3D in high-D*

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The world as we ordinarily conceive of it, both in everyday life and in classical physics, is three-dimensional.[1] 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 (which is usually called "wavefunction realism" or "configuration-space realism", and which has been defended by David Albert and others), the world is ultimately not like this *at all*.[2] 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.

There are strong, though certainly not decisive, reasons in favor of the high-dimensional viewpoint: the wavefunction "lives" in the high-dimensional space, and the dynamics are local in that space (Albert, 2015; Ney, 2021; North, 2013). But our focus lies elsewhere. If high-dimensionalism implied that rocks, trees, subatomic particles, and other three-dimensionalia are simply *illusions*, or *intellectual mistakes*, akin to phlogiston and phrenology, and should be purged from our cognitive lives, then in addition to being literally unbelievable, high-dimensionalism would be self-undermining. The empirical evidence for any

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[1]Or four-dimensional; issues about time won't be our concern.

[2]See Albert (1996, 2013, 2015, 2023*a*); Ismael (2020); Lewis (2004); Ney (2021); North (2013). Opponents of high-dimensionalism include Allori (2013*a*); Emery (2017); Maudlin (2007, 2010, 2018); Monton (2002, 2006). I prefer 'high-dimensionalism' to 'wavefunction realism' because many three-dimensional views intuitively count as being "realist" about the wavefunction (on this point see Chen (2019, p. 5); Ney (2021, p. 62)); and I prefer it to 'configuration space realism' because reserving the term 'configuration space' for mathematical configuration space forestalls certain kinds of confusions.

scientific theory is three-dimensional, consisting of observations of pointer positions, computer readouts, and the like. So if high-dimensional quantum mechanics implied that statements about pointer positions and the rest are all false, it would seem to be incapable of empirical confirmation.

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.

But how, exactly, does this "giving rise to" work? How can a high-dimensional fundamental reality give rise to a nonfundamental three-dimensional manifest image that is utterly unlike it? Familiar models of giving-rise-to, in which nonfundamental three-dimensional entities are wholes composed of fundamental three-dimensional parts, do not apply.

The answer, it is generally agreed, involves a certain kind of structural match between high-dimensional reality and the manifest image. But as we will see, extant versions of this answer are unsatisfactory, for metaphysical reasons. A new conception of the relation between high- and low-dimensional reality will be developed, which not only will yield a better understanding of high-dimensionalism, but also will overcome some of its most difficult challenges. However, 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, based on different solutions to the measurement problem.[3] Our focus will be on the one based on Bohmian mechanics, according to which a single "marvelous particle" moves through the high-dimensional space. The dynamical laws of this theory are 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 adapted to fit them, for instance a GRW version (in which the wavefunction is "all that there is", and evolves probabilistically, periodically undergoing collapses) and an Everettian version (in which the wavefunction is again "all that there is", and always obeys Schrödinger's equation). My focus on Bohmian high-

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

dimensionalism is not due to a judgment that it is the most defensible form, but rather because the story I want to tell is simplest in that setting.[4]

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.

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 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. We could consider other views, based on other conceptions of fields and other stances on the substantivalism/relationalism debate.)

In standard (i.e., three-dimensional) Bohmian mechanics, the wavefunction is 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 whose points correspond, by stipulation, to the possible ways in which the system of particles could be distributed in three-dimensional physical space (i.e., to all possible assignments of N three-dimensional locations to the N particles). (The fact that the wavefunction is so different from more familiar fields, which live in three-dimensional space, is tied up with the most striking aspects of quantum mechanics: nonseparability, entanglement, and nonlocality.) And at any time, a single "marvelous point" in the mathematical configuration space represents, by stipulation, the actual three-dimensional locations at that moment of the N three-dimensional particles. But for the high-dimensionalist, although the high-dimensional space and marvelous particle are structurally similar to the configuration space and marvelous point, they are nonrepresentational, nonmathematical, physically fundamental entities. At the fundamental level, there is no association whatsoever between these entities and locations of three-dimensional particles, since at the fundamental level there simply are no three-dimensional particles.

[4] As Ney (2021, pp. 36–47) points out, high-dimensional Bohmianism is dialectically unstable if one's reason for liking Bohmianism is the thought that three-dimensional particles simply must be recognized at the fundamental level. But an adjacent thought is compatible with high-dimensionalism: that the fundamental level must contain something or other that directly corresponds to three-dimensional particles (whether that something is three-dimensional particles themselves or the marvelous particle).

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, 'analysis', 'building', and 'ground' (Nagel, 1961; Kim, 1993; Dorr, 2004, 2016; Bennett, 2017; Fine, 2012; Schaffer, 2009). 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" (Sider, 2011). 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 this language. Truths expressed in the fundamental language are ultimate, deriving from nothing else.

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 derivatively true. For sentences in nonfundamental languages can be *translated* into the fundamental language; their truth then amounts to nothing more than the 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".

'Translation' is not intended here in the ordinary, everyday sense. 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 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.

Although the fundamental language is "metaphysically prior to" nonfundamental languages, the nonfundamental language we speak is epistemically and conceptually prior: we learn it first and use it to state the things of which we are most certain. Also we speak it when we 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. Using the nonfundamental language, we propose a theoretical role for the expressions in the fundamental language (involving hypotheses about what fundamental sentences are laws and also about metaphysical translation), and we posit that the role is occupied. If the role is indeed occupied (near enough), the fundamental language is in good standing.

In these terms, our question becomes the following: how can the language of the manifest image be translated into statements about high-dimensional reality?

3.

The most promising answer is "functional" in nature. 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 *causal profile*—to occupy a certain *node* in the overall network of causal relations" (2023*b*, p. 92). 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.[5] 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

[5]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).

etc.

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 'some x and y are such that x has causal profile C_1, y has causal profile C_2, and x bears causal relation R_1 to y'.

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 the high-dimensional 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 of points 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 "pattern" be regarded as some sort of set? We will return to this in section 6, but for now, let's set aside the idea that "patterns" or "nodes" are to literally be recognized as entities.)

The problem with the usual functional approach 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) from high-dimensional reality. 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 its classification as a rock; but the functionalism must also account for the entity itself.

Instead of supplying translations of *predicates*, we must instead supply translations of *entire sentences* (or sets of sentences). Instead of translating 'x is a rock', we should translate 'There is an x such that x is a rock', and other full sentences that quantify over rocks.[6] Instead of saying "*to be a rock* is to have a certain causal profile", we should say: "*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 high-dimensional 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 three-dimensional objects are nodes or patterns in the causal network, but rather that sentences about

[6]This approach delivers, in the first instance, only purely general three-dimensional sentences, so there remains a question of how to extend it to sentences containing names of particular three-dimensional things. This extension faces distinctive challenges; see Adams (1979); Dasgupta (2014, 2020); Russell (2017).

three-dimensional objects express propositions about the causal features of 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.[7]

I have suggested that 'there exists a rock' can be regarded as being *true*, albeit derivatively or nonfundamentally, if its translation into the fundamental 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 its translation into the fundamental language). In fact, the most natural understanding of what is going on here is that the quantifiers themselves—'there exists', 'for all', and related expressions—have different meanings in the two languages.[8] 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.[9]

[7]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.

[8]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, whereas the form at issue here is inegalitarian (Dorr, 2005; Sider, 2009).

[9]Arguing that high-dimensionalists *must* accept quantifier variance is a little delicate. One argument would be that 'there is something that is neither a subatomic particle nor a point of

4.

How, exactly, will the high-dimensionalist's translation procedure be defined? Our strategy, following Albert, will appeal to the fundamental dynamical laws.[10] Those laws will enable us to define translations of sentences about three-dimensional locations of three-dimensional particles. There will then remain the project of translating sentences about rocks, trees, and other three-dimensional macroscopic objects in terms of three-dimensional particles, but this project belongs equally to the low-dimensionalist, and I won't discuss it further.[11] We'll begin with a classical example, and then move to the quantum case.

In standard (i.e., three-dimensional) classical physics, there are familiar methods, due to Hamilton and Lagrange, for representing systems of three-dimensional particles using mathematical high-dimensional spaces. The interactions between the particles can be encoded in a simple mathematical formula defining a quantity E (the Hamiltonian or Lagrangian, respectively) at each point in the high-dimensional space, under a coordinatization of that space that is stipulatively tied to the states of the particles in the real, physical, three-dimensional space. The equations of motion for the particles can then be recovered from E; and we can think of those equations as governing the motion through the high-dimensional mathematical space of a "marvelous mathematical point" that represents the three-dimensional state of the system.

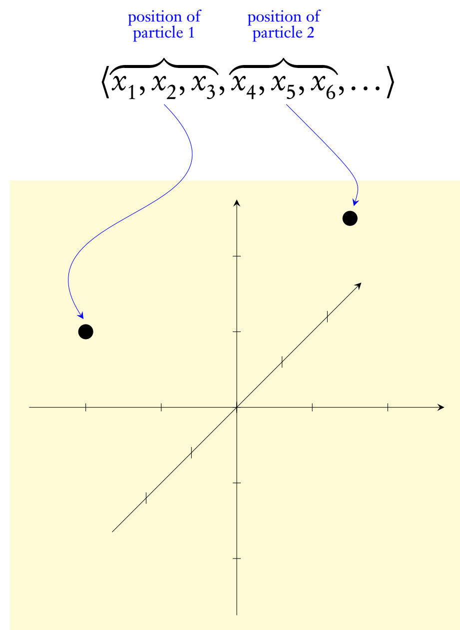
For example, in the Lagrangian version of this approach, the three-dimensional positions of N particles are represented by points in their $3N$-dimensional configuration space: a point with coordinates $x_1, \ldots, x_{3N}$ (where each x_i is a real number) represents particle 1 (under some chosen ordering of the particles) as having three-dimensional position x_1, x_2, x_3 (under some chosen coordinatiza-

the high-dimensional space' is true in the fundamental language but not in the nonfundamental language; the propositional connectives and the predicates 'subatomic particle' and 'point of the high-dimensional space' mean the same things in the two languages; therefore the quantifiers have different meanings in the two languages. One might resist this argument by denying its implicit semantic atomism.

[10] See also Wallace and Timpson (2010, p. 705).

[11] A high-dimensionalist interested only in sentences about macroscopic three-dimensional entities might bypass the three-dimensional particles and translate directly to facts about the wavefunction and marvelous particle. But the three-dimensional world studied by the sciences (chemistry, genetics, thermodynamics, …) includes myriad microscopic objects. The natural scope of our translation project includes sentences about three-dimensional objects all the way down to point-particles.

tion of the three-dimensional space), particle 2 as having position x_4, x_5, x_6, and so on:



E in this case is the Lagrangian, L, which at each point in the configuration space is a number representing the difference between the kinetic and potential energy of a system represented by that point.[12] The formula defining L makes reference to the coordinatization x_i and takes the simple form that it does only in that sort of coordinatization. (For instance, in the portion of the definition of L for potential energy, there might be a term representing a gravitational interaction between particles 1 and 2 as a function of the distance between them, $\sqrt{(x_1 - x_4)^2 + (x_2 - x_5)^2 + (x_3 - x_6)^2}$. This simple formula for the Euclidean distance depends on there being a separate coordinate for each spatial degree of freedom of each individual particle.) L can then be used to derive equations of motion governing a mathematical marvelous point through the configuration space, representing the evolution of the three-dimensional system.

A high-dimensional approach to classical mechanics would invert this procedure. We now begin with a single, concrete, marvelous particle, moving in a concrete space with some large number, D, of dimensions; the three-dimensional space and particles no longer fundamentally exist. The high-dimensional space

[12] More accurately, L is defined on the tangent bundle of the configuration space, and represents kinetic-minus-potential energy of a particular dynamical state of the system.

will have many coordinatizations—many ways of smoothly assigning D-tuples of real numbers to its points. None of these coordinatizations is privileged by the intrinsic geometry of the space (the space is isotropic and homogeneous, let's stipulate); and we no longer have three-dimensional space or particles to pick out one coordinatization stipulatively. However, suppose that under one of these coordinatizations, C, if we define the quantity E using the same formula as before (using the C-coordinates), the resulting equations of motion exactly describe the motion of the marvelous particle through the high-dimensional space. (This is a nontrivial supposition. If the high-dimensional space has the wrong number of dimensions or the marvelous particle doesn't move appropriately, its motion won't be thus describable in *any* coordinatization.) Indeed, suppose the laws of nature specify that this is so—that equations of motion induced by E are obeyed under some coordinatization. About a situation like this, in which the number D of dimensions is divisible by 3, Albert says the following:

> Looked at in C (then) the position coordinates of [the marvelous particle] will evolve in time exactly as if they were the coordinates of $D/3$ 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… This particle, in this space, … formally enacts (you might say) a system of $D/3$ classical three-dimensional particles—the i^{th} of which is the projection of the world particle onto the [subspace of the high-dimensional space picked out by the i^{th} triple of coordinates in C]. (2015, p. 128)

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. Nonfundamental sentences saying that there exist $D/3$ three-dimensional particles whose trajectories are given by the evolution over time of the $D/3$ triples of the marvelous particle's C-coordinates will count as true under this translation procedure.

The story is similar when we shift from a classical to a (Bohmian) quantum-mechanical high-dimensional world. The high-dimensional space now includes a wavefunction in addition to the marvelous particle. If the laws guarantee that in some coordinatization C, the wavefunction over time obeys the Schrödinger equation (as written in C), and that the wavefunction and marvelous particle obey the guidance equation (as written in C), then triples of coordinates in C can be thought of as representing the locations of three-dimensional particles; and a translation procedure for a nonfundamental three-dimensional language can be constructed on this basis.[13] But whereas there was no particular reason to adopt a high-dimensionalist view in the classical case, here in the quantum mechanical case there are such reasons (as argued by Albert and others).

Thus we pick out the association between the marvelous particle's motion and the motions of three-dimensional particles "dynamically". Zooming out, the central idea is one of "reverse engineering": the total set of truths in a nonfundamental 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 ask: are the high-dimensional facts structured as if they were high-dimensional mathematical represenions of the low-dimensional description? If so, then 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.

This approach yields sentence-for-sentence, not predicate-for-predicate, translations. It specifies which sentences in a nonfundamental, three-dimensional language can be used to (nonperspicuously) express the fundamental facts. 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.

[13] Since the coordinatization C is not geometrically distinguished, the dynamical laws must be of the "embedding" or "ramsifying" variety: they must take the form "there is a coordinatization of the high-dimensional space, relative to which the Schrödinger and guidance equations are obeyed". This would be akin to other attempts to shed allegedly excess structure, e.g., Bhogal and Perry (2017); Esfeld (2020); Huggett (2006); Miller (2013). See Dorr (2010, p. 160ff) and Sider (2020, section 4.12) for misgivings. An alternative would be to regard the high-dimensional space as being much more structured, so that the coordinatization C is geometrically distinguished after all (compare Wallace and Timpson (2010, pp. 700–1)).

5.

According to some critics of high-dimensionalism, the three-dimensional facts must emerge from the fundamental facts by a very simple and transparent process. We should be able to discern the manifest image in any proposed picture of fundamental reality simply by "squinting" at it, blurring fine details but retaining the macro-pattern.[14] If reality consists of fundamental particles moving in three dimensions, it is said, we *can* discern rocks and trees and other three-dimensional entities 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 particle moving in a high-dimensional space, there is no way to squint and see the rocks and trees and the rest.

In my view, adequate critiques of this squintability constraint on metaphysical translation have been given in the literature. Whatever squinting is supposed to amount to, you presumably can't discern *heat* that way (Albert, 2023*b*, pp. 91–2). And even in the best case, that of visual evidence of macroscopic spatial facts like the existence of a rock, you can't tell just by squinting that a configuration of rock-arranged particles is *solid* and *visible* (Rubenstein, 2022). Finally, and perhaps most deeply, when rid of the metaphors, the squintability constraint boils down to the assumption that metaphysical translation must always be "trivial", or "transparent", or "a priori"; and that assumption just isn't sustainable (Rubenstein, 2022; Schaffer, 2017).

But other concerns about Albert's functional/dynamical approach to the emergence of three-dimensional reality strike me as more pressing. Consider this passage from Tim Maudlin (2018, p. 126):

> 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 chairs and baseballs will formally enact, in Albert's sense, the tables and chairs and baseballs and observers whose projections they are. But these "formal enactments" are clearly not tables and chairs, and the 3-foot

[14] The language of squinting is from Maudlin (2007, p. 3167). See also Allori (2013*a*,*b*).

> 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.

The challenge is to say why the three-foot-to-the-north projections don't count as real tables and chairs and people with headaches.

Now, the letter of Maudlin's objection depends on Albert identifying three-dimensional objects with "projections", whereas I have rejected such identifications, and instead offered translations of entire sentences about three-dimensional entities. Also, Maudlin appears to be objecting to the consequences of Albert's approach in a fundamentally *three*-dimensional possible scenario. But Albert needn't be committed to the correctness of his approach in such a scenario; different fundamental scenarios call for different approaches to metaphysical translation. The task of giving the metaphysical translation of a given language is an explanatory one, namely that of explaining speakers' use of language, given their environment. The best way of carrying out this task 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" in a three-dimensional world by a more "direct" form of translation.[15]

Despite these concerns, it's natural to wonder whether there remains a challenging objection in the vicinity of Maudlin's. As a first attempt to state the objection, one might ask why the high-dimensionalist's translation scheme should assign tables (and chairs, and people with headaches) their correct spatial locations, as opposed to uniformly displaced locations. Why should it count the first of the following sentences as being true, rather than the second:

(1) There exists a table located at point p

(2) There exists a table located at point p'

where p is the "correct" location and p' is the point in space three feet to the north of p?

But the high-dimensionalist scheme won't count *either* as being true, since they name particular points of three-dimensional space. The high-dimensional ontology doesn't contain points of three dimensional space (any more than

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

it contains tables), so the translation procedure for talk of points of three-dimensional space will apply only to sentences containing quantifiers over spacetime points (as well as over tables, etc.), such as:

> There exists a table and there exists a point at which the table is located

But then it's hard to see how the objection could get off the ground. When constructing a translation scheme, we can no longer ask why it should assign a table to *this* point rather than *that* point, because the points aren't "given in advance".

The only way I can see to overcome this problem, in stating a challenging Maudlinean objection, runs as follows. Consider two translation schemes: a "normal" scheme, under which the following comes out true:

(3) There exist a table, particles that are parts of the table, and points of three-dimensional space, such that the table is located at the same points as the particles

and a "perverse" scheme, under which (3) is false and the following is true (and indeed means the same as (3) means under the normal scheme):

(4) There exist a table, particles that are parts of the table, and points of three-dimensional space, such that the table is located at points that are three feet to the north of the points at which the particles are located

In general, the perverse translation scheme gives systematically bizarre translations of sentences about macroscopic locations, treating every macroscopic object as being located three feet to the north of its microscopic parts.The high-dimensionalist wants to "functionally interpret" the movements of the marvelous particle according to the normal scheme. But the perverse scheme also counts as a perfectly good functional interpretation.

My reply is that even though the perverse scheme gives a kind of functional interpretation, it is not *ours*. The normal, rather than the perverse, scheme gives the truth-conditions of the language we in fact use. It is (3), not (4), that is true in English. Semantically descending: tables are located where their parts are.[16]

Two things disqualify the perverse scheme from being ours. The first is right at the surface: it clashes with how we ordinarily speak. We don't speak as

[16] See also Rubenstein (2022, section 5.2).

if tables and chairs are located at different places from their parts, and there is no countervailing reason for a radical interpreter to overturn this aspect of our linguistic behavior. (Saying this requires only the weakest imaginable commitment to the importance of charity in metasemantics.)

The second thing that disqualifies the perverse scheme is that it is gratuitously more complex than the normal scheme, since it systematically inserts 'the point three feet south of' into its translations; and it has no compensating virtue. This defect is like that of an interpretation that interprets all of our words as having "gruified" meanings. (The second defect is more "objective" than the first. In light of it, the perverse scheme isn't merely not-ours; it is also *worse*.)

The appeal to gratuitous complexity might seem a bit glib. To do better, imagine "metasemantic gods", looking down on humans and asking how best to interpret their language in light of its partial mismatch with high-dimensional reality.[17] The gods are engaged in a theoretical project: how best to understand human linguistic activity. This theoretical project, like any other, can be approached in better and worse ways; and gratuitious complexity always makes a theory worse.[18]

Any high-dimensional translation scheme will be more complex than the simplest schemes that would be available if reality were fundamentally three-dimensional.[19] For since the dynamical approach described in section 4 only provides translations of sentences about three-dimensional *particles*, sentences about ordinary objects like tables and chairs will require a second component in the theory of metaphysical translation, which will translate them into sentences about three-dimensional particles; and only the second component would be needed in the overall theory of metaphysical translation if reality were fundamentally three-dimensional.

This fact might be argued to count against high-dimensionalism. In deciding the question of high-dimensionalism, we must consider high- and three-dimensional "package deals", in which each fundamental ontology is coupled with its approach to metaphysical translation.[20] The greater complexity of its translational component might be seen as disfavoring the high-dimensional

[17] Of course, since humans don't fundamentally exist, they aren't part of what the gods initially see when looking down. Rather, the gods seek a translation scheme S under which 'there exist creatures speaking a language that is best interpreted under S' comes out true.

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

[19] Thanks to Nina Emery here.

[20] Compare Rubenstein (2022); Schaffer (2017).

package.

Although this is a difficult issue, it would seem that the epistemology of the fundamental and translational parts of these packages are quite different. We should decide which fundamental theory to accept on ordinary scientific grounds (broadly construed), setting aside how complex metaphysical translation would need to be.[21] When deciding whether, in light of the special theory of relativity, to regard spacetime as Minkowskian or Galilean, the fact that the former choice would call for a more complex approach to metaphysical translation of ordinary language (since everyday thought and speech include no parameters for frame of reference) doesn't favor the Galilean approach. It doesn't favor it even a little bit: it couldn't overturn a marginally stronger case for Minkowski spacetime, or break a tie. Similarly, when deciding whether to accept string theory, we should simply disregard the fact that ordinary speech will require a more complex metaphysical translation (since we must set aside some of the spatial dimensions). In the same way, when deciding whether to accept high-dimensionalism, we should disregard the fact that its approach to metaphysical translation is more complex.

Returning to the perverse translation scheme: we could *stipulate* that we are using the language of the manifest image under that scheme. Sentence (4) would then be true and (3) false. This is unproblematic, and consistent with the fact that (3) is true and (4) is false under the normal scheme. For the vocabulary of the manifest image has different meanings under the two schemes; (4) under the perverse scheme means exactly what (3) means under the normal scheme.

Consider two theories made of interpreted sentences. Theory 1 consists of all the sentences (in the language of the manifest image) that are true under the normal translation scheme; and Theory 2 consists of all the sentences (in the same language) that are true under the perverse translation scheme. Thus Theory 1 looks like this:

> {'There is a table located where its particles are located', 'There is a chair located where its particles are', ...}

And Theory 2 looks like this:

[21]This isn't quite right. As we will see in section 6, for some fundamental theories, *all* putative translation schemes for the manifest image are disqualified because of their complexity (or as I say there, "physical arbitrariness"); and those fundamental theories should be rejected on that basis. A better statement is this: when deciding between package deals, each of which contains a translation scheme that would be adequate if its fundamental part were true, one should disregard the complexity of the translation schemes.

{'There is a table located three feet to the north of its particles', 'There is a chair located three feet to the north of its particles', ...}

As I just said, each of these theories is true, given its interpretation. But the correct *picture* this should give us is *not* that of a world containing *both* tables, chairs, and the rest in their "normal" locations and also some *extra* tables and chairs (or table- and chair-like entities) located three feet to the north. There is of course no suggestion of a *fundamental* reality in which table-like and chair-like arrangements of particles always come in pairs separated by three feet. But nor is there a suggestion of a *nonfundamental* reality with doubled-up tables and chairs. 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 the truth of both Theory 1 and Theory 2 does *not* amount to accepting the truth of sentences like:

(5) There are two tables, one located where its parts are, and the other located three feet to the north of its parts

in *either* language. Nor does it amount to accepting their truth in *our* language, which is what "true in nonfundamental reality" amounts to.

To be sure, we could introduce a third translation scheme, under which (5) means what (3) means under the normal translation scheme and thus is true. But that isn't absurd; all it means is what we would ordinarily express in our language by saying "there is a table, located where its parts are". Moreover, this third translation scheme (if somehow spelled out in full generality) is an even worse candidate for being *ours* than the perverse scheme. For it is even more gratuitously complex, and departs even more from ordinary usage.

6.

A second important challenge to Albert's functional/dynamical approach comes from Albert (2023*b*) himself. Consider a world whose fundamental space is N-dimensional, where N is a multiple of 6, and which contains a single marvelous particle that *never moves*—indeed, the laws specify that it never moves. It seems obvious that such a world could not give rise to the manifest image. However, one could think of the points of the N-dimensional space as representing the *dynamical* states of a system of $N/6$ three-dimensional particles. That is, we could think of the fundamental space as a counterpart of a mathematical *phase* space, a space in which each point represents a complete specification of the positions and momenta of a system of three-dimensional particles. (The usual coordinates in the phase space come in groups of six numbers, with the first three in the i^{th} group representing the location of the i^{th} particle and the second three representing its momentum.) Further, one could think of each such point as representing the dynamical state of the three-dimensional system *at some particular time* t_0. And one could, further, think of that system as obeying certain deterministic laws, so that its dynamical state at t_0 determines its dynamical state at all other times. Putting all this together, one could think of each point in the static N-dimensional world as representing an entire history of $N/6$ particles (namely, the one resulting from evolving the dynamical state associated with the point forward and backward in time via the deterministic laws), and think of the (stationary) location of the marvelous particle as representing which such three-dimensional history is actual; and one could define a corresponding translation scheme from the fundamental language to the 3-dimensional language. Thus the static N-dimensional world could give rise to an entire three-dimensional history. "This way lies madness", Albert says; and I agree. Since the functional/dynamical approach seems to allow the madness, we have a problem.

The idea that time itself could emerge from a fundamentally non-temporal reality isn't madness (in my view). The madness is, rather, the suggestion that a fundamental reality that is *so simple* could give rise to the manifest image. If nothing fundamentally exists but a single static particle in a homogeneous and isotropic high-dimensional space, there wouldn't be anything structurally rich enough to give rise to any particular nonfundamental reality as opposed to any other.

In order to begin approaching a solution, consider a more extreme challenge. Suppose the space containing the static particle is only *one*-dimensional. It is even more obvious that such a world could not give rise to the manifest image. But it's easy to show that the set of possible dynamical states of finitely many three-dimensional particles has the same cardinality as the set of points in the one-dimensional space; thus there exists some one-to-one function, f, from the former set onto the latter. So we could construct a translation procedure under which any description of a complete dynamical state, s, of some finite number of particles gets translated as "the one-dimensional static particle is located at $f(s)$".[22] (This could then be extended to translate descriptions of

[22] We are in the vicinity of a familiar class of problems for broadly-speaking "structuralist"

complete histories, as before.)

It's pretty obvious what is wrong with this translation procedure: it is *physically arbitrary*. It isn't distinguished in any way by the fundamental physical 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 physical structure or 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 one-to-one function f'.)

The mapping Albert imagines for his static world is just as physically arbitrary.[23] For nothing in the fundamental features of the N-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 points of a phase space of a three-dimensional world over any other mapping.[24] And the selection of the deterministic laws used to map a given global dynamical state to an entire history is also wholly arbitrary.

The situation is very different in the cases in which the functional/dynamical approach is plausible, such as those discussed in section 4. For in those cases, the translation schemes were highly *non*arbitrary. They were not defined via an arbitrary one-to-one function, but rather were uniquely determined by the dynamics, the geometry of the fundamental space, and the total history of the motion of the marvelous particle.

(What if the high-dimensional facts fit two quite different, physically nonarbitrary, translation schemes—a three-dimensional and a one-dimensional one,

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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.

[23] Well, perhaps not *quite* as arbitrary: since we are told that the fundamental space has a dimensionality that is divisible by 6, it's not wholly arbitrary to think of it as representing the phase space of a system of 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 dynamical states of those particles *is* arbitrary.

[24] 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 particle 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 three-dimensional description according to which human beings never existed.

say? Answer: each scheme fits a legitimate nonfundamental language. Thus two true, "equally good" but quite different nonfundamental theories can be given, which nonperspicuously describe the same fundamental reality in two quite different ways. (One might fit *our* talk and thought better, but that would not be an objective privilege.) As pointed out in section 5, this would not amount to recognizing the existence of both one-dimensional and three-dimensional objects, since the quantifiers would have different meanings in the two languages.[25])

There are, to be sure, difficult questions about how exactly to understand the crucial distinction between being "physically arbitrary" and "physically distinguished". One choice-point is whether to invoke an unreduced notion of lawhood. I myself favor a reductionist approach to laws, and an account of physical distinction 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.

The notion of being physically distinguished (or, as it's sometimes put, "physically significant", or "physical") 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 won't need the functional approach to the ontology of the manifest image, but we will still need that approach to certain properties of manifest-image entities, such as being a *pointer* or a *rock*, and even about more basic classifications such as being *solid* or *visible*. Fundamental three-dimensional entities will be 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 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

[25]In fact, this case raises questions about the grounding approach to "giving rise to". 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 single domain of grounded entities. So in the case at hand, will grounders posit *both* a grounded three-dimensional world and also a grounded one-dimensional world? What about cases where one translation scheme is just a bit more physically arbitrary than another? Will grounders say that some grounded objects are "less real" than others?

fundamental physical properties and dynamical laws—then even this more limited functional/dynamical approach will have intolerable results.

In his discussion of the challenge posed by his static world, Albert objects to a response that is somewhat similar to my own by saying: "the business of being 'not too complicated' seems too vague and too arbitrary and too insubstantial a distinction to figure in the fundamental metaphysical principles of the world" (Albert, 2023*b*, pp. 18–19). 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 translation schemes based on arbitrary one-to-one functions to be hopelessly physically insignificant. Still, some vagueness and arbitrariness cannot be denied. But what is under discussion here is *not* "fundamental metaphysical principles", but rather the theory of "giving rise to"—in my terms, the theory of metaphysical translation. And it is unproblematic that an account of *that* would have some vagueness and arbitrariness. Indeed, it is hard to see how it could be avoided. Regardless of one's stance on high-dimensionalism, it is clear, given the variety of possible forms a fundamental physics might take, that there can be no sharp or nonarbitrary line between those possibilities for fundamental reality that would, and those that would not, give rise to the existence of rocks or other ordinary (solid, visible, etc.) objects.

Still, the high-dimensionalist is committed to the potential for a new and unfamiliar sort of vagueness or arbitrariness. The familiar sort is over whether *a given thing* counts as being a rock—or being red, or being tall, or being bald, whereas for the high-dimensionalist, there can also be vagueness or arbitrariness concerning 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" or "nodes", understood as entities in the fundamental ontology—certain kinds of sets, say. Under this approach, the translation of the nonfundamental language of three-dimensional objects can be predicate-for-predicate after all, rather than sentence-for-sentence, since the nonfundamental language "shares the ontology" of the fundamental language.

But the identification of particles with sets will be artificial, arbitrary, and indeterminate. Even in a high-dimensional world whose dynamical structure uniquely picks out a unique three-dimensional translation scheme of the sort I have proposed, there is no single best way to identify three-dimensional entities with *particular* sets.

Consider some coordinatization $x_1, \ldots, x_{3N}$ of a $3N$-dimensional fundamental space that is "privileged by the dynamics" in the sense of section 4. We might identify the i^{th} three-dimensional particle with the function f_i that maps any time to the point, p, in the high-dimensional space all of whose coordinates have value zero except that its x_i, x_{i+1}, and x_{i+2} coordinates are the same as those of the point occupied then by the marvelous particle. In other words, f_i projects the location of the marvelous particle onto the three-dimensional subspace in which all coordinates other than x_i, x_{i+1}, and x_{i+2} have the value zero. Other objects could then be identified with functions from times to sets of particles thus construed.

These identifications seem "artificial". They *work* in the sense that a systematic translation procedure can be based on them, but the functions f_i don't seem particularly intrinsically suited to be three-dimensional particles. The identifications have the feel of conventions rather than discoveries.

The identifications are also arbitrary, because of the arbitrariness of the choice of zero as the value to assign to all coordinates other than x_i, x_{i+1}, and x_{i+2}. (Equivalently: because of the choice of the origin of the coordinatization.) Alternate choices would have resulted in equally good but entirely different—albeit coordinated—identifications for all three-dimensional things.

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 rocks only when other sets are regarded as being 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.[26] 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, or one particular set of sets that can be regarded, once and for all, as containing all the cities. It is only relative to a certain global set of choices

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

of meanings of ‘Paris’, ‘city’, ‘rock’, ‘located’, ‘causes’, and every other word, that a given set counts as Paris or as the set of cities.

Given the arbitrariness, artificiality, and resulting indeterminacy of the identifications, 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, since it is only the network of quantified sentences about particles that is nonarbitrarily and nonartificially and (relatively) determinately generated by the fundamental high-dimensional facts.

There are alternate methods for identifying particles with set-theoretic constructions of points. For instance, we could replace the functions mapping times to single points with functions mapping times to sets of three points, namely, the three points that are the projections of the world particle’s location onto three chosen lines singled out by the three coordinates of the triplet in question. That would introduce even more arbitrariness, etc., but a third method would introduce less: we could identify a particle with a function mapping any time to the set of three *lines* (which are themselves sets of points), namely the three-dimensional axes associated with that particle’s triplet of coordinates that intersect at the location of the marvelous particle at the time. That is, the i^{th} particle is the function mapping any time to the set of these three lines:

$$\{p : p\text{'s coordinates other than } x_i = \text{those of the world particle then}\}$$

$$\{p : p\text{'s coordinates other than } x_{i+1} = \text{those of the world particle then}\}$$

$$\{p : p\text{'s coordinates other than } x_{i+2} = \text{those of the world particle then}\}$$

The choice of these three lines is not arbitrary (the division of the coordinates into triplets is privileged by the dynamics), so there is no *further* arbitrariness after this third method is chosen. But the choice of the third method itself is arbitrary, as opposed to the first or second method, or other methods in the vicinity of the third, such as mapping times to sets of rays or segments rather than lines. The presence of these alternate methods only increases the arbitrariness of any one of them.

Incidentally, given certain assumptions one could identify particles with *concrete* (as opposed to set-theoretic) entities in the high-dimensionalist’s ontology. Suppose that in addition to points of the high-dimensional space, that ontology also includes fusions (aggregates) of points. And suppose, further, that the high-dimensional space is actually a $3N + 1$-dimensional spacetime, which has a privileged foliation into $3N$-dimensional leaves of simultaneous points, which we may call times. Then any of the aforementioned methods of identifying particles with functions can be converted into a method of identifying particles with fusions of points of the high-dimensional spacetime. For instance, construct as before the functions of the first method, only now let the function f_i map any time to a projection of the world particle's location onto a three-dimensional subspace *of that time* (i.e. of that leaf of the foliation). The spacetime points in the range of f_i may be identified with the "temporal parts" of the i^{th} particle, and the particle itself with the fusion of these temporal parts. (Thus the particle is the projection of the worldline of the marvelous particle onto the four-dimensional part of the high-dimensional space that results from setting all spatial coordinates other than the chosen group of three to zero.) Such mereological methods "work" just as well as the set-theoretic ones, but they are just as arbitrary, artificial, and indeterminate.

8.

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

Nina Emery (2017) argues that, just as both ordinary people and scientists rightly dismiss (or ignore) skeptical hypotheses of traditional epistemology, as well as contemporary analogs like the possibility that we might be living in a computer simulation, so we should dismiss high-dimensionalism.[27]

But there is an important difference between high-dimensionalism and some "skeptical scenarios"—Descartes' evil demon hypothesis, for instance.

[27] See also Monton (2006, pp. 783–4). Emery also mentions Boltzmann brains: disembodied intrinsic duplicates of brains like ours whose beliefs are radically false because, rather than being embedded in an environment that matches their memories, they have instead randomly and spontaneously arisen after the heat death of the universe, in which matter is uniformly spread out, in thermodynamic equilibrium. There is arguably some tiny but nonzero chance per unit time that a Boltzmann brain will emerge from thermal equilibrium; thus they likely will eventually emerge if the equilibrium state lasts long enough. This is an interesting and difficult case, though importantly different from the others. Presumably we cannot rightly 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 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.

High-dimensionalism is part of a scientific theory that is both attractive by ordinary 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 human bodies can be taken to be real physics (if the scenario 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 the way the world appears to be; the hypotheses are bad theories by the lights of other epistemic norms that govern ordinary science. In contrast with these "skeptical hypotheses", high-dimensional quantum mechanics is *not* a bad theory by ordinary scientific standards (other than Emery's minimal divergence norm). It contains simple and strong laws, and its descriptions of particular matters of fact are not gratuitously complex.

But even though high-dimensionalism escapes Emery's challenge, there is an important lesson in her comparison 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 manifest-image sentences to fundamental truths about the demon or 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 translation scheme based on the simulation is "trumped" by a more straightforward scheme under which most of our beliefs are false.[28] Nevertheless the schemes are nowhere near as physically arbitrary as those based on arbitrary one-to-one functions, as discussed in section 6. 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 a binary, on-off distinction; but there is a related distinction that comes in degrees. Consider a series of possibilities for fundamental reality:[29]

Three-dimensional particles and their composites

Three-dimensional particles but no composites

Three-dimensional particles embedded in many more dimensions

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 series we presumably reach falsity, but long before, something truth-*like*—call it "match"—has started to erode. As we progress through the series, ordinary beliefs increasingly become partial epistemic failures, even when true, because of their decreasing match with reality. (The failure of match is more drastic than, for instance, that between ordinary beliefs about solidity and the atomic theory of matter.) If high-dimensionalism is true, our ordinary beliefs are thus akin to if not

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

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

quite so bad as the beliefs of Matrix-dwellers. I don't see this as undermining high-dimensionalism, but it is nonetheless disturbing.

Also disturbing is the potential non-uniqueness of the manifest image. Suppose, as imagined in section 6, the high-dimensional dynamics happens to lend itself to two quite different translation schemes, one of which represents nonfundamental reality as being three-dimensional and the other as being one-dimensional. The second presumably wouldn't give the truth conditions of our language (since it clashes with how we talk), and thus wouldn't affect the *truth* of the manifest image, but it would partially undermine its *objectivity*, just as the discovery of equally good alternate conceptual schemes (however mind-independent) for talking about "beauty" undermines the objectivity of our own. And even if the high-dimensional dynamics doesn't in fact lend itself to a second low-dimensional translation scheme, the fundamental language itself, as an alternate and indeed *more* physically significant conceptual scheme, constitutes a sort of threat to the objectivity of the manifest image.

In the case of Bohmian high-dimensionalism, 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). A critic might question how this "marvelous" particle, this *miserable speck*, can play such a central role in the emergence of the manifest image. If 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?[30]

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

[30]The critique of Brown and Wallace (2005) is somewhat related but importantly distinct. 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".

which something does, is significant enough to affect what fundamental reality gives rise to.

But even if a translation procedure taking account of the speck can eke out a victory over the competition (over a many-worlds translation and the claim that no manifest-image-translation is correct), the margin of victory is disturbingly small—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. (We may assume that our evidence possesses truth, but not objectivity or match.) But if we are to accept high-dimensionalism, it should be with eyes wide open.

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