Parthood and Naturalness

Abstract: Is part of a perfectly natural, or fundamental, relation? Philosophers have been hesitant to take a stand on this issue. One of reason for this hesitancy is the worry that, if parthood is perfectly natural, then the perfectly natural properties and relations are not suitably "independent" of one another. (Roughly, the perfectly natural properties are not suitably independent if there are necessary connections among them.) In this paper, I argue that parthood is a perfectly natural relation. In so doing, I argue that this "independence" worry is unfounded. I conclude by noting some consequences of the naturalness of parthood.

1. Introduction

There is a familiar distinction that one may draw among features of the world. Some properties and relations characterize the fundamental nature of the world, what the world is like "at bottom" – these are the ones that ground (in some intuitive sense) everything else. Call these properties and relations *perfectly natural*.[1] Canonical examples of perfectly natural properties are those posited by an ideal physics (such as *two grams mass*), and canonical examples of perfectly natural relations are the spatiotemporal distance relations (such as *three feet from*).

Other properties and relations characterize the superficial and gerrymandered features of world – features that obtain because of how things are at a more fundamental level. Canonical examples include properties such as *grue* and *bleen*, and relations such as *richer than* and *happier than*.

Now consider the relation *part of*. Is *part of* perfectly natural? *Prima facie*, parthood seems to be among the properties and relations that comprise the fundamental structure of the world.[2] But philosophers have been surprisingly hesitant to take *part of* as perfectly natural. David Lewis, for instance, does not consider it a "clear" example of a perfectly natural relation, if it is an example at all.[3] In their paper "Naturalness," Dorr and Hawthorne are likewise

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[1] Lewis (1983)

[2] Parthood plays a key role within Lewis's metaphysical framework. As Bennett (2015) notes, mereology "is central to [Lewis's] thought, appearing in his discussions of set theory, modality, vagueness, structural universals, and elsewhere." Note that Lewis takes the *part of* relation to be "perfectly understood" and not in need of any further analysis (1991, 75). Given that the properties that are not perfectly natural "are connected to the most elite [the perfectly natural properties] by chains of definability" ([1984] 1999, 66), this suggests that Lewis would take *part of* to be perfectly natural.

[3] "It seems a little strange to discuss naturalness of relations in a general way when we have only one really clear example: the spatiotemporal relations." (Lewis 1986*a*, 67)

noncommittal.[4] One of the main reasons for this hesitancy is that, if parthood is perfectly natural, then the perfectly natural properties and relations are not suitably "independent" of one another. (Roughly, the perfectly natural properties are not suitably independent if there are necessary connections among them.)[5]

In this paper, I argue that parthood is a perfectly natural relation.[6, 7] In so doing, I argue that this independence worry is unfounded. In sections 2 and 3, I lay out some background, and in section 4, I formulate precisely what I take the independence requirement to be. In sections 5-7, I argue that parthood must be a

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[4] "Whether [parthood and identity] should count as perfectly natural is a vexed issue: they don't fit so well with *Independence*, but do fit quite well with many of the other roles." (Dorr and Hawthorne 2013, 19)

[5] Another reason sometimes noted is that the perfectly natural properties and relations should be the ones mentioned by an ideal physics, and *part of* does not seem to be the sort of relation that would figure in such a theory. (Thanks to Dan Greco and Ted Sider for pushing this line of thought.) While this paper is not primarily concerned with this line of argument against the naturalness of parthood, it is worth addressing briefly. First, even if the our actual physics included no mention of the parthood relation, the set of perfectly natural properties is not determined solely by the ones instantiated at the actual world – if *part of* plays a role in the physics of some world, and so is perfectly natural at some world, then it is perfectly natural at all worlds at which it is instantiated. Second, I think it is plausible that parthood does figure importantly in our physical theories. Consider, for example, the additivity of *mass*; given Newtonian physics, an object with two proper parts, one with 2g mass and one with 3g mass, has a mass of 5g. But in relativistic physics, (rest) mass isn't additive in this way (Okun 1989 and 2009). (For example, consider a particle composed of two smaller particles, orbiting each other. The rest mass of this particle is greater than the sum of the rest masses of the smaller particles, because of the additional contributions of their kinetic and potential energy.) So the way in which the mass of the parts of an object relate to the mass of the whole is not a straightforward matter, and there are worlds (like the actual world) where the mass of an object is not the sum of the masses of the object's parts. And so it seems plausible that parthood is, in fact, a relation that may be crucially invoked in an ideal physical theory. Another example comes from Hartry Field's (1980) project of nominalizing physics. In reformulating physical theories to avoid quantification over abstract entities like numbers, Field crucially invokes the logic of mereology. So if Field's approach is on the right track, then the parthood relation plays a key role in physics.

[6] In this paper I focus on the relation *part of*, though one may substitute one's preferred mereological primitive instead (e.g., proper part of, overlap, etc.). The main thrust is that *some* mereological relation must be perfectly natural. See also Parsons (2014).

[7] Suppose one wants to make a distinction between the ideology of a theory and the ontological commitments of that theory, such that the "parthood" predicate appears in the ideology of the theory but does not appear in its ontology (i.e., it does not appear in the scope of the theory's unrestricted quantifier). In that case, does it even make sense to ask whether parthood is perfectly natural? Yes. First, we are assuming that properties are abundant. Take the set of ordered n-tuples that corresponds to the parthood predicate; given abundance, there is some relation corresponding to that set. So we can certainly ask whether this abundant relation is perfectly natural. Second, even if one is a nominalist about properties, one can still ask whether predicates are perfectly natural. (Perhaps the predicate "is massive" is perfectly natural, while the predicate "is happy" is not.) So for any property or predicate, one can coherently ask whether it is perfectly natural.

perfectly natural relation if the perfectly natural are to comprise an appropriate supervenience base. In section 8, I suggest that we reject the independence requirement entirely, and in section 9, I note some consequences of taking parthood to be perfectly natural.

2. Perfect Naturalness and Supervenience

Assume that properties are abundant – there is a property corresponding to every set of possible individuals. The perfectly natural properties are an elite minority of the abundant properties. Lewis argues for this primitive distinction among properties by appealing to the role that the perfectly natural plays in philosophical theorizing. For instance, the perfectly natural properties are put to work in analyses of intrinsicality, laws, causation, counterfactuals, meaning, and so on.[8] But many of these uses are contentious, and one might want to adopt something akin to a natural/non-natural distinction without taking on board anything like a Best System Analysis of lawhood or the Duplication Account of intrinsicality. For this paper, I assume only that the perfectly natural properties and relations are such that they "characterise the world completely." (Lewis 1986*a*, 60) More specifically, I assume that the perfectly natural properties and relations together comprise a "supervenience base" for all the qualitative (i.e., non-haecceitistic) features of the world. Any two worlds alike with respect to their distributions of perfectly natural properties and relations are alike with respect to their distributions of all the qualitative properties and relations. They are alike *simpliciter*.

But what does it mean to say that worlds that are "alike with respect to their distributions" of the perfectly natural are thereby "alike with respect to their distributions" of the qualitative? This gloss on the requirement that the qualitative *globally supervene* on the perfectly natural is underspecified, and there are several ways to make it more precise.

Let ϕ be a set of properties and relations. Let a ϕ-preserving isomorphism be a bijective function f from the domain of w_1 to the domain of w_2 such that for any $<x_1, \ldots, x_n>$ in w_1 and any n-place property or relation R in ϕ, $<x_1, \ldots, x_n>$ instantiate R *iff* $<f(\mathrm{x}_1), \ldots, f(x_n)>$ in w_2 instantiate R. Now consider the following three notions of global supervenience[9]:

[8] See Lewis (1983).
[9] See Bennett and McLaughlin (2011).

Weak Global Supervenience: Some set of properties *A weakly globally supervenes* on another *B iff* for any worlds w_1 and w_2, if there is a B-preserving isomorphism between the domains of w_1 and w_2, then there is an A-preserving isomorphism between them

Intermediate Global Supervenience: *A intermediately globally supervenes* on *B iff* for any worlds w_1 and w_2, if there is a B-preserving isomorphism between the domains of w_1 and w_2, then there is at least one *B*-preserving isomorphism that is also an *A*-preserving isomorphism

Strong Global Supervenience: *A strongly globally supervene*s on *B iff* for any worlds w_1 and w_2, every *B*-preserving isomorphism between the domains of w_1 and w_2, is an *A*-preserving isomorphism

When we say that the perfectly natural comprises a "supervenience base" for the qualitative, or that the qualitative properties globally supervene on the perfectly natural, what strength of supervenience should we expect? The intuitive idea we want to capture is that the perfectly natural properties and relations form the basis for, or ground (in some intuitive sense), everything else. I suspect that the notion of supervenience that best corresponds to this is strong global supervenience.[10] However, none of my arguments rely on this. All of the cases I present assume only that the qualitative properties and relations weakly globally supervene on the perfectly natural. Since strong global supervenience entails intermediate global supervenience, which in turn entails weak global supervenience, it follows that if the qualitative properties and relations do not weakly globally supervene on the perfectly natural, then they do not globally supervene on the perfectly natural in any of these three senses.

3. Background

In what follows, I make some minimal assumptions about the parthood relation. I assume that parthood is reflexive (everything is a part of itself), transitive (if *x* is a part of *y* and *y* is a part of *z*, then *x* is a part of *z*), and anti-symmetric (if *x* is a part of *y* and *y* is a part of *x*, then *x* is identical to *y*)[11]. Other mereological notions may be defined in terms of parthood:

x is a *proper part* of *y iff x* is a part of *y* and *x* is not identical to *y*

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[10] Though one of the ways that Dorr and Hawthorne suggest we understand this requirement seems to assume that the qualitative need only intermediately globally supervene on the perfectly natural. See Dorr and Hawthorne (2013, 11).

[11] One could reject this assumption without affecting my arguments (see also footnote 21). Here I am following Varzi (2014) in taking these three features as our starting point.

x overlaps y iff there is some *z* that is a part of *x* and a part of *y*
x is *disjoint* from *y iff x* and *y* do not overlap
x is a *fusion* of (or is *composed* of) the *y*s *iff* each of the *y*s is a part of *x* and every part of *x* overlaps at least one of the *y*s
x is *gunky iff* every part of *x* has a proper part
x is *atomic iff x* has no proper parts

There is considerable debate about whether any collection of things whatsoever has a fusion, or whether composition is restricted in some way. Unrestricted Composition is the thesis that for any collection of things, there exists a fusion of those things. Restricted Composition is the thesis that for some, but not all, collections of things, there is a fusion of those things. One kind of Restricted Composition is Brute Composition, the thesis, roughly, that whether a collection of things has a fusion is a "brute" fact.[12] The two views about composition that will be important here are Unrestricted Composition and Brute Composition. (I am setting aside Nihilism about parthood. According to the Nihilist, nothing is ever a part of anything else. Since, given Nihilism, the *part of* relation is only trivially instantiated (everything is a part of itself), there is no interesting question about whether it is perfectly natural.)

I assume that spacetime is comprised of regions, some of which are proper sub-regions of others. I do not assume that for any region R that is a sub-region of R′, R is a part of R′, though that assumption is harmless. A *pointy spacetime* is a spacetime such that all of its sub-regions are fusions of "pointy" sub-regions – sub-regions that *a*) have no proper sub-regions and *b*) have no extension (i.e., these sub-regions have dimension-zero extension). A *gunky spacetime* is a spacetime such that all of its sub-regions have proper sub-regions, where the size of these sub-regions becomes arbitrarily small, but is never zero. Crucially, I make no assumptions about mereological harmony; i.e., I make no assumptions about whether an object's mereological structure must "match" the structure of the spatiotemporal region it occupies.[13, 14]

4. An Argument Against Parthood as Perfectly Natural

One reason to be resistant to positing *part of* as perfectly natural stems from the assumption that the perfectly natural properties and relations need to be suitably

[12] Ned Markosian formulates Brute (or "Brutal") Composition as the thesis that "there is no true, non-trivial, and finitely long answer to the Special Composition Question." (Markosian 1998, 214)
[13] See Saucedo (2011), Uzquiano (2011), and Gilmore (2013) for discussion of mereological harmony.
[14] McDaniel (2006) argues that gunky objects may occupy non-gunky regions.

"independent" of one another. It is an interesting question what independence amounts to. Here is one natural understanding of independence:

> *Minimality*: No perfectly natural property or relation supervenes on any set of other perfectly natural properties or relations[15, 16]

Why might one think that adopting Minimality entails that parthood is not perfectly natural? Suppose one adopts Minimality, and one also adopts Unrestricted Composition. Now consider two worlds, exactly alike with respect to all their non-mereological perfectly natural properties and relations. Given

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[15] Dorr and Hawthorne call this "Non-Supervenience" (2013, 13).

[16] Another understanding of independence that Dorr and Hawthorne consider is what they call "Combinatorialism," taken from Lewis (2009), where he writes: "we can take apart the distinct elements of possibility and rearrange them… Here let us take them [the distinct elements] to include not only spatiotemporal parts, but also abstract parts – specifically, the fundamental properties" (2009, 208-209). Dorr and Hawthorne take this to mean that "no perfectly natural property is entailed by any other." (2013, 14)

The general idea is this: for any perfectly natural n-adic relation R, the instantiation of R by some objects does not place any constraints on what other perfectly natural relations those objects or any others may instantiate. And more generally, for any perfectly natural n-adic relations $R_1, \ldots, R_n$, whether $R_1(x_1, \ldots, x_n), \ldots, R_n(y_1, \ldots, y_n)$ obtains does not place any constraints on what other perfectly natural relations anything may instantiate.

Combinatorialism is violated if *part of* is perfectly natural. This is because parthood is transitive: if a is a part of b and b is a part of c, then a is a part of c. And any necessarily transitive relation will conflict with Combinatorialism. Similarly any necessarily asymmetric relation will conflict with Combinatorialism – for if some relation R is asymmetric, then a bearing R to b means that b cannot also bear R to a. If the perfectly natural properties and relations satisfy Combinatorialism, then there are no perfectly natural relations that are either asymmetric or transitive.

I am not here arguing that Combinatorialism is thereby untenable. But it is worth pointing out that Combinatorialism is a very strong principle, and is inconsistent with many tacit assumptions regarding the perfectly natural. For consider the spatial distance relations – a paradigm case of perfectly natural relations. If some object a is three feet from b and b is three feet from c, then it is not possible for a to be just any distance from c, for the distances between them must satisfy the triangle inequality.

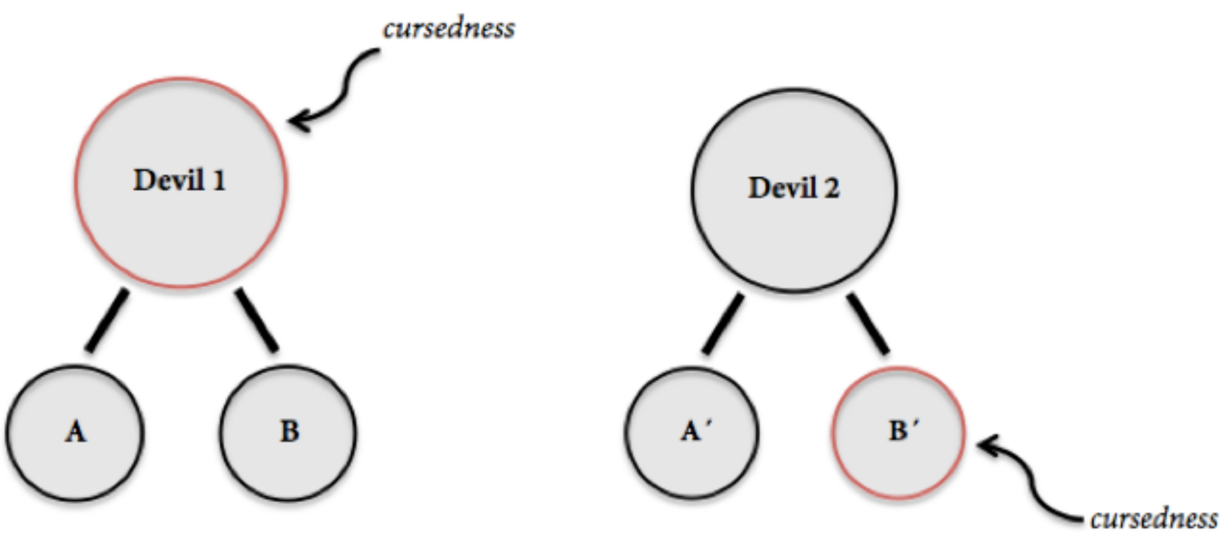
Moreover, all quantitative properties and relations are in tension with Combinatorialism. For if a is three feet from b, then a cannot be four feet from b. If c has three grams mass, then c cannot also have four grams mass. And so on. If Combinatorialism is true, then no quantitative properties and relations are perfectly natural. But quantitative properties and relations are often considered paradigmatic examples of the perfectly natural, for they are the sorts of properties and relations posited by our best fundamental physics. (And replacing monadic quantitative properties with relations like *betweenness* and *congruence* will not help, since these relations violate Combinatorialism as well.) So, even apart from the question of whether parthood is perfectly natural, it is not clear how to square Combinatorialism with the claim that the perfectly natural properties and relations comprise a (weak global) supervenience base for the qualitative. So I will set aside this understanding of independence.

Unrestricted Composition, for any collection of things at either of these worlds, there exists a fusion of those things. So if the two worlds are otherwise exactly alike, then, it seems, they are alike with respect to their pattern of parthood relations. But if that is so, then *part of* supervenes on the non-mereological perfectly natural properties and relations. If *part of* supervenes on the non-mereological perfectly natural properties and relations, and is itself perfectly natural, then Minimality is false. Therefore, *part of* is not perfectly natural.

5. Unrestricted Composition and Parthood

But this is a bad argument. Even if Unrestricted Composition is true, *part of* does not supervene on the non-mereological perfectly natural properties and relations.

To see why, suppose one adopts Unrestricted Composition, and let us assume that there are no other relevant restrictions on the space of metaphysical possibility. Consider two objects: Devil 1 and Devil 2.[17] Both Devil 1 and Devil 2 have exactly two proper parts, each of which is atomic. Suppose that *cursedness* is a perfectly natural property. Devil 1 instantiates *cursedness*, but that is the only perfectly natural property instantiated by any of Devil 1's parts. As for Devil 2, exactly one of Devil 2's proper parts instantiates *cursedness*, but that is the only perfectly natural property instantiated by any of Devil 2's parts. (Neither Devil 1 nor Devil 2 instantiates any perfectly natural relations; in particular neither instantiates any spatiotemporal relations. So, neither Devil 1 nor Devil 2 has any spatiotemporal location.)



[17] Thanks to Cian Dorr for pointing out this particularly simple example.

Finally, Devil 1 is located in world w_1, and Devil 1 is lonely – there is no object in w_1 that does not overlap Devil 1. Devil 2 is located in world w_2, and Devil 2 is likewise lonely – there is no object in w_2 that does not overlap Devil 2.

Suppose *part of* is not perfectly natural. Then, there is a mapping between the objects in w_1 and the objects in w_2 that preserves the perfectly natural properties and relations – map Devil 1 to B′, A to A′, and B to Devil 2. But there is no mapping between the objects in w_1 and the objects in w_2 that preserves the qualitative properties and relations. For Devil 2 has the qualitative property of *having a proper part instantiating cursedness*, and there is nothing in w_1 that instantiates this property. So there is no mapping between the objects in w_1 and w_2 that preserves the qualitative property of *having a proper part instantiating cursedness*, and so no mapping that preserves the qualitative properties and relations.

There are two morals to draw from this example.[18] First, the argument given in the previous section fails because the qualitative properties and relations (including properties like *having a proper part instantiating cursedness*) fail to supervene on the perfectly natural and non-mereological properties and relations. So there is no violation of Minimality, whether or not one takes parthood to be perfectly natural.

Second, and more importantly, this example demonstrates that parthood (or some related mereological notion) *must* be perfectly natural. For if parthood is not perfectly natural, and it fails to supervene on the perfectly natural, then the perfectly natural properties and relations do not comprise a weak global supervenience base for the qualitative. Since the perfectly natural properties and relations do comprise a weak global supervenience base for the qualitative, *part of* is perfectly natural.[19]

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[18] This assumes, of course, that one grants that the Devils example is possible. But one might maintain that this example is not possible. For instance, one might say that any objects that instantiate parthood relations must also instantiate spatiotemporal relations (and, presumably, that the parthood relations supervene on the spatiotemporal relations). If so, then because the Devils do not instantiate any spatiotemporal relations, this example is impossible. I pursue this line of thought in section 7.

[19] One response to this line of argument is to claim that mereological properties and relations, including properties like *having a proper part instantiating cursedness*, are not qualitative. If they are not qualitative, then they need not supervene on the perfectly natural, and Devil 1 and Devil 2 do not constitute a counterexample to the argument in section 4.

The term "qualitative" is ambiguous, and there are a few different distinctions it might be used to name. Clearly there is some sense of qualitative where it is used to refer to "Humean" or "descriptive" properties like color and shape, and to exclude so-called "logical" or "structural" properties. And there is another sense of qualitative where it is used to mean something like "non-haecceitistic."

6. Brute Composition and Parthood

We have seen one argument against the claim that *part of* is perfectly natural, and we have seen where this argument goes wrong. Even if Unrestricted Composition is true, it is not the case that worlds alike with respect to their non-mereological features are thereby alike with respect to their mereological features.

But Unrestricted Composition is a contentious thesis, and not everyone accepts it. Suppose one wants to adopt Brute Composition instead of Unrestricted Composition. What is the status of *part of* then?

Consider two objects: Angel 1 and Angel 2. Every part of Angel 1 and Angel 2 instantiates the same perfectly natural property – *holiness* – and no part instantiates any other perfectly natural property or stands in any other perfectly natural relation.

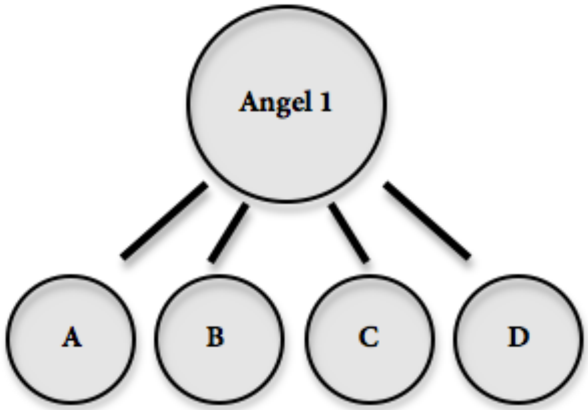
Angel 1 has four atoms as proper parts – A, B, C, and D – none of which are proper parts of any other object. So, Angel 1 has exactly five parts: itself, A, B, C, and D. Angel 2 also has exactly five parts. But Angel 2 differs from Angel 1 in the following way: one of Angel 2's proper parts is the fusion of two of its other proper parts. So Angel 2 has three atoms as proper parts – A′, B′, and C′ – and one non-atomic proper part – D′ – which is the fusion of B′ and C′. (As with the Devils example, neither Angel 1 nor Angel 2 instantiates any spatiotemporal relations. So, neither Angel 1 nor Angel 2 has any spatiotemporal location.)

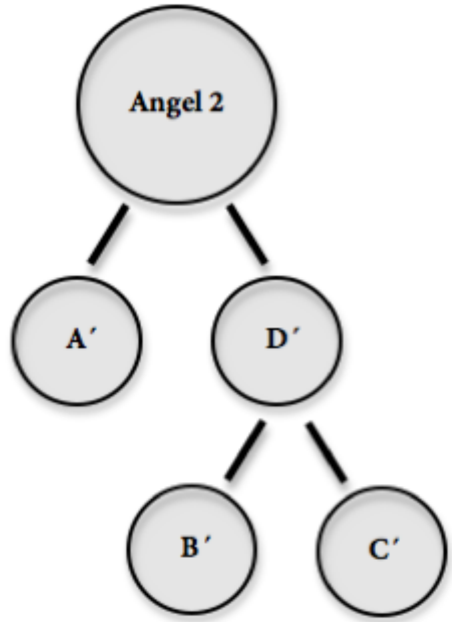
Finally, suppose that Angel 1 is located in world w_1, and Angel 1 is lonely – there is no object in w_1 that does not overlap Angel 1. Angel 2 is located in world w_2, and Angel 2 is likewise lonely – there is no object in w_2 that does not overlap Angel 2.

Luckily, I do not need to take a definitive stance on which set of properties "qualitative" refers to. All I need is for the qualitative properties to be those that play (closely enough) the roles we need them to play. So, for instance, two things are duplicates when they're alike with respect to their perfectly natural properties. Take Devil 1 and Devil 2 – if parthood isn't qualitative, then they're duplicates. But clearly they're not duplicates; they differ in an important way.

Here's another case. The laws of nature are deterministic *iff* any worlds alike with respect to their laws and their histories up to a time t are alike after t as well (see Lewis 1983). So take two worlds, w_1 and w_2, with the same laws L and the same histories H up to t. At t, Devil 1 appears at w_1, and Devil 2 appears at w_2. Clearly these worlds diverge, as they differ after t. And since they diverge, it follows that the laws L are not deterministic. Or that's what *should* follow. If parthood isn't qualitative, then these worlds are exactly alike before and after t. And so the apparent divergence of w_1 and w_2 does not in fact show that the laws L are indeterministic, which is the wrong result.

In sum, the properties that supervene on the perfectly natural need to play, more or less, the roles expected of them. Given this, it seems that parthood is qualitative in the sense required. (Thanks to Sam Cowling and Phil Bricker for discussion.)





Suppose *part of* is not perfectly natural. Then, there is a mapping between the objects in w_1 and the objects in w_2 that preserves the perfectly natural properties and relations – map Angel 1 to Angel 2, A to A′, B to B′, C to C′, and D to D′. But there is no mapping between the objects in w_1 and the objects in w_2 that preserves the qualitative properties and relations. For Angel 2 has the qualitative property of *having exactly three atomic proper parts*, and there is nothing in w_1 that instantiates this property. So there is no mapping between the objects in w_1 and w_2 that preserves the qualitative property of *having exactly three atomic proper parts*, and so no mapping that preserves the qualitative properties and relations.

So, assuming that Brute Composition is possibly true, and that there are no other relevant restrictions on the space of metaphysical possibility, then *part of* must be perfectly natural. For if it is not, then the perfectly natural properties and relations fail to comprise a weak global supervenience base for the qualitative.

7. Spacetime and Parthood

In the preceding examples, the Devils and Angels did not have any spatiotemporal locations, and so their parts did not bear any perfectly natural spatiotemporal relations to one another. This meant that there were no other perfectly natural properties or relations besides *cursedness* or *holiness* that we needed to worry about preserving.

But suppose one believes that objects must be spatiotemporally located, and that there are constraints on the relationship between an object's parts and the spatiotemporal regions those parts occupy. In this section, I consider various restrictions one might place on how objects and spatiotemporal regions are related to one another, and I evaluate the status of *part of* in light of these restrictions. I assume throughout that spatiotemporal relations of distance and size are perfectly natural. I also assume both Unrestricted Composition and

Minimality. (I do this to stack the deck in favor of those who want to reject the claim that *part of* is perfectly natural.)

Let us say that an object is *exactly located at* or *exactly occupies* a region R when, intuitively, the object "perfectly fills" or "fits into" R – "where this is meant to guarantee that the thing and the region have precisely the same shape, size, and position." (Gilmore 2006, 200) Now consider the following principle:

> *Location*: Necessarily, for every object, there is some spatiotemporal region at which that object is exactly located.[20]

Suppose one adopts Location, and no other constraints are placed on the relationship between an object and the region it occupies. What is the status of *part of* then?

Consider Fiend 1 and Fiend 2. Fiend 1 and Fiend 2 are exactly like Devil 1 and Devil 2, except that they are located in spacetime. Fiend 1 exactly occupies spacetime point P, and both of Fiend 1's proper parts – A and B – also exactly occupy P. Fiend 2 exactly occupies spacetime point P', and both of Fiend 2's proper parts – A′ and B′ – also exactly occupy P'. Since Fiend 1 and all its parts exactly occupy the same point, every part of Fiend 1 bears the *same size as* and *zero distance from* relations to every other part. Likewise, since Fiend 2 and all its parts exactly occupy the same point, every part of Fiend 2 bears the *same size as* and *zero distance from* relations to every other part. Finally, Fiend 1 is located in world w_1, and Fiend 1 is lonely – there is no object in w_1 that does not overlap Fiend 1. Fiend 2 is located in world w_2, and Fiend 2 is likewise lonely – there is no object in w_2 that does not overlap Fiend 2.

Suppose that *part of* is not perfectly natural. Then there is a mapping between the objects in w_1 and w_2 that preserves all the perfectly natural properties and relations (map Fiend 1 to B′, A to A′, and B to Fiend 2). But there is no mapping between the objects in w_1 and the objects in w_2 that preserves the qualitative properties and relations. For Fiend 2 has the qualitative property of *having a proper part instantiating cursedness*, and there is nothing in w_1 that instantiates this property. If *part of* is not perfectly natural, then the perfectly

[20] There are a few reasons to be unhappy with Location. One obvious reason is that it rules out objects located outside of spacetime. As a result, it is incompatible with views according to which some objects are contingently nonconcrete or non-spatiotemporal (see Linsky and Zalta (1996) and Williamson (1998)). Second, it rules out the possibility of a point-sized object inhabiting a gunky spacetime. For a gunky spacetime does not have any point-sized regions – so it does not have any region that a point-sized object can exactly "fit into." See Gilmore (2006, 203). (See also McDaniel (2006) for arguments that pointy objects may inhabit gunky regions.)

natural properties and relations fail to comprise a weak supervenience base for the qualitative. Therefore, *part of* must be perfectly natural.

So we see that as long as no constraints are placed on *how* objects are located at regions, dropping the assumption that objects need not have any spatiotemporal location does not affect the status of *part of*. *Part of* is still perfectly natural.

Next let's consider a different constraint on the relationship between an object and the region it occupies:

> *Identity*: Necessarily, for all *x* and *y*, if *x* and *y* are exactly located at the same region, then *x* and *y* are identical.[21]

Suppose one adopts Identity as well as Location, and suppose that there are no other constraints on the relationship between an object and the region it occupies. How does this affect the status of *part of*?

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[21] There are a few reasons to be unhappy with Identity. One sort of view ruled out by Identity is a theory of immanent universals, according to which universals are located wherever they are instantiated. On such a view, multiple things (an object and a universal) are exactly located at the same region, which would conflict with Identity. Similarly, one might adopt a view according to which sets are located where their members are – for instance, my singleton set is exactly located at the region at which I am exactly located. On this view, again, multiple things are exactly located at the same region, which conflicts with Identity.

Conflict with Identity may also come from paradoxes of material constitution. Consider a statue made up of a lump of clay. The lump can survive squashing, the statue cannot; and so it seems the statue is not identical to the lump. Wiggins (1968) and Thomson (1998) propose views according to which the statue and the lump are not identical. Wiggins holds that the statue and the lump share all their parts; this requires rejecting Uniqueness of Composition, according to which objects with the same parts are identical. Thomson (1998) argues that the statue and the lump are parts of one another (Cotnoir (2010) and (2014) defends the "mutual parts" view and argues that it requires replacing the assumption that parthood is anti-symmetric with the assumption that it is asymmetric). But this entails that two objects are exactly located at the same spatiotemporal region – which is ruled out by Identity.

Another source of conflict comes from physics. For instance: consider two point-sized particles travelling towards each another. What will happen when these particles meet? On some views, it is nomologically possible for them to pass through one another. But then there would be a time at which they are exactly located at the same region, which is ruled out by Identity. Another instance: some have argued that, on some interpretations of quantum mechanics, qualitatively indiscernible particles like bosons can be co-located. This, too, conflicts with Identity. In general, one might be wary of metaphysical principles that rule out apparent nomological possibilities. (For discussion of all of these, see Gilmore 2013.)

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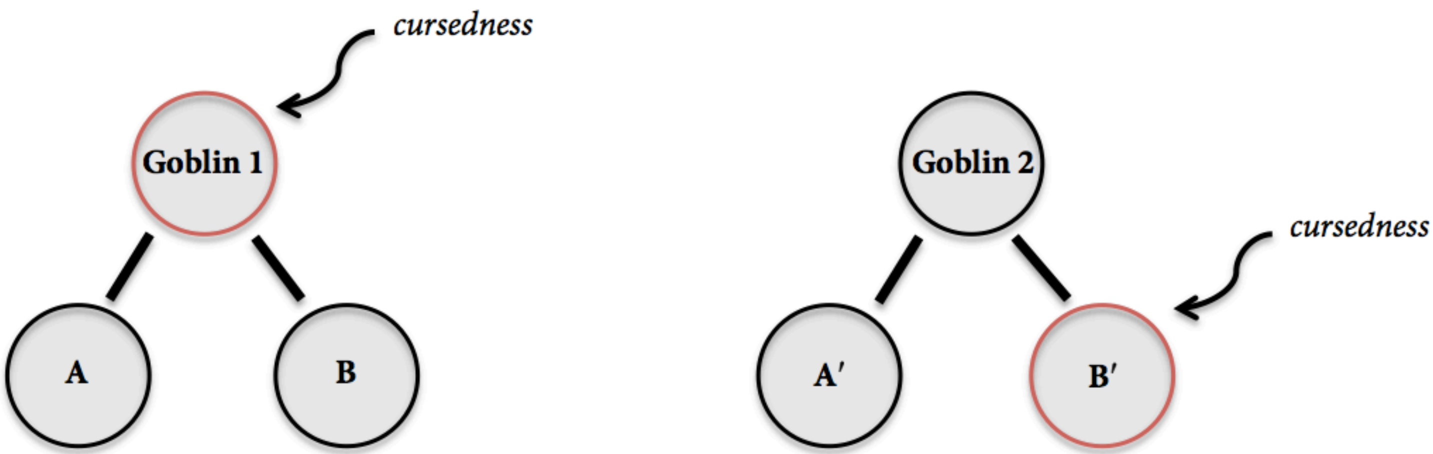
Consider Goblin 1 and Goblin 2. Goblin 1 and Goblin 2 are very similar to Fiend 1 and Fiend 2. But unlike the Fiends, the Goblins and each of their parts occupy distinct regions:



In this diagram, the circles and their spatial arrangement represent the size, shape, and spatial arrangement of the Goblins and their parts. (As before, the lines between the circles indicate the parthood relations.)

Both Goblin 1 and Goblin 2 have exactly two proper parts, each of which is atomic. Goblin 1 instantiates *cursedness*, which is the only perfectly natural property instantiated by any of Goblin 1's parts. As for Goblin 2, exactly one of Goblin 2's proper parts instantiates *cursedness*, and that is also the only perfectly natural property instantiated by any of Goblin 2's parts. Finally, Goblin 1 is located in world w_1, and Goblin 1 is lonely – there is no object in w_1 that does not overlap Goblin 1. Goblin 2 is located in world w_2, and Goblin 2 is likewise lonely – there is no object in w_2 that does not overlap Goblin 2.

The Goblins differ from the Fiends and the Devils in only this way: the Goblins and their proper parts each exactly occupy a distinct spatiotemporal region. So *Identity* is satisfied.

Suppose *part of* is not perfectly natural. Then, there is a mapping between the objects in w_1 and the objects in w_2 that preserves the perfectly natural properties and relations – map Goblin 1 to B′, A to Goblin 2, and B to A′. But there is no mapping between the objects in w_1 and the objects in w_2 that preserves the qualitative properties and relations. For Goblin 2 has the qualitative property of *having a proper part instantiating cursedness*, and there is nothing in w_1 that instantiates this property. So there is no mapping between the objects in w_1 and

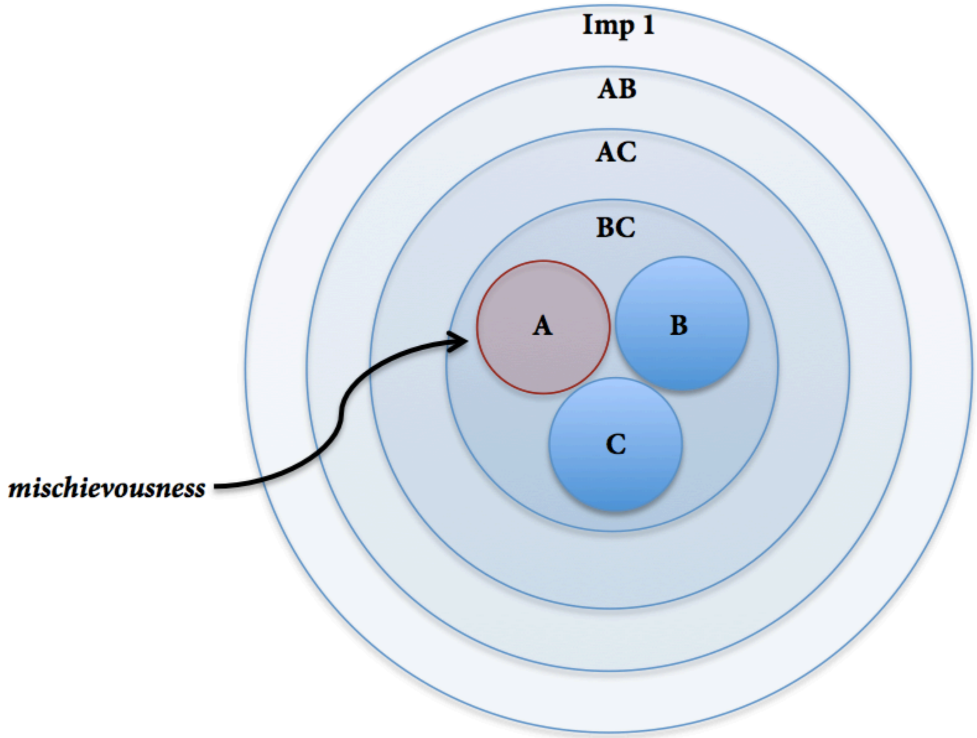
w_2 that preserves the qualitative property of *having a proper part instantiating cursedness*, and so no mapping that preserves the qualitative properties and relations. Once again, if *part of* is not perfectly natural, then the qualitative properties and relations fail to weakly globally supervene on the perfectly natural. Since the qualitative does weakly globally supervene on the perfectly natural, *part of* is perfectly natural.

More generally, the reason examples like this may be constructed is that we have not placed any constraints on how the parts of an object are related to the spatiotemporal region the object occupies. We have not said that each proper part of Goblin 1 must be exactly located at a sub-region of the region at which Goblin 1 is exactly located, for instance. But one might wonder what happens to the status of parthood if we add a constraint like this. So consider the following principle:

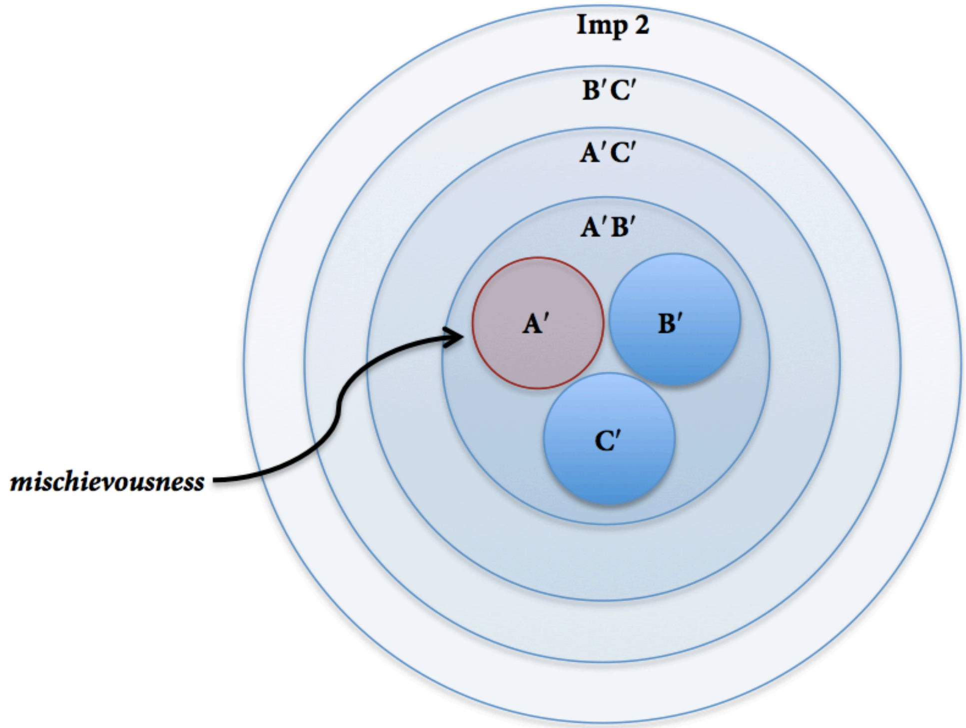
> *Inside*: Necessarily, if x is exactly located at some region R, then any proper part of x is exactly located at a proper sub-region of R (every proper part must be "inside" R).

Suppose one adopts Inside as well as Location and Identity. What is the status of *part of* then?

Consider Imp 1 and Imp 2. Imp 1 is located at w_1, and has exactly three atomic proper parts – A, B, and C. What is interesting about Imp 1 is that the fusions of its proper parts exactly occupy regions that are *larger* than the union of the regions occupied by the parts. So, the fusion of B and C – BC – occupies a region that includes the region occupied by A; the fusion of A and C – AC – occupies a region that includes the region occupied by BC; the fusion of A and B – AB – occupies a region that includes the region occupied by AC; and the fusion of A, B, and C – Imp 1 – occupies a region that includes the region occupied by AB. And while it's somewhat odd that AB, BC, AC, and Imp 1 occupy regions that are larger than the union of the regions occupied by their parts, Imp 1 nonetheless satisfies *Inside*. Finally, the only perfectly natural monadic property instantiated at w_1 is *mischievousness*, and the only object that instantiates *mischievousness* is A. (In the following two diagrams, the circles and their spatial arrangement represent the size, shape, and spatial arrangement of the Imps and their parts.)



Next consider Imp 2. Imp 2 is located at w_2, and is almost exactly like Imp 1. Imp 2 has exactly three atomic proper parts – A′, B′, and C′. Like Imp 1, the fusions of Imp 2's proper parts exactly occupy regions that are larger than the union of the regions occupied by the parts. But the fusions of Imp 2's atomic parts are arranged slightly differently than the fusions of Imp 1's atomic parts. So, the fusion of A′ and B′ – A′B′ – occupies a region that includes the region occupied by C′; the fusion of A′ and C′ – A′C′ – occupies a region that includes the region occupied by A′B′; the fusion of B′ and C′ – B′C′ – occupies a region that includes the region occupied by A′C′; and the fusion of A′, B′, and C′ – Imp 2 – occupies a region that includes the region occupied by B′C′. Finally, the only perfectly natural monadic property instantiated at w_2 is *mischievousness*, and the only object that instantiates *mischievousness* is A′.



Suppose *part of* is not perfectly natural. Then there is a mapping between the inhabitants of w_1 and w_2 that preserves the perfectly natural properties and relations (*mischievousness* and the spatiotemporal relations): map A to A′, B to B′, C to C′, BC to A′B, AC to A′C′, AB to B′C′, and Imp 1 to Imp 2. But there is no mapping that preserves the qualitative properties and relations. For Imp 1 has the property of *being such that the second (spatiotemporally) largest part has a proper part instantiating mischievousness*, and Imp 2 does not have this property. Instead, Imp 2 has the property of *being such that the fourth (spatiotemporally) largest part has a proper part instantiating mischievousness*, a property that Imp 1 lacks.

All the examples considered in this section are generated by taking advantage of a sort of "mismatch" between an object's parts and the spatiotemporal regions these parts occupy. Any mismatch of this sort will mean that the pattern of parthood relations cannot be "read off" the spatiotemporal relations that hold among an object's parts. And so, if the qualitative weakly globally supervenes on the perfectly natural, then *part of* needs to be perfectly natural.

8. Parthood and Independence

Note that Minimality plays no role in any of the above arguments for the naturalness of parthood. In all of those cases, we've seen that *part of* must be perfectly natural if the perfectly natural are to comprise a supervenience base for the qualitative. And this is so whether or not one believes that the supervenience base should be a minimal one.

Minimality only comes into play if the non-mereological perfectly natural properties and relations comprise a supervenience base on their own. As we've seen, though, most views regarding mereology and location entail that the non-mereological perfectly natural properties and relations do not comprise a supervenience base on their own. But that is not to say that there is *no* view that has this result. The more constraints we place on the relation between an object and the region at which it is exactly located, the harder it is to find cases involving the sort of mismatch the examples in the previous section took advantage of. And we could eliminate such cases entirely by adopting enough background assumptions to ensure that the parthood relations supervene on the non-mereological perfectly natural properties.[22] What should we say about the status of parthood then?

There are two paths one might take here. One is to hold fast to an antecedent commitment to Minimality, and to take any violation of Minimality to show that the property in question is not perfectly natural. Another is to reject Minimality, and to take violations of Minimality to reveal little about whether the property in question is perfectly natural.

I think both options are defensible, though I am inclined towards the second. For one thing, there are independent reasons to reject Minimality. First, Sider (2011) argues that principles like Minimality require us to make arbitrary choices regarding what is fundamental or perfectly natural, an unwelcome result.[23] Second, Minimality entails that properties necessarily instantiated by everything cannot be perfectly natural. But we may want to be open to a view according to which some such properties *are* perfectly natural; perhaps *exists* in one such property,[24] and perhaps the identity relation is another.[25] Third, Minimality also entails that necessarily obtaining properties or relations cannot be perfectly natural. But Eddon (2013) has argued that the higher order relations that ground quantitative structure are perfectly natural; if these relations are necessary, then this requires rejecting Minimality. So there are several sources of pressure against Minimality.

There is also a methodological pressure against Minimality which is, perhaps, more germane to the context of parthood. If we accept Minimality, then in some cases the naturalness of some properties will necessarily exclude the

[22] Recently, Markosian (2014) and Nolan (2014) have presented accounts of parthood that attempt to reduce it to spatiotemporal relations.
[23] See Sider (2011, 217-220).
[24] Fine (2012, 60) suggests that existence cannot be reduced to identity or other related notions.
[25] See Sider (2011, 216).

naturalness of other, apparently unrelated, properties. And to the extent that one thinks that the core notion of naturalness involves joint-carving and objective similarity, one might find this objectionable. For one might think that whether *part of* is among the properties and relations that carve nature at the joints, make for objective similarity, and are those in virtue of which all else obtains, should not hang on how we resolve issues concerning, say, the location relation between objects and regions. It should not depend on whether objects are necessarily located in spacetime, or whether distinct objects may inhabit the same region, or whether the parts of an object must be tied to regions in some specific way. It should not depend on whether interpenetration is possible, or whether multi-location is possible, or whether pointy objects may inhabit gunky spacetimes, and so on. And it should not depend on whether contentious mereological principles are true.

I think we should welcome the flexibility to consider the naturalness of various properties or relations on a case-by-case basis. If we take seriously the notion that the perfectly natural properties and relations are "rock-bottom," joint-carving, or those in virtue of which all else obtains, then it is not clear what we gain by adopting Minimality. While this is not a knockdown reason to reject Minimality, it is a consideration that may weaken the case for it.[26]

9. Consequences

Suppose that, in the end, we take parthood to be perfectly natural. The naturalness of parthood has a few interesting consequences. One consequence concerns the formulation of Lewis's doctrine of Humean supervenience: "[Humean supervenience] is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact… We have geometry: a system of external relations of spatiotemporal distance between points… And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated." (Lewis 1986*b*, *ix*-*x*)

Lewis goes on to say that the thesis of Humean supervenience concerns the "inner sphere" of possibility – worlds where no perfectly natural properties or relations alien to our world are instantiated. Among such worlds, "there is no difference in worlds without a difference in their arrangement of qualities." (1986*b*, *x*) So, if Humean supervenience is true, then (within the inner sphere of

[26] One position impacted by Minimality is the view that there are multiple fundamental mereological relations (see McDaniel (2004) and (2009)). If any of these mereological relations supervene on any others, then Minimality precludes such a view. But if we abandon Minimality, then the door is open to adopting this sort of *parthood pluralism*.

possibility) any worlds alike with respect to their point-by-point distribution of perfectly natural properties and spatiotemporal relations are alike *simpliciter*.

But if we restrict the perfectly natural relations to just "the relations of spatiotemporal distance between points," then there *are* differences of worlds without a difference in the arrangements of qualities. Suppose Fiend 1 inhabits world w_1 and Fiend 2 inhabits world w_2, and suppose that there is nothing disjoint from Fiend 1 inhabiting w_1, and nothing disjoint from Fiend 2 inhabiting w_2. So, w_1 and w_2 are exactly alike with respect to their distribution of perfectly natural properties and spatiotemporal distance relations (for simplicity, let's assume that *cursedness* is not an alien property). Given Lewis's characterization of Humean supervenience, either one of w_1 or w_2 is not within the inner sphere of possibility, or Humean supervenience is false. Clearly w_1 and w_2 are both within the inner sphere of possibility: neither world instantiates a perfectly natural property or relation not instantiated at the actual world. But surely w_1 and w_2 do not constitute a counterexample to Humean supervenience. For whether Humean supervenience obtains is an empirical issue, say Lewis,[27] and the possibility of worlds containing Fiend 1 and Fiend 2 does not seem to be an empirical issue. The solution, I believe, is to augment the thesis of Humean supervenience to include parthood relations: in addition to a system of external relations of spatiotemporal distance between points, we have external relations of parthood as well. So we should say that Humean supervenience is the thesis that, within the inner sphere of possibility, any worlds alike with respect to their perfectly natural properties instantiated at points, and the spatiotemporal and parthood relations among points, are alike *simpliciter*.

Here is another consequence. It is sometimes said that it is constitutive of the definition of parthood that it obeys certain axioms – for instance, Unrestricted Composition.[28] If Unrestricted Composition follows from the meaning of "parthood," then there should be no need to proffer additional arguments in its favor (such as the argument from vagueness (see Lewis (1986*a*)). But if *part of* is perfectly natural, then this position is hard to maintain.

Here is why. Let "part of*" be the predicate that expresses the relation that obeys Unrestricted Composition. Assume that properties are abundant – there is a property corresponding to every set of possible individuals. Given abundance, there is guaranteed to be *some* relation that corresponds to "part of*" (since there

[27] "I have conceded that Humean supervenience is a contingent, therefore an empirical, issue… [W]hat I uphold is not so much the truth of Humean supervenience as the *tenability* of it. If physics itself were to teach me that it is false, I wouldn't grieve." (Lewis 1986*b*, *xi*)
[28] See, for example, Bricker (2016).

is a property or relation corresponding to nearly any predicate whatsoever). And because we stipulated that "part of*" refers to a relation that satisfies Unrestricted Composition, there is a sense in which this relation satisfies Unrestricted Composition "by definition." However, we cannot stipulate that this relation obeys Unrestricted Composition *and* is perfectly natural. For while abundance guarantees that there is a relation obeying Unrestricted Composition, it does not guarantee that there is a perfectly natural relation obeying Unrestricted Composition. If parthood is perfectly natural, then whether Unrestricted Composition is true is a substantive matter concerning the nature of the parthood relation, and the matter cannot be resolved by appealing to the definition of parthood.[29, 30]

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[29] There are other reasons to be unhappy with the claim that the referent of "part of" is fixed by the mereological axioms (including possibly contentious ones like Unrestricted Composition). First, one might think it is implausible that this is the only kind of constraint on the meaning of "part of." Second, when applied more widely claims of this sort may lead to the widespread semantic indeterminacy of Putnam's Paradox (thanks here to an anonymous referee).

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