Science and the Special Composition Question

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Contents

Abstract: Mereological nihilism is the thesis that composition never occurs. Some philosophers have thought that science gives us compelling evidence against nihilism. In this article I respond to this concern. An initial challenge for nihilism stems from the fact that composition is such a ubiquitous feature of scientific theories. In response I motivate a restricted form of scientific anti-realism with respect to those components of scientific theories which make reference to composition. A second scientifically based worry for nihilism is that certain *specific* scientific phenomena (quantum entanglement, natural selection) might require ineliminable quantification over composite objects. I address these concerns, and argue that there seem to be nihilist-friendly construals of the scientific phenomena in question.

1 Introduction

Peter van Inwagen's "Special Composition Question" (SCQ) asks what must some objects be like in order for there to be some *further* object of which they are proper parts?[1] Put more informally, when does composition occur?[2] There are a number of possible answers to the SCQ, but one of them, mereological nihilism (or just "nihilism") gives us a particularly sparse ontology. According to the nihilist, composition *never* occurs.[3] One often cited reason to believe that nihilism is the correct answer to the SCQ is because of nihilism's theoretical simplicity, namely insofar as nihilism gives us a simpler picture of the world.

Of course, a theory's simplicity isn't the entire story. Non-empirical theoretical virtues like simplicity are often brought in to decide between competing theories which are more or less equally empirically adequate. Whether some answers to the SCQ are more empirically adequate than others has generally not been discussed. Rather, the debate regarding the correct answer to the SCQ has generally been conducted on *a priori* grounds. More recently, however, several philosophers have argued that scientific inquiry gives us valuable information regarding the nature and scope of physical composition (see, in particular, Schaffer 2007, 2010; Morganti 2009, 2013: Ch.5; Calosi et al. 2011; Calosi 2014; Graziani and Calosi 2014; Calosi and Morganti forthcoming; Gillett 2013; Healey 2013). What particularly interests me here is the claim that scientific inquiry gives us evidence for composition, and ergo evidence against a nihilist answer to the SCQ. In this article I defend nihilism against this objection – I argue that we do not have scientific evidence for composition sufficient to refute nihilism. While the scientific objection to nihilism has been addressed before (see Dorr 2002: §1.4.2; Dorr and Rosen 2002: §7; Sider 2013: §11), it has not received as full a response as we might like. What's more, there are scientific phenomena (quantum entanglement, higher-level units of selection in evolutionary theory) which represent particularly pressing challenges for nihilism, but which nihilists have so far largely passed over in silence. I aim to help fill these gaps in the literature.

While I defend the conclusion that, at present, science does not refute

[1] van Inwagen 1990: 30-31.

[2] Throughout this article I will generally assume that it is *objects* which may or may not enter into composition relations, rather than, say, stuff, or some other ontological category which doesn't fit neatly into the object/stuff dichotomy. This assumption is for ease of expression only, as I do not mean to endorse any particular positive ontology in this article (for example, an ontology of objects).

[3] Defenders of nihilism include Hossack 2000; Dorr 2002, 2005; Dorr and Rosen 2002; Horgan and Potrč 2008; Cameron 2010; Sider 2013; Brenner 2015a, 2015b; Caves forthcoming.

nihilism, this conclusion must be somewhat provisional. Much more could be said on this subject, and the present article does not pretend to be entirely comprehensive. One important subject which I do not address here is whether, as a general rule, nihilist-hostile scientific theories can be reduced to, or replaced by, new unobjectionable nihilist-friendly scientific theories. This subject has been dealt with before, and I do not have anything original to contribute (see especially Dorr and Rosen 2002: 162-163; Gillett 2007; Brenner 2015a). Previous nihilist writings on this subject argue that nihilist-hostile scientific theories can in general be replaced by new nihilist-friendly scientific theories, and Dorr and Rosen in particular have given a general recipe for how we can modify most nihilist-hostile theories so as to make them compatible with nihilism. If these philosophers are correct, it would go a long way toward showing that science does not refute nihilism – it would show that, while perhaps some well confirmed scientific theories are incompatible with nihilism, we can at any rate, as a general rule, construct new nihilist-friendly theories to replace them. Again, a discussion of this subject is beyond the scope of this paper, although interested readers are referred to the literature cited above.

The rest of this article will be organized in the following manner. First, I consider alleged evidence for composition which consists in the fact that references to composition are such a ubiquitous feature of well confirmed scientific theories. In response I motivate a limited form of scientific anti-realism with respect to those components of scientific theories which refer to composite objects or composition relations. I'll then turn to two phenomena which might be thought to be particularly difficult for the nihilist to accommodate (given a realist construal of the phenomena in question), namely quantum entanglement and natural selection.

2 Ubiquitous Reference To Composition In Science

An initial challenge facing nihilism stems from Williamson's (2007: 223) suggestion that actual scientific practice depends upon the existence of ordinary macroscopic (composite) objects, insofar as such objects include our scientific instruments (microscopes, telescopes, etc.). The idea seems to be that there is something incoherent in believing in objects on the basis of evidence provided by such instruments (for example, believing in microscopic mereological simples on the basis of evidence garnered from particle colliders), if one doesn't believe in the measuring instruments. I don't think this argument is very

compelling. Simples arranged instrument-wise[4] can (collectively) function as measuring instruments just as well as composite measuring instruments can. For example, if we're using a microscope, and suddenly the simples which composed the microscope stop composing a microscope (but they otherwise remain the same), then we wouldn't know the difference. It isn't as if the magnified image we're looking at would suddenly become blurry, or disappear altogether. Rather, the simples arranged microscope-wise will continue to perform the function performed by composite microscopes.

A more compelling challenge facing nihilism stems from the fact that references to composition seem to be such a ubiquitous feature of scientific theories. This difficulty is emphasized by Thomasson when she writes (with disapproval):

> Neo-Quinean metaphysicians do not merely wait on and reiterate the results of the sciences; instead they seem to assume that the work of metaphysicians may overturn the declarations of the sciences – for a great many, perhaps most, metaphysical theories plainly reject a number of entities one or more of the natural sciences quantify over (organisms, composite objects, etc.) (Thomasson 2015: 17; see also Morganti 2013: 172)

(Thomasson's point can also be directed toward nihilists who are not neo-Quineans.)

I have neither the space nor the expertise to examine every purported case in which a well confirmed scientific theory is alleged to provide evidence for composition, although in subsequent sections I'll take a more detailed look at two particular scientific phenomena (quantum entanglement and natural selection) which might be thought to provide evidence for composition. In this section I'll take a broader look at the relationship between science and composition, in an attempt to shift the burden of proof onto those who think that the near ubiquitous presence of apparent quantification over composites in scientific theories is sufficient to compel us to believe that composite objects exist. We shouldn't simply read off the existence of composites from their presence in any particular scientific theory. Rather, we should, I think,

[4]The "arranged F-wise" locution is a bit of jargon introduced by van Inwagen (1990), and subsequently employed by others (for example, Dorr and Rosen 2002; Merricks 2003). Following Merricks, we might say that some things (or stuff, although I will generally ignore this alternative) are "arranged composite object F-wise" iff "they both have the properties and also stand in the relations to microscopica upon which, if [Fs] existed, those [things'] *composing [an F]* would non-trivially supervene" (Merricks 2003: 4). For further discussion see Brenner 2015a.

adopt an instrumentalist interpretation of those components of scientific theories which refer to composition. More weakly: we should not be realists with respect to those components of scientific theories which refer to composition. The latter thesis is strictly speaking all I need to establish in this paper, even if the former anti-realist thesis is, I think, warranted as well.

There are often pragmatic motivations for formulating scientific theories in terms which involve quantification over composites, but such quantification need not lead us to believe that our acceptance of the relevant scientific theories requires that we believe in composites. The sense in which we "accept" the theories in question will not, of course, amount to accepting *as true*. But there are other ways to accept some theory. We might believe, for example, that the theory is empirically adequate (van Fraassen 1980), or that it is a useful fiction (Dorr and Rosen 2002), or perhaps that the theory is false (or false for all we know), but "correct" in some sense which does not require that the theory be true (Merricks 2003). I don't think I need to work out the details here. Just take whatever sort of scientific anti-realism you think is best, and apply it to this case. But note that I do not advocate any sort of across-the-board scientific anti-realism.[5] Rather, the anti-realism I advocate here is restricted to those components of scientific theories which refer to composite objects and composition relations. Feel free to believe the components of those theories which do not make reference to composition, as long as you *merely accept* the components of those theories which do make reference to composition.

As anyone familiar with the ongoing debate over scientific realism is aware, there are powerful arguments for adopting an anti-realist stance with respect to scientific theories, or with respect to unobservables in particular. While these arguments are worth taking seriously, they are not what motivate the limited sort of scientific anti-realism which I advocate here. Regardless of what you think of scientific anti-realism more generally, there are particularly compelling grounds which should motivate us to accept an anti-realist interpretation of composite objects and composition relations within scientific theories. Again, it would also serve my purposes if the following considerations do not lead you to adopt the relevant sort of restricted anti-realism, but rather merely lead you to refrain from endorsing a realist interpretation of those components of scientific theories which refer to composition.

First, that the world includes mereological relations generally functions as an *unquestioned assumption* in scientific theory construction, so that alter-

[5]And, of course, were we to adopt this broader sort of anti-realism then we should not feel compelled to believe in composite objects on the basis of their inclusion in successful scientific theories.

native nihilist-friendly theories have generally never been considered. I don't mean simply that such theories have generally never been taken seriously. I mean, rather, that in many cases it hasn't even *occurred* to the relevant segments of the scientific community that there might be nihilist-friendly alternatives to their theories – in other words, that the mereological relations referred to by their theories might be gratuitous. Until such nihilist-friendly theories have been formulated and evaluated, or until we find that nihilist-friendly theories cannot in principle be constructed, we need not take a realist stance with respect to the potentially gratuitous mereological components of the scientific theories in question.[6] Dorr makes the same point:

> If a scientific theory makes some assumption which has never been tested – which has been taken so much for granted that alternative theories which do not make the assumption have never even been formulated – then the parts of the theory that rely on that assumption do not deserve the sort of deference that the rest of the theory may have earned. This seems precisely to be the status of the assumptions about mereology that are built into our scientific theories (Dorr 2002: 27-28)

The problem is not, I would like to stress, *merely* that nihilist-friendly alternative theories have generally not be considered. The fact that nihilist-friendly alternative theories tend not to be formulated is a symptom of a deeper problem, namely that scientific theories should be formulated in terms which make reference to composition is generally taken for granted, and it does not generally occur to those scientists formulating the theories that the mereological components of those theories might function as a gratuitous metaphysical assumption. Of course, we might find that, while the mereological components of the theories in question were not initially included because they made some epistemically relevant contribution to the theory (improved the theory's predictive accuracy, simplified the theory, etc.), any attempts to remove the mereological components from the theories in question, or to formulate new nihilist-friendly theories, will give us theories which are not as empirically adequate as the theories with which we began, or which suffer

[6]This point somewhat resembles Stanford's "problem of unconceived alternatives" (Stanford 2006), which Stanford uses to defend a much stronger sort of scientific anti-realism than that which I advocate here. I should mention that there are important differences between Stanford's problem of unconceived alternatives and my own similar argument in favor of a restricted anti-realism. One important difference is that while Stanford uses historical evidence to argue for the claim that many of our scientific theories will probably have plausible unconceived competitors, my argument does not take the form of a historical induction.

from some other epistemically relevant defect. In that case we may be warranted in accepting the mereological components of the theories in question, because they turn out after all not to be gratuitous. Until the mereological components of our scientific theories undergo this test, however, and earn their place, we will be unable to rule out the suspicion that they are metaphysically gratuitous.

A second reason to doubt whether it is appropriate to adopt a realist interpretation of those components of scientific theories which refer to composition is that it's just natural for us to think in terms involving composition relations and composite objects – just as it's natural for us to, say, impute mentality to inanimate objects – for contingent reasons (presumably) involving the manner in which our evolutionary history has shaped our cognitive architecture. So, arguably, we'd have a tendency to employ mereological thinking in our scientific theories whether or not we were justified in doing so (cf. Osborne 2016).

Third, it is often useful to describe some phenomenon in terms which involve composition because this will result in an easier to work with approximate description of the phenomenon. So, for example, we can approximate the future behavior of simples arranged billiard-ball-wise by supposing that they compose a ball of a particular mass, velocity, etc., and by applying relevant laws of nature (for example, Newton's laws of motion) capable of describing the future behavior of macroscopic objects on the basis of those sorts of properties. What's more, we can make such predictions without supposing that the simples in question actually compose a billiard ball. Similarly, to give another example, "from the mere contingent fact that we can describe the behavior of gasses with few macroscopic variables (e.g., temperature, pressure, volume) without resorting to the actual collisions between the (roughly) 10^{23} molecules the gas is believed to be composed of, it doesn't necessarily follow that the gas has an independent ontological status, on a par with its molecules" (Hagar 2014). There's a significant amount of research in cognitive science which highlights the fact that, in response to our limited cognitive resources, we naturally "chunk" objects together and represent them as a single unit, rather than trying to keep track of all of the individuals which allegedly make up the unit (Gobet et al. 2001; Alvarez 2011).[7] So, for example, it is often easier for human visual representational systems to monitor the behavior of a *flock* of birds, rather than all of the individual birds making up the flock – and this would be so *whether or not* there are actually such things as "flocks," since the chunking in question occurs as a

[7]For a discussion of the relevance of "chunking" to the debate over composition see Osborne 2016: §3.4.

result of our limited cognitive resources, not as a result of the existence of flocks. Additionally, as Brase et al. (1998) note, our evolutionary history has endowed us with cognitive faculties which favor statistical inferences involving some sorts of objects rather than others – objects, for example, which are cohesive, bounded, and move as a unit, rather than arbitrary proper parts, or arbitrary sums, of such objects.

Fourth, in practice it may be impossible for us to think only in terms of the simples involved in some complex phenomena, in part because any description of the simples would be wildly complex and beyond our ken, but also because *we may not know what simples there are*. So, even if in principle I might have reason to suppose that statements regarding some particular composite object could be replaced by statements regarding simples arranged composite-object-wise, I may in practice be incapable of formulating the relevant nihilist-friendly replacement statements. Until I am, it may prove convenient, as a result of practical limitations on my part, to continue to refer to the composite object.

Finally, a recurring pattern within science is that the composition relations cited to explain empirical phenomena are apt to change when convenient. For example, in one theoretical context scientists may model some system as involving such-and-such composition relations, but in another theoretical context it may prove more convenient to model the system as involving some incompatible set of composition relations. The following example from Healey will serve to illustrate the sort of phenomenon I am getting at:

> The question 'Is sunlight composed of photons or of electromagnetic fields?' has no context-independent answer according to contemporary quantum theories of light. In one context ... it may be appropriate to treat sunlight as a mixture expressed in a photon-number basis, in which case one can regard it as composed of an unknown number of photons of various energies and polarizations. In another context ... it may be appropriate to treat sunlight as the same mixture expressed in a coherent-state basis, in which case one might regard it as composed of electromagnetic waves of different wavelengths.... In yet other contexts ... some third expression may be preferable to thinking of light as composed of photons or of electromagnetic fields. The quantum theorist of light repeats and expands on the *same* kind of pragmatist answer as the classical wave theory – that sunlight has whatever parts it is most useful to regard it as being composed of (Healey 2013: 52-53)[8]

[8]See also: "How one answers the question as to whether A's are composed of B's

The fact that scientists are apt to model composition relations in incompatible ways depending on their explanatory needs has been independently noted by Healey (2013) with respect to physics and Lewontin (2000: 77-82) with respect to biology, although neither Healey nor Lewontin notes the implications of this observation for the special composition question. Here's another example, drawn from Lewontin (2000: 77-78). Evolutionary biologists have sometimes wondered whether the human chin serves some adaptive function. But the chin, Lewontin suggests, does not in fact exist. Where we think there is this composite object, the chin, there are really just two independent bones. The latter bones protrude in a distinctive manner, and our cultural and scientific practices have, accordingly, through a process of reification, assumed that there is a single composite object, the chin, to which the protrusion corresponds. This is one more example where what composite objects we take to exist, or what sorts of composition relations we take to obtain, will, in scientific contexts, depend on our theoretical needs and preferences.

In all such cases (in physics or biology) we could continue to believe in the composition relations in question, and suppose that which composition relations obtain in any given context depends on our needs and preferences. It is better, however, to drop the composition relations entirely rather than accept this sort of anthropocentrism with respect to those composition relations.[9] It may nevertheless be *useful*, for certain purposes, to construct theories which make reference to composition. What sort of composition relations we make use of in our theories will, naturally enough, depend on the theoretical purposes for which we're constructing those theories. An anti-realist interpretation of the relevant scientific practices makes sense of this fact, while the realist alternative would, again, leave us saddled with the implausible view that what composition relations obtain is a matter of human stipulation.

In this section I've defended nihilism against the following challenge: if nihilism is true, why are references to composite objects so ubiquitous in science? In the next two sections I'll take a more detailed look at phenom-

depends on the context of inquiry in which one is engaged, and the criterion for correctness of the answer is whether it works – whether it helps one further that inquiry. The question of composition is pragmatic in this way because what *constitutes* composition is negotiable, and not settled prior to and independently of the considerations advanced in the process of answering it" (Healey 2013: 53).

[9]For what it's worth, Kenneth Pearce (forthcoming) defends a view which he calls "mereological idealism," according to which what composite objects exist really *is* a matter of human stipulation, in the sense that some objects compose another object when they are "unified in thought under a concept."

ena which some philosophers have claimed represent particularly pressing challenges for nihilism: quantum entanglement and natural selection.

3 Case Study: Quantum Entanglement

One of the distinguishing features of quantum theory (versus classical mechanics) is the phenomenon of quantum entanglement, in which (on one standard way of framing the matter) the properties of distinct and spatially separated objects are correlated in an apparently non-causal manner. In more formal terms, the state vector of an entangled system "is not factorizable into tensor products of the state vectors of its ... components" (Schaffer 2010: 51). Accordingly, quantum entanglement has variously been characterized as giving rise to "holism" and/or "nonseparability" of the relevant properties of the spatially separated objects in question (see, e.g., Healey 1991). "Holism" and "nonseparability" are frequently given a mereological reading. Healey tells us that "The idea of entanglement is often illustrated by considering a pair of spin 1/2 particles: for example, an electron-positron pair emerging from the decay of a neutral pion. The pair is naturally taken to be composed of the electron and positron as its parts" (Healey 2013: 56). In a similar vein, Morganti tells us that "entangled systems certainly count as composites" (Morganti 2013: 170). One frequent way to characterize what's going on in cases of quantum entanglement is in terms of a whole[10] being "more than the sum of its parts," in some sense. Maudlin, for example, commenting on quantum entanglement, tells us that "In quantum theory ... the physical state of a complex whole cannot always be reduced to those of its parts, or to those of its parts together with their spatiotemporal relations, even when the parts inhabit distinct regions of space" (Maudlin 1998: 55).

It may be the case that, *if*, say, entangled particles compose some whole, then one or more properties of the whole will not supervene on the intrinsic properties, and spatial relations between, the particles in question. The issue in which I'm interested here, however, is whether quantum entanglement gives us a compelling reason to suppose there *are* any wholes to begin with. Explicit arguments for this sort of nihilist-hostile interpretation of entanglement are relatively rare, although recently a few philosophers have given such arguments (Morganti 2009, 2013; Schaffer 2010; Calosi and Tarozzi 2014; Calosi and Morganti forthcoming; Ismael, Schaffer forthcoming).

An initial and rather straightforward concern with the idea that entanglement results in composition is that entanglement need not occur between

[10]Terminological aside: "whole" is, in this context, just another term for "composite object."

distinct physical objects. For example, entanglement can occur between distinct degrees of freedom (e.g., spin, path, energy) within a *single* physical object such as a neutron (Hasegawa 2012). In this case entanglement can't result in composition, since the entanglement doesn't involve distinct relata which can enter into proper parthood relations. Perhaps this difficulty can be avoided. But, as I now aim to show, extant arguments for the view that entanglement results in composition are unconvincing, even where the entanglement in question occurs between distinct physical objects.

3.1 Quantum Wholes and Entanglement Relations (Schaffer; Calosi and Tarozzi)

I'll begin with the argument given by Schaffer (2010)[11] and, following Schaffer's lead, Calosi and Tarozzi (2014). A standard illustration of quantum entanglement involves two electrons in the singlet state, in which the total spin of the electrons is 0. Before measuring the spin state of either of the electrons, there's a probability of .5 that electron_1 will be measured to be spin-up and electron_2 will be measured to be spin-down, and a probability of .5 that electron_2 will be measured to be spin-up and electron_1 will be measured to be spin-down. Importantly, there is a probability of 0 that both electrons will be measured as being spin-up or spin-down.

Consider Healey's characterization of the notion of spatial nonseparability:

> *Spatial nonseparability:* There exists a compound physical system, not all of whose qualitative, intrinsic physical properties supervene on the qualitative, intrinsic physical properties of its spatially separated component systems together with the spatial relations among these component systems (Healey 1991: 412)

As long as "compound physical system" can be understood in a mereologically neutral manner so that, for example, "physical system" might function *either* as a singular term, *or* as a disguised plural term for the components of the alleged system, the electrons in the singlet state *do* seem to exhibit

[11] In a previous publication (Schaffer 2007) Schaffer argues that nihilists *can* accommodate quantum entanglement, but only by adopting existence monism, according to which only one thing exists. In Schaffer (2010) he is primarily concerned with defending priority monism, according to which the universe as a whole grounds everything else that exists. Schaffer appeals to entanglement as one line of evidence in favor of priority monism. That being said, Schaffer's appeal to entanglement can also be seen as part of an argument for the weaker thesis that *any* object (the universe, or something else) is a whole, and it is this feature of Schaffer's discussion of entanglement which concerns me here.

the requisite sort of spatial nonseparability. Put in a mereologically neutral manner, the property "has total spin 0" is in some sense true of the two electrons jointly, but their jointly instantiating that property seems to supervene neither on the intrinsic properties of the individual electrons, nor on their spatial relations to one another. But why should it follow that those electrons compose some *further* object – that is, that those electrons are thereby both proper parts of the same object? A gloss on the nonseparability in question which is less amenable to nihilism is that the sense in which the electrons "jointly" instantiate the property in question (has total spin 0) is that they are both *proper parts* of some whole which instantiates that property. If *that's* what's going on when particles are in an entangled state, then the nihilist is indeed incapable of accommodating the relevant sort of entanglement. But why should we suppose that this nihilist-hostile interpretation of the situation is correct?

Schaffer's response is this. If we don't endorse this nihilist-hostile interpretation of quantum entanglement, then we'll have to posit irreducible entanglement relations to account for the correlations between properties of entangled particles. There are at least two reasons we should not posit these sort of entanglement relations (Schaffer 2010: 54). First, quantum field theories, which supersede non-relativistic quantum mechanics, plausibly will not include entanglement relations between distinct particles, since they'll probably not include particles in their ontology to begin with.[12] Interestingly, Schaffer's appeal to quantum field theory seems to me to undermine his own argument: if there aren't any particles, then there aren't any wholes composed of entangled particles, which is precisely the position endorsed by the nihilist in the present context. Of course, in quantum field theory we'll still have entanglement. Perhaps the correct ontology of quantum field theory will include relata which, by virtue of entanglement, enter into composition relations.[13] But then we'll be left wondering whether to posit irreducible entanglement relations between the relata in question, and, of course, Schaffer

[12]Schaffer makes a similar point in Schaffer 2007: 185, n.28.

[13]For an overview of the various proposed ontologies which quantum field theories might be thought to give us, see Kuhlmann 2014: §5.1; Morganti 2013: Ch.3.3. I should take this opportunity to emphasize that, while in this section I frequently write as if there are particles, I do not mean to endorse an ontology which includes particles, and in fact I endorse no positive ontology in this article. In this section I am responding to arguments which happen to be framed in terms of an ontology of particles. Entanglement will very likely be retained in any future physical theory, even if a particle ontology will not. So, arguments from entanglement to composition can perhaps be reframed in terms of whatever ontology future physics (or current physics – e.g., quantum field theory) will give us, despite the fact that such arguments are currently formulated in terms which presuppose a particle ontology.

won't be able to appeal to the ontology of quantum field theory as support for the view that we shouldn't posit such irreducible entanglement relations – at any rate, Schaffer will not be able to appeal to the ontology of quantum field theory *in the manner in which he does so here*, as grounds for thinking the relata of the irreducible entanglement relation do not in fact exist. In short: Schaffer's appeal to the ontology of quantum field theory does not give us any reason to refrain from positing irreducible entanglement relations.

Schaffer's second objection to irreducible entanglement relations is borrowed from Healey (1991), and is also endorsed by Calosi and Tarozzi (2014: 72):

> If one treats entangled systems holistically, then one accords them basic intrinsic spin properties, and crucially one can attribute *the very same property* to different systems with different number of components. For instance, a single electron, and various systems, might each have the same spin property. But if one treats entangled systems via parts in entanglement relations, then one cannot attribute *the same relation* with different numbers of components (Schaffer 2010: 54)

As Bohn succinctly puts the worry, "The relation of entanglement between n particles is not the same relation as the relation of entanglement between n + 1 particles. They differ in their addicity, and hence must be different relations" (Bohn 2012: 219). In other words, we might wonder: how can we attribute a spin state (total spin 0) to, say, two entangled electrons, while saying that some greater number of entangled particles also has that spin state?

The correct response to this concern is, I think, the following one. The nihilist should think that electrons in the singlet state *collectively* instantiate the multigrade relation "have total spin 0," in the same manner in which the nihilist suggests that simples "arranged bookshelf-wise" collectively hold up simples "arranged book-wise," despite the fact that there are neither books nor bookshelves. This is the sense in which, as I suggested above, the electrons might "jointly" instantiate the property "has total spin 0," without composing some whole which instantiates that property.[14] Compare: some dogs might collectively surround a cat, even if those dogs do not compose some further object which surrounds the cat.

[14]That electrons in the singlet state might merely *collectively* instantiate the relation "have total spin 0" is, I think, a fairly straightforward interpretation of the matter, but one which is widely overlooked. Two exceptions are Bohn 2012: §2.2; Caves forthcoming.

The nihilist should suggest, then, that a single Higgs boson could instantiate the property "has total spin 0," although it would not *collectively* instantiate that property, while two electrons in the singlet state *would* collectively instantiate that property (or, more accurately, that relation). In both cases the same property or relation ("has/have total spin 0") is instantiated (cf. Bohn 2012: 219; Caves forthcoming). What differs is the *manner* in which that property is instantiated. Compare: we might say that "simples arranged shelf-wise" instantiate the relation "holding up some books." Alternatively, some *single* object (a shelf), might also instantiate the property "holding up some books." In both cases the same property/relation is instantiated. The difference between the two scenarios is just that in the former scenario the simples in question collectively instantiate that relation, while in the latter scenario the shelf instantiates the property by itself, so to speak.

Here is a concern: We might doubt that, e.g., a single particle, as well as distinct ensembles of particles with different numbers of relata, will all instantiate the *same* multi-grade relation, "has/have total spin 0", given that the relevant mathematical formalism will represent each of these relations in very different manners, depending on, for example, the number of relata involved.[15] In response I would note that the same relation (in this case "has/have total spin 0") can be described by, or at any rate supervenient upon, a variety of formal mathematical descriptions, just as, for example, a wide combination of objects can instantiate the property/relation "has/have total mass 5kg," or a wide range of paint patterns can satisfy the predicate "is polka dotted." And in fact we have reason to believe that in the case under discussion (electrons in the singlet state) the particles in question are such that their total spin is 0, just as, e.g., a Higgs boson's total spin is 0. In both cases, then, the same property/relation is instantiated, despite the fact that a different number of relata are involved, and despite the fact that the property/relation in question will be given a different formal mathematical representation in each of these cases.

3.2 Quantum Wholes and Brute Facts (Calosi and Morganti)

The nihilist, I have suggested, can say that particles in the singlet state *collectively* instantiate a relation (have total spin 0) which is generally erroneously attributed to a whole composed of those particles. Calosi and Morganti (forthcoming) maintain that this view is untenable, insofar as it

[15]Thanks to an anonymous referee for suggesting I address this worry.

saddles us with a brute fact which we will otherwise not be forced to countenance: the brute fact that the collective properties in question occur under *these* circumstances (when certain sorts of entanglement occur), rather than some other circumstances.[16] This might very well alarm the nihilist (nobody wants to posit brute facts if they can help it), but is the non-nihilist in any better position *vis a vis* positing brute facts? As Calosi and Morganti put the worry: "An objection could be levelled at this point to the effect that we are simply replacing a primitive with another: that is, primitive facts of exemplification of entanglement relations/collective properties with facts of composition" (Calosi and Morganti forthcoming: 11). In response to this concern Calosi and Morganti note that the sort of composition required to make sense of entanglement is the same sort of composition almost everyone else will be comfortable with anyway. Making sense of entanglement in mereological terms (i.e., electrons in the singlet state compose some further object which instantiates the property "has total spin 0") will leave us with just as many brute facts as composition more generally will require.

This article is a partial defense of the view that composition never occurs, so we cannot take it for granted, as Calosi and Morganti do, that we will have to posit composition *regardless* of the manner in which we interpret quantum entanglement. Calosi and Morganti tell us that mereological nihilism is "certainly a non-negligible additional cost" (Calosi and Morganti forthcoming: 11), but they do not tell us what that additional cost for the nihilist is supposed to be. Elsewhere (Brenner 2015b) I've argued that nihilism is simpler than its competitors precisely because it allows us to avoid positing a number of brute facts which those who believe in composition will have to posit – as we've seen, this is just the sort of argument employed by Calosi and Morganti against collective properties instantiated by entangled objects. But whereas the nihilist will have to posit, at most, relatively few brute facts to accommodate quantum entanglement (namely, a fact to the effect that entanglement between distinct relata – as opposed to distinct degrees of freedom within the same object – results in the instantiation of collective properties), those who believe in composition will have to posit quite a number of brute facts, regarding the circumstances under which composition occurs, mereological laws, the modal properties of composite objects, the nature of constitution, the pairing of wholes with their proper parts, and the truth status of the weak

[16]Calosi and Morganti's main target is Humean supervenience, which I have no desire to defend here. In virtue of his endorsement of collective properties instantiated by entangled particles the proponent of Humean supervenience may be left with additional explanatory burdens which I do not address here (see Calosi and Morganti forthcoming: 9-10; note: all page references for Calosi and Morganti forthcoming refer to the online version of the article, as it has not yet been assigned to an issue).

supplementation principle (for further details see Brenner 2015b, especially §3).

Take, for example, mereological laws, those laws which govern the manner in which properties of composite objects supervene on, or are determined by, the properties of their proper parts. Those who believe in composition generally take it for granted that the properties of composite objects vary in certain systematic ways with the properties of their proper parts – the composite is located where its proper parts are located, has the shape and mass of its proper parts, is the color(s) of its proper parts, etc. But, as Cameron (2014: 90-91) emphasizes, it is very mysterious that the properties of composite objects vary in these sorts of systematic ways with the properties of their proper parts, since composite objects are, pace proponents of composition as identity, not identical with their proper parts. More generally, "when one relatum drags along the other(s), it calls out for explanation; when some facts supervene on others, it calls out for explanation" (Cameron 2014: 91). I've argued (Brenner 2015b) that at least some mereological laws will be brute, neither reducible to nor explainable in terms of some more fundamental laws or principles. So, those who believe in composition will have to posit at least some brute laws regarding the manner in which the properties of composite objects supervene on the properties of their proper parts, but the nihilist will not need to posit such laws.[17]

So, absent some independent reason to believe in composition, the nihilist interpretation of entanglement arguably satisfies Calosi's and Morganti's methodological constraints (reduce the number of brute facts we'll have to posit) better than their own nihilist-hostile interpretation of entanglement.

3.3 Entangled Systems As Extended Simples

So far I've been discussing a nihilist-friendly construal of entanglement which involves the idea of properties collectively instantiated by the relata of some entanglement relations. Here's another nihilist-friendly interpretation of entanglement: the nihilist might suppose that when two or more objects be-

[17]One concern here is that the sorts of laws of mereology cited above are contained by definition in the notion of proper parthood or composition. So, once one posits a proper parthood or composition relation (a non-negligible theoretical cost) one gets the laws for free. In Brenner 2015b (331) I note that if one takes this route, then the proper parthood or composition relations will make larger contributions to the theoretical complexity of those theories which posit that composition occurs, since the notion that proper parthood or composition occurs will contain more content (i.e., not only do proper parthood relations obtain, but they have such-and-such features as well).

come entangled they go out of existence and are replaced by a new spatially scattered simple ("scattered" because it occupies non-contiguous regions of space).[18] So, for example, when electrons in the singlet state become entangled they go out of existence and are replaced by a new extended simple which has the property "has total spin 0." I should be clear that I don't endorse this idea. But is it really so much worse than the nihilist-hostile interpretation of entanglement endorsed by Schaffer, et al.? Of course it *seems* odd to suppose that the particles in question go out of existence and a new spatially extended simple mysteriously comes into existence to replace them, but this is not much weirder than what believers in composition generally already believe. They generally believe that a whole new object pops into existence when some simples begin to instantiate certain properties – for example, when those simples become entangled. Morganti is explicit on this point: in the formation of entangled systems, "*interaction* between separate particles gives rise to a radically new entity, with completely new features – most notably, as we have seen, the non-factorizability of the total state" (Morganti 2009: 229).[19]

Admittedly, composition merely involves the creation of a new object, while the idea proposed here involves both the creation of a new extended simple as well as the destruction of those particles which enter into an entanglement relation.[20] This might give us some reason to prefer the mereological interpretation of entanglement over the extended simple interpretation. I'll leave the matter here, since in any case I do not endorse the extended simple interpretation of entanglement. The extended simple interpretation should be born in mind, however, as one possible, though neglected, way of interpreting what's going on when some particles enter into an entanglement relation.

3.4 Quantum Wholes and Quantum Statistics (Morganti; Calosi and Tarozzi)

The points I've made up to this point can be used to respond to Morganti's (2009) argument in favor of interpreting entangled systems as wholes of which

[18]Or maybe it wouldn't be spatially scattered if, per some of Bohm's (1980: 236-240) speculations, the entangled particles are merely three dimensional projections of some single (non spatially scattered) higher dimensional object. Howard (1989: 251) makes a similar suggestion.

[19]The suggestion in this paragraph, that entangled systems are really just spatially scattered simples, was proposed as one possible nihilist-friendly interpretation of quantum entanglement in Schaffer 2007: §6.

[20]Thanks here to an anonymous referee.

the entangled components are proper parts (this argument is, again, endorsed by Calosi and Tarozzi 2014: 72). Morganti's suggestion is that the relevant sort of composition explains the peculiar nature of quantum statistics:

> the statistically relevant properties of many-particle systems of quantum identical particles are inherent properties possessed by those systems as unitary wholes; ... they describe the many-particle systems they belong to without saying anything about the specific particles, and only conveying information about (correlated) future measurement outcomes; hence, in a way that is insensitive to permutations of the particles... (Morganti 2009: 228)

To give just one example, what explains why there are only two possible states for the spin states of two electrons in the singlet state (i.e., electron_1 spin-up and electron_2 spin-down; electron_1 spin-down, electron_2 spin-up)? Why are there two possible total states rather than four? The explanation, Morganti suggests, is that the electrons compose a *whole* which instantiates the property "has total spin 0." In response, I'd note that the peculiar statistics in question are equally well explained in the manners discussed above: the electrons *collectively* instantiate the relation "have total spin 0," the electrons instantiate an irreducible entanglement or correlation relation, or, when they become entangled, the electrons are replaced by a spatially extended simple which instantiates the property "has total spin 0."

3.5 Quantum Wholes As Common Causes/Grounds (Morganti; Ismael and Schaffer)

I will address one final argument for the view that entanglement should be understood in terms which involve composition. On some views wholes composed of entangled objects are *explanatory posits* – the whole's being in the singlet state, for example, is supposed to *explain* why the two electrons in question are in an entangled state (Morganti 2013: 171-172; Ismael, Schaffer forthcoming). Henceforth I'll speak of the explanatory relation in question as a grounding relation,[21] since this seems to me to be the best way to cash out the sort of explanatory relation in question (for details see Ismael, Schaffer forthcoming).[22] Just as we might infer to a common cause from the properties

[21] Although Morganti thinks of it as a causal relation.

[22] Below I'll often write as if the relata of the grounding relation is, or can be, particulars. This is controversial. If you don't like the idea that particulars can be the relata of grounding relations, substitute my talk of particulars instantiating grounding relations

of two objects being correlated in particular ways (two checks seeming to have the same signature, for example), so too we might infer to a common ground from the fact that the properties of two electrons are correlated in a particular manner. Is there any merit to this idea? If there is then it would give us some pressure toward accepting composite objects into our ontology: we should posit wholes because they function as useful explanatory posits, insofar as (for example) a whole composed of two electrons in the singlet state can explain (via a grounding relation) why those electrons have opposite spins.

This argument for composition seems to me to be more promising than the arguments for that conclusion which I considered above, and I am not sure it is entirely without merit. Note first, however, that the theoretical benefits which accrue from postulating wholes as common grounds for entanglement relations carry theoretical *costs* as well, namely ontological commitments, ideological commitments, and other theoretical commitments (mereological laws, for example) which are not incurred by the nihilist.

Second, as I note above, entanglement can occur between distinct degrees of freedom of a single object. In these sorts of cases we have no grounds for positing any sort of whole as a common ground for the entangled degrees of freedom. Take, for example, an object O with entangled degrees of freedom D_1 and D_2. What whole would function as a common ground for the entangled degrees of freedom? There aren't any plausible candidates: Not O, since O would then ground itself having certain properties (e.g., the spin or path of O, or whatever), and in any case O might be a simple; not some object partially composed of D_1 or D_2, since D_1 and D_2 don't strictly speaking exist, and so can't enter into parthood relations.[23] If we need not postulate composites as common grounds to account for entanglement between distinct degrees of freedom within a single object, we might wonder whether composites as common grounds might be dispensable explanatory posits in other contexts involving entanglement, for example in the case of electrons in the singlet state. In other words, if we don't need composition to explain the former sort of entanglement, perhaps we don't need it to explain the latter sort of entanglement.

Morganti, Ismael, and Schaffer can, of course, claim that there is a significant metaphysical difference between the two sorts of entanglement, namely that one sort of entanglement involves correlations between properties in

with whatever ontological category you do regard as the relata of grounding relations (propositions regarding those particulars, facts regarding those particulars, whatever).

[23]If the entangled degrees of freedom can't enter into parthood relations, you might wonder how they can enter into entanglement relations. In response I'll note that, since degrees of freedom don't strictly speaking exist, any talk of degrees of freedom (including their entering into entanglement relations) should in principle be amenable to paraphrase.

distinct objects, while the other sort of entanglement involves correlation between distinct properties of the *same* object. This is, of course, a noteworthy difference between the two sorts of entanglement, but the important point to note here is that despite the metaphysical distinction between the two sorts of entanglement, both cases make the same sort of explanatory demand: what, if anything, accounts for the correlations between the entangled properties? What makes the nihilist-hostile common grounds explanation for the correlations tempting is that it gives us a response to this explanatory demand. But if we have this sort of explanatory demand in one sort of cases (that is, with respect to one sort of entanglement), it seems to me to be objectionably *ad hoc* to suggest we have no such explanatory demand in the other sort of case (that is, with respect to entanglement between distinct degrees of freedom in a single object), merely because the latter sort of entanglement is not conveniently amenable to the sort of common ground explanation to which the former sort of entanglement is amenable. Of course, Morganti, Ismael, and Schaffer might suggest that the "explanatory demand," as I've put it, in cases of entanglement between distinct degrees of freedom in a single object can be met, although as we've seen it cannot be met by a common ground explanation. In that case, however, why couldn't the explanatory strategy employed here be used to offer an explanation for the correlated properties of distinct objects which have entered into entanglement relations? But if we have this sort of nihilist-friendly explanation with respect to the latter sorts of entanglement, this will, it would seem, undermine the need to endorse the nihilist-hostile common ground explanation of that entanglement.

4 Case Study: Natural Selection

As a second case study, I'll consider whether evolutionary biology requires quantification over composites.

David Hull thinks that evolutionary biology will require us to quantify over species, and he endorses a conception of species as mereological sums, against the standard alternative conception of species as sets or classes.[24] Here's at least one of the thought processes motivating Hull's view: "Selection can act only on spatiotemporally localized entities, but if it is to act on entities more inclusive than organisms in the same sense in which it acts on organisms, these entities must be cohesive wholes...." (Hull 1980: 314).

Why think that natural selection might "act on entities more inclusive than organisms"? Well, you might think that natural selection selects for

[24]For other philosophers who defend the view of species as mereological sums see Ghiselin 1974, Brogaard 2004.

traits possessed by so-called "higher-level" units (demes, species, groups more generally), rather than merely traits possessed by organisms or genes. So, for example, it is often thought that traits of a group can be promulgated at the expense of the promulgation of the traits possessed by some of the individual organisms in that group. For instance, group selection might result in intra group sex ratios favoring females to males, since groups with such sex ratios would be more successful at replicating themselves (Colwell 1981), even when organism selection would not result in these sorts of sex ratios. There is mounting evidence for the presence of some such female biased sex ratios in nature (Gould 2002: 648-649). Similarly, there is some empirical evidence for selection operating at the species level, in, for example, the apparent fact that having a relatively large geographic range is an adaptive and potentially heritable trait of species (Jablonski 1987). Let's assume, for illustrative purposes, that such cases are genuine cases of higher-level (group, species, etc.) selection, and that they can't be explained as cases of selection operating on some lower level (the level of genes or individual organisms, for example). What should the nihilist make of such cases? Don't they require that we quantify over groups and species? And if that's true, should we think of the groups and species in question as mereological sums, as Hull suggests?

Here's my response. Natural selection doesn't literally "act on entities more inclusive than organisms" (as Hull puts it). Rather, selection might, say, select for *traits* (*predicates* or *properties* or *relations*) possessed by organisms collectively – or, more accurately, traits possessed by simples arranged organism-wise arranged group-wise. A similar point can be made with respect to any of the standard options in the units of selection debate. Let's say, for example, that the unit of selection is the individual organism. If there are organisms then they are presumably composite objects, so the nihilist shouldn't admit organisms into her ontology unless she wants to give up on nihilism. But rather than suggesting that natural selection selects for traits possessed by organisms, the nihilist can simply say that natural selection selects for traits collectively possessed by simples arranged organism-wise. Some simples arranged organism-wise will be more successful than other simples arranged organism-wise at "replicating" themselves. What that means is that some relevant subset of the properties instantiated by such simples arranged organism-wise will be more successful at propagating themselves, so that over time the proportion of groupings of simples arranged organism-wise which instantiate the properties in question will increase relative to some wider number of groupings of simples (i.e., relative to some simples arranged population-wise).

Of course, this is just a sketch of how a nihilist-friendly construal of natural selection would work. My account is consonant with the fact that

natural selection really selects for *traits*, rather than for genes, or individual organisms, or whatever, and the debate over the units of selection can be reframed in terms of the question "*which* traits are selected by natural selection?" More specifically, which *sorts* of traits are selected? As a nihilist might put it: traits collectively possessed by simples arranged gene-wise, simples arranged organism-wise, simples arranged population-wise, simples arranged species-wise, etc.? The important point to note here is that there doesn't seem to be any particular reason to characterize natural selection in terms involving composites, regardless of the unit of selection one chooses to endorse.

The full story regarding nihilist paraphrasis of talk of genes, organisms, and so forth, will be a bit more complex than replacing "gene" with "simples arranged gene-wise," "organism" with "simples arranged organism-wise," and so on. For example, a purported organism will be associated with different simples at different times, in virtue of the gradual replacement of simples within the simples arranged organism-wise over time, by ingestion, excretion, and similar processes. Simples at t_1 and some other simples at t_2 will be associated with the same (illusory) organism in virtue of there being particular causal and spatio-temporal relations between the former and the latter simples, of the sort which are associated with the life of a single organism. Similarly, there are characteristic causal and spatio-temporal relations associated with simples at different times, by virtue of which they are generally regarded as simples in the same species, or genus, or family, etc., and nihilist paraphrases of sentences such as "that species has been around for millions of years" can exploit this fact.

Here's a test case for whether nihilism can accommodate evolutionary theory. In a widely cited article, Lewontin (1970) gives the following general characterization of the conditions which are necessary and sufficient for evolution by natural selection, one which is intended to be neutral with respect to the ontology required by natural selection, or the units of selection involved:[25]

> 1. Different individuals in a population have different morphologies, physiologies, and behaviors (phenotypic variation).

[25]Lewontin's summary of the conditions necessary and sufficient for evolution by natural selection is not entirely uncontroversial, but then again no such summary is. Lewontin's proposal is, however the most widely cited summary of this sort (Godfrey-Smith 2007: 1-2), so it can function as an adequate case test in the present context (that is, a case test for whether nihilism can satisfy whatever conditions are necessary and/or sufficient for evolution by natural selection to occur).

> 2. Different phenotypes have different rates of survival and reproduction in different environments (differential fitness).
>
> 3. There is a correlation between parents and offspring in the contribution of each to future generations (fitness is heritable). (Lewontin 1970: 1)

Let's start with (1). Can (1) be satisfied if nihilism is true? Yes, as long as we take care to specify that "individuals" can function as a plural term for some simples. Clearly enough, simples can collectively exhibit particular "morphologies, physiologies, and behaviors" – just think, for example, of simples arranged dog-wise versus simples arranged cat-wise. The former simples will (collectively) bark, while the latter simples will (collectively) meow.

(2) is also compatible with nihilism, as long as "survival" and "reproduction" are characterized in an ontologically neutral manner. For the nihilist, the sort of reproduction in question can't involve the creation of new organisms (or genes, or whatever), or new objects of any sort (I say a bit more about this below). Rather, reproduction will involve simples which were previously not collectively alive becoming such that they are now collectively alive, so that some simples which were previously not arranged organism-wise (or gene-wise, or population-wise, etc.) now *are* arranged in that manner. Similarly, "survival" should be characterized in terms of the continued instantiation of certain collective relations by simples. For example, "survival" might cease if some simples which were arranged organism-wise are no longer so arranged. On a nihilist-friendly interpretation, then, (2) will say that certain relations which are collectively instantiated by simples (for example, "being arranged dog-wise") are more successful than other such relations at propagating themselves – i.e., more successful, roughly, at making it the case that more groupings of simples come to instantiate that relation.

(3) is also compatible with nihilism, as long as "parent" and "offspring" can function as plural terms for some simples arranged organism-wise (or gene-wise, or population-wise, etc.). To say that there is a "correlation" between the traits of parent and offspring would, on a nihilist account, amount to saying that relevant properties instantiated by simples arranged parent-wise can be transferred in an appropriate manner to simples arranged offspring-wise.

So, in short, there seems to me to be a strong *prima facie* case for the view that natural selection can be reconciled with nihilism. Why, then, did Hull insist that species exist and that they are mereological sums? For starters, Hull seems to just take it for granted that species exist. What he is primarily concerned to establish is that species are, like genes and

organisms, *spatiotemporally located*, in part because "Both replication and reproduction are spatiotemporally localized processes" (Hull 1978: 341) (see also Hull 1978: 337). Hull may have been under the impression that species can only be spatiotemporally located if they are mereological sums. But there's another option which Hull did not consider: species do not exist, but there *are* spatiotemporally located simples arranged species-wise, and talk of "species" can be replaced for all theoretically important purposes by talk of "simples arranged species-wise."

Before ending this section, I'd like to note some interesting consequences of my nihilist-friendly characterization of natural selection. First, reproduction, an important component of natural selection on any construal of the latter concept, is regularly characterized in such a manner that, for reproduction to occur, a *new* object (i.e., a new organism) must come into existence (see, e.g., Godfrey-Smith 2009: 69). Strictly speaking, on my account, reproduction of this sort doesn't occur. Rather, where we might naïvely suppose that this sort of reproduction takes place, we really have nothing more than the redistribution of pre-existing simples. For example, perhaps some simples arranged fish-wise cause some other simples, which previously were not arranged fish-wise, now to be so arranged. Interestingly, however, the nihilist insistence that reproduction does not occur immediately solves two puzzles which plague traditional attempts to give precise characterizations of reproduction within the context of evolutionary theory:

> (1) *Reproduction versus growth.* When is the production of new biological *material* the production of a new *individual*?
>
> ...
>
> (2) *Collective entities.* When do we have reproduction of a higher-level unit, as opposed to reproduction only of lower-level constituents that also come to have a particular organization? (Godfrey-Smith 2009: 70)

These are *metaphysical* questions, questions which ask when certain sorts of individuals do or do not come into existence. Nihilism provides ready answers to these questions: according to the nihilist, reproduction only results in the creation of a new individual if it results in the creation of a new mereological simple. The sort of reproduction which interests biologists presumably does not result in the creation of new mereological simples. So, there may actually be theoretical pressure toward adopting a nihilist-friendly construal of reproduction within the context of evolutionary theory, insofar as it helps us avoid the sorts of conceptual difficulties which beset alternative characterizations of reproduction.

Another theoretical cost associated with nihilist-hostile interpretations of evolutionary theory is the *ontic vagueness* which will have to be admitted. Take, for example, quantification over species.[26] Where does one species end and another begin? Species are, in Dawkins' memorable phrase, "like clouds in the sky or dust-storms in the desert" (Dawkins 1989: 34). In other words, it is a vague matter which individual organisms are to be included in any particular species. Many philosophers will be unwilling to posit this sort of vagueness.

Gould notes that the portion of a species' duration which is vague will compare favorably with the portion of a human organism's duration which is vague (Gould 2002: 606). Similarly, Hull writes that if we are willing to posit the existence of organisms, despite the fact that they would have vague boundaries, then species' vague boundaries should not concern us either (Hull 1976: 177). True enough, it is not just *species* which would have vague temporal and spatial boundaries if they existed. Smaller units of selection (organisms, and for that matter genes as well) will also have vague boundaries, although on much smaller temporal and spatial scales. But, pace Gould and Hull, the fact that organisms would have vague boundaries if they existed *does* give us some reason to avoid including them in our ontology – we can't take the existence of organisms for granted.

That many composite objects' existence may involve objectionable ontic vagueness is a well known motivation for nihilism with respect to those composite objects (cf. Horgan and Potrč 2008), so the points I'm making here are by no means original ones. What strikes me as noteworthy, however, is that while biologists and philosophers of biology have sometimes correctly noted that quantification over species may be problematic because of the ontic vagueness which we will have to countenance as a result, they have been much less willing to note that every other unit of selection faces the exact same difficulty – genes will be vague, organisms will be vague, and so on. If we are unwilling to posit this sort of ontic vagueness, then we will have to admit that every unit of selection is objectionable, or we may have to rethink whether commitment to a particular unit of selection (genes, or species, whatever) commits us to quantifying over the thing adverted to in the unit of selection (genes, species, etc.). It is the second option which I've defended in this section.

[26]The vagueness objection to species as individuals is quite popular. See, for example, Williams 1992: 121-122, and citations therein.

5 Conclusion

Quantification over composite objects is a ubiquitous component of scientific theories. This poses an obvious *prima facie* difficulty for the mereological nihilist, but one which can be met. In particular, we have good reason to think that the components of the relevant scientific theories which make reference to composites need not be interpreted in a realist manner. I've taken a closer look at two particular scientific contexts which some philosophers have argued make use of ineliminable quantification over composite objects: quantum entanglement and natural selection. I've shown that arguments for the conclusion that these phenomena should be interpreted in terms involving quantification over composites are not compelling.[27]

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