The Structure, the *Whole* Structure, and Nothing *but* the Structure?

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This paper is structured around the three elements of the title. Section 2 claims that (a) structures *need* objects and (b) scientific structuralism should focus on *in re* structures. Therefore, pure structuralism is undermined. Section 3 discusses whether the world has 'excess structure' over the structure of appearances. The main point is that the claim that only structure can be known is false. Finally, Section 4 argues directly against ontic structural realism that it lacks the resources to accommodate causation within its structuralist slogan.

> "All right," said the Cat; and this time it vanished quite slowly, beginning with the end of the tail, and ending with the grin, which remained some time after the rest of it had gone.
>
> "Well, I have often seen a cat without a grin," thought Alice; "but a grin without a cat! It's the most curious thing I ever saw in all my life!" [Lewis Carroll, *Alice's Adventures in Wonderland*]

1. Introduction. Structuralism in the philosophy of science comes in many varieties. It ranges from a methodological thesis (concerning the nature of scientific theories and claiming that they are best understood as families of models) to an ontic position (concerning what there is and claiming that structure is all there is). In between, there is an epistemic view: there is more to the world than structure, but of this more nothing but its structure can be known. In this paper, I shall discuss the radical ontic

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position. Ontic structuralism (henceforth OS) is still quite an amorphous, though suggestive, position. The slogan is: "all that there *is*, is structure" (da Costa and French 2003, 189). But then there are different claims of varying strengths. Here are some of them.

- Objects should be reconceptualized in "purely structural terms" (French and Ladyman 2003b, 37).
- "[T]here are no unknowable *objects* lurking in the shadows" (French 1999, 203).
- Objects play only "a heuristic role allowing for the introduction of the structures which then carry the ontological weight" (French 1999, 204).
- "[T]he only non-structural understanding of the nature of such objects is metaphysical and unwarranted by the physics itself" (French and Ladyman 2003b, 45).
- "[T]here are mind independent modal relations between phenomena (both possible and actual), but these relations are not supervenient on the properties of unobservable objects and the external relations between them, rather this structure is ontologically basic" (French and Ladyman 2003b, 46).

There are different ways to read OS. Here are four interpretative candidates, concerning objects. Eliminative OS: there are *no* objects. Reconstructive OS: there *are* objects but they are reconceptualized in a structuralist way. Formal OS: structurally reconceptualized, 'objects' are mathematical entities. Semiformal OS: it is only unobservable 'objects' that have to be reconceptualized structurally as mathematical entities. And then there is the issue of how to understand properties and relations. Mild OS: structure is ontologically basic, being not supervenient on the intrinsic properties of objects. Radical OS: structure is ontologically basic because there are *no* objects.

Presently, I won't examine these interpretative issues. I will focus on the slogan: all that there *is*, is structure. The slogan captures the spirit of OS, namely, pure structuralism. According to the slogan, 'objects' are, at best, positions in structures. What makes French and Ladyman's OS distinctive is that it means to be a realist position: ontic structural realism (OSR). The slogan aims to refer to the mind-independent structure of the world. This structure is meant to be modal (or causal): hence, modal ontic structural realism.

This paper is structured around the three elements of the title. In Section 2, I highlight a substantive nonstructural assumption that needs to be in place before we can talk about *the* structure. By drawing on some relevant issues concerning mathematical structuralism, I claim that (a) structures *need* objects and (b) scientific structuralism should focus on *in re* struc-

tures. Therefore, pure structuralism is undermined. In Section 3, I discuss whether the world has 'excess structure' over the structure of appearances. The main point is that the claim that only structure can be known is false. Finally, in Section 4, I argue directly against OSR that it lacks the resources to accommodate causation within its structuralist slogan.

2. *The* Structure. Structuralists often talk about *the* structure of a certain domain. Is this talk meaningful? If we consider a domain as a set of objects, it can have any structure whatever. In particular, it can have a structure W isomorphic to another, independently given, structure W', provided that the domain has enough objects. This can be seen in various ways. Given enough building blocks and rods, they can be arranged so that they have the structure of the London Underground or of the Paris Metro. Given that a whole can be divided into any number of parts, isomorphic structures can be defined on any two distinct wholes, for instance, a brick wall and the top of my desk. The operative notion here is the standard definition of similarity of structure: two classes A and B are similar in structure (isomorphic) iff there is a one-to-one correspondence f between the members of A and B, and whenever any n-tuple $\langle a_1, \ldots, a_n\rangle$ of members of A stand in relation P, their image $\langle f(a_1), \ldots, f(a_n)\rangle$ in B stands in relation $f(P)$. It's a consequence of this definition that any two similar classes (i.e., any two classes with the same cardinality) can have the same structure. The upshot is that if we start with the claim that a certain domain D has an arbitrary structure W and if we posit another domain D' with the same cardinality as D, it follows as a matter of logic that *there is* a structure W' imposed on D' that is isomorphic to W. This claim has been the motivating thought behind Newman's critique of Russell's structuralism and of Putnam's model-theoretic argument against metaphysical realism (see Psillos 2001; Demopoulos 2003).

Things can be worse. Take Newtonian mechanics, where $\mathbf{F} = m\mathbf{a}$, and compare it with a reformulation of it, according to which $\mathbf{F}$ always is the vector sum of two more basic forces $\mathbf{F}_1$ and $\mathbf{F}_2$. Here we have two non-isomorphic structures, which are nonetheless empirically equivalent. Which of them is *the* structure of the Newtonian world? Or consider the set $S = \{1, 2, \ldots, 12\}$ and take R to be such that xRy if x evenly divides y. This structures the domain in a certain way: R is reflexive, antisymmetric, and transitive. But then define R' on S as follows: $xR'y$ if 3 evenly divides $(x - y)$. The structure of S is now different since R' is reflexive, symmetric, and transitive.

Ergo, *the* structure of a domain is a relative notion. It depends on, and varies with, the properties and relations that characterize the domain. A domain has no inherent structure unless some properties and relations are imposed on it. Or, two classes A and B may be structured by relations

R and R' respectively in such a way that they are isomorphic, but they may be structured by relations Q and Q' in such a way that they are *not* isomorphic.

Following the terminology introduced by Dummett (1991, 295) and Shapiro (1997, 85), let's call a 'system' a collection of objects with certain properties and relations. We may even call it a 'relational system' to emphasize the fact that it's so structured that it satisfies a certain condition, for example, Peano's axioms or Newton's laws. A 'structure' then is the *abstract form* of this system. Focusing on structure allows us to abstract away all features of the objects of the system that do not affect the way they relate to one another. It is clear that the *system* comes already structured. We can then talk about its abstract *structure*, but this talk is parasitic on the system being a particular and already structured complex.

This ushers in the *basic structuralist postulate*. Among the many structures that can characterize a system, some are privileged. This is *the* structure of this system as specified by the relationships among the objects of the system. It's this postulate that renders talk about *the* structure of system meaningful.

This postulate rests on a nonstructural assumption. That a system has a definite structure (*this* rather than *that*) follows from the fact that certain relations and not others characterize it. But that certain relations (and not others) characterize a system is a basic nonstructural feature of this system. The issue then is what exactly makes a structure privileged.

Following Shapiro, we might distinguish between two versions of structuralism. *Ante rem* structuralism has it that structures are abstract, freestanding, entities: they exist independently of systems, if any, that exemplify them. In a sense, they are like universals (more like Platonic universals than Aristotelian ones). *In re* structuralism takes systems as being ontically prior to structures: it denies that structures are freestanding entities. Structures are abstractions out of particular systems, and claims about *the* structure are, in effect, to be understood in one of the following ways. Talk, say, about *the* natural-number structure is talk about *any* system structured in a certain way, namely, having an infinite domain, a distinguished element e in it, and a successor function s on it such that the conditions specified by the Peano axioms are satisfied. Or, talk about the natural-number structure is talk about *all* systems structured in the above way.[1] Both ways take talk about structure to be relative to systems, but the first takes *the* structure to be that of a certain system (admitting, however, that any other isomorphic system would do equally well), while the second takes *the* structure to be a generalization over all isomorphic

1. For more on this, see Reck and Price (2000).

systems. Both ways take it that were there no systems, there would be no structures.

One important difference between *ante rem* and *in re* structuralism concerns the role of objects in structures. Since *in re* structuralism focuses on relational systems, it takes the objects of a structure to be whatever objects systems with this structure have. According to *in re* structuralism, there are no extra objects that 'fill' the structure. It's then obvious that the objects that 'fill' the *in re* structures have more properties than those determined by their interrelationships in the structure. They are given, and acquire their identity, independently of the abstract structure they might be taken to exemplify.

By hypostatizing structures, *ante rem* structuralism introduces more objects: those that 'fill' the abstract structure. Of these 'new' objects nothing is asserted than the properties they have in virtue of being places (or roles) in a structure. These places cannot be identified with the objects of any or all of the *in re* structures that are isomorphic to the abstract pattern. This is what Shapiro calls the "places-are-objects" perspective. The 'fillers' of the abstract (*ante rem*) structure are places, or positions, in the structure; yet if one considers the structure in and of itself, they are genuine objects. After all, they *must* be such since the abstract structure instantiates itself (cf. Shapiro 1997, 89). Given that an instantiated abstract structure needs objects to be instantiated into, the places of the abstract structure must be objects. Mathematical structuralism, then, does not view structures without objects. It's not revisionary of the underlying ontology of objects with properties and relations.

Intermediate moral: Structures need objects. This holds for both *ante rem* and *in re* structuralism. These two kinds of structuralism might need different objects, but they both need them.

The distinction between *ante rem* and *in re* structuralism may cast some light on the question noted above; namely, what makes a certain structure privileged? Let's assume, for the sake of the argument, that there are *ante rem* (freestanding) structures. Perhaps, one may argue, what makes a structure W of a system S privileged (i.e., what makes it *the* structure W of system S) is that W is isomorphic to an *ante rem* structure W'. But this thought leads to regress. For the same question can be asked about *ante rem* structure W': what makes *this* structure privileged? If the answer is that it is isomorphic to another *ante rem* structure W'', we are led to regress. If the answer is different, some independent reason has to be given as to why an *ante rem* structure W' is privileged. Perhaps in pure maths the point is innocuous. Mathematicians define and study all sorts of structures, and *any* structure, defined implicitly by a set of axioms, will do.

Things are more complicated when it comes to physical systems. Here *ante rem* structuralism is ill-motivated. For finding the structure of a

natural system is an a posteriori (empirical) enterprise. Its structure is *in re*. And it is a natural structure in the sense that it captures the natural (causal-nomological) relations among the objects of the system. It is *the* structure that delimits a certain domain as possessing causal unity. Hence, it is grounded on the causal relations among the elements of the domain. It's these facts (that the structure is *in re* and that it confers causal unity) that make some structure privileged vis-à-vis all other structures that *can* be defined on the elements of a system. But then it's odd to argue that a certain structure W is privileged because it is isomorphic to an abstract structure W'. First, it may not be. Given that the discovery of the *in re* structure is an empirical matter, it may not be isomorphic to any of a set of antecedently given *ante rem* structures. Second, even if the discovered *in re* structure turns out to be isomorphic to an *ante rem* one, the order of ontic priority has been reversed: the *ante rem* structure is parasitic on the *in re*; it's an abstraction from it.

Take, then, an *in re* structure W and an *ante rem* one W' that are isomorphic. Let us add that W is the structure of a concrete physical system and that W has a certain causal unity and role. W' instantiates itself, but since it is *ante rem*, W' has no causal unity and plays no causal role. Yet, W and W' are isomorphic. It follows that the causal unity and the causal role of W are not determined by its structural properties, that is, the properties it shares with W' and in virtue of which it is isomorphic to W'. If it were so determined, W' would have exactly the same causal unity and causal role as W. But it has not. So, if we take structures to be causal, we should *not* look to their structural properties for an underpinning of this causal unity and activity. This is not surprising. Places in structures and formal relations do not cause anything at all. It's the 'fillers' of the places and concrete (*in re*) relations that do.

Consider what Ladyman (2001, 74) says: "[T]here is still a distinction between structure and non-structure: the phenomena have structure but they are not structure." And French and Ladyman (2003a, 75) claim: "What makes a structure 'physical'? Well, crudely, that it can be related—via partial isomorphisms in our framework—to the 'physical' phenomena. This is how 'physical' content enters." Claims such as these still waver between an *ante rem* and an *in re* understanding of structures. But they seem to concede the point that structuralism cannot be pure: the phenomena are able to give 'content' to a structure precisely because they are *not* themselves structure.

Moral: To be able to talk meaningfully about *the* structure (of anything), OS needs to respect the basic structuralist postulate. This compromises pure structuralism. OS will take structures to be either *ante rem* or *in re*. Objects are needed in either case. If OS reifies *ante rem* structures, their

causal unity, role, and efficacy are cast to the wind. If OS gives ontic priority to *in re* structures, there is more to the world than structure.

3. The *Whole* Structure. Can the structure of a domain be known, and is it necessary for science to discover the whole of it? Structural empiricism (one form of which is constructive empiricism) allows that the structure of appearances can be known, but denies that science should or need aim at knowing more. Structural empiricism stresses that a theory is successful if the structure of appearances is isomorphically embedded in a model of the theory. This allows that the theory is empirically adequate if it captures *just* the (abstract) structure of appearances. But there is nothing in structural empiricism that prohibits it from arguing that the *in re* structure of appearances is *identical* to the empirical submodel of the theory. Structural empiricism (and in particular constructive empiricism) is not pure structuralism. It's not revisionary of the idea that appearances consist of (observable) objects with (observable) properties and relations: it takes appearances to be *in re* structures. These *in re* structures are knowable (at least in principle). If they were not, no theory could save them.

Structural empiricism takes scientific theories literally and rests on the notion of truth as correspondence. This means that it takes seriously the possibility that the world might well have excess structure over the appearances. After all, the world *must* have excess structure if one of the many incompatible theoretical models of the appearances is to be correct. But for this excess structure to exist it should be causally connected to the structure of appearances. Perhaps this excess structure might exist in complete causal isolation. But this thought would be revisionary of actual science. And it would leave totally unmotivated the view that theories should be taken at face value, as telling a causally unified story as to how the world might be. A scientific theory does not describe two causally disconnected systems (the system of appearances and the system of what happens 'behind' them). Rather, it tells a story as to how these two systems are causally connected. Structural empiricism should at least leave it open that the excess structure of the world is causally connected to the structure of appearances. The price for this is that structural empiricism buys into a substantive metaphysical assumption: that it's at least possible that the structure of appearances is *causally connected* to a deeper unobservable structure.

(Epistemic) structural realism is more optimistic than structural empiricism. It claims that the structure of the world behind the appearances is no less knowable. In its Russellian stripe, structural realism claims that there is an inferential route, from the structure of appearances to the structure of their (unobservable) causes, based on the claim that the appearances and their causes have the same structure. But this program fails

on many counts (cf. Psillos 2001, 2006). In its Maxwellian-Worrallian stripe, structural realism improves on the Russellian version by denying the inferential route: the world has excess structure over the appearances, but this excess structure can be captured (hypothetico-deductively, as it were) by the Ramsey-sentence of an empirically adequate theory.

The chief problem with this view is that, on a Ramsey-sentence account of theories, it turns out that an empirically adequate theory *is* true (cf. Psillos 1999, 61–69; 2006). The supposed 'excess' structure of the world turns out to be illusory. One point brought home by the discussion over constructive empiricism is that we should take seriously the idea that the world may have 'excess structure' over the appearances. A theory describes a way the world might be and an empirically adequate theory might be false: the world might be different from the way it is described by an empirically adequate theory. This idea is not honored by Ramsified structural realism, unless it drives a wedge between empirical adequacy and truth. This wedge can be driven in position only if it is accepted that the world has already built into it a natural structure, a structure that the Ramsey-sentence of the theory might *fail* to capture. This is a nonstructural principle. And since we are talking about the world, this has to be an *in re* structure.

Structural realism in both of its foregoing stripes is not pure structuralism. It treats the world as a relational system with objects and properties and relations. Its point is epistemic rather than ontic. But in the end, the epistemic claim that only structure can be known comes to nothing. To cut a long story short, given that we talk about *in re* structures, there are objects that 'fill' the structures; these objects have properties over and above those that are determined by their interrelationships within the structure; (at least) some of these (nonstructural) properties are knowable (e.g., that they are not abstract entities, that they are in space and time, that they have causal powers, etc.); and, in any case, these *in re* structures are individuated by their nonstructural properties since it's in virtue of these (nonstructural) properties that they have causal unity and are distinguished from other *in re* structures.

Moral: Epistemic structural realism promises that the 'excess structure' of the world can be known, but fails to deliver on its promise unless more than structure can be known.

4. And *Nothing but* the Structure. Ontic structuralism is meant to be a substantive thesis. The structure of the world (which, presumably, is all there is) is a *causal* structure. French and Ladyman (2003a, 75) write that "causal relations constitute a fundamental feature of the structure of the world." But OS cannot accommodate causation within the structuralist slogan.

There is a prima facie promising way to understand causation in a structuralist framework: we can think of it as structure persistence or structure preservation. This approach has been captured in Russell's (1948) structural postulate: events (complex structures) form causal chains, where the members of the chain are similar in structure. The idea is that causation involves structural persistence without qualitative persistence. However, as Russell recognized, there are causal changes that do not involve structure persistence, for example, the explosion of a bomb. Besides, we need to specify more precisely what exactly it is that persists. For in any process, and with enough ingenuity, *something* that persists can always be found. We need, therefore, an account of those characteristics of a process whose persistence renders this process causal. The natural candidate for such an account should involve objects and their properties.

To see that structural persistence is not enough for causation, consider what I call the 'which is which' problem. Suppose that a causal chain consists in some kind of structural similarity between events *c* and *e*. Suppose also that we accept the strong view that this structural similarity is all there is to causation. Which then is the cause and which the effect? Structural considerations alone cannot afford us a distinction: cause and effect are isomorphic. A corollary of this is that structural considerations alone cannot distinguish between a case of persistence (where an event persists over time) and a case of change (where an event causes another event to happen). Both cases are structurally identical if causation consists in structural continuity. Another corollary is that structural considerations cannot distinguish which of two isomorphic (but qualitatively distinct) systems is the cause of a certain event. One might try to avoid these by taking structures to be in space and time and by arguing that the cause is the structure that precedes in time the other structures. This would take structures to be *in re*. Only concrete systems can be in space and time. Now, being in space and being in time are *not* structural properties. So nonstructural properties are necessary for causal relations.

But even if we leave all this behind, we can still question the *rationale* for taking causation to be exhausted by a chain of isomorphic structures. If causation is a relation of dependence between events (where dependence can be understood in any of the standard ways: nomological, counterfactual, probabilistic), then it should be clear that the idea of isomorphism between cause and effect is undermined. There is nothing in causation-as-dependence that dictates that cause and effect should share structure. If '*c* causes *e*' is understood in any of the above dependence senses (e.g., *e* counterfactually depends on *c* and the like), *c* and *e* have any structure whatever. What if we take causation as a productive relation between events? If we take the cause to produce the effect, or if we think that

there is a mechanism that connects cause and effect, we might also think that structure persistence or structure transference offers the local tie that links cause and effect.

Note an irony. If we take this line, that *c* causes *e* depends on a nonstructural principle. The relation of transference of structure from one event to another is not structural. Two events (or systems) may have the same structure though they are not causally connected. That this structural similarity is due to a causal connection between them is a nonstructural claim. It cannot depend solely on the structural properties of the events (or systems). Though critical of the structuralist metaphysics, Chakravartty (2003, 873) suggests that OS might take causation to be brute regularity: one structure follows the other. Yet OS cannot have it both ways. If it goes for Chakravartty's suggestion, it can no longer claim that causation consists in structure preservation or transference. Besides, if it goes for Chakravartty's suggestion, it will inherit all the problems with understanding modality within a regularity account of causation.

Another way to highlight the problems that OS has with accommodating causation concerns the causal relata. Standardly, the relata are taken to be either events or facts. On either view, causal relations depend on objects having properties and standing in relation to each other. Perhaps a Davidsonian view of events might seem congenial to OS: events are *particulars* that can be described in a number of ways. But Davidsonian events are *in re*: they are in space and time. Hence, they cannot be abstract structures. Notice, a propos, that there is an interesting but innocuous way to understand the structuralist claim. Most objects (with the exception of fundamental particles) are structured complexes. Events or facts involving these objects will involve their structure. Consequently, their structure (e.g, the structure of a molecule) is causally relevant to what these objects can do. But these are *in re* structures: they depend on the properties and relations these objects have. There is no entry point for OS here. To put the point bluntly: the truth-makers of causal claims require objects and properties.

Could ontic structuralism adopt *causal structuralism*? As Hawthorne (2001) explains it, causal structuralism is the view that all there is to properties is their causal profile, that is, the causal powers they confer on their possessors. It is a structuralist view because it denies quidditism, the view that there is something to a property—a *quiddity*—over and above its causal profile. We may think of causal structuralism as the view that properties have no intrinsic nature over and above their causal profile. So, for every (nonlogical or nonmathematical) property, there *isn't* its causal role (profile) and its 'role filler'; there is only its causal role. If ontic structuralism is taken to be causal structuralism, it amounts to the denial of quidditism. Is this, however, progress? First, it's not obvious that quid-

ditism is wrong. But suppose it is. Causal structuralism does not eliminate or avoid properties. Though it dispenses with their quiddities, it accommodates properties and secures their existence and causal efficacy via their causal profile. OS would in fact require a kind of causal *hyperstructuralism*, whereby causal profiles are purely structural. But then we end up with nothing but formal structure, with no substantive properties and relations to tell us what this structure is, how it causes anything to happen, and so forth. Second, causal structuralism would commit ontic structuralism to a substantive account of causation, where causal facts are determined by the causal powers of properties. But this account of causation cannot be purely structural or formal. Causal facts would depend on the causal powers themselves and not on their structure or formal properties. The bottom line, I think, is that causal structuralism is at odds with the slogan that structure is all there is.

Moral: By going modal, OS promises to close the gap between abstract *ante rem* structures and concrete *in re* ones. But the modal features of the world are not purely structural. Nor can causation be anything like 'the cement of the universe' if structure is all there is. Worse, we cannot make sense of causation if structure is all there is.

REFERENCES

Chakravartty, Anjan (2003), "The Structuralist Conception of Objects," *Philosophy of Science* 70: 867–878.

da Costa, Newton C. A., and Steven French (2003), *Science and Partial Truth*. New York: Oxford University Press.

Demopoulos, William (2003), "On the Rational Reconstruction of Our Theoretical Knowledge," *British Journal for the Philosophy of Science* 54: 371–403.

Dummett, Michael (1991), *Frege: Philosophy of Mathematics*. London: Duckworth.

French, Steven (1999), "Models and Mathematics in Physics," in Jeremy Butterfield and Constantine Pagonis (eds.), *From Physics to Philosophy*. Cambridge: Cambridge University Press, 187–207.

French, Steven, and James Ladyman (2003a), "The Dissolution of Objects: Between Platonism and Phenomenalism," *Synthese* 136: 73–77.

——— (2003b), "Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure," *Synthese* 136: 31–65.

Hawthorne, John (2001), "Causal Structuralism," *Philosophical Perspectives* 15: 361–378.

Ladyman, James (2001), "Science, Metaphysics and Structural Realism," *Philosophica* 67: 57–76.

Psillos, Stathis (1999), *Scientific Realism: How Science Tracks Truth*. London: Routledge.

——— (2001), "Is Structural Realism Possible?" *Philosophy of Science* (Supplement) 68: S13–S24

——— (2006), "Ramsey's Ramsey-Sentences," in M. C. Galavotti (ed.), *Cambridge and Vienna: Frank P. Ramsey and the Vienna Circle*. Dordrecht: Springer, 67–90.

Reck, Erich H., and Michael P. Price (2000), "Structures and Structuralism in Contemporary Philosophy of Mathematics," *Synthese* 125: 341–383.

Russell, Bertrand (1948), *Human Knowledge: Its Scope and Limits*. London: Routledge.

Shapiro, Stuart (1997), *Philosophy of Mathematics: Structure and Ontology*. Oxford: Oxford University Press.