Fundamental Physics and Middle-Sized Dry Goods*

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There's a certain mindset that some people have when they think about fundamental physics and the world of middle-sized dry goods.[1] The mindset is that the middle-sized stuff is somehow "less real" than the stuff that physics describes — elementary particles, quantum fields, etc.[2] There are quite a few philosophers, and some scientists, who hold this view with great conviction, and whose research is driven by a desire to validate it.

There are other people who have a completely different attitude about reductionism: they see it as the enemy of the good and beautiful, and as a force to be stopped. The worries of the anti-reductionists do seem to be well-motivated. If, for example, your wife is nothing more than some quantum fields in a certain state, then why vouchsafe her your eternal and undying love? More generally, is the existence of trees, horses, or our own children nothing more than a convenient fiction that biology or religion has tricked us into believing? If physics shows that these things are not fully real, how should we then live?

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[1] "But does the ordinary man believe that what he perceives is (always) something like furniture, or like these other 'familiar objects'—moderate-sized specimens of dry goods?" (Austin, 1962, p 8)

[2] My friends in metaphysics tell me that the fashionable view now is that everything is real — and the interesting question is where these things are found in the hierarchy of metaphysical dependence. I don't think that my claims in this essay are sensitive to that subtlety. According to that way of thinking, the question is just whether middle-sized things are metaphysically dependent on the world that is described by fundamental physics. Reductionists say that they are; anti-reductionists say that they are not. For example, hylomorphists say that there are middle-sized *substances*, where "substance" means by historical definition something that doesn't depend on other things.

Reflective people often have strong opinions about reductive physicalism, and they tend to polarize over it. There are the reductionist types, and then there are the anti-reductionist types. We know the reductionist types from the dramatic pop science books touting this bold new worldview. And we know the anti-reductionist types from the academic articles with fascinating examples of phenomena that seem to defy reduction to microphysics. One's attitude toward physicalist reduction seems to be just as central to one's intellectual personality as one's attitude toward theism, free will, or objective morality.

1 The debate

The debate about reductionism that I know best is the one that has been carried out in academic philosophy journals. That debate has been clarifying — although it often becomes so technical and esoteric that one easily loses track of what really is at stake.[3] So I will not rehash that debate here, or try to add anything decisively new to it. Instead I will focus on the question of whether the discovery of the quantum of action has any bearing on reductive physicalism. More particularly, I will consider the arguments of the "new hylomorphists" to the effect that quantum physics sits most comfortably in their anti-reductionist framework.

Recall that "hylomorphism" is the name for a family of ontological theses that trace back to Aristotle's view of objects as a combination of matter and form.[4] Hylomorphism was enshrined in Aquinas' natural philosophy, but then came under severe attack during the scientific revolutions of the sixteenth and seventeenth centuries. On an overly simplistic retelling of the history, modern physics refuted hylomorphism and replaced it with "the mechanical worldview".

But then everything changed in the first quarter of the twentieth century — between 1901, when Max Planck discovered the quantum of action, and 1925, when Werner Heisenberg discovered matrix mechanics. Quantum mechanics (QM) has not infrequently been presented as striking a blow to the mechanical worldview — not so much by professional philosophers, but cer-

[3]For example, "functionalists" about the mind insist that they are not reductionists (see Bealer, 1978).

[4]For many more details, see (Simpson, 2023).

tainly by popular science writers.[5] It is for this reason, that some people are so troubled by the quantum measurement problem. In some presentations of the measurement problem, the primary issue is that we lack an "observer free" account of what happens in the microphysical world.[6] Put this way, it sounds like QM pushes either in the direction of interactive mind-body dualism (of the sort adopted by Descartes), or subjective idealism (of the sort championed by Berkeley).[7] So it's not surprising that some people have welcomed QM as providing a sort of science-motivated relief to the picture of physicalist reductionism that is so hard to square with common sense and with our view of ourselves as moral agents.

Of course, Cartesian dualism and Berkeleyan idealism are not exactly common-sensical views, and they bring a host of additional philosophical problems with them. What's more, both Descartes and Berkeley advanced a sort of "methodological materialism" for physics, where one can and should ignore the existence of non-material substances, and where one should reduce medium-sized physical objects to the microphysical. (Both of them were, of course, opposed to scholastic substantial forms.) For Descartes, it's a mystery how non-material substances (God and finite spirits) interact with the material world, and science can say nothing about it (see Garber, 1992). Thus, if QM supports mind-body dualism, it doesn't follow that it supports a philosophical revolution *in* physics.[8] It was the arch-dualist Descartes who, to a great degree, set the methodological aims that directed physics until the early twentieth century.

For Berkeley (as well as for Leibniz) the material world does not *interact* with mental things. Rather, the material world just is stable patterns of ideas, and physics can proceed *as if* reductive physicalism were true (see Atherton, 2022; Solomon, 2022). In both cases, physics is still defined by the Galilean aim to reduce everything to the smallest and most mathematically tractable elements of reality.

[5]I know of very few real arguments for the claim that quantum physics undermines reductive physicalism. Of course, von Neuman and Wigner hinted that conscious beings collapse wavefunctions, and there was an explicit anti-physicalist program of London and Bauer. An earlier stage of me argued that physicalism is complicit in the measurement problem (see Halvorson, 2011); but I would put matters differently today.

[6]Karl Popper and then John Bell were intent on banishing "the observer" from QM. In at least the former case, the fervor strikes one as political, if not quasi-religious.

[7]See (Chalmers and McQueen, 2022).

[8]With a nod here to Richard Healey's book: *The Quantum Revolution in Philosophy.*

There are contemporary philosophers and physicists who claim that QM supports idealism or immaterialism. For example, Quantum Bayesians (QBists) claim that the task of physics is not to describe the world, but only to give a recipe for updating expectations for subsequent sensations.[9] While space won't permit me to engage in detail here with QBism, I note that QBist idealism is nothing like the view of Berkeley himself, whose idealist metaphysics was not supposed to be revolutionary in regard to the aspirations of physics — except that it put fundamental non-material reality out of the reach of physical science. Unlike the QBists, Berkeley didn't think that physics was supposed to describe mental states. To the contrary, he claimed that physical science is restricted to the outer world of shared experiences. So QBism is no Berkeleyan idealism. But inconsistency with Berkeley is hardly the most serious problem for QBism. Indeed, QBism is even more eliminative about middle-sized things than reductive physicalism is. While physicalists claim that middle-sized things can be reduced to smaller things, QBism doesn't have any place for middle-sized things in its anti-ontology.

Most philosophers of physics reject the idea that QM pushes us toward dualism or idealism. In fact, many philosophers of physics are self-identified naturalists, and their work at interpreting QM is partly aimed at showing that it's no threat to the naturalistic worldview.[10] In the meantime, hylomorphism has come back onto the table, and is having a renaissance in the work of, among others, Robert Koons and Williams Simpson[11]. For me, the most interesting claim of these hylomorphists is that it provides a more satisfying interpretation of QM. In contrast to dualists and idealists, the hylomorphists claim that the discovery of the quantum of action calls for a methodological revolution in physics. It is no longer plausible that middle-sized things can be reduced to subatomic things. In fact, physics can, and should — say the hylomorphists — explain some things about the micro-world in terms of the properties of middle-sized things. In one sense, then, hylomorphists have much in common with Niels Bohr, who claimed that: (a) each description presupposes a describer, and (b) all describers — as far as we know — have middle-sized bodies.[12] In contrast to many contemporary interpretations of

[9]For more on QBism, see e.g. (Glick, 2021).

[10]For example, the title of Abner Shimony's collected papers is *Search for a Naturalistic Worldview*. And when Shimony says that his aim is to "close the circle", it's hard to see how his view differs substantively from reductive physicalism.

[11]See, e.g., (Koons, 2014; Simpson, 2021; Simpson, 2023).

[12]One might be tempted to say that for Bohr, a world without middle-sized things is

quantum physics, the hylomorphists share with Bohr the distinctive view that middle-sized things are as real and fundamental as anything else in the world.

2 Meeting in the middle

There is a historical narrative that is popular among well-educated Christians, both of the Catholic and of the Protestant variety. According to this narrative, Thomas Aquinas did an amazing thing by integrating Aristotelian philosophy with Christian theology. This Thomistic synthesis functioned well until various rebellious currents of thought — nominalism, neo-Platonism, Protestantism — came into play. Then things broke down.

It's at this point that Catholic and Protestant thinkers tend to continue the narrative differently. According to neo-scholastics, the rebellion against the Thomistic synthesis was largely a bad move that has had numerous bad results, both in the realm of ideas and in practical life. (At least this is how I understand the narrative in Alasdair MacIntyre's *After Virtue*.) Some Protestant thinkers, in contrast, understand the demise of the Thomistic synthesis in a very different way. According to this second reading, the scholastic tradition became unhealthily dependent on Aristotelian philosophical doctrines, and wasn't quite suitable, as a worldview, to support the growth of the empirical sciences.[13]

To be completely honest, I favor this second reading of the intellectual history of natural philosophy after Aquinas. And this means, in particular, that I look charitably upon the ideas of Galileo, Descartes, Locke, Kant, et al., who were struggling to find a worldview adequate to the science of their day. I do, however, join contemporary Thomists in rejecting a more radicalized and secularized version of the second interpretation — where the demise of the Thomistic synthesis was just the first step on the road to the truly enlightened view, viz. naturalism, and more specifically, reductive physicalism. In particular, I agree with the hylomorphists that middle-sized things are no less real than the physical objects that appear in the models of

unimaginable. But such a statement is ambiguous. A world without middle-sized things is imaginable, but only if there are middle-sized things in some world who can imagine it.

[13]Of course this kind of narrative was quite popular in, and shortly after, the heat of the battle of the Protestant Reformation. In recent years there have been some efforts among Protestants to reconsider whether they didn't throw out the baby with the bath water.

mathematical physics. I also agree that programs for reducing middle-sized things to fundamental physics are baroque metaphysical projects that are more likely to retard than advance the empirical sciences. Indeed, the desire to reduce to fundamental physics is more of a quasi-religious urge to find something absolute than it is a scientific urge for finding interconnections in nature.

While I'm not immediately inclined to turn to Aquinas for lessons in natural philosophy, he nonetheless had many insights that are still valid today, and some of which might not be noticed by people with a reductionist ax to grind. What about the complaint that substantial forms are bad for scientific practice, since they permit trivial and circular explanations? Consider the famous example of Moliere's doctor who says that opium causes sleep because it has a dormitive virtue. While that example suggests that hylomorphists are committed to uninformative explanations which are inconsistent with the modern scientific method, sophisticated hylomorphists wouldn't accept the doctor's answer as fully satisfying. After all, Aristotle claimed that there were multiple kinds of causes, and presumably he believed that we understand events best when we take into account all of their causal relations.[14]

It seems to me, then, that hylomorphists can and should accept a kind of perspectivalism that permits distinct correct causal explanations of a single phenomenon. For example, if you ask me why there are leaves on my lawn, then there is more than one correct answer. One answer is to cite all of the preceding physical causes: the growth of the trees, the change of the seasons, the blowing of the wind, etc. Another answer is to cite the intentions of some agent, e.g., I decided to join the "no raking" movement, because of claims that it's good for the environment.

Of course, reductionists will claim that the second answer is not the "real" or "fundamental" answer, because, they will insist, my decision to join the no raking movement can itself be explained in terms of preceding physical events. However, this argument rules out the teleological cause only if causal monism is true. If one is already a causal pluralist, then pointing out that there is a physical explanation of my action does not show that my choice is not also an explanation of my action.

It must be admitted that most human beings are de facto causal plu-

[14]Recent metaphysics has also seen a revival of "powers". See e.g. (Williams, 2019; Hill, Lagerlund, and Psillos, 2021).

ralists in the sense that they regularly switch back and forth between these different modes of explanation. Even reductive physicalists don't manage to get through their day without conceiving of themselves as agents who have goals and who do things for reasons. We simply do explain things in this way, even if we stand in the seminar room once a week and declare such explanations to be inferior to those in terms of efficient physical causes.

It's one thing to say that people do operate in a certain way, and it's another thing to give a coherent explanation of why they operate in this way. That was the problem that David Hume faced when he argued that their is no rational justification for inductive inference. Human beings just do make inductive inferences, and Hume never recommended that a person undergo a course of therapy to help them stop doing so. His skepticism about induction is a philosopher's skepticism, not one that calls for any real changes in our day-to-day lives.

So let us similarly grant that human beings do explain things teleologically, and indeed, they might not be capable of avoiding such explanations. How are we do understand this? There are several options. At one extreme, the reductive physicalist will want to provide some kind of "error theory" for teleological explanations, i.e. a theory that explains why people make certain kinds of assertions, even if such assertions cannot be judged to be true. At the opposite extreme, one could be a causal pluralist in an ontological sense, e.g. by claiming that objects have substantial forms, and hence "goals" toward which they strive. A third option, and the one which I prefer, is a causal pluralism in the semantic sense, where we can explain events in terms of efficient causes *or* in terms of final causes, but where there is a kind of complementarity between the two kinds of descriptions.

Analytical metaphysicians might be willing to go in for a plurality of causes (in an ontological sense), but they are not likely to be attracted to a semantic form of causal pluralism, where the correctness of a causal description depends on the intentions of the describer. Throughout the history of western philosophy, metaphysicians have aspired to describe reality as it is "in itself" — i.e. to give the final picture of the ultimate constituents of reality and how they are related to each other. Such was the goal of Baruch Spinoza, Christian Wolff, and, in recent days, David Lewis, Kit Fine, and Barry Loewer.[15] But you don't have to be a skeptic or anti-realist to

[15] One might savor the irony of Kit Fine's "fragmentalism" (see Fine, 2005). It is an attempt to give a coherent description of reality as consisting of incoherent fragments.

recognize a mismatch between things in themselves and human modes of description. Even Leibniz — who wasn't averse to bold speculation — believed that explanation in terms of efficient causes has limits for human beings, who are, by nature, unable to trace infinite chains of conceptual connections (see McDonough, 2009).

Corresponding to different ways that one can be a causal pluralist, there are different ways that one can be a anti-reductionist about middle-sized objects:

1. Ontological anti-reductionism: In the final ontological catalog of the structure of reality, there are middle-sized objects with causal powers.

2. Semantic anti-reductionism: There is probably no final ontological catalog that would be of any use to human beings. However, human modes of description presuppose a context of middle-sized objects which we can act upon, and which can act upon us.

The differences between these two kinds of anti-reductionism are subtle, and it's tempting to think that semantic anti-reductionism is just a less courageous version of its ontological sibling. But the key difference between the two views is in which philosophical projects are worth undertaking. Since ontological anti-reductionists aim to provide a catalog of fundamental objects, they will want arguments for why middle-sized objects shouldn't be omitted from this catalog. In contrast, semantic anti-reductionists have just decided that it's a will-o'-the-wisp to write an ontological catalog in which no middle-sized things occur. For some of us semantic anti-reductionists, we are willing to admit that we don't have knock-down arguments that such a catalog cannot exist. We are simply betting against it!

Ontological anti-reductionists have a heavy burden of proof to bear; and I worry that some of their arguments come dangerously close to another kind of faulty argument that one frequently encounters in debates about science and religion. According to "god of the gaps arguments", there is some phenomenon that cannot be explained in terms of natural causes, and so can only be explained by a a supernatural being (such as God). For example, intelligent design theorists claim that there are physical objects of such immense complexity that they couldn't have evolved from simpler life forms — if not for some sort of nudge from an intelligent being. Similarly, some Theists have argued that Big Bang cosmology is evidence for God's existence, since physics cannot explain how time began. I find these kinds of arguments to be individually unconvincing, and collectively ill-motivated. The goal of natural science is to find explanations for things in terms of natural causes; if no natural cause has been found, then science should simply continue looking.[16]

The same general problem plagues certain anti-reductionist arguments. If we run across a phenomenon φ that doesn't seem to be derivable from fundamental physics (e.g., from quantum field theory), then I don't think that we should immediately conclude that reality has another layer in which QFT is invalid. It would be more reasonable to conclude that either our current physical theory is false, or that we haven't worked hard enough to try to find an explanation, or that we are conceiving of φ in a way that doesn't permit further analysis via the tools of physics. (For the latter case, I'm thinking, for example, of conceiving of something as an agent who has intentions. The differential equations of mathematical physics aren't any good for describing such agents.)

According to hylomorphism, the world consists of many layers, each of which displays some degree of autonomy, but where causal influences run in both directions — from the small to the middle-sized and back down. For example, George Ellis' contextual wavefunction collapse model of QM is intended to be a view of this kind, where the middle-sized things, e.g. heat baths, have features that cannot be explained by QM, and where these middle-sized things act upon smaller things, causing them to do things that they wouldn't do in absence of those middle-sized things.[17] Doubtless, it is an attraction of this view that middle-sized things have genuine causal powers of their own. This view sits comfortably with our own experience of agency, avoiding what is perhaps the most problematic consequence of reductionist views.

I agree with the spirit behind this approach to QM, but it has some rather serious internal problems. I will focus on two such problems. First, there's a problem about how to describe middle-sized objects. Second, there's a problem about how to describe quantum-mechanical objects. I claim that the contextual wavefunction collapse view stumbles on both of these problems.

First, as for describing middle-sized objects: the question is whether or

[16] I wouldn't get hung up on the question of whether there is some other "science" that is higher than natural science. I don't know what that question would mean, except as an indication of what practices we believe to be valuable.

[17] To be clear, George Ellis is not an avowed hylomorphist. He's a physicist whose views about middle-sized objects appear to be congenial to hylomorphism.

not middle-sized objects should be described in the same way as quantum-mechanical objects. To oversimplify to some degree: for any two states of a quantum-mechanical object, there is a superposition state. In contrast, there are states of macroscopic objects that we never find superposed in nature, e.g. the alive and dead states of Schrödinger's cat. So the question is: is the cat properly described as a quantum-mechanical object, where there is such a superposition state? Or is the cat properly described as in classical physics, where there is no such superposition? The former view takes QM to be universal. The latter view takes quantum mechanics to be of limited validity, in particular, limited to some regime of smaller-sized things.

In recent discussions of the measurement problem, it has typically been assumed that the burden of proof is on those who would deny the universal validity of quantum physics. After all, if someone says that quantum physics applies only at certain small length scales, then where is the cutoff, and what explains its existence? But Drossel and Ellis turn this dialectic on its head. They argue that there is little to no evidence that quantum physics remains valid at larger scales. So who are we to trust on this matter? Is quantum mechanics valid or not for middle-sized things?[18]

In one sense, everybody would love it if turned out that quantum mechanics is of limited validity. People don't like the measurement problem — it's a problem in the bad sense of the word. So if we found out that there are middle-sized things that violate the laws of QM, and if by doing so they cause measurements to have outcomes, then that is a solution that we can all embrace. Nobody I know has a vested interest in maintaining the universal validity of QM; they simply don't feel entitled to deny that fact.

Drossel and Ellis, in contrast, claim to be able to show that quantum mechanics is not universally valid. For example, Drossel (2017) provides a panoply of reasons why a heat bath cannot be assigned a quantum wavefunction.

I will not go through Drossel's arguments one by one, but just note a general worry, as well as some ambiguities that I'd like to see clarified. My

[18] I am switching freely here between "quantum physics" and "quantum mechanics". What I actually mean here are theories whose algebra of observables is a non-commutative C^*-algebra. For such theories, the Kochen-Specker theorem entails that there are no hidden variables (i.e. dispersion-free states). The only exception to the KS theorem is the two-dimensional case, and nobody believes that this exceptional case has any real significance. Hence, anyone who uses these theories to describe the world needs a solution to the "description problem".

general worry here is that quantum-mechanical composition is, as best we can tell, unrestricted in principle: smaller quantum-mechanical things compose to form larger quantum-mechanical things. So if we have any reason for denying that a larger thing is quantum-mechanical, it is not a reason derived from the micro-theory. It is instead an empirical reason. And while I aspire to be an empiricist, I prefer principled solutions. In particular, I don't want to say that QM is valid *except for* those cases where its predictions turn out to be wrong.

Let me explain what I mean by saying that quantum-mechanical composition is unrestricted. If a physical object is composed of many particles, each of which is described by quantum mechanics, then that physical object is, in a completely precise sense, also described by QM. Indeed, if we take the state spaces of all those particles and combine them into a single tensor product $H_1 \otimes H_2 \otimes \cdots$, then that is, by definition, the state space of the composite object. And that state space is also a Hilbert space, and the vectors inside it can be superposed.

Nor would it help the quantum non-universalist to deny that the middle-sized thing is composed of smaller particles. In fact, the picture of being composed of smaller particles is not the most fundamental picture we have. In relativistic quantum field theory, corresponding to each region of spacetime O, there is an algebra $R(O)$ of quantities localized in O. Moreover, this algebra $R(O)$ is non-commutative, which means precisely that the corresponding states can be superposed. So even if we deny that, say, a heat-bath is composed out of smaller particles, there is still good reason coming from physics to think that the quantities associated to the heat bath have *conjugates*, and hence that the states of the heat bath can, in principle, be superposed; and the heat-bath can, just like Schrödinger's cat, become entangled with microphysical objects.

In summary, Drossel and Ellis claim that there are some physical objects that cannot be described by the formalism of QFT.[19] But this claim comes with an extremely high burden of proof. QFT supplies a formalism that

[19] Once again, I'm taking the formalism of QFT to be C^*-algebras, plus possibly some additional structure, e.g. a correspondence between spacetime regions and subalgebras. Even classical physics can be represented in such a formalism, by using commutative algebras. So the real question is not whether phenomena can be modeled via this formalism, but whether such phenomena demand the use of incompatible (i.e. non-commuting) quantities. It is the existence of such quantities that is responsible for the measurement problem.

applies to the finest-grained elements of reality that we know. What's more, we know of no case where the formalism of QFT applies to multiple elements of reality, but not to situations where they are all present. If someone then claims to have an example of a physical object to which the formalism of QFT cannot be applied, then it cries out for a "superformalism", i.e. a new theory, that is an improvement on QFT. I do not see that we have been offered such a theory, and so I'm not yet willing to say that the validity of QFT is limited.

There are two further things to say here vis-a-vis the question of how to describe middle-sized objects. The first thing is that the argument I just gave was about how to describe the kinematics of a physical object, i.e. what properties it can have, and what states it can be in. Could it be that there are physical objects that have quantum kinematics, but whose dynamics are such that they become effectively classical? It would seem so. Indeed, it is a central tenet of the Everett interpretation of QM that the dynamics of the universal wavefunction is such that effectively classical branches emerge. But this kind of dynamical process is not what Drossel and Ellis have in mind. It is precisely their claim that the classical world does *not* emerge from the quantum world via decoherence and Everettian branching.[20]

I now turn to the second problem with the idea of contextual wavefunction collapse, and this has to do with how we describe the quantum-mechanical objects whose wavefunctions are supposed to collapse.

There is a common understanding about the "problem" with quantum mechanics, and the story is sometimes told this way:

> Sometimes quantum systems are in a superposition state, where things are indefinite. So there has to be some kind of mechanism that causes the superposition state to collapse onto one of its two terms.

Drossel and Ellis themselves give a version of this story, and they go on to propose a solution: it's the interaction of the quantum system with a classical heat bath that causes the superposition state to collapse onto one of its two terms. Thus, the interaction between the heat bath and the quantum-mechanical object causes that object to enter into a definite state.

Unfortunately, this story is misleading. First of all, what does it mean to say that a quantum state is a superposition? Well obviously that it is

[20]See (Pruss, 2018) for a hylomorphic gloss on the Everett interpretation.

a sum of two other states, right? In that case, every quantum state is a superposition — including the state in which the cat is alive, and the state in which the cat is dead. When somebody worries that the quantum state is a superposition, what they are really worried about is that it is a superposition *relative* to some properties that they presume to be definite. But then solving that problem, i.e. finding a mechanism by which the wavefunction collapses, does not solve the deeper problem of what it could mean for such a property *not* to be definite. For example, if we say that the cat is in a superposition of being alive and being dead, then what are we saying about the world?

Let's call this the *description* problem. It is related to, but distinct from, the infamous *measurement* problem. The description problem asks how to read the quantum formalism in all circumstances, whether or not some measurement is being performed.[21]

We already know that it's hard to solve the quantum measurement problem. Won't it be even harder to solve the quantum description problem? And do we need a solution of that problem? Can't we just remain silent about what the quantum state means, and speak only of what the quantum state says about what we will observe when we make measurements? I don't think we can remain silent — at least if we want to speak coherently.

Here's the problem. There are "solutions" to the quantum measurement problem that involve dynamical processes; in fact, Drossel and Ellis' contextual collapse theory is supposed to be a solution of this kind. What these solutions want to do is to describe a dynamical process that ends in a definite measurement outcome. Let me emphasize that phrase: "describe a dynamical process". In other words, there is an initial way that the world is D_0, some subsequent ways that the world is, say D_t for $t \in (0, 1)$, and then some final way that the world is, say D_1. What's more, D_1 says things like "the cat is alive" or "the cat is dead". For this kind of story to be coherent, it must mean that earlier states, such as D_0, describe a way that the world can be. So what is this way that the world is when the initial state is, say, a superposition of going through the top slit and going through the bottom

[21] Here I disagree to some extent with Koons' claim that "Quantum mechanics changes the situation dramatically, apparently dividing the world into quantum and experimental 'images'" (Koons, 2024, p 1). The problem, I'm claiming, is that the quantum formalism doesn't obviously provide an "image". A solution to the quantum description problem would explain how to translate the formalism of matrices and wavefunctions into the kind of language that humans use to form images of the world. I happen to think that Niels Bohr already made a pretty good proposal about how to do this.

slit? In short, to give an *explanation* for definite outcomes of measurements, one must have already solved the quantum description problem. That is, one must know what it means to say that a quantum system is in state ψ.

Now one might think that there is a rather simple and straightforward solution of the quantum description problem: the phrase "a quantum system is in state ψ" is primitive, and need not be cashed out in terms of ordinary language. I have my doubts about whether this idea is plausible. The first problem is simply one of communication: if you tell me that a quantum system is in state ψ, then I have exactly zero information about which quantum state you are talking about. Am I supposed to think that there are infinitely many different quantum states, but that there is nothing more to be said about what makes them different from each other?

Aha, you say, what makes quantum states different from each other is that they assign different probabilities for quantities such as position and momentum. That is a good point, but more needs to be said now about what that means to assign probabilities. One might cash that out in terms of relations between the quantum object and something else — but then one lands more comfortably in relational quantum mechanics than in a dynamical collapse theory.

The best worked out theory of dynamical collapse of the wavefunction is the Ghirardi-Rimini-Weber theory; and defenders of that approach have proposed a few solutions to the quantum description problem. Setting aside some subtleties, the preferred solution is that a quantum state ψ should be understood as a function on a high dimensional configuration space, and this function describes an actual mass density in this space. In this case, the quantum mechanical formalism describes a field on a high dimensional configuration space, and quantum-mechanical objects are profoundly different in kind from the middle-sized objects that fill our lives.

I can hardly think that Drossel and Ellis would want to avail themselves of the GRW picture that some things live in a high-dimensional configuration space while other things live in three dimensional space. If they did, then they would have an entirely new problem of showing how these two spaces interact with each other — and this is precisely the kind of problem that hylomorphists claim not to have. But if Drossel and Ellis do *not* want to adopt GRW's solution to the description problem, then how do they propose to solve it? And whatever solution they do offer, is it not going to lead to a rift between two radically different kinds of reality? My sense is that something has gone quite wrong with this attempt to secure the reality of middle-sized objects. We don't want to insist that middle-sized and subatomic objects are of radically different kinds — at least not so very different that we can hardly imagine the two kinds of things interacting with each other. It was exactly this point that Galileo made against the Aristotelians, with their distinction between terrestrial and celestial matter.[22]

Suppose now that one accepts my claim that we need a solution to the quantum description problem. The final point to make is that solving the quantum description problem is almost a solution to the quantum measurement problem. In particular, if you solve the description problem then there is no need to explain how "events occur" or how "something becomes definite". No, if we use QM to describe something, then we are describing something definite.

3 Do thermalized systems have wavefunctions?

Are middle-sized objects correctly described by QM? Raising this question could lead, I think, to some fun satire. For example, what is the superposition of the state in which my wife is happy with me and the state in which she is mad at me?

But the universal validity of QM cannot be refuted by satire. If I were a reductive physicalist, I would say that my wife's being happy with me corresponds to many different possible microstates of her brain, and similarly for the state of her being mad at me. But then to ask about "the superposition" of these macrostates is an error, because the resulting state might depend sensitively on which representative microstate of each macrostate is chosen.

The same point can be made about Schrödinger's cat. Being dead corresponds to many different microstates, as does being alive. There isn't really any single superposition of being dead and alive. Could it be, in fact, that there is a microstate ψ_d in which the cat is dead and another ψ_a in which it is alive, such that in state $\frac{1}{\sqrt{2}}(\psi_d + \psi_a)$ the cat is definitely alive? I don't see why not. There is no compelling reason that I can see to assume that the set of microstates corresponding to a macro-property such as "the cat is alive" is a subspace of the Hilbert space. If the cat is alive in microstates ψ_1 and ψ_2, then we don't know anything at all apriori about whether it's alive

[22]The question now is whether one wants to commit to finding an coherent ontology to make sense of the approach to the physics championed by Drossel and Ellis. For an effort in that direction, see (Simpson, 2021) and Simpson, 2022.

in state $\frac{1}{\sqrt{2}}(\psi_1 + \psi_2)$. So even if we assume that the cat's microstates can be superposed, that doesn't immediately tell us that its macro-properties (such as "being alive") can be modelled by quantum-mechanical observables.[23]

Drossel (2017) argues that there are middle-sized objects that are not described by any wavefunction. Now, I certainly agree with the practical claim: we do not currently, and probably could never, know the wavefunction of middle-sized warm things — to be more specific, "heat baths". Thus, in practice, QM is not a good theory for predicting the behavior of a heat bath. But does this mean, as Drossel claims, that a heat bath doesn't have a wavefunction? We need to distinguish between two kinds of arguments for this claim. The first kind is quite weak, but the second does point to an interesting fact about different kinds of scientific descriptions.

The first sort of argument runs from epistemology to ontology: we can't know what a heat-bath's wavefunction is, so it doesn't have one. This kind of argument was put forward by Walter Kohn, as paraphrased by Drossel and Ellis (2018, p 4): "a wave function of 10^{23} particles is not a legitimate scientific concept, since it can neither be prepared nor measured with sufficient accuracy." But if this is supposed to show that heat-baths don't have wavefunctions, then it's a bad argument. The fact that something cannot be prepared to be just so, or cannot be measured to be just so, does not entail that it cannot be just so. Hopefully Kohn meant to make the more modest claim that scientists don't have any reason to ascribe a particular wavefunction to any heat-bath, because otherwise he's appealing to a form of verificationism that is quite contrary to the spirit of science.

The second kind of argument that heat baths cannot be described by quantum wavefunctions appeals to more detailed physical facts about heat baths. Here the issues are more nuanced, and one must admit that physicists do assume things about heat baths that wouldn't be warranted if they assumed nothing more than that they are arbitrary systems of many quantum-mechanical particles. For example, physicists assume that the spatially sepa-

[23]It's tempting to think that the superposition of two "cat alive" microstates would have to be a state in which the cat is alive. After all, if we measured "alive or dead" in that state, then there is a 100% chance of its being alive. But that argument mistakenly assumes that "alive or dead" forms a quantum-mechanical observable, and that is precisely the issue in question. Consider an analogy: a superposition of two "energy is definite" microstates is not necessarily an "energy is definite" microstate; similarly, a superposition of two "is entangled" microstates is not necessarily an "is entangled" microstate (see Wallace, 2012, p 296).

rate parts of a heat bath are not entangled with each other, even though the typical quantum state of a multi-particle system will be internally entangled. How are we to understand such assumptions? Do they show that physicists don't really believe that the heat bath obeys the laws of quantum physics?

I'm skeptical that this is the correct reading of what's going on with quantum statistical mechanics. When we describe an object X as a heat-bath we are assuming that the concept of "temperature" is applicable to X. So, for example, we are assuming that X is not a single electron. We are also assuming several things about X that wouldn't be expected of a typical aggregate of quantum-mechanical particles. Does this mean that a new kind of object has emerged, with a new kind of laws? I don't understand what this claim would even mean. It seems that we can specify, in terms of the properties of the particles that compose X, when X qualifies as a heat bath. That is, the concept "is a heat bath" is definable in terms of the formalism of quantum statistical mechanics. What's more, the dynamics of X are just a special case of quantum-physical dynamics: X has a Hamiltonian operator H, and the evolution of the observables of X follows the standard quantum-mechanical rule: $a \mapsto e^{-itH}ae^{itH}$. We might not have apriori expected to get this Hamiltonian operator as opposed to some other (e.g. one with longer range interactions), but that's just to say that we wouldn't have apriori expected for an aggregate of quantum-mechanical particles to form a heat bath.

The defender of emergent properties for heat baths is likely to reply that no, in fact, the dynamics of X is not unitary, i.e. doesn't follow the rule $a \mapsto e^{-itH}ae^{itH}$. I have yet to see a case, however, of a non-measurement scenario where non-unitary dynamics provide the better description.

These are the kind of challenges that I would put to the claim that there are physical objects that fall outside of the domain of quantum physics. The important thing here is that we pay attention to our own choices about how we are conceiving of phenomena. In ordinary life, the notion of a phenomenon is a mish-mash of physical and mental elements. For example, the phenomenon "my wife is listening to an audio book", as I conceive it, is a hybrid of physical and mental events. And if you ask me whether physics can explain such a phenomenon, I would say first that I do not understand the question. Then I would say that I can reconceptualize this phenomenon in such a way that physics can shed some light on its occurrence; but that reconceptualization requires me to omit some of the original content of my conception.

A similar claim can be made about ordinary physical objects. It seems perfectly legitimate to conceive of an object in a way that contains elements that are alien to fundamental physics. For example, there is a book on my desk. But "book" is not a concept from fundamental physics, and it plays a different kind of role in our lives than concepts from fundamental physics. To ask whether fundamental physics could explain the existence of books is ambiguous.

To extend the point yet further, the concept of a "heat bath" isn't fundamental in quantum physics, i.e. it is only applicable under special circumstances. And when it is applicable, we're dealing with a regime where classical physics is more useful than quantum physics. The claim that heat baths don't have wavefunctions shouldn't be given an ontological gloss; it is rather a meta-theoretical statement to the effect that "heat bath" belongs to an effective theory in which Planck's constant is approximately zero.

It has been a traditional aspiration of metaphysics to find the ultimate description of reality that explains all the facts. Quantum fundamentalists claim that middle-sized things are not part of ultimate reality, but depend for their existence on the wavefunction (or spacetime states, or whatever the most recent ontological epicycle is). In contrast, hylomorphists argue that middle-sized things are fundamental, and so cannot be reduced to anything else. As for myself, I take the common sense view that middle-sized objects are real, and the practical view that we don't know what we're talking about if we don't connect things back to the world we live in, which is made up of middle-sized objects. This makes my attitude, if not my metaphysics, more similar to hylomophism than to reductive physicalism.

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