3D in high-D*

Theodore Sider October 13, 2021

The world as we ordinarily conceive of it, both in everyday life and in classical physics, is three-dimensional. The objects of the manifest image (rocks and trees, people and planets), the theoretical entities of pre-quantum physics (electromagnetic fields, elementary particles), and everything between (molecules, gases, cells) are conceived as located in and moving around in three dimensions.

According to the "high-dimensional" approach to the foundations of quantum mechanics, the world is ultimately not like this *at all*. Three-dimensional entities just don't exist, not at the fundamental level anyway. The fundamental space, in which all of the theoretical posits of physics are housed—in particular, the wavefunction—has an unfathomably large number of dimensions. (Perhaps 10^{85}, plus or minus several orders of magnitude.) And it isn't as if the high-dimensional world consists of an ordinary three-dimensional part with more added on (like the extra dimensions of string theory). No three-dimensional part of fundamental reality is anything like ordinary physical space.[1]

This might suggest that rocks, trees, subatomic particles, and other three-dimensionalia are *illusions*, or *intellectual mistakes*, akin to phlogiston and phrenology, and should be purged from our cognitive lives. But high-dimensionalists cannot, and do not, take this hard line. In addition to being literally unbelievable, the view would be self-undermining. The empirical evidence for any scientific theory is three-dimensional, consisting of observations of pointer positions, computer readouts, and the like. If quantum mechanics implies that statements about pointer positions and the rest are all false, it does not imply any of our evidence, and thus it is incapable of empirical confirmation.[2]

*Thanks to David Albert, Chris Meacham, and Jill North for helpful discussion.

[1]David Albert (1996, 2015, 2012, 2021) was the earliest defender. See also Ismael (2020) (though her commitment is not to high-dimensionalism as stated here but rather to the more general claim that three-dimensional facts are emergent in some way or other); Lewis (2004); Ney (2021); North (2012) (though her focus is not on ontology but rather structure). Opponents include Allori (2013); Maudlin (2007, 2010, 2018); Monton (2002, 2006).

[2]Though this epistemic argument is clearly correct in broad outline, it would be good to have a clearer understanding of how exactly it works. Does it merely need to be *true* that a high-dimensional fundamental reality would give rise to the three-dimensional evidence, or must we take into account our credences about this giving-rise-to? Does it matter whether the person doing the confirming is in an ordinary scientific context, or is trying (like a philosopher)

Accordingly, what high-dimensionalists say is not that three-dimensional matters are *unreal*, but merely that they are *nonfundamental*. High-dimensional fundamental reality "gives rise to" a nonfundamental three dimensional world. Thus high-dimensional quantum theories do, after all, imply facts about the three-dimensional evidence, and are therefore capable of confirmation.

But how, exactly, does this "giving rise to" work? It is generally agreed that it relies on some sort of structural match between the manifest image and the fundamental realm, and that it takes certain forms in certain special cases. But this consensus leaves a lot open. A fleshed-out and general view can be given, which will yield answers to some of the most challenging objections to high-dimensionalism. But it will also show that high-dimensionalism is closer than its defenders suppose to the claim that the three dimensional world is, after all, illusory.

1.

There are a number of "high-dimensional" theories, differing from one another not only in their fundamental ontologies but also in their dynamical laws.[3] Our focus will be on the high-dimensional view inspired by Bohmian mechanics, according to which in addition to the wavefunction and the high-dimensional space there is a single "marvelous particle" that moves through the high-dimensional space.[4] This theory is dynamically deterministic: the wavefunction evolves deterministically, as described by Schrödinger's equation, and the motion of the marvelous particle is determined by the wavefunction, as described by the guidance equation. But there are other versions of the high-dimensional view, and I believe that my account could be extended to them: a version inspired by GRW (in which the wavefunction is "all that there is", and evolves probabilistically, periodically undergoing collapses, and thus

to secure a more reflective justification for the theory? (Cf. Sosa (1991) on animal knowledge vs reflective knowledge.)

[3] As is usual in this literature, I consider only artificially simple quantum theories, for instance nonrelativistic ones, hoping that lessons learned here will be useful in a more general context.

[4] It's usually called the "marvelous point"; I choose the present name to emphasize that it is a further entity, distinct from the points of the high-dimensional space. 'Marvelous point' would be a better name given an alternate high-dimensional Bohmian view: one that deleted the marvelous particle from its ontology, and instead posited a property that is instantiated at any moment by exactly one point in the high-dimensional space, where the guidance equation determines which point instantiates the property at any given moment.

not always according to Schrödinger's equation) and one inspired by the many worlds view (in which the wavefunction is again "all that there is", and evolves deterministically as described by Schrödinger's equation).[5]

Let's be more explicit about the ontology of the (Bohmian) high-dimensional view. According to it, the only objects that fundamentally exist are i) the points of the high-dimensional space, and ii) the marvelous particle, which is always located at exactly one point in the high-dimensional space.[6]

If those are the only entities, then what of the wavefunction? I will assume that the facts about the wavefunction consist of the instantiation of properties corresponding to the wavefunction amplitudes by the points in the high-dimensional space. Thus "the wavefunction" does not refer to some extra entity. (This assumption about the metaphysics of fields is only for the sake of definiteness, however, and will play no essential role in my arguments.)

It is important to be clear that the high-dimensional space is claimed to be physically fundamental. The wavefunction is usually represented mathematically by a function defined on the *configuration space* of a system of N particles in three-dimensional space—a mathematical $3N$-dimensional space each of whose points represents, by stipulation, a location in three-dimensional space for each of the N particles. (The fact that it must be represented that way, rather than as a more ordinary sort of field living in three-dimensional space, is tied up with the most striking aspects of quantum mechanics: nonseparability, entanglement, and quantum nonlocality.) The fundamental high-dimensional space does indeed have a number of dimensions that is divisible by three, but it is misleading to refer to it as a "configuration space", since that suggests a

[5]The high-dimensional version of GRW faces the question of how the collapse law is to be understood. The usual understanding of the law is that each particle has a certain probability per unit time of taking a "hit" (i.e., multiplication of the wavefunction by a gaussian whose center is probabilistically determined by the global wavefunction and the particle in question at the time). Since this law mentions particles, it must be understood differently under the high-dimensional view. (Unless, as Jill North pointed out, a fundamental law like the collapse law can make reference to nonfundamental entities such as particles.) It must instead be understood differently, as somehow tying the collapses to certain degrees of freedom of the wavefunction. There is a question, though, whether there is a unique and nonarbitrary way to choose the degrees of freedom in question. If not, the law might need to take the form: "there are degrees of freedom of the wavefunction satisfying such-and-such constraints, such that for each degree of freedom there is such and such chance of collapse per unit time…". This would be akin to other attempts to shed allegedly excess structure (for instance inertial frames in classical mechanics), e.g., Bhogal and Perry (2017); Esfeld (2020); Huggett (2006); Miller (2013). See Dorr (2010, p. 160ff) and Sider (2020*b*, section 4.12) for misgivings.

[6]I'll leave open exactly how time should be construed.

picture in which three-dimensional space and particles have been posited, and a mathematical space representing configurations of the particles in the space has been constructed.[7] The current picture is rather that the $3N$-dimensional space in which the wavefunction lives is a fundamental physical posit. At the fundamental level, there is no association whatsoever between points of this space and configurations in any three-dimensional space, since at the fundamental level there simply are no three-dimensional space or particles.

2.

There are old and difficult questions (long predating the debate over high-dimensionalism) about what it means for the fundamental physical facts to "give rise to" the manifest image. Labels that have accumulated in this vicinity include 'bridge laws', 'supervenience', and, in the more recent metaphysics literature, 'ground' and 'analysis' (Nagel, 1961; Kim, 1993; Fine, 2012; Schaffer, 2009; Dorr, 2004, 2016). Some of the differences between these labels don't matter for present purposes, but some do; and I think the most illuminating approach in the present context is in terms of "translation".[8] Here is the picture.

A certain language, call it the "fundamental language", occupies a distinguished position in the foundations of physics. It is this language in which we describe the fundamental facts. Talk about what "fundamentally exists" is talk about what exists, when speaking the fundamental language. When a sentence in the fundamental language is true, its truth is fundamental, deriving from nothing else.[9]

The fundamental language contains no predicates like 'tree' or 'rock'; its vocabulary is limited to fundamental matters. (This is so whether reality is fundamentally three- or high-dimensional.) However, we can introduce other languages, call them "nonfundamental languages", that do contain such predicates; and we can introduce interpretations of these other languages under which their sentences can be regarded as being "nonfundamentally" or "deriva-

[7] See Maudlin (2010) on the dangers of being careless about this terminological issue.

[8] I develop this account, and an associated general metaphysics of fundamentality, and discuss its relation to rival accounts, in Sider (2011). What I say here is independent of many of the details of my general account.

[9] It would be possible to hold that a foundational physical theory is *physically fundamental* but not *metaphysically fundamental* (compare North (2018, section 3.3)). If so, my term 'fundamental' should be understood as meaning *physically* fundamental. But my own—broadly physicalist—view is that the two coincide.

tively true". For sentences in nonfundamental languages can be *translated* into the fundamental language; their truth then amounts to nothing more than the fundamental truth of their translations. This is the sense in which fundamental facts "give rise to" nonfundamental facts: sentences in nonfundamental languages can be translated into true sentences in the fundamental language. Sentences in nonfundamental languages describe the very same facts as sentences in the fundamental language, albeit less "directly" or "perspicuously".

Although the fundamental language is "metaphysically prior to" the nonfundamental language in that the former is the metaphysical basis for the latter, the nonfundamental language is epistemically and conceptually prior: we learn it first and use it to state the things of which we are most certain. Also we use it to to introduce the fundamental language in the first place; but that does not make fundamental sentences mere abbreviations of nonfundamental sentences (any more than theoretical terms in physics must be mere abbreviations of complex observational terms). The introduction of the fundamental language works rather as follows. We use the nonfundamental language to lay out a proposed theoretical role for the expressions in the fundamental language (where that role may include, not only hypotheses about what fundamental sentences are laws, but also hypotheses about how how fundamental sentences can translate nonfundamental sentences); we posit that the language thus introduced makes contact with reality; and if it does (near enough, anyway—not all of the hypotheses need to be true), the fundamental language is in good standing.

A number of issues may be left open here; all that is crucial is the distinction between fundamental and nonfundamental languages, and the claim that the fundamental language gives the interpretation of nonfundamental languages. We may leave open, for instance, whether each sentence must receive its own translation individually or whether instead only entire classes of sentences are translated, and whether translations must be necessary and sufficient (in some appropriate sense) for their targets or merely sufficient.[10] It can even be left somewhat open exactly what "translation" means, except that the ordinary notion of 'translation' is clearly *not* intended, since correct translation in the ordinary sense can generally be achieved simply by virtue of competence in the two languages, whereas a person competent in ordinary English and the language of physics might have no idea how to translate sentences about trees and rocks into statements about the wavefunction and marvelous particle. Ordinary translation must preserve *sense*, whereas translation in the present

[10]The latter is what the fans of grounding think, transposed into linguistic terms.

context—which we might call "metaphysical translation", to disambiguate—is metaphysical in nature: the metaphysical translation of a nonfundamental sentence must specify what its truth *amounts to* in fundamental physical terms.

(The intrusion of this sort of metaphysics into a discussion about the foundations of quantum mechanics might seem odd, but in fact it is entirely appropriate, and indeed, mandatory. The core of the concern about high-dimensionalism is a distinctively metaphysical one: how can facts about a wavefunction living in a high-dimensional space *give rise to* the facts about manifest image, in particular those facts that constitute our evidence?)

The mere adoption of the translational approach to "giving-rise-to" doesn't yet broach the main questions facing high-dimensionalism. It remains to ask what a high-dimensional translation scheme might look like, and whether the facts expressed by ordinary sentences under such a translation scheme can really be seen as constituting the manifest image.

3.

The most promising idea about how facts about three-dimensional things might be translated into high-dimensional terms is that the translation scheme should be "functional". David Albert puts it this way: "there is nothing more or less to being a rock, or a tree, or a chair, or a person, or a haircut, or a lawsuit, or a university, or a molecule, than to have a certain particular causal profile—to occupy a certain particular node in the overall network of causal relations" (2021). David Wallace says something similar (albeit in a different context, defending an Everettian view rather than high-dimensionalism), that a manifest-image entity is "a pattern or structure in the physical state" (2003, p. 92).

Although I believe the functional approach to be on the right track, these characterizations are misleading in a certain respect.[11] They suggest claims of the following form:

> To be a rock is to have causal profile C_1
>
> To be a tree is to have causal profile C_2
>
> etc.

[11] See also Ney (2021, p. 223). I don't mean to suggest that Albert and Wallace are unaware of the issues here. For instance, see Albert (2015, p. 129, note 6).

Put in terms of translation, the proposal would be to translate predicates from the manifest image as follows:

translate 'x is a rock' as 'x has causal profile C_1'

translate 'x is a tree' as 'x has causal profile C_2'

etc.

That is, each one-place predicate from the manifest image would be translated as a one-place predicate describing a causal role. Multi-place predicates, too, would be translated as causal predicates of the appropriate 'adicy:

translate 'x is five feet from y' as 'x bears causal relation R_1 to y'

translate 'x sat on y' as 'x bears causal relation R_2 to y'

etc.

Notice that under this "predicate-for-predicate" translation scheme, the logical form of a nonfundamental sentence will match the logical form of its translation, in the sense that a nonfundamental sentence of the form 'There is an x that is F' will be translated as 'There is an x that is G', where 'x is G' is the (no doubt very complex) fundamental translation of 'x is F'. Singly existentially quantified sentences get translated as singly existentially quantified sentences, doubly existentially quantified sentences receive doubly existentially quantified translations, and so on. For instance, the ordinary sentence 'There is a rock' would receive the metaphysical translation:

There is an x such that x has causal profile C_1

Likewise, 'some rock is five feet from some tree' would be translated as 'there exist x and y such that x has causal profile C_1, y has causal profile C_2, and x bears causal relation R_1 to y', and similarly for other sentences from the manifest image.

But this means that for the translation of an existential sentence in the manifest image to be true, there must *fundamentally exist* entities with the causal profiles in question. For 'there is a rock' to be true, 'some x has causal profile C_1' must be true in the fundamental language, and so some entity in the high-dimensionalist's fundamental ontology must have a "rockish causal profile". Now, what counts as having a rockish causal profile is normally left

pretty unspecific, but we can only assume that it amounts to having causes and effects that are normally associated with rocks—e.g., being capable of breaking windows (or rather, since 'breaking' and 'window' will themselves receive functional analyses: bearing the causal relation associated with 'breaking' to things that have the causal profile associated with 'window'). But there simply isn't anything in the high-dimensionalist's ontology that has such a causal profile. The marvelous particle doesn't. No point in configuration space does. And that exhausts the high-dimensionalist's ontology.

(Or does it? Supposing high-dimensionalism to also include a fundamental ontology of sets, could some set-theoretic construct from points of configuration space and the marvelous particle be said to have the causal profile? Could the "nodes" that Albert is referring to be such set-theoretic constructs? Wallace says that "A tiger is any *pattern* which behaves as a tiger" (2003, p. 93); could a tiger be regarded as a pattern, and a pattern regarded as some sort of set? Perhaps. Some will balk at the idea that mathematical entities stand in causal relations.[12] That strikes me as closed-minded; but at the very least, additional metaphysical translation would be needed of causal language, to extend it to set-theoretic entities. Further, the approach would require a deep commitment to an ontology of sets, which some high-dimensionalists may want to avoid.[13] Most importantly, as we'll see below, this set-theoretic idea will lead to the same conclusions I will draw (though in a more artificial way, I think). So for now, let's set aside the idea that "patterns" or "nodes" are to literally be recognized as entities, and low dimensional entities identified with them.)

The problem with the usual characterizations of global functionalism is that it isn't only *predicates* like 'rock' that need to be translated. Put nonlinguistically, it isn't only *properties* that need to "emerge" (as Albert and Wallace like to put it). The very ontology of the manifest image needs to emerge. The slogan "to be a rock is to have a certain causal profile" treats the *entity* that is to be classified as being a rock as *given*, and applies the functionalism only to the classification of that entity as a rock; but the functionalism must also account for the entity itself.

Instead of supplying functionalist translations of *predicates*, global functionalism should instead supply functionalist translations of *entire sentences*. Instead of translating 'x is a rock', it should translate 'There is an x such that x is a

[12] E.g, perhaps, Maudlin (2018, p 127).

[13] In the alternative approach to translation I develop below, I do appeal to mathematical language in order to define a translation procedure; but the translations themselves do not refer to sets. Some may prefer this "lower grade of involvement" of abstract entities.

rock', and other full sentences that quantify over rocks. Instead of "*to be a rock* is to have a certain causal profile", we should say rather: "*For there to be a rock* is for such-and-such to be true", where the "such-and-such" involves the state of the entire fundamental high-dimensionalist universe. (We will say more below about what exactly the "such-and-such" will be.) No particular bit of that universe will be identified with the rock; rather, a *proposition about the universe* will be identified with the *proposition* that there exists a rock. The slogan should not be that 3D objects are nodes or patterns in the causal network, but rather that sentences about 3D objects express propositions about the causal features of fundamental high-dimensional reality. We need a sentence-for-sentence translation scheme, not a predicate-for-predicate scheme. Or put nonlinguistically, we should not give an "entity-for-entity" reduction of the manifest image, but rather a "proposition-for-proposition" reduction.[14]

The distinctive feature of the high-dimensional ontology that calls for the sentence-for-sentence approach is that it does not contain any entities that can be identified with the entities of the manifest image. If fundamental reality were instead three dimensional and contained both three-dimensional particles and composite objects made up of them, then a predicate-for-predicate translation scheme would suffice. However, suppose the composite objects were subtracted from this picture. That is, suppose a "mereological nihilist" three-dimensional fundamental ontology, which contains only i) points of three-dimensional space, and ii) three-dimensional particles, and does *not* include composite objects made up of multiple particles (or points of space). Then a sentence-for-sentence approach would again be needed, even though fundamental reality remains three-dimensional. For if the fundamental ontology includes only particles and points, it contains no entity that could be identified with a given rock or tree.[15]

I have suggested that 'there exists a rock' can be regarded as being *true*, albeit derivatively or nonfundamentally, if its translation into the fundamental

[14]In Kit Fine's (2003) terms, we should not employ a "proxy reduction". Compare also Hawthorne's (2010, p. 146) "liberal" approach to low-dimensional ontology.

[15]If, on the other hand, the fundamental ontology also included sets, and if one were willing to identify ordinary physical objects with sets of particles, a predicate-for-predicate translation scheme could be reinstated.

It's tempting—and one sees philosophers of physics yielding to this temptation all the time—to deny the need for composite objects (or sets) since particles can be identified with "collections" of particles. But what is a "collection", if it isn't a set (containing the particles as members), or a composite (containing the particles as parts)? The sober view in the vicinity is to refrain from reifying collections, and say that entire sentences about rocks and the like are translated as sentences about the particles "in the collection".

language is true. But how can that be? How can a high-dimensionalist admit the existence of a rock? Doesn't high-dimensionalism say that nothing exists other than points of the high-dimensional space and the marvelous particle?

The answer is that 'there exists a rock' and 'nothing exists other than points of the high-dimensional space and the marvelous particle' are sentences in two different languages, the fundamental language and a nonfundamental language, which have two different interpretations—the interpretation of the nonfundamental language being given by the way we translate its sentences into the fundamental language.

In fact, the most natural understanding of what is going on here (in my view) is that the quantifiers themselves—'there exists', 'for all', and related expressions—have different meanings in the two languages.[16] This is the sense in which "the ontology of the manifest image is different from the fundamental ontology": the truths of the manifest image are given in a language in which the quantifiers mean something different from what they mean in the language used to describe fundamental reality. What it means for *there to be something* differs when we shift from the fundamental to the nonfundamental language. The difference results from the difference in logical form between a nonfundamental sentence and its translation, given the high-dimensionalist's sentence-for-sentence (and not predicate-for-predicate) translation scheme. A sentence like 'there is a rock' is translated as a sentence about high-dimensional reality that does *not* take the form of saying that there exists some one entity that plays a rock-ish role, so it is natural to view what we mean by saying *there is* a rock as different from what we mean in the fundamental language by saying *there is* a high-dimensional point or marvelous particle.[17]

[16]In the metaphysics literature this is known as "quantifier variance". The term comes from Hirsch (2011), although Hirsch's version is "egalitarian" in that all the quantifier meanings are on a par (this is tied up with his ontological deflationism), whereas the form of quantifier variance to which high-dimensionalists (at least, high-dimensionalists like Albert, who regard the high-dimensional ontology as privileged) are committed is naturally viewed as inegalitarian. See Dorr (2005) and Sider (2009) on inegalitarian quantifier variance.

[17]I say that this is the natural view to take, but *arguing* for it is a little delicate. An argument for a parallel conclusion is comparatively straightforward in certain other cases. Return to the "mereological nihilist" three-dimensionalist view of fundamental reality, but now replace the commitment to substantival space with a relationalist view. Thus the fundamental ontology of this view consists *solely* of three-dimensional particles, and in particular, a finite number of them, let's suppose. Now, let's construct, using a proposition-for-proposition reduction, a new language—call it the "language of particles plus composites", in which one can continue to quantify over particles, but also quantify over composite objects composed of them. In this new

4.

How, exactly, will be the association of fundamental high-dimensional sentences with manifest-image sentences be defined? As Albert emphasizes, the association will be dynamical in nature.[18] The dynamics of the marvelous particle suggests a certain way of associating various of its degrees of freedom with the degrees of freedom of N "derivative" particles moving and interacting in 3-dimensional space. He illustrates the idea as applied to a non-quantum-mechanical world whose fundamental space is $3N$-dimensional, containing a single marvelous particle, but instead of a wavefunction, a field representable by a classical Hamiltonian taking the following form (relative to a certain

language, a sentence like 'there is a rock composed of particles $p_1, \ldots$' is (nonfundamentally) true, because its metaphysical translation is '$p_1, \ldots$ are in a rock-like arrangement', which is true in the fundamental language (once 'in a rock-like arrangement' is spelled out in fundamental terms, that is). One can then argue that the quantifiers have different meanings in these languages. Suppose there are N particles. Then the following sentence is true in the language of particles and composites:

$$\exists x_1 \ldots \exists x_{N+1} (x_1 \neq x_2 \wedge x_1 \neq x_3 \wedge \ldots \wedge x_2 \neq x_3 \wedge x_2 \neq x_4 \wedge \ldots \wedge \ldots)$$

For this says that "there are at least $N + 1$ things"; and in the language of particles and composites one can say truly that there exists a rock, in addition to the N particles. However, this sentence is not true in the fundamental language. So if we make the reasonable assumption that the identity sign has the same meaning in the two languages (and that the propositional connectives also have the same meanings), we may conclude that the existential quantifier has a different meaning. (One might resist this argument by denying its implicit semantic atomism, and claim that—at least when an interpretation is given holistically, in the way that a proposition-for-proposition reduction requires—although it is true that entire sentences have different meanings in the two languages, there are no facts of the matter whether a particular expression in one language means the same as it means in the other.)

This kind of argument won't work in the case of high-dimensionalism and the corresponding nonfundamental language because the ontologies of the two languages have the same cardinality (so to speak). Another argument is available, but it requires the assumption that, not only do the identity sign and the propositional connectives mean the same thing in the two languages, but also, the predicates 'subatomic particle' and 'point of the high-dimensional space' mean the same thing. Then, since 'there is something that is neither a subatomic particle nor a point of the high-dimensional space' is true in the fundamental language but not in the nonfundamental language, we can conclude that the quantifiers have different meanings in the two languages.

[18] Solely appealing to the structure of the high-dimensional space, without bringing in the dynamics, would not single out a sufficiently unique association, as Monton (2002) points out.

coordinatization C of the fundamental space):

$$H = \sum_{i=1}^{N} m_i \left(\left(\frac{dx_{3i-2}}{dt} \right)^2 + \left(\frac{dx_{3i-1}}{dt} \right)^2 + \left(\frac{dx_{3i}}{dt} \right)^2 \right) + \sum_{i=1}^{N} \sum_{j=1}^{N} V_{ij} \left(\left(x_{3i-2} - x_{3j-2} \right)^2 + \left(x_{3i-1} - x_{3j-1} \right)^2 + \left(x_{3i} - x_{3j} \right)^2 \right) \quad (1)$$

He then says (p. 128):

> Looked at in C (then) the position coordinates of [the marvelous particle] will evolve in time exactly as if they were the coordinates of [N] classical particles floating around in a three-dimensional space and *interacting* with one another in accord with a law which is built up out of the *geometrical structures* of that three-dimensional space, and which depends upon the interparticle *distance* in that three-dimensional space, and which is invariant under the *symmetries* of that three-dimensional space, and which has the particular mathematical form:
>
> $$H = \sum_{i=1}^{N} m_i \left(\left(\frac{dx_i}{dt} \right)^2 + \left(\frac{dy_i}{dt} \right)^2 + \left(\frac{dz_i}{dt} \right)^2 \right) + \sum_{i=1}^{N} \sum_{j=1}^{N} V_{ij} \left(\left(x_i - x_j \right)^2 + \left(y_i - y_j \right)^2 + \left(z_i - z_j \right)^2 \right) \quad (2)$$
>
> This particle, in this space, moving around under the influence of the Hamiltonian in equation (1), formally enacts (you might say) a system of N classical three-dimensional particles—the i^{th} of which is the projection of the world particle onto the $(3i-2, 3i-1, 3i)_C$ subspace of the [$3N$]-dimensional space in which the world particle floats.

In light of the previous section, these remarks should be understood as indicating a certain translation procedure from a nonfundamental language to the fundamental high-dimensional language. Sentences in the nonfundamental language describing particles moving in three dimensions under the influence of the Hamiltonian described in (2) are to be translated into sentences in the fundamental language that, collectively, describe the marvelous particle moving in the $3N$-dimensional space under the influence of the Hamiltonian described in (1). Moreover, the introduction of this translation procedure amounts to specifying an interpretation of the fundamental language, an interpretation

under which the quantifiers mean something different from what they mean in the fundamental language.

Albert illustrates this idea with special cases (including the one just described), but it's worth giving a (more) general account. I see the general idea as one of "reverse engineering": the total set of truths in a non-fundamental language is reverse-engineered as that which "fits", in a certain sense, the totality of high-dimensional facts. Holding fixed a certain high-dimensional fundamental reality, we consider various low-dimensional descriptions, which posit various numbers of dimensions, various numbers of particles instantiating various sorts of low-dimensional properties, and obeying various sorts of low-dimensional laws. For each low-dimensional description, we consider a high-dimensional description that it induces; and we seek, amongst all the low-dimensional descriptions, the one whose induced high-dimensional description fits the actual high-dimensional facts. This low-dimensional description—complete with its specification of a number of dimensions, and low-dimensional particles, properties, and laws—gives the translation into nonfundamental terms of the high-dimensional fundamental reality in question.

I doubt whether a detailed and rigorous description of this reverse-engineering procedure can be given in full generality—general enough to apply no matter what fundamental reality is like—but it's worth looking at the details in a somewhat general account, namely, that applying to a Bohmian fundamental reality which is well-represented by nonfundamental descriptions consisting of particles moving in three dimensions.

Begin by introducing two languages. The *fundamental language* we have seen already: it is the language we use to express the fundamental facts. Here we may assume that it includes predicates appropriate for describing the geometry of the high-dimensional space, the wavefunction, and the motion of the marvelous particle over time, and the fundamental physical laws governing them.[19] The *3D language* is a language that, in addition to the vocabulary of the fundamental language, also contains the vocabulary needed to describe the geometry of a three-dimensional space, particles and perhaps fields in three-dimensional space, and laws of nature governing these three-dimensional matters. (Since the language allows the description of a 3D realm *in addition to* the high-D realm, it might better be called the "high-D-plus-3D" language.[20])

[19] According to reductionist views of laws of nature, the fact that a statement *S is a law* would not be a truth in the fundamental language. But all that is assumed here is that the law itself, *S*, is true in the fundamental language.

[20] In an alternate approach, we would construct a purely 3D language, but one that contains

The 3D language also needs vocabulary to connect the high- and low-dimensional realms. Following Cian Dorr, let the 3D language contain a predicate 'high-dimensional-space point p *puts* particle x at three-dimensional point q'.[21] This predicate's purpose, intuitively, is to allow us when speaking the 3D language to treat the high-dimensional space as functioning like a configuration space for the three-dimensional particles. For any configuration of those particles, we can pick out the point in the high-dimensional space that "represents" the configuration as that high-dimensional point, p, such for each particle x and its location, q, in three-dimensional space in the configuration, p puts x at q. I say "intuitively", however, because we do not at this stage assume the 3D language's sentences to be true, or even fully interpreted: no interpretations of the theoretical terms in the theory—the terms for describing the geometry of three-dimensional space, predicates of particles (like 'mass'), and 'puts'—have yet been specified, nor has an interpretation for the quantifiers of the 3D language been specified.

Let a *3D world* be any complete, consistent set of sentences in the 3D language. 3D worlds correspond to metaphysically possible worlds in which reality is fundamentally both three-dimensional and high-dimensional, rather than being solely high-dimensional. And consider 3D worlds that posit some finite number of particles. That is, consider consistent, complete sets of 3D sentences that include (or at least logically entail) a sentence saying that there exist exactly N three-dimensional particles, for some natural number N. Amongst such 3D worlds, restrict our attention to those in which the predicate 'puts' behaves so that the high-dimensional space functions as the configuration space of the 3D particles and the marvelous particle corresponds to their trajectories, in the

mathematical language to construct the mathematical configuration space of the 3D particles in 3D space, and then consider the match between the induced mathematical high-dimensional theory and the actual high-dimensional facts.

[21]Dorr (2009). Incidentally, Dorr's putting relation lets a "dualist", who accepts both a fundamental high-dimensional space containing the wavefunction and also a fundamental three-dimensional space containing particles (or flashes, or a mass-density field), reply to Albert's (2015, pp. 124–5) objection that since the wavefunction lives in a different space from the particles, the theory would require "new and very ungainly metaphysical structure" to connect the two spaces, such as privileged axes in the high-dimensional space and haecceitistic laws. A little new physical structure is indeed needed (a fundamental *putting* relation), but it wouldn't be especially metaphysical or ungainly. The argument against dualism, I think, should instead be broadly Occamist, as in North (2012): the structure of the dynamics suggests the high-dimensional space, and a three-dimensional wouldn't add anything of explanatory importance.

sense that the worlds contain these two sentences:

S1 Each possible configuration of the three-dimensional particles is represented by exactly one point in the high-dimensional space

S2 For each time, the point in the high-dimensional space that represents the configuration at that time of the three-dimensional particles is occupied then by the marvelous particle

(where 'represents' is defined as above, in terms of the predicate 'puts'). A 3D world of this sort is capable of including descriptions of laws of nature governing the 3D particles that are quantum-mechanical in nature. It can include descriptions of dynamical laws of the high-dimensional variety governing the wavefunction's evolution and the marvelous point's trajectory; given S1 and S2, such a world could then imply sentences saying that the 3D particles trace out trajectories through 3D space exactly as prescribed by standard Bohmian quantum mechanics.

Now suppose that a 3D world of this sort—still just a mere set of sentences in an only partially interpreted language—"fits" the fundamental high-dimensional world, in the sense that what it says about the high-dimensional space, wavefunction, marvelous particle, and the laws governing them, *exactly matches the fundamental truth about these matters*. That is, every sentence in the 3D world that contains neither 3D vocabulary nor 'puts' is *true* when construed as a sentence of the fundamental language.[22] The sentences in this 3D world, as a group—including the sentences about a three-dimensional space and particles therein—may be thought of as the translation into the 3D language of the entire set of high-dimensional facts. Indeed, we might regard each of the sentences in this 3D world as being "nonfundamentally" or "derivatively" true.

(The holistic procedure just given does not specify a sentence-by-sentence translation from the 3D language into the fundamental language; it merely tells us which 3D sentences may be regarded as derivatively true, given the fundamental facts. But it could be extended to such a translation if the fundamental language has sufficient expressive power. Define a high-dimensional world

[22] Well, that's not quite right, since sentences like 'something is neither a high-dimensional point nor the marvelous particle' will be true in the 3D world but are not true as sentences in the fundamental language. The correct formulation is that any sentence in the 3D world containing neither 3D vocabulary nor 'puts' is such that, if each quantifier in the sentence is replaced by a corresponding quantifier restricted by the predicate 'is either a high-dimensional point or the marvelous particle', the result is true as a sentence in the fundamental language.

as a complete, consistent set of sentences in the high-dimensional language. For each sentence, S, in the 3D language, we may consider the set H_S of all high-dimensional worlds that would, if actual, fit some 3D world containing S. Suppose the fundamental language is sufficiently powerful that for any such H_S, it can formulate a single sentence $\mathrm{Tr}(S)$ to the effect that some member of the set H_S is actual. It could satisfy this, for instance, by containing sufficiently long infinitary conjunctions and disjunctions. $\mathrm{Tr}(S)$ could then be regarded as the metaphysical translation of S into the fundamental language. Of course, for certain sentences—perhaps all those of interest—the translation might be expressible in some finitary way.)

This translation procedure is (at best) sentence-for-sentence, not predicate-for-predicate. It specifies which sentences (or classes of sentences) in the 3D language can be used to express the fundamental facts—those same facts which can be expressed more perspicuously by sentences in the fundamental language. Thus it says how one may speak of rocks and trees and the like in a fundamentally high-dimensional world, but it does not do so by specifying particular bits of the high-dimensional world to be identified with the rocks and the trees.

5.

According to some critics of high-dimensionalism, the three-dimensional facts ought to be discernible in the fundamental facts by a very simple and transparent process. We ought to be able to "just see" the manifest image in any proposed picture of fundamental reality; we shouldn't need to do more than "squint" to see it.[23] If reality consists of fundamental particles moving in three dimensions, it is said, we *can* discern the telescopes and stopwatch hands and the rest merely by squinting, since such objects are merely ensembles of fundamental particles. But if, on the other hand, reality consists of a wavefunction and marvelous point moving in a high-dimensional space, there is no way to squint and see the telescopes and the rest.

In my view, adequate rebuttals of the "squintability constraint" on metaphysical translation that seems to be presupposed by the argument (that the manifest image must be discernible by squinting from its metaphysical translation) have been given in the literature. Whatever squinting is supposed to amount to, you presumably can't discern *heat* that way; and surely theories can be confirmed via their predictions about heat (Albert, 2021). And even in the best case, that

[23] The language of squinting is from Maudlin (2007, p. 3167).

of visual evidence of macroscopic spatial facts like the position of a stopwatch hand, you can't tell just by squinting that a configuration of stopwatch-hand-arranged particles is *solid* and *visible* (Rubenstein, forthcoming). I might add that in addition to implying the (metaphysical translations of the) evidence, we might also require the theory to imply *that it is evidence*, which presumably cannot be discerned by squinting.[24] Finally, and perhaps most deeply, when purged of the metaphors, the squintability constraint ultimately seems to be the assumption that metaphysical translation must always be "trivial", or "transparent", or "a priori", or something else in this vicinity; and that assumption, on closer examination, just isn't sustainable (Rubenstein, forthcoming).[25]

[24]On one prominent view of evidence, for instance, a proposition counts as evidence for a person only if that person *knows* the proposition (Williamson, 1997). Even if I can discern by squinting at fundamental particles that the stopwatch hand is at 6, I presumably can't discern by squinting that *I know that* the stopwatch hand is at 6.

[25]Rubenstein treats pairs of physical theories and proposals about metaphysical translation (or in his terms, claims about grounding connections between high- and low-dimensional facts) as being package deals (compare also Schaffer's (2017) important paper on the parallel aspect of the mind-body problem). I agree that we are simultaneously uncertain about both grounding/translation and the fundamental facts, and that beliefs about each can be adjusted in response to new information. For instance, acquiring the empirical evidence favoring quantum mechanics has also raised our rational credence in the claim that a fundamentally high-dimensional world could give rise to the manifest image. However, although I am far from clear on this issue, I think it goes too far to treat the two parts of the package deals as being epistemically on a par. The principles (however ill-understood) that govern theory choice in fundamental physics are very different from the principles that govern what we should believe about metaphysical translation or grounding. For instance, in physics we can sometimes simply *posit* something new (a new sort of particle, or fundamental force, or dimension), if by so doing the laws can be simplified, apparent experimental anomalies can be explained, and so on. But the very idea of positing a grounding connection or metaphysical translation seems wong. Correctness of metaphysical translation needs to be earned (somehow!), and can't be posited. Suppose, for instance, that someone posited a fundamental physics according to which nothing exists but a single particle moving on a line, but also posited, as part of a package deal, a certain function from points on the line to total sets of truths in a 3D language. This posit would be completely misguided, and could not be justified by any alleged benefit in terms of simplicity and empirical adequacy. Relatedly, to save a theory that is mostly working but doesn't fit some narrowly circumscribed experiments, one can posit a small theoretical addition (Neptune, dark matter), but one cannot posit a small change to the nature of grounding, so that the physical theory stays the same but the very same fundamental facts are now taken to ground different macro-facts, namely, exactly those we experience. This is illegitimate even if the tweaked grounding connection is somehow systematic. Metaphysical translations just aren't "independent parameters", in the way that posits can be. A related fact is that physical theories are stated in perfectly fundamental language (let us assume), whereas theories about

But other concerns about global functionalism strike me as more pressing. Consider this passage from Tim Maudlin:[26]

> Consider a regular low-dimensional Newtonian world with tables and chairs and baseballs all composed of particles. And now define the "3-foot north projection" of any particle to be the point in space exactly three feet to the north (i.e. in the direction from the center of the earth to the center of Polaris) of the location of the particle. Then trivially the 3-foot north projections of all the particles in a table will be a set of locations that have the same geometrical structure as the particles in the table. And the 3-foot north projections of all the actual particles in tables and chair and baseballs will formally enact, in Albert's sense, the tables and chairs and baseballs and observers whose projections they are. But these "formal enactment" are clearly not tables and chairs, and the 3-foot north projection of a person having a headache is clearly not an actual sentient person with a headache. It might, in fact, just be a set of points in a vacuum (if the person is in a spaceship). But the 3-foot north projections in this world have all the same credentials—indeed even better credentials in terms of geometrical structure—as Albert's more abstract projections do. So Albert's argument cannot go through.

Now, some of what Maudlin says here depends on the fact that Albert's language suggests a literal identification of three-dimensional objects with certain entities, namely projections, whereas the global functionalist approach I have proposed makes no such identifications, instead offering translations of entire sentences about three-dimensional entities. Still, there remains the objection that translation schemes according to which objects are spatially displaced in bizarre ways ought to count, if global functionalism is true, as being just as legitimate as "normal" translation schemes. As we will see, this objection doesn't succeed, but it is important and instructive to consider.

A first point is that Maudlin is attempting to refute global functionalism by showing that it has unacceptable consequences in a scenario in which the

---

metaphysical translation (including the distinctive predicates of metaphysical translation itself, such as 'sentence S_1 is a metaphysical translation of sentence S_2') are stated in higher-level language; very different epistemic norms, in my view, govern theory choice in these two cases. Also, the package-deal picture applies in the first instance to the (somewhat aspirational) epistemic goal of achieving fully reflective justification in physics (recall note 2). There is a question of how it should be extended to the confirmation of a physical theory by someone, a scientist, say, who has never given thought to metaphysical translation or grounding.

[26](2018, p. 126). Maudlin is responding to a different passage from Albert than that quoted above, but the import is the same.

world is fundamentally *three*-dimensional. But someone who offers a global functionalist approach to metaphysical translation with respect to fundamental *high*-dimensional scenarios need not adopt that approach in fundamental three-dimensional scenarios. If there really do exist, at the fundamental level, entities with the causal profiles of tables and rocks—aggregates of fundamental particles, say—then the global functionalist should be happy to identify rocks and trees and other objects of the manifest image with such aggregates. The translation of the language of the manifest image, in such a case, should be predicate-for-predicate rather than sentence-for-sentence.

There is nothing ad-hoc with offering different forms of translation—sometimes predicate-for-predicate, other times sentence-for-sentence—in different scenarios. The task of giving the metaphysical translation of a given language is an explanatory one, namely that of explaining speakers' use of language to get around in the world, given the environment the speakers are in. The best way of carrying out this project will naturally be sensitive to the nature of the environment. A form of metaphysical translation that is required in a high-dimensional world might be "trumped" by a more "direct" form of translation that is only available in a fundamentally three-dimensional world.[27]

However, consider a fundamentally three-dimensional world just like Maudlin's, but which does *not* contain "tables and chairs and baseballs all composed of particles", for the simple reason that it doesn't contain anything at all composed of particles. It contains the particles, all right, spatially arranged over time in exactly the way they are in Maudlin's world; but it doesn't contain any further objects *composed of* those particles. Moreover, although it contains points of space, it doesn't contain any aggregates of points of space. This is the mereological nihilist three-dimensional world considered earlier.

(Many philosophers of physics will, no doubt, be suspicious of the idea that this is a genuinely different possibility, as opposed to a (somewhat perverse) re-description of the same possibility that Maudlin described. My own view is that it is indeed a genuinely different possibility, though the matter is complex.[28] At the very least, note that the most extreme "same possibility" attitude is unavailable to anyone who takes the question of high-dimensionalism itself seriously, for such a person regards high-dimensionalism and low-dimensionalism as descriptions of distinct possibilities for fundamental reality.)

[27] Compare Hawthorne (2010, p. 152).

[28] The cluster of issues in this vicinity are known in the metaphysics literature as those of "metaontology". See Chalmers et al. (2009); Hirsch (2011); Sider (2011, chapter 9); Thomasson (2015); van Inwagen (1998).

As observed earlier, just as a predicate-for-predicate translation of the manifest image is unavailable if the world is fundamentally high-dimensional, it is also unavailable in the mereological nihilist three-dimensional world. A rock or tree cannot be identified with any one fundamental particle, nor can it be identified with any one point of space; and that's all there is in the world in question to identify things with. Thus even here we need a sentence-for-sentence translation. "There is a rock", on this view, will be translated as some assertion about particles—as meaning that there exist some particles in a "rockish arrangement". And we can then ask what Maudlinean challenges to global functionalism can be based on such a view.

Consider two candidate translation schemes. The first translates sentences about macroscopic objects (like rocks) in the obvious way, and in particular, assigns "ordinary" truth conditions to sentences about the spatial locations of such objects. For instance, the formula:

(R) There is a rock that is located (in part) at spatial point *p*

will be assigned a translation of the following form:

> There are some particles in a rock-ish arrangement, one of which is located at point *p*

The second translation scheme gives systematically different translations of sentences about macroscopic locations, assigning (intuitively) to macroscopic objects locations that are three feet to the north of the correct ones. For instance, it translates (R) as follows:

> There are some particles in a rock-ish arrangement, one of which is located at the point three feet south of *p*

On this alternative translation scheme, each macroscopic object is said to have a location three feet north of the location of its particles, so to speak. (Notice, by the way, that in this example, quantifiers over points of three-dimensional space, and a predicate for location at such points, are present in both the fundamental language and the language of the manifest image. This will no longer be true when we move to cases in which fundamental reality is high-dimensional.)

The second translation scheme differs from the first by systematically inserting 'the point three feet south of' into the translations of all formulas about

spatial location. The scheme is thus gratuitously more complex than the first; it has no compensating virtue. That on its own is a disqualifying feature.[29]

To be sure, the rules governing which proposals about metaphysical translation are correct is exactly what is at issue; and it isn't as if those rules are antecedently well-understood. So dismissing the scheme because it is "gratuitously complex", and just leaving it at that, is a bit glib. Let's try to do better.

Imagine ourselves as gods, looking down on the mereological nihilist 3D world, seeing humans (or rather, humanish swarms of particles…) using language, and asking how best to interpret their language in light of its partial mismatch with fundamental reality. In doing so we are engaging in a theoretical project: how best to understand human linguistic activity and linguistic interaction with the world. This theoretical project, like any other, can be approached in better and worse ways; and gratuitious complexity in the theory is one way that makes a theory worse, just as gratuitious complexity in *any* theory (and not just semantic theories) makes the theory worse. I propose to view the disqualification of the second translation scheme in that spirit.[30]

But we should understand its "disqualification" properly. We can stipulatively construct an interpretation according to the second scheme. Under this interpretation of the language of the manifest image—including its quantifiers and its locational predicate—the string of symbols 'there is a rock that is located three feet to the north of its particles' is true. This is unproblematic, since all the string means, under that interpretation, is that there are some particles in a rock-like arrangement. Moreover it is consistent with the fact that under the first translation scheme, the sentence "no rock is located three feet to the north of its particles" is true. For although the two sentences are syntactic contraries, the vocabulary in them has different meanings in the two languages. The disqualification is not that language couldn't be used as the second scheme prescribes. It is rather that as a descriptive matter, the second scheme doesn't capture the actual truth conditions of the sentences that we ordinarily utter. (And, we might add, it doesn't capture truth conditions that it would be *reasonable* to assign to them.) And if the first does indeed capture those actual truth conditions—if it corresponds to what we in fact mean—then

[29] Actually there is a further disqualifying feature, if the speakers of the language of the manifest image know about the existence of particles; for they may well utter sentences like 'rocks are located where their parts are located', and indeed treat them as being something like "analytic".

[30] Compare Williams's (2007) analogous defense of "reference magnetism".

we may say, more simply and straightforwardly and disquotationally, that there is a rock located at a certain point (a point containing appropriately-arranged particles), and no rock located three feet to the north of that point.

One final, related matter. Consider two theories made of interpreted sentences. Theory 1 consists of all the sentences in the language of the manifest image, as interpreted under the first translation scheme, that are true under that interpretation; and Theory 2 consists of all the sentences in the language of the manifest image, as interpreted under the second translation scheme, that are true under that interpretation. Thus Theory 1 looks like this:

> {'There is a rock located at points p_1,…', 'There is a tree located at points q_1,…', …}

And Theory 2 looks like this:

> {'There is a rock located at the points that are three feet to the north of p_1,…', 'There is a tree located at the points that are three feet to the north of q_1,…', …}

(where 'p_1,…' and 'q_1,…' are understood to refer to particular points of the fundamental three-dimensional space). As I have been saying, each of these theories is true (although the interpretation involved in the language of the second theory is not *our* interpretation). But note also that the correct *picture* this should give us is *not* that of a world containing *both* rocks, trees, and the rest in their "normal" locations and also some *extra* rocks, trees, etc. located three feet to the north. The view being suggested is of course not that of a *fundamental* reality in which rock-like and tree-like arrangements of particles always come in pairs separated by three feet. But nor has it been suggested that *nonfundamental* reality contains doubled-up rocks and trees and the rest. Theory 1 and Theory 2 are not theories in a common interpreted language. In particular, their quantifiers don't mean the same thing. So to accept that 'There is a rock located at points p_1,…' is true in the language of Theory 1, and that 'There is a rock located at the points three feet to the north of p_1,…' is true in the language of Theory 2, does *not* amount to accepting the truth of:

(2R) There are two rocks, one located at points p_1,…, the other at the points three feet to the north of p_1,…

in *either* language—this conjunctive sentence is in fact false in both languages. Nor does it amount to accepting its truth in *our* language, which is really what calling something "true in nonfundamental reality" amounts to.

To be sure, we could introduce a third translation scheme, which would translate (2R) into the fundamental language as:

There are particles in a rock-like arrangement, located at points $p_1, \ldots$

Given this interpretation, (2R) is indeed true. But that isn't absurd; all it means is what we would ordinarily express in our language by saying "there is a rock, located at points $p_1, \ldots$". Moreover, this third translation scheme (if somehow spelled out in full generality) is an even worse candidate for being *ours* than the second. For one thing it is even more gratuitously complex. Also, it is massively uncharitable to ordinary use. For instance, a typical ordinary utterance of "there is just one chair in this vicinity" would turn out false. Finally, notice that it would seem unlikely that simple dynamical laws could be stated in this third language.

Now let's turn to the case where fundamental reality is assumed to be high-dimensional. The discussion of Maudlin' argument here is mostly parallel. There is, as we will see, a subtle difference, but it doesn't make the objection to global functionalism more powerful (if anything, it makes it weaker).

In the three-dimensional case, although the ontology of the nonfundamental language differs (so to speak) from that of the fundamental language (because only the former includes composite objects like rocks), the three-dimensional particles and points are common to both ontologies. The high-dimensional fundamental ontology differs more drastically from the nonfundamental ontology. It isn't just ordinary objects like rocks that are "emergent"; three-dimensional particles and points are now emergent too. Better: the translation scheme can no longer supply translations of expressions like (R), which is in effect a predicate of spacetime points, but must rather supply translations of full sentences containing quantifiers over spacetime points.[31]

This means that there no longer exists a contrast between translation schemes exactly like the first and second ones considered above. Those schemes differed, as it were, over which three-dimensional points, regarded as fundamental entities, are assigned as the locations of a given nonfundamental entity like a rock; and three-dimensional points are no longer regarded as fundamental entities. When constructing a translation scheme, we can no longer ask why it should assign a rock to *this* point rather than *that* point (so to speak), because the points aren't given in advance; rather, quantification over three-dimensional points (and over particles as well) must be assigned a meaning

[31]One might consider sentences with names of spacetime points, but this leads to some difficult questions about translation.

alongside quantification over rocks (and alongside three-dimensional locational predicates).

There is, however, a parallel contrast. We now have, on one hand, an "ordinary" translation scheme in which quantification over three-dimensional points, quantification over three-dimensional particles, and quantification over rocks (and other composite three-dimensional entities), and the predicate of three-dimensional location, are simultaneously translated so that sentences like 'there is a rock and there are particles that are parts of the rock and there are points of three-dimensional space at which the particles are located, such that the rock is located at those points' come out true, and, on the other hand, a perverse translation scheme in which sentences like 'there is a rock and there are particles that are parts of the rock and there are points of three-dimensional space at which the particles are located, such that the rock is located at the points that are three feet to the north those very particles' comes out true. And we can say things about this perverse scheme that are parallel to what we said about the perverse scheme in the case of the mereological nihilist three-dimensional world. Although sentences of the perverse language can be used to express truths (if its interpretation is stipulated), it is disqualified from being the descriptively correct translation scheme for *our* language by its gratuitous complexity (and also by its lack of interpretative charity to ordinary usage). Moreover, the acceptance of the truth of ordinary sentences (under the first scheme) and the truth of perverse sentences (under the second scheme, when stipulated) should not be pictured as corresponding to a single world containing both macro-entities in the "normal" locations and also an additional set of displaced entities, for the two languages have different interpretations. (As before, we could introduce a third translation scheme, in which sentences like 'for every rock, there is another rock located three feet from it' come out true, but this scheme is even more gratuitously complex and uncharitable.)

6.

A second important challenge to global functionalism comes from Albert (2021) himself. Put in my terms, he worries that in addition to the "right" translation scheme, global functionalism allows for some translational schemes that are clearly unacceptable.

Return to Albert's illustration of global functionalism that we discussed above: a fundamental world consisting of a $3N$-dimensional space and single

marvelous particle, moving under the influence of the classical Hamiltonian described by (1) above. According to global functionalism, ordinary talk of three-dimensional entities is true, albeit nonfundamentally, in such a world, because, roughly, the marvelous particle moves through its space exactly as it would if the space were the configuration space of N particles moving in three dimensions, and if the marvelous point represented at each time the three-dimensional configuration of those particles.

Next consider a different possibility for fundamental reality: a high-dimensional space with $6N$ dimensions that is structured like the *phase* space of N particles moving in three dimensions, again containing a single marvelous particle which moves through the space as if it represented the three-dimensional phase of three-dimensional particles—i.e., the marvelous particle's position in the $6N$ dimensional space at any point corresponds at each moment to a specification of the positions and momenta of each of the three-dimensional particles. Global functionalism implies that this fundamental world would also give rise to the manifest image, since ordinary talk of three-dimensional entities can again be "reverse engineered" (albeit in a slightly different way). This cannot be denied: it would be indefensible to allow reverse-engineering that treats the marvelous particle as if it represented three-dimensional configurations, but not as if represented three-dimensional phases.

So far there is nothing problematic. Each of these two worlds could indeed give rise to the manifest image.[32] But Albert then goes on to consider a fur-

[32]Well, one might worry that if the $3N$-dimensional fundamental possibility were actual, then it would give rise *both* to the nonfundamental world of the manifest image, and *also* to a $6N$-dimensional world. But I don't see that as problematic, given our observations about sentence-for-sentence translations and quantifier variance. Reality would be such as to be aptly describable both using the 3D language, and also using a "$6N$D language". Accepting this does not, of course, require that the $6N$ dimensional description should be regarded as *ours*; the way we actually talk fits the three-dimensional description. (Still less does it require regarding a single language including *both* three- and a $6N$-dimensional language as being ours. We must continue to resist picturing the existence of multiple possible languages as corresponding to multiple worlds.)

By the way, I'm inclined to object to the grounding approach to "giving rise to", on the basis of this case. In place of my nonfundamental languages with different nonfundamental meanings of the quantifiers, the grounding approach posits a single meaning of the quantifiers, and a corresponding single domain of nonfundamental entities. So in the case at hand, will grounders posit *both* a nonfundamental three-dimensional world and also a non-fundamental $3N$-dimensional world? What about cases where fundamental reality favors one translation scheme just a bit better than another? I don't see a happy description of such cases available to grounders.

ther world, whose fundamental space is $6N$ dimensional, containing a single marvelous particle that never moves—indeed, in which the *laws* specify that nothing ever moves. But as he points out, one could think of each point, p, in this 6N-dimensional world as representing a point in the phase space of a system of N three-dimensional particles. And one could, further, think of that point in the phase point as representing the phase of a three-dimensional world at some particular time t_0. And one could, further, think of the three-dimensional world as obeying deterministic laws, so that the phase of the particles at t_0 determines the configurations of those particles at all other times. Putting all this together, one could think of each point in Albert's static $6N$-dimensional world as representing an entire history of a three-dimensional world of N particles, and think of the (stationary) location of the marvelous point as representing which such three-dimensional history is actual; and one could define a corresponding translation scheme from the fundamental language to the $3D$ language. Thus the static $6N$-dimensional world could give rise to an entire three-dimensional history. "This way lies madness", Albert says; and I agree. Since global functionalism seems to allow the madness, we have a problem.

Before attempting to solve the problem, consider a more extreme challenge. Suppose fundamental reality consists of nothing other than a particle, moving in a one-dimensional space, according to no simple dynamical laws whatsoever. The set of points of the one-dimensional space has the same cardinality as the set of points in the configuration space of some fixed number, N, of three-dimensional particles; thus there exists some mapping, f, from the points of the one-dimensional space to 3D worlds with N particles—i.e., to maximal consistent sets of sentences in the 3D language describing N particles in motion. A translation scheme can then be defined which maps any set of sentences completely describing the state of the fundamental universe in which the marvelous particle is located at point p to the set of sentences contained in $f(p)$.[33]

If we know anything about giving-rise-to, we know that the linear universe with the haphazardly moving particle could not give rise to the manifest image. Thus we may take as a fixed point of our inquiry that something is wrong with this translation scheme. And it seems pretty obvious what that is: it is *physically arbitrary*. It isn't distinguished in any way by the fundamental physical

[33]We are in the vicinity of a familiar class of problems for broadly-speaking "structuralist" views in metaphysics, epistemology, and metasemantics: the Newman problem (Newman, 1928), the model-theoretic argument against realism (Putnam 1978, part IV; 1980; 1981, chapter 2), Skolem's "paradox" (Bays, 2014), and the like.

features of the world we are considering. For it is based on the mapping, f, whose existence is established solely by a cardinality argument, rather than being distinguished by the world's structure and dynamics. (A symptom of this physical arbitrariness is the fact that there exist many other translation schemes—indeed, infinitely many other schemes—radically different from one another, and no less physically distinguished; there is one for each alternate function f' based on any other bijection between the linear space and the configuration space of N particles.)

The mapping Albert imagines for his static world is just as physically arbitrary.[34] For nothing in the fundamental features of the $6N$-dimensional static world, or its dynamics (which says merely that the marvelous particle is always stationary) favors any particular mapping from its points to the phase points of a three-dimensional world over any other mapping.[35]

The situation is very different with the cases in which global functionalism is plausible. Return to the 6N dimensional world that is "structured like the phase space" of a three-dimensional world, as I put it above. This is a world whose fundamental space has a geometry that is identical to that of the mathematical phase space for a system of N particles moving in three dimensions. Moreover, if I understand Albert correctly, there are further fundamental facts about this world, which are the correlates in this high-dimensional setting of the classical Hamiltonian defined over the phase space: a fundamental scalar field defined over the fundamental $6N$ dimensional space, and fundamental dynamical laws specifying the motion of the marvelous particle as a function of this scalar field. The translation scheme between the fundamental language and the 3D language, for *this* world, is highly *non*arbitrary. There is just one translation scheme that is nonarbitrarily determined by the geometry of the fundamental space, the scalar field on that space, and the dynamical laws governing the motion of the marvelous particle. It is determined by reverse-engineering. We

[34] Well, perhaps not *quite* as arbitrary: since we are told that the fundamental space is $6N$-dimensional, it's not wholly arbitrary to think of it as representing the phase space of a system of N three-dimensional particles. But nothing about the dynamics particularly suggests thinking of it this way; and moreover, the correlation of particular points in that space with particular possibilities for the global phase of those particles *is* arbitrary.

[35] Again, this is a little overstated. Mappings that don't respect the topology of the high-dimensional space (i.e., mappings that map adjacent points of the high-dimensional space to nonadjacent points in the phase space) are presumably disfavored. But a mapping that associates the actual location of the marvelous point with the three-dimensional description we take to be true of actual history is not favored over another mapping that associates that point with, say, a 3D world in which human beings never existed.

consider various descriptions, in the 3D language, of finite numbers of particles moving according to various laws in three dimensions. Of all such descriptions, just one of them will "fit" the actual fundamental facts (in the sense defined earlier); this will be the one according to which there are N particles, moving in three dimensions according to Newton's laws, and interacting with each other in certain ways as a function of the distances between them, such that the scalar field on the high-dimensional space behaves exactly like the Hamiltonian on a phase space for those N particles.[36] The definition of this translation scheme makes no reference to an arbitrary bijection; it is uniquely determined by the world's physical structure and dynamics.

There are, to be sure, difficult questions about how exactly to understand the crucial distinction being used here, between being "physically arbitrary" and "physically distinguished". One choice-point in understanding the distinction is whether to help ourselves to an unreduced notion of lawhood. I myself favor a reductionist approach to laws, and an account of physical distinguishedness in terms of syntactic complexity of definition in a language in which the primitive predicates express natural properties in David Lewis's (1983; 1986, pp. 59–69) sense; on this approach, the ultimate explanatory notion is naturalness (Sider, 2011). But in the present context, any reasonable way of understanding the distinction will do.

It's worth noting that it isn't only high-dimensionalists who need to appeal to the distinction between being physically distinguished and being physically arbitrary (or, as it's sometimes put, the idea of "being physically significant", or "being physical"). The distinction is ubiquitous in the metaphysics of science. (To take just one example, in describing the sense in which no foliation is "privileged" in Minkowski spacetime.) Of particular dialectical significance is that even low dimensionalists need the distinction, when they try to say how fundamental reality gives rise to the manifest image. If fundamental reality contains three-dimensional particles and composites of them, we needn't be functionalists about the ontology of the manifest image, nor need we be functionalists about geometric facts about that ontology. But we will still presumably want to be functionalists about other properties of manifest-image entities, such as being a *pointer* or a *rock*, and even about more basic classifications such as being being *solid* or *visible*. The entities will be seen as nodes in an appropriate causal structure only if that structure is somehow enacted by the fundamental dynamics. But this enactment must be in a physically significant

[36] Spelling this out in more detail will require an analog of 'puts', and analogs of S1 and S2.

way. If no requirement is made that the structuring relations in the causal array must be physically significant—must be non-arbitrarily related to the fundamental physical properties and the fundamental dynamical laws—then even this more limited functionalism will have intolerable results.

In his discussion of the challenge to global functionalism caused by his static world (and related examples), Albert considers a response that is close to my own:[37]

> Maybe there ought to be a… requirement on the mappings from the fundamental vocabulary to the non-fundamental vocabulary—a requirement to the effect that those mappings should be "relatively simple". But this is not very promising. "Relatively simple" seems too vague and too arbitrary and too insubstantial a distinction to figure in the fundamental metaphysical principles of the world."

I'm not sure what the concern about "insubstantiality" is supposed to be, but Albert is right that there will likely be some vagueness and arbitrariness here: both in how exactly "physical significance" is measured, and also in how, given any standard of measurement, a threshold will be set for how much physical significance is required. The vagueness and arbitrariness should not be overstated, since there is presumably nothing vague or arbitrary about considering a translation scheme based on arbitrary bijections f as being hopelessly physically insignificant. Still, some vagueness and arbitrariness cannot be denied. But what is under discussion here is *not* "fundamental principles of the world". It is rather the theory of "giving rise to"—in my terms, the theory of metaphysical translation. And it is unproblematic that an account of giving-rise-to would have some vagueness and arbitrariness.

Indeed, it is hard to see how any reasonable account could avoid it. Regardless of our stance on whether a high-dimensional reality could give rise to the manifest image, we will surely not suppose that there is a sharp or nonarbitrary line between which possibilities for fundamental reality would give rise to the existence of a rock (for instance) and those that wouldn't. Consider all the

[37] Albert (2021, p. 16) He goes on to say: "And (anyway) if 'simplicity' has anything to do with usefulness in the practical everyday business of doing physics—then the mappings alluded to above are the very model and paradigm of simplicity." I believe he has in mind the fact that the mappings needed for the static $6N$-dimensional world are like Hamilton-Jacobi transformations. But the fact that the *kind* of mappings is useful in doing physics isn't what's important for the relevant kind of simplicity; what's important is that the *particular* mapping used in defining a given translation scheme has no simple definition.

possible forms a fundamental physics might take. There is variation in the number of fundamental dimensions: just the three familiar ones; the three familiar ones and some extra dimensions (as in string theory); massively many as the high-dimensionalist thinks; or perhaps there are fewer than three. Also the fundamental geometry might vary: it might be that there are no fundamental metrical facts, with the metrical facts "emerging from the dynamics";[38] and there is a range of possibilities for the dynamics, some under which the emergence is straightforward, others less so. There is then possible variation in the nature of the dynamical laws. Even given a fundamental three-dimensional ontology, on some dynamical laws governing this ontology there would definitely be no emergence of ordinary (solid, visible, etc.) objects; on others there definitely would be; and then there are all the possibilities in between. It is hard to believe that, amidst all this possible variation, there are always sharp, nonarbitrary facts about whether a given possibility for fundamental reality would give rise to the existence of a rock, or a city, or a smile, or some candy.

When fundamental reality "gives rise to" nonfundamental facts, the fact of the giving-rise-to is just as nonfundamental as the facts that arise. So just as it is unsurprising that there can be vagueness or arbitrariness in whether there is a rock, there can be vagueness or arbitrariness in what it takes for fundamental reality to give rise to there being a rock.[39]

Still, the potential vagueness or arbitrariness is quite different from the familiar sort of vagueness or arbitrariness that there can be in whether *a given thing* counts as being a rock—or being red, or being tall, or being bald; for here, the vagueness or arbitrariness potentially concerns the very existence of all of the objects of the manifest image. We will return to this in the final section.

7.

But first we should tie up a loose end. Let's return to an idea we set aside earlier, that of treating ordinary objects as "patterns" and "nodes", understood as entities in the fundamental ontology—certain kinds of sets, say.[40]

[38]Albert [??] defends a view of this sort.

[39]There are closely connected issues in the metaphysics literature, over whether grounding is grounded, and over whether relative fundamentality is fundamental. See Bennett (2011); Sider (2020*a*, 2011, sections 7.1–7.5).

[40]But let's continue to set aside dogmatic insistence that sets couldn't ever cause anything, that *I* at any rate am not a set, and the like.

Under the set-theoretic approach, we continue to talk about nonfundamental languages. These languages can now be given predicate-for-predicate translation schemes rather than sentence-for-sentence ones, since they "share the ontology" of the fundamental language. Still, it remains the case that there are multiple nonfundamental languages, since there are multiple possible ways one could associate impure sets with ordinary predicates. Put another way: there is no single array of sets that, by its nature, is suited to play the role of being a causal structure. Rather, there is a vast multiplicity of candidates, within the universe of impure sets, which because of their internal structures, and because of the physical features of their members (and their members' members, and …), can be regarded (with varying degrees of justification) as counting as causal structures.

Section 5 answered the challenge of Maudlin's objects displaced by three feet; the defender of the set-theoretic approach can give a parallel response. As before, there is a "normal" nonfundamental language, describing ordinary objects as being located where their parts are, and a perverse nonfundamental language that describes ordinary objects as being located three feet to the north of their parts. The languages differ over which sets they count as being in the extensions of predicates like 'rock', 'part', and 'located'. Maudlin's challenge may then be answered by the following observations. i) The nonfundamental languages describe the same fundamental reality (consisting of a high-dimensional space with wavefunction values, a marvelous particle moving around it, and the corresponding impure set-theoretic hierarchy). ii) Because the assignment of extensions in the second language is gratuitously complex, that language is not our own. iii) A picture of normal *and* displaced things is wrong, both at the fundamental level of course, but also at the nonfundamental level since our language's extensions for 'rock' and locational predicates does not count 'there are both rocks and displaced rocks' as being true (and a language that did would be even more complex and noncharitable).

The response to Albert's static world will also be parallel to that given in section 6. In the fundamentally static $6N$-dimensional scenario, there are indeed assignments of set-theoretic constructs to the extensions of ordinary predicates that would count sentences of the manifest image as being true, but those assignments are physically arbitrary (because based on arbitrary bijections) in a way in which the assignments under other high-dimensional scenarios are not.

If the set-theoretic approach can respond to the arguments, why not accept it? One reason is its artificiality. There is presumably no single best way to model "causal structures" in impure set theory. The set-theoretic approach

will, as a result, need to posit massive semantic indeterminacy. Moreover, the indeterminacy will be of a global sort. Certain sets will count as being the rocks only when other sets are regarded as being the windows, only when still other sets are regarded as the extension of 'breaking', and so on. There are multiple global, coordinated choices for the entirety of the manifest image's set of predicates.[41] Thus we don't have what we might have at first envisioned, when we were offered an "entity-for-entity" reduction. It isn't as if there is some particular set that can be regarded, once and for all, as being Paris. It is only relative to a certain global set of choices for what to mean by 'Paris', 'city', 'rock', 'located', 'causes', and every other word, that a given set counts as Paris. Given all this, it seems more forthright to abandon the idea that the ontology of ordinary language is the fundamental ontology, and instead offer sentence-by-sentence translations. But again, I don't think much turns on this.

8.

A high-dimensional reality can, after all, give rise to the manifest image. The evolution over time of the global quantum state and the location of the marvelous particle secures, by reverse-engineering, a unique translation scheme from the nonfundamental, three-dimensional language of the manifest image to the fundamental language of physics. Ordinary sentences with true translations under this scheme may be regarded as being themselves true, albeit nonfundamentally so. Such sentences express truths about reality, but they do so "non-perspiciously" since their structure is radically unlike the underlying structure that they represent.

In my view, high-dimensionalism might well be true. But I think it is even more intellectually radical than many of its defenders suppose.

Nina Emery (2017) argues that, just as both ordinary people and scientists rightly dismiss (or ignore) skeptical hypotheses of traditional epistemology (like Descartes's dream hypothesis), as well as contemporary analogs like the possibility that we might be living in a computer simulation, so we should dismiss high-dimensionalism.[42]

But there is an important difference between high-dimensionalism and some "skeptical scenarios"—Descartes' evil demon hypothesis, for instance. High-dimensionalism is part of a scientific theory that is both attractive by ordinary

[41] That is, we have Finean (1975) "penumbral connections" on a massive scale.

[42] See also Monton (2006, pp. 783–4).

scientific standards and also is detailed enough to predict the evidence. The bare hypothesis that there is an evil demon causing me to hallucinate things makes no particular predictions about the evidence. If the hypothesis is enriched in a list-like way, to say that there is an evil demon causing me to hallucinate $X, Y, \ldots$, listing everything I've ever experienced, it fails to be an attractive theory on ordinary scientific grounds. And if it is enriched by outfitting it with a "demonic physics" that is sufficiently detailed so as to make predictions about evidence, there is no guarantee that the result will be an attractive theory by ordinary scientific standards. A skeptic might meet this challenge by outfitting the skeptical hypothesis with the very same physics as its nonskeptical competitors. Consider the Matrix hypothesis, according to which we are bodies hooked up to a giant computer, the Matrix; what we ordinarily take the world to be (at least, before we take the red pill and learn the truth) is just a computer simulation. The physics governing the machine overlords of the Matrix and the bodies of humans being force-fed the simulation can be taken to be real physics (provided this scenario really is physically possible). But then the Matrix hypothesis would have a different theoretical shortcoming: although its laws look fine from an ordinary scientific perspective, its descriptions of particular matters of fact are gratuitously complex, since it posits what amounts to a conspiracy theory. It's as if, when given what seems to be straightforward evidence that the butler done it, we posit—without any independent evidence—that the gardener done it, but covered up her tracks perfectly to implicate the butler. To rule out skeptical hypotheses, it isn't clear that we need Emery's "minimal divergence norm" (p. 565), which requires us to, other things being equal, choose theories that match our ordinary conception of it; the hypotheses are bad theories by the lights of the epistemic standards that govern ordinary science.[43] Unlike

[43]There is also a tradition of dismissing skeptical hypotheses for broadly-speaking pragmatic reasons: if we could not dismiss them, intellectual paralysis would result. (Perhaps we must take this pragmatic stance in response to skeptical demands to justify ordinary scientific standards.) This tradition, too, could be seen as allowing dismissal of traditional skeptical scenarios but not of high-dimensionalism. I doubt, though, whether the range of dismissable propositions should be seen as fixed, on such an approach. See also (Sider, 2013, sections 2–6) on all of the above.

Emery mentions the fact that we dismiss the possibility of being Boltzmann brains. This is an interesting and difficult case, though importantly different from the others. Presumably we cannot dismiss the idea that *there are* Boltzmann brains, or even that there are many more Boltzmann brains than ordinary brains, since that would mean dismissing scientifically mainstream ideas about statistical mechanics and cosmology. At most we can dismiss the "*de se*" hypothesis that *we* are Boltzmann brains. But then it becomes unclear what role Emery's

what we usually think of as "skeptical hypotheses", high-dimensional quantum mechanics can be supported by ordinary scientific reasoning. Indeed, broadly scientific considerations can be adduced for high-dimensionalism as against low-dimensional rivals, such as the match between its fundamental space and the dynamics of quantum theories (North, 2012), and the preservation of locality in the laws [reference??].

But even though high-dimensionalism escapes Emery's challenge, there is an important lesson in her comparison of high-dimensionalism with skeptical scenarios. Suppose the evil demon or Matrix hypothesis really is true. Or better, given where we are heading, suppose one of these hypotheses is *fundamentally* true. There would still be translation schemes, of the broadly-speaking functionalist/reverse-engineering variety, mapping the sentences that we ordinarily believe to fundamental truths (about the demon, about the Matrix). Perhaps these schemes are somewhat worse candidates than the high-dimensionalist's schemes for being legitimate translation schemes—for giving the actual truth conditions of our beliefs; whether that is so would depend on various matters. In the Matrix scenario, for instance, since there fundamentally exists a three-dimensional world that matches *somewhat* our ordinary beliefs about the manifest image, there is a question of whether the functionalist scheme based on the simulation is "trumped" by a more straightforward scheme under which most of our beliefs are false.[44] Nevertheless the schemes are nowhere near as physically arbitrary as the schemes based on arbitrary correspondences discussed above, in connection with Albert's static world and the one-dimensional world of the erratically moving particle. They are at least *close* to being legitimate, and thus the sentences they translate are, in a sense, close to being nonfundamentally true.

Whether the manifest image is illusory and false, or true but nonfundamentally so, is not a binary, on-off distinction, but rather a matter of degree. Consider a continuum of various possibilities for fundamental reality:[45]

Three-dimensional particles and their composites

Three-dimensional particles but no composites

Three-dimensional particles embedded in many more dimensions

minimal divergence norm (which is not *de se*) is playing. A full discussion of the case will presumably require wrestling with difficult issues in *de se* epistemology.

[44] I would use this fact to reply to Chalmers (2005).

[45] Compare Sider (2011, p. 63).

High-dimensionalism

Various physical theories even less hospitable to the manifest image

The Matrix

Ideas in the mind of God

Truth and falsity are too-blunt instruments to describe the important dimension of variation here, which is that of our ordinary beliefs making less and less contact with fundamental reality. By the end of the continuum we presumably reach falsity, but long before, something truth-*like* is lost. Ordinary beliefs become a partial epistemic failure, even if true. If high-dimensionalism is true, our ordinary beliefs are thus partial epistemic failures, akin to if not quite so bad as beliefs about the simulation of the Matrix. I don't see this as undermining the confirmation of high-dimensionalism, but it is nonetheless disturbing.

Also disturbing is the non-uniqueness of the manifest image. If reality is $6N$-dimensional, containing a marvelous particle moving as if in the phase space of a system of N three-dimensional particles, in addition to reverse-engineering a three-dimensional world, we could also reverse-engineer a $3N$-dimensional world, decorated as if it were the configuration space of a three-dimensional world. A translation scheme based on this second reverse-engineering is presumably no less physically distinguished than one based on the first scheme; its only demerit is that it doesn't fit how *we* think. This partially undermines the *objectivity* of the manifest image, just as the discovery of equally good conceptual schemes (however mind-independent) for talking about "beauty" undermines the objectivity of our own.

The objectivity of the manifest image is also threatened in a second way. The marvelous particle is just one small bit of the overall structure of a high-dimensional Bohmian world, dwarfed in complexity and size by the wavefunction. It has no dynamical influence whatsoever on the rest of the structure, and its motion is almost entirely determined by the wavefunction (the only other relevant factor being its prior position; even its prior velocity is irrelevant).

Now, an opponent of the Bohmian picture might question why this "marvelous" particle, this *miserable speck*, should play such a central role in the account of the emergence of the manifest image. (As with 'configuration space', it's important to not be misled by re-using terminology from a three-dimensionalist setting.) Suppose the speck were deleted. The fundamental world would then not give rise to a *single* world of the manifest image: it would either give rise to

many worlds of the manifest image, as contemporary Everettians think, or else to no manifest image at all, depending on one's views about giving-rise-to. But then, one worries, why should the addition of this miserable speck make such a huge difference?[46]

I do think this concern can be answered. The speck does after all play a distinctive, even if comparatively small, dynamical role; and the Bohmian can insist that the rules of giving-rise-to—the rules governing correct metaphysical translation—are such that the difference between the wavefunction-only world, in which nothing plays this role, and the wavefunction-plus-speck world, in which something does, is significant enough to affect what fundamental reality gives rise to. (The more nomically distinctive the dynamical role of the speck is, the more compelling this response is. It would be more compelling, for instance, if there were a fundamental law of nature saying that there is exactly one speck. I doubt such a law is available to Humeans about lawhood.)

But even if a translation procedure taking account of the speck can eke out a victory over the competition (over a many-worlds translation procedure and the claim that no manifest-image-translation is correct), the margin of victory is disturbingly small—far smaller than if a fundamentally three-dimensional Bohmian view were correct, for instance. This undermines the objectivity of the manifest image, just as the objectivity of our moral standards would be undermined if we discovered that the world only marginally privileges them over competing standards.

I don't see any of this as refuting high-dimensionalism, or even making it significantly less likely. But if we are to accept it, it should be with eyes wide open.

References

Albert, David Z. (1996). "Elementary Quantum Metaphysics." In J. T. Cushing, A. Fine and S. Goldstein (eds.), *Bohmian Mechanics and Quantum Theory: An Appraisal*, 277–84. Dordrecht: Kluwer Academic Publishers.

— (2012). "Wave Function Realism." In Albert and Ney (2012), 52–7.

[46]The critique of Brown and Wallace (2005) is different in a number of ways. For one thing, it is directed at a *three*-dimensionalist Bohmian view. For another, as Maudlin (2010) points out, Brown and Wallace contentiously assume that it is common ground between Bohmians and their opponents that a single localized wavepacket can "represent a measurement outcome".

— (2015). "Quantum Mechanics and Everyday Life." In *After Physics*, 124–43. Cambridge, MA: Harvard University Press.

— (2021). "Beginning in the Middle." .

Albert, David Z. and Alyssa Ney (2012). *The Wavefunction: Essays in the Metaphysics of Quantum Mechanics*. Ed. David Z. Albert and Alyssa Ney. Oxford: Oxford University Press.

Allori, Valia (2013). "On the Metaphysics of Quantum Mechanics." In Soazig Lebihan (ed.), *Precis de la Philosophie de la Physique*. Vuibert.

Bays, Timothy (2014). "Skolem's Paradox." Stanford Encyclopedia of Philosophy. Available at `https://plato.stanford.edu/archives/win2014/entries/paradox-skolem/`.

Bennett, Karen (2011). "By Our Bootstraps." *Philosophical Perspectives* 25: 27–41.

Bhogal, Harjit and Zee R. Perry (2017). "What the Humean Should Say About Entanglement." *Noûs* 51: 74–94.

Brown, Harvey and David Wallace (2005). "Solving the Measurement Problem: De Broglie-Bohm Loses Out to Everett." *Foundations of Physics* 35(4): 517–40.

Chalmers, David J. (2005). "The Matrix as Metaphysics." In Christopher Grau (ed.), *Philosophers Explore the Matrix*, 132–76. New York: Oxford University Press.

Chalmers, David J., David Manley and Ryan Wasserman (2009). *Metametaphysics*. Ed. David J. Chalmers, David Manley and Ryan Wasserman. Oxford: Oxford University Press.

Dorr, Cian (2004). "Non-Symmetric Relations." In Dean W. Zimmerman (ed.), *Oxford Studies in Metaphysics*, volume 1, 155–92. Oxford: Oxford University Press.

— (2005). "What We Disagree About When We Disagree About Ontology." In Mark Eli Kalderon (ed.), *Fictionalism in Metaphysics*, 234–86. Oxford: Oxford University Press.

— (2009). "Finding Ordinary Objects in Some Quantum Worlds." Available at `http://users.ox.ac.uk/~sfop0257/papers/Finding.pdf`.

— (2010). "Of Numbers and Electrons." *Proceedings of the Aristotelian Society* 110(2pt2): 133–81.

— (2016). "To Be F is to Be G." *Philosophical Perspectives* 30(1): 39–134.

Emery, Nina (2017). "Against Radical Quantum Ontologies." *Philosophy and Phenomenological Research* 95(3): 564–591.

Esfeld, Michael (2020). "Super-Humeanism: The Canberra Plan for Physics." In David Glick, George Darby and Anna Marmodoro (eds.), *The Foundation of Reality: Fundamentality, Space and Time*, 125–38. Oxford: Oxford University Press.

Fine, Kit (1975). "Vagueness, Truth and Logic." *Synthese* 30: 265–300. Reprinted in Keefe and Smith 1996: 119–50.

— (2003). "The Problem of Possibilia." In Michael J. Loux and Dean W. Zimmerman (eds.), *Oxford Handbook of Metaphysics*, 161–79. Oxford: Oxford University Press.

— (2012). "Guide to Ground." In Fabrice Correia and Benjamin Schnieder (eds.), *Metaphysical Grounding: Understanding the Structure of Reality*, 37–80. Cambridge: Cambridge University Press.

Hawthorne, John (2010). "A Metaphysician Looks at the Everett Interpretation." In Simon Saunders, Jonathan Barrett, Adrian Kent and David Wallace (eds.), *Many Worlds?: Everett, Quantum Theory & Reality*. Oxford University Press.

Hirsch, Eli (2011). *Quantifier Variance and Realism: Essays in Metaontology*. New York: Oxford University Press.

Huggett, Nick (2006). "The Regularity Account of Relational Spacetime." *Mind* 115(457): 41–73.

Ismael, Jenann (2020). "What Entanglement Might Be Telling Us: Space, Quantum Mechanics, and Bohm's Fish Tank." In David Glick, George Darby and Anna Marmodoro (eds.), *The Foundation of Reality: Fundamentality, Space, and Time*, 139–53. Oxford: Oxford University Press.

Keefe, Rosanna and Peter Smith (eds.) (1996). *Vagueness: A Reader*. Cambridge, MA: MIT Press.

Kim, Jaegwon (1993). *Supervenience and Mind*. Cambridge: Cambridge University Press.

Lewis, David (1983). "New Work for a Theory of Universals." *Australasian Journal of Philosophy* 61: 343–77. Reprinted in Lewis 1999: 8–55.

— (1986). *On the Plurality of Worlds*. Oxford: Blackwell.

— (1999). *Papers in Metaphysics and Epistemology*. Cambridge: Cambridge University Press.

Lewis, Peter J. (2004). "Life in Configuration Space." *British Journal for the Philosophy of Science* 55(4): 713–729.

Maudlin, Tim (2007). "Completeness, Supervenience, and Ontology." *Journal of Physics A: Mathematical and Theoretical* 40: 3151–71.

— (2010). "Can the World Be Only Wavefunction?" In *Many Worlds? Everett, Quantum Theory, and Reality*. Oxford: Oxford University Press.

— (2018). *Philosophy of Physics: Quantum Theory*. Princeton University Press.

Miller, Elizabeth (2013). "Quantum Entanglement, Bohmian Mechanics, and Humean Supervenience." *Australasian Journal of Philosophy* 92(3): 1–17.

Monton, Bradley (2002). "Wave Function Ontology." *Synthese* 130(2): 265–77.

— (2006). "Quantum Mechanics and 3NDimensional Space." *Philosophy of Science* 73(5): 778–89.

Nagel, Ernest (1961). *The Structure of Science: Problems in the Logic of Scientific Explanation*. New York: Harcourt, Brace & World.

Newman, M. H. A. (1928). "Mr. Russell's "Causal Theory of Perception"." *Mind* 37: 137–48.

Ney, Alyssa (2021). *The World in the Wave Function: A Metaphysics for Quantum Physics*. New York, NY, USA: Oxford University Press.

North, Jill (2012). "The Structure of a Quantum World." In Albert and Ney (2012).

— (2018). "A New Approach to the Relational-Substantival Debate." In Karen Bennett and Dean W. Zimmerman (eds.), *Oxford Studies in Metaphysics*, volume 11. Oxford: Oxford University Press.

Putnam, Hilary (1978). *Meaning and the Moral Sciences*. Boston: Routledge and Kegan Paul.

— (1980). "Models and Reality." *Journal of Symbolic Logic* 45: 464–82. Reprinted in Putnam 1983: 1–25.

— (1981). *Reason, Truth and History*. Cambridge: Cambridge University Press.

— (1983). *Realism and Reason: Philosophical Papers, volume 3*. Cambridge: Cambridge University Press.

Rubenstein, Ezra (forthcoming). "Grounded Shadows, Groundless Ghosts." *British Journal for the Philosophy of Science* .

Schaffer, Jonathan (2009). "On What Grounds What." In Chalmers et al. (2009), 347–83.

— (2017). "The Ground between the Gaps." *Philosophers' Imprint* 17: 1–26.

Sider, Theodore (2009). "Ontological Realism." In Chalmers et al. (2009), 384–423.

— (2011). *Writing the Book of the World*. Oxford: Clarendon Press.

— (2013). "Against Parthood." In Karen Bennett and Dean W. Zimmerman (eds.), *Oxford Studies in Metaphysics*, volume 8, 237–93. Oxford: Oxford University Press.

— (2020*a*). "Ground Grounded." *Philosophical Studies* 177: 747–67.

— (2020*b*). *The Tools of Metaphysics and the Metaphysics of Science*. Oxford: Oxford University Press.

Sosa, Ernest (1991). *Knowledge in Perspective: Selected Essays in Epistemology*. Cambridge: Cambridge University Press.

Thomasson, Amie L. (2015). *Ontology Made Easy*. New York: Oxford University Press.

van Inwagen, Peter (1998). "Meta-Ontology." *Erkenntnis* 48: 233–50. Reprinted in van Inwagen 2001: 13–31.

— (2001). *Ontology, Identity and Modality*. Cambridge: Cambridge University Press.

Wallace, David (2003). "Everett and Structure." *Studies in History and Philosophy of Science Part B* 34(1): 87–105.

Williams, J. Robert G. (2007). "Eligibility and Inscrutability." *Philosophical Review* 116: 361–99.

Williamson, Timothy (1997). "Knowledge as Evidence." *Mind* 106(424): 1–25.