Carving Up Reality

Can Physics Provide a Moderate Solution to the Special Composition Question?

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Abstract

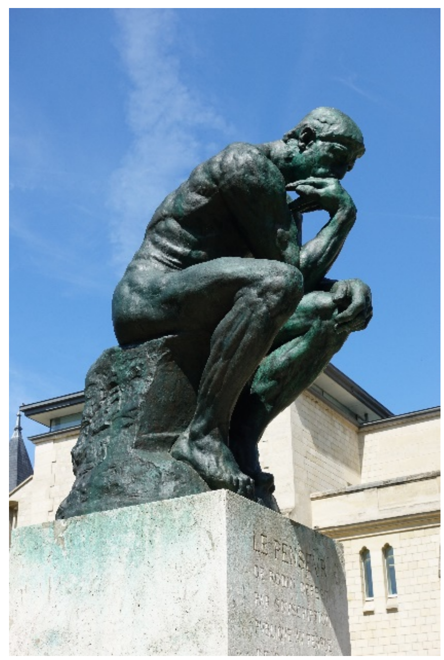
In 1990, Peter van Inwagen formally posed the Special Composition Question (SCQ). The puzzle is: under what conditions does a set of objects $S = \{a_1, \dots a_j\}$ compose a new object A? Possible answers fall into two camps: conventionalist or "extreme" answers, and restrictivist or "moderate" answers. Restrictivist mereologies are rare to come by these days, but recently, some philosophers have invoked physics in an effort to preserve so-called *ontological realism*. The two leading contenders are the *Bound State Answer* (McKenzie and Muller; Calosi) and the *Entanglement Proposal* (Calosi; Brenner). After giving an overview of the SCQ and some primitive responses, this paper challenges the aforementioned restrictivist solutions and further questions whether an appeal to physics is even useful when investigating the mereological problem of composition.

"I know that I am not a category. I am not a thing—a noun. I seem to be a verb, an evolutionary process—an integral function of the universe"—Buckminster Fuller

1. Introduction

Begrudgingly, to avoid any vagueness, we must get some philosophy jargon out of the way. We will be using "metaphysics" in the non-pejorative sense—it is simply the philosophical study of reality. Usually studying metaphysics typically entails considering a handful of archaic paradoxes concerning persistence, identity, and infinite series. *Ontology* is the branch of metaphysics concerning the nature of existence, and *mereology* in particular is concerned with material composition: the relations between parts and wholes.

When philosophers claim the set of objects S composes object A, they mean to say A is something "over and above" its parts. On the surface (and arguably, upon further investigation), this question seems banal. An object, presuming it is made of matter, is identical to its constituent atoms. But let us mull over an old puzzle.



Study the picture to the right. Disregarding the surroundings, if I asked how many things are in this picture, consider how you might respond. Those who do not thrive on being abstruse would likely answer just one. Obviously! The statue—*The Thinker* by Rodin.

Now I, the contrarian, come along and assert "No! There are clearly two objects here—the statue and the lump of bronze from which the statue has been constructed!" You would rightfully roll your eyes and disengage from the conversation. However, what if I then melt down *The Thinker* so that only an amorphous lump of bronze remains? Logically, I have destroyed the statue, but I have not destroyed the lump of bronze. So, it cannot be the case that the statue and the lump of bronze are identical. The statue was something "over and above" its material constituents.

Now, as an intelligent person, you are likely thinking, "…who cares? Do people actually ask under what conditions atoms 'make up' solids? This is not a metaphysical issue, it's a semantic one."

My response to such concerns is this: Indeed, I agree that this is unequivocally a puzzle of linguistic convention. However, this has not discouraged others from treating it as a metaphysical or even physical quandary.

2. *How to Answer the SCQ*

Typical responses to the SCQ fall into one of two categories: extremist or conventionalist approaches and restrictivist approaches. Of the conventionalist positions, there are two: mereological nihilism and mereological universalism.

Nihilism outright rejects the thesis that there are any composite objects in the universe. The world contains only *simples* (the alleged smallest constituents of nature—be they the entities of the standard model, the strings of string theory, or what have you). The existence of anything "over and above" those parts is merely an artifact of human perception. Universalism, on the other hand, accepts any and all non-overlapping objects, no matter how disjoint or seemingly unrelated. Subatomic particles, atoms, ordinary objects like chairs, people, the solar system are all objects. Moreover, the two-particle system of electron A on Earth and electron B on Neptune, as well as the combination of my left ear and the tail of every cat in Vienna are equally valid "objects." We just find some concepts more practical than others, which is why we do not have a word for the "ear-cat tail" composite object.

For all of our intents and purposes, these positions amount to the same thing. Whichever side you personally claim to fall on is largely informed by whether or not you accept the existence of *simples*. We have the luxury of remaining agnostic here and can just consider these both under the umbrella of conventionalist solutions. The primary motivation against conventionalism is that both positions are associated with antirealism. Under this view there is no correct way to cut up the universe; there may be things objectively *happening*, but the words we use to describe those things—well, that's all just convention. What we call "chair" is just some stuff arranged *chair-wise*. "Object-ness" is a property we as humans imbue events with.

Many are naturally uncomfortable with the prospect of antirealism. Common sense tells us that of course there are composite objects. We interact with them all the time—we are composite objects! A tree is a tree, and a dog is a dog. Yet my dog and the tree in my backyard do not compose a third, new object called a "trog" (Korman, 2015). This is the common-sense position known as mereological conservativism. Other restrictivist mereologies fall into the camp known as eliminativism. Like conservativism, eliminativism accepts some, but not all, composite objects. However, the conditions for composition tend to be more stringent. Inwagen himself embraces a view known as organicism—the belief that *only* living things exist. Or as Sean Jennings puts it, "Organicists are committed to the claim that although there are people, strictly speaking none of them are wearing clothes."

A trog. Tree-part (L) and dog-part (R)

3. Motivation for a Science-Based Answer to the Question: Vagueness

Until recently, the only moderate solution to the SCQ that had been extensively written about was organicism. Even at surface level, it is difficult to accept because, for starters, we do not even have a universal definition of life. Animals, plants, fungi, protists, bacteria, and possibly viruses? It is unclear why he would leave out biological complexes such swarms, hives, or ecosystems. Moreover, organicism sniffs of a residual sort of anthropocentrism—the idea that life occupies some sort of privileged place in the universe. Which one may accept. Far be it from me to call Inwagen's life meaningless in the grand scheme of things. In any case, let us set aside biology and question whether physics might provide any insight into the Question.

One would be foolish to embrace a metaphysics unsupported by physics. In a similar vein, one's own interpretation of physics is to some extent informed by an underlying metaphysics. However, it would be a mistake to assert that metaphysicians are in any place to solve modern problems in physics. Would it then be an equally foolish endeavor to attempt to solve a metaphysical problem with physics? I think yes, but a few would disagree. Restrictivist arguments *are* rare to come by these days, but they are out there since, as we noted, conventionalist solutions lead to anti-realism. We would hope that our descriptions track nature accurately and are true, independent of fallible human perception.

Consider that it may simply be the case that *vagueness* is an unavoidable feature of natural language. Bertrand Russell argued just that in 1923. Even so, one may wonder about *formal* languages. What about something like mathematics?

Consider the fact that it is only due to *convention* that we use the decimal system. We could just as well utilize hexadecimals or a duodecimal system. The Mayans opted for base twenty. Furthermore, what is significant about the fact that all *n*-dimensional vector spaces are isomorphic to each other? Isn't it curious that we can build multiple valid models given the axioms of hyperbolic geometry?

Yes, these are conventions, but the findings of mathematics are *necessary* truths. The truth value of a proposition like "the chair is blue" is contingent on a number of conditions. Yet the proposition "$1 + 1 = 2$" is contingent on nothing. It seems the language of mathematics is governed by an internal precision often lacking in ordinary languages. Since physics uses mathematics more than any other natural science, it should be perfectly positioned to generate a moderate solution for the SCQ that avoids all this troublesome vagueness.

4. The Bound State Answer

The first physics-based restrictivist proposal for the SCQ was posited by Kerry McKenzie and F.A. Muller in 2017: the so-called *Bound State Answer (BSA)*. Here, "bound state" is an umbrella term meant to encompass a plethora of bound systems, from atomic orbitals to collections of gravitationally bound objects. Under the authors' purview, we too have living organisms, but we also have ordinary objects of perception like chairs and the objects of physics like atoms. We even have more abstract objects like the solar system or the Milky Way.

The BSA supposedly offers three virtues over conventionalist and other restrictivist approaches: (1) it preserves our common-sense judgements about what counts as an object (2) it evades the problem of vagueness by appealing to the sharp distinction between "bound" and "unbound" (3) being a generic solution, it evinces a unity not offered by other accounts. The proposal is as follows.

Let $Comp(S, A)$ mean "the objects in set S compose A", and let $a \sqsubseteq A$ mean "a is a part of A":

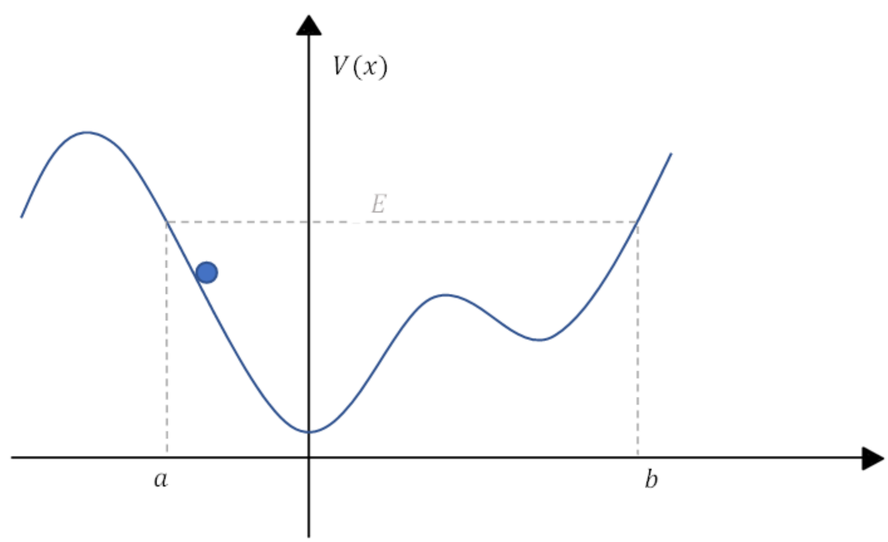
Let $S = \{a_1, a_2, \dots a_j\}$. Then $Comp(S, A)$ iff:

(i) $\forall a_i \in S, a_i \sqsubseteq A$

(ii) $E_A < 0$ (i.e., the objects in S are in a common bound state)

A surface-level reading might leave one scratching their head at the notion of a mereological theory which is both mathematically rigorous enough to evade concerns of vagueness yet generic enough so as to include a wide array of seemingly disparate objects. Indeed—I scratched my head!

For one thing, a bound state is precisely defined in quantum mechanics. In quantum, E refers the energy eigenvalue corresponding to the wave function (eigenstate) acted upon by the Hamiltonian operator. However, the meaningful physical quantity here is not E in isolation, but energy *differences*. The mathematic condition the authors mean to identify here is that the total energy E is less than $V(\pm\infty)$.

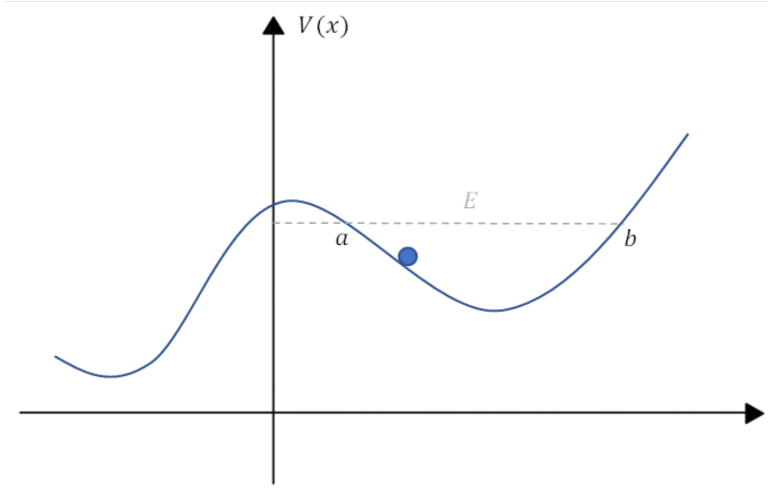


A bound state with classical turning points a and b.

Quantum mechanics is concerned with the $V(\pm\infty)$, and it is the case that for most real-life potentials,

$$\lim_{x\to\pm\infty} V(x) = 0$$

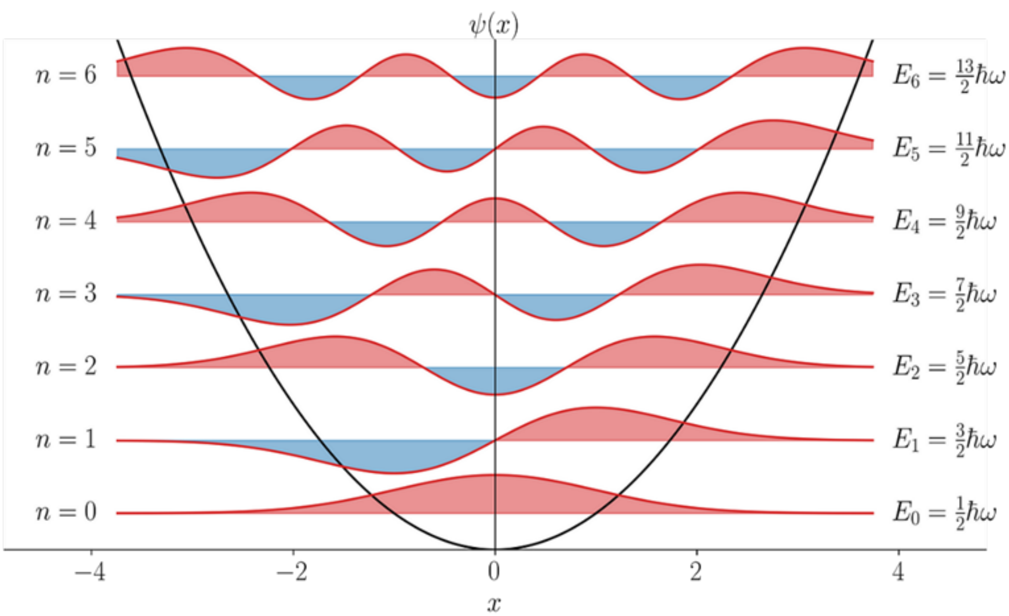
It just so happens that the condition $E < V(\pm\infty)$ often amounts to $E < 0$ in quantum systems. However, we all know this is not a universal rule. For instance, the quantum harmonic oscillator models a local minimum at a point x_0 in an arbitrary potential V as a parabola:



A classically bound but quantum scattering state.

$$V(x) = \frac{1}{2}m\omega^2x^2$$

The energy states are bound, since as we move away from x_0 the V becomes arbitrarily large. Yet we know V is always positive (assuming $x \neq 0$), so it is not the case that $E < 0$. The quantum harmonic oscillator permits *only* positive bound states.



Discrete energy spectrum of a quantum harmonic oscillator. For each n,

$E_n = \left(n + \frac{1}{2}\right)\hbar\omega > 0$

Okay, now suppose we are a generous audience and try our hand at amending the BSA. Propositions in math may be unquestionably true or false, but physics is not pure math. For any equations or inequalities we employ, we need to describe the corresponding physical system before we are able to interpret anything in a meaningful way.

Formally, we may say a quantum particle in a bound state is subject to a potential V such that it will remain localized unless sufficient energy is added to the system.

It is an improvement. However, the author's use of the phrase "bound state" for classical systems leads to even more ambiguity. We might find a classical particle to be bound anywhere we find a local minimum in the potential energy function U. For composite system A bound by gravity for instance, $|U| > |K|$. By convention, $U < 0$ and necessarily, $K \geq 0 \Rightarrow E_A = U + K < 0$. So, what can be said here?

Well, formally, a classical object in a gravitationally bound system is subject to a potential V such that it will remain localized unless sufficient energy is added to the system.

Great. This is analogous to a bound state in the quantum realm. Hence, the sun, planets, asteroids, the Kuiper belt, the JWST, and objects that are in the gravitational potential wells of *those* objects like moons, rings, and people, together compose the solar system. Although, the Voyager Probes are not part of this set, as their velocities have surpassed the escape velocity of the sun. It may still be a little hazy, but this formulation does admittedly fall more in-line with common sense than other moderate proposals. So far, atoms are real, people are real, the solar system is real. But, what about *tagnets*?

A "tagnet" is a composite object that's parts are two magnets. If I bring one bar magnet close enough to the other in the same alignment, the system moves to decrease the overall potential energy until the electrostatic forces of the individual atoms prevent the magnets from melding together completely.

In other words, an object in a magnetically bound system is subject to a vector potential A such that it will remain localized unless sufficient energy is added to the system.

Why, that's almost a copy-and-paste description of the other bound systems we discussed. So, if the solar system is a thing, and Hydrogen atoms are a thing, *tagnets* must be a thing too! We can even throw out the silly label too, since the composite behaves like the individuals—we really just have a new magnet. Also, what would the authors have to say about the composite object formed by a valley and a ball resting at the bottom?

Let us check if this mereology truly boasts the three virtues suggested by McKenzie and Muller. I will address (1) momentarily, but first let us consider the latter virtues. (3) promises a "generic" solution, and to this end, the BSA delivers. Unfortunately, this broadness serves to undermine the purported advantage detailed in (2). While the expression "$E < V(\pm\infty) \vee E \geq V(\pm\infty)$" describes mutually exclusive events (i.e., there is no ambiguity to the symbol for "or"), the authors have no choice but to leave the *physical quantity* described by E malleable. We cannot appeal *only* to mathematical syntax if we are to build a mereology; we must first make a semantic judgment about what our measurables even *represent*.

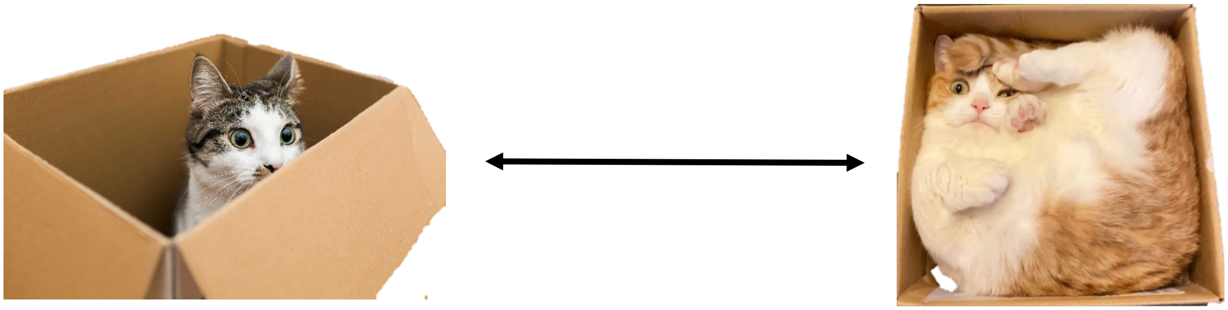
Finally, as far as (1) is concerned, I am personally wary of anyone who appeals to common sense as a virtue at all. And to the authors' credit, they at least express discomfort in appealing to intuitive judgments in mereological debates. Nevertheless, they *insist* that the BSA aligns well with our ordinary findings. For the sake of argument, let us agree that a common-sense mereology is desirable. I remain unconvinced that the BSA is up to the challenge. After all, *tagnets* may or may not be real. That leaves us with a bit of an over-counting problem. Conversely, the BSA regards other seemingly ordinary objects as strictly convention. For example, a formal jacket and pant set does not compose a suit, nor does a bikini emerge from two matching pieces of swimwear. Yet *my* common sense indicates that bikinis are real, but two decorative magnets stuck together are still just two decorative magnets stuck together. This may not align with McKenzie's and Muller's everyday intuitions. However, this is not an issue for me, since I am not alleging that *my* chosen use of language is anything other than conventional.

Overall, it seems the authors' solution falls short of rescuing restrictivism from the problem of vagueness. Their proposal may rest on the sharp distinction that an object cannot be both bound and unbound. However, the term "bound" itself is not nearly as specific as they might like to think.

5. The Entanglement Proposal

In their paper concerning the BSA, McKenzie and Muller spend a period discussing an alternative solution, the entanglement proposal. However, they fail to offer it a fair chance given their unwavering commitment to the bound state answer. Both Andrew Brenner (2016) and Claudio Calosi (2021) offer the notion of entangled composites more generosity than do the previous authors. Now, we will lay out the entanglement solution and see whether it is any more or less forceful than the BSA.

For starters, we should be careful not to conflate general entanglement with actual quantum entanglement. We can have classically entangled systems—no "spooky" interactions or correlations necessary. For example, suppose I put two cats in identical boxes, take one to California, and send the other off with a friend to Vermont. If I facetime my friend, the second they open their box on camera, I *immediately* can say for sure which cat is in the box I have, without having to actually open the box. This is a classically entangled system.



A classically entangled system.

Now, instead of cats, consider a two-particle quantum system with individual wave functions Ψ and Φ described by the states $\alpha_1|\psi_1\rangle + \alpha_2|\psi_2\rangle$ and $\beta_1|\varphi_1\rangle + \beta_2|\varphi_2\rangle$.

The state of the composite system would be given by the tensor product:

$$[\alpha_1|\psi_1\rangle + \alpha_2|\psi_2\rangle] \otimes [\beta_1|\varphi_1\rangle + \beta_2|\varphi_2\rangle]$$

Which, expanded yields:

$$\alpha_1\beta_1|\psi_1\rangle \otimes |\varphi_1\rangle + \alpha_1\beta_2|\psi_1\rangle \otimes |\varphi_2\rangle + \alpha_2\beta_1|\psi_2\rangle \otimes |\varphi_1\rangle + \alpha_2\beta_2|\psi_2\rangle \otimes |\varphi_2\rangle$$

Now, an entangled system may take on a form resembling:

$$|\psi_1\rangle \otimes |\varphi_1\rangle + |\psi_2\rangle \otimes |\varphi_2\rangle$$

So, what is the motivation for asserting such a system "composes" a unique object in some significant sense? Well, let us ask ourselves: can we describe such a system in terms of its parts *independently*? Can we describe *one* entangled particle *without* invoking properties of the other? Mathematically, can we factorize the third expression into something of the form $|\Psi\rangle \otimes |\Phi\rangle$?

Looking back to the expanded tensor product, we want both the middle products to vanish. The desired form leaves us with four conditions:

$$\alpha_1\beta_1 = 1 \qquad \alpha_2\beta_2 = 1 \qquad \alpha_1\beta_2 = 0 \qquad \alpha_2\beta_1 = 0$$

Alas! Such conditions are incompatible; the entangled state is *unfactorizable*. We can say everything there is to be said about the system as a *whole*, yet nothing of its *parts*. Why, that is a rather peculiar phenomenon. In fact, this is what Einstein found so distressing about quantum mechanics.

Entanglement is certainly a unique way to think about composition—while most moderate solutions to the SCQ appeal to locality and/or fixation, this one throws the spatial component out the window and relies *only* on correlation of intrinsic properties. Entanglement relations are governed by *behavior* rather than location. We might formalize the entanglement proposal as such:

Let $S = \{a_1, a_2, \dots a_j\}$. Then $Comp(S, A)$ iff:

(i) $\forall a_i \in S, a_i \sqsubseteq A$
(ii) For the composite wavefunction ψ_A, $\psi_A \neq \left(\psi_{a_1} \otimes \psi_{a_2} \otimes \cdots \otimes \psi_{a_j}\right)$

McKenzie and Muller acknowledge this as a plausible alternative to the BSA. While they recognize that the entanglement proposal represents a unique way for objects to compose in a significant sense, they reject that this sort of composition is relevant to mereology and the Special Composition Question. I, too, reject that the phenomenon of entanglement gets us any closer to solving the SCQ, but on different grounds.

My problem with the entanglement proposal stems from its conflation of epistemic constraints with supposedly "metaphysically significant" phenomena. My position is not fully disjointed from the discomfort Einstein felt with the Copenhagen interpretation. Unlike Einstein, I have no real issue accepting the possibility of indeterminism. On the other hand, it *is* undeniably intriguing that some systems are epistemically *irreducible* to the properties of their constituents. It is likewise fascinating to note how entanglement challenges our notions of locality. However, when our epistemology reaches its limits, albeit mathematically, instrumentally, or both, this need not persuade us to embrace unfalsifiable metaphysical claims.

Do entangled particles *compose* something over and above themselves? Well, if by "compose" one means "particles behaving such that their parallel intrinsic properties are exactly anti-correlated" then sure. If, by "compose" one means "occupies an ontologically significant place in the world", well, I do not know what that would even mean. Physics, like biology, does not have anything to say about metaphysical significance. Such would be tantamount to art criticism for the natural sciences—and as far as I am aware science criticism is not a burgeoning field. Physics cannot tell us whether systems bound by a potential or systems of entangled particles are more or less valid in their status as "wholes." Thus, we are left with the personal task of deciding what counts as a bona fide object. In other words, it all comes down to our preferred convention.

6. Conclusion

Both the BSA and the entanglement solution appear to fall short of justifying the composite status of their preferred objects. Bound states were supposed to offer relief from the vagueness of everyday language, but even the language of science is not wholly exempt from ambiguity.

Entanglement piqued our curiosity with a shiny, new conception of constitution. However, we end up with the task of deciding whether or not this conception is interesting enough to “count” as a form of composition in the same way any other arrangements do.

Philosophers should be careful not to take the language of physics as prescriptive in nature. Wittgenstein challenged our natural intuitions about what we do when we use language. It is often thought that when we identify a natural entity, the meaning of the word we assign it corresponds to *that* entity. How presumptuous we are. For the most we can be sure of is that our words correspond to our internal representations *of* that entity.

As humans, we have a natural tendency to “noun-ify” events, so to speak. This is undoubtedly a valuable endeavor. It is the goal of the scientific method to explain patterns, and patterns are most easily identified in relatively stable systems. The more stable an event is, the more inclined we are to give it the label of “thing”. However, no phenomenon in the universe is perfectly stable. Time passes, things decay. External energy gets added to bound states and entangled systems de-cohere. Objects are events. We are not nouns; we are verbs.

The Special Composition Question asks, “What does it *mean* to compose?” Phrased this way, it is easy to see why physics is ill-fitted to solve the puzzle. Physics does not concern itself with meaning—that is a headache for the linguist to nurse.

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