Critically examine Structural Realism

John Williamson

Scientific realism, in its most general form, is the view that good scientific theories make true statements about unobservable reality. The 'stuff' a theory postulates – particles, forces and so on – is then not simply a useful fictional framework for deriving predictions, but a substantive ontological claim about what really exists. This elevation in the status of science from exercise in the prediction of phenomena to an enterprise that is "often thought to have replaced metaphysics as the study of the fundamental structure of reality" (Ladyman 2002: 129) is highly contentious, in large part thanks to two well-known and opposing arguments.

In support of realism, the no-miracles argument says that the increasing success of theories would be miraculous if they were not describing reality with increasing accuracy. Against it, the pessimistic meta-induction argues that there is compelling historical evidence of once-successful theories turning out to be false in their claims about reality, and that the trust we invest in our best current theories is therefore misplaced (Ladyman 2007).

Both arguments are powerful, yet it is clearly impossible to accept both of them if the conception of realism described above is used without qualification. However, this 'gross' brand of realism, whereby *all* the entities postulated by a successful theory are taken to exist, is by no means required. Even scientists, Psillos argues, "do not normally believe … that *all* that a successful theory says is truthlike" (Psillos 2006: S311, my italics). In light of this, there have been various attempts to resolve the conflict not by defeating either of the arguments, but by instead advancing a more restricted, precise form of realism, taking into account the merits of both. In this essay I will examine one such attempt.

Structural Realism (SR), principally advanced by Worrall, proposes that we limit ourselves to realism about the structure or mathematical form of the world. Using as an example the transition from Fresnel's ether theory of light to Maxwell's theory of the electromagnetic field, Worrall claims that although the ether (which an antirealist might mischievously refer to as the "central theoretical term" was subsequently discarded, "if we restrict ourselves to the level of mathematical equations … there is in fact complete continuity between Fresnel and Maxwell's theories" (1989: 119). Whereas standard realism advocates belief in the existence of entities postulated by a theory, SR only requires belief in the accuracy of postulated structural relations between entities. Hence, SR allows realism about the parts of a theory involved in predictive success (thus satisfying the no-miracles argument), while removing the need for realism about the parts that are vulnerable to the pessimistic meta-induction.

An important starting point to interpreting SR, identified by Ladyman (1998: 410), is the question of whether it makes an epistemological or ontological claim. Epistemic Structural Realism (ESR) asserts that while we can only know about the *structure* of physical reality, there nevertheless exist real unobservable *objects*, whose nature is outside the scope of our knowledge. Poincaré, whom Worrall credits with originating SR, called these "the real objects which Nature will hide for ever from our eyes" (1905: 161), suggesting ESR on his part. In the absence of an explicit denial of this point of view by Worrall it seems reasonable to think that he too subscribes to ESR. However, the lack of an explicit endorsement allows Ladyman (1998: 410), to suggest that he may in fact be advocating Ontic Structural Realism (OSR), the view that we cannot know about more than the structure of the world because the structure is all there is. To this end, Ladyman makes use of Worrall's statement that "… what Newton really discovered are the relationships between phenomena …" (*Ibid*). Although this quote seems to me to be perfectly compatible with ESR and certainly provides no convincing reason to ascribe OSR to Worrall, a significant portion of the subsequent literature has been devoted to the formulation and analysis of OSR. As we will see, the two brands of SR constitute dramatically different claims.

ESR implies a principled distinction between the part of reality we can know about – structure – and what Psillos calls the "unknowable extra *X*" (2001). The problem of how to characterise this distinction is therefore of central importance. Worrall, in reference to the Fresnel-Maxwell transition, talks about the difference between the "structure" and "nature" of light. Taking his cue from Poincaré, he states that "although from the point of view of Maxwell's theory, Fresnel entirely misidentified the *nature* of light, his theory accurately described not just light's observable effects but its *structure*" (1989: 118). For Worrall, the nature of light is determined by what it is that is oscillating, whereas the structure of light is determined by the mathematical form of that oscillation. In this example, ESR suggests the following analysis: we know that light is an oscillation described by a particular set of equations, but we do not and cannot know the nature of the thing that is oscillating.

However, the apparent ease with which the line can be drawn in this case does not necessarily imply that a satisfactory general principle can be formulated. One way in which Psillos in particular has attacked ESR is by denying that the distinction between nature and structure is tenable. If he is right, then the defence ESR provides against pessimistic meta-induction – i.e the identification of parts of theories pertaining to nature that we do not need to be realists about – is damaged, in the absence of a consistent way of saying what those parts are.

His central claim is that "the nature and structure of a physical entity form a continuum" (1995: 31). The reasoning behind this is the idea that the properties of a physical entity are defined in terms of the structure it is part of; that is, the equations and laws which govern it. Ladyman illustrates Psillos' point with the example of electrons: "We have a theory of electrons that describes their behaviour in terms of the laws, interactions, and so on, to which they are subject. This description, which may be termed a structural one, gives us the last word on electrons, says the realist" (1998: 414). For Psillos, then, once we have a full structural knowledge of an entity, "talk of 'nature' over and above this structural description (physical and mathematical) is reminiscent of the medieval 'forms' and 'substances'" (1995: 31) and is superfluous. If we accept Psillos' argument, the position of the line between nature and structure that Worrall draws in the case of Fresnel-Maxwell transition cannot have been fixed by appeal to any general principle, and indeed may have been largely influenced by *post hoc* knowledge of which parts of the theory were *in fact* retained.

Votsis, who devotes no small amount of time to defending ESR from Psillos, has attacked this thesis along the lines that the logico-mathematical properties of an entity constitute a subset, rather than an exhaustive list, of *all* the properties of the entity (which is taken to be its 'nature') (2007: 16). In response, I would point to Psillos' analysis of the electron. It has various structural or relational properties; quantities such as charge (determining the strength with which it attracts or repels other charged entities), mass (similarly, how much acceleration a given force imparts to it), and it is difficult to imagine what other properties might lie outside of this 'subset'. If any there be, physical science could not educate us about them, since the nature of the experimental method is such that it arrives at knowledge of properties in a structural fashion – that is, by observing an entity's interactions with other entities.

If examples of such non-structural (and therefore unknowable by science) properties are provided, I suspect these properties would then be of a very different kind to the properties of the supposed optical ether: that it is an elastic solid which fills all space and disrupts planetary motion. These properties of the ether make it discoverable in essentially the same way as those of the electron, rendering the 'nature' of light, insofar as whether or not it is transmitted through ether, a structural property.

It seems that the parts of theories that have rendered them vulnerable to pessimistic induction (ether, caloric, non-relativistic mass and so on) fall within Psillos' continuum; as such there can be no principled way in which to sever them from the rest of the theory that we are trying to rescue. On this view, 'nature', as *ontologically distinct* from structure, can only refer to some metaphysical essence or substance that lies outside the scope of the science as we know it. Worrall is therefore seen as misusing the term, applying it as if to suggest the presence of a dividing line between the 'nature' and 'structure' components of a scientific theory, where in fact there is none. While Psillos allows that the Worrall's thesis may have merit as "just a sober report of the fact that there has been a lot of structural continuity in theory-change," (1996: S313) he forcefully rejects the dichotomy between nature and structure that is required for ESR to convincingly answer the pessimistic meta-induction.

One might even argue that, in order to prove that the nature/structure distinction is well-defined, we should be able to draw it on one of our current best theories, and then wait and see which parts are retained in the future. In the absence of such a demonstration, Psillos' argument provides powerful grounds for holding that the distinction is untenable, its apparent applicability to historical theories merely a benefit of hindsight, and so removes a central plank of Epistemic Structural Realism.

One response to the problems raised by attempting to define nature as distinct from structure is to dispense with the former altogether, and this is what Ontic Structural Realism does. To call it an 'interpretation' of Worrall's original thesis would be stretching things – although OSR has its roots in Ladyman's identification of ambiguity in Worral's paper, it differs from ESR in both its motivation, and fundamental metaphysical claim.

Ladyman characterises OSR (he admits, crudely) as the claim that "there are no 'things' and that structure is all there is" (2007). That is to say, Psillos' "unknowable extra *X*" is unknowable simply because it doesn't exist – a striking departure from ESR, and standard realist metaphysics. OSR's picture of a world constituted entirely from structures and relations seems at first to be an overly drastic response to the problems raised by the pessimistic induction but, as we shall see, that is not the main motivation behind OSR – rather, it is primarily inspired by developments in modern physics.

A simple but forceful initial objection to OSR might ask: if relations are all that exist, what are they relations between? This is articulated (although not endorsed) by Chakravartty as the idea that "relations and thus structures are not meaningful … in the absence of actual things which are putatively related according to the structures considered" (1998: 402). The objection rests on the intuitively sensible idea that relations are ontologically dependent upon their relata, and the OSR programme is accordingly seen as an attempt to cheerfully dispense with the very foundations of physical reality.

In considering the reply to this objection, I will focus on the particular brand of OSR held by Ladyman. There are others, but his "Eliminativism" (2007) has a simple central thesis which stands in clear contrast to standard realist metaphysics, making it a useful illustration of the motivation and justification for adopting OSR.

His response is to say that "the relata of a given relation always turn out to be relational structures themselves on further analysis," (*Ibid.*) a clear statement of the revisionary metaphysics that OSR implies. On this view, things which are or have been considered to be elemental or unanalysable objects – water, atoms, even sub-atomic particles – only appear thus because we are ignorant of, or choose to disregard, their actual, relational structure. The idea that the world is constituted by a never-ending sequence of "relations between relations between relations …" (Stachel 2006 54) may be an intuitively troubling one, but it is given some credibility if we look at developments in modern physics. A large portion of research in the 20th and 21st centuries has focussed on analysing the structure of matter at ever-decreasing scales, and there seems to be no indication yet that an ontologically distinct, 'fundamental' layer of reality has been reached.

Furthermore, quantum mechanics seems to undermine the standard notion of objecthood. Indeed, according to Chakravartty, "The case for OSR proceeds from the interpretation of quantum mechanics" (2003: 873). He makes a comparison between classical Maxwell-Boltzmann statistics, whereby an arrangement of particles in which some are then interchanged counts as a new arrangement, and quantum (Fermi-Dirac, Bose-Einstein) statistics, where particles cannot, even in principle, be labelled, making it physically meaningless to speak of interchanging them. (On my understanding, he slightly misses the point when he says, "Interchanging the particles has no physical significance according to QM [quantum mechanics]" (2003: 874). This could be the case for certain *classical* systems, for which the values of the physical variables describing the system might be invariant under some particle swap. The point is that classically, the particle-interchanged system is treated as a distinct arrangement, whereas quantum statistics does not treat it as such – this feature gives rise to qualitatively different physical behaviour in classical and quantum statistics.)

A further example: in a Bose-Einstein condensate, a system ostensibly composed of many individual particles is treated by quantum mechanics as being a single entity – not as an approximation, but in a literal, physically complete sense. In short, there are cases in our best current physical theories where it is unclear in what sense entities can be characterised as individual objects. In light of this, OSR's supporters conclude that "on the basis of the physics alone, we cannot say whether the particles are individuals or not," (Rickles, French, Saatsi 2006: 33) and hence, Ladyman says, "It is an *ersatz* form of realism that recommends belief in the existence of entities that have such ambiguous metaphysical status" (1998: 420).

According to OSR, components of a theory beyond its mathematical structure – be it ether, electrons, photons or whatever – are, at best, a heuristic aids. In this capacity, they may be useful, or even indispensable in the way we think about the world – Ladyman speculates that "we [may not be] able to think about certain domains without hypostatising individuals as the bearers of structure" (2007). Importantly, however, the discontinuity in postulated entities that occurs through theory change, and allows (on traditional realism) the pessimistic induction to take a grip, is neutered. From the point of view of OSR, we were never committed in any substantive way to the reality of the ether; only to the reality of the equations that it was heuristically useful to think of as being descriptions of the motion of an ether. We might one day say the same about the postulated 'strings' of string theory. The radical metaphysical revision that this solution to the pessimistic induction requires would be difficult to swallow if motivated solely by want of that solution, but Ladyman presents strong independent grounds (viz. modern physics) for adopting OSR.

Structural Realism began as an attempt by Worrall to make a principled distinction between the parts of scientific theories that are vulnerable to the pessimistic meta-induction, and the parts that are retained through theory change and are held to responsible for predictive success. His characterisation of this distinction in terms of 'nature' and 'structure' has been attacked (in my view, convincingly) by Psillos, along the lines that the part which Worrall tries to describe as 'nature' (for example, the involvement or otherwise of an ether in the transmission of light) is not qualitatively distinct from the 'structure' (the mathematical equations describing the transmission of light). Nature, as Worrall wants to use it, is continuous with structure; there is therefore no principled way to separate the two, and his strategy for defeating the pessimistic induction fails.

Ladyman's brand of Ontic Structural Realism takes the idea of a nature-structure continuum one step further, dispensing with the notion of individual objects with 'natures' as anything other than heuristic devices for thinking about a purely structural reality. This embodies a thorough reworking of standard realist metaphysics, which is motivated and supported by reference to cases in modern theories where the metaphysical status of the objects commonly taken to support the mathematical structure of a theory is not well-defined. OSR extends structuralism well beyond the initial remit that Worrall intended for it, but in doing so it avoids some of the key difficulties in Worrall's original thesis, as well as acknowledging and taking into account the questions that modern physics raises about the notion of individual objecthood at the quantum level.

Word count = 2816.

References:

Chakravartty A. (1998), 'Semirealism', *Studies in History and Philosophy of Modern Science* **29**, pp. 391–408.

Chakravartty, A. (2003), 'The Structuralist Conception of Objects', *Philosophy of*

Science **70**, pp. 867–878.

Ladyman, J. (1998), 'What is Structural Realism?', *Studies In History and Philosophy of Science Part A* **29**, pp. 409-424.

Ladyman, J. (2002), *Understanding Philosophy of Science*, London: Routledge.

Ladyman, J. (2007), 'Structural Realism', *Stanford Encyclopedia of Philosophy* (http://plato.stanford.edu/entries/structural-realism/#ObjStrRea). Accessed 18/01/09.

Poincaré, H. (1905) *Science and Hypothesis*, New York: Dover.

Psillos, S. (1995), 'Is structural realism the best of both worlds?', *Dialectica* **49**, pp. 15–46.

Psillos, S. (1996), 'Scientific Realism and the Pessimistic Induction', *PSA* **3**, pp. S306-S314.

Psillos, S. (2001), 'Is structural realism possible?', *Philosophy of Science* **68** (supplementary volume), pp. S13–S24.

Rickles, D., French, S. and Saatsi, J. eds. (2006), *Structural Foundations of Quantum Gravity*, Oxford: Oxford University Press.

Stachel, J. (2006), 'Structure, individuality and quantum gravity', in D. Rickles, S. French and J. Saatsi (2006).

Votsis, I. (2007), 'Uninterpreted Equations and the Structure-Nature Distinction', *Philosophical Inquiry,* **29**(1-2), pp. 57-71.

Worrall, J. (1989), 'Structural Realism: The best of both worlds?', *Dialectica* **43**, pp. 99-124.