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Building the world from its fundamental constituents

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What is the fundamental structure of the world? To clarify: I take fundamentality to be metaphysical priority, where "metaphysical priority" is best understood in the traditional sense, such that the metaphysically prior is that in which everything else consists.[1] The fundamental structure concerns the fundamental constituents of the world, the constituents from which everything else is constructed, and the fundamental categorical structure.[2] The fundamental categorical structure is determined by the fundamental kinds or natures of the world, i.e., by the fundamental categories. The fundamental constituents are the constituents of these categories.

Unless we are nihilists or monists, to have a world, we need more than just its fundamental constituents and categories: we need a building relation as well.[3] This relation may itself be fundamental, even if the constituents it ties together generate a less fundamental entity, the world.[4] I hold that there is a world built from more fundamental constituents, and that the building relation is composition: the world is built by mereologically fusing its constituents. The *composition intuition*, as we may call it, is based on the thought that we enjoy a direct grasp of the nature of proper

[1] This is different from Schaffer's (2010) understanding of priority. I suspect that our differences come from our different views about the role and direction of composition.

[2] As Ted Sider points out, when examining the fundamental structure one considers the fundamental ontology (what is there?) and the fundamental ideology (what expressions are primitive?) (Cf. Sider 2008, 2012).

[3] See Bennett (2011) for a relevant discussion of world-building.

[4] Some think the relation can't be fundamental if it has a non-fundamental relatum. I don't see why, unless we are reducing relations to their relata. But why think we non-nihilists should be reductionists like that, especially when the relation in question is the world-building relation? In any case, we need it, whether we count it as strictly fundamental or something that occupies some intermediate status.

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parthood (or perhaps we enjoy a direct grasp on the nature of composition) that makes a compositional approach to world-building superior to any other sort of approach.[5] On my view, composition is definable from a primitive, *proper parthood*, along with certain other mereological suppositions. I think that if we understand what proper parthood is, we can grasp the nature of composition—and I think we do understand the nature of proper parthood. I will assume the truth of the composition intuition in what follows.

The project of determining the nature of the fundamental constituents, categories and composition is a resolutely metaphysical project, a project that involves making claims about the nature of the world itself. Such a project must be informed by science, and so is a posteriori because it is constrained by relevant empirical facts, and it also involves inference to the best metaphysical explanation.

These two features help to calibrate the delicate balance between metaphysics and science. Metaphysics is not governed by science. But it must be informed by science, since it must not involve claims about the world that have been empirically refuted. But while metaphysics is constrained by science, it also extends past science to engage with the nature of parts of the world that science ignores or presupposes, because it involves speculative theses and assumptions that are either unnoticed, ignored or simply assumed as obviously true in scientific theorizing.[6] The distinctive nature of the philosophical project comes from the fact that the style of theorizing involved uses inference to the best explanation to draw conclusions from a mix of (defeasible) ordinary judgments, a priori suppositions, and empirical results from natural science and psychology.[7] We can think of such theorizing as modeling the true nature of the world.

In this paper, I argue that a popular way of modeling the fundamental constituents, structure and composition of the world, the *spatiotemporalist* approach to the world, has taken a wrong turn. Spatiotemporalist approaches to fundamental structure take the fundamental nature of the world to be spatiotemporal: they take the category of *spatiotemporal* to be fundamental. These approaches tend to start with questions about whether and how spatiotemporal parts and spatiotemporal composition interact, and try to build the entire physical world using spatiotemporal mereology. Supersubstantivalism, the view that everything physical reduces to spatiotemporal regions, is spatiotemporalism taken to an extreme.

The traditional spatiotemporalist view assumes, given a natural way of thinking about ordinary experience, that the fundamental constituents of the world are the smallest spatiotemporal parts, and takes the category of the spatiotemporal to be a fundamental category: hence she takes the world to be fundamentally spatiotemporal. She then builds the world from "propertied and related" spacetime regions in accordance with classical mereology or a close variant (e.g., perhaps she restricts composition). The mereological and categorical premises for the view are usually

[5] We might also want to add the thought that it is analytic that building is a kind of fusing.

[6] For example, scientists and ordinary people don't care whether composition is identity, whether it is like identity, or about whether to restrict it. They usually (implicitly) assume it exists in some commonsensical way to the extent that they even consider the issue at all.

[7] See Paul forthcoming for more details.

supposed to be known a priori or are supposed to be drawn somehow from ordinary experience and common sense. Nihilist and monist versions of spatiotemporalism reject the composition intuition, but still take the category of the spatiotemporal to be a fundamental category. Nihilists take the fundamental constituents of the world to be smallish propertied and related spatiotemporal simples, and monists take the propertied and related spatiotemporal whole to be fundamental.[8]

If we are interested in the *fundamental* structure of the world, I think this is the wrong place to begin, both for methodological reasons and for empirical reasons. Our thoughts about the fundamental ontology of the world need to extend past thinking of the world in terms of propertied and related spatiotemporal regions, and hence to extend past thinking of world-building in terms of spatiotemporal mereology. Methodologically, metaphysics should focus on categorically more fundamental entities than spatiotemporal parts and wholes when limning worldly structure. Empirically, the evidence for the possibility that ordinary spacetime is either emergent or perhaps even merely phenomenal suggests that we need to be more cautious when making claims about what the fundamental ontology might involve, and bolsters the methodological need to look to a more flexible compositional approach, one that draws its constituents from the most fundamental categories.

Below, I'll challenge spatiotemporalism with the fact that there exist well-accepted theories of quantum mechanics that reject the idea that spacetime is fundamental, and hence reject the idea that the world is fundamentally spatiotemporal. Some of these theories allow spacetime to emerge, some deny its existence. While there are empirical arguments in physics that support the existence of varieties of spacetime or argue that "local beables" need to be part of our fundamental ontology, determining the nature of the space of the world is more of an empirical matter than spatiotemporalists have explicitly recognized. Moreover, even if the existence of some sort of fundamental spacetime is ultimately endorsed, it isn't clear how well the characteristics of the preferred spacetime will support the spatiotemporal mereological premises of the spatiotemporalist.[9]

I will not argue for any particular theory of fundamental physics. Instead I'll argue that the debates over the nature of the fundamental space in the physics show us that (i) the fact that it is conceivable that the manifest world could be exactly as it appears to us, even though spatiotemporal entities are not fundamental, means that a central premise of spatiotemporalism, that we may *assume*, given ordinary experience, that the world is fundamentally spatiotemporal, is false. (ii) Spatiotemporalism must be seen as a contingent, a posteriori physical truth: if, say, one of the fundamental physical theories that take the fundamental space to be

[8] For representative approaches towards monism, see Schaffer (2010) and Horgan and Potrč (2008). For representative approaches towards nihilism, see Dorr (2005), Cameron (2010) and Sider (draft ms). (Horgan and Potrč defend a version of monism that denies the existence of proper parts. In this sense, it can also be thought of as an extreme version of nihilism according to which there is only one extended simple).

[9] For example, string theory endorses the existence of a high-dimensional spacetime, not the 3-dimensional space of the manifest image. For a defense of fundamental spatiotemporal entities, see Allori et al. (2008). Tim Maudlin (2007) has argued that we need to include local beables in our ontology.

configuration space is true, spatiotemporalism is empirically false. Moreover, even if some version of spatiotemporalism is defensible as an empirical truth, its details, including "metaphysical" details such as details about how properties supervene on fusions of spatiotemporal parts, the number of dimensions of the parts, and the overall mereology will depend on the empirical details drawn from the fundamental physics, not primarily on principles drawn from ordinary experience.

Finally, (iii) I'll argue that a metaphysically deeper conclusion follows from the debate over the nature of the fundamental space. Even apart from the empirical issue of which physical theory we will endorse at the end of all enquiry, the debate in physics over which sort of space is the fundamental space suggests that physicists have discovered that, even if a spacetime is an actual constituent of the world-space category, there is a world-space category that is more fundamental than the category of spacetime. The spacetime category, the category of spatiotemporal entities or regions, is not the most fundamental space category: it does not define the nature or character of space. There is a more fundamental world-space category, one we can describe as the category of an *existence space*, which is a category for a space understood as a kind of arena in which the world unfolds. (Here I will draw on Albert 1996 for inspiration.) The debate in the physics can be seen as, in part, a debate over what sort of space occupies the existence category: is ordinary spacetime the actual occupant of this category, or is it some sort of high-dimensional spacetime, or is it configuration space, or some other sort of space?

Any version of spatiotemporalism which takes spacetime to be the most fundamental world-space category is refuted by my interpretation of the debate in the physics. And if the thesis that spacetime is a fundamental category is dropped, then the version of spatiotemporalism that remains is merely an empirical view about some derivative features of the world, and so (unlike the original versions of spatiotemporalism) it isn't telling us about the fundamental categorical structure of the world after all.

As a result, spatiotemporalism does not model the fundamental structure of the world. It might model the derivative structure of the world, but if we are interested in the fundamental constituents, categories and mode of building, it simply won't do. To think it will do is to run together a metaphysics of our manifest image—a metaphysics that is merely a metaphysics of ordinary experiences with a metaphysics of the real or fundamental nature of the world. At the end of the paper, I'll argue that theories of more traditional metaphysical categories should replace spatiotemporalism, and briefly describe my preferred version of such a category theory, mereological bundle theory.

1 Spatiotemporalism

Let's start by giving a more careful account of spatiotemporalism and its intuitive basis. A seemingly natural way to think about the world is as a vast whole constructed by somehow sticking together many smaller pieces. One way to think about this takes the world to be a material or physical thing contained in spacetime: a hunk of matter, constructed in some sense from many physically smaller pieces of

matter, where the smaller hunks of matter are arranged into a big hunk in a way that allows for small empty spaces here and there. The world might be taken to be a spatially three-dimensional hunk of matter existing at only a dimensionless temporal point, at a time we can describe as "the present," or, it might be taken to be a four-dimensional hunk of matter that occupies a wider temporal span, for example, from the beginning of time through to the present time, or even into the distant future.

Spatiotemporalists have tried to develop an account of the fundamental elements of the world and how they are built that respects this natural view of the material world. The deep intuition here is that the world is built from small spatiotemporal pieces of ordinary space in what we can describe as a "geometric" way, a way that fits ordinary spatiotemporal shapes together to arrange the world. Call this the *geometrical intuition*. The commonsensical appeal of classical extensional mereology, if there is any such appeal, derives largely from the way it embeds the geometrical intuition into its axioms and theorems. Accordingly, a popular philosophical approach that preserves the geometrical intuition casts the material or concrete world as a spatiotemporal whole fundamentally constructed using spatiotemporal mereological composition, usually from smaller 3D or 4D spatiotemporal parts of ordinary spacetime.[10] This is what I am calling a traditional spatiotemporal (or spatiotemporalist) view of the material world. This sort of spatiotemporalist holds, just as I do, that there is a world, that the fundamental building relation of the world is composition, and that the world is built by fusing together its fundamental constituents. So this sort of spatiotemporalist also endorses the composition intuition.[11]

The assumption undergirding the traditional spatiotemporal view is that the material world is composed, at bottom, from smallish spatiotemporal parts individuated by their locations. These spatiotemporal parts are thus defined as spatiotemporal regions that include their contents (if they have any), and, importantly for our purposes, the smallest parts are taken to be the fundamental units or building blocks of the world. The spatiotemporal composition relation is the relation that fuses smaller spatiotemporal parts to make larger ones, culminating in the whole material world. In this sense, smaller spatiotemporal parts are more fundamental than larger ones, and the smallest spatiotemporal parts are the fundamental constituents used to make the material whole.[12] This whole is taken to be the entire material world (what Jonathan Schaffer 2010 calls the "cosmos").

[10] For simplicity, I'll ignore endurantist moves like the one where we take parts to simply be *spatial* parts. Such views are also spatiotemporalist in the intended sense.

[11] Many, but not all, traditional spatiotemporalists hold it to be an a priori truth that that there is a world and that the fundamental building relation of the world is composition.

[12] "Fuse into" and "compose" pick out the same relation, as in "the xs fuse into a y" and the "xs compose a y." Composition may be partially defined by its relata, so a spatiotemporal composition relation is a composition relation between spatiotemporal parts. One possibility I am leaving aside for the moment is the possibility that there are no spatiotemporally smallest parts, that is, that the world is gunky. If the world is gunky, then the spatiotemporal view cannot give us the fundamental constituents of the world, although its proponents may argue that very small spatiotemporal parts are somehow suitably fundamental corpuscles. Gunk theorists take the world to be fundamentally spatiotemporal, and so fall victim to the same problems as the traditional spatiotemporalist. Arntzenius and Hawthorne (2005) argue

Figuratively speaking, the idea is that the material world is a sort of jigsaw puzzle that is constructed from fusing together a bunch of smaller spatiotemporal parts. The smallest parts are the fundamental constituents of the world, and by fitting together two or more smallest parts, we fit together small, qualitatively rich, spatiotemporal units to create larger, qualitatively rich spatiotemporal units whose properties and relations supervene on the properties of the parts.[13] The width of the temporal dimension of this spatiotemporal whole depends on one's ontology. If one is a presentist, it is very thin, but if one is an eternalist, it is very thick. The key idea for our purposes is that the material world built in accordance with the geometrical intuition, and all objects, property instances, states of affairs, and other concrete ontological paraphernalia are included in the whole in virtue of having all of their parts included in the contents of the spatiotemporal subregions that define the proper spatiotemporal parts of the whole (Lewis describes this sort of view as a "mosaic" picture. In a recent paper (2011), Richard Healey disparages it as a "Lego" picture of the world).

Recently, two nontraditional sorts of spatiotemporalism have been defended: one sort is a monistic version, according to which the fundamental spatiotemporal entity is the whole world, whether the world is partless or has its parts derivatively. The other sort is a nihilistic version, which takes spatiotemporal simples to be fundamental and denies the existence of composition. Both types of view reject the composition intuition. But most types of spatiotemporalism take the world to be fundamentally spatiotemporal, and take the character of the fundamental space to be defined in part by versions of the geometric intuition. For now, I'll set monistic and nihilistic versions of spatiotemporalism aside in order to focus on the traditional view. I will come back to monism and nihilism later.

David Armstrong describes a substantivalist version of the traditional spatiotemporal approach: "The spacetime world is a structured (that is, related) set of spacetime points. These points are the fundamental particulars. That the points have certain properties and are related to each other in certain ways constitutes the fundamental states of affairs" (Armstrong 1997, p. 6). David Lewis described his preferred picture this way: "all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another… We have geometry: a system of external relations of spatiotemporal distance between points. Maybe points of spacetime itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated… all else supervenes on that" (1986a, pp. xi–x). On the interpretation of "point" that takes it to mean "spacetime point," Lewis is advocating a traditional spatiotemporalist view. That this is his default picture is obvious from his later (1986b) views

Footnote 12 continued
that, for empirical and theoretical reasons deriving from physics and mathematics, the actual world is unlikely to be a gunk world.

[13] Note: for simplicity in Sects. 1 and 2, when talking about the spatiotemporalist view, I will assume substantivalism about spacetime, although I myself prefer relationalism. The relevant issues won't change if we move to a relational theory of spacetime and build in fundamental, external spatiotemporal relations along with the puzzle pieces.

about possibilia, recombination and world-construction based on discrete spacetimes and parts of spacetimes and his acceptance of spatiotemporal mereology. I think some version of this picture is adopted, either implicitly or explicitly, in a wide range of contemporary metaphysical views.[14]

Now, there are two key features of the traditional spatiotemporalist or jigsaw puzzle picture, along with two optional constraints, that I want to develop in order to give the reader a richer sense of the view. One key feature, *compositional structure*, involves the role of composition: each puzzle piece is a spatiotemporal region, a region that needs to be no larger than point-sized, and to build the world, the puzzle pieces are simply fitted together using spatiotemporal mereological composition. The smallest puzzle pieces are the fundamental spatiotemporal parts, and the world is the spatiotemporal whole that they compose, i.e., the smallest spatiotemporal parts are the fundamental constituents, and the world is built by fusing these constituents. But the other key feature, *qualitative regionalism*, concerns the fact that there is more to the puzzle pieces than just being a region of spacetime and thus having a certain spatiotemporal size and shape. Many of the puzzle pieces, in addition to being chunks of spacetime, are qualitatively rich, that is, they have specific qualitative characters in virtue of instantiating various properties and relations. They are "propertied and related." The idea is that the spatiotemporal region of the puzzle piece (or perhaps a substance that fully occupies that spatiotemporal region and is exactly located in that region[15]) is the bearer of the properties of the region.

These two features give us the basics of the traditional spatiotemporal view. On this view, the material world is a kind of glued-together jigsaw puzzle constructed using spatiotemporal composition as the glue. The effect of this method of building is that properties of larger spatiotemporal regions are built by spatiotemporally fusing together smaller, qualitatively rich spatiotemporal regions. In other words, on the spatiotemporal view, properties of larger regions are constructed via the spatiotemporal fusion of their qualitatively rich spatiotemporal parts, so the qualitative character of a larger spatiotemporal region supervenes on the spatiotemporal fusion of its smaller spatiotemporal parts. It's worth noting that the way I've described the view assumes that nothing else is added to make the whole apart from the smallest spatiotemporal parts and the compositional relations: that is, at no point is any other (nonsupervenient) ontological thing added into the world. The

[14] Strictly speaking, Lewis's view only requires the existence of a basic, very spacetime-like entity that occupies the spacetime role and captures the geometric intuition. Lewis usually assumes that spacetime is the occupant of the spacetime role. My arguments apply to this sort of spatiotemporal-role-ism as well, since the intended spacetime role is not filled by, e.g., configuration space, given how different configuration space is from spacetime. (See my discussion of the difference between ordinary spacetime and configuration space in Sect. 2.).

[15] This possibility introduces certain complications that I will ignore below. In particular, we need to be clear about how the substances are mereologically fused when the spatiotemporal regions are fused. Spatiotemporalists usually gloss this issue, assuming that the substances are somehow identical to the spatiotemporal parts, so fusing spatiotemporal parts is the same as fusing the substances. But there is room for a view where the substances are not *spatiotemporal* substances, but prime matter or some such. The issues about building with exactly-located-substances also involve questions raised in Gabriel Uzquiano Cruz's nice paper "Mereological Harmony" (draft ms).

mereological way of capturing this assumption defines the whole as supervenient solely on its (geometrically arranged) spatiotemporal parts. Finally, spacetime is taken to be a fundamental category.

Versions of this view seem to be backed, at least implicitly, by a wide variety of metaphysicians and philosophers of mind, and it is especially prevalent in discussions of spatiotemporal composition and supersubstantivalism among metaphysicians. Many of these philosophers endorse a restrictive version of the spatiotemporal view, a version restricted with two additional constraints. The first constraint holds that all the properties and relations borne by the smallest or fundamental puzzle pieces are intrinsic to their pieces, that is, that these properties and relations do not ontologically depend on any other puzzle pieces, or on the properties and relations of any other puzzle pieces. This is the *locality constraint*: the instantiations of the properties and relations of a puzzle piece are fully defined and restricted by that piece. This adds an additional dimension to qualitative regionalism: the character of a puzzle piece is bounded by that piece. The locality constraint ensures that the properties and relations borne by a specific spatiotemporal region are ontologically independent of the properties and relations of other puzzle pieces. Since puzzle pieces are individuated by spatiotemporal region, this entails that the instantiation of the properties and relations of a puzzle piece are ontologically bounded by the spatiotemporal boundaries of the piece. Each puzzle piece has its own properties and relations if it has any at all, so a puzzle piece is basically a chunk of spacetime that instantiates some properties (and perhaps some relations) within its region. The instantiated properties and relations are had by points or subregions (or substances occupying the points or subregions) in the region, so in this sense, the region is the bearer of the properties and relations, and the instantiation of its ontologically fundamental properties and relations is thus bounded by its spatiotemporal boundaries.

The locality constraint makes sense if we are thinking of the world as a big block constructed from smaller building blocks: if we are to start with a bunch of separate, spatiotemporal pieces and fit them together to create a spatiotemporal whole, the intuitive picture is that each piece has its own regionally specified intrinsic character, and the intrinsic characters, fitted together, are what give us the character of the whole (That said, there are well-known problems with locality given physical facts about nonseparability that need to be addressed. Perhaps the spatiotemporalist will try to hold that the locality constraint fails in certain specifiable ways. See Healey 1989, 1991, for discussion). So we have two key features, the feature that the jigsaw puzzle picture has a certain compositional structure and the feature that the puzzle pieces exhibit qualitative regionalism, and the locality constraint, making the qualitative characters of the smallest regions intrinsic. This gives us a picture where the fundamental constituents of the world are located, qualitatively rich material spatiotemporal points or smallish spatiotemporal regions, where instantiated properties are somehow bounded by the regions that instantiate them, and these regions are fitted together to create larger, qualitatively rich regions.

Qualitative regionalism plus spatiotemporal composition, plus the locality constraint, leads us to the view that the whole material world is built from fusing together spatiotemporal parts that instantiate locally bounded properties, and all

properties of larger spatiotemporal regions are built by simply fusing together smaller spatiotemporal regions. But there is one more constraint that the materialist usually wishes to add: a constraint that prevents the possibility of metaphysically emergent properties. Call this the *reductive constraint*. If we add in skepticism about the possibility of metaphysically emergent properties, the more restrictive version of the spatiotemporal view holds that the complete qualitative character of a spatiotemporal region reductively supervenes on the intrinsic qualitative characters of its fundamental spatiotemporal parts plus the spatiotemporal compositional facts. The reductive constraint ensures that the qualitative character of larger pieces is also intrinsic, and that no new properties, apart from those that are new in the sense that they reductively supervene on the spatiotemporal parts and their relations, emerge when the pieces are joined together.

The most well-known defender of the spatiotemporal view in the last half of the twentieth century was Lewis: he preferred the restricted, traditional version, dubbed it an endorsement of the "Humean Mosaic" and supported it with the defense of his thesis of Humean supervenience. I see echoes of the Lewisian view in many contemporary discussions of fundamental metaphysics, such as in work by authors such as Hudson, Markosian, Cameron, Zimmerman, Horgan, Sider, Schaffer, and many others, although I am not sure any of these authors would commit to every tenet of spatiotemporalism, and I know some of them would reject, at the very least, some of the tenets of the traditional version. My concern is rather that the discussion of mereology, world-building and the nature of the world in spatiotemporal terms in the metaphysics literature seems to proceed without its participants recognizing the empirical and metaphysical implications that traditional spatiotemporalism, monistic spatiotemporalism and nihilistic spatiotemporalism carry with them. That said, Sider and especially Schaffer do recognize and explicitly discuss the empirical connections between their views and interpretations of quantum mechanics. My criticism regarding their spatiotemporalist approaches is merely that the implications of their empirical commitments need to be better understood by others, since their empirical commitments to particular ways of thinking of the fundamental physics are shaping their metaphysical views in ways that need to be explicitly recognized.

In any case, the basic features of the traditional spatiotemporalist view have been around for much longer than the latter half of the twentieth century. The first key feature of the spatiotemporal view, which holds that the compositional structure of the material world derives from the fusion of spatiotemporal parts, seems to be a vestige of ancient Greek ontology that descends from a species of atomism where the world is built by simply sticking together a bunch of atoms and voids. Just substitute in "spatiotemporal parts" for "atoms and voids," taking the atoms to be the qualitatively rich spatiotemporal parts and the voids to be spatiotemporal parts that consist merely of regions of empty spacetime. The second key feature, qualitative regionalism, seems to derive both from atomism as well as seventeenth century corpuscularism, where material corpuscles were the bearers of material properties like charge and mass. For example, in Locke's system, "Much of the persuasiveness of the corpuscular hypothesis lay in its reductive promise. Secondary qualities in particular, such as colors and sounds, but also ideas of macrolevel

primary qualities, including visual sensations of shapes and sizes, and tertiary qualities were to be reduced to the primary qualities of corpuscles…" (Kochiras).[16] In the mechanistic philosophy of the seventeenth century, material corpuscles were taken to be located, qualitatively rich bits of divisible matter; a less restrictive version of corpuscularity might only require that the corpuscles be spatiotemporally defined, qualitatively rich spatiotemporal substances of some sort. Corpuscularism held that corpuscles were the bearers of physical properties, and in this sense, when joined together, could be the ontological (or perceptual) basis for complex properties of larger entities. In corpuscularism and atomism, the qualitative character of macroscopic material entities is determined in a certain sense by the qualitative character of smaller material entities, whether the entities are corpuscles (and hence possibly divisible) or atoms (and hence indivisible and ontologically fundamental). In perfect accordance with the geometrical intuition, one sticks together the corpuscles to get larger material bodies. The traditional spatiotemporalist view is just a modern version of corpuscularism: just take the corpuscles to be potentially divisible qualitatively rich regions of ordinary spacetime that together with empty space (or perhaps the aether) are both the bearers of properties and the spatiotemporal parts fused to build the material world. Nihilism is a modern version of atomism, retaining a version of the geometrical intuition and taking the atoms to be simples arranged in different ways. The monistic versions of spatiotemporalism, on the other hand, bear strong connections to Spinozistic monism.

So spatiotemporalism has a rich philosophical pedigree, from the time of the ancient Greeks to the twentieth century. Nevertheless, we should reject it as an account of the fundamental constituents and construction of the world. Why? Here is a purely "in-house" initial worry about the metaphysics: A broad ontological objection to just about every spatiotemporalist view is that it runs roughshod over concerns about the nature of other categories. If qualitatively rich regions of spacetime are fundamental, does this amount to some sort of nominalist claim, where properties are to be constructed from sets of regions? Or is the view a substance-based claim where the regions are substances? Or is it a substantivalist claim, such that points of spacetime are substrata in which properties inhere? Or some kind of trope bundle theory? If we are proposing to build the world from its most (ontologically, i.e., truly rock-bottom) fundamental constituents, then almost every theory except that of the nominalist breaks propertied and related spatiotemporal parts into more fundamental entities, such as substances instantiating universals. And if that's the case, the spatiotemporal parts aren't the fundamental constituents of the world, something else is (e.g., the substances and universals that compose the spatiotemporal parts), and the fundamental categorical structure of the world is defined by these fundamental constituents rather than by its spatiotemporal constituents. At the end of the paper we'll see how this point supports a return to traditional questions about the natures of the categories.

But there is a powerful additional reason to reject spatiotemporalism (and thus an additional reason to return to more traditional category theory),[17] one that crops up

[16] Kochiras (2009).

[17] See Peter van Inwagen (forthcoming) for two important papers on category theory.

as the result of the variety of interpretations of quantum mechanics that have been developed over the last eighty years or so. We can start with the point that the spatiotemporal view's account of the fundamental nature of the world is inconsistent with a number of contemporary interpretations of quantum mechanics in the philosophy of physics according to which the fundamental space of the world is configuration space, not spacetime. This makes the spatiotemporalist's metaphysics of fundamentality much more dependent on controversial interpretative matters in physics than is comfortable. An account of what is fundamental should be able to make room for a spatiotemporalist view as an option (perhaps after dropping or revising the locality constraint), but should also be able to make room for other interpretations of the quantum state.

More deeply, what the variety of views on spacetime brings out is that there is a kind of methodological mistake involved in the way the traditional spatiotemporal view implicitly relies on ordinary experience and the geometrical intuition when building the world from its fundamental constituents. At the end of enquiry, we should allow physics to tell us what the fundamental physical properties and relations are, and bring those facts into our metaphysical model of the world. Moreover, physics should constrain our theorizing when there are empirical reasons to do so. That said, we should not simply let the physics "tell us" everything about what the world-building relation is, for determining this involves the distinctive sort of metaphysical modeling that philosophers do, and involves a number of philosophical presuppositions about the nature of building, composition, fundamentality, and grounding that are glossed over by the physics. But we have to attend to the science: nobody wants to be inadvertently committed, as a result of unexamined metaphysical presuppositions, to some sort of empirical thesis about the nature of the world that derives from discredited assumptions about spacetime stemming from a seventeenth-century, Cartesian, mechanical picture of the world (Or stemming from the picture given by its close cousin, Newtonian mechanics, often assumed in introductory college physics).

But if the world must necessarily be understood in spatiotemporal "jigsaw-puzzle" terms, this is exactly the position that the traditional spatiotemporalist finds herself in. The versions of spatiotemporalism that reject the composition intuition, monism and nihilism, are in the same (sinking) boat if such views also assume that the physical world is spatiotemporal or assume it conforms to the geometrical intuition at the fundamental level. And even when empirical considerations are explicitly brought to bear, any version of spatiotemporalism that *requires* spatiotemporal regions to be the fundamental constituents relies on a particular, potentially controversial physical view.

Until the end of all theory, it would be better if one's metaphysics of the fundamental construction of the world were not committed to particular, potentially controversial views in physics, and it would be even better if one's metaphysics of the fundamental nature of the world were flexible enough to accommodate the whole range of plausible realist interpretations of quantum mechanics. In fact, I think it is more than just better: I think it is part of the project of metaphysics to provide an account of the world couched in more general categorical terms than those of physics, viz. to operate at the most fundamental categorical levels.

2 Balancing metaphysics with physics

To develop this point, I want to say some more about the methodological issues concerning the objective of metaphysical inquiry. Spatiotemporal views are usually explicitly advanced as ontological claims, that is, as claims about the nature of the actual, material world. Such views are not merely about our conceptual scheme, although, as I will note below, they may be more successful when repackaged as such. The concern is with the determination of the actual, fundamental nature of the world, and as such it is a traditional concern of the metaphysical realist.

How does the project of the metaphysical realist fit together with the project of the scientific realist? Both have the objective of determining the truth about the fundamental nature of reality. Setting aside contexts involving major conceptual revolutions, the two goals are not incommensurable. Rather, they are complementary. For the scientific project is to determine what the fundamental physical constituents of the material world are, where "physical" here picks out the entities that the physical theory needs to quantify over. These physical constituents are the most fundamental constituents of the world that physics can determine using a combination of a priori and a posteriori methods: crucially, there is an empirical or testability constraint on these theories. The standard, and I think correct, view is that an important job of physics is to determine what the most fundamental natural physical properties are. Put another way, the job is to determine which physical properties are perfectly natural, and (as some think) to determine the perfectly natural characteristics of the bearers of these properties.

Metaphysical realism adds to this project, for there is more to determining the fundamental nature of the world than just enumerating which physical properties and bearers of properties exist in the actual world. Some of the additional work is done by philosophers of physics who focus on determining implicit first-order ontological commitments of physical theories. But some of the additional work to be done derives from the metaphysics of category theory, whose project is to determine the natures of the fundamental constituents of the world, and thus the fundamental categories of the world. The categorical project is not to determine *which* physical properties and objects there actually are, but *what* physical properties and objects fundamentally are. This involves the study of what the categories *are*, not just what they actually contain.

To elaborate: the metaphysician asks about what sorts of things properties *are* (e.g., universals or tropes)? Or, for example, what *are* bearers of actual properties? And: do the objects of scientific theories have further fundamental ontological structure (e.g., are events composed of individuals having properties at locations)? Although the division of labor is not sharp, roughly, we can think of science as telling us which physical properties, structures and objects actually exist and are perfectly natural, while metaphysics tells us what it is to be the sort of thing that these properties, structures and objects are. Science tells us which physical entities are instantiated, while metaphysics explores their categories. The point connects to world-building: the scientist may tell us that the constituents of a cell are certain molecules and bonds arranged in a particular way, while the metaphysician may tell us that these constituents arranged in this way make the cell in virtue of *composing*

the cell, that is, they tell us what it *is* for the molecules and bonds to be constituents of the cell.

So metaphysics is concerned to tell us what the categories of the fundamental constituents are and whether and how members of these categories are combined to create the material world, while science tells us what many of the actually instantiated members of the categories are.[18] Physics tells us which fundamental (i.e., perfectly natural) physical objects, structures and properties are the actual members of the ontological categories, and metaphysics takes it a level deeper, by telling us what the fundamental categories are, and adding any needed supporting properties and relations (such as identity, ground, composition, etc.). If we take composition to be the world-building relation, as I think we should, we can think of metaphysics as telling us whether there is such a relation, what it relates, and what its features are.

The separate-but-connected relationship between science and metaphysics means that even though metaphysicians have their own job to do, they need to pay attention to the science. Metaphysicians need to pay attention to the science for many reasons: it could turn out that the perfectly natural physical properties of the world do not include or even preclude the sorts of properties that metaphysicians initially wanted to use in their construction of the bearers of the properties of the material world, or that the perfectly natural physical properties of the world do not include the sorts of properties that metaphysicians wanted to use as elements of the worldly structure. In particular, it might turn out that according to our best physical theories, the fundamental or perfectly natural physical properties of the world do not include spatiotemporal properties. There are further ways in which science could inform metaphysics. It could conceivably turn out that the perfectly natural physical structures of the world violate principles of classical extensional mereology, such as uniqueness. Or that there exist physical cases where the sum or whole of some parts includes more than just those parts and their relations. If such cases turn up, the metaphysician should re-evaluate the relevant ontological claims she is using to build her model of the world, and make sure her compositional assumptions do not violate the known empirical facts.

In any case, the metaphysician who wishes to build the world from its fundamental constituents must build the world using properties and relations and objects that are fundamental. She must not build the world using properties and relations and objects that are not fundamental, or worse yet, try to build the world using properties and relations and objects that physics denies the existence of.

With this perspective in mind, we can now develop the difficulty for the spatiotemporal view. Recall that the objective is to understand the fundamental ontology, the fundamental categorical structure, and how the world is built from its fundamental constituents. The traditional spatiotemporal view takes some or all of the fundamental constituents of the world to be spatiotemporal parts, i.e., chunks of spacetime, many of which are qualitatively rich, and the building relation to be

[18] As I said, the division of labor isn't sharp. For example, science can force revision of category theory on metaphysicians, as demonstrated by my view that physics tells us about the category of an existence space. I discuss these methodological issues in my (2012).

spatiotemporal composition. Spatiotemporal parts are then fused to create larger parts with more complex properties, until we reach the material whole, which is the fusion of all the spatiotemporal parts, the spatiotemporal manifold.

The trouble is, taking the fundamental constituents of the world to be chunks of spacetime is inconsistent with interpretations of quantum mechanics that take configuration space as the fundamental space (for example, see Albert 1996). According to a range of configuration space realist or "wave function realist" interpretations of the ontology of quantum mechanics, qualitatively rich hunks of spacetime are not the physically fundamental constituents of the world. In particular, wave functions for particles are defined on the configuration space of the system, not on spacetime as we know it. As David Wallace and Chris Timpson describe the idea: "If wave-function realism is correct (and if it alone, and not some hidden variables, is the physical basis for observed reality), the world is really 3 N-dimensional at its most fundamental level, and our 3-dimensional world is in some sense emergent from it" (Wallace and Timpson, 2009). Wallace and Timpson are using "emergent" in a broader sense, consistent with the view that spacetime metaphysically emerges, but also consistent with the more minimal claim that spacetime is merely phenomenally emergent. Loewer (2004) notes that we could take some theories of fundamental physics to suggest that spacetime is just a kind of phenomenal shadow that arises from the real world, the configuration space world.

The main thing to understand here is that, if configuration space is the fundamental space, then the fundamental ontological facts are very different from what the spatiotemporalist take them to be. In particular, configuration space is so different from ordinary space that the geometrical intuition that stems from our ordinary experience may no longer capture the nature of the space. This is most obvious in the case of the traditional spatiotemporalist, for the configuration space realist or "wave function realist" holds that qualitatively rich hunks of spacetime are not the fundamental constituents of the world. If any such view is right, this implies that traditional spatiotemporalism is false and that spatiotemporal composition cannot be the fundamental composition relation used to build the world. Although the problem is the most glaring for the traditional spatiotemporalist, the possibility that the fundamental space is configuration space is obviously equally serious for the nihilist or monist spatiotemporalist. Don't be lulled into complacency by the use of the term "space" in "configuration space," for the problem runs deep: in other words, it isn't just a terminological issue. We cannot simply replace our talk of "spacetime" with "configuration space," and go on as before, as the nature of configuration space is very different in kind from the nature of ordinary space. In particular, the nature of the space is no longer determined by the geometrical intuition.

It is worth expanding on this difference to bring the point home. We'll have to do this in a rough, capsule form, but here's a go, using Alyssa Ney's (forthcoming a) way of bringing out how, at least under a standard interpretation of configuration space realism, configuration space is different from the ordinary space of our manifest image. Imagine a table leg that, in ordinary spatial terms, is 29″ high. Roughly speaking, we can capture this in a mapping of a system S of two particles of the table leg using the usual notion of spatial length in the y-dimension. We do it

by taking a particle at a point at the top of the table leg located on the y-dimension 29 inches above a particle at a point at the bottom of the leg located at 0 on the y-dimension to represent the height of the table leg. The height or extension of the table leg in the y-dimension of three-dimensional space is captured by the representation of the particles as being located at these two points along the single dimension. But in configuration space, the same system S is represented by a single particle in a six-dimensional space, where there is nothing that corresponds to our ordinary notion of the height of the table leg in the y-dimension. Instead, in the configuration space version of the system, all we have is a single particle with a location in a six-dimensional space, with its position partly defined by two different values assigned to two different dimensions of configuration space. "None of the … dimensions of the configuration space correspond to our ordinary dimension of the height, nor to any of the other two dimensions of our manifest image." (Ney forthcoming a). There is no dimension of extension in configuration space that corresponds to our ordinary dimensional representation of the height of ordinary objects, nor is there a dimension that corresponds to our ordinary or manifest dimensional representation of the length of ordinary objects, or of the width of ordinary objects. Thus, our classical way of thinking of objects as extended, three- or four-dimensional objects composed from three- or four-dimensional spatiotemporal parts simply fails to carry over to the way that configuration space represents these objects. And thus, it is entirely unclear how the geometrical intuitions drawn from the manifest and built into classical spatiotemporal mereology would have anything to do with the way we'd want to mereologically build the world from fundamental constituents in configuration space.

To bring the point home, let's look at one way the world could be from the point of the configuration space realist. In David Albert's Bohmian interpretation of quantum mechanics, we have a wave function that determines the features of the world particle at points of configuration space. Instead of a many-particle world, on Albert's interpretation, our world is a single particle that lives in a very high-dimensional configuration space. Ordinary objects are recovered at a less fundamental level by means of an account of how the world particle in its high-dimensional space plays a role in giving rise to the 3D features of our manifest image.

On this sort of physical picture of the world, at the fundamental level, the commonsensical picture painted by the spatiotemporalist is entirely lost. Consider the world at a point of configuration space. Think back to the guiding image of the traditional spatiotemporalist: each spatial stage of the world at a time is built by fusing together small propertied and related regions. On the Albert picture, in contrast, each stage of the world is a single point of a high-dimensional configuration space. There is no "fitting together" in our geometrical sense of fitting together spatiotemporal parts to create a stage of the world—hence the world at that point has no (fundamental) internal spatiotemporal compositional structure. For this reason, it is manifestly false (given Albert's interpretation) to take the fundamental world-building relation of the world at a point in configuration space to be *spatiotemporal* composition, for the fundamental constituents of the world at this

point in configuration space are only the point, the wavefunction and the properties and relations of the world particle.[19]

What we can retain, as I'll explain in Sect. 3, is the notion of world-building as composition, even in a configuration-space world. This is because we can retain the world-building relation without retaining spatiotemporal composition or the geometrical intuition. More precisely, we may retain some of the *formal* principles of our compositional approach, *if* enough of the formal compositional principles that guide our new mereology are the same formal principles that we used to guide our discarded spatiotemporal mereology. What we should not retain are the *material* compositional principles of the spatiotemporalist: the principles tied to the character of ordinary spacetime and its ordinary spatiotemporal parts, i.e., principles that embed the geometrical intuition (See Fine 2010 for a related formal-material distinction).

As I mentioned above, there are other competing interpretations of the quantum state available, including Wallace and Timpson's (2009) spacetime state realism, which make room for spacetime at the fundamental level. But even they point out that "it is also worth keeping in mind that many workers in quantum gravity have long taken seriously the possibility that our four-dimensional spacetime will turn out to be emergent from some underlying reality that is… not spatiotemporal at all (as in the case of loop quantum gravity)." So we need to be prepared for the possibility that spacetime is entirely phenomenal. And, even if spacetime turns out to be physically fundamental, the resulting picture is very different: for example, Wallace and Timpson's spacetime-state view must explicitly reject the locality constraint and may even reject the reductive constraint and regionalism in order to accommodate empirical facts about entangled systems and nonseparability.

No matter what interpretation of the physics one prefers to defend, my point is intended to draw out the general lesson that it is by no means clear that spatiotemporal regions will end up being classified as among the perfectly natural, physically fundamental entities—and it is even more unlikely that spatiotemporal parts and properties will end up being classed as the *only* fundamental constituents of the world. The empirical lesson from physics is that metaphysicians *must not assume* a priori that the nature of the world is fundamentally spatiotemporal or that spatiotemporal regions are the fundamental constituents that are fused together to compose the material, physical world. And so they must reject all naïve, a prioristic versions of spatiotemporalism. And if they do decide to endorse some a posteriori version of spatiotemporalism, they need to be clear about their empirical commitments and defend their views in an empirically informed way. To not realize one has even made an empirical choice by defending spatiotemporalism is a naïve commitment. To make an empirical choice in fundamental physics based only

[19] There is a related issue here involving a possible move, analogous to the spatiotemporalist's treatment of temporal parts, of fusing the points of configuration space together to make an extended whole. Since we aren't preserving spatiotemporalism (recall how, for example, our ordinary notions of height along a dimension and length along a dimension are replaced in the configuration-space picture), the rules of configuration-space composition need to be examined. In particular, it isn't clear to me that a classical extensional mereological treatment of configuration space generates the best metaphysical picture of the evolution of the world particle through configuration space. We certainly can't just *assume* this.

on how well the interpretation satisfies common sense intuitions about the manifest is even more naïve.

There is another lesson in the offing, one that can raise problems even for a spatiotemporalist who is up front about her empirical commitments. The lesson involves metaphysical category theory: in brief, the range of interpretations of quantum mechanics tells us that neither ordinary spacetime nor the higher-dimensional spacetime of string theory define fundamental ontological categories. Contemporary physics has discovered that the world is such that there might be other, potentially more attractive options for what we mean by a "space."[20] And this tells us, at the very least, that it is conceivable that the most fundamental category of the space of the world is not a spatiotemporal category. If so, the most fundamental category of the space of the world is a more basic category—a category that a spacetime could be a member of. And this means that any version of spatiotemporalism that, either implicitly or explicitly, takes it to be a conceptual truth that the most fundamental category of the space of the world is a spatiotemporal category, is false.

The more fundamental category for the space of the world suggested by the proliferation of quantum–mechanical theories is the category of an *existence space*. David Albert, in his account of a world where configuration space is physically fundamental, tells us:

> There are (you might say) *two* ideas we're accustomed to having in mind when we think of 'physical space'. There is, to begin with, the space of possible *interactive distances*, the space (if there is one) that one reads off of the formal Pythagorean relations among the individual terms in the world's Hamiltonian—irrespective of whether those terms are considered as classical variables or quantum–mechanical operators… And then there's an altogether different idea (and an altogether more *fundamental* one, it seems to me; but let's not squabble about that for the moment) of an *arena* within which the dynamics does its work, a *stage* on which whatever theory we happen to be entertaining at the moment depicts the world as *unfolding*…" (pp. 282–283, Albert 1996).

The existence-space category is a category of the space of the world understood as an arena or stage where the world unfolds. Perhaps some n-dimensional spacetime is its most basic member. Or perhaps it is configuration space. Or perhaps it is some other sort of space.

Once we see that it is conceptually and empirically possible to make sense of a more fundamental sort of world-space category, a category of an existence space, it becomes straightforward to argue for a corresponding metaphysical conclusion. What the proliferation of alternatives to ordinary spacetime teaches us is that what the fundamental space of the world metaphysically *is*, that is, what the category or the nature of the fundamental space of the world is, is not spatiotemporal. The *essential nature* required of the most fundamental space of the world is an ability to function as a stage or as an arena. Ordinary spacetime can function this way, but so

[20] This also ties to issues about a Kantian notion of space or location that might actually work as a synthetic a priori hypothesis.

can other sorts of spaces. And thus, the most fundamental nature or category of the space of the world is an existence space category, not merely a spacetime category. And it is precisely this fact, the fact that the fundamental nature of the space of the world is not defined by the spatiotemporal, but rather by something *deeper*, that undermines the central metaphysical intuition supporting spatiotemporalism.

There is an interesting consequence of this objection to spatiotemporalism. As I've noted, we need to recognize the possibility that we might ultimately endorse the view that spatiotemporal entities are among the fundamental constituents of the world. But now we also know that, given our best empirical evidence and current conceptual stance, we should not construct a model of the world where "spatiotemporal" names a fundamental metaphysical category. So—here's the interesting consequence—we should instead endorse categories that are more general, ones that can handle the variety of possibilities that physics gives us.

And what this means is that our reflection on the quantum mechanical facts provides a route to a much older way of thinking about the metaphysical categories. An especially good way to capture the lessons we've learned from quantum mechanics may be, interestingly, to go back to a way of thinking about the world that descends from Aristotle. Instead of assuming that the world is fundamentally spatiotemporal, what we need for our categories are more general fundamental categories like "n-adic property category" or "substance category" along with a new category, the category I've described as an "existence space." Think of the fundamental properties and relations as members of the n-adic property category. Think of the fundamental individuals, points or regions as members of the substance category. Think of the most fundamental space of the world as an existence space, or as an arena. Then—to preserve the composition intuition—think about how these categories are related and how the world should be mereologically built from members of these categories. Part of what we need to do is to make sure the category of the fundamental space fits with the other categories, whether it fits by being reduced to these other categories or as an additional fundamental category in its own right. We need the right fundamental categories, we need the right relations between the categories, and we need the right sort of composition, and then we can develop the right sort of account of compositional world-building (varying the material principles as the science directs us).

The reason why, then, that we need to reject spatiotemporalism, is that we need a more flexible or more ontologically friendly way to understand the fundamental nature of the world. The trouble with all the spatiotemporalist views is that they commit us to a very particular sort of outcome in physics, viz. they commit us to the view that the final interpretation of the quantum mechanical state will take a spacetime to be the fundamental space. Versions of the view that endorse the composition intuition commit us even further, to a picture of the world where the world is built with spatiotemporal mereological composition as the fundamental glue. As I've emphasized, I have no problem with the metaphysical thesis that composition is the fundamental glue, if anything is. But having one's theory based on the view that the fundamental nature of the world must be spatiotemporal, or that three or four dimensional spatiotemporal regions are the fundamental constituents, or that the fundamental glue is *spatiotemporal* composition involving

spatiotemporal regions or parts as relata, or that the world must be built in a way that respects the geometrical intuition, involve problematic commitments to empirically controversial features of the natural world, and fail to capture the metaphysically fundamental categorical facts. It runs together a metaphysics of the manifest image with a metaphysics of the real, that is, a metaphysics of the fundamental nature of the world. Thus, spatiotemporalism should be shunned by the metaphysician who wants to develop the best account of the fundamental structure of the world.

So what we want is an understanding of the world that is not dependent on a particular, spatiotemporalist interpretation of the physics. As metaphysicians, we need to look for a deeper account, ideally one that can capture the composition intuition and the categorical facts while being consistent with a wide range of physical possibilities.

3 Building the world from its fundamental constituents

As I've been arguing, an important job for the metaphysician is to determine the fundamental structure. We need to focus on the right structure when we are making claims about what the fundamental joints of the world are; in particular, we need to focus on the right categorical structure. A way to put the point about categorical structure uses an example. Imagine taking a pile of blocks and gluing them together to build a tower, and now imagine the tower to represent the whole material world (Not everything about the world-as-Lego picture is wrong). Recall the metaphysical task: to discern the fundamental categories, constituents, and world-building relation. To accomplish this metaphysical task, we need to discern the categories that the constituents (the blocks) belong to, and the rules that govern the "sticking together" relation (the glue). To discern the fundamental structure of building we must discern what is categorically common between different physically possible ways of building the world, and we need to discern the rules followed by the building relation.

In terms of our tower of blocks example, the metaphysician would be making a mistake if she focused on the color of the blocks, or on how they were made of wood or how they were made of plastic, or on irrelevant features of the glue used, to get insight into what is needed to build the tower of blocks. Even if, as a matter of contingent fact, I selected only blue wooden blocks and blue glue to build my tower, the same categories and structure would obtain if I'd used some yellow plastic ones along with some blue ones, or if I'd built the whole thing using red blocks and orange glue. The metaphysician doesn't want an account of how to build the tower that is restricted only to yellow blocks and yellow glue. She doesn't want an account of how to build the world given only in terms of blue blocks and blue glue. She wants to know how to build a tower of blocks with any color of blocks, using any kind of glue (as long as it performs its function, of gluing); her job is to figure out that we need the category of *blocks* and the category of *glue* to do the building, in order to arrive at a model of the *fundamental* structure.

Once we have our fundamental categories and our world-building relation, facts about the physics play a larger role (Physical facts played a pretty large role already, but here they come into their own). The philosopher of physics may argue that our best physical theories will tell us at some point that, say, the world actually is built from a wavefunction. Or perhaps it is built from some sort of spatiotemporal entity. Or perhaps from something else. In terms of the building-blocks metaphor, the philosopher of physics may argue that the world is constructed from (the equivalent of) blue blocks and blue glue, say, by arguing for particular entities as members of the class of perfectly natural physical properties.

As I've emphasized, the trouble with the traditional spatiotemporal view is that it was defined in terms of a particular sort of natural feature of the world (e.g., being a *blue* block): i.e., in terms of spacetime and spatiotemporal regions instead of in suitably neutral or suitably categorical terms (i.e., in terms of simply being blocks of some sort, or in terms of being a member of the *block* category). And this, in turn, led to the false assumption that we had to use blue glue (a form of spatiotemporal composition that embedded the geometrical intuition) to build the world. While this might not have seemed like a problem before the scientific discoveries of the twentieth century (it might have seemed like the tower *had* to be made from blue blocks, since that was the only color of block in the toybox), recent advances in physics have shown us that space, time and spacetime may not be fundamental entities, and indeed, that there may not even be any such thing as spacetime. Physics has shown us that the possibilities for fundamental entities are wider than we thought (somebody had a birthday, and got more blocks).

If we don't presuppose traditional spatiotemporalism, but we have the composition intuition, how do we build the world? In other words, how can we build the world if we don't build it in accordance with the geometrical intuition, that is, if we don't build it by fitting together spatial shapes?[21] As follows. The fundamental constituents we use to build the world are determined by first correctly identifying the ontological categories. I've already suggested that one of these fundamental categories is the category of *property*, where this includes relations (which are dyadic, triadic, etc., properties). Are there other fundamental categories? Some think there must be at least one more fundamental category in addition to the property category. In particular, some think there must exist at least two categories: a category of substance (or of nonqualitative individuals) and a category of property (including relations). This view has some historical precedent. I've also argued that the category of an existence space is more fundamental than the category of spacetime. Perhaps it is a fundamental category, though I doubt it; it is more likely a subcategory of the category of property or substance.

There are some interesting issues here: issues that I will largely put aside in this paper (See my "One-Category Ontology" and my "Categorical Parsimony" as well as Dasgupta 2009; Koslicki 2008; Wilson 2012 for discussion of many of these issues). Nevertheless, a few words are in order. The choice of which categories are the fundamental categories of the world is a choice about the world's structure, for

[21] Take fitting together unextended spatiotemporal points to be the "null" case of fitting together spatiotemporal shapes.

the number and nature of the world's fundamental categories determines the fundamental categorical structure of the world, as it determines the fundamental natures from which everything else is constructed. To see this with a bit of context, contrast two views, the view that, to capture the fundamental structure of the world, we need a category of substrata along with a category of properties, with the view that we only need a category of properties.

These two views clash with respect to how many and what types of fundamental categories they endorse, and this clash is defined by the debate over whether, to capture the nature of reality, we need properties *plus* ontologically distinct bearers of the properties, or whether we can construct everything there is from properties alone. The defender of the substratum view in effect argues that we need a distinction between the bearer and what is borne in order to capture the structural facts about, say, the qualitative symmetries of the world. For example, can a world without substrata have a structure that includes multiple purely qualitative duplicates scattered across different locations? Or do we need primitively distinguished bearers to serve as distinct structural nodes? These questions interact with how the world is supposed to be built: can we build the world purely mereologically with only properties as its constituent parts? Or do we need fancy additional relations like "consubstantiation" in addition to the composition relation in order to recover needed structure? The questions continue: if we endorse the substratum ontology, can the distinction between property and bearer work in such a way so as to support world-building using only a conservative, classical extensional mereology? Can we think of "bearing" as a mereological relation, or do we need yet another primitive constructive relation at the fundamental level to generate the overall structure of the world? Etc.

These are difficult questions, and I don't propose to answer them here. My own view is that the structure of the world requires only a single category and a single building relation: the category of property and the building relation of composition, but that the building does not need to respect the geometrical intuition. We can characterize the structure of reality while maximizing ontological parsimony by taking the sole fundamental category to be the property category, and taking the building or making relation to be property composition. The composition relation is one of the relations in the n-adic property category, and the category of existence space is folded into the n-adic property category by taking the space to be defined by its characteristic properties and relations.

My point in this paper, however, extends past my particular views about which category theory to adopt. Here, I mean to argue only that metaphysicians need to dispense with the parochialism of spatiotemporalism and its geometrical intuition and move to a compositional account of the world in terms of fundamental category theory. I take it that there are a variety of ways to give a compositional account in terms of category theory: a way that might appeal to former fans of spatiotemporalism could involve building the world mereologically from substrata and properties. My work elsewhere argues that there is no deep ontological reason to endorse a categorical distinction between bearer and borne, but here I argue only that the metaphysican should dispense with spatiotemporalism by taking the

fundamental categories to be suitably general and building mereologically from the fundamental categorical constituents.

That said, we need a case study to develop the way we should be thinking about how to replace the spatiotemporalist view. So I propose to take my view, mereological bundle theory, as a case study to show how a more flexible, ontologically more general approach to the construction of the world could work.

My view builds the world from n-adic properties (which include relations) using property composition. So I take properties and relations as the blocks, and property composition as the fundamental glue. Thus, I propose a property mereology, where the fundamental building blocks are properties or qualities (we might be able think of them as universals of some sort, although I am not wedded to any specific view), cemented by a (primitively restricted) composition relation that takes n-adic properties as its relata.[22] For further details see the Appendix, "Mereological Bundle Theory."

According to mereological bundle theory, the world (here, I need not confine myself to the physical world, so by "world" I mean the whole world, not just the cosmos) is a vast mixture of properties, some with a single location (whether in configuration space, or in spacetime, or in something else), some with many locations, some located everywhere, and perhaps even some without any location at all (Locations are defined by n-adic properties. For simplicity, take the fundamental space to be relational, and define up "points" in the space using these relations and properties). The world is constructed from arrangements of properties and relations that are fused together to make things of all sorts: concrete objects, abstract objects, events, states of affairs, facts, fields, regions, and anything else there is. So, according to the mereological bundle theorist, fields, particles, entangled systems of particles, spaces, molecules, cells, bodies, persons and societies are all constructed, most fundamentally, from fusions of properties and relations.

Objects may have their locations in virtue of being fused with whatever location properties and relations there are that define the actual space of the world, and many objects will have a physical structure in virtue of having location properties and relations as parts of their fusions, or in virtue of being part of a larger fusion which has location properties and relations as parts. The character of the space might not be what we take the character of ordinary spacetime to be, but the structure of the space is generated by fusing qualitative properties with relevant properties and relations that define the space as determined by modern physics. Hence, the view is consistent with (and explicitly accommodating of) various approaches in modern physics: it is friendly to structuralism, and is perfectly consistent with realist interpretations of the ontology of quantum mechanics, for example, with realism about the wavefunction.[23]

[22] I find Wilson (2012)'s defense of fundamental determinables interesting and plausible.

[23] Note: because I am concerned primarily with various sorts of "spaces" needed in fundamental physics, my discussion does not need to engage directly with some other common themes in the philosophy of physics, such as the dispute between advocates of Bohmian mechanics and the Copenhagen interpretation about how to handle the measurement problem. (For example, we can understand Bohmian mechanics in terms of configuration space, and the same goes for the Copenhagen interpretation).

(What about spatiotemporal composition? Whether we need it or some spatial analogue will depend on the ultimate empirical facts. We might need to add it to our ontology, perhaps by taking it to supervene on certain sorts of qualitative compositional facts. It exists, it just isn't fundamentally spatiotemporal composition, it's a restricted kind of property composition. Another thing we might do is become fictionalists about spatiotemporal composition. We can regard it as a handy conceptual tool, but one without ontological import. The view of spatiotemporal composition as a purely conceptual tool has interesting intersections with methodological questions. In the latter part of the twentieth century, work in contemporary metaphysics shifted from a focus on the analysis of various concepts to the investigation of the ontological entities those concepts referred to. Some of the work done on the metaphysics of mereology, especially some of the work on composition, makes more sense to me when understood as an attempt to analyze mereological concepts rather than to determine the mereological ontology. For example, I find some of the work on the nature of spatiotemporal composition that takes a nihilist stance very convincing when understood as an evaluation of whether claims we make about the compositional structure of complex objects (such as a claim that such and such object is "a whole composed of parts") are analytic or synthetic. For similar reasons, claims about a particular sort of composition as necessary or as entailed by metaphysical laws seem much more plausible when understood as claims about analyticity: for example, it might be analytic that our usual concept of composition is a concept of restricted composition. This sort of thesis is much clearer to me than the claim that composition itself is necessarily restricted: how can we tell whether it is a necessary *fact* that the composition relation itself is restricted? We can't go to merely possible worlds and check, and there is no contradiction in taking composition to be restricted, or in supposing that there are different "metaphysical laws." I also suspect that it is perfectly conceivable that the compositional facts according to our usual concept of composition could be different in different worlds, and so deny the analyticity claim too).

Getting back to the main point, mereological bundle theory entails a rejection of two related assumptions. The first rejected assumption is that we need a fundamental ontological distinction between objects and properties, one that is somehow reflected in our use of predication and predicative description. This rejection is expressed by the fact that, according to mereological bundle theory, all we need to build the world are n-adic properties.

The second rejected assumption, the one which I want to focus on here, is a rejection of the geometrical intuitions of spatiotemporalism. I reject the intuition that we should think of the world as built by fitting small spatiotemporal pieces together into larger spatiotemporal pieces, perhaps culminating in a largest spatiotemporal piece, the spatiotemporal manifold and its contents. This rejection is expressed by the fact that mereological bundle theory supplants classical extensional mereology with a fundamental mereology of properties. By holding that the world is built from properties rather than spatiotemporal parts, the mereological bundle theorist rejects the assumption that the fundamental blocks of the world must be spatiotemporally localized units that build larger regions based on "geometrical"

principles. Instead of building from small shapes to big shapes, we build from the qualitatively fundamental to the qualitatively supervenient. The overall structure of the world is created by the fusion of fundamental properties, not by fusions of fundamental localized particles or their equivalents, qualitatively rich spatiotemporal regions, leaving room for the likely possibility that some of the fundamental properties fused to make the world are holistic properties effectively distributed across a region. Mereological bundle theory thus rejects the corpuscularism embedded in traditional and nihilistic spatiotemporal views where the world is fundamentally a vast mosaic of localized properties instantiated at spatiotemporal points (or the version described by Armstrong where we have located states of affairs), along with the corpuscularism embedded in traditional trope bundle theories like that of Williams (1953), where the world is assumed to be constructed from spatiotemporal fusions of point-sized spatiotemporally localized bundles of compresent tropes (It's worth noting that even though I've rejected the corpuscularism of spatiotemporal views in the sense that I reject that the world must be understood in these corpuscular ways, I leave room for an account of the world as built from fusions of spatiotemporal properties and relations with a geometrical structure, should this turn out to be the best empirically supported option).

The main feature I am retaining from the traditional spatiotemporalist way of building the world is the notion that "building" is a compositional notion, so I retain the composition intuition while jettisoning the geometrical intuition. Keeping the compositional structure of the world, even if changing its character by changing the nodes of the structure to qualitative nodes rather than spatiotemporal ones, means that we keep a form of the picture of the world as layered with "smaller" parts building "up" into "larger" wholes. A fan of compositional nihilism could reject the composition intuition along with the geometrical intuition and take the world to be a world of arranged pluralities of properties. And a fan of priority monism could reject the geometrical intuition and reverse the order of fundamentality, so that the property-whole is fundamental and decomposes into less fundamental property parts.[24]

So property mereology is a more flexible sort of composition: it is based on fusing properties together rather than on fusing entities with only the sort of qualitative character suitable for geometrical building (e.g., the qualitative character of being 3D or 4D spatiotemporal). In property-theoretic terms, since mereological bundle theory does not require the fundamental property category to include spatiotemporal properties, it can accommodate a much wider range of possibilities for the qualitative character of the fundamental entities. This means that a property mereology could accommodate the possibility of spacetime and spatiotemporal

[24] The priority monist who takes the spatiotemporal whole to be fundamental can do so as long as she is clear that this is an empirical claim that relies on spacetime being the most fundamental constituent of the world-space. By extension, she should not take the metaphysical nature or essence of the world-space to be spatiotemporal: instead, its nature is (at least in part) to be an arena or a stage. If it turns out that configuration space is the fundamental space, this sort of monist would replace spatiotemporal decomposition with a mode of decomposition appropriate for configuration space—perhaps a mode of property decomposition. This version of monism would be broadly consistent with Schaffer's (2010) approach (Jonathan Schaffer, personal communication).

properties playing a role at the fundamental level as the actual occupants of the fundamental categories (although the composition would still be in terms of properties), could accommodate the higher-level emergence of the spatiotemporal, or could even accommodate spacetime as merely phenomenal.

For example, if some suitably conventional realist version of string theory or, perhaps more broadly, a version of Wallace and Timpson's spacetime state realism turns out to be right, the property mereologist can take the fundamental building blocks to be spacetime states or regions that are, fundamentally, fusions of properties including certain abstract properties, local or nonlocal, emergent or not, perhaps represented by density operators associated with those regions (Wallace and Timpson champion such abstract properties). These in turn could be fused together to create the world, either using property fusion or using emergent spatiotemporal fusion (And the property fusion of certain *located* properties or regions could mimic spatiotemporal composition). But a property mereological view can also accommodate a very wide range of other possibilities for the fundamental constituents of the world. For example, it can handle a straightforward view where particles of some sort that instantiate properties, such as having a certain position (in some defined sense) or a certain momentum, function as the fundamental entities. Such particles would be fusions of n-adic properties, and could be further fused together to build the world. Or take the wavefunction in configuration space to be fundamental, where properties are thought of, roughly, as intensities at locations that are represented by complex numbers. Take the value of the field at a point of configuration space to be the instantiation of a property (say, an intrinsic property), and fuse these properties to create larger entities.

Indeed, as long as a physical theory is formulated in terms of properties and relations, however abstract, property mereology can be used to describe the way the fundamental entities are composed to construct the world. Different relations or structures play different roles in different theories, but in each case, we simply take the properties and relations described by the theory as fundamental, and take the internal (and external) structure of the fundamental entities to involve relations included in the fusion, and the view can be understood in a property-mereological sense.

To underline this last point: every fundamental physical theory ever given, including all of those currently on offer, is or can be couched in terms of properties and relations, even if these properties and relations are extremely abstractly specified. As long as a physical theory about the fundamental nature of the world is developed in these terms, it is in effect a theory that tells us what the physically fundamentally or perfectly natural properties (and relations) are, and so it is a suitable candidate for a property-mereological approach to the world. Of course, physical theories also talk about objects and structures: structures are just systems of relations, and any physical structure imputed to the world is either part of the fundamental structure of the world, and so part of the fundamental relations or properties fused to create higher levels, or supervenient on fusions of properties and relations. But objects, according to the property theorist, are also fusions of n-adic properties, so the objects specified by the physics reduce to fusions of n-adic properties as well (Part of my argument against the substratum view is that the assumption that we need primitive substrata or individuals is simply an artifact of

our default Aristotelian picture of the world, or perhaps it's a bad hangover from the ordinary language party at Oxford).

Let's look quickly at another property-mereological treatment of fundamental physics using the perspective of the wave-function realist who takes the world-whole to be a wavefunction defined on configuration space. On the GRW theory of the world, the world is a universal wave function that evolves in accordance with the dynamical laws. Understood in terms of mereological bundle theory, the wavefunction at a point of configuration space is the fusion of amplitude and phase properties (along with any other properties of the system) with structuring properties or relations, including the structuring relations described by Schrödinger's equation and by the collapse postulate. A variant of this view can fit the view we discussed above, David Albert's (1996) treatment of Bohmian mechanics, by adding a world-particle that is a fusion of properties to the plurality of things.

There is something important going on here with the mereology in these two systems: the GRW theory and Albert's Bohmian interpretation of quantum mechanics both involve a certain amount of holism. What exactly is meant by "holism" is tricky, but it is standardly understood to involve the thesis that objects are not reductively composed of smaller spatiotemporal or "physical" parts, or to involve the thesis that the qualitative intrinsic physical properties and relations of an extended region do not supervene on the qualitative intrinsic physical properties and relations of their smaller spatiotemporal or "physical" parts. Take Albert's view: one of the fundamental constituents is the world particle at a point of configuration space, and this world particle is not composed of smaller spatiotemporal or "material" parts. Support for holism comes from, among other things, empirical facts about entangled states that occupy spatiotemporal regions, for their qualitative intrinsic physical properties and relations do not supervene on the qualitative intrinsic physical properties and relations of their subregions.

What our discussion brings out is that support for holism in quantum mechanics needs to be disentangled from theses that provide support for compositional monism. That is, holism in quantum mechanics is perfectly consistent with the composition intuition, and thus to support holism we need not reject the composition intuition that composition runs from part to whole. Once we distinguish between varieties of categorical composition, we can distinguish between different options for the kinds of composition involved in world-building and the question of whether, if there is composition, it runs from part to whole or from whole to part. In particular, with mereological bundle theory, we can preserve the deeply intuitive notion that the world is built using composition, and that the world-building composition relation runs from part to whole where the parts are prior to the whole, even while respecting the holism of modern physics. We can even do all of this and remain monists about spacetime and spatiotemporal composition, since we can take spacetime to supervene on the fusion of fundamental constituents, while allowing that it might obey different, less fundamental, compositional principles.[25] What we have done, by replacing

[25] I take this point to relate to Sider's (2008) arguments for subworld objects. We can endorse the existence of subworld objects under the categorical views I've been defending here: the world particle, for example, is either a fusion of properties or a fusion of a substrate and its properties, but in each case it and its constituents are subworld objects with the requisite sort of metaphysical priority.

spatiotemporalism with a more neutral, category-based way of building the world, is to disentangle the issues about composition from issues about building the world using spatiotemporally localized entities and the geometrical intuition. Once we disentangle them, we can see that questions about monism can be decided on purely metaphysical grounds, for the holism in physics can be consistent with a wide range of metaphysical theories of the fundamental constituents of the world, including theories opposed to any variety of compositional monism.

Clarity about how to understand the relationship between category theory, composition as world-building and fundamental physical theories also starts to address what has seemed to be a fundamental divide between metaphysicians and philosophers of science. As Hilary Greaves (2010) observes, it is unclear how to match the metaphysicians' account of what is fundamental with what we see in the physics. Metaphysicians sometimes talk as though classical physics were a guide to the fundamental nature of the world, either with respect to issues involving spatiotemporal composition, or when making fundamental claims sketched solely in terms of geometrical intuitions based on our experience of hunks of matter with macrolevel characteristics. In the context of contemporary physics, it has been difficult to see how talk of, say, wavefunctions with amplitudes measured at points of configuration space fits with talk of atoms, partless simples, or gunk. Even fitting the talk of physics to metaphysical talk of objects, properties and relations has been difficult, especially since some philosophers of physics like to claim that the mathematics of a theory exhibits a structure, and the world is simply isomorphic to that structure. One way to flesh out the problem (Greaves 2010) is to worry about how various traditional metaphysical commitments about objects, properties, relations and composition are supposed to fit with the phenomenally bizarre descriptions of the structure of the world, couched largely in mathematical terms, given to us by various fundamental physical theories. As a result, philosophers of physics are often mystified by work in mainstream metaphysics, and in particular tend to be dismissive of mereology, wrongly thinking that its concepts fail to apply in fundamental physics (cf. Healey 2010; Ladyman and Ross 2007), or worse, don't apply anywhere at all.

I have tried to connect the talk of properties and substances in metaphysics with the view from science by showing how category theory connects with physics. A different sort of attempt to avoid these problems motivates a certain sort of structuralism, a view which its advocates think avoids commitment to any particular type of ontology (French and Ladyman 2003). I think this sort of structuralism does require some ontology after all, but it does not require the ontology of spatiotemporalism. Rather, it requires an emphasis on relations as the fundamental constituents, perhaps with relations "all the way down," so that certain relations, or structures, are fundamental, and higher-level relations supervene on these. Although this is probably not what French and Ladyman have in mind, structuralism also suggests that part of what science seems to be converging on is agreement about some of the properties of the network of (suitably) fundamental relations. On this version of structuralism, the various kinds of relations proposed by various fundamental physical theories seem to exhibit a certain kind of isomorphism, which means they are similar or share features with respect to the nature of the structure.

For example, certain properties of asymmetry or transitivity carry over across different networks. In this way, one takes the network of relations to provide a certain form, and the different physical theories to imbue the same form with different content. Understood in the context of the discussion here, we can see structuralists as defending the view that the fundamental categorical structure of the world is the category of relations (there is no separate category for substances or objects) and that the fundamental nature of the world involves building a network of these relations. Further, they hold that physics is actually converging on many of the properties of the network or on how the relations are arranged, even while physicists are still disputing over what the perfectly natural character of these relations is (so physics is still trying to determine the content to assign to the form).

Such structuralists can make good use of an n-adic property mereology, since they don't need substances or even monadic properties in order to construct the world. What are the relata of the fundamental relations? Perhaps the structuralist can take fundamental relations to be related to other fundamental relations, and to deny that the relata of fundamental relations need to be ontologically prior to the relations themselves. Or, if monadic properties are included in the structuralists' fundamental category, so that the fundamental category is what I've described as the "n-adic property" category, then take (suitably) fundamental relations to supervene on the fundamental monadic properties, and build from there.

A weaker (and thus, more plausible) sort of structuralism simply seeks to defend the thesis that the objective of fundamental physics is to describe fundamental structure (North 2009; Maudlin 2007). Property mereology is also friendly to this sort of approach, again because it agrees that the fundamental entities of the world are n-adic properties and relations, consistent with, e.g., Jill North's phase space structure. The property mereologist takes the metaphysical view to be that there is an overall compositional structure to the world, one that fits in the networks of relations defended by the structuralist in physics. One can even understand Lewis himself (1983) as advocating a kind of structuralist understanding of scientific theories when he argues that we should interpret a scientific theory as a big Ramsey sentence, such that the real focus of the scientific theory is to discover the perfectly natural properties and relations needed to make the theory, or model, true. And we can capture some of the spirit of Lewis's mosaic picture of the world by thinking of the "points" of the mosaic as locations in configuration space (understood in appropriately property-theoretic or relational terms), and of the whole as a fusion of the fusions of the properties at the locations in configuration space (See Loewer 2004 for an account that can do this while respecting locality constraints).

The support that property mereology provides for ontologically minimalist theories like these varieties of structuralism derives from the fact that property mereology, as I've been emphasizing above, is more general with regard to its categorical commitments and hence with its mode of building. Because it simply requires properties and relations, *not properties and relations of some specific sort*, the best physics can tell us which properties and relations are the ones metaphysicians should embrace. In this sense, the metaphysics imposes fewer requirements on our fundamental physical theories. We just need a theory to tell us what the fundamental n-adic properties are, not, for example, that some of those

properties are spatiotemporal. Such minimalism also captures an attractive feature of instrumentalist and empiricist approaches towards physics (Indeed, as a metaphysical realist, I think it captures the only attractive feature of such views). The attractive feature captured is the claim that, given the existence of multiple interpretations of what is physically fundamental, given the antirealism displayed by many practicing physicists, and given the highly abstract nature of many of the attributes that physics ascribes to the world, we should avoid commitments to the truth of any particular theory of what the fundamental constituents of the world actually are. Property mereology gives us a way to endorse this sort of agnosticism without giving into antirealism about ontology, and thus holds a significant advantage over other approaches.

How, exactly? First, note that the history of science, especially the history of scientific revolutions, shows that scientists display a disconcerting tendency to revise theories of the fundamental constituents. However, what the history shows is not that there are no such things as properties and relations. Rather, it shows that we have not been able to settle on *which* properties and relations are fundamental. It is for this reason that we can endorse the view that physics is devoted to discovering the perfectly natural properties and relations, whatever they will turn out to be. We can see the history of science as involving a series of revolutions about what the fundamental properties and relations are.[26]

This means that the metaphysical realist who commits at the right level of ontology—at the property-categorical level—can respect the facts about the history of science. She can hold that there is a way the world is, absolutely, and that there exist a limited number of perfectly natural n-adic properties that will make the best scientific theory objectively true, but she need not commit to any particular one of the interpretations of fundamental physics on the table (nor to any that may be proposed in the foreseeable future) in order to give a metaphysically realist specification of the fundamental way the world is.[27]

Whatever one's stance on the larger issues of realism and metaphysical category theory, I hope the methodological and broadly metaphysical reasons for rejecting spatiotemporalism are clear.

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[26] David Wallace (2004) argues for a similar kind of neutrality and against letting our metaphysical ontology be determined solely by the current state of fundamental physics. Ney (forthcoming b) challenges his defense of neutrality.

[27] The thorough-going constructive empiricist or instrumentalist may agree, but take the fundamental category of n-adic properties to be some sort of neo-Kantian conceptual category rather than as an objective, ontological category of the world. Such empiricism might also be combined with suitably empiricist versions of structuralism to arrive at a clean, ontologically light understanding of the science. But as should be clear, I am happy—unlike the empiricist—to rely on inference to the best explanation, so I prefer the metaphysically and scientifically realist approach, with a correspondingly ontologically heavier understanding of the science.

Appendix: Mereological Bundle Theory[28]

I take the derivative ontological structure of the world, the structure built from the basic constituents of the world, to be mereological structure. Mereological structure is based on relationships between parts and wholes. Such structure is not categorical: sums of properties do not create new natures or real categories (In this sense, composition is like identity). I take composition to be the basic building relation of the world, and the individuals that are the basic parts are used to construct everything else there is. What sorts of individuals are the fundamental constituents of the world, the metaphysically prior simples that are fused to create the world- whole? This is the delicate question. In my view, the fundamental constituents are properties, or qualitative natures, and all else is mereologically composed from these.

So the world-whole is built by fusions of qualities. I shall take the basic notion of my mereology to be the primitive notion of "proper part," and assume that proper parthood is analytically irreflexive, asymmetric and transitive. With these notions, along with a principle of supplementation and what I take to be uncontroversial presuppositions about identity and existence, I capture the meaning of "part" with my account of qualitative parts and go on to define qualitative composition (Cf. Simons 1987).

Hence I develop my qualitative mereology by starting with thin notions of parthood and composition, ones which are perfectly well-defined mereologically and are also the basis for classical extensional mereology. Of course, classical extensional mereology takes parts and wholes to be spatiotemporal parts and wholes, where parts are individuals that are—or are defined in terms of occupying—four-dimensional regions of spacetime. But we can apply the basic notion of parthood to other sorts of constituents, and define composition as a relation between these sorts of constituents, just as well as we can develop these notions so that they apply to spatiotemporal regions.

My qualitative mereology is the basis for my mereological bundle theory: properties are literally objects and parts of objects, and properties are bundled using the composition relation. Assuming an appropriate first-order predicate calculus with identity, here are the basic axioms and definitions of my qualitative mereology **M** ("qualitative parts" are property parts).[29]

A1. For any *x, x* is not a proper qualitative part of itself (Proper qualitative parthood is *irreflexive*).

A2. For all *x* and *y,* if *x* is a proper qualitative part of *y, y* is not a proper qualitative part of *x* (Proper qualitative parthood is *asymmetric*).

A3. For all *x, y,* and *z,* if *x* is a proper qualitative part of *y* and *y* is a proper qualitative part of *z, x* is a proper qualitative part of *z* (Proper qualitative parthood is *transitive.*).

[28] This material is presented and developed in detail in my (forthcoming).

[29] Elsewhere I've argued (Paul 2006) that puzzles concerning material coincidence show how "ordinary objects" cannot be modeled using classical extensional mereology. It's worth noting that in that paper and in other previous work I was more willing to take spatiotemporal parts and other entities as fundamental existents. I am not committed to that view here.

A4. For all *x, y,* and *z,* if *x* is a proper qualitative part of *y,* y has a proper qualitative part *z* qualitatively disjoint from x (This is *weak supplementation:* if an individual has a proper qualitative part, it has at least one other proper qualitative part).

D1. For all *x* and *y, x* is a *qualitative part* of *y* iff *x* is a proper qualitative part of *y* or *x* is identical to *y* (An object's improper qualitative part is just itself).

D2: For all *x* and *y, x qualitatively overlaps y* iff *x* and *y* have a qualitative part in common.

D3: For all *x* and *y, x* is *qualitatively disjoint* from *y* iff *x* and *y* have no qualitative part in common.

D4: For all *x* and *y, x* is *qualitatively composed* of *ys* (or *x* is a *qualitative fusion* of *ys)* iff *x* has all the *ys* as qualitative parts and has no qualitative part that is qualitatively disjoint from each of the *ys.*[30]

Qualitative composition is neither covertly nor overtly spatiotemporal, nor is it somehow tied to spatiotemporal location or occupation. Like many fans of mereology, I take composition to be restricted, and I recognize the serious problems associated with adequately determining the conditions under which composition occurs. Hence I endorse a brute restriction and correspondingly reject a general qualitative fusion axiom.[31,32]

I have described my properties as "qualitative natures," and taken them to be a kind of repeatable universal, perhaps akin Aristotle's nonsubstantial forms. Properties are located in virtue of being qualitatively fused to spatiotemporal relations or relational properties. They are the basic constituents of the world, hence all universals are instantiated, where this just means that they exist and are parts of the world-whole. Not just any predicate defines a property, properties are sparse, and there are no negative properties, merely negative predicates (if an object is $\sim$F then it does not include *F* as a part). Properties can be monadic or polyadic (a.k.a., relations).

My property mereology allows fundamental relations, if there are any, to fuse with other properties in just the same way as monadic properties fuse with other properties. The fundamental relations have what we can metaphorically describe as "ends" that fuse to *n-adic* properties.

Now, there might not be any fundamental asymmetric relations. If not, **M** could be made extensional (replacing the axiom of weak supplementation with something stronger to give extensionality). But if there are fundamental asymmetric external relations, I take such relations to be relations with a certain sort of intrinsic

[30] I suspect that qualitative parts are the only parts there are, but I include the designation here for clarity. Note that haecceitistic and other impure properties can still be qualitative parts as I am using "qualitative" and that the fusion relation is the composition relation.

[31] Cf. Markosian (1998).

[32] Note that since qualitative fusion may be restricted we have the resources to make sense of cases where proper qualitative parts P, Q and R are qualitatively fused together but there is no fusion of P and R, and so no object that includes P and R. Imagine an object O that includes red, round and squashed in its fusion. Is there an object that is simply round and squashed? If so, then we grant that there can exist incomplete objects, perhaps as long as such objects are part of a complete object. If not, then this is an instance of restricted fusion.

character: character that influences the structure of a fusion that includes them. Metaphorically speaking, we can understand this as the view that the asymmetric external relation has places, and which of these places other properties and relations are fused with determines the overall character of the fusion that includes the asymmetric relation. Less metaphorically speaking, the asymmetric external relation has an intrinsic direction such that when it is fused to other properties, the resulting fusion has a certain sort of structure. When asymmetric fundamental external relation R is fused with properties A and B, R is such that the fusion of ARB is different from the fusion of BRA. On this view, asymmetric external relations provide fusions with structure via the mereological composition of properties with relations that have places, so qualitative composition is not extensional. We might describe the result as "neopredicational" fusing.[33] For example, perhaps there is a fundamental temporal relation of direction. If so, then the world will include an asymmetric temporal structuring relation *R,* such that the fusion of ARB has an intrinsic direction because it includes the intrinsic character of R. If so, then the fusion of BRA has a different intrinsic direction, even though it has the very same proper parts. To mark such a difference, we may define primitive predicates *D1* and *D2* that apply to ARB and BRA, respectively.

Broadly speaking, there are two models the mereological bundle theorist might use to represent the nature of the world as built from properties.[34] The first model accommodates most of the mainstream metaphysical intuitions about spatiotemporal composition by endorsing two different composition relations, one for qualitative parts and one for spatiotemporal parts, and building the world up from quality-points plus spatiotemporal fusions. The second model builds the world entirely from qualitative parts, and captures a kind of holism that is congenial to certain sorts of fundamental physical theories. I'll discuss each model briefly.

The first model for mereological bundle theory starts with properties qualitatively fused together with locations (understood to be relations or relational properties of having such-and such locations) to create a mosaic-like lowest compositional level of located, unextended qualitative fusions distributed through a network of spatiotemporal relations. I'll call this model the *mosaic* model. **M** is the mereology that applies to this level of composition. Extended objects are then created using a *different* composition relation and hence a different mode of mereological construction. This second composition relation is defined in the following way. Call each (maximal) located unextended qualitative fusion a "spatiotemporal part." Proper spatiotemporal parthood is defined in the usual way, as asymmetric and transitive, and one can accept a strong supplementation principle to make the spatiotemporal mereology extensional. Further axioms and definitions consistent with classical extensional mereology can be accepted, including unrestricted composition. We might then call our new composition relation "spatiotemporal composition."

On this model, spatiotemporal parts and spatiotemporal composition are embedded in a qualitative, one category ontology, and the relation between

[33] Related issues are taken up in Fine (1999).

[34] I'm indebted to conversation with Ted Sider here.

qualitative and spatiotemporal composition is clear. The fundamental spatiotemporal parts or "spatiotemporal simples" are qualitative, located fusions of properties, and larger spatiotemporal parts are constructed from a relation defined on these spatiotemporal simples.[35] Rocks, persons, stars, and abstract objects are all fusions built from quality-fusions then fused together by spatiotemporal composition. Such fusions, in addition to being complex constructions of quality and spatiotemporal fusions, are also plain-jane property fusions, where the properties fused are the whole (distributed) properties of the object. Take the spatiotemporal fusion of simples s1 and s2, where s1 has the properties of *having a mass of one gram* and *having a semi-circular shape* and s2 has the property of *having a mass of one gram* and *having a semi-circular shape.* When there is a spatiotemporal fusion of s1 with s2, giving us an object with a mass of 2 grams and the shape of a circle, this is also the fusion of the distributed property of *having a mass of two grams* with the distributed property of *having a circular shape.*

Although there are two sorts of compositional structure in the world, the mosaic theorist fiercely denies that fusing properties together to create located quality bundles gives us an emergent or otherwise irreducible category of "objects," or that the different compositional structures demarcate different fundamental categories in any way. The world is purely qualitative, and spatiotemporal parts are fusions of properties (not emergent objects of any sort). We are simply building the world with n-adic properties, albeit with different sorts of properties at different compositional "levels." The loss of parsimony here is a loss of parsimony with respect to the number of composition relations, since there are two species of composition relation, but not with fundamental categories, since there is still just one, and we still build the world with one (generic) kind of relation, composition.

The view has appeal for those who like Lewis-style Humean mosaics, and indulges our corpuscular intuitions and our attraction to classical-mechanical or particle-based depictions of the world. If we understand fields in appropriately property-theoretic terms, the model can even capture Barry Loewer's (2004) Humean supervenience-friendly account of the Lewisian mosaic, which Loewer designs in order circumvent worries about quantum nonlocality for the fan of mosaic-style views.

The mereological bundle theorist might further develop the mosaic model. One way of developing it goes fictionalist about spatiotemporal (or, alternatively, configuration-space) composition. The fictionalist denies the existence of any sort of equivalent of spatiotemporal composition after the level of the mosaic of located, unextended qualitative fusions distributed through a network of spatiotemporal relations. On this sort of (spatiotemporal compositional) fictionalist approach, one might describe what seems to be a table as "some qualitative fusions- arranged-tablewise."

A very different way of developing mereological bundle theory, the *global* model, denies that strictly speaking, spatiotemporal composition is used to build the

[35] The mosaic model also makes very good sense of Goodman (1966), who takes qualitative parts to be appearances of spatiotemporally located trope-like entities or patches of the overall phenomenological quilt and builds a mereology of appearances in the spatiotemporal manifold.

world. Instead, the extended world is wholly and immediately constructed from a fusion of *n-adic* properties, including spatiotemporal relations and perhaps a structuring lawlike relation, resulting in a distribution of properties across a spatiotemporal manifold. It is the whole, structured world that results from the original fusion of fundamental properties and relations. Although we can pick out portions of the manifold and describe them as "spatiotemporal parts" or imagine them as the products of the spatiotemporal composition of simples, all of this is merely a useful fiction. The real parts of the world are the properties and relations that compose the extended world- whole, and here, parthood is transitive.[36]

On this sort of fictionalist approach towards spatiotemporal composition, one might describe what seems to be a spatiotemporal part of a table as "a portion of the qualitative world- fusion that is distributed table-top-wise." The fictionalism exactly parallels that of the compositional nihilist, except instead of taking the phrase "this table-top" to refer to a certain plurality of unextended simples arranged table-top-wise, it takes it to refer to a certain region of the world-whole. One might also look to Horgan and Potrc (2008) for assistance with the semantics here.[37] Another alternative would be to adopt a version of Jonathan Schaffer's (2010) priority monism for spatiotemporal parts (not monism in general, since the world is still built from quality parts), taking spatiotemporal parts to be real, but derivative. Here, again, we have two different kinds of parts, and so transitivity would fail to apply. Such a view has costs with regard to parsimony, but might be attractive overall: we just need to remember that classical extensional mereology is either derivative or just a handy toy model, and that the fundamental ontological basis for reality is a qualitative mereology.

The global model has more physical plausibility than one might initially think: consider the wave-function realist who takes the world-whole to be a wavefunction. On the GRW theory of the world, the world is a universal wave function that evolves in accordance with the dynamical laws. Understood in terms of mereological bundle theory, the wavefunction is the fusion of amplitude and phase properties (along with any other properties of the system) with structuring properties or relations, including the structuring relations described by Schrödinger's equation and by the collapse postulate. A variant of this view can fit the Everettian approach, and one can also fit David Albert's (1996) treatment of Bohmian mechanics by adding a world-particle that is simply a fusion of properties to the plurality of things.[38] For this reason, I find the global model more appealing than the mosaic

[36] I think this view has interesting connections to the holistic view Dasgupta's (2009) describes as "generalism"—although my view is still atomistic in his sense.

[37] Horgan and Potrc (2008) defend the view that the world has no proper spatiotemporal parts and develop a contextual semantics intended to accommodate our ordinary ways of speaking.

[38] We can extend the global model in a way that is parallel to the first way we extended our first model of mereological bundle theory. Instead of holding that there is only a single world-whole, or (as in the mosaic model) holding that there are many unextended fundamental qualitative fusions of the world, we might hold that there are some or many *extended* fundamental qualitative fusions, where such fusions are arranged as a mere plurality, that is, they do not spatiotemporally compose into a larger whole. If our world is like this, then the fundamental entities are extended qualitative fusions (perhaps they are the "spacetime states" of Wallace and Timpson (2009) or successive stages of the "world particle" of Albert 1996).

model. The empirical facts about the world, especially given facts about the existence of entangled states, just don't seem to support the sort of atomistic world that the mosaic view describes (although, admittedly, Loewer's model is consistent with these facts). However, the jury is still out on what the best fundamental physical theory will be, and so for some, at least for the moment, the mosaic model retains its appeal.

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