Beefing Up Recipe Realism: Stir a Pinch of Metaphysics into the Pot

Steven French
School of Philosophy, Religion and History of Science
University of Leeds

Abstract
Recent developments in the scientific realism debate have resulted in a form of 'exemplar driven' realism that eschews general 'recipes' and instead focuses on the specific, 'local' reasons for adopting a realist stance in particular theoretical contexts. Here I suggest that such a move highlights even more sharply the need for the realist to incorporate a health dose of metaphysics in her position, particularly when it comes to the theories associated with modern physics. Turning to another set of recent developments, having to do with the relationship between metaphysics and science, I argue that the exemplar driven realist can appropriate certain current metaphysical devices to help make concrete her commitments. Specifically I focus on a kind of exemplar based structural realism and examine the adequacy of, first, the determinables-determinate relationship as presented by Wilson and, second, Paul's 'one category ontology, as such devices within this framework.

Introduction

This paper sits at the intersection of two recent debates: the first concerns the contrast between so-called 'recipe' realism and an exemplar driven form (Saatsi 2016), whereas the second has to do with the relationship between metaphysics and science (Callender 2011; Ladyman and Ross 2007). In essence it represents an attempt to delineate a more moderate, 'third' way in each debate, using the example of structural realism to give concrete form to this attempt.

I shall begin by outlining 'exemplar-driven' realism which has been offered as an alternative to the traditional, 'recipe-based' framework. As an example of a form of realism that adheres to the latter, structural realism has been held up for criticism and I shall argue that this criticism is either unwarranted or can be accommodated. In effect, I shall suggest that structural realism can be articulated as an exemplar-driven project. However, when it comes to the relevant examples, it is metaphysical considerations that crucially motivate the shift to structures and this takes us into the second debate.

A number of commentators have noted the apparent divergence of much of current metaphysics from modern science. Metaphysicians have been admonished for failing to pay attention to developments in modern science, especially physics, and various metaphysical devices, principles and theories have been taken to be ruled out by these developments. However, French and McKenzie (2012, 2015) have argued that metaphysics may yet have instrumental value in providing a kind of toolbox that philosophers of science can use for their own ends. In particular, I shall suggest that metaphysics offers an array of tools that the realist can deploy to help make good on the claim that science offers a view of how the world is, and not just how it could be. And in particular I shall argue that these tools can help the structural realist further articulate her position and respond to various criticisms and concerns.

Exemplar-driven Realism

In a recent analysis, Saatsi has argued that the realism debate is in the grip of what he calls 'recipe realism', where such a recipe is '… capable of distilling the trustworthy aspects of a theory, applicable to *any* good, predictively successful mature theory. ' (2016 p. ???; see also Asay 2016). The example he gives (indeed, which leads the paper), is that of structural realism, according to which the structural realist insists that given any empirically successful, mature theory, it will 'get the structure right'. Of course other examples can be given – the entity realist will insist that such theories nail down the right entities, the dispositionalist semi-realist will insist that they get the relevant bundles of dispositional properties 'right' and so on – but they are all akin in spirit by virtue of proposing some abstract schema for capturing the truth-content of our best theories or, more generally, characterising the sense in which such theories 'latch onto' the world.

Thus, structural realists express their epistemic commitments in such general terms: 'all that we know is structure'. And in that spirit, the debate then focuses on the letter of how that notion of structure may be metaphysically characterised and represented. Some, such as Worrall (1989), have tended to highlight the relevant equations and deploy Ramsey sentences as representational devices, whereas 'ontic' structural realists (Ladyman and Ross 2007; French 2014) have emphasised symmetries and the associated group-theoretic structure and have used the semantic approach to represent these features of theories. But Saatsi argues that the underlying approach is the same: to give a general recipe that can be applied to any historical episode or any new scientific development (that meets the realists' general criteria of empirical success, maturity etc.).

Thus, the aim of recipe realism is '…to capture theories' epistemic commitments across a wide range of disciplines and different areas of scientific theorising in unified terms, offering recipes or algorithms that are first motivated by particular considerations and case-studies, and then optimistically projected well beyond those to the rest of science.' (Saatsi 2016, p. ???). However, Saatsi argues, this aim is thwarted for a number of reasons: first of all, the sheer diversity of science and the inhomogeneity of theorising suggests that there is really little reason to expect that one recipe will fit all disciplines. Of course the very abstract nature of these recipes may delude their advocates into viewing science as more homogenous than it actually is, but to expect that theories in high energy physics, on the one hand, and immunology, on the other, 'latch onto reality' in the same way is surely unwarranted.

Furthermore, Saatsi continues, the fact that we have so many different realist recipes should give us pause; perhaps, instead of thinking of them as competitors, we should regard them from a pluralistic perspective as capturing the different possible ways that a theory can 'get the world right' – i.e. get it right in its structural aspects, in its causal aspects and so on. But of course, the fact that each recipe fits certain cases gives no reason to think it can be 'projected' even within that particular science, much less across disciplines, nor that the other recipes are somehow ruled out across the board.

And the very abstract nature of such recipes means they actually say little about precisely how the theories concerned latch onto reality. Again, in the case of structural realism, to give content to the recipe the nature of the structure that is appealed to must be spelled out but this has proven contentious, or so it is claimed. Here we have the contrasting examples of Ramsey sentences and the semantic approach, and it is argued that '[i]t is entirely unclear why these recipes should in general be at all good for discerning something that will be carried over in various theory changes, something that furthermore genuinely accounts for the past theories' empirical success.' (*ibid*., p. ???) Even giving illustrative exemplars such as the famous Fresnel case or phlogiston, is of little help, since they may pull in different directions, thereby watering down the content of the recipe; after all, in what sense can 'the structure' in the case of light and phlogiston be the same?

Nevertheless, Saatsi agrees that focussing on such exemplars is the way to go – except he recommends giving up on the recipe entirely: 'Recipe realists are right in leaning heavily on exemplars in explicating their realist commitments, but they go wrong in trying to generate a general recipe that captures the gist of those exemplars. ' (*ibid*., p. ???) Instead, we should regard realism in general in terms of adherence to the 'positive attitude' that theories' empirical success is due to their getting something right about the world and specific exemplars then give content to this attitude by specifying what that something is, with no expectation that it can be exported to other theories within that discipline, much less across disciplines. Thus we have a global attitude, applied locally and as Saatsi notes, this gives new meaning to the 'divide et impere' slogan that also underpins structural realism.

Now, there is much that is positive about this suggested reorientation of the realism debate. And indeed, despite being held up as an example of 'recipe realism', there seems little to prevent structural realism from being articulated within the framework of 'exemplar realism'. Although the epistemic form of structural realism was indeed originally presented as a general and perhaps abstract response to the Pessimistic Meta-Induction (Worrall *op. cit.*), the ontic variant allies that response to an attempt to accommodate the specific metaphysical implications of quantum mechanics (Ladyman 1998). And as has been noted (French 2006), that alliance may in fact come apart. Consider: towards the end of his classic paper, Worrall speculated that his form of structural realism might be extended to quantum physics. Now, although attempts have been made to articulate an appropriate sense of continuity between classical and quantum mechanics (see Saunders 1993, French 2014 pp. 15-20), it might be argued that such attempts can only be deemed to be successful to the extent that we accept a certain 'plasticity' in the relevant structures (so that the Poisson brackets of classical mechanics can be deemed to be appropriately related to the Moyal brackets on the quantum side for example; see French *ibid*.). If one were to conclude that the bridge between the two is just too tenuous one might then be inclined to conclude that either one should acknowledge that the structures one should be realist about are different in the classical and quantum cases, with no relevant continuity between them (and hence convergent realism is in trouble, as Laudan famously suggested), or that if one has grounds to be a structural realist when it comes to quantum physics, one may have no such grounds in the classical context, where one should be an entity realist perhaps. This second option would certainly fit with exemplar realism.

And of course, setting aside the issue of responding to the Pessimistic Meta-Induction, the relevant grounds for shifting to structures will vary both within a particular discipline, such as physics, and between disciplines, such as physics and biology. Thus when it comes to quantum mechanics, part of the original motivation for ontic structural realism concerned the perceived metaphysical underdetermination between the views of particles as individuals and as non-individuals, both of which are supported by the relevant quantum statistics (see Ladyman 1998; Ladyman and Ross 2007; French and Ladyman 2011; French 2014). In response to van Fraassen's conclusion that such underdetermination undermined the realist's position, it was argued that it could be effectively dissolved by giving up on the underlying object-oriented metaphysics and claiming that, to repeat the slogan, 'all that there is, is structure' (Ladyman 1998). This is less a 'recipe' than a metaphysical commitment that of course then needs to be cashed out.

However, that cashing out of what is meant by 'structure' should not be understood in terms of Ramsey sentences or set-theoretic structures or category theory or whatever. As French (2014 Ch. 5) emphasises, these are the devices that we use as philosophers of science to *represent*, for our own purposes and aims, theories, data models, programmes and, yes, empirical and theoretical structures. But our realist commitments should not be to these devices in and of themselves. In deploying them we are not so much giving content to the relevant 'recipe' as using a meta-level tool. Thus it should come as no surprise that different philosophers of science, with their different meta-level commitments, should use different sets of such tools. Worrall, for example, is famously antagonistic towards the semantic approach and thus prefers the syntactic formulation of Ramsey sentences to capture the structural commitments manifested at the object level of the theories themselves in the form of the relevant equations. Others have opted for category theoretic frameworks (Bain 2104; Landry 2007), although these have been criticised for failing to appropriately represent the relevant structural features (Lal and Teh 2015; Lam and Wuthrich 2015). And, of course, the set theoretically based semantic approach has long been advocated as an appropriate means of capturing the inter-theoretic commonalities that are claimed to form the basis of the structural realist's response to the Pessimistic Meta-Induction (Ladyman 1998; French 2014, Ch. 5)

Furthermore, that cashing out at the 'object level' of the science itself will be specific to the relevant theoretical context. Thus in the context of the theory of light and, subsequently, electromagnetism, the relevant structure is presented by Worrall in terms of the equations of first, Fresnel, and then Maxwell (and beyond), taken to be interpreted of course. And although we find such features as Galilean invariance in the classical context, it is in the quantum physics that symmetries really come to prominence, beginning with the permutation invariance that lies at the heart of the quantum statistics underpinning the above metaphysical underdetermination. And just as the laws are presented mathematically via the appropriate differential equations, for example, these symmetries are presented via the mathematics of group theory. Hence in this case the 'structure' is cashed out in terms of the relevant laws plus symmetry principles (see French 2014)[1], where these are then clothed in an appropriate metaphysics.

Shifting to quantum field theory, we no longer have the original motivation in the form of the above metaphysical underdetermination (although we do have another kind of underdetermination in the form of fields-as-substantival versus fields-as-instantiated properties) but we still understand the structure in play through a combination of symmetries and laws, with the Poincaré symmetry of relativistic space-time playing a particularly significant role (French and Ladyman 2003; French 2014). And since it is quantum field theory that provides the framework for the Standard Model of high-energy physics, we can again cash out the relevant structure via laws and symmetries, with the gauge symmetries involved in representing interactions now added to the mix (French 2014)[2].

So, in one sense, we don't have the same recipe cashed out in each case, since the motivation for structural realism that is presented in the context of quantum mechanics is not present in that of high-energy physics, where the

---

[1] Actually, following Cassirer the structure of the world is understood in terms of a three-way interwoven complex of symmetries, laws and determinate phenomena (French *ibid*.).

[2] Curiously, Nounou (2015) suggests that ontic structural realism is almost exclusively focussed on quantum mechanics with very little attention paid to quantum field theory and hardly any at all to high-energy physics, although the former is covered in French and Ladyman (2003) and the other papers in the special issue of *Synthese* in which this appeared (in particular Cao 2003 and Saunders 2003), as well as in French (2014) which also tackles the latter.

motivation has more to do with the way that fundamental properties such as spin and charge effectively 'drop out' of the relevant symmetries. But of course, in another sense it can be alleged that we do, insofar as it is the relevant symmetries that are focussed on in each case, as presented in the theoretical contexts by the appropriate groups. However, one can insist in response that this is entirely driven by the relevant context not by some adherence to a particular realist recipe: it is because of the framework provided by quantum field theory that we find Poincaré symmetry also playing a fundamental role in the context of the Standard Model and it is because of the role of gauge symmetries more generally that we find the notion of structure cashed out in this context in this manner as well. In other words, what appears to be the same recipe applied again and again is in fact due to the features of the relevant physical theories.

But then of course we should not expect these same features to be exemplified either by other theories within physics or by the theories of other disciplines. So, no one of course would claim that when it comes to theories of light and phlogiston the structure is the same. Indeed, insofar as the latter example might be seen as falling under 'chemistry' (and here we might need to be sensitive to disciplinary boundaries), we would clearly not expect to encounter the same equations or laws much less any symmetries (see French 2014 section 12.2). Likewise when it comes to biology, where we not only have no symmetries but no laws either, except perhaps for natural selection. Nevertheless, although we clearly no longer have the motivation for shifting away from objects that was articulated in the quantum context, the kinds of concerns with the nature and role of the notion of 'organism' and biological object more generally that have been articulated by Clarke, Dupré and others (see, for example, the papers in Guay and Pradeu 2016) have been taken to power a similar shift from understanding biological entities in object oriented ways to conceiving of them in terms of certain kinds of biological structures and processes (French 2014 Ch. 12; French 2016). Again it might be emphasised that it is reflection on the science itself rather than sticking to a particular realist recipe that is driving these moves.

All of which amounts to saying that in certain respects structural realism is already exemplar-driven and there seems to be no inherent barrier to rendering it explicitly so. Thus, from this perspective, the structuralist would acknowledge that, at the very least, the motivations and reasons for this shift will vary from context to context and discipline to discipline and indeed that in some cases there simply will be no such grounds. In other words, whether structural realism is the appropriate stance to adopt would have to be tested on a case by case basis.

However, if our realism is going to be exemplar based then there is even greater need to be clear on what it is we are going to be realist about. Consider: the structural realist has long pointed out that underlying the 'recipe' of standard realism is a certain kind of 'object orientation'. In effect this smuggles in an implicit metaphysics so that when the standard realist declaims 'I am a realist about electrons' and is then pressed on what these electrons are, she can then say 'they are objects, like tables and chairs, albeit subject to the laws of quantum physics which make them behave in weird ways …' As far as the structural realist is concerned, the object oriented standard realist gets away with a lot by means of this manoeuvre, since she never seems to face the equivalent to 'what is this ‘structure’ of which you speak?’; that is, she never seems to have to answer ‘what are these objects that electrons are supposed to be?’ In other words, the recipe masks the underlying metaphysics.

If that mask is then stripped away and we ground our realist stance in distinct exemplars, then we cannot get away with keeping the metaphysics implicit – it must be stated explicitly in each case. The alternative is to adhere to an entirely epistemic form of realism (or what Magnus calls ‘shallow’ realism; Magnus 2012) which would amount to pointing, if pressed, to the relevant features of the theory, as expressed in its equations or models or whatever, and insisting ‘I am a realist about *that*!’. But as a response to the demand to say how the world is according to the theory, that hardly seems adequate. Hence we need to appeal to some appropriate metaphysics in each case. The question then is how to avail ourselves of that metaphysics.

Metaphysics as a tool for the realist

As I noted in the introduction, the relationship between metaphysics and science has recently come under scrutiny, with a number of commentators declaring the former not fit for purpose, given recent developments with regard to the latter. This rejection proceeds on (at least) two bases: first of all, many of the big debates in current metaphysics, such as monism vs. pluralism or fundamentality vs. gunk seem to proceed with little or no regard to the impact of the relevant science. At best, it is claimed, when science is dragged into the debate, it is in the form of a crude, long since discarded picture, amounting to little more than high school chemistry (Ladyman and Ross *op. cit.*). Secondly, a number of the concepts and principles that lie at the core of modern metaphysics appear to have been ruled out of court by developments in modern science.

Now some caveats are in order here. With regard to the first point, it has to be said that not all metaphysicians are ignorant of developments in science. Paul and Schaffer, for example, have both appealed to features of quantum mechanics in support of their different positions (a one-category ontology and monism respectively; see Paul 2013; Schaffer 2013). And when it comes to the second, this ‘ruling out’ is not always definitive (French and McKenzie 2015). Take Leibniz’s Principle of Identity of Indiscernibles for example. Following French and Redhead (1988) it has long been held to be violated by quantum physics yet a ‘Quinean’ version has recently been constructed that is compatible with the physics (Muller and Saunders 2008; but for criticism, see Bigaj and Ladyman 2010). However, it might be felt that these are exceptions and that in general the dismissal of much of current metaphysics by philosophers of science is well justified on the grounds that it is simply out of touch with modern science (think, for example, of the way the notion of intrinsicality is usually understood in terms of ‘lonely objects’ and how this is discussed in the absence of any consideration as to whether physics can even accommodate a model in which there is a lone particle in the universe).

Now if one is a realist, exemplar based or otherwise, seeking to articulate a locally delineated view of how the world is, what are one’s options given the above?

One, of course, is simply to eschew metaphysics entirely and in answer to the question ‘what is the world like according to theory T?”, to simply point to T, set out in all its glory on a whiteboard, say, and to declare ‘That! It is like that!’.

Now, that setting out will typically be – and certainly so in the case of physical theories – in terms of the relevant mathematics but only a radical Platonist will leave it at that. Physical realists will of course insist that the relevant terms must be interpreted, and those in eschewal mode will further insist that this interpretation will be 'purely' physics based. Now of course, purity is a slippery notion but one can imagine our eschewalling realist declaiming 'That! The world is like that! Where this term refers to the electron and that to the electro-magnetic field ….' and refusing to say anything more. But of course the door to metaphysics has already been opened via this interpretation, since it invites the further question 'Yes, but what *is* the electron? Is it a particle? Is it a wave? Is it even an object?' Of course, one could simply refuse to answer such questions, insisting that to do so would take us beyond what can be legitimately grounded in the relevant physics. But I suspect that many would feel that in so refusing the realist hasn't really lived up to the name and that our understanding of how the world is remains thin and impoverished.

And of course, even appealing to the 'pure' interpretation of T invites comparison to similar interpretations of both related theories and its predecessor. The term 'electron' for example is freighted with certain connotations associated with its deployment in, say, classical mechanics. There the electron is regarded as a particle and, further, as an object that possesses certain properties and, further still, as an *individual* object, assemblies of which can be statistically considered in certain ways which are dependent on permutations of those objects being counted. Here we see the door to metaphysics opening wider and wider. And the next obvious question would be 'Well, when our theory T is quantum mechanics, is the electron like *that*? Is it an individual object, permutations of which are counted in the appropriate statistical analysis of the objects' collective behaviour?' Now again the metaphysics eschewing exemplar based realist can maintain the line and simply utter the response 'No. It is not.' But that is going to invite obvious further questions and refusing to spell out in some metaphysical terms how the world is such that permutations of electrons do not count, or make a relevant difference, is again going to leave us with only the thinnest of understandings (indeed, one that is cast in largely negative terms).

An alternative is to eschew metaphysics *as it is currently formulated* and adopt some form of 'bespoke' metaphysics constructed to directly clothe the relevant features of modern science. We have been here before of course. One example is that of Whitehead, who drew on the early (or 'old') quantum theory and its apparent 'vibratory' features to motivate his process philosophy (see for example Whitehead 1926; for a recent consideration of this motivation see Epperson 2004). Another would be Eddington, who took the above feature of quantum statistics in particular (that is, its permutation invariance) to motivate a form of structuralism according to which objects are not prior to but on a par with the relevant relations and subsequently went on to articulate this structuralist metaphysics in the context of what can be considered to be an early form of quantum gravity (Eddington 1946). The obvious problem with such a move – which is evident in the later works of both Eddington and Whitehead – is that such a bespoke metaphysical framework must be elaborated via bespoke terms, concepts, principles and categories and runs the risk of descending into incomprehensibility.

Fortunately, there is a third and, I would argue, more reasonable alternative: treat current metaphysics as a kind of toolbox that although it may contain some devices that are not 'fit for purpose' may still contain others that the realist can use (French 2014; French and McKenzie 2012 and 2015). So, although we might conclude that notions such as intrinsicality or principles such as Leibniz's are ruled out by modern physics, there may be others that we can adapt to fit. Let me expand on an example from (French 2014) and express it in the context of exemplar based realism.

Symmetries, Structure and Determinables

Consider the so-called Standard Model, which has been the subject of much discussion in the popular and philosophical literature, especially following the discovery of the Higgs boson. The overarching framework is quantum field theory. Here the non-counting of permutations of electrons, for example, is explicitly built into the theory via a fundamental symmetry known as Permutation Invariance, expressed mathematically by the permutation group. This yields the fundamental division of 'elementary particles' into the kinds fermions (to which electrons belong) and bosons (to which photons, for example, belong), corresponding to two of the irreducible representations of the permutation group. Quantum field theory is also relativistic, so it incorporates the symmetries of Minkowski space-time which are represented mathematically via the Poincaré group, the irreducible representations of which yield a classification of all elementary particles, with these representations indexed or characterised by mass and spin (the invariants of the group).

Furthermore, the Standard Model is a gauge theory, represented by the group SU(3) x SU(2) x U(1) via which further relevant symmetries can be captured within the theory. What this means, broadly speaking, is that the Lagrangian of a system – which basically captures the dynamics – remains invariant under a group of transformations, where the 'gauge' denotes certain redundant degrees of freedom of that Lagrangian. Thus, consider electrodynamics, for example, for which U(1) above is the relevant gauge symmetry group associated with the property of charge and the photon (a gauge boson) effectively drops out of this requirement that the theory be gauge invariant. Extending this requirement to the other forces, we obtain, for the weak nuclear force, the SU(2) symmetry group associated with isospin, a property of protons and neutrons, and for the strong nuclear force, SU(3) associated with the colour property of quarks. Mass is then accounted for via the Higgs boson associated with the breaking of the isospin symmetry of the unified electro-weak force.

That, crudely sketched, is the relevant exemplar. Now, it has been argued that the appropriate realist stance that should be adopted towards this exemplar is that of the structuralist, where the metaphysical notion of 'object' is at best set on a par with that of 'relation' (Ladyman and Ross 2007) or removed from the picture altogether in favour of a fundamental conception of 'structure' (French 2014). The obvious question that has been asked (repeatedly) is 'What is that structure?', or putting it more generally, 'What is the world like, if it is structural?". Again, one answer would be to write out the details of the Standard Model on a whiteboard and pointing, insist 'It is like that!'. As before, this yields a thin sense of metaphysically informed understanding. An alternative is to attempt some form of bespoke account. Thus Eddington, before he went off the metaphysical deep end as it were, expressed such group theoretically described invariances in terms of 'patterns of interweaving', which at least is evocative if not perhaps very precise (and perhaps not really very bespoke, given the connotations associated with 'weaving'!).

Instead we might appeal to certain devices in the metaphysical toolbox to help capture the nature of 'structure' in this context. So, consider the way in which the fundamental properties from 'being a fermion' to charge and spin 'drop out' of the above symmetries. This is a core feature of this structuralist view: rather than considering the world as built from the bottom up, as it were, beginning with objects that have properties, between which there hold relations, which are expressed by laws, that are constrained, in some sense, by these symmetries, the structural realist inverts that order, and sees the relevant metaphysics as proceeding from the top down, so that we take the symmetries and laws as fundamentals, and the properties to be derivative. How can we metaphysically express that inversion and capture the relationship between the above symmetries and the properties that drop out of them? One tool we can use is the determinable-determinates relation (French 2014 Ch. 10).

This has been extensively discussed of course (for an excellent overview of the various positions, issues and concerns that have been raised, see Wilson forthcoming) and the central idea is that determinables and determinates stand to one another in a certain specification relation, as the determinable 'colour' does to the determinate 'red', or the latter as determinable does to a particular shade of red, or as mass, qua determinable, does to a specific mass value. Part of the extensive discussion here has focussed on the nature of this relation but the crucial point is that it relates properties that are more or less specific, relative to one another; so, 'red' is more specific than 'colour' and a particular value of mass is more specific than 'mass'. 'Increased specificity' is just one of the features of the determinable-determinate relationship that Wilson helpfully lists (*ibid*., pp. 8-9). Others that also motivate its deployment in this case include: 'determinate incompatibility', according to which if something has a certain determinate of a given determinable, then it cannot at the same time have a different determinate of that determinable (at least, not of the same or lower specificity); 'determinate opposition', according to which different determinates of the same determinable are not just incompatible but are relevant alternatives (so 'red' and 'blue' are determinates of 'colour' but 'red' and 'square' are not); 'requisite determination', which requires that anything that has a given determinable, must have some determinate of it; and 'asymmetric dependence' which states that for any determinable of some determinate, anything that has that determinate must have that determinable, but something could have that determinable without having that determinate (so anything that is red must be coloured but something coloured, may not be red of course).

Now, the suggestion is that we can apply this metaphysical tool to the case of the symmetries that the structural realist takes to be a fundamental feature of the structure of the world, in the sense that we regard such symmetries as relational determinables generating determinable properties and associated determinate values. Thus, consider the permutation group, mentioned above: this encodes a range of possible particle statistics, but in this world it appears that only two of those determinates are manifested, namely those corresponding to the kinds fermion and boson (yielding Fermi-Dirac and Bose-Einstein statistics and characterised by anti-symmetric and symmetric state functions, respectively). Likewise, the symmetry of relativistic space-time, characterised by the Poincaré group can be regarded as a determinable which also yields spin as a property-determinable, which in turn yields the property spin ½, associated with the electron for example, as a determinate. Again, it is through the determinable (with the emphasis on the -able) that the relevant possibilities are encoded (French 2014, p. 283). So, being a fermion, say, is more specific than being subject to permutation symmetry, so we have increased specificity; and being a fermion and being a boson are not just incompatible but are relevant alternatives; and anything that is subject to permutation symmetry must behave according to some particle statistics, whether fermionic, bosonic or, but not apparently in this world, parastatistical. Finally, of course, anything that is a boson is subject to permutation symmetry but something that is subject to the latter may not be a boson – it could be a fermion, for example.

Now applying this device to help flesh out the metaphysics of structure raises a number of issues. First of all, some have argued that increased specificity feature implies that determinates must be metaphysically prior to or more fundamental than determinables and if this were accepted, we could not take permutation symmetry to be prior to and more fundamental than bosonic or fermionic statistics. And hence we could not take that symmetry to be a feature of the fundamental structure of the world, in line with the core shift of structural realism from objects possessing properties to relations and structures. But this argument is problematic, not least because there is a lacuna that has to be filled: what has specificity to do with fundamentality? (French *ibid..,* p. 284) And this lacuna needs to be filled in a non-question begging way: so, it is not going to impress the structural realist to insist that maximal specificity corresponds to fundamentality because maximally specific determinates are the properties possessed by objects, such as elementary particles. Nor is it going to persuade the non-Humean structuralist by insisting that maximally specific determinate properties are categorical and only categorical properties can be in the fundamental base. Such a structuralist takes her structure to be modally informed and thus has no qualms about admitting modality into the fundamental base. Finally, it might be objected that reality must be maximally determinate else we allow a form of ontic vagueness to enter the world (Wilson *op. cit*., p. 14) and as Lewis reminded us, '[t]he only intelligible account of vagueness locates it in our thought and language.' (Lewis 1986, p. 212). But Lewis' claim is highly contentious of course, and quantum physics has again been appealed to in order to motivate arguments that the world is ontically vague, in a certain respect (French and Krause 2003). Note that this is still in accord with the weaker claim that there cannot be *only* determinable features of the world (Wilson, *op. cit*. p. 14). The structure of the world incorporates both determinable and determinate features, such as the distinct bosonic and fermionic kinds and the specific spin of the electron, which Wilson refers to as 'existential witnesses'.

Not only can we use metaphysics as a constructive tool, but we can also use it as a contrastive one. Thus to get a (hopefully) clearer picture of the view being presented, and of the way in which the determinable-determinate relation can help as a metaphysical tool in fleshing out that picture, let us compare it to Paul's recent development of a 'one-category' ontology (2012; 2013).

She begins with the core question that obviously resonates with the structural realist: 'What is the fundamental structure of the world?' (2012, p. 221). Answering this question is a partly metaphysical project, where that metaphysics is informed and constrained by science but not governed by it.[3] Thus, by ' fundamental structure' here she understands fundamental constituents, from which all else is constructed via some 'building rule', and the fundamental categories, which are determined by the fundamental kinds or natures of things. In the balance that has to be achieved between metaphysics and science, the latter will determine what we take to be the fundamental constituents of the world, in terms of the physical properties, structures and objects that should be regarded as 'perfectly natural', to use Lewis' phrase. But metaphysics will take the lead in determining both the rule by which things are composed out of these constituents and the nature of the latter, in the sense of determining the fundamental categories to which they can be assigned.

So, for the 'building rule' she takes composition, on the grounds that we have a direct, intuitive grasp of proper parthood which forms the heart of the composition relation. Here immediately the likes of Ladyman and Ross might object that such intuitions, based as they are on naïve view of 'everyday' objects or, at best, classical mechanics, fail utterly when it comes to modern physics where the notion of being a part of is much slipperier and harder to grasp.

However, when it comes to the fundamental categories, Paul does draw on certain features of quantum physics to argue, first, that we should reject what she calls the 'traditional spatiotemporal view' that runs throughout much of contemporary metaphysics and which '…takes some or all of the fundamental constituents of the world to be spatiotemporal parts, i.e., chunks of spacetime, many of which are qualitatively rich, and the building relation to be spatiotemporal composition. ' (*ibid*., pp. 233-234). And here she acknowledges that the fault of such a view is that it conflates the metaphysics of the everyday, or 'manifest image' with that of 'the real' (ibid., p. 239) Secondly, and more importantly for my purposes, she maintains that we can still retain 'the world-building relation' but now applied to a different set of fundamental categories.

Thus Paul collapses the category of property into that of substance (2013). On her view the world is built from n-adic properties via property composition, which effects a kind of fusion or bundling (2012, p. 242) and since this 'mereological bundle theory' does not require this fundamental category to include spatio-temporal properties, it can accommodate a much broader range of possibilities when it comes to the nature of the fundamental entities. And since '…every fundamental physical theory ever given, including all of those currently on offer, is or can be couched in terms of properties and relations, even if these properties and relations are extremely abstractly specified …' (*ibid*., p. 245), such theories will mesh with this particular metaphysics.

This is certainly an attractive metaphysics and it is for that reason that it acts as a useful contrastive tool. The contrast, of course, comes from Paul's reading of physical theories as couched in terms of properties and relations and the concomitant insistence on a metaphysical 'bundling' or property composition relation. Although the former is obviously true to a certain extent, this reading

[3] Paul explicitly considers how metaphysical realism meshes with scientific realism (2012, p. 232)

omits the crucial role of laws and symmetries. Indeed, if we take this role seriously in the context of the Standard Model say, then it would seem that although Paul has gone some way in the right direction by dropping spatio-temporal composition, she still retains an overall 'bottom-up' approach. At the very least mereological bundle theory needs to be able to accommodate the relationship between symmetries and kinds, as in the case of permutation symmetry and the boson/fermion distinction, and properties, as in the case of Poincaré symmetry and spin, say.

Paul herself explicitly invites the structural realist to adopt her mereological bundle theory, on the grounds that, '… structuralists can make good use of an n-adic property mereology, since they don't need substances or even monadic properties in order to construct the world.' (2012, p. 248; see also 2013 pp. 110-111). Indeed, she suggests, such a marriage would lead to a 'super-sophisticated structuralism' (2013, p. 111) that avoids certain of the problems that its less sophisticated form is held to face.[4] The idea then is that we take relations as constituting our fundamental base and then apply bundling as the appropriate building relation, thereby effectively constructing the structure of the world via fusion (Paul 2012 p. 245), with putative objects as 'nodes' in this structure, or as Cassirer put it, as 'intersections' of these relations.

Understood this way, mereological bundle theory would be in effect a further metaphysical tool that the structural realist could use (see French 2014, pp. 186-189). However the issue of how to accommodate symmetries remains. If they are viewed as merely 'by-products' of laws, expressing certain features of the latter then with laws themselves expressing the relations that sit in the fundamental base, mereological bundle theory might seem the appropriate metaphysical device for accommodating the relevant structure construction. On this account, each such relation would exhibit a certain feature that when 'fused' to create the network of relations that the laws of physics describe manifest the global features that we describe via symmetries. Of course, further work is required to 'mesh' this metaphysics with the physics.

In particular it might be objected that in the practice of physics, symmetries act as constraints on laws, or as 'meta-laws', which suggests more of a 'top down' stance, in contrast with Paul's. Now of course, one could respond that this might be correct when it comes to the heuristic use of symmetries but that doesn't require that they be regarded as 'standing above' laws, metaphysically speaking. A third way between these two extremes is to follow Cassirer and take symmetries, laws and measurement results as being on a par and together constituting the structure of the world (French 2014). This removes the necessity of adopting either a 'bottom up' or 'top down' stance towards symmetries but of course the relationship between them and the properties typically taken to be monadic must still be accommodated. In particular, although it might be regarded as merely 'loose talk' to say that a property such as spin 'drops out' of Poincaré symmetry, the close relationship here on the physical side needs to be matched by a similar relationship on the metaphysical.

[4] Her emphasis on n-adic properties as fundamental also resonates with Mertz's ontology, which has also been taken to be a suitable metaphysics for OSR (see Mertz 2016).

Consider again permutation symmetry and the distinction between bosons and fermions. One could begin with that distinction as fundamental, so that quantum entities possess 'being a boson' or 'being a fermion' as kind properties. Bundling such properties together yields the relevant feature of assemblies of such entities that is represented by either the bosonic or fermionic representation of the permutation group, respectively. And the fact that this group yields other representations, corresponding to paraparticle statistics, for example, is primarily of mathematical rather than physical significance – unless of course, such statistics turns out to be physically realized (as was suggested for a short time in the case of quarks), in which case the relevant group representation would be applied (so this comes down to an issue in the applicability of mathematics), but metaphysically, of course, according to mereological bundle theory we would still begin with 'being a paraparticle (of a certain order)' and build up from that.

The alternative is to begin with the symmetry itself as part of the fundamental base and take the 'dropping out' of bosonic and fermionic statistics to express the relationship between this symmetry, as part of the fundamental structure of the world, and these kind properties. In terms of the mathematics this amounts to no more than the relationship between the group and its representations but this obviously needs to be matched on the metaphysical side. Here the determinable-determinate relationship seems to do the job, so that 'being a boson' or 'being a fermion' are simply determinate aspects of that partly determinable structure. Note the further contrast with mereological bundle theory: instead of a 'building relation' we have something akin to a 'manifestation relation' and instead of thinking of the structure as built up from certain parts (even if these are properties and relations rather than objects and substances), we are invited to think of it as given holistically, as it were, and as manifesting certain determinate features.[5]

Another way of seeing the contrast between this and Paul's approach is to consider the question of what should be our attitude towards the other possible properties, such as 'being a paraparticle' for example. According to mereological bundle theory we begin our construction with the properties that we actually discover in the world, such as 'being a boson.' We represent those properties mathematically via group theory and we find that such mathematics includes alternatives that do not appear to be realized – from this perspective these are just so much 'surplus structure'. According to the alternative, this 'surplus' represents certain possibilities which may or may not be actualized and the determinable nature of the structure flags the point that it encodes such possibilities. Thus rather than beginning with the actual, and building up from that, we begin with what is modally allowed and show how the actual world fits into that, as a determinate manifestation of that modally informed structure.

There is more to say here, of course, but this is perhaps enough to highlight the differences between these metaphysical tools. [6]

Conclusion

[5] In a sense still be spelled out, this stance sits somewhere between metaphysical nihilism and monism.

[6] Paul herself remarks that she finds Wilson's defence of determinables 'interesting and plausible' (2012, p. 245 fn 22).

I began by sketching recent moves towards a more local or 'exemplar based' form of realism and suggesting that such moves do not preclude the adoption of a structuralist stance. However, if we are to take this move seriously then we need to pay close attention to the relevant exemplars, one such, in the context of modern physics, being the Standard Model with its emphasis on certain symmetry principles. The exemplar realist is then faced with the issue of spelling out how the world is according to that model. One option is just to point to the relevant physics and insist 'it is like that!', but that is obviously unsatisfactory. The alternative is to treat current metaphysics instrumentally, as a kind of toolbox and apply certain devices in an effort to generate a sense of understanding how the world could be that way. Focussing on the issue of capturing the relationship between such symmetry principles and certain properties, I've presented two such 'tools': the determinable-determinate relationship and mereological bundle theory. The former, I think, does a better job in meshing with the physics, but the latter cannot be discounted. And there may be other devices that can be used as well. The point is, if we are going to 'go local' and focus on the particularities of a given set of exemplars, whether historical or current, then in adapting our realism to those particularities there must be an even greater emphasis on spelling out what this realist stance commits us to, in terms of, as Paul puts it, not only the fundamental constituents, but the categories they fall under and the kinds of relations that hold between them. With particular metaphysical tools adapted to particular exemplars, this overall approach may reinvigorate and strengthen the currently strained relationship between metaphysics and science.

References

Asay, J. (2016). Going local: a defense of methodological localism about scientific realism. *Synthese*. Online First (DOI 10.1007/s11229-016-1072-6)

Bain, J. (2013). Category-Theoretic Structure and Radical Ontic Structural Realism. *Synthese, 190*,1621–35.

Bigaj, T., and Ladyman, J. (2010). The Principle of Identity of Indiscernibles and Quantum Mechanics. *Philosophy of Science 77*, 117–36.

Cao, T. (2003). Structural Realism and the Interpretation of Quantum Field Theory. *Synthese 136*, 3–24.

Callender, C. 2011. Philosophy of Science and Metaphysics. In S. French and J. Saatsi (eds.) *The Continuum Companion to the Philosophy of Science,* pp. 33-54. London: Continuum.

Eddington, A.S. (1946). *Fundamental Theory*. Cambridge: Cambridge University Press.

Epperson, M. (2004). *Quantum Mechanics and the Philosophy of Alfred North Whitehead*. New York: Fordham University Press.

French, S. (2006). Structure as a Weapon of the Realist. *Proceedings of the Aristotelian Society 106*, 167–85.

French, S. (2014). *The Structure of the World.* Oxford: Oxford University Press.

French, S. (2016). Eliminating Objects Across the Sciences. In A. Guay and T. Pradeu (eds.), *Individuals Across Sciences*, pp. 371-394. Oxford: Oxford University Press.

French, S. and Krause, D. (2003). Quantum Vagueness. *Erkenntnis 59*, 97–124.

French, S. and Ladyman, J. (2003). Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure: A Reply to Cao. *Synthese 136*, 31–56.

French, S. and Ladyman, J. (2011). In Defence of Ontic Structural Realism. In A. Bokulich and P. Bokulich (eds), *Scientific Structuralism*, pp. 25-42. Dordrecht: Springer: 25–42.

French, S. and McKenzie, K. (2012). Thinking Outside the (Tool)Box: Towards a More Productive Engagement Between Metaphysics and Philosophy of Physics. *The European Journal of Analytic Philosophy 8*, 42-59

French, S. and McKenzie, K. (2015). Rethinking Outside the Toolbox: Reflecting Again on the Relationship Between Philosophy of Science and Metaphysics. In *Metaphysics in Contemporary Physics*. ed. T. Bigaj and C. Wuthrich , 145-174, Poznan Studies in the Philosophy of the Sciences and the Humanities, Rodopi.

French and Redhead, M. (1988). Quantum Physics and the Identity of Indiscernibles. *British Journal for the Philosophy of Science 39*, 233–46.

Guay, A. and Pradeu, T. (eds.) (2016). *Individuals Across Sciences*. Oxford University Press.

Ladyman, J. (1998). What is Structural Realism? *Studies in History and Philosophy of Science 29*, 409–24.

Ladyman, J. and Ross, D. 2007. *Every Thing Must Go: Metaphysics Naturalized*. Oxford: Oxford University Press.

Lal, R. and Teh, N. (2015). Categorical Generalization and Physical Structuralism. *British Journal for the Philosophy of Science*. Advanced Access (doi:10.1093/bjps/axv002)

Lam, V. and Wuthrich, C. (2015). No Categorial Support for Radical Ontic Structural Realism. *British Journal for the Philosophy of Science 66*, 605-634

Landry, E. (2007). Shared Structure Need Not Be Shared Set-Structure. *Synthese, 158*, 1–17.

Lewis, D. (1986). *On the Plurality of Worlds*. London: Blackwell.

Magnus, P.D. (2012). *Scientific Enquiry and Natural Kinds: From Planets to Mallards*. Palgrave Macmillan.

Mertz, D.W. (2016). *On the Elements of Ontology: Attribute Instances and Structure*. De Gruyter.

Muller, F., and Saunders, S. (2008). Discerning Fermions. *British Journal for the Philosophy of Science 59*, 499–548.

Nounou, A.M. (2015). For or against structural realism? A verdict from high energy physics. *Studies in History and Philosophy of Modern Physics, 49*, 84-101.

Paul, L.A. (2012). 'Building the World from its Fundamental Constituents'. *Philosophical Studies 158*, pp. 221–56.

Paul. L.A. (2013). Categorical Priority and Categorical Collapse. *Proceedings of the Aristotelian Society 87*, 89-113.

Saatsi, J. (2016). Replacing recipe realism. *Synthese,* First Online, 2016. DOI:10.1007/s11229-015-0962-3.

Saunders, S. (1993). To What Physics Corresponds. In S. French and H. Kaminga (eds). *Correspondence, Invariance, and Heuristics; Essays in Honour of Heinz Post*, 295-326. Dordrecht: Kluwer.

Saunders, S. (2003). Structural Realism, Again. *Synthese 136*, 127–33.

Schaffer, J. (2013). The Action of the Whole. *Proceedings of the Aristotelian Society 87*, 67-87.

Whitehead, A.N. (1926). *Science and the Modern World*. Cambridge: Cambridge University Press.

Wilson, J. (forthcoming). Determinables and Determinates.

Worrall, J., (1989) Structural realism: The Best of Both worlds? *Dialectica 43*, 99–124. Reprinted in Papineau, D., (Ed.)., *The Philosophy of Science*, Oxford: Oxford University Press, 139–165.