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The Dependence of Objects on Structure: Tailoring our Metaphysics to Fit the Physics

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Abstract

The composition of objects is a much discussed issue in metaphysics. In this paper I look at various approaches to this issue in the context of two examples: the relationship between ‘everyday’ objects, such as tables, and their constituent physical entities, and the relationship between structures and objects, from the perspective of structural realism. My aims are first, to defend forms of eliminativism in both cases, whereby one can still make statements about the entities to be eliminated (tables and objects, respectively); and second, to highlight some of the metaphysical moves that are available to the structuralist in articulating their ontology. In doing so I hope also to indicate how metaphysics and the philosophy of science can be brought into a more productive relationship.

1. Introduction

The relationship between composite objects and their constituents can be approached from both physical and metaphysical directions. Some will insist on the priority of one such approach over the other but one of my aims in this paper is to urge that we need both to fully understand the nature of this relationship. In particular I will suggest that metaphysics presents a range of useful tools and techniques that we can pull down off the shelf, as it were. In this way I hope to contribute to a fuller appreciation of the inter-relationships between science, metaphysics and the philosophy of science, following recent suggestions by Callender (forthcoming), Chakravartty (2010), Hawley (2006a) and others.

The particular ontological standpoint from which I shall consider the above relationship is that of 'ontic structural realism' (OSR). This is a view which, it has been argued, meshes significantly with modern physics (Ladyman 1998; French and Ladyman 2003; Ladyman and Ross 2007; Rickles et. al. 2006). My claim is that this will help shed new light on the compositional relationship and in that light I shall then examine the similarities between OSR and certain metaphysical accounts of objects that have recently been put forward, such as so-called 'blobjectivism' and Mereological Bundle Theory (MBT).

Let me begin then with a quick sketch of the composition of objects from a metaphysical perspective.

Part, Whole and Composition

Famously, van Inwagen approaches this issue in terms of three questions:

The General Composition Question (GCQ): What *is* composition?

The Special Composition Question (SCQ): In which cases is it true of *certain objects* that *they* compose something?

The Inverse Composition Question (ICQ): In which cases is it true of *an object* that there are objects that compose *it?* (Inwagen 1990, pp. 39-48)

According to Hawley, GCQ has been comparatively neglected, following van Inwagen's own suggestion that there is no way of answering it. However she points out that the criteria for a satisfactory answer to his question appear to be much stricter than for the other two and that by relaxing these requirements we may yet learn something interesting about composition (Hawley 2006b). What is required as an answer is a 'principle of composition' of the form 'the *x*s compose *y* iff ....'., where what follows the iff is a sentence containing no mereological terms. However, Hawley points out that 'Van Inwagen demands that an answer to the GCQ be not only a necessary truth but also something like a conceptual truth, to which counterexamples are inconceivable.' (p. 5) That this is the case seems clear from van Inwagen's consideration of a putative answer that he himself puts forward:

The *x*s compose *y* iff no two of the *x*s occupy overlapping regions of space and *y* occupies the sum of the regions of space occupied by the *x*s.

This fails, he thinks, because a counterexample is conceivable: he suggests that a sceptic could insist that they could imagine an object which is not one of the things that the *x*s compose but which occupies the sum of the regions of space occupied by them. This is not the case for answers to

either SCQ or ICQ, where the biconditionals must be necessary truths but needn't be conceptual truths. By relaxing van Iwagen's requirement, Hawley maintains, we can open up some logical space for informative answers to GCQ, in the form of 'a principle of composition which does not achieve a non-mereological analysis of 'composition' but which is nevertheless metaphysically necessary.' (p. 6) Indeed, we might go further and drop the requirement that the answer be a necessary truth[2]. Doing so allows for different principles of composition for different kinds of things, by analogy with different criteria of identity (Hawley ibid.).

This analogy is worth pursuing a little because it reveals what may be seen as a fundamental flaw with contemporary metaphysics. Thus Hawley notes that just as with a principle of composition, a criterion of identity is a biconditional with an identity claim on the left, and a correlated condition on the right. And just as conceivability can be allowed to undermine answers to GCQ, so in the case of the proposal that Leibniz's Law and the Principle of Identity of Indiscernibles jointly constitute a necessarily true criterion of identity, so someone could always say, 'I think I can imagine two objects which share all their properties and yet are distinct'. The way forward, Hawley argues, is to allow both principles of composition and criteria of identity to be sort-relative. And of course, in the former case, such principles may vary both with the sort of object that is composed and the sort of objects doing the composing. Thus, to use an example I shall come back to later, a table might be said to have both legs and elementary particles as parts, but we might expect the relationship between legs and table to be different from that between particles and table (Hawley uses the example of a cat).

Hawley herself puts this sortal-relative notion of composition relation to work in an analysis of the classic example of the statue and the lump of clay but what is important for my purposes are two features of her discussion. First, as I indicated above, the stringent demand for conceivability-proof criteria of composition is revelatory of the problematic state of contemporary metaphysics. Such a demand and that of necessary truths immediately puts it in a difficult relationship with contemporary physics, since any metaphysical principles will have to be immune from contact with the relevant physical ones. (Of course, we do not need to go to the extremes of conceivability to rule out even van Iwagen's own attempted answer to the GCQ: a light beam may be said to be composed of photons, yet photons do not 'occupy' (in the standard sense) regions of space.) Following Hawley's analogy with identity, we might recall Hacking's defence of the Principle of Identity of Indiscernibles through the admonition that bland metaphysical assertion of putative counter-examples was not enough (Hacking 1975). Hacking's point was that we should not take the Principle to be undermined by conceiving of a world with, say, two indiscernible iron globes, since if such a conception is regarded in an appropriately robust manner (and this is contentious of course) it will include an appropriate spatio-temporal background, the inclusion of which effectively blocks the attempt to refute the Principle (unfortunately the specific way in which Hacking includes such a background fails). Blocking such bland assertions, or restraining

conceivability, allows room for the development of metaphysical principles – of both composition and identity – that mesh with our physical picture of the world, even if they do not count as conceptual truths.

Secondly, as Hawley concludes, recognition that there might be a variety of compositional relations, each appropriate for particular sorts of objects, say, itself provides a new tool for metaphysics, and for metaphysically informed philosophy of physics. Even if one concludes that from the perspective of OSR composition might not be the right way to go, this is an important conclusion that is echoed by Ladyman and Ross in their now classic excoriation of contemporary metaphysics:

'It [the general composition relation] is supposed to be the relation that holds between the parts of any whole but the wholes [typically considered] are hugely disparate and the composition relations studied by the special sciences are *sui generis*. We have no reason to believe that an abstract composition relation is anything other than an entrenched philosophical fetish.' (Ladyman and Ross 2007, p. 21)

Thus we might expect that in different scientific contexts, different composition relations will hold.

Before we move on to consider the kind of structuralist stance Ladyman and Ross adopt, however, there is a further issue to consider. In his discussion of SCQ, van Inwagen also sets out two desiderata that answers must satisfy, which I shall characterise as follows (ibid. p. 18):

Unitarity: the answers should be general and systematic;

Meshing: the answers should yield an ontology that conforms reasonably well to pre-theoretic and scientific beliefs.

In their recent defence of 'austere realism (which I shall be returning to below), Horgan and Potrc (2008), insist that 'unitarity' should trump 'meshing', on the grounds that '… a metaphysical theory should keep to a minimum the unexplained facts that it posits.' (p. 18) By analogy with physics, a metaphysical explanation of how certain objects compose others should 'bottom out' in general and systematic laws, rather than specific compositional facts that are themselves inexplicable. In particular it cannot be the case that there is '… a body of specific compositional facts that are collectively disconnected and unsystematic and are individually unexplainable.' (ibid., p. 19). This ontological arbitrariness would not be a result of Hawley's programme but if metaphysics is to be appropriately naturalistic, it must allow for non-unitary and possibly *sui generis* answers to composition questions, as Ladyman and Ross suggest[3].

2. Meshing, Humility and Structural Realism.

Prioritising 'meshing' over unitarity might satisfy our naturalist hankerings (cf Ladyman and Ross's 'Principle of Naturalistic Closure'; op. cit.) but it faces a well-known problem, that of the underdetermination of metaphysics by physics. An example of this arises in precisely the context that Hawley introduces as an analogy with composition, namely issues of identity in physics. Here two metaphysical packages are equally natural in the quantum context, namely that which regards quantum objects as individuals and that which takes them to be non-individuals (French and Krause 2006). This is an example of the presentation of an array of metaphysical 'facts' about which we can have no knowledge and towards which we are urged to adopt an attitude of 'metaphysical humility' (Langton ref). An obvious response is to adopt a less humble stance by eliminating from our adopted ontology as many of such facts as we can, and my claim (defended elsewhere; French forthcoming), is that Ontic Structural Realism is more effective in this regard than other current forms of realism.

There has already been a lot written about OSR (for a recent summary see French and Ladyman forthcoming) so I here I will only sketch the position.

Structuralism in general can be characterised in this context as urging a shift in ontological focus from objects to structures. It has a long history, entwined with that of twentieth century physics and is exemplified in the works of Duhem, Poincaré, Cassirer, Russell, Eddington, and Born, among others. It is multiply motivated, with the two most significant being the desire to overcome the Pessimistic Meta-Induction, or, more generally, to address the problem of theory change by focussing on the commonalities offered by the relevant structures presented by the theories; and the concern to respond to the metaphysical implications of modern physics, and, for example, undercut the above example of metaphysical underdetermination, by adopting a structure oriented ontology.

Famously this view comes in two forms, which can be expressed in slogan form as follows:

Epistemic Structural Realism (ESR): All that we *know* is structure

This form maintains a form of agnosticism about the 'objects' that are assumed to exist 'behind the structure (see Worrall 1989; recent ref?) and in doing so retains considerable humility (French forthcoming).

Ontic Structural Realism (OSR): All that there *is*, is structure

This urges a reconceptualisation of physical objects via structure and a characterisation of that structure via the resources deployed in physics such as group theory (Ladyman 1998; French and Ladyman 2003; Ladyman and Ross 2007; French 2006). It also comes in two variants:

Eliminativist OSR: as the name suggests this attempts to eliminate objects entirely, in favour of the appropriate structures, so that at best putative 'objects' come to be seen as mere 'nodes' in the structure or as dependent upon that structure (I shall be touching on this notion of dependence below).

Non-Eliminativist OSR: this incorporates a 'thin' notion of object, whose identity is given contextually via the relations of the structure. Thus

Saunders has developed a notion of ‘weak discernibility’ along these lines that is applicable to fermions (Saunders 2006); its extension to bosons by Muller and Seevinck is more contentious (Muller and Seevinck 2009; see Ladyman and Bigaj 2010 for a useful discussion of the issues).

These positions have been much discussed and I shall not run through the criticisms or the responses here (see French and Ladyman forthcoming). Both offer a stance that is less humble that either Worrall’s or other forms of realism, and both offer new insights into the compositional relationships assumed to hold between certain physical entities (see also Ladyman, this volume). Let us now begin to consider these relationships in the context of exploring answers to the following questions: What is the relationship between everyday objects and the entities posited by physics? And: What is the relationship between those entities and the structure towards which the advocate of OSR adopts his realist stance?

3. Dependence and Elimination

Consider, as an exemplar of an 'everyday' object, the table at which I am sat. An obvious answer to the first of the above questions in this case would be to say that the table is somehow dependent upon the relevant assembly of physical entities (whether these are taken to be particles, fields, strings or whatever). However, as Correia notes, in his useful survey (2008), the term 'dependence', as deployed in metaphysics, covers a whole family of properties and relations. Broadly speaking, it is typically taken to denote some form of 'non-self-sufficiency':

'A dependent object … is an object whose ontological profile, e.g. its existence or its being the object that it is, is somehow derivative upon facts of certain sorts – be they facts about other particular objects or not.' (ibid., p. 1013)

One can then distinguish two forms: existential and essential dependence (ibid; Lowe 2005). Existential dependence obtains when the existence of the object requires that a condition of a certain sort be met; essential dependence obtains where the object would not be the object that it is had a condition of a certain sort not been met (Correia op cit., p. 1014).

Taking existential dependence first, its denial captures the following intuition:

object ***a*** could have existed even if object ***b*** did not

and if this is the case, we can say that ***a*** is ontologically independent of ***b***. Thus my table could have existed even if the chair on which I am sitting did not, and in this sense is independent of it. However, my table could not have existed if its constituent particles/fields/strings/whatever did not, and in this sense is existentially dependent upon them (ibid., p. 1015). The relevant modality here is understood as metaphysical, rather than logical or conceptual, and one can read the sense of dependence here in terms of 'rigid necessitation', so that the table rigidly necessitates its specific constituent particles. Sortal considerations enter with 'generic necessitation', in the sense that my table generically necessitates the existence of fermions.

Similar considerations apply to essential dependence, so one can distinguish 'rigid essential involvement', such that, for some relation, x is essentially related by that relation to y, and 'rigid essential necessitation', whereby x is essentially such that it exists only if y does (ibid., p. 1017), together with their generic counterparts. Leaving aside concerns as to the relationship between existential and essential dependence (ibid.), a further useful notion here is that of 'explanatory dependence', in forms such as 'if *x* exists, then this is in virtue of the existence of *y*' and 'if *x* exists, then this is in virtue of some feature of *y*' (ibid., p. 1020).

Returning now to the initial idea that dependence involves non-self-sufficiency, not all of the notions of dependence currently in play possess the appropriate feature of derivative-ness, or fundamentality. So, x rigidly necessitating y does not imply that the existence of x is derivative upon or less fundamental than that of y, for rigid necessitation is not asymmetric (ibid., p. 1023). Thus, take Socrates and his life, for example: Socrates' life depends on the existence of Socrates and vice versa, yet Socrates and his life are not identical since they each possess properties (weighing so many kg,

being so many years long) that the other does not (Lowe 2005). Moving to the essentialist notion and that of explanatory dependence may help, because if the obtaining of y is essential to x, then the identity of x may be said to be derivative upon y, and likewise, if the existence of x is objectively explained by y, then the existence of x is less fundamental than y (Correia op. cit., p.1023). Thus if the solidity of my table is explained by the Pauli Exclusion Principle, or, more fundamentally, the anti-symmetry of the relevant wave-functions and the role of Permutation Invariance, then the existence of that solidity can be said to be less fundamental than, or derivative upon, those features associated with symmetry. More generally, we might capture the asymmetry involved here by asserting that *x* is dependent upon *y*, iff the identity of *x* is dependent on the identity of *y* (Lowe 2005).

As we shall indicate later, the notion of essential dependence, with its articulation in terms of identity, can be usefully applied in the structuralist context. Sticking with tables for the moment, an obvious issue is whether the dependence of the table on its constituent physical entities entails the elimination of the table as an element of our ontology. In general terms, the answer is surely not, since we can imagine two things as being dependent upon one another without either being eliminated in favour of the other. Indeed, as Correia has noted above, x existentially rigidly necessitating y does not entail that x should be eliminated in favour of y. However, in the case of explanatory dependence, if all the facts about x hold in virtue of and are explained by facts about y, then we can certainly mount a case that x is at best derivative upon y, or may even be eliminable in favour of y. A similar conclusion can be pushed from the claim that x essentially rigidly necessitates y so that the identity of x is dependent upon y. Not surprisingly perhaps, these conclusions have been resisted and in what follows I shall consider two examples of this resistance – one historical, one current – in order to indicate how one might respond to them in a way that is relevant to our overall discussion.

4. Eddington's Two Tables and the Elimination of Everyday Objects

When it comes to tables, we have been here before, of course, with the famous case of Eddington and his 'two tables'. In the introduction to his popular exposition, based on his Gifford lectures (1928), he compares the 'commonplace' table which has extension, is coloured and 'above all' is substantial, with the 'scientific' table, which is mostly empty and is not substantial at all (ibid., pp. xi-xiii). It is the latter that is 'really there', whereas the former is an illusion (ibid., p. 323). Presented thus, this seems a standard example of the presentation of scientific eliminativism. This is certainly how Stebbing views it in her dismissal of Eddington's claims as 'preposterous nonsense' (1937, p. 54). Her core objection is that the object of scientific descriptions is not the 'table', as this term is used in common discourse, and thus there cannot be two tables, with one granted ontological priority over the other. Furthermore, the 'scientific' cannot duplicate, and consequently replace, the everyday, since the properties of the latter, such as colour, cannot be duplicated via entities that do not possess such properties.

Now, Stebbing is certainly right in pointing out that Eddington's language and lack of training in philosophy does not help his case. More importantly, his articulation of the relationship between 'everyday' objects and the entities we should take as fundamental is less than clear in the passages she considers. Nevertheless, a more charitable reading would have filtered out the rhetoric deployed in the service of a set of public lectures and perhaps pulled together arguments and claims from across Eddington's works, both scientific and popular, in order to produce a (more) rational reconstruction of his position. Two aspects of these works might then have become clear. The first is that like many who have sought a radical ontological reconceptualisation, Eddington struggles to find a language that is not corrupted by the very ontology he is trying to replace. The cost of constructing such a language is evident in the difficulty one encounters in trying to understand his final work which attempted to construct a form of quantum gravity (1946). This ontology that he is trying to get away from is one of things and, in particular, substances. This brings us to the second aspect, which is Eddington's structuralism, something that Stebbing fails to grasp (see French 2003)[4]. The crucial feature of 'everyday' objects that Eddington wants to eliminate from our ontology is their substantiality and, as with other structuralists of the time, such as Cassirer, his structuralism can be characterised in those terms. How one expressed that elimination was a central problem for Eddington but it can be understood as an appropriately contextualised version of the issue we are facing here, namely how to characterise and represent the relationship between 'everyday' objects and the underlying structures that physics presents to us.

Stebbing's attack has been taken up again more recently by Thomasson (2007) who defends an ontology of ordinary objects against eliminativist arguments. She explicitly addresses the impact of science on such an ontology, identifying two forms of this impact (ibid., Ch. 7): according to one, associated with Eddington, science and the 'everyday' are in conflict; according to the other, associated with Sellars, they are merely rivals. With

regard to the first, there can be only conflict if the two sides are talking about the same thing.[5] However, here again, sortal considerations enter the picture as Thomasson argues that reference to things is fixed via some categorical framework. Hence, she maintains that,

'… scientific theories … do not use sortals such as 'table', and if science and common sense are using sortals of different categories, the 'things' picked out by the two descriptions cannot be identical.' (Thomasson 2007, p. 142)

One might try to present the conflict in terms of some neutral sense of 'thing' but 'thing' in that sense would not then be a sortal term and could not be used to establish reference. Or one could appeal to a common notion of 'physical object' or 'occupant of a spatio-temporal region', but, she argues, the first finds no place within physics itself, and the second is hardly common in everyday descriptions. Hence there is no conflict between science and ordinary discourse: both have their distinct ontologies.

With regard to the Sellarsian view of a rivalry between the 'scientific image' and the 'manifest image', in which the former has primacy over the latter, Thomasson again argues that any account of what there is presupposes a certain sortal framework. Such accounts can only offer a complete description in terms of that framework in the sense of covering all the things in those categories. However, the scientific and manifest images presuppose different sortal frameworks and hence cannot be complete in any way that renders them rivals (ibid., p. 148). Consequently, acceptance of the scientific image does not require rejection of the ontology of the manifest.

Eddington's position is also undermined, according to Thomasson, not least because on a structuralist interpretation, there is a '… lack of conflict between the merely structural properties physics imputes to the world and the qualitative content involved in ordinary world descriptions.' (ibid., p. 139). Now, the distinction between structure and content is one that has arisen repeatedly in discussions over structural realism but it evaporates as far as the ontic form is concerned, since all relevant content is taken to be cashed out in structural terms. Insofar as the 'qualitative content' that Thomasson refers to goes beyond this, it becomes part of the more general issue having to do with the relationship between the scientific and the 'everyday'.

Here a number of concerns arise, not the least being that Thomasson's account creates a vastly inflationary ontology. Let me be clear about this: it is not that Thomasson is claiming that ordinary objects are somehow derivative; rather, they count as metaphysically robust elements of our ontology, just as elementary particles are. As a result her metaphysics is entirely detached from the relevant physics, since the latter incorporates an assortment of physical relations that hold between, for example, protons, neutrons and electons, atoms and molecules, molecules and polymers and so on. One option for the kind of naturalistic approach indicated previously is to explore the possibility of meshing the metaphysics with the physics by constructing metaphysical relations that effectively track the physical ones; another, as we shall see, is to radically reconfigure the relevant ontology so as to remove the necessity for positing certain such relations. Either way, we

keep the metaphysics and physics in touch with each other, as it were, rather than cleaving them entirely apart as Thomasson does.

A further major worry has to do with the central role played by sortal frameworks in her view[6]. First of all, it is also worth noting the difficulty involved in constructing such a framework in the quantum context, particularly if one adopts the view of quantum particles as non-individuals (French and Krause 2006b). Of course, this may be taken as further fuel for Thomasson's position, since if the relevant frameworks are so different, not just in terms of the kinds of things they cover, but in terms of their underlying metaphysics and even logic, then how can then be said to rival or compete with one another? However efforts are being made to relate the two kinds of framework and attempts to construct a form of 'quantum mereology' can be seen as contributing to the establishment of an appropriate relationship. If these efforts are successful then one might regard this as bringing the logic and metaphysics into line with the physics, insofar as the explanations of the latter can be taken to relate the frameworks concerned.

The issue then is whether the establishment of such a relationship effectively guts the ontology of the 'manifest' framework by reducing it to the scientific. Consider a general metaphysical characterisation of such relationships in terms of 'grounding', say: *a* is said to be grounded in *b* in the sense that *a* holds in virtue of *b*, without it being the case that only *b* exists. Thus the 'fact' of there being a table in front of me (or Eddington) is grounded in facts about the relevant aggregate of quantum particles in the sense that the former fact holds in virtue of the latter (see North forthcoming, p. 26). Now, explanatory relations such as this crop up elsewhere, of course and offer a broader framework than, say, causal accounts, whilst not trivialising the relationships as deductive accounts do. However, as we saw in our brief discussion of dependence above, one worry here is that if we take this relation seriously, metaphysically speaking, then the kind of dependence that 'in virtue of' signifies effectively evacuates all there is to *a* in favour of the relevant features of *b*. If all there is to *a* is explained in terms of features of *b*, then what is left that has any independent existence? Of course, one might point to standard examples, such as the explanation of the shadow cast by the flagpole in terms of its height, the angle of the sun and some elementary geometry and insist that this does not imply that the shadow does not exist. However – leaving aside issues as to the nature of shadows – this just pushes the issue back a step or two: once I have given the best and most complete explanation available, articulated in terms of quantum field theory perhaps, then what is there to a shadow, as an object in its own right, that is not cashed out in terms of features that are more fundamental?

Talk of 'facts' here may actually obscure the issue: granted that the fact expressed in the claim 'there is a table in front of me' is a 'real', albeit non-fundamental fact (North op. cit.), this does not imply that the table itself should be taken as an element of our ontology. Consider the property that Stebbing focuses on in her critique of Eddington, namely solidity. As already noted, this holds in virtue of the relevant physics as expressed in the

Exclusion Principle and, more fundamentally, the antisymmetrisation of the relevant aggregate wave function. In this case one might then insist that the latter feature of quantum mechanics entirely explicates the solidity of everyday objects and in doing so eliminates the predicate from the scope of our fundamental ontology. Of course, as we shall see, one may still utter truths about tables, how solid they are and so on and these truths may be regarded as further facts beyond those that are fundamental, but one can still have all this and deny that the entities exist. I shall return to this point shortly.

There is also an obvious concern here that Thomasson appears to have introduced a form of sortal relativism into this context. Note that the role of sortals in her account is different from the role they play in Hawley's approach: in the latter case, it is the composition relations that are tied to different sortal frameworks; in Thomasson's case, it is the existence of objects. The latter has obvious problematic implications for realism. This is something that Schaffer takes up in his critical review (2009): the invocation of appropriate sortal concepts is crucial for various aspects of Thomasson's account but in particular, existence claims appear to be sortal relative (ibid., p. 149). This would not only have radical implications for the semantics of existential quantification (ibid.), but would also take her account outside of the broadly realist stance that is being adopted here. However, as Schaffer notes (ibid.), Thomasson attempts to evade this conclusion and retain the standard account of simple quantification while maintaining her radical conclusions about everyday ontology, by arguing that what her account of reference determination via sortal frameworks does is specify the *domain* of quantification. Thus, existence claims are only evaluable once an appropriate domain is specified, where that involves specifying or presupposing the relevant sorts of entities involved (Thomasson, op. cit. pp. 464-465).

In response, Schaffer points out (op. cit., p. 150) that although sortals can act as perfectly good domain specifiers, so can properties, for example, and so we don't need to dally with sortal relativism. But then Thomasson's defence of an ontology of ordinary objects would fall apart. Furthermore, Schaffer argues that we can straightforwardly specify the total domain of 'everything' and do so in a way that does not involve a non-category-specific sense of 'thing' (ibid., pp. 150-151). Again, with the prop of sortal specificity taken away, Thomasson's account collapses. And for our purposes here, the latter response allows us to talk of the universal domain, as it were, while the former allows us to talk of putative things belonging to different domains, and the relationships between them, without presupposing a sortal framework that, in effect, existentially neuters these relationships. Obviously 'domain' here is better understood as 'level', so we can now talk of the relationship between the level of ordinary objects, such as tables, and that of elementary particles, without having to accept that the specification of such levels necessarily involves sortals in terms of which distinct ontologies must be acknowledged, as Thomasson demands. In particular, we can articulate a reductive relationship in terms of which such ordinary objects are eliminated.

Eliminativism about ordinary objects may seem a radical position to adopt[7] but it is one that meshes with our understanding of contemporary physics, according to which there is only a limited number of certain fundamental kinds of elementary particles and four fundamental forces – everything else is effectively composed out of these. I aim to take this picture seriously, in the sense of indicating, in at least a preliminary way, how an appropriate metaphysics might be constructed on this basis[8].

Now one reason this seems such a radical line to take is that we have considerable everyday experience of tables: we use them in various ways, set chairs around them, bump into them and so on. Thus we face a dilemma: according to eliminativism, tables don't exist and yet the statement 'Tables exist' appears to be true! Indeed, the fact expressed by such a statement might well be taken to be 'Moorean' in the sense that we have better knowledge of it than the premises of any argument that seeks to deny it. In that sense, it trumps any attempt at eliminativism. However, this is a dangerous line to take as it would not simply undermine scepticism as in Moore's 'here is a hand' case, but would preclude the possibility of the kind of reductive analysis that physics appears to push us toward.

Let me now briefly sketch different metaphysical manoeuvres we can deply to help resolve the above dilemma:

5. Metaphysical Manoeuvres

5.1 Manoeuvre 1: Revise our Semantics

We could adopt a form of error theoretic approach, according to which the sentence 'Tables exist' is understood to be simply false but it is allowed that we can still pragmatically use such sentences. Such approaches can be found in the philosophy of mathematics and ethics and Miller (2010) distinguishes them as follows: one can reject the claim that the relevant objects exist, or one can admit that they exist but deny that they instantiate the relevant properties. Thus, in the philosophy of mathematics one can find forms of fictionalism that deny that mathematical objects exist and the statements of mathematics are strictly false. Nevertheless mathematics serves a pragmatic purpose in helping derive relevant conclusions, and the relevant statements can be taken as 'true-within-the-derivational-context' or more broadly, within the 'story' of mathematics, just as statements about Sherlock Holmes, for example are true within the stories of Arthur Conan Doyle. Likewise, one could insist that ordinary objects do not exist, that all our statements about them are strictly false, but that nevertheless beliefs about such objects serve a pragmatic purpose and the relevant statements can be regarded as 'true-within-the-narrative-we-construct-for-our-everyday-lives'.

Alternatively, one could adopt something like the error-theoretic account one finds in ethics: there, it is not denied that people exist (at least not typically) but the error-theorist insists they do not have the moral qualities usually attributed to them and hence the declarative statements one finds in ethics are strictly false. Now the argument for such a view depends on the claim that there are no objectively prescriptive qualities (see Miller op. cit. for a nice summary) and the qualities attributed to everyday objects certainly do not seem to be prescriptive. Furthermore, adapting something like this for everyday objects would lead to the bizarre conclusion that there are tables, but they do not possess the properties they are usually taken to have, such as solidity for example. One could certainly maintain that solidity can be reduced to the antisymmetry of the collective wave function, as indicated above, and thus that insofar as it is regarded as more than that, nothing is solid (contra Stebbing and Thomasson), but then the table, as an object, would possess neither the properties it is usually said to have, nor those the latter are reduced to, since these are only attributable to quantum particles and their aggregates.

5.2. Manoeuvre 2: Revise our notion of existence, truth and/or ontology

We could account for the appearances – that is, our apparent experience of tables – and maintain the truth of the relevant sentences by introducing some notion of derivative existence, or by deploying a form of truth as indirect correspondence, or by developing the well-known account of truthmakers. There are undoubtedly other metaphysical tools we could use, but I shall focus on these.

5.2.1. Manoeuvre 2a: Derivative existence:

So, we could maintain that the sentence 'Tables exist' is true but take the sense of 'exist' here to be derivative. This is not, perhaps, a well trodden metaphysical path to take, given our standard understanding of existence.

Although as we shall see, the other two sub-options can be thought of as leading to a form of derivative existence, it is not a metaphysically robust form; that is, when it is introduced in these contexts we are reassured that it is just a way of speaking. A notion of derivative existence that is more than this does not seem to feature prominently in the metaphysicians' toolbox, and for good reason perhaps, since it would require modifications to the standard syntax and semantics associated with the existential quantifier.

However, and interestingly, given the structuralist theme of this paper, Eddington can be thought of as adopting something like this kind of view in his application of structuralism to the concept of existence itself (French 2003). He rejected ''any metaphysical concept of 'real existence''' (1939, p. 162) and introduced in its place a ''structural concept'' of existence (1946, p. 266). This followed from his analysis of claims such as ''Tables exist'' as half-finished sentences, requiring completion in structuralist terms[9]. Thus, atoms and electrons, for example, ''exist,'' in this derivative sense, since they are analyzed as aspects of structure. The question then is, what about the world structure itself, does that exist? To say that this exists would result in another half-finished sentence by Eddington's lights, for what further structure could the physical structure be a part of? Eddington maintained that this question never actually arises within his epistemology: having described the nature of physical knowledge, understood itself as a description of the physical universe, nothing further is added to our knowledge of it if one were to say ''and the physical universe exists.''

He then went on to consider the structure of existence itself, characterised as having only two values and thus represented in terms of idempotent symbols (French op. cit. pp. 249-250). Interestingly, this takes him toward the occupation number interpretation of quantum field theory, couched in terms of a group theoretic analysis from which particles effectively emerge. Returning to the issue of the two tables, Eddington was explicit that it was by analyzing existence in this way that one could respond to the concerns of philosophers such as Stebbing. Thus to recapitulate, 'Tables exist', on this view, must be understood as a half-finished sentence, to be completed by incorporating structure. The full sentence will then be 'Tables exist within a certain structure' and in this sense their existence can be understood as derivative.

Interestingly, given the themes of this issue, it seems we can usefully apply this analysis to the quasi-particles of condensed matter physics. These arise from the collective effect of a macroscopic aggregate with an atomic lattice structure, such as a crystal (for a useful analysis, see Falkenburg, 2007, esp. pp. 243-46). There is a considerable body of theoretical and experimental work devoted to studying such effects, as they may play a crucial explanatory role with regard to certain phenomena. The quantum Hall effect, for example, has been taken to provide compelling grounds for accepting the existence of anyons, quasi-particles that arise in systems that are confined to only two spatial dimensions and whose statistics differ from either Bose-Einstein or Fermi-Dirac (for an excellent review see Stern 2008). Nevertheless, quasi-particles in general are 'nothing more' than excitations of such a lattice which propagate through the structure and

interact as if they were ‘standard’ or ‘normal’ particles. Of course, for the ontic structural realist, the latter are ‘nothing more’ than nodes in the fundamental structure of the world, but the crucial difference is that both the dynamical properties of quasi-particles and their independence arise from certain approximation procedures applied to the excitations of the relevant collective (Falkenburg op. cit., p. 240). In particular, without the collective, the quasi-particles would not exist; hence Falkenburg refers to them as ‘fake entities’.

5.2.2. Manoeuvre 2b: Tweak Truth:

On Eddington’s view, statements such as ‘Tables exist’ cannot be taken as either true or false, since they are incomplete. Taking such statements to be non-truth-apt might be seen as forcing too radical a revision of our standard semantics, so an alternative would be to continue to take them to be true, but explicate truth in something other than the standard correspondence sense. Horgan and Potrc canvas just such a view in their defence of what they call ‘austere’ realism, which also eliminates ‘everyday’ objects, but on the grounds that they appear to be vague and since ontological vagueness is impossible, they must be removed from our ontology qua objects (Horgan and Potrc 2008; see also Horgan’s contribution to this issue). The extension of this argument to the objects of ‘scientific’ ontology may be blocked by the lack of sorites susceptibility in such cases (Darby 2010), which would render their realism considerably less austere. However, what is important for my purposes here is Horgan and Potrc’s use of contextual semantics. Thus they write:

‘Numerous statements and thought-contents involving posits of common sense and science are true, even though the correct ontology does not include these posits. …

Truth for such statements and thought contents is indirect correspondence.’ (Horgan and Potrc 2008, p. 3)

Note that they accept that tables, for example, are not to be included in our ‘correct ontology’ but we can continue to utter statements about them and regard these statements as true, but with truth understood not in terms of correspondence along the usual Tarskian lines, but in that of indirect correspondence. This is understood as semantic correctness under contextually operative semantic standards (ibid., p. 370, in terms of which the relevant statement is made true not by some truthmaker but ‘… by the world as a corporate body …’ (ibid.). Thus the claim ‘There are tables’ is true, in the ‘indirect correspondence’ sense, under the contextually operative standards governing ‘ordinary’ usage. However, these are not the standards appropriate for the context of ‘serious ontological enquiry’. If we designate in bold those posits which feature in this enquiry, then ‘There are tables’ is true but there are no tables. In particular, ‘There are tables is true, under the contextually operative standards governing common usage and ‘There are no tables’ is true, under the much rarer semantic standards that apply to ‘direct correspondence’, where this involves the standard Tarskian account of truth. The typical reaction of many to the elimination of objects can then be dismissed as a competence based performance error (ibid., p. 122).

Even if we were to accept that 'scientific' objects are vague and can also be eliminated, there may be more than one outcome of 'serious ontological enquiry' compatible with austere realism. Horgan and Potrc survey and dismiss two broad and potentially viable austere ontologies (Ch. 7): 'snobjective non-compositionalism', which includes only non-vague, perfectly precise simples and no composites; and 'snobjective universalism', which allows 'snobjects' to compose unrestrictedly. Three variants of the first are considered: those that countenance snobjective 'non-regions' – that is precise objects that are not spatio-temporal regions – those that involve spatio-temporal points only ('snobjective pointillism') and those that involve both. The first and third are ruled out on the grounds that the only candidates for such precise objects are elementary particles and these, they claim, are more like clouds than billiard balls. Hence they count as vague and can be dismissed. Here, as elsewhere in current metaphysical discussions, we find the argument depending upon a rather crude semi-classical framework. As it turns out, a metaphysics of individual 'snobjects' can be made compatible with quantum physics (see French and Krause 2006), although so can alternative accounts, of course.

With 'snobjective pointillism' eliminated on the grounds of the problems it would cause for the instantiation of mental properties, it is 'universalist snobjective regionalism' that is left as the main contender to blobjectivism. Here considerations of 'deep ontological parsimony' are brought into play: we should treat as few features of our metaphysics as actual and ontologically basic as we can. Since universalist snobjective regionalism yields a compositionally unrestricted plethora of spatio-temporal regions, all of which are actual and ontologically fundamental, Horgan and Potrc take blobjectivism to be preferable on grounds of parsimony. Their conclusion, then, is that there can be only one concrete object – the 'blobject' – about which statements are true in the standard correspondence sense.

There are two things to note. First, this obviously yields a radically minimalist ontology in one sense, although as Horgan and Potrc point out, the blobject manifests considerable spatio-temporal structural complexity and local variability. I shall briefly return to this below. Secondly, although this is an interesting way of resolving our dilemma, it raises an obvious worry about the context dependence of this notion of truth (which Horgan and Potrc acknowledge). Korman (2008) argues that it leads to a form of relativism with regard to the content of the relevant statements: suppose Julie is in our 'everyday' context, and Kate is in that of 'serious ontological enquiry'. Each utters the sentence 'tables exist'. According to Horgan and Potrc, Julie said something true (but in the indirect sense) and Kate something false (in the direct sense). However, if the content of the sentence is invariant across context in the way that Horgan and Potrc appear to suggest (op. cit. section 3.5), then, Korman insists, the truth and falsity of that content must vary with context, and relativism results. However, the examples that Horgan and Potrc consider – that cover both diachronic and synchronic meaning change – all involve differences governed by the relevant standards, whether those of direct or indirect correspondence. In the case of Julie and Kate, we have different standards brought into play (we

recall that on this view truth is just semantic correctness, under operative semantic standards), rather than simply different contexts, and hence the possibility of relativism is denied. Instead what we have is precisely what Horgan and Potrc are seeking to capture, namely the elimination of tables, as objects of serious ontological enquiry, whilst maintaining the truth (in the indirect sense) of our everyday statements about tables. That is not relativism. Nevertheless, one might still feel uneasy about tampering with truth in this way, so let us consider a further option that retains truth as we know and love it but introduces truthmakers.

5.2.3. Manoeuvre 2c: Try Truthmakers

The final option we shall consider retains both our standard understanding of existence and the standard interpretation of truth in terms of direct correspondence but urges us to reconsider what it is that makes statements such as 'Tables exist' true.

According to the Quinean view of ontological commitment, with its famous slogan of 'to be is to be the value of a variable', we should be committed to those things that lie within the domain of the quantifiers if the relevant sentences of the theory are to be held as true. This is now perhaps the most widely held view about determining ontological commitment. However, it is not without its problems. First of all it requires an appropriate regimentation of the theory concerned such that the relevant variables are made manifest. Secondly, and relatedly, the mode of regimentation may itself bear on this issue of ontological commitment – the debate over whether a form of 'thin' individuality can be ascribed to quantum particles and a weak form of the Principle of Identity of Indiscernibles sustained depends, in part, on not only differences as to the formal framework chosen for the regimentation but also whether that such regimentation is a prerequisite for such commitment to begin with (see French and Krause 2006, Ch. 4). Thirdly, the metaphysician may find the Quinean criterion operates on too high a level to address the ontological questions she has in focus. Thus, returning to the Special Composition Question, Quine's approach is of no help in helping resolve the debate between the universalists who think that every collection of things composes something, and the nihilists who hold that none do (Cameron 2008, p. 4). And this is because the relevant variables in our regimented theory will pick out 'things' at the level of tables, dogs and electrons, rather than composite parts; that is, it applies at too high a metaphysical level. Of course, some might well insist that it is at precisely this level that our ontological commitments should lie and that thinking of the Quinean commitment in this way reveals what is problematic about such metaphysical debates as those between the universalist and nihilist – namely that, in these Quinean terms, they are ontological empty. I'm going to leave that issue to one side because my concern here is to indicate how some of the manoeuvres developed by the metaphysicians can be put to use in the context of a structuralist view of the part-whole relationship.

So, according to the alternative 'truthmaker theory', the ontological commitments of a theory are not whatever is referred to by the variables of an appropriately regimented theory, but are just those things that have to

exist in order to make the relevant sentences of the theory true. Now, on the standard understanding of this account, the truthmaker for the claim 'x exists' is always x (see, for example, Armstrong 2004), and thus in the case of 'Tables exist', we must be committed to the existence of tables. However, one can modify this approach in order to shift ontological commitment elsewhere:

'I think one of the benefits of truthmaker theory is to allow that <x exists> might be made true by something other than x, and hence that '*a* exists' might be true according to some theory without *a* being an ontological commitment of that theory. '(Cameron 2008, p. 4)

When it comes to the debate regarding SCQ, Cameron points out that this has mainly focused on the issue of whether we need to take as true sentences referring to complex objects, with the attendant commitment to such objects. Cameron sees this as completely wrong-headed:

'serious ontological questions are being decided by linguistic facts; whether we are committed to complex objects is being decided by whether or not sentences concerning them can be paraphrased away into plural quantification over simples. What's wrong, in my opinion, is the Quinean idea that we have to resist the literal truth of 'there are tables' if we want to avoid ontological commitment to tables.' (ibid., p. 5)

Thus the idea here is to retain truth (à la Tarski) for such sentences but avoid an inflationary ontology by taking the constituent objects themselves to make it true that there is a sum, or composite, of those objects. What makes the sentence 'Table exist' true are whatever we take the fundamental constituent objects of tables to be: molecules, atoms, elementary particles, table parts, whatever. Metaphysicians employ a generic term to cover those objects which are fundamental in the sense that they themselves have no proper parts – they call them 'simples', which is perhaps unfortunate because in some cases these fundamental elements of our ontology will not be simple, at least not physically. However, bearing that point in mind, I shall use the term here.

Cameron offers a range of responses to criticisms of his view and indicates its benefits with regard to various metaphysical issues but here I shall simply note two things: first, it is clearly no contradiction on Cameron's view, even on a disquotational view of truth, to maintain that 'Tables exist' but deny any ontological committment to tables (ibid., p. 6)[10]. What we are committed to when we utter such a sentence is whatever it is that makes it true, and on Cameron's view that would the relevant metaphysical simples. Secondly, although this approach may appear to mesh with the idea of derivative existence, the suggestion that tables exist in such a sense is just a way of talking, for what really exist, and all that really exist are the relevant metaphysical simples (ibid., p. 7).

So, we can accept that 'Tables exist' is true but refrain from any ontological commitment to tables, because 'Tables exist' is made true by the relevant 'simples' (arranged table-wise, one might say, although the notion of 'arrangement' here will have to be fleshed out using the relevant physics, in particular the Pauli Exclusion Principle – or, better, the antisymmetrisation of fermionic wave-functions). This line on our dilemma

retains the literal (and non-contextual) truth of sentences and captures the thought that what we should really be focussing on, in setting out our fundamental ontology, are not tables, chairs, and so forth, but the fundamental entities of which they are composed.

Now there are well-known worries about metaphysical simples – whether they must be understood as point-like, for example, or can be extended. More significant for this discussion is the concern over whether they must be broadly spatio-temporal, in the sense of being localisable in space-time. This raises obvious difficulties if the relevant simples are taken to be quantum particles (so, can a photon be a simple?) and brings into the picture something that that is not prima facie a simple and may be subject to analysis itself, namely the spatio-temporal background (certainly the structuralist will want to give this a particular interpretation). But in this context at least I see no reason why we cannot release simples from such a (spatio-temporal) constraint and allow them to be the kind of 'building block' from which one constructs space-time, elementary particles and so on. This should become clearer when we consider structuralist simples below.[11]

6. Ontic Structural Realism and the Elimination of Particles (as Objects)

Having canvassed various manoeuvres that we might adopt when faced with our dilemma regarding tables, let us now consider a similar dilemma regarding particles: the ontic structural realist insists that all there is, is structure and quantum objects are at best re-conceptualised, or even eliminated altogether, depending on which variant is chosen. This yields two forms of our dilemma: following the example of high energy particle physicists we may wish to assert that 'particles exist', yet according to the ontic structural realist, either there are no particles (as objects) at all, or at best they are metaphysically 'thin' with their identity cashed out in relational terms[12]. Here we seem to have something similar to the table example – from the structuralist perspective particles *as objects* do not exist but we still want somehow to accommodate talk of them. In particular, we want to accommodate statements such as 'Particles exist', or 'Particle x exists', while acknowledging that fundamentally or ultimately, they are merely aspects of structure and hence do not[13]. Again, it seems, we can deploy the metaphysical tools used above.

Thus the Eddingtonian approach would allow us to continue to assert that 'Particles exist…' (expressed in the 'practical language of elementary particle dynamics') but insist that we must understand this in the structural sense of existence ; that is, the sentence must be understood as incomplete, with its completion articulating the claim that particles only exist as aspects of structure.

Or we could understand 'Particles exist' as (contextually) true in the indirect correspondence sense but false in the context of 'serious ontological enquiry'; that is, there are no particles (as objects), just structure or aspects thereof.

Or we could take 'Particles exist' to be (literally) true but maintain that what makes the sentence true are not particles as objects; that is, the truthmakers are structures or aspects thereof (arranged, to put it one way, 'particle-like').

In this last case (which has the advantages of retaining our standard understanding of truth, the relevant metaphysical simples obviously cannot be particles-as-objects, or their metaphysical correlates. One could follow Quine (1976) in his assertion that physical objects have metaphysically withered away under the glare of quantum mechanics, leaving only space-time points. The latter would then be our 'simples'. However, this depends on a particular understanding of quantum mechanics as requiring particles (qua objects) to be non-individuals, a requirement that, ironically, the application of Quine's own criterion of ontological commitment in support of a 'thin' notion of object shows can be resisted (Saunders 2006; French and Krause 2006, Ch. 4). This latter notion is itself a structuralist one (see French and Ladyman forthcoming), and whether one builds one's structural realism on this directly or takes it as comprising one horn of the metaphysical underdetermination that has also been taken to power OSR, one might be inclined to understand the 'simples' themselves in structuralist terms.

Two further broad options then present themselves: one can take the relevant 'features' of structures as acting as the appropriate 'simples' or truthmakers. These features will obviously not be the kind of thing that metaphysicians may have in mind, where they typically think of this notion in broadly 'atomic' terms. Here they will include symmetry principles and fundamental laws and the truth-making relation will be reversed of course, insofar as it is not objects and properties that make true law statements and the like, on this view, but rather the laws, and symmetries, that ground the properties and behaviour of the putative objects (for discussion of this reversal, see Cei and French forthcoming). Nor will these simples be spatio-temporal, unless one views the physical structure with all its features as sitting in or contained by space-time. It has long been part of the structuralist programme to incorporate space-time within this ontology (French and Ladyman forthcoming; Auyang 1995), and the structure of the world has been taken to include space-time structure, although the details of that inclusion are waiting on a viable theory of quantum gravity (Rickles and French 2006),

Alternatively, one might want to say that there is only one 'simple', namely the structure of the world in all its glory, considered as a single entity. This invites obvious comparisons with blobjectivism. The problem now is that faced by all forms of monism: how to account for the apparently manifest complexity and variety of 'the appearances'. As Horgan and Potrc note, one cannot say that physical magnitudes, in all their huge variety, are instantiated by *parts* of the blob, since strictly speaking, it has no parts. Instead, they refer to 'manners of instantiation', in the sense that the blob itself instantiates in a certain manner (and, in particular, in a spatio-temporally local manner) the relevant properties and relations (op. cit., p. 169). However, there is the obvious concern that this metaphysical move is merely parasitic upon (and therefore adds nothing to) the account offered by physics with regard to the relationship between the physical correlate of the blob (the quantum field, say; see Healey forthcoming) and the relevant physical magnitudes. More acutely, perhaps, the notion of a 'manner of instantiation' remains obscure.

If the idea of structure, of features of structure, functioning as metaphysical simples is less than compelling, then there are further options that one might consider.

7. Bringing Back the Bundle

Thus a further, broad option would be to stick with truth, standardly understood, resist truthmakers and offer some form metaphysical account in terms of which we 'recover' the relevant features we are interested in, in this case, particles, from our base ontology, in this case, structures, or features thereof. There are various routes one might take, but here I shall consider one that has particular relevance in the structuralist context.

As noted previously, the early structuralists, such as Cassirer and Eddington, expressed their ontological commitments in terms of opposition to what they saw as the generally accepted substantivalist views of the day. This naturally leads to comparisons with another well-known anti-substantival ontology, namely the so-called' bundle' view of objects, according to which the latter are nothing more than bundles of properties (French 2001). Indeed, more recently, Chakravartty (2007) has defended a form of structural realism that holds this view at its core. Specific forms of this view will then vary according to their account of the nature of properties, their instantiation and so forth. Chakravartty prefers a dispositionalist account (for criticism and a response see French forthcomingb and Chakravartty forthcoming, respectively); others opt for trope-theoretic formulations (Morganti 2009). Whatever form one adopts, some modification will be required when importing it into the quantum context. Standardly the Principle of Identity of Indiscernibles has been allied to the bundle view as a kind of metaphysical guarantor of the discernibility of these object-bundles in the absence of substance, which rules out qualitative duplicates, but that Principle faces well-known problems here (see French and Krause 2006, Ch. 4). Again as indicated previously, Saunders' revival of the Principle in Quinean form may offer a way forward and the consequent inclusion of relations into the bundle, although taking this view away from the original Leibnizian vision, takes it closer to a structuralist conception, which in turn meshes with Chakravartty's version of the bundle view for example[14].

The question now is, can this bundle view of objects be allied with an appropriate mereological metaphysics that is consonant, at least, with a structuralist base ontology? Paul's 'Mereological Bundle Theory' (MBT) suggests a positive answer. The key move is to regard 'our knee-jerk way of thinking about the things physicists describe as "objects" or "particles" as little material-like hunks of stuff [as] fundamentally mistaken.' (Paul forthcoming; see also her contribution to this issue). According to this account, the world is not built from the bottom up, 'spatio-temporal hunk by spatiotemporal hunk', as it were. Rather, we are presented with a one category ontology in which the only category is that of properties, with 'objects' understood as bundles of these properties and 'bundling' conceived of as restricted qualitative composition involving fusion. Thus, Paul writes,

'My personal preference is for a contingent, purely qualitative mereological bundle theory where spacetime, as well as everything else there is, is constructed from fusions of properties.'

Earlier bundle theories invoked primitive and hence rather mysterious relations of ‘compresence’ or ‘concurrence’ to tie the bundle together and form an object. Paul avoids the mystery by understanding bundling in terms of fusion or part-hood, a well-known relation from mereology in general. In particular, fusion is taken to capture the idea that bundling involves the *creation* of objects and by restricting the relevant composition appropriately, the creation of bizarre or generally unwanted objects can be avoided. Everyday objects and those that can be spatio-temporally located in general are effectively created by fusing the relevant properties with spatio-temporal location, where the latter is also understood in property terms, rather than a ‘sui generis entity’ (see op. cit. p. 12). I will return to this aspect shortly but its worth noting here that Paul takes the relationship between property fusion and spatio-temporal fusion to be crucial for understanding how objects can be composed of property parts and also smaller spatio-temporal parts (p. 6). In particular, it is crucial for her view in general that property parts be seen as no different in kind from spatio-temporal parts – the former are not to be understood as abstract, with the latter as concrete; rather properties, or at least some of them, and in particular those that are everyday objects, are concrete.

This understanding of properties also sheds light on the nature of fusion: it does not somehow produce concrete entities out of abstract ones but rather just creates the one (object) from many (properties). All fusions, on this account, are fundamentally qualitative fusion. Thus,

‘There is no mystery about how material objects are built from smaller material objects while also being built from property parts, because material objects are only built from property parts.’(ibid., p. 9)

What about the individuation of objects on this view and, in particular, the role of the Principle of Identity of Indiscernibles? As Paul notes, the alliance of this Principle with the bundle theory depends on accepting the ‘supervenience of identity thesis’ which holds that the ‘identity of x’ reductively supervenes on the qualitative properties of x. But as she says, one could deny this thesis and thus avoid having to adopt the problematic PII. One way of doing this would be to accept haecceities, primitive thisnesses or suchlike as grounding identity, although that would undermine a crucial motivation for adopting the bundle view in the first place. Alternatively, one could take the thesis to be false on the grounds that identity facts do not supervene on any qualitative properties but simply on the object x itself (ibid., p. 16). As Paul states, this amounts to a form of primitive individuation but one that involves an ungrounded difference and hence avoids a lot of ‘ontologically heavy machinery’. Again, I’ll come back to this point below, but its important to note the motivation here is to accommodate the kinds of symmetries that the structuralist sets such store by:

‘… the primary ontological choice one must make, given the seeming possibilities of various sorts of qualitative symmetries, is not between ontologies but between accommodating the possibility of these symmetries or not. Only if one chooses to accommodate the possibilities, must one then choose between ontologies: between a universe with primitive grounded

differences and a multiplicity of categories, or a universe with primitive ungrounded differences and a single category.' (ibid., p. 19)

However, a well-known problem arises in the current context, as Paul acknowledges, namely the possibility of multiple, qualitatively indiscernible particles at the same location, or, more generally, in the same state (ibid., pp. 21-27). If we reject the attempt to extend Saunders' approach to bosons, then the existence of n-boson states appears to pose a problem for Paul's property based mereology. The solution she suggests is that such states do not have the quantitative structure their name implies: what we have is a property instance of 'two boson-ness', where the latter is an example of what Armstrong called 'fundamentally intensive properties', in the sense that they lack structure and cannot be reduced to co-instantiations or co-occurrences of multiple instances of unit properties such as 'being a boson' (a well-known example of an intensive property would be 'being sweet'; ibid., p. 24). Thus, the bundle view can accommodate the above possibility by accepting structureless intensive properties and in effect denying that we have two, or more, objects in such states – a move that also allows the view to mesh with QFT (ibid., p. 24).

Now, this is an interesting attempt to bring novel metaphysical considerations to bear on issues of identity and objecthood in quantum physics, and I think it generates a useful comparison with structuralist views, as I shall briefly discuss below. I also have a number of concerns, however. First of all, it comes at a cost: that of introducing many intensive properties. As Paul notes, Armstrong's vision of eliminating such properties has to be given up in the face of the above analysis of boson states, but even those who do not share his vision may balk at the inflation of our property ontology that this entails. Of course, the alternative objects-as-distinct-from-properties ontology is likewise vast in terms of the number of items it entertains but at least it presents fewer *kinds*: the kind 'boson', under which fall numerous objects, as opposed to numerous 'kinds' of property, such as two-boson-ness, three-boson-ness and so on. Secondly, the denial of internal structure does not sit well with the experimental 'facts': we can manipulate such states and obtain what appear to be single particles from them. Of course, between observing the flash on the scintillation screen and asserting the existence of a single particle a number of inferential steps must be laid down, but something needs to be said about how the property instance of 'two-boson-ness', say, can yield an instance of 'one-boson-ness' (perhaps one could say that an operation of 'de-fusion' is involved).

Thirdly, and restricting ourselves to QM with QFT left to one side for the moment, Paul's analysis is explicitly couched in terms of the so-called 'Received View' of the implications of QM for identity and individuality (although she herself thinks it is a mistake to think of these implications in these specific terms). She takes permutation invariance to imply that n-boson states, for example, should not be understood as involving multiple indiscernible bosons, but, as indicated above, as partless intensive properties. However, as is well-known, quantum statistics and permutation invariance in particular is also compatible with a metaphysics of quantum particles – even bosons – as individual objects (French and Krause 2006).

Of course, such a view comes at a cost, with regard both to how identity and individuality are characterised, and to how we understand quantum states. However, instead of introducing intensive properties, we can regard such states in terms of properties that are non-supervenient (Teller 1986; French and Krause op. cit. Ch. 4), an option that does not seem incompatible with MBT. As for the former cost, Paul would presumably want to advocate an understanding of individuality in terms of ungrounded difference. Here the basis of the difference would be the 'two-ness' or, more generally, 'n-ness' of the state, but again there doesn't seem to be anything there that would conflict with this view. Alternatively, she could appeal to Saunders' understanding of PII – for fermions at least – and take this as grounding the particles' identity. This would involve the inclusion of irreducible relations within the bundle, something that takes this view closer to a structuralist understanding. In either case, one will still be able to accommodate the relevant symmetry represented by permutation invariance without having to accept intensive properties.

Of course, one could reject this latter option and embrace the Received View on the grounds that it meshes better with QFT. As a way of deciding between interpretations of particles in *QM* I think this is a problematic manoeuvre (see French and Krause op. cit., pp. 192-197) but Paul's application of MBT to QFT is certainly suggestive. A standard way of understanding fields in this context is in terms of field quantities instantiated at, or smeared over, space-time regions (for a discussion of possible ontologies for QFT see, again, French and Krause op. cit., Ch. 9). Typically the latter are given some form of substantivalist interpretation, with the former taken to be properties-as-universals possessed by or instantiated in this substance. Taking the field to be a bundle of qualitative and spatio-temporal properties is an interesting step and bears comparison of Auyang's structuralist view of physical structure and space-time structure as emerging together as aspects of the world-structure , a view that is also similar to Eddington's (Auyang 1995).

The anti-substantivalist stance that lies behind mereological bundle theory obviously meshes well with structural realism, particularly insofar as MBT offers a one-category ontology in which the distinction between objects (qua bearers of properties) and properties themselves evaporates[15]. Indeed, if the latter include, as they should, relations and non-monadic properties in general, then the distinction between bundle theory and a structuralist ontology likewise evaporates (cf. Chakravartty 2007). Furthermore, the co-occurrence of certain properties lends itself to a structuralist understanding. Paul acknowledges this as a possible worry about MBT: properties, it is claimed, differ from objects in that the former may be co-dependent in ways that the latter are not (op. cit., p. 11). Her response is that the fact of co-occurrence (understood on her view as involving fusion) does not imply ontological co-dependence:

'It just means that there are certain facts about the universe that result in certain connections: for example, that anything with mass also has extension.' (ibid.)

I think that understanding MBT from a structuralist perspective offers a more robust response: the supposed ontological independence of objects is problematic to begin with. Cashing out this independence in terms of the grounds for identity and individuality leads to the metaphysical underdetermination in the quantum context that OSR aims to overcome. Dropping this presumption of independence (derived ultimately from reflections on everyday objects as bits and pieces of matter banging about in the container of space-time) then removes the source of the worry. Furthermore, Paul's suggestion that these connections can be related to the role of laws can be bolstered by a structuralist understanding of this relationship. Thus she writes,

'Perhaps these connections are simply contingent facts about how the qualitative profiles of objects are to be completed that are derived in some way from the physical laws of the world.' (ibid.)

As articulated elsewhere (Cei and French forthcoming), the structuralist reverses the current (mainly dispositionalist) understanding of the relationship between (intrinsic) properties and laws by taking the latter to have ontological priority as features of the structure of the world, with the former as derivative. On this view, the connections Paul speaks of are precisely those that the structuralist will want to highlight as physically significant (not perhaps the mass-extension relationship but certainly that between spin and particle kind as given by the relevant statistics, for example). Further connections are expressed by the symmetry principles that play such a prominent role in current physics and which the structuralist sets at the core of her ontological world-view. As already indicated, the most basic kind distinction between fermions and bosons is captured via symmetry considerations, as represented by group theory. And as is well-known Wigner established the connection between symmetry and the relevant characterising properties via the irreducible Hilbert space representation of the (restricted) Poincaré group. In addition there are the so-called internal symmetries, such as that associated with colour (in quantum chromodynamics) as represented by SU(3), which famously underpins the classification of hadrons[16]. Again, the relevant properties that characterise both the kinds and their inter-relationships are connected to the relevant symmetries in such a way that the meaning of a physical quantity such as spin can be understood as deriving from its representation in terms of the eigenvalues of the generators of the relevant group algebras and the (second-order) properties of these quantities is given by the associated structure.

And just to pursue this line a little further, as Paul notes, the 'flip side' of her response to the above worry is that it also answers the worry about unrestricted composition since if there are 'deep' facts about the co-occurrence of properties there will also be 'deep' facts about which cannot co-occur. Thus there will be contingent restrictions on composition on this view. Of course, a little care needs to be taken in understanding the sense of contingency here since on a unificationary view of the progress of science the extent of co-occurrence will spread until we arrive, presumably, at the Theory of Everything on which all (physical) properties are connected.

In this context we might then bring together blobjectivism and the bundle theory under the structuralist umbrella. A ‘global’ bundling of the relevant polyadic properties will yield the blob as structure of the world, with a ‘local’ bundling of the relevant properties giving us the putative ‘objects’. Of course, there remains the issue of accounting for the complexity of the appearances, either through manners of instantiation, or an appropriate notion of parthood with restricted composition.

Furtherrmore, on a naturalistic view these ‘deep’ facts will ultimately be physical facts and hence the restrictions on composition will ultimately be read off from the relevant physics. The danger here is, again, that the metaphysics is effectively gutted by the physics and contributes at best some form of label for the relationships that are fundamentally explicated in physical terms. Thus consider again the interesting suggestion of bringing space-time within the remit of MBT, with the spatio-temporal location of physical objects understood in terms of the fusion of ‘physical’ properties with spatio-temporal ones. The notion of ‘fusion’ is carrying all the metaphysical weight here, and explicating it further so as to relieve some of that burden runs the risk of cashing it out entirely in physical terms. Of course, this is a general worry when it comes to the relationship between metaphysics and science, but it has particular bite in this context.

Conclusion: Back to Composition

We recall the Hawley's suggestion that there will be different answers to the General Composition Question for different sorts of things. Thus we might expect that the answer obtained when it comes to 'everyday' objects such as tables and their constituent particles will be different from what we get when we consider particles (as objects) and structures. In the former case, and from a naturalistic stance, we would expect the metaphysics of composition to track the relevant physics. This raises the twin possibilities that there may be little more for the metaphysics to add to this physicalist account; and that it may push us towards eliminativism. This may not be as problematic as some seem to think since there are ways in which we can still make statements about these everyday objects without having to incorporate them into our ontology. Of course, some of these ways – such as Cameron's version of truthmaker theory – deny the significance of the GCQ to begin with. When it comes to particles and structures, the comparison with identity criteria that Hawley makes with regard to the GCQ again needs to be treated with some care when it comes to quantum particles, at least. Again we recall that there is a fundamental form of underdetermination in this context, one response to which is to abandon objecthood and associated identity criteria entirely, leading to the eliminativist form of OSR. Likewise, from that perspective we should abandon (general) object based composition, for obvious reasons.

Thus taking the Special Composition Question as a constraint, the 'right' ontology must provide systematic and general answer to the question: Under what circumstances do several distinct objects compose an object? From the perspective of the view that the latter have a kind of derivative existence, composite objects 'exist', but only derivatively so the answer to the SCQ is 'never', since there are, strictly, no composite objects. Likewise, according to blobjectivism there is only one concrete particular and no composite objects. So, again, the answer to the SCQ is never, but in this case because there is only one real object. When it comes to simples and truth-makers, acceptance of the existence of the (purportedly) composite object does not bring ontological commitment to such objects. There are no such objects over and above the simples, although we can of course still make statements and utter truths about composite objects – they are, as it were, an 'ontological free lunch' (Cameron 2008).Yet again, then, the answer to the SCQ is never, as no collection of objects ever composes and there are no composite objects, just the simples. Mereological Bundle Theory, on the other hand, does allow for composition. Here we have very many objects, since properties count as such, and composite entities will compose according to the nature of the bundling. As Paul insists, this composition is not unrestricted and on a naturalistic approach the relevant restrictions will track the kinds of relationships represented in the physics.

Finally, we can then apply the notions of existential and esssntial dependence to the relationship between structures and objects (see French 2010). Here it is useful to distinguish what can be called,

'Identity Dependence':

(ID) ‘objects’ are dependent for their existence on features of the structure iff the identity of such objects is dependent on the structure;

from

‘Constitutive Dependence’:

(CD) ‘objects’ are dependent for their existence on features of the structure iff the constitutive nature/ ‘essence’ of such objects is dependent on the structure.

ID captures what is behind Non-Eliminativist OSR, where the identity of (putative) objects is given in terms of the relevant relations – those exemplified by the singlet state in the case of fermions (Saunders 2006), or spatio-temporal relations in the case of space-time points (Stachel 2002). The worry here is that if the identity, as in weak discernibility, of these objects is explained in terms of the relevant relations, then it is derivative upon the latter. In that case, the only grounds for claiming that we retain a notion of objecthood at all, even as ‘thin’ as this, is by adopting a particular Quinean reading of ontology off theories, which may be contested. CD, on the other hand, obviously fits with with Eliminativist forms of OSR and captures the intuition behind the derivative existence of objects on this conception.

All of these moves come with some cost. However, at the very least they can be used to assuage some of the concerns associated with the kind of revisionary ontology that structural realism presents. In particular, we can still say things about everyday objects while maintaining that only elementary particles exist, either by adopting Horgan and Potrc’s division between truth as indirect- and direct-correspondence, or a form of truthmaker theory with simples. Proceeding down a metaphysical level, we can still say things about elementary particles while maintaining that there are no objects, only structures. How composition looks from this structuralist perspective then depends on which of the above metaphysical moves one decides to make and, of course, on the form of ontic structural realism adopted.

According to ‘eliminativist’ OSR, there are no objects, whether composite or composing, so at first glance the answer to the SCQ would again seem to be ‘never’, but now because there are no composing objects. Even at second glance, as it were, one might reach the same answer: if one thinks of the structure of the world in a monadic fashion, and draws the comparison with ‘the blob’, then again the answer is ‘never’ but now of course the reason is that there is only one ‘object’ (broadly understood), namely the structure, with the requisite ‘manners of instantiation’. Alternatively, one could take the features and aspects of the structure as the appropriate simples on the truth-makers approach and still give the same answer to the SCQ. If, however, one thinks of the structure as a big bundle (and relational too), then the nature of composition, and hence the answer to the SCQ, will depend on which features one is talking about, the nature of the physical relationships and so on.

Non-Eliminativist OSR, with its talk of ‘thin’ objects, may appear to invite consideration of composition, but the worry here is that the ‘objects’ may be too thin to compose. Remember: for fermions we have weak

discernibility in entangled states, for bosons the situation is more problematic. Of course, if one were to adopt MBT, with Saunders' revised form of PII, perhaps, the issue would be moot: even thin, the 'objects' would be nothing but bundles of properties and composition would proceed along the lines sketched above. Alternatively, as thin as they are, these objects may be robust enough to act as simples without the concerns attendant upon regarding 'features of structure' in this way. Such concerns have to do with discerning such features in such a way that we can say they function as distinct simples appropriate for making true the relevant statements – weak discernibility may just be enough for that.

At this point, one might well feel that we have proceeded too far down the level of detail, to the 'nit-picking' stage. However, I believe that deploying such metaphysical moves is absolutely crucial if we are to develop forms of realism that are appropriate for current physics. Ladyman and Ross have famously berated the metaphysicians for constructing speculative proposals that at best draw on images of physics that have long since been outdated. More generally, 'physics-lite' metaphysics runs the risk of floating free from any contact with modern science (Ladyman and Ross, 2007 p. 9). On the other hand, metaphysics-lite realism runs the risk of incomprehension and certainly it is not enough to pose a revisionary ontology, whether of wave-functions in configuration space, density operators in space-time, or structures, in whatever form, without articulating that ontology in metaphysical terms. And one of the things I want to emphasise is that, however one views the current state of metaphysical research, it lays out for us an array of tools and manoeuvres that we can deploy in the service of that articulation.

Less obviously, perhaps, the humility that has to be adopted towards many features of today's metaphysical views allows these views to be insulated from physics (cf. Ladyman and Ross 2007, p. 22). Consider the question whether the metaphysicians' simples are individuals or not? Quantum physics can't answer that, because of the underdetermination touched on previously. The correct response, I believe, is to reduce the level of humility that has to be adopted, in order to bring these metaphysical views into closer accordance with the relevant physics. Doing this involves reducing the number of unknowable metaphysical facts by reducing the basis for such facts. The obvious example would be the notion of 'object': removing that from our pantheon resolves the above underdetermination and moves our metaphysics closer towards modern physics. But to make sense of an object-less ontology, we need to draw on the kinds of moves I've sketched here. Talking of wholes and parts and composition in the absence of a consideration of the relevant physics is just armchair metaphysics mongering; but simply pointing to the physics leaves us with just a set of equations, at worst, or at best, a partial interpretation cashed out in crude metaphysical terms that sit uneasily with the physics itself. What I've tried to do here is indicate a possible 'third way' in which the physics motivates a certain kind of realism and we then draw on the range of options available to help make metaphysical sense of it. This is not the only way to proceed, but proceed we must if we are to construct a *philosophy* of physics.

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Notes

1 Acknowledgments: Thanks to Jos Uffink and Richard Healey for organising such a congenial workshop and to the Lorentz Centre for providing such excellent facilities. Thanks also to Otavio Bueno, Angelo Cei, Terry Horgan, James Ladyman, Kerry McKenzie, Laurie Paul, and David Wallace for helpful discussions. The responsibility for any philosophical misjudgments lies with me, as always.

2 One might wonder in what sense van Inwagen's own answer can be necessarily true given that the implicit claim that there exist regions of space is physically false!

3 Horgan and Potrc are keen to allow unitarity to trump meshing, since it is by reflecting and pressing upon common sense beliefs that they are arrive at their one-object ontology they call 'blobjectivism'.

4 Relatedly, she fails to grasp what Eddington took to be the fundamental implications of the new quantum mechanics with regard to the individuality of particles. Perhaps this is because she relied on her colleague, William Wilson, for her understanding of quantum physics (1937, p. xiii). Wilson is perhaps most well known for his work on the quantum conditions of the 'old' quantum theory and Stebbing clearly drew heavily on his paper 'The Origin and Nature of Wave Mechanics' (1937), which makes no mention of the kinds of implications that Eddington, Cassirer (and indeed the likes of Born, Heisenberg and Schrödinger) were concerned with. These are relevant precisely because insofar as they were understood in terms of the non-individuality of the particles they were taken to rule out the possibility of such particles being ontologically characterised as objects.

5 This is where Thomasson differs from Stebbing, who focuses on predicates, such as 'solid' and argues that unless we understand what this means, we cannot understand what the denial of solidity means, and we can only understand it if we can 'truly say' that an everyday object such as a plank is solid. Of course, one does not need to rely on Eddington's rhetoric to advance a form of eliminativism in this case, as we shall see.

6 One might also question the dismissal of the notion of 'physical object' in this context; or examine more closely the relationship between the scientific and manifest images.

7 Actually it may not seem such a radical position to some: many metaphysicians adopt a deflationary ontology, including nihilists of course. Nevertheless, the reaction I get whenever I mention it (much less argue for it!) is surprising for its intensity.

8 There are of course important issues here as to what we mean by 'fundamental'; see McKenzie forthcoming.

9 Stebbing's critique was published before this later work of Eddington and hence she makes no mention of it.

10 Returning to the broader issue that has to do with how we read off our ontology from our theories, we recall that the Quinean insists that our ontological commitments are revealed by what the relevant sentences quantify over. Cameron's approach rejects this: our ontological commitments lie with whatever must be included in our ontology to ground the truth of the relevant sentences. The former requires the theory to be presented in an appropriately regimented form; the latter requires a clear view of what 'grounding the truth' consists in such that it is clear what should be included among our commitments. In cases like that of tables, the relevant physics helps us to get a grip on this grounding but when it comes to physics itself, we may find that grip slipping. Nevertheless, I'm sympathetic to Cameron's approach.

11 There is a further concern that the kind of metaphysical nihilism associated with simples is undermined by the suggestion that science could reveal layer after layer of fundamental 'atoms' – from atoms to electrons and nuclei, from nuclei to protons and neutrons, to quarks and so on (see Wasserman, 2009). Cameron himself shies away from denying the existence of tables. But even if one did, it is not clear how powerful the inference is from the relevant observation of the history of science to the conclusion that science will never reach a layer of entities whose lack of further proper parts would entitle them to be called 'simples'. If the latter are taken to be associated with some notion of fundamentality, then there is a batter argument against this which draws on the bootstrap

approach to elementary particles (see McKenzie forthcoming). However, this is entirely consistent with the structuralist line adopted here (ibid.).

12 The particle notion becomes problematic in the context of QFT. Fraser has argued that when interactions are considered, QFT cannot sustain an interpretation in which the quanta are countable (Fraser 2008), and Halvorson and Clifton (2002) have shown that even if we drop interactions and consider only the 'free' theory, we cannot describe the putative particles as localized at or even around space-time points. These results seem to rule out a particle interpretation of QFT (although see French and Krause 2006, Ch. 9 for some possible concerns with regard to this conclusion). However the interpretive situation is even worse, as Baker has recently concluded that the same arguments that Fraser uses can also be deployed against fields (Baker 2009). An obvious option would be to attempt a structural interpretation of QFT (as suggested in French and Ladyman 2003), but Howard has raised the problem of unitary inequivalent representations in this context (forthcoming). A possible response is laid out in French (forthcoming).

13 Thus Cao criticised OSR for eliminating particles and thus rendering physicists' talk false (Cao 2003); as was pointed out, it is not particles-as-elements-of-the-scientific-lexicon that are eliminated but particles-as-metaphysical-objects (French and Ladyman 2003).

14 Nevertheless, other considerations that support the structuralist conception may undermine the bundle view. McKenzie has pointed out that the role of symmetry in elementary particle physics yields an ontological picture that is significantly different from the bundle view since the relevant symmetry relationships specify both the kinds of particles and the compositional relationships that hold between these kinds.

15 It may also mesh with other views, such as Esfeld and Lam's 'moderate structural realism' and Saatsi's 'eclectic' realism, although I shall leave the exploration of these possibilities to another paper.

16 Again, my understanding of both the history and philosophical implications of the relevant physics has been significantly enhanced and deepened by the work of Kerry McKenzie. Her concern about the bundle theory in this context noted in fn 14 may be alleviated by modifying MBT in this way.

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