**Symposium review of *The Structure of the World*, OUP 2014 (forthcoming in *Metascience*): Author’s Response to Dorato, Landry and Psillos**

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I’d like to thank all three reviewers for such detailed and thought-provoking comments. And to apologise both for not being able to deal with all of them to the extent they deserve and for any confusions resulting from my lack of clarity in *The Structure of the World*.

Let me begin by recalling the primary motivation for my eliminativist version of ontic structural realism (EOSR) which lies in the compatibility of quantum statistics with two distinct metaphysical ‘packages’: that which goes back to the quantum revolution itself and takes the particles to be non-individuals; and that which takes them to be individuals, however that is then cashed out. This underdetermination led van Fraassen to conclude his analysis of quantum mechanics by throwing down a challenge to the realist: if you have no physical grounds for determining whether the objects to which you attach your realist beliefs are individuals or not, then you should ‘say goodbye to metaphysics’ altogether and adopt the empiricist stance (1989). EOSR offers an obvious response: withdraw your realist commitment from particles-as-objects and invest it in the underlying structure. In the case of quantum statistics, the relevant aspect of that structure is associated with permutation symmetry, as presented via the permutation group, from which we obtain the fundamental natural kind distinction between fermions and bosons.

Now, we need to be clear about the nature of this underdetermination: it holds between quantum-objects-as-individuals and quantum-objects-as-non-individuals. The former ‘package’ can be cashed out in various ways: via the metaphysics of haecceities, primitive individuality, ‘weak discernibility’ (for fermions at least), whatever, plus standard set theory as the relevant formal framework. The latter can be represented via quasi-set theory and so-called Schrödinger logic (see French and Krause 2006). Thus, it is not correct to say, as Dorato does, that I take it for granted that ‘*x* counts as an object if and only if *x* possesses an identity, and therefore is an *individual*.’. I do not. Objects may be non-individuals and we do not get to that metaphysics by opting for a ‘reduction of individuality to properties’ – that would just give us individuals again, underpinned by a form of Leibniz’s Principle of Identity of Indiscernibles grounded in ‘weak discernibility’ perhaps. Thus my response is not to eliminate ‘talk of individuals altogether’ but to eliminate *objects* from our metaphysics (while retaining talk of them via certain metaphysical devices).

Of course, one might resist the motivational force of this metaphysical underdetermination (see French 2014, Ch. 2). Psillos, for example, wonders if we should not adopt the same attitude towards it as we do towards empirical underdetermination – i.e. wait for further theoretical developments. However, it is not clear how such developments might bear on these different metaphysical packages. If we remain within the context of quantum mechanics, then the only opportunity for such developments would be with regard to the interpretation of this theory. But insofar as these retain compatibility with the formalism, the underdetermination will still be present. And I would argue that all the extant interpretations can be given a structuralist gloss; this is perhaps most obvious in the case of the Everett interpretation but even the Bohm interpretation, which many, mistakenly, take to involve a commitment to individual particles, can be understood in this way (this is why I did not discuss a particular structuralist solution to the measurement problem in *Structure*, much to Esfeld’s dismay (2015), since I would argue that all of the current solutions can be brought within OSR’s ‘big tent’).

Of course, Psillos may have in mind a more significant theoretical shift, from quantum mechanics to quantum field theory, say, but I have argued that the latter is also compatible with EOSR (French and Ladyman 2003; French 2014 Ch. 11). We can broaden our horizons even further, to encompass quantum gravity but I’m afraid this too cannot escape the structuralist maw (French and Rickles 2006)! Perhaps, at some point, we will accept a theory whose ontological posits cannot be metaphysically reconceptualised in structuralist terms, or whose fundamental structure is very different from that of current quantum physics, leading to a structuralist from of the pessimistic meta-induction as Bueno suggests, but we are nowhere near there yet and as with all realist stances, all we have to go on are our best current physical theories.

The crucial role of permutation symmetry exemplifies, of course, that played by group theory within modern physics in general. And the former perfectly illustrates why there is no contradiction in my position, as Dorato tries to argue. Formally, all the work is done by the permutation operator which commutes with the Hamiltonian, and we can interpret that result in terms of either non-individuals or individuals. Methodologically, when it comes to articulating the metaphysics, we should adopt an iterative approach, as I repeatedly say in *Structure*: we begin by supposing that we have an assembly of particles and we apply the permutation operator to these (strictly the particle labels); we can then interpret the results in either of the above two ways, in terms of individuals or non-individuals, generating the underdetermination which then compels us to revisit the metaphysics that we initially assumed with regard to the particles and take objecthood out of the picture, reconceptualising them as features of structure. This is a time-honoured manoeuvre: Weyl, Eddington and, indeed, Poincaré, all deployed it, in their different ways - in lieu of a completely new formal framework we must use what we have inherited, assume elements as objects, apply the group theoretic operators and then interpret the result in structuralist fashion by reconceptualising those elements we began with. There is no contradiction here, just an iterative process that takes us from the initial object-infected framework to a deeper structuralist reconceptualisation of that framework.

There is therefore no need to provide arguments to show that primitive individuality, or differences solo numero, are implausible within the group-theoretic approach in general, as Dorato demands. One could, of course, maintain that quantum particles are ‘primitive’ individuals and that would be perfectly compatible with the application of group theory. But that would be to simply adopt one horn of the above underdetermination, requiring some justification as to why you have adopted that one (and indeed, primitive individuality rather than weak discernibility), rather than the alternative. And any such justification cannot be sought in the physics but must involve extra-physical factors of one kind or another, leading the likes of van Fraassen, again, to point out the fragility of one’s realism in this case – incorporating as it must on this option, the relevant metaphysics of objecthood.

What group theory presents to us, at the level of physics, are the relevant symmetries – permutation symmetry, or the space-time symmetries of the Poincaré group or gauge symmetry and so on – that I (like Cassirer and Eddington and many others of course) take to be a fundamental aspect of the structure of the world. Now, with regard to this role of group theory, Psillos raises the point that symmetry captures redundancy and thus yields no new information, citing Wigner. As I noted in *Structure* (pp. 149-151), Wigner was able to claim this whilst also maintaining that symmetries could be regarded as kinds of ‘meta-laws’ or ‘almost necessary prerequisites’ for them – a stance that chimes with that of Weinberg and other supporters of the Standard Model – because he adopted a broadly Humean view according to which geometrical symmetries constrain laws, qua summaries of correlations between events, by virtue of themselves summarizing certain spatio-temporal features of these correlations. Dynamical symmetries, such as gauge invariance, on the other hand, merely reflect certain (second-order) properties or features of the associated laws, according to Wigner, and thus can be regarded as mere ‘by-products’ of them. But as I also noted (p. 152), this is not the only combination of views on laws and symmetries that is possible; in particular, one can also adopt a non-Humean view of both and drop Wigner’s hierarchical relationship in favour of Cassirer’s ‘reciprocal interweaving’. (Of course, Psillos is right – Cassirer was no realist, but as I have long maintained, the structural realist, channelling the ‘Viking Approach’, can appropriate many elements of his work, stripped of their neo-kantian overtones.)

Psillos follows the above Wignerian stance and hence he suggests that symmetry is not a substantive metaphysical ‘add-on’. But as I go on to argue in *Structure*, the distinction between symmetries as constraints and as ‘by-products’ becomes blurred from the perspective of EOSR: If the idea of acting as a constraint is understood in terms of some further modal strength that symmetries are supposed to have, then this is ungrounded in the practice of physics. At best this idea can be cashed out in terms of the symmetries representing the interconnections between the laws but in a manner such that we should not conceptually imagine the symmetries as existing distinct from the laws; in that sense, they are like by-products. But this, in turn, is not to cede ontological priority - both symmetries and laws are aspects of the structure of the world and there is a form of mutual dependence between them. And of course, this non-Humean approach is not forced upon us – as I take pains to emphasise throughout *Structure*, in at attempt to keep the flaps of the Big Tent open, one can be a Humean structuralist, as Lyre, for example advocates, although I think that comes with certain costs (see pp. 232-238).

My own approach ‘reverse engineers’ the dispositionalist account of laws and properties: instead of beginning with the latter, conceived under the Dispositional Identity Theory as clusters of modally informed dispositions for specific relations and which thus encode the relevant laws, we begin with the laws, conceived as aspects of the structure of the world, from which we obtain that which we call relations, and thence properties. Psillos writes that I take laws to *express* networks of relations, and then insists that the crucial question the structuralist has to answer is *how* these relations are expressed or embodied in laws. But that suggests the kind of metaphysical gap between ‘networks of relations’ and laws that I repeatedly urge should be kept closed. It is not that the networks are somehow ‘there’, ontologically prior to the laws, which ‘express’ them. Rather, the relations and consequent properties are merely features of the structure of the world that (appear to) ‘emerge’ from the laws and symmetries, in specific contexts. Explicating that sense of emergence answers Psillos’ question but he dislikes the framework of determinables and determinates that I appropriated for this purpose.

Thus he insists that if a determinate relation of Coulomb’s Law, say, is that which holds between two charges at a certain distance, then this is a relation ‘ordinarily understood as involving relata with specific spatio-temporal locations’. But of course, this sort of ‘ordinary’ understanding threatens to beg the question. Care must be taken: ‘holds between’ must not be understood in terms of the charges having ontological priority – rather, the property is dependent on the relation, which in turn emerges from the law. More importantly, Psillos argues, such determinates cannot be exclusive, as required, and so, he concludes the idea of laws as relation-determinables fails. Of course, if we take the determinates as Psillos does, to be ‘the state-of-affairs of two electrons with charge e being at distance d from each other’, then that does not exclude ‘… *these very same electrons* being at different distances’. But again that would be to adopt the very object oriented stance that OSR seeks to move away from. In structuralist terms, the determinate has to be characterised as the dependent state of affairs involving charge that is obtained from the relevant law – the claim that such a state of affairs and a different one involve ‘the very same electrons’ is an object-oriented add-on. And of course, conceived structurally, the relevant states of affairs do exclude one another, in precisely the sense that if one obtains, the other cannot – the only reason Psillos’ determinates do not is because they are ontologically grounded in the same electrons, ontological grounding that EOSR reconceptualises (c.f. the reconceptualisation of causal interactions on p. 213). Following Searle (cited on p. 281), the two–charges-separated-by-distance-r determinate excludes any other charge-laden determinate.

These determinates do indeed yield a kind of ‘particularity’ but it is a structurally dependent form – to ask, as Psillos does, what properties are instantiated ‘into’ if not objects, is again to assume the very ontological picture I reject. As I note on p. 198, we must be careful not to load the notion of instantiation with this assumption – it would be better to read it as ‘making manifest’, as Paul does. Without objects to instantiate the properties, Psillos worries how laws, as universals, could yield any regularities and hence for them to have any ‘concrete and worldly content’. However, this is again to presuppose a kind of metaphysical gap between the laws, as universals, and the regularities of the world. Dorato presupposes a similar gap when he asks ‘what instantiates the group structure?’. On the structuralist view there is no such gap: the laws and symmetries, even as determinables, are features of the structure of the world and as such they are already ‘worldly’. What we call ‘regularities’ are determinate manifestations of this structure and there is no need to posit objects in order to obtain this ‘concrete content’. Indeed, this reveals the further ontological savings that EOSR yields – we can dispense with objects and the mysteries of property instantiation too.

As Wilson put it, these determinates act as ‘existential witnesses’ to the determinables and hence, in my terms, to the structure of the world. Psillos sees this as introducing a non-structural element, taking the example of the representations obtained from permutation symmetry. Here we get lots of different kinds of particle statistics – including the infamous paraparticle statistics that quarks were at one time thought to obey – but only the bosonic and fermionic kinds are manifested in the actual world. As I’ve long maintained, one can see the fact that only these sectors of the total Hilbert space are occupied in our world as kinds of ‘initial conditions’. And as I discuss in *Structure*, the fact that the permutation group yields other possibilities further reveals the modal ladenness of the structure of the world, something that acquires particular significance in the context of quantum field theory and unitarily inequivalent representations (see Ch. 11). That we are confined to these sectors is no more a non-structural element in the structure of the world than is adopting a Bayesian account of theory confirmation to select the ‘right’ structure (see p. 211). And of course, accommodating such initial conditions is just as much a problem for the Humean, since they cannot be taken to be regularities, or parts thereof – but the best way to dissolve that problem is of course to insist that they are simply not candidates for regularities to begin with!

Landry agrees with me that it is these group-theoretic representations that are doing all the realist work but she insists that this mathematical presentation cannot be regarded as an ontological representation of the structure of the world ‘…unless a realist argument can be given for the claim that the structure *of the theory* is shared by the structure of the phenomena *of the world*,’. But surely the required argument here is some form of the venerable No Miracles Argument that takes us from the success of the theory – in this case, group theory *as presented within the relevant physics* – to the claim that it has ‘latched onto the world’. I don’t see what else is required *for this claim* and I certainly don’t see the need for what Landry calls a ‘theory of the structure of the phenomena’ in this regard.

In her terms, EOSR is supposed to provide such a theory but, she argues, the motivation for EOSR provided by metaphysical underdetermination cannot underpin an argument that this is *the* theory of the structure of the world, rather than just *a* theory of that structure. But we need to be clear what we mean by the term ‘theory’ – on the one hand we have the relevant theory of physics, quantum field theory, the Standard Model, etc., incorporating group theory; on the other, we have the metaphysical interpretation of that in terms of object-less structure. Given the faillbility of such interpretations and our realism in general, what argument *could* demonstrate that this interpretation is the *only one* applicable to the structure of the world (particularly given that such interpretations and indeed realism in general are not subject to the kinds of success claims that underpin the NMA)? Of course, the whole point of my book is to argue that other interpretations are clearly (!) deficient and that EOSR is by far the best, but as passionate as I am, even I must concede that metaphysics is not subject to the same constraints as physical theory and that the grounds for EOSR are, by the nature of the beast, weaker than those for quantum field theory, say.

Landry will no doubt reply that this is indeed the point, that in the absence of any such conclusive argument we must back away from any such metaphysical commitments and adopt her and Brading’s minimalist form of structuralism. I am not entirely unsympathetic to such a move and in the past, when asked ‘well, what *is* the structure of the world?’ I have indeed pointed to the permutation group, say, and replied, ‘It is *that*, at least in part’! But I see this as swimming in the ‘shallow’ end of the realism pool (to use Magnus’ term – Magnus 2012) and just as when the object-oriented realist is unable to tell us whether electrons, *qua* objects, are individuals or not, it risks vacuity. We need to swim a little deeper, metaphysically speaking.

Dorato is likewise unhappy with my distinction between the way in which group theory is presented at the level of the relevant physical theory and the way in which we, philosophers of science, represent that presentation via the set-theoretic resources of the Semantic Approach, such as partial isomorphisms etc. But his point that such isomorphisms, partial or otherwise, strictly only hold between mathematical structures and not between such structures and the physical world was dealt with some years ago (French and Ladyman 1999; see also *Structure* p 195, fn 7). As have his concerns about accommodating idealisations etc. within such an account.

More importantly, he follows Brading and Landry in asking why I insist on such a ‘meta-theoretical’ representational framework to begin with. But as I argue in some detail in Ch. 5, that distinction is grounded in the fact that as philosophers of science we have our own aims, goals, practices etc. which are, of course, different from those of scientists. In order to further those aims etc. – to develop accounts of theory change, for example, or of explanation, or indeed, of scientific representation itself – we need an appropriate meta-representational framework. As I also indicate in Ch. 5, one can be a pluralist about such matters but the point is, without such a framework, there is the danger of our philosophy of science degenerating into a meta-positivistic recitation, according to which all we could do, in discussing theory change for example, is point to the relevant historical record, with no overarching framework to help us discern those features we, as philosophers, deem important or to support our claims. Some may find that vision of the philosophy of science attractive; I do not.

Now, in taking the metaphysical plunge, as I suggest above, we must face Psillos’ question: if the structure of the world is presented to us via group theory, what would it be for the theory *not* to get the structure of the world *right*? Does EOSR eliminate the possibility of divergence between the group-theoretic presentation of the structure of the world and the way the structure of the world *really* is? Now, it seems a curious demand that EOSR should contain within its articulation the seed of its own denial! The situation seems entirely analogous to that which applies to standard, object-oriented realism: this takes our best current theories and insists that the world is as those theories say it is, only with an object-oriented spin. So, the world according to this position is a world of electrons and quarks etc., all conceived as objects, in which properties are instantiated and so forth. Of course, the object-oriented realist will agree that she is fallible, that her view is defeasible, that the world may not be as our theories suggest it is or as she thinks. Ditto the ontic structural realist but of course that defeasibility is not expressed within the position itself; rather it is an aspect of the attitude that we, its advocates and critics, adopt towards it.

And as for saying how the structure of the world might be different from the group-theoretic structure of even the best theory, it is not at all clear that the *only* option is to admit what EOSR denies, namely that the world could be a world of objects and properties. Of course, as already noted, we may discover that the Standard Model, say, with its group theoretic underpinnings, is only that which is obtained in some limit from some more fundamental theory. In that case, sure, we would have to revise or even abandon EOSR; but that’s just to admit our fallibility and its defeasibility. Indeed, it has been suggested by Bueno that such a possibility can already be found in the historical record: von Neumann, that great architect of the quantum revolution, was unhappy with the very Hilbert space formulation that he himself had helped introduce and proposed an alternative, better able to accommodate the way quantum mechanics treats probabilities, in his view. Here, according to Bueno, we have the possibility of a structuralist form of the Pessimistic Meta-Induction. However, von Neumann’s alternative never caught on and to put it bluntly, we don’t have the kind of empirical success associated with it that would lead to it being regarded as a serious contender to or replacement of the Hilbert space based approach. As far as any realist is concerned, it is simply not up for consideration. As to what the world would look like, were we to abandon (utterly? With no recovery in the limit??) the Standard Model, I don’t know (how could I?) but , again, surveying possible future directions of research in physics, from string theory to various approaches to quantum gravity, there is little if anything that suggests major obstacles to the structuralist programme.

But then, Dorato asks, if the structure of the world is presented within our theories via group theory, how can it be causally efficacious? If it is not, he insists, then such efficacy must be pinned on everyday, macroscopic objects and hence EOSR’s eliminativism cannot go through. Here a certain degree of care must be taken. The kind of mereological reductionism that Dorato is concerned with forms no part of the eliminativism that I advocate, and not because of Healey’s arguments (which my PhD student Fabio Ceravolo has suggested are problematic anyway). I argue that we can have this eliminativism without worrying about reductionism, as traditionally conceived. And we can do that by appropriating certain devices from the metaphysicians’ ‘toolbox’: one such is Horgan and Potrc’s contextual semantics, put to the service of their ‘austere realism’ which involves a form of monism that they call ‘blobjectivism’. This allows us to regard statements about ordinary objects as true, in the sense of ‘indirect correspondence’, while those about fundamental features (the blob in their parlance, structure in mine) are true in the direct correspondence sense. Another such device is Cameron’s version of nihilism which also allows us to take statements about tables, chairs, people etc as true but insists that the truthmakers of such statements are, again, certain fundamental features (‘simples’ in metaphyscians’ parlance, aspects of structure in mine). Personally I am inclined toward the latter and to leaving truth itself alone but the point is that here we have some metaphysical moves that the advocate of EOSR can adopt to the cause and thus avoid all those age-old issues to do with the reduction of temperature and so on. They simply have no grip in this context.

Now, when it comes to causation, as I tried to indicate in *Structure*, the debate is hugely complex, involving a jumble of competing definitions, positions and arguments and I am certainly not going to attempt to summarise all the nuances here. Nevertheless, as I also tried to argue, we can delineate an appropriate sense of dependence in terms of which we can articulate how putative particle positions in a cloud chamber making up a ‘track’ can be regarded as manifestations of the fundamental structure. And insofar as causal process theory, with its deployment of conservation laws, can be made to work in the context of fundamental physics (and in this regard I have recently started to view it more favourably, following the work of my PhD student, Jakob Sprickerhof), the form of causation it involves does not go far, if at all, beyond that sense of dependency. Does that give us the deliberative aspect that underpins the asymmetry of causation? No, clearly not, but that could never be found in physics; hence I incline towards the view that that aspect is to be found elsewhere, in our agency for example (see Ch. 8). Of course that is all a bit promissory but as far as structuralism is concerned, if it is mysterious to imbue structures with causal powers, then it is no less so to say the same about objects.

However, Dorato worries that if I don’t give a structuralist reading of these powers themselves (which according to Psillos would yield a regress), then we must embrace a form of monism. The idea seems to be that if we suppose that two particles each having mass entails that they have a power to attract other particles and therefore a power to generate a gravitational force Grav(m1,m2), then the two masses taken together can be regarded as a bundle constituted by that relation Grav(m1, m2), that in its turn must be related to other masses, m3, m4, and their bundles and so on until we end up with a monistic ‘blob’. Now, leaving aside the object-oriented set-up, and the point that my response to the worry about hyper-structuralism with regard to causal powers was in the spirit of my ‘Big Tent’ approach, I am actually inclined to agree (as I make clear on p. 201) – we do end up with, not ‘the blob’ as certain metaphysicians would have it, but the world-as-structure which, by virtue of being structural and hence not an unstructured One, sits somewhere between monism and nihilism insofar as it is the world, as a whole, as one, if you like, that is structural and features of that structure can be distinguished – such as laws and symmetries – albeit as interlocking elements. Thus Dorato’s dilemma, between Tegmarkian Pythagoreanism and blobjectivism, simply dissolves as far as I am concerned, since the structure I am interested in is the structure *of the world* !

Again I would like to thank Elaine, Mauro and Stathis for their comments and criticisms. I appreciate that I have not done justice to them all or to their various subtleties here but I hope the discussion will continue.

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