Chapter 9
Adding Modality to Ontic Structuralism: An Exploration and Critique

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Everyone needs a little magic somewhere.
John Bigelow & Robert Pargeter [3]

Effective magic is transcendent nature.
George Eliot, Middlemarch

9.1 Introduction

Ontic Structural Realism (OSR) gives ontic priority to structures over objects. In its most extreme form (captured, admittedly, by a slogan) it states that "all that there is, is structure" [6, p. 189]. If this is true, if there is nothing but structure(s) in the world, the very idea of contrasting structure to non-structure loses any force it might have. Actually, if the slogan is right, the very idea of characterising what there is as *structure*—as opposed to anything else—becomes incoherent. Traditionally, characterising something as a structure has made full sense—and has served excellent scientific and philosophical purposes—precisely because structure was understood as an entity with slots, which could be occupied by objects and whose individuation-conditions involved objects only qua slot-fillers. If objects altogether go, whatever remains can be called 'structure' only if we take 'structure' to be a term of art.

Well, Ontic Structuralists are happy to 'mimic' talk of non-structure, or objects in particular, but they hasten to add that this mimicking does not imply any serious metaphysical commitment to them. Here are a couple of characteristic passages:

- The notion of objects should be reconceptualised in "purely structural terms" [11, p. 37].
- The objects play only "a heuristic role allowing for the introduction of the structures which then carry the ontological weight" [8, p. 204].

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E.M. Landry, D.P. Rickles (eds.), *Structural Realism*, The Western Ontario Series in Philosophy of Science 77, DOI 10.1007/978-94-007-2579-9_9,
© Springer Science+Business Media B.V. 2012

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I have criticised OS's abandonment of objects—as a distinct and separate ontic category—in my [21]. Steven French [9] has replied to this criticism. I think we have reached a stalemate. Can there be any progress in the debate?

In an attempt to pursue further my (hopefully constructive) criticism of OSR, I want to examine in some detail a key recent idea that seems to shape the very kernel of this view, viz., that structures are *modal*. Perhaps, James Ladyman is more explicit than French in requiring that structures display or possess primitive modality. He says: "the structure described by scientific theories is the modal structure of the phenomena", adding (somewhat puzzlingly) that "the phenomena have structure but they are not structure" [15, pp. 73–74]. But French too intends to give structures causal power [9].

In Section 9.2, I argue that Ontic Structuralism has to work with a notion of structure that is meant to play two roles at once: it should be abstract enough to be independent of concrete physical systems (and hence shareable by distinct physical systems) and concrete enough to be part of the causal identity of physical systems. I then reveal the tensions there are in this mixed view. In Section 9.3, I take on a more moderate version of OS—advocated by Michael Esfeld—which identifies structure with causal structure. I then argue against the resulting causal structuralist view of the world. In Sections 9.4 and 9.5, I explore a natural way to modalise structure, viz., taking structures to be structural universals. I argue that, despite all prima facie advantages, this view inherits all problems that structural universals face and in particular the so-called 'mereology or magic' dilemma. In Section 9.6, I examine a prima facie plausible way to avoid this dilemma, which is based on the claim that there are certain spatial (or arrangement) universals that capture pure structure. I explain why this view fails to offer solace to ontic structuralism. I conclude that certain plausible attempts to modalise structure leave deep scars on ontic structuralism.

9.2 Adding Modal Force to Structures

There is an immediate problem with adding modal force to structures. If by 'structure' we mean *mathematical* structure, how can it be the locus of modality? To be sure, if mathematical structures exist at all, it is plausible to think that they exist necessarily. But there is where their modal status ends. Being abstract, mathematical structures cannot enter into causal relations; they cannot support counterfactual conditionals etc. In my [21], I borrowed several conceptions of structure from mathematical structuralism (*ante rem*, *in re*) and claimed that OSR, armed with a mathematical understanding of structure, is unable to accommodate causation. Hence the modal force of structures that OS advocates is under threat.

This reading of OSR was based on French's reading of structure as primarily group-theoretic [8] and [10] as well as on (repeated) claims of the form: "[T]he structural dissolution of physical objects leads to a blurring of the line between the mathematical and the physical" [11, p. 41]. In fact, the official position is mixed. Ladyman [16, p. 24] says:

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> The *ante rem* structuralism about mathematics defended by Stewart Shapiro among others, and the ontic structural realism about physics defended by Steven French and myself among others, are both metaphysical positions. They have in common the idea that relational structure is ontologically more fundamental than individual objects. There are of course important differences between them, the most essential of which is that ontic structural realism is a form of realism about the modal (causal or nomological) structure of the world, whereas *ante rem* structuralism is only concerned with mathematical reality.

French [9, p. 174] goes one step further by arguing that "the comparison with mathematical structuralism is misleading". Here is how he thinks an OS should conceive of the matter:

> The quantum structure, say, does not exist independently of any exemplifying concrete system, as in the *ante rem* case, it is the concrete system! But that is not to say that such a structure is simply *in re*, because the ontic structural realist does not—or at least should not—accept that the system, composed of objects and relations is prior to the structure. Indeed, the central claim of OSR is that it is the structure that is both (ultimately) ontically prior and concrete.

I find this kind of claim *very* puzzling. To avoid vacuity, where talk about structures is just a roundabout way to talk about actual and concrete physical systems (like a hydrogen molecule, or a water molecule, or a pair of entangled electrons or what have you), OSR should work with a notion of structure that plays two roles. On the one hand, it should be abstract enough to be independent of concrete physical systems (so that it can be said that it is shared by distinct but structurally similar physical systems; it can be represented mathematically independently of the actual details of concrete physical systems and the like). On the other hand it should be such that it should be instantiated by (and hence be part of the identity of) concrete physical systems (so that it plays a role in making a physical system what it is; it contributes to the explanation of its causal role and the like). Given these two roles (more on this below), my feeling puzzled has to do with the fact that I simply cannot see how French's claim above makes any headway in understanding how these two roles are actually fulfilled by structures as conceived by ontic structuralists. To put the point crudely, French seems to require a conception of structure which renders structures both concrete (qua particular spatiotemporal physical systems) and abstract (qua shareable by distinct physical systems). In any case, if structures are all there is, what are they said to be ontically prior to?

In my [21], I suggested that there might well be a certain understanding of OSR which does render structures modal. This is what John Hawthorne [13] has called 'Causal Structuralism'. CS is the (popular) view that properties are identified via their causal profile, that is by the causal powers they confer on their possessors. This causal profile is a network of causal relations among properties. CS is *structuralism* because it denies quidditism, viz., the view that there is something to a property—a *quiddity*—over and above its causal profile, which makes this property what it is, independently of its causal profile, if indeed it has one. On the quidditist view, two properties may have the same causal profile and yet be distinct, because they have different quiddities. Denying quidditism, we may conceive of CS as the view that properties have no intrinsic nature over and above their causal profile. So, for

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every property (i.e. for every non-logical or non-mathematical property), there *isn't* its causal role (profile) *and* whatever fills in (or plays) this role; there is *just* its causal role.

French is not entirely clear on CS, but he [9, p. 182] seems to be open to reading OSR as a version of CS. The official view, as it were, is that OSR can "appropriate" whatever the settled view is on whether properties are powers or not. He, then, goes on to say:

> What we are faced with is a choice between particular relations or kinds of relations having, as features, causal aspects particular to those relations or kinds and some form of underlying causal activity which imbues the relevant relations with causal powers. Granted that the former seems more clearly structuralist, I can't see why the second couldn't be incorporated as well.

This kind of move does not take us too far ahead. It is one thing to particularise causal activity to relations—denying that there is a generic causal activity underlying all relations—and it is quite another matter to endow relations with causal activities *in the first place*. The latter claim is presupposed by French in both options stated in the quotation above, and it is precisely this claim that is problematic. If relations are imbued with causal powers (idiosyncratic or generic), a story needs to be told as to how this is possible. These causal powers will either supervene on the causal powers of the properties of particulars or they will not. If they do so supervene, this move leads to causal structuralism *simpliciter*. If they do not supervene, they become mysterious: they are just posited so that the resulting relational structure has the required modal force. A story should, then, be told as to how they emerge and how they are what they are. Recall that, as French himself admits, what we are after is an account of how structures have causal powers; claiming that they actually *do* is nowhere near the required account.

Let me press this point a bit more. There are cases of relations that cannot be said to embody causal power or activity, for instance spatio-temporal relations. There are also the properties and relations of relations themselves, especially the quasi-logical ones, that cannot be imbued with causal activity, e.g., being reflexive or being asymmetric or being reducible to etc. More importantly for our purposes the (higher-order) relations that are supposed to capture the modal relations that are supposed to exist between properties and relations (e.g., metaphysical entailment, necessitation, exclusion etc.) cannot themselves be treated as embodying causal activity, on pain of circularity. Are they then identified in a non-causal way? This move would amount to attributing a kind of quiddity to them in opposition to the dicta of causal structuralism. Trying to move in between the horns of this dilemma, friends of causal structuralism (certainly Lowe and possibly Mumford) take these higher order relations to be *formal*. This characterisation might well place them in a special category *vis-à-vis* all other relations, but it is not clear at all what exactly it is attributed to these relations (what it is for them to be formal other than being second-order and non-causal) and what the independent motivation for this characterisation is.

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There is perhaps a reason why French is not *so* keen on CS. Causal structuralism does not eliminate or avoid properties altogether. It dispenses with their quiddities, but, as a matter of fact, it accommodates properties and secures their existence and causal efficacy via their causal profile. Ontic structuralism would in fact require a kind of causal *hyperstructuralism* [13, p. 223], whereby causal profiles are *purely* structural as well. But then we end up with anything but a formal structure, with no modal profile at all.

What is absolutely clear is that the friends of OSR do *not* want to endorse hyperstructuralism. What is unclear is whether and how they might succeed in this. Writing on related things, Ladyman [16, p. 39] raises the following worry: "If only (...) structural aspects of the mathematical formalism of physical theories are relevant to ontology in physics, then there is nothing to distinguish physical and mathematical structure". His reply (ibid., p. 40) however is deeply puzzling:

> Physical structure exists, but what is it? What makes the world structure physical and not mathematical? Ladyman and Ross [17] advocate a kind of neo-positivism according to which when questions like this arise it is time to stop (...).

Refraining from asking a question does not eliminate the problem raised in it! One way to proceed might well be to try to see whether there can be a meaningful distinction between mathematical structure and physical structure that can be raised *within* OSR. It will turn out that the problems faced by attempts to draw such a distinction are bigger than the possible benefits of drawing it. But it is worth exploring the options, before we pass a judgement.

9.3 Causal (Hypo)structuralism

There is, in the market, a moderate version of OSR, advocated by Michael Esfeld among others, according to which "physical structures are networks of concrete, qualitative physical relations among objects that are nothing but what stands is these relations, that is, do not possess an intrinsic identity over and above the relations in which they stand" [7, p. 180]. M-OSR, let's call it, does not do away with objects altogether. One (certainly, I) may have qualms about what exactly it is for something to have 'no intrinsic identity over and above the relations in which it stands'. I take it that this can only tell us *how many* objects there are, without saying a lot more about *what* they are. But let's pass that over in silence. The key claim of interest is that M-OSR adopts Causal Structuralism and thereby promises to ground/explain the modal features of ontic structuralism. Indeed, Esfeld advertises his programme as filling a lacuna (this concerned with modality) in OSR [7, p. 180].

Before we discuss how the lacuna is filled and how successfully this is performed, let me raise a couple of preliminary points. The master argument for Causal Structuralism is anti-quidditism. More specifically, the standard rendition of the master argument is that if properties have quiddities, these will end up being unknowable. Indeed, Lewis has famously called this view 'Ramseyan Humility'. Lewis is happy with the humility—hence, there is no problem with positing quiddities—but others

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think that the cocktail Quidditism & Humility is poisonous. Hence, they deny Quidditism, which implies Humility. I am not going to review this debate here, in the interest of speed. Suppose, however, that quidditism is wrong (though I very much doubt it). Esfeld (and others) think that Causal Structuralism avoids Quidditism. In a sense, it does, since if all properties are powers, and if powers are individuated by their causal profile only, there is no further issue of what makes a causal power what it is. Nor is there room for positing an extra individuating factor which marks the identity of the power independently of its causal profile. Two putative distinct causal powers which have exactly the same causal profile are one and the same property. Esfeld (and others) also think that Causal Structuralism avoids Humility. In a sense, it does, since if all properties are powers, and if powers are the kind of entities that cause things to happen, and if knowledge requires causal contact with the thing known, knowledge of properties is *in principle* possible.

There is a certain sense, however, in which Causal Structuralism simply relocates the quiddity. The identifying feature of a property is simply transformed from a local individuating feature to a global feature of the causal network in which the property participates. What is more, this global feature is no longer individuating! Let me explain.

Causal Structuralism advances a holistic account of the individuation of properties. Strictly speaking, this is not necessary. There can be an 'essentialist' version of CS according to which not all elements that are parts of a property's causal profile are essential to this property being what it is. On an essentialist causal structuralism, only some parts of the causal profile of a property P (perhaps some particular relations to some other properties or some particular effects) fix the identity of P. Though this *is* a genuine option, it is hard to defend it unless there is a natural distinction to be drawn between the essential and the accidental parts of a causal profile.

To the best of my knowledge, most causal structuralists are in favour of an anti-essentialist holistic individuation of causal powers. In its clearest form, this position is found in [19], but is also explicitly present in [5] and others. Mumford says that "a property's identity is fixed by the (causal) role it plays in relation to other properties" but adds that though the identity of a property "is fixed by relations to other properties, its existence has no ontological dependence on those properties [19, p. 171]. Later on, he explains that he accepts holism, whereby "the world is a single whole, composed of properties whose essence and identity are determined by their place in that whole" [19, p. 184]. And again: "the properties that are real in a world must (. . .) form an interconnected web: a system with no property standing alone or outside".

If this image is taken seriously, a property cannot be identified, unless what all other properties to which it is related are has already been specified; that is, unless all other properties have already been identified. But since this tangle arises for *any* property whatever, it follows that no property can be identified unless some other properties have already been identified, and because of this, no property can be identified *simpliciter*. All we get, at best, is a web of causal profiles, but no other way to tell how the several parts of the web are related to (or flow from) certain

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properties. This way to understand the identity of properties was motivated, at least partly, by an attempt to avoid the supposedly mysterious quiddities qua unknowable metaphysical identifiers of properties. Nothing much is gained by replacing them with a more mysterious holistic network of relations among properties, which is supposed to confer identity on properties, without in the end identifying any of them. Quiddities are not dispensed with; they become a global *totalitas*.

Hawthorne discusses a version of this problem and notes that it is not too disturbing. His idea is this. Take all the laws that characterise all properties in the world and express them in a lawbook. Then use the Ramsey-Lewis technique to Ramsify away the properties, by replacing each property-name by a distinct variable and prefixing the resulting open sentence with an equal number of existential quantifiers. Call this, Hawthorne says "the Ramsified lawbook". He then [13, p. 220] adds:

> We can now articulate causal structuralism very easily, and whatever its merits, we cannot be accused of vicious circularity. Since the variable 'F1' replaced [property name] A, we can give a theory of the individual essence of A by the open sentence you get by dropping the existential quantifier prefixing 'F1'. According to causal structuralism, it is a necessary truth that anything that satisfies that open sentence is identical to A. Generalizing, the causal structuralist will say that any natural property can be defined by a suitable open sentence delivered by the Ramsified lawbook for that property.

Fair enough! But this strategy won't take us very far if *all* properties are taken to be structurally identified powers that are Ramsified away. For if all properties are identified by their relations to all other properties and all properties are Ramsified away, nothing will be left to tell us what these properties are. The suitable open sentence delivered by the Ramsified lawbook for a certain existentialised away property will include all other existentialised away properties; hence it will not specify any of them. All it will succeed in identifying is the whole network of properties that satisfy the Ramsified lawbook, without identifying any of them in particular. Here again, we get, at best, a *totalitas* (the Ramsified lawbook) and a specification of properties in relation to it. But if everything is Ramsified, even this relative specification will leave us in the dark as to what property is what. There is a way out, of course, and this is to keep some part of the lawbook unRamsified. But this would imply that at least some properties get their identity in a different manner.

Mutatis mutandis, the same goes for Alexander Bird's attempt to disarm the problem with holistic individuation noted above. He favours a graph-theoretic account of the relations among causal powers (or potencies, as he prefers to call them). The details need not detain us here. The relevant point is that according to Bird if the relations that structure the fundamental properties have certain features or characteristics—they are asymmetric, non-irreflexive relations—then the properties so structured can be individuated. As he [4, p. 142] put it:

> Thus if we consider that the fundamental properties are structured by the asymmetric, non-irreflexive relation between a power and its essential manifestation property, then we can see that there could be any number of fundamental properties, represented by the vertices on directed graphs that may contain loops.

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There is no disagreement with what Bird asserts. However, the nodes in the holistic causal network are told apart from each other because (and only when) the network is of a certain sort: the relations that structure it have certain properties which are individuated non-structurally and independently of their causal role (though it is doubtful that they have a causal role in the first place). To put the point a bit provocatively, causal structuralism (of the sort discussed so far) does offer individuation conditions for causal powers that acquire their identity by their place in a network of causal profiles, provided that *some* properties or relations (or, indeed, the network itself), get their identity independently of the their place in this network. Actually, for causal structuralism to get off the ground, causation itself must be a relation which is identified independently of its role in a causal network. But this is a different story. The bottom line is that Causal Structuralism ends up being causal *hypostructuralism*.

Mumford [19, pp. 186–187] appeals to a standard move, which is common to all friends of powers. This is that some powers are, ultimately, identified by the effects they have on us and our sensory modalities in particular. He [19, p. 187] says:

> We are able to interact with properties. Among the effects they have in their cluster of causal powers, are the effects they have on us, namely their phenomenal appearance. We can thus know properties either by the phenomenal appearance they cause in us or by the phenomenal appearance on us of other effects they cause. Some of the relations borne by properties are thus experienced and in this way we are able to break into the circle of interdefinability for the nature of a property.

In a similar fashion, Chakravartty [5, p. 136] says:

> Every case of warranted causal property attribution is facilitated by some properties that are known independently of a knowledge of their further effects. These latter property instances are the direct objects of our perceptions.

There is no doubt that *some* properties have effects on us. But if we took a property's effects on us to give us privileged access to the identity of a property—assuming we can tell which property has what effects on us—the very idea that a property is identified by its relations to all other properties to which it is related would be threatened. As noted already, some such relations would become the essential identifiers. We would therefore end up with essentialist causal structuralism. To sum up my first preliminary point, there is a sense in which Causal structuralism replaces *quiddity* with *totalitas*. And there is also a sense in which this is avoided only by retreating to causal *hypo*structuralism.

My second preliminary point is that there is also a sense in which CS replaces Humility with Audacity *only in name*. The friends of CS take pride in claiming that if properties are powers, they are in principle knowable; hence Humility is avoided. Esfeld sums up this sentiment by saying that on CS "what the properties are can in principle be discovered via the effects they produce" [7, p. 184]. If CS holds sway on all properties, Humility (associated with quidditism) is replaced by Audacity: *all* properties can be known. Even without a lot of reflection, this claim appears too strong. The chains by means of which causal properties are detected (and hence known) are long, complicated and sometimes devious. Some properties—too

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remote causally, or too shielded by other causal properties—might not be known, even if CS is true. On reflection, however, things are worse. Given the problem identified above concerning the individuation of properties, it might well turn out that even if the total network of causal profiles—what I called *totalitas*—might be knowable, what properties play what role *within* this totality might not be knowable after all—unless the nexus of interdependent and interconnected properties is broken at several places (e.g., at the level of phenomenal effects on humans) in such a way that among the several effects that a property has, the effect that has on us is singled out as *the* identifier of this property. Not only is CS in danger of being abandoned. More importantly, humility is still with us, despite claims to the opposite, for all those properties that are not fortunate enough to yield effects on us.

9.4 The Abstract and the Causal

These, I am afraid, are preliminary skirmishes. The key battle is still to come. At stake is Esfeld's claim that CS can make good on the OS promise to modalise structure. He [7, p. 185] declares: "the fundamental physical structures are causal in themselves so that there is no need to postulate underlying causal properties". And he (ibid., p. 187) adds:

> if the fundamental physical structures are modal structures, being the power to produce certain effects, then (...) any difference in the fundamental structures, accounting for there being two different types of arrangements of fundamental structures in two possible worlds, automatically leads to some difference in the effects that these structures produce and thereby also to some difference in the domain of observable phenomena.

The thought here is that different structures produce different effects and in particular different observable effects. This, however, does not seem quite right. Take Newtonian mechanics, where $\mathbf{F} = m\mathbf{a}$, and compare it with a reformulation of it, according to which $\mathbf{F}$ is always the vector sum of two more basic forces $\mathbf{F}_1$ and $\mathbf{F}_2$. Suppose further that $\mathbf{F}_1$ and $\mathbf{F}_2$ are such that they sustain each other and can act only in tandem to produce acceleration. Suppose further that $\mathbf{F}_1$ and $\mathbf{F}_2$ have no other effects. We have two modally-laden structures which are non-isomorphic but, nonetheless, empirically equivalent.

Indeed, it is only by fiat that CS can block the following from being a genuine possibility. Two properties A and B act in tandem to generate a certain causal profile Q. Suppose, further, that A or B, taken individually, do not have any further causal role. Causal structuralism entails that, all else being equal, a world W_1 with A&B having causal profile Q would be identical with a world W_2 in which a *single* property C has causal profile Q. We may never be able to figure out whether we live in W_1 or W_2, but to make sense of this metaphysical difference we need to go beyond causal roles.

Still, the main thought remains: CS can make OSR more attractive by taking physical structures to be genuinely causal, their essence being their power to pro-

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duce certain effects. Esfeld takes it that one of the advantages of this move is that the distinction between mathematical and physical structure is no longer blurred. In what follows, I shall argue that Esfeld's blending of ontic structuralism with causal structuralism is misplaced.

Concrete structures are best seen as relational systems—that is systems of entities having properties and standing in certain definite relations to each other. As such, they are concrete systems, located in space and time. They can stand in causal relations to other systems, where, as a rule, these causal relations are determined, at least partly, by the properties and relations of the elements of the relational system. They have a structure in the sense that they have a certain spatial-geometric arrangement. Their unity—qua concrete relational systems—is causal-nomological.

Qua concrete structures, relational systems can share structure; they can instantiate a common structure. In fact, two or more distinct relational systems fall under the same *type* partly because they share structure. Two or more water molecules—qua concrete relational systems—are *water* molecules precisely because they have the structure of a water molecule, which is a type of structure distinct from other types of structure not just on the basis of the elements that compose it but also on the basis of their structural properties. The structure or form of a water molecule is an abstract entity. It is shareable among distinct (and spatially separated) particulars. Unlike a concrete water molecule, it has slots—which can be occupied by distinct elements. Structure, in general, is like a universal which is instantiated in many particulars. It is an one over the many; a recurring and repeatable characteristic of distinct particulars.

The question then, as already noted in Section 9.2, is: how can this structure—qua *abstract*—be modal? How can it have modal features? Can it stand in causal relations? Can it support counterfactuals? If we think of structures as universals, that is properties, it transpires that they can be both abstract and modal. Properties, qua universal, are abstract—they are not concrete; they are shareable by many particulars; they are not 'in' space and time in the way particulars are—and yet they are causal in that they can and do cause things to happen. They can also stand in nomological relations, relations of counterfactual dependence and the like. At least this is what a lot of realists about properties qua universals think. But what kind of universals could structures be?

9.5 Structural Universals to the Rescue?

The most natural suggestion is that qua universals, structures should be taken to be *structural universals*. Structural universals have been explicitly introduced in order to account for the sharing of structure among particulars. They have been seen as universals of structure. Bigelow and Pargeter [3, p. 82], for instance, say:

> Chemical compounds are structures which are formed from the elements. The property of *having* such a structure is a universal which is related in quite distinctive ways to the universals which determine the elements. It is a *structural* universal.

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And David Lewis [18, p. 82], while opposing the idea of structural universals, admits that a good reason for admitting structural universals is to explain "structural resemblance as the sharing of universals". The key idea is that the fact that distinct particulars are composed of similar parts which are arranged in a similar way—that is the very idea of sharing structure—might be explained by positing structural universals.

Structural universals are *universals*—they are repeatable and recurring features of the world; they are instantiated by spatio-temporaly distinct particulars; they are in some non-spatial sense 'in', or 'part of', the particulars that instantiate them. Structural universals are *structural*: they have other universals as parts (again in non-spatio-temporal sense) and the particulars that instantiate them have proper spatio-temporal parts in which the universals that are 'parts' of the structural universal are instantiated. *Methane* is a standard example. A methane molecule is made of one carbon atom and four hydrogen atoms, arranged in a certain spatial way. The bonds between the carbon atom and the hydrogen atoms are co-valent. *Methane* molecules—actual particulars—are supposed to instantiate the methane universal. This is a structural universal in that its components (in a non-spatio-temporal sense) are two monadic universals (being carbon, being hydrogen) and a dyadic universal (being bonded). Actually, within a concrete particular structure which is a methane molecule (by virtue of instantiating the universal *Methane*), the universal *Hydrogen* is instantiated four times, the universal *Carbon* is instantiated once, and the universal *Bonded* is instantiated four times. We will come to the difficulties that this generates in a moment, but for the time being let us explore the idea that *Methane—qua* structural universal—is both abstract *and* modally laden. There is a pattern of entailments such that, for instance, when the universal *Methane* is instantiated, the universal *Hydrogen* is instantiated too. There is also a pattern of exclusions such that, for instance, when the universal *Carbon* is instantiated as part of *Methane*, the universal *polar bond* is not instantiated. Besides, the very idea of structural universals, allows for the possibility that there is 'structure' all the way down; that is, that there are no simple universals at all.

This kind of account can capture Esfeld's view that physical structures are causal. It's *not* part of the theory of structural universals that properties are powers, but there is no incompatibility here at all. So coupled with causal structuralism, structural universals can account for "the essence of a causal structure" being "in the power to produce certain effects [7, p. 188] while at the same time ground the obvious fact that causal structures—qua structures—are shareable. Esfeld, to be sure, talks of *fundamental* physical structures and focuses his attention on quantum structures of entanglement. But I take it that this is a side issue. There is no principled problem in applying the theory of structural universals to quantum systems, and conversely staying at the level of molecular structures does not detract from the fact that there is a way to accommodate modal features to structures by going for structural universals.

An advantage of going for structural universals is that there might be a way to explain sameness of structure in terms of isomorphism. Particular concrete systems can be said to be isomorphic to the structural universal they instantiate. Besides, particular concrete systems can share the same structure by instantiating the same

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structural universal. This can be explained, as Armstrong does it, by a process of abstraction. We start from concrete physical systems, e.g., methane molecules and proceed by abstracting away the particulars. What thereby remains is a pattern of interrelated universals. This is a structural universal which can be described, as Armstrong [2, p. 432] put it, as "an individual that is a carbon atom, four further individuals that are hydrogen atoms, and where ... etc. etc.".

This cannot be quite right. The universals that constitute the structural universal occur once in it. The universal *Hydrogen*, for instance, is one; it might be instantiated four times in the methane molecule, but this does not mean that it occurs four times in the *Methane* universal—if it did, universal *Hydrogen* would not be a proper universal. Lewis [18], who identified this problem first, noted that structural universals defy mereology. He then presented the friends of structural universals with a dilemma: either structural universals have literally other universals as proper *parts*, but then they cannot be isomorphic to their instances, or structural universal are mereologically atomic but then it becomes magical how they share structure with the particulars that instantiate them; how, in particular, they impose a certain structure on the proper parts of the particulars that instantiate them.

There are various ways in which the friends of structural universals have replied to this dilemma, but the bottom line is to claim that structural universals have a *sui generis* non-mereological constitution. Armstrong captured this, at least partly, by denying that structural universals have parts—as opposed to *constituents*. He also toyed with the idea that the non-relational constituents of a structural universal are *particularing* universals, that is they are such that we can speak of them as having universals as instances—for instance, *Hydrogen* is a particularising universal in that it can have four hydrogen universals as instances in the structural universal *Methane* [1, p. 88]. Lewis called "amphibians" these particularised denizens of structural universals and claimed, quite correctly I think, that positing them makes things a lot more complicated. For instance, how many universals of *Hydrogen* do we now have? One? One plus all the particularised instances?

Bigelow and Pargeter, on the other hand, argued that a structural universal R is a relational property of a particular, where the relational property is such that it stands in "a pattern of internal relations of proportion to other properties [3, p. 88]. Accordingly, the structural universal *Methane*

> relates the molecule to various properties. These properties are being carbon, being hydrogen, being bonded. Being methane, then, is to be identified with a highly conjunctive second-order relational property of an individual (molecule): the property of having a part which has the property of being hydrogen, and having a part which is distinct from the first part which has the property of being hydrogen, and.. [3, p. 87].

Still, this is supposed to be a non-mereological mode of composition, which is characterised by a pattern of essential internal relations among properties and relations. Part of the problem with this move has to do with the appeal to essentialism. It should be accepted as a primitive (modal) fact that there is an essential relation between *being methane* and *being carbon*. This is already magical enough. But as Katherine Hawley [12] has noted, even if this were granted, it does not follow

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from it that there is a link between the thus understood structural universal *being methane* and the patterns of co-instantiation of the universals *Carbon*, *Hydrogen* and *Bonded* that characterises a *Methane* molecule. In other worlds, that *Methane* essentially involves *Carbon*, *Hydrogen* and *Bonded* related by internal relation *R* does not, as it stands, explain why a particular methane molecule has the structure it does.

The problem that Lewis has identified is that there should be a nontrivial explanation of how the structural universal shares structure with the particular it is instantiated in. This problem becomes more acute when we consider cases in which two structural universals which are 'made of' the same universals are structurally distinct. The standard example is butane and isobutane. Butane molecules are made up of four carbon atoms, ten hydrogen atoms and thirteen co-valent bonds in a particular configuration. Isobutane (methylpropane) molecules consist of exactly the same atoms as butane but in a different configuration. *Butane* and *Isobutane* have the same components (the simple universals *carbon*, *hydrogen* and *bonded*); the same number of instances of these universals; and yet they differ in structure because their components are combined in different ways. Their molecular diagrams are given in Figs. 9.1 and 9.2.

Cases such as these suggest that distinct structural universals can be composed of exactly the same parts and this defies the principle that the parts determine the whole (and in particular the same parts-same whole principle). This is known as the Principle of Uniqueness of Composition (PUC): given some parts, there is only one whole they can compose. Lewis adheres to this principle and hence denies structural universals. Armstrong, on the other hand, accepts structural universals and defies PUC arguing that states of affairs violate it anyway. [Take a non-symmetrical relation *R* and two particulars *a* and *b*. PUC suggests that there is only one mereological sum with these three as parts, but state of affairs *Rab* is different from state of affairs *Rba*. So states of affairs violate PUC.]

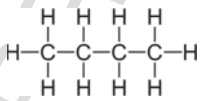

Fig. 9.1 Molecular diagram of Butane

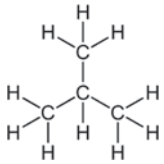

Fig. 9.2 Molecular diagram of Isobutane

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9.6 Arrangement Universals

But there is a different way to proceed, which is relevant to our current concerns. This has been explored by Javier Kalhar [14]. If you think of it, *Butane* and *Isobutane* are different because they instantiate different spatial arrangements, or better, different bonding arrangements. This is obvious by the molecular diagrams above. Kalhat's idea is that *Butane* and *Isobutane* are different structural universals because they involve—as parts—different arrangement universals, alongside the universals *Carbon*, *Hydrogen* and *Bonded*. These arrangement universals are *being butane-like structured* and *being isobutane-like structured*. That *being butane-like structured* is a universal is obvious since it can be instantiated—qua spatial arrangement—not just by carbon atoms and the like but by anything whatever. (Similarly for *being isobutane-like structured*.) But *being butane-like structured* is also shared by all butane molecules. It explains their structural similarity and also the difference between butane molecules and isobutene molecules. Arrangement universals are, to be sure, second-order universals; more specifically, second order relations over first order relational (*Bonded*) and non-relational (*Carbon, Hydrogen*) universals. But this is not a problem that needs to give us pause. What's interesting is that these arrangement universals can be seen as the product of a double abstraction. First, the particulars are abstracted away (and we get the structural universal, *à la* Armstrong); second, the first-order universals are abstracted away, and we get a spatial structure, viz., the *pure* structure of the structural universal. So the arrangement universal *being butane-like structured* could be represented as follows:

If arrangement universals are parts of structural universals, it follows that PUC above need not be violated. Structural universals can be distinct because they have as parts distinct arrangement universals. In this sense, the structure of the structural universal is part of its very constitution; it contributes to making it what it is and to what modal features it has. This account seems to suit particularly well Esfeld's approach, according to which physical structure is modally laden. It also helps explaining how "different types of arrangements of fundamental structures" lead to some difference in the effects they have [7, p. 187].

Admitting spatial universals is a step forward in this debate at least in the sense that we can now think of the *structure* of a structural universal as something repeatable and shareable. It is instantiated by the particular that instantiates the structural universal, but it is also instantiated by other particulars. It is a genuine one over the many. Besides, it can be instantiated by distinct types of particulars, making sense of the claim that, for instance, a methane molecule and a toy-model arrangement with spheres and pegs can share structure (thereby explaining how the

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toy-model can represent the structure of the methane molecule). More importantly, being a universal, it can embody modality; it can enter into causal or nomological relations etc.

We therefore seem to have a conception of physical structure (qua structural universal) which is both abstract (repeatable, recurring, shareable) *and* modal. But there is bad news too: we are not yet done with the mereology vs magic problem. Spatial universals—structures—have slots alright, but they are 'filled in' by other universals many times over. This is not quite right, since the universal *Hydrogen*, for instance, is one and not the 10 particularising instances or whatever required to 'fill in' the butane-like structure. *Butane* and *isobutane* do differ because they have different structural parts (spatial universals), but we still do not get isomorphism with particular molecules, since a particular butane molecule, for instance, has 10 hydrogen atoms, whereas the universal *Butane*, alongside the *being butane-like structured* universal, has one *Hydrogen* as its part (since *Hydrogen*, qua universal, is one and not ten).

It follows that an appeal to spatial universals cannot ultimately offer a mereological account of the relations between the structural universal and the particular that instantiates it. It can certainly explain why PUC need not be violated if two or more universals have some of their parts the same, provided they differ in their structure (in their arrangement universals). But it fails to explain the relation between the structural universal and the particular in which it is instantiated as one of isomorphism.

There is a further problem with spatial universals in particular, which would remain even if all other problems disappeared. This is that there is no clear sense in which they can be seen as powers or as embodying power. If anything, arrangement (spatial) universals should be seen as categorical properties, capturing structural arrangements among universals. What is more, a spatial universal (a certain geometrical arrangement, let us say, qua structural universal) is not a physical structure in the sense that a concrete molecule is. It could be isomorphic to a concrete physical structure, if all of the above problems were indeed resolved, but the isomorphism would not hold between two physical structures, but rather between a concrete physical structure (e.g., a concrete molecule) and a structure such that it would much more plausible to think of it as a geometrical structure.

Trying to disarm Lewis's criticism of structural universals, Hawley [12] has recently claimed that the dilemma 'mereology or magic' is false. She explored a different way forward, arguing that there is space for "a non composition relation" of the structural universal by its constituents. The details of her way forward are interesting, exploring the possibility of viewing composition as partial identity. But when it comes to the crunch (how does a structural universal impose a certain structure on the parts of the particulars that instantiate it?), what she says is rather puzzling. She says:

> Perhaps there is sense in which *being methane*, *being butane*, and being isobutene stand in a different relations to the same parts (*being carbon*, *being hydrogen* and a bonding relation). What relations? Well, those relations that underpin the relevant patterns of co-instantiation.

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She does admit that this is not terribly illuminating, but adds that for friends of structural universals the difference between *Butane* and *Isobutene* is not brute; they can see this difference "as grounded in the different relations each universal bears to its parts" [12, p. 129].

But why should that be so? Why should it be the case that the relations that "underpin the relevant patterns of co-instantiation" are exactly the relations that structure the structural universal? Without further explanation, it seems we are being asked to accept this in the spirit of natural piety.

There have been indeed other attempts to characterise structural universals. Armstrong, in his later work [2], has characterised them as *types* of states of affairs. Pagès [20] has criticised this view and has gone for an account of structural universals in terms of formal relations among first-order properties and relations. But Pagès's account seems, in the end, to replace structural universals with structures of universals [2, p. 432], the idea being that the unity of the structural universal is lost.

9.7 Concluding Thoughts

Structural universals, combined with the claim that properties are causal powers, were meant to offer a way to explain how physical structures have modal force while at the same time are abstract and shareable among the particulars that instantiate them. This kind of avenue had not been explored so far. But despite its initial promise, it stumbles over important problems that structural universals face. The key problem is that though structure is meant to represent by isomorphism, structural universals fail to do that, despite some ingenious attempts to make them succeed. This has a direct bearing on the modest version of ontic structuralism, which aligns ontic structuralism with causal structuralism and aims to pin modality on physical structure. I am not claiming there are no other ways to think of physical structure. What I *am* claiming, however, is that if we take talk of physical structure *seriously*—if that is, we think of structure as a universal of a sort, recurring and repeatable and being instantiated by different concrete relational systems—thinking of it along the lines of structural universals is both natural and initially promising. If the arguments above hold any water, the promise is not fulfilled.

There is a certain optimism around that causal structuralism is the right way to think of properties. Esfeld [7, p. 192] sums it up thus:

> The metaphysics of causal properties holds hence all the way down from common sense including the experience of ourselves as agents in the world via the special sciences to fundamental physics. It therefore provides for a complete and coherent view of the world that reaches from fundamental physics via biology to psychology and to the social sciences. The argument for the metaphysics of causal properties, taking, as physics teaches us, the form of a metaphysics of causal structures, cannot simply be that it is anchored in common sense. The argument is that it leads to a complete and coherent view of the world, including all the domains of empirical science, and avoiding a gap between metaphysics and epistemology by not having to postulate that there is something in the world whose essence is a pure quality that can in principle not be known because it does not make any difference.

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If what was said above has any grain of truth, there are important cracks in the causal structuralist 'complete and coherent view of the world'. Indeed, there are cracks in the structuralist metaphysics anyway.

Acknowledgments Versions of this paper were presented at the SIFA conference in Padova in September 2010 and at a seminar in the University of Cologne in January 2011. Many thanks to the participants for many useful comments and in particular to Mauro Dorato, Steven French and Andreas Hüttemann.

References

1. Armstong, D.M. (1986) In Defence of Structural Universals. *Australasian Journal of Philosophy* **64**: 85–88.
2. ———— (1993) A World of States of Affairs. *Philosophical Perspectives* **7**: 429–440.
3. Bigelow, J. and R. Pargeter (1990) *Science and Necessity*. Cambridge: Cambridge University Press.
4. Bird, A. (2007) *Nature's Metaphysics*. Oxford: Oxford University Press.
5. Chakravartty, A. (2007) *A Metaphysics for Scientific Realism*. Cambridge: Cambridge University Press.
6. Da Costa, N.C.A. and S. French (2003) *Science and Partial Truth*. New York: Oxford University Press.
7. Esfeld, M. (2009) The Modal Nature of Structures in Ontic Structural Realism. *International Studies in the Philosophy of Science* **23**: 179–194.
8. French, S. (1999) Models and Mathematics in Physics: The Role of Group Theory. In J. Butterfield and C. Pagonis (eds.), *From Physics to Philosophy* (pp. 187–207). Cambridge: Cambridge University Press.
9. ———— (2006) Structure as a Weapon of the Realist. *Proceedings of the Aristotelian Society* **106**: 167–185.
10. ———— (2011) Metaphysical Underdetermination: Why Worry? *Synthèse* **180**(2): 205–221.
11. ———— and J. Ladyman (2003) Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure. *Synthèse* **136**: 31–65.
12. Hawley, K. (2010) Mereology, Modality and Magic. *Australasian Journal of Philosophy* **88**: 117–133.
13. Hawthorne, J. (2006) *Metaphysical Essays*. Oxford: Oxford University Press.
14. Kalhat, J. (2008) Structural Universal and the Principle of Uniqueness of Composition. *Grazer Philosophische Studien* **76**: 57–77.
15. Ladyman, J. (2001) Science, Metaphysics and Structural Realism. *Philosophica* **67**: 57–76.
16. ———— (2007) Scientific Structuralism: On the Identity and Diversity of Objects in a Structure. *Aristotelian Society Supplementary Volume* **81**: 23–43.
17. ———— and D. Ross (2007) *Every Thing Must Go*. Oxford: Oxford University Press.
18. Lewis, D.K. (1999) *Papers in Metaphysics and Epistemology*. Cambridge: Cambridge University Press.
19. Mumford, S. (2004) *Laws in Nature*. London: Routledge.
20. Pagès, J. (2002) Structural Universals and Formal Relations. *Synthèse* **131**: 215–221.
21. Psillos, S. (2006) The Structure, the Whole Structure and Nothing but the Structure? *Philosophy of Science* **73**: 560–570.

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