphysical determination entails supervenience. That is, we will try to appeal solely to (what has been called) the ‘entailment principle’ and try to avoid, so far as we can, making appeal to any hyperintensional notions when crafting our arguments.<sup>40</sup>

The **entailment principle**: if  $p$  metaphysically determines  $q$ , then  $p$  entails  $q$ .

Utilizing this plan of attack, Section (4.i) will consider the prospects for a structuralist determination of the *plurality* aspect of objects. Section (4.ii) will focus on the *kind properties*.

#### 4i. Priority-based Structuralism I: Determining Plurality

We begin by examining whether the existence of pluralities of objects – that is, the existence of entities that are *numerically distinct* – can be accounted for. Our discussion here will be rather condensed given that the issues are discussed extensively elsewhere, including in the previous paper.

The argument of that paper was predicated Saunders’ discussion of the logic of identity, and its implications for the identities of particles in entangled states.<sup>41</sup> But the true starting point for the argument is unabashedly metaphysical, being an assumed rejection of ‘primitive identities’.<sup>42</sup> For Saunders’ argument assumes at the outset that whatever facts there are about what is identical with what, and what distinct from what, are to be consequences of facts *not* involving identity. The numerical distinctness of entities satisfying different qualitative predicates is ensured by the law of non-contradiction. This, together with the fact that qualitative and non-qualitative features are jointly complete, means that any facts about what is identical with what must be consequences of qualitative *similarity*. As such, the denial

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<sup>40</sup> Rosen *op cit*, p. 118.

<sup>41</sup> Saunders 2003.

<sup>42</sup> See Ladyman [2009], Section 4.

of primitive identity commits us to the *principle of the identity of indiscernibles* (PII).<sup>43</sup> The less controversial converse may be referred to as the *principle of the indiscernibility of identicals*: together these principles are expressed in the *Hilbert-Bernays analysis of identity*.<sup>44</sup>

As is by now well-known, quantum mechanics, at least in the standard formalism, raises puzzles for the PII. It may be shown that a pair of same-kind fermions in an entangled state – a state both highly generic and highly symmetric – cannot be distinguished from one another in terms of the physical properties attributable to them, either intrinsic or extrinsic; further, given that every relation they stand in is symmetric, it is also hard to see how there can be any relational predicate satisfied by one and not the other. Yet pretheoretically the two are taken to constitute a *pair*, raising the question of what could secure their assumed numerical diversity consistently with the PII. It was Saunders’ insight that there is in fact no contradiction here, for among the relations that entangled particles satisfy there is always at least one relation – in particular, the relation of entanglement itself – that is *irreflexive*, hence at least one relation for which it is not true that each object bears that relation to the very same things. (Supposing that *x* bears it to *y*, *y* will not bear it to *y*.) As such, there is at least one relation that discerns them and hence, by the principle of indiscernibility of identicals, entails their non-identity. Thus qualitative facts *do* account for the ‘numerical distinctness’ of the particles in the state after all: it is the irreflexive nature of the relation of entanglement between them that has this as a logical consequence.

In my previous paper, this analysis was put into contact with Fine’s essentialist analysis of ontological dependence, concluding that a dependence of objects on structure can be sustained in this context. Put briefly, the argument was that since particles have been shown, thanks to the attendant irreflexivity, to be numerically distinct, it then follows from Fine’s analysis that it is *essential* to them to be distinct; the demand that something accounts for this distinctness, coupled with the failure of any monadic properties of the particles to do so, then entails that there is something essential to those particles that implies the existence of a relation. From this an ontological dependence, in Fine’s sense, of objects on relations may readily be deduced. But while that analysis may be as correct as far as it goes, following the

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<sup>43</sup> When the objects concerned are worlds themselves, this is the thesis of anti-haecceitism.

<sup>44</sup> See e.g. Saunders *op cit*.



discussion of Section 3 it can no longer be seen as directly relevant to the question at hand – the question of metaphysical priority. What, then, do the same considerations suggest for structuralism in the idiom of determination?

Luckily, however, the argument that is needed may be straightforwardly adapted from that which has been reviewed here. What makes the adaptation so straightforward in this case is the fact that the denial of ‘primitive identity’ which forms the starting point is *itself* a demand for determination: it is the statement that facts involving identity are to be settled by qualitative facts. And what Saunders’ analysis demonstrates is that the irreflexivity of some qualitative relation logically entails the distinctness of the particles (the principle of indiscernibility of identicals being a logical truth after all). Of course, given that logical entailment is necessary but not sufficient for metaphysical determination, that observation by itself is not enough to secure that it grounds their distinctness, as would be required for their non-fundamentality. But given the assumption, embedded in the denial of ‘primitive thisness’, that identities *must* be metaphysically determined, together with the demonstrable absence of any *other* qualitative feature available to do so, it follows that this relation *does in fact* do the job. As such, the plurality taken to be essential to objects *qua* objects may be shown to be secured by structure, and moreover in a way that at no point requires an appeal to whatever unknown feature promotes mere logical into metaphysical determination. Further, the famed non-supervenience of the relations themselves – given that supervenience is a *sine qua non* of determination in any more demanding sense – by contrast secures that *they* have fundamental status.<sup>45</sup> So in sum, the plurality of objects can be regarded as metaphysically determined by a fundamental structural feature – precisely the conclusion sought by priority-based structuralism.

Of course, nothing has been said here to *defend* the idea that identity facts are ‘not primitive’ in the first place, nor will I argue for that doctrine here.<sup>46</sup> Suffice to say that if this doctrine is denied, as some think it perhaps should be, then priority-based OSR is arguably falsified before it even gets out of the gate. That said, the structuralist in no way begs the question by

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<sup>45</sup> For a discussion of how this non-supervenience may be maintained across the various interpretations of quantum mechanics, including hidden-variable interpretations, see Belousek 2003.

<sup>46</sup> See again Ladyman 2016 for discussion.

assuming this – for it is only the vagaries of quantum mechanics that obstruct any *properties* from doing so. Should the kind properties essential to fundamental objects prove similarly amenable to structuralist analysis, then, priority-based structuralism will be home and dry. Unfortunately, however, things are not so easy in the case of kind properties. On the contrary, it seems that these pose an obstacle to priority-based structuralism that we currently have no idea how to circumvent.

#### **4.ii The standing of structuralism II: determining kind properties**

Following our discussion of Section II, priority-based structuralists must account not only for the *plurality* of objects, but also for the fact that they come packaged into *kinds*. As noted previously, kinds are defined by *specific combinations* of *determinate kind properties* – specific combinations of, for example, determinate mass, charge and spin – and the *fundamental* kinds by specific confederations of *fundamental* such properties. The fundamental kinds are taken to pose a threat to structuralism because they are standardly ranked as fundamental features of the world: indeed, they are often presented as paradigms of such features.<sup>47</sup> But the determinate properties out of which kinds are forged are also standardly taken to be intrinsic. If that is right, then by our definitions in Section 2 there exist fundamental features of the world that are at least partly non-structural in character, contrary to ontic structuralism. In light of this, it seems the structuralist must embrace one of two strategies. They can either accept the intrinsicity of at least some fundamental kind properties, but maintain that they are ontologically secondary – hence a feature determined by structure. Alternatively, they can accept that what kinds the world contains is a brute and undetermined feature, but deny that any of the determinate kind properties are intrinsic. By O3 above, the latter strategy will, if successful, result in a form of eliminativism, while the first will result in a priority-based structuralism.

Since our focus in this section is on priority-based approaches, we begin by presuming that at least some of the fundamental kind properties are intrinsic. That this is the case for all fundamental kind properties is a wholly orthodox assumption of scientific metaphysics,

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<sup>47</sup> See e.g. Sider 2011, p. 77 *et passim*.

furnishing a rare example of view shared by Humeans and anti-Humeans alike. It is indeed an assumption that structuralists seem to overwhelmingly adhere to, with French and Ladyman, Lyre, and Saunders all referring to them in this way (at least at times).<sup>48</sup> Indeed, practitioners as familiar with the field as Bird have even hazarded that ‘*no-one* has suggested that charge, rest mass and spin are not intrinsic’.<sup>49</sup> Priority-based structuralists depart from orthodoxy, however, in holding that such properties are *not fundamental*. As such, whatever determinate properties are instantiated in the fundamental level must be shown to be secondary to structure. Since most of the material that will be relevant to this argument is already spelled out in the literature, our treatment here will again be brief.<sup>50</sup> But in order that the relevant mathematical and empirical facts can be perspicuously translated into the language of ontological priority, we should at least remind ourselves how the connection between kinds and structure goes.

At the heart of this connection is a certain *correspondence* between particles kinds and the *symmetries of the laws* they accord with, one that is forged by the *irreducible representations* of the relevant symmetry groups. An irreducible representation, or ‘irrep’, of a group is easiest to conceptualize in the context of symmetries pertaining to the spatiotemporal properties of physical system, known as ‘external’ symmetries. Here the relevant groups are comprised of transformations between differently-situated observers under which the dynamics remains form-invariant. An *irrep* of the Poincaré group — that relevant to QFT — is identified with the *set of states* that may be mapped into one another by the action of these transformations. Since only those properties common to all states in the irrep could be counted among the essential properties of the system whose states are transformed, it is only these that seem apt to be identified with the kind properties. It may be shown that these properties correspond to the values of the *Casimir operators* for the Poincaré group, and the task of determining these operators and their possible values was systematically undertaken by Wigner. What he found was that the values of these operators for each different irrep are confined to the following combinations: either the particle has some  $mass \in \mathbb{R} > 0$  and a  $spin \in \mathbb{Z}/2$ , or a

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<sup>48</sup> See e.g. French 2014, p. 157; French and Ladyman 2003, p. 39; French and Redhead 1988, p. 244; Lyre 2004, p. 663; Saunders *op cit*, p. 294.

<sup>49</sup> Bird 2007, p. 125 (italics added).

<sup>50</sup> See e.g. Weinberg 1995 for a classic introduction.

mass=0 and a helicity  $\in \mathbb{Z}$ . (Here helicity is a property sufficiently analogous to spin as to often be referred to by the same term.) But these are paradigms of what we mean by *fundamental kind properties*. And the determinate values of mass and spin (or helicity) for all the kinds with which we are familiar *do* conform to these rules of combination. Thus while it is typically held that which determinate properties coalesce to form kinds (or in Chakravartty’s terminology, to ‘socialize’) is simply a ‘brute fact’, it seems that, on the contrary, there is at least *some* explanation that can be given of what kinds there are – something that of course at least points to the possibility of their non-fundamentality.<sup>51</sup>

Wigner’s interpolation between symmetries and kind properties surely stands out as “one of the remarkable monuments to unity between mathematics and physics”.<sup>52</sup> But we can now go much further than Wigner could in deriving constraints upon the fundamental kinds, by considering the symmetries now understood to pertain to the laws of *interaction* (the so-called ‘internal symmetries’). As noted in Section 2, structuralists focus their sights on the *fundamental level*, and hence (given our assumptions) on the physics in the limit that energies tend to infinity. Since one would not *a priori* expect any particular function to stay well-behaved in an infinite limit, we can expect there to be significant constraints on any law of nature that is apt to describe that level. Owing to the mathematical intractabilities involved, we still do not know what those constraints are in their full generality. But we *do* know what they are for any theory that is treatable via perturbation theory (our standard tool for calculation in QFT). First among them is that any such law must possess a *local gauge symmetry*. This means we have some reason to expect the truly fundamental kinds to correspond to irreps of gauge symmetry groups. Here, however, the associated representation theory is even more constraining than it is in the external case. For in this case we find that the existence of any specific local gauge symmetry *uniquely prescribes* the kinds of bosons that are required to mediate the interaction, since these particles correspond to the so-called *adjoint representation* unique to each symmetry group.<sup>53</sup> In particular, the symmetry prescribes *how many* gauge bosons there will be, that they have *spin 1*, and – in the case of unbroken

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<sup>51</sup> Chakravartty 2007, p 171. For elaboration of this claim, see French 2014 Section 9.8.

<sup>52</sup> Tung 1985, p. 191.

<sup>53</sup> See again Weinberg 1995.

symmetries at least – that they are *massless*.<sup>54</sup> By contrast, however, which kinds of fermions we can expect to be instantiated is *not* similarly uniquely determined.<sup>55</sup> While we know that what determinate properties they have must correspond to the Casimir operators of the relevant groups, we do not know, for example, which *determinate masses* these fermions will exhibit out of the continuum-many possibilities that the group representation theory leaves open. Nor do we know *how many* of them we can expect to find. Nevertheless, it may be shown via symmetry considerations that there remain *significant limits* on the *number* of fermion kinds that can co-exist consistently with the fundamentality of the associated law. For example, it turns out that if QCD, with its SU(3) gauge symmetry, is a truly fundamental law, then the world can admit of no more than 16 kinds of fermions interacting through it before the consistency of the theory in the  $E \rightarrow \infty$  limit is lost. This relative ‘fine-tuning’ of matter content required of a fundamental theory generates what I have elsewhere called the *Goldilock’s principle* for fundamental kinds:<sup>56</sup>

*Goldilock’s principle for fundamental kinds (GP)*: Whatever the set of fundamental kinds is, it will take the form  $\{B_1, \dots, B_N; F_1, \dots, F_M\}$  for some  $N > 0$  and with an upper bound on  $M$ , and with the values of  $M$  and  $N$  connected via symmetry considerations, where the  $B_i$  denote bosonic and the  $F_i$  fermionic kinds.

It seems, then, that there is a rich story interweaving kinds, symmetry, and fundamentality to be told here – a story that bland assertions to the effect that what kinds the world admits is simply a ‘brute fact’ wholly fails to convey. And it is a story that prepares the ground for an attempt at a structuralist takeover of kind properties. Thus in the OSR literature one finds claims to the effect that objects, *qua* members of kinds, are ‘constituted’ by the group operators; that they have a merely ‘derivative status’, and that particle physics in general amply displays that symmetries occupy ‘the deepest layer in the ontological hierarchy’.<sup>57</sup> In

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<sup>54</sup> ‘Broken’ gauge symmetries complicate the story but do not change the overall morals.

<sup>55</sup> As Kantorovich (2005, p. 668) puts it, ‘The number and properties of the gauge bosons are dictated by the gauge symmetry, whereas the identity and properties of the matter particles that interact with the gauge bosons are not.’

<sup>56</sup> See McKenzie 2016.

<sup>57</sup> Castellani 1998; Lyre 2004, Section 3.2 (also quoted in Ladyman and Ross 2007, p. 147; Ladyman

order to actually demonstrate such claims, however, we must explicitly connect these facts about symmetries and kinds to the language of ontological priority. In my previous paper I argued, largely on ‘small-k Kantian’ grounds, that an ontological dependence of objects on spacetime symmetry could be secured. But as we now know, what we need to focus on is not this but rather whether there is an appropriate *determination* relation running from symmetries to fundamental kinds. Thus is it the case that symmetries at the fundamental level metaphysically determine the kinds that we find there?

But it is plain already that the answer, at present, is *no*. Recall first that, whatever metaphysical determination ultimately is, it must respect the *entailment principle*: that is, the world’s symmetries must entail what the fundamental kinds are if those symmetries are to be supremely fundamental. As such, particle types must *supervene* on the symmetries of the world. But we know already that this is not the case, at least in the case of fermions. For while we know (or assume) that the world exhibits Poincaré symmetry, and while we know that whatever kinds there are must conform to the possibilities admitted by the associated representation theory, there is a *continuously infinite range of possibilities* for what those combinations can be – one for each  $m \in \mathbb{R}$ . Yet we do not of course think that all of these are in fact realized. And since there is seemingly nothing further in the logic of the situation that entails, given a specific symmetry, what the associated fermionic kind content is, it follows from this that there cannot be determination in any more discerning sense either. Thus claims made by structuralists that the ‘properties of elementary particles like mass, charge and spin-magnitude... are determined by symmetry relations, which makes them acceptable for the structural realist’ would in fact seem to be simply untrue.<sup>58</sup> On the contrary, it seems that while the suite of *possibilities* is determined, what is *actually the case* remains, while importantly constrained, very much underdetermined. As such, it must – as it is – be simply settled by experiment.

The only conclusion to draw, then, is that structure *cannot* be said to be more fundamental

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2016); Kantorovich 2003, p. 673.

<sup>58</sup> Muller 2011, p. 232. (I note that Muller is explicit in his intention to give a structuralist analysis of actual-world entities, not mere possibilia (p. 226).)

than objects according to our best current science. Hence priority-based OSR framed – as it ought to be – in the idiom of determination must be regarded as unfounded. However, to give the position its full due, let us consider a couple of objections that might be made against the argument just given.

The first objection the structuralist might lodge is to protest that, in asking for full determination of all the actual-world kinds, we are simply asking too much.<sup>59</sup> After all, it can hardly be denied that there is a rich seam to be mined here regarding the metaphysical connection between symmetries and kinds, even if it is one that falls short of full determination of the latter by the former.<sup>60</sup> To this, however, I reply that while that is undoubtedly the case – hence that metaphysical views that at least ‘resonate’ with structuralist themes are no doubt sustainable in this context – *priority-based* OSR must nevertheless commit to determination *given that that is what we mean by ‘priority’*. Nor is it the case that we should allow structure to be more fundamental than the actual-world objects if the former merely determine the *possibilities* for the latter and not what they *in fact are*. For otherwise we would be able to say, for example, that determinable properties are more fundamental than the corresponding determinates – a view that seemingly everyone rejects, including those who attribute fundamental status to determinables.<sup>61</sup> While there is of course more that could be said here, the bottom line is that priority-based structuralism has set itself a high bar, and at present it fails to clear it. Nor, I note, should we be particularly surprised about this. OSR is after all supposed to be a revolutionary thesis, not one we would expect to be easily sustained.

A different objection is that, although I do not ask too much of structuralism by demanding determination, I am too restrictive in the material I include to support a determination claim. For even if it is conceded that there is nothing *within our best current theories* that shows that the actual fundamental kinds are determined by structure, it was also admitted that there are implications of QFT for the physics of the fundamental that we have yet to discover, *and*

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<sup>59</sup> Thanks to F.A. Muller for putting this objection to me.

<sup>60</sup> See French 2014, *passim*.

<sup>61</sup> For example, Wilson’s defence of the fundamentality of determinables concedes that reality cannot fundamentally consist of them alone (Wilson 2012, p. 13).

that QFT is in any case likely not a truly fundamental framework. As such, what we also know *about* those theories is that there is room for them to improve. But it has not been shown either that some superseding framework (such as string theory), or that QFT in the relevant limit, is *incompatible* with kind determination – hence there is at present no reason to think that the possibility is foreclosed. Still more positively, we should note that physicists too are hopeful that kind parameters will eventually be determined on theoretical grounds. For example, some physicists continue to pursue Wheeler’s dream of deriving ‘mass without mass’, and should that succeed then the kind properties that have so far eluded us may well turn out to be dynamically derivable, and in a way that vindicates structuralism.<sup>62</sup> But since OSR is a naturalistic thesis, it should presumably be based not only on our best current science, but also our best *metascience*, and this must include scientists’ judgments both of the limitations and the prospects of those theories. Since physicists clearly think that deriving kind properties is a future possibility, so should we. As such, it still remains reasonable to believe *in the present* that OSR is the right metaphysics of the fundamental.<sup>63</sup>

While I appreciate the rhetorical force of these observations, they nevertheless strike me as ultimately weak. The task that we set ourselves was to determine whether one can justifiably claim OSR to be established *today*, and in particular its priority-based version. To do so, more would need to be done than merely asserting that this position might, for all we know, be established in the future, since I doubt anyone would deny that: it is after all not as if there is anything inherently contradictory in OSR, at least not if properly understood. However, the only content that is seemingly being added here to this rather vacuous claim is that physicists hope that it will one day be true. But the fact of hope is not itself a reason for belief – not least since those hopes have so far been frustrated.<sup>64</sup> Of course, the fact that the prospects of structuralism chime with the hopes of physicists is another noteworthy and nice-making feature of structuralism, one that partly accounts for its enduring appeal. But such a virtue is clearly not enough to secure an *ontological* claim about the relative priority of metaphysical categories.

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<sup>62</sup> See Hansson 2014 for discussion of these ambitions.

<sup>63</sup> Thanks to Sam Schindler for putting this point to me.

<sup>64</sup> See again Hansson *op cit.* Section 1.



## 5. A reinvigorated eliminativism

Of course, there is much more on all of this that could and ought to be said. But I stand by my conclusion that we are not, as of now, in any position to subscribe to priority-based OSR. Since the priority-based version is widely taken to be its more plausible incarnation, this might be taken to entail that OSR *simpliciter* cannot be endorsed as the metaphysics of nature. Such a conclusion would be too hasty, however, for it follows only if the prospects for eliminativism really are poorer than those for its priority-based formulation. Now admittedly, as already noted, the version of eliminative structuralism that is familiar from the literature is predicated on a purported ‘metaphysical underdetermination’ of which few have been convinced. But as I will argue in closing, some of the resources from physics that have already been cited graft new prospects onto eliminativism. Further, it seems that the resulting eliminativism, were it shown to be sustainable, would be more attractive from a naturalistic point of view than that which was proposed initially.

To see this, first let us at least gesture at the reasons why the above discussion about kinds, fundamentality, and QFT mitigate against the intrinsicity of the fundamental kind properties. The argument that is needed here must unfortunately remain in the very broadest of brushstrokes, but the basic idea underlying it is not difficult to grasp.<sup>65</sup> For consider again the Goldilock’s principle introduced above in Section 4ii – a principle that we know expresses a constraint on the field content in any world in which there are interactions. And recall that what this constraint on field content reflects is the difficulties involved in retaining consistency in an interacting theory in the  $E \rightarrow \infty$  limit. One consequence of the GP is that, in any world in which QFT reigns and in which there are interacting fermions, we know that *there must exist bosons in addition* to mediate those interactions. Furthermore, it implies that in any world in which there are bosons, we also know that there is a *strict upper limit on how many fermions* can co-exist alongside them, with that limit determined via symmetry considerations. This suggests that at least *some* of the essential properties of the fundamental kinds are not intrinsic properties: for such properties *by definition carry no such*

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<sup>65</sup> I discuss it in more detail in a companion paper: see McKenzie 2016.

*constraints* on what can and cannot co-exist with their bearers. Further, the fact that symmetries demand that certain fundamental properties *co-exist* alongside others (as for mass and spin / helicity) lends additional plausibility to the idea that *all* fundamental kind properties may eventually be established as extrinsic.<sup>66</sup>

Of course, at this stage the argument is only suggestive, and much more would need to be done to actually establish this as the right conclusion to draw.<sup>67</sup> But for now, I want to press two things that suggest that that further work is work worth doing. First, the fact that there is something about fundamentality in QFT that so much as suggests the possibility of such a conclusion undermines the idea that there is something *obvious* or *a priori* about the intrinsicity of any given fundamental property. On the contrary, it seems, it is to the physics that we must look in order to examine the relevant dependences between physical objects, even if this in retrospect rather obvious point seems thus far to have elided most parties to the debate. But secondly, note that if the physics does indeed adjudicate against the intrinsicity of the fundamental kind properties, an eliminativism secured on that basis would be far less controversial than that which has been argued for hitherto. For were the strategy based on the Goldilock's principle to succeed, the *physics itself* would be determining that a feature that is taken by *all parties to the debate* to be an essential feature of objects – namely, the possession of some intrinsic properties – is in fact not instantiated at the fundamental level. But the original argument for eliminativism was predicated on an insistence that objects possess a *further and controversial* feature – namely, a determinate 'individuality profile', supplementary to its possession of kind properties – *as well as* an insistence that the physics must be able to determine what that profile is if objects are to be regarded as possessing it. Failing this, so the claim went, only an 'ersatz' form of realism would be warranted.<sup>68</sup> But clearly, the principle that *whatever our physics cannot determine cannot be sanctioned* is more contentious a principle of naturalistic metaphysics than the principle that

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<sup>66</sup> Note that the fact that the fundamental properties must be regarded as extrinsic does not mean that they can all be regarded as relations. On the contrary, part of what makes the fundamental properties classifiable as extrinsic is the fact that their presence *prohibits* the presence of other objects (as does e.g. the property of *loneliness*). But properties that are classified as extrinsic on these grounds cannot naturally be interpreted as implicitly *relations between* objects. Clearly, however, more work needs to be done to more fully spell out the property metaphysics here.

<sup>67</sup> Again, for more details see McKenzie *op cit*.

<sup>68</sup> Ladyman 1998, pp. 419-20.

*whatever the physics determines is the case, is the case.* For while there is wide disagreement on what ‘naturalism’ means, it is hard to see how *any* position could be called naturalistic if it were to sanction the outright contradiction of our best science: indeed, it is unclear if any contemporary metaphysician at all is comfortable with denying the latter principle.<sup>69</sup> By contrast, metaphysicians who buy into the former principle seem prohibitively limited in the metaphysical debates that they may engage in.<sup>70</sup> Indeed, as Chakravartty has pointed out, given the (apparently) underdetermined character of the traditional dispute over the nature of properties (concerning whether they are universals, tropes, and so on), it is unclear that the structuralist is entitled to support their position by an appeal to *any* consideration regarding properties at all. As such, an OSR supported by the Goldilock’s principle would, should it be shown to work, be far less controversial than that on the menu before now.

For all these reasons, the question of whether the fundamental kind properties are intrinsic properties is surely one that is worth pursuing. Should it be answered in the negative, we may at last find support for a thesis of naturalistic metaphysics that has proved of enduring appeal, but for which a compelling justification so far seems to have escaped us.

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<sup>69</sup> For example, even a metaphysician as defensive of *a priori* approaches as Paul asserts that metaphysics must be consistent with physics (see e.g. 2012b, p. 6).

<sup>70</sup> Again, see Chakravartty 2003.

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