**The Model View Meets Quantum Ontology**

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**Abstract**

What is here called the “model view” of science is a distinct perspective associated with Ronald Giere and Paul Teller, which places the construction and use of models at the center of scientific theorizing. This paper offers friendly critical discussion--and significant revision--of the Giere-Teller model view, emphasizing the relevance both of evolutionary psychology and the economic concept of value subjectivism. The result is a sharper contrast with the common image of science as discovering real entities and natural laws governing them in a cumulative process converging on ultimate truth. In the context of the model view, a contentious issue in the philosophy of quantum mechanics is resolved: Is the Everett interpretation with wave function realism rendered untenable by the absence of a separate three-dimensional ontology? (It is not.)

**Keywords** Model view **.** Perspectivism **.** Quantum mechanics **.** Everett interpretation **.** Wave function realism

**1 Introduction: The Giere-Teller Model View**

This work addresses a perspective on science, which I will refer to as the “model view,” advanced in philosophy by Ronald Giere with important contributions from Paul Teller.1 This view places the construction and use of models at the center of scientific theorizing. The relation of a model to the world (or to some physical system in the world) is taken to be one of similarity, in certain respects and to certain degrees (Giere 1988, 81). “Laws” are true within the models; they do not apply directly to the world (Giere 1999, 67; 2004, 749; also Teller 2001, 395). Postulated entities “exist” within the model (Teller 2019, 59; also private communication). A model itself does not represent the world; rather, it is the scientist who represents the world by means of the model (Giere 2004, 747). There is no formal or general account of the similarity, or “fit” of a model to the world; models are employed for purposes and judged by their service to the modelers. Virtually anything might serve as a model of anything else, though perhaps not a very useful one (Giere 2010, 269; Teller 2001, 397). This model view stands as an alternative to the dominant image of science as progressively discovering real entities and true natural laws governing their behavior in a cumulative process converging on ultimate truth. Ultimate truth: that would be a perfect model, wouldn’t it? Then the dominant view could be characterized as a “perfect model model” of science. Teller (2001) finds the prospects increasingly dim. Nevertheless, Giere (1988, ch. 4) and Teller (2019) both characterize the model view as a brand of realism.

 In what follows, I offer friendly critical discussion and revision of the Giere-Teller model view, focusing on physics. The result is arguably a more coherent and thoroughgoing perspective, implications of which become most strikingly evident in the process of resolving a contentious issue in the philosophy of quantum mechanics: Does the Everettian interpretation with wave function realism require a separate three-dimensional ontology? (It does not.)

 First, it is worth mentioning that a remarkably similar vision was sketched by physicists Stephen Hawking and Leonard Mlodinow (2010) in a popular science book, independently of2 and with no reference to modern philosophers. They called their view “model-dependent realism.”

*There is no picture- or theory-independent concept of reality.* Instead we will adopt a view that we call model-dependent realism: the idea that a physical theory or world picture is a model (generally of a mathematical nature) and a set of rules that connect the elements of the model to observations. (p. 42-43**,** emphasis in the original).

According to the idea of model-dependent realism…our brains interpret the input from our sensory organs by making a model of the outside world. We form mental concepts of our home, trees, other people, the electricity that flows from wall sockets, atoms, molecules, and other universes. These mental concepts are the only reality we can know. (p. 172).

In those few sentences, Hawking and Mlodinow supply two crucial insights we use below.

**2 Models, yes. Similarity, not so much.**

Giere never defines “similarity,” but he repeatedly refers to a model’s similarity or fit to the world despite explicitly, in Giere (2010, 271-72), ruling out direct model-world comparison. Teller (2018, 157), too, says that representations can only be compared with other representations. Nor does “model” receive a definition, although we are offered many examples. Giere (2004, 747) tells us that “what is special about models is that they are designed so that elements of the model can be identified with features of the real world” but that would appear to be impossible if direct model-world comparison is ruled out. Hawking and Mlodinow (2010, 42-43) put their finger on an essential point: models connect to our observations, i.e., our experiences, not to the world directly.

 I take a model to be something, whether physical or abstract, that one allows to stand in place of the world, such that by examining the model, or manipulating it, or setting parameters and permitting it to evolve according to specified laws, one hopes to anticipate one’s experiences in observing or interacting with the world, and/or to achieve a satisfying sense of understanding how those experiences may arise. Physics offers a plethora of models that can be characterized in this way: Newton’s laws of motion and of gravitation3, the ideal gas, the harmonic oscillator (classical and quantum), models of stellar structure, ray optics, the standard model of particle physics, etc. A recipe is not a model, nor is an oracle, nor a claimed limitation on the possible implications of all future models. Once we have established a working concept of what a model is and is not, and given that the appraisal of the model is in terms of how well it serves the purposes of the user, the concept of similarity is not essential to the formulation of the model view. (It may serve us to exploit a dynamical similarity between two models, such as an idealized spring/mass system and a simple pendulum. Nevertheless, the similarity is between models, and it is the service, not the similarity, that is fundamental.)

**3 Models All the Way?**

Not all established theoretical principles in physics are models. The second law of thermodynamics, for example, asserts the impossibility of a refrigerator that operates without a net input of work. It is not a model, but rather a purported constraint on all future models. Similarly, the postulates of special relativity, in asserting the invariance of physical law with respect to relatively moving inertial reference frames, purport to limit acceptable models but do not themselves constitute a model. The general acceptance of some non-model principles in physics need not be an embarrassment for the model view, because the model view is itself a model, which, like models generally, we expect to be limited in the respects and degrees of its service of one’s purposes. Nevertheless, rather than constituting a problem for the model view, I suggest that at least some non-model elements of physical theory may reflect challenges for physics itself.

 For example, Einstein (1919) classified thermodynamics and relativity as “principle” theories, in contrast to “constructive” theories such as Newtonian mechanics and Maxwellian electrodynamics. Einstein clearly preferred constructive theories and expressed disappointment at having to settle for the relativity postulates after years of seeking a satisfactory constructive theory of electromagnetism and matter. These concerns and their relation to the example of thermodynamics are captured in a letter (Einstein 1908) to Arnold Sommerfeld:

It seems to me too that a physical theory can be satisfactory only when it builds up its structures from *elementary* foundations. The theory of relativity is not more conclusively and absolutely satisfactory than, for example, classical thermodynamics was before Boltzmann had interpreted entropy as probability. If the Michelson-Morley experiment had not put us in the worst predicament, no one would have perceived the relativity theory as a (half) salvation. (Emphasis in the original).

Asserting relativistic invariance as a limiting principle versus constructing a theory from elementary foundations: the distinction tracks non-model theorizing versus models. Indeed, the subsequent concept of Minkowski space with its peculiar geometry may be seen as a model to underlie the postulates. Boltzmann sought to ground the second law of thermodynamics in the statistical mechanics of atoms and molecules, and many subsequent decades saw no end of efforts at furthering or completing that project. These examples (and the next) suggest that theories lacking underlying models tend to be regarded as unsatisfying.

 Interpretations of quantum mechanics falling under the Copenhagen banner stand as another example of non-model theorizing. In applying the quantum formalism, Bohr and his followers offered a recipe for calculating experimental results and actively discouraged the development of models that might underlie the success of the recipe.4 Nevertheless, Bohmian mechanics, variants of Everett’s interpretation, and spontaneous collapse theories eventually became areas of active research. The field has evolved to the point where Tim Maudlin, in a monograph on quantum philosophy, simply walks away from the Copenhagen recipe as not constituting a proper physical theory at all:

A physical theory should clearly and forthrightly address two fundamental questions: what there is, and what it does. The answer to the first question is provided by the *ontology* of the theory, and the answer to the second by its *dynamics*…. All three of the theories [Bohmian, Everettian, spontaneous collapse] we will examine meet these demands. The Copenhagen Interpretation, in contrast, does not. (Maudlin 2019, xi, emphasis in the original).

From the perspective of the present paper, what Maudlin is demanding is a model. If we distinguish between modeling and non-model theorizing, we identify an essential difference—and are free to argue that models are preferable—without implying that, for example, Bohr and his followers were not legitimately theorizing at all.

 It may be that most physicists (Hawking and Mlodinow notwithstanding) see themselves not merely as generating models, but as uncovering, once and for all, the true laws and thing-itself nature of the world.5 We need not accuse them of misunderstanding their own research, in order for us to recognize an essential difference in perspective between scientific practice and critical or constructive reflection on that practice. Physicists may usually be well served by taking a full-throated realist view of their theories, just as it serves us in everyday life to accept at face value the world of our perceptions and facts of the matter about, say, whether Forbes and Oakland Avenues intersect in Pittsburgh. Yet even the everyday world of our perceptions consists of models, as we heard already from Hawking and Mlodinow (2010, 172). Here’s Teller:

*Heights, people, rooms* full stop, are idealizations. On this modeling approach we use such idealizations to put together models, big and small, that work well enough for us, that, in many fortunate cases, function as accurate guides to an independently operating world. (Teller 2011, 471, emphasis in the original).

We are psychologically primed to seize on some model as constituting the actual state of affairs, presumably because modeling the environment evolved to facilitate decisive action. Does a tiger approach in yonder grass? Our distant ancestors could not afford to entertain too many doubts. This built-in tendency is evident in the gestalt-switch figures found in introductory psychology textbooks, where our mind seems unable to remain neutral as to which are the indentations and which the protrusions represented in a line diagram on flat paper, or whether another diagram depicts a vase or two faces in profile. The so-called “phantom Necker cube” (Griggs and Jackson 2020, 131), is a striking example of how the mind can perceive an object that on closer inspection is not present (or not directly represented).

 That humans (and many animals) create mental models of the environment, and that this capability is the result of biological evolution, has been advocated in psychology going back at least to Kenneth Craik (1943). Craik’s point was that we create mental models as predictive devices, a theme taken up in modern neuroscience (see, e.g., Kelly et al. 2019). Johnson-Laird (2004) finds adumbrations of mental modeling in physics in the writings of Kelvin and Boltzmann. Nersessian (1999) draws the connection between the biological evolution of mental modeling and theorizing in science:

[Mental modeling] evolved as an efficient means of navigating the environment and solving problems of matters of significance to existence in the world. Humans have extended its use to more exotic situations, such as constructing scientific representations. That is, the cognitive resources scientists call upon in creative problem solving are not different in kind than those humans use in more ordinary circumstances. (Nersessian 1999, 14).

The lesson is clear: whatever the underlying reality may be, our very perception of a familiar macroscopic world is a model (or, a constellation of models). We all seem to share it, take it for granted, rely on it constantly and instinctively in our everyday affairs. Nevertheless, the familiar macroscopic world--as we perceive it--cannot serve as bedrock reality on which to construct an understanding of science as a process that reveals further thing-itself reality. A critical perspective on science requires a critical attitude toward the intuitions and prejudices that we take to have been impressed on our thinking by evolution and by the bulk of our everyday experiences. If scientific theorizing is an extension of innate modeling processes, we should not be surprised to find that the picture of the world we get from science is comprised of models from start to finish. Nor should we be surprised to find scientists regarding their favorite models as having captured thing-itself reality.

**4 Value Subjectivism**

If, as Giere and Teller both emphasize in numerous passages, models are deployed to serve purposes, then models must be judged by how well they serve those purposes. But whose purposes, and judged by what standards? Giere (2010, 275) says that whether a model fits aspects of its intended target well enough “may depend on individual or communal understandings…or on the purpose for which the model is being employed.” Teller (2001, 401) refers to the “interests of the model users.” Fair enough, but individuals and their purposes may differ; communal standards are seldom explicit and may sometimes be usefully flouted; and model users are not a homogeneous group. Both Giere and Teller are pointedly skeptical (as I am) regarding the prospect of formulating general rules to judge the efficacy of models. Is there, then, any bedrock to be found?

 In his (2012, 266-67), Teller cites Thomas Kuhn’s famous list of “epistemic virtues”: accuracy, simplicity, fruitfulness, explanatory power, and consistency, and he notes with apparent approval Kuhn’s conclusion that “since the balance among these is a matter of personal judgment, differential satisfaction of the individual epistemic virtues provides no objectively fixed rational mandate for choice among paradigms.” (I think we can safely replace “paradigms” with “models” here.) Teller further notes that “the virtues themselves embody personal values.” But, he continues, “once the values are set, often there will be an objectively correct evaluation of the extent to which one or another modeling approach will achieve the values in question.”

 *Can* the values be “set”? I think effectively yes, most of the time, if only because differences may often not be relevant to, or significantly impact, a particular issue at hand. We may even choose to adopt certain values of those with whom we disagree, in order to demonstrate that given *those* values a particular model succeeds or fails. During periods of theoretical upheaval, value differences that are usually lurking beneath the surface may come to the fore. And yet, issues do seem to get resolved, at least for a while, the scientific or specialist community settling on new models, relegating old or competing ones to the dust bin or to limited ranges of application.

 Perhaps this situation has a familiar ring. In a market economy, each individual is the ultimate judge of their own satisfaction: that is, value is *subjective*.6 To say that goods and services have value is to say that there are people who value them. Valuations differ, yet the interaction of large numbers of people with diverse preferences results in a complex productive order, not mere chaos. New products appear and are widely adopted—or not—while others are left behind. Most people, comparing the present with the past, see progress. Much depends (as it does in science) upon institutions and culture, which I will not address here.7 For the present purposes it suffices to identify individual valuation of scientific models with this broader economic concept of value subjectivism. Scientists, like people generally, make choices in pursuit of their goals and values, and each is the ultimate judge of their own satisfaction. There lies the bedrock, for the model view of science.

 Which is not to say that people never change their minds. Further experience may result in one’s losing satisfaction with a model and/or finding more value in another. Such changes may come about for conventionally “rational” or “scientific” reasons, or, perhaps, for social and personal ones: clinging to an unpopular model may threaten to leave one professionally isolated, lacking recognition and support. Where to draw the line is a matter of individual judgment, and a diversity of choices arguably allows for a scientific community that in effect pursues a mainstream approach while hedging its bets and being susceptible to radical change. The parallel with entrepreneurship in a market economy is surprisingly robust (Walstad 2002).

**5 Realism?**

I have adopted Teller’s term “model view” but Giere (1988, ch. 4) called his view “constructive realism”, as an alternative to the well-known “constructive empiricism” of Bas van Fraassen and the “social constructivism” of some sociologists of science (neither of which will be addressed here). This evolved into “perspectival realism”, in which Giere (1999, 150) adds the “insistence that our theories do not ever capture the totality of reality, but provide us only with perspectives on limited aspects of reality.”

 Giere’s argument for perspectivism as a brand of scientific realism is characterized as “thin” by Teller (2019, 50):

Giere asserts that although all scientific claims are from within a perspective, such claims count as a kind of realism when the perspective in question and the way it has been used meet high standards of scientific practice. Why? All Giere tells us is that such are “the most reliable conclusions any human enterprise can produce.” (Teller’s quotation of Giere is from Giere 2006, 92).

Teller (2019) seeks to improve on Giere’s argument by addressing what he takes to be the three main elements of “generic” realism: 1. “[T]here is a mind-independent world that is the target of scientific (and perceptual) knowledge and understanding.” 2. “[S]cientific claims are to be taken literally….” 3. “[M]ature theories succeed in giving us true, or approximately true, statements about the world and the things in it.” He claims that, given a proper understanding of “approximate truth,” perspectivists embrace all three. Teller’s understanding of approximate truth is context dependent and interest dependent: “Close enough to the truth for what? That will depend on what our interests are, on what is at stake” (Teller 2019, 58). But this is just another way of saying that we judge models by how well they serve our purposes.

If perspectivism, or the model view, tells us about the mind-independent world, what it tells us about that world is that, in certain respects and to certain degrees, it behaves *as if* the entities posited in our models exist and obey the posited laws governing them. Any further claim, that those entities *do* exist and *do* obey those laws, would require further demonstration.

 The burden of demonstration will not be shirked through questions of the form “But how can our models work so well if they do not correctly invoke properties of an external world?” Whatever else we may say about reality, it has not been so haphazard as to render models useless. From a myriad of imaginable models, we have selected those that work for us. No further answer is required. Nevertheless, we may note that mid-19th century celestial mechanists could have asked (and perhaps did), regarding gravitational force: how could it not exist, if it explains and predicts so well the motions of planets and comets? Then along came general relativity, in which particles follow spacetime geodesics and the only forces are those which cause deviation from the geodesic path. Nature has proved again and again to be more subtle and interesting than our models of it.

 In the model view we learn about the world, but we do not acquire direct knowledge of the world in itself (“thing-itself knowledge”). Teller (2018, 159) detects a Kantian flavor here. We explain and understand our experiences in terms of models—or else, since all we have are models, we don’t explain or understand at all. The history of physics is marked by a succession of incompatible ontological commitments, from absolute space and time to relativistic spacetime, from gravitational force to spacetime curvature, from classical mechanics to quantum mechanics, from electromagnetic waves to photons, etc. If physicists were to discover the ultimate reality that underlies all our experiences (and if they could prove it—how, exactly?), it would be a truth beyond the limits of the model view. Nevertheless, we would still rely on a train of models to connect this underlying reality to our actual experiences, including the results of experiments, the observations mediated by instruments, and our unaided perceptions. Teller notes that

…even supposing wonderfully simple and universal laws, including a complete description of forces and dynamics, such laws would not by themselves provide a theory we could much use, for the initial conditions are much too messy…To have theories which we can actually apply in describing and understanding the world we have no choice but to work with nature to do what it does not sufficiently do itself: We must simplify further. (Teller 2001, 393-94).

Thus, even if all phenomena including human thought itself were ultimately the outcome of the interactions of thoroughly understood fundamental physical entities, we would still be constructing models and evaluating them according to our judgment of their service.

**6 Finding Our World in the Wave Function**

We noted earlier Maudlin’s (2019) dismissal of the Copenhagen interpretation of quantum mechanics for not satisfying the requirements of a proper physical theory, as opposed to Bohmian mechanics, spontaneous collapse theories, and Everett’s interpretation, which do. I would agree with Maudlin, except that the distinction is in my view between a recipe, on one hand, and models on the other. In the Bohmian model, particles have exact positions at all times but are guided by the wave function, which obeys the Schrodinger equation. In spontaneous collapse models, particles randomly localize and the wave function, which otherwise obeys the Schrodinger equation, changes accordingly.

 Hugh Everett (1957) had the insight that Schrodinger evolution by itself might account for our experience that quantum measurements have definite outcomes. Superpositions at the microscopic level entangle with macroscopic superpositions of measuring instruments and human observers who see different results. Further research clarified that decoherence would make the corresponding parts of the overall wave function highly unlikely to interfere in the future, leaving the way open to regard macroscopic superpositions as coexisting, independently evolving worlds. But, where in this wave function do we find so-called local “beables” as John Bell (1987, ch. 7) called them: localized objects in the familiar three-dimensional world? Maudlin (2019, 199) articulates the concern as follows: “If tables and chairs and cats are structured collections of local entities in space-time, then stripping the local entities out from the theory strips out all the familiar material objects as well.” I wish to address this concern in the context of “wave function realism,” a model in which the wave function evolving in 3N-dimensional space (N being the total number of presumed particles) is all there is.

 Among the answers that have been offered so far, one type of answer finds 3D space in the dynamics governing the evolution of the wave function—that is, in the Hamiltonian, which depends on triplets of coordinates in configuration space (and time) in just the way we would expect if the triplets of coordinates were the familiar spatial coordinates of interacting particles. For Albert (1996) the result was an “illusion” of objects in 3D space. For North (2013), the dynamics grounds 3D space as inferred, existing structure. Wallace and Timpson (2010) emphasize the role of decoherence in the emergence of macroscopic objects evolving quasi-classically in 3D space, and Wallace (2010) goes on to identify 3D objects with emergent patterns in the overall wave function. Ney (2021, ch. 6) criticizes such proposals as failing to demonstrate how a 3D world can be *constituted* by a wave function in 3N-dimensional space. Ney (2021, ch. 7) goes on to argue that symmetries in the wave function can suggest the possibility of a 3D ontology and follows up with a proposal for identifying a mereological (part-whole) relationship between particles and the wave function.

 How does this issue—finding the familiar 3D world in a wave function in 3N-dimensional space—look from the model view? These are both models. The question is, from the perspective of the second model can we understand how the first one would arise and take on such an essential role? The history of physics proceeded in the opposite direction. Assemblages of particles, classically, can be modeled as a point in configuration space, which moves deterministically on a trajectory in that space as the particles interact. The evolution of the world can be captured by the motion of a single point because the 3N coordinates of the point in configuration space encode the coordinates of N particles in 3D space. If Darwinian evolution could occur in a classical world, the moving point could represent creatures that acquire resources, avoid predation, propagate, and, through many generations, develop survival-enhancing capabilities, including the ability to construct models of their environment.

 Let us suppose that life forms in this world reached the level of sophistication to theorize, to discuss the relative merits of models including classical models of particle interaction and their representation in configuration space. Suppose further that a model of the world were proposed in which the point moving in configuration space is taken as not merely a mathematical representation, but as the entire ontology. Many might find this model untenable because they “know” from experience that the world is three-dimensional, but of course they know no such thing: all they have are their models, as useful as they may be. Every perceived object, event, and process has its counterpart in the location and motion of the point in configuration space, including all the physical correlates of consciousness and felt experiences.

 Nevertheless, the configuration space ontology would surely seem unmotivated: what would be the payoff for such a counter-intuitive move?

 Classical mechanics is inadequate to account for all the phenomena in our perceived world, including Darwinian evolution based on molecular chemistry. Quantum mechanics was developed to account for what we take to be structures and processes at the microscopic level; eventually, as noted earlier, models were developed to relate wave function evolution at the microscopic level to the probabilistic results of experiments at the macroscopic level. Among these, Everettian models take the entire world to be quantum mechanical and Schrodinger evolution to proceed unbroken and unmodified. A world of macroscopic objects is represented in configuration space, not by a point but by a limited region of high amplitude. This region not only moves but can split up, with decoherence leading to effectively isolated regions of relatively high amplitude, hence “multiple worlds.” Within the Everettian paradigm, wave function realists (e.g., Ney 2021) offer a model in which the wave function evolving in configuration space is the entire ontology.

 This model is thought by some to be untenable, as in the classical parable, because the ontology does not include a world of three-dimensional objects that we “know” exist; but, as in the classical parable, we know no such thing. In a thoroughgoing model view, our very perception of a 3D world is part of a system of acquiring and economizing on information that contributed to the survival of our evolutionary ancestors, whether they were in fact 3D creatures in a 3D world or perhaps clusters of coordinate triplets that partially characterize the location of a high-amplitude region in configuration space (or something else entirely). It may well be easier to imagine intricate 3D chemical machines evolving to acquire beliefs and construct models than it is to contemplate a high-dimensional alternative. Nevertheless, unlike in the classical case, wave function realism is well-motivated by quantum entanglement, which leads to correlations between the results of measurements on widely separated systems—correlations that require nonlocal influences in 3D space but not in configuration space.

 Why, then, would our perceptual models themselves be limited to three spatial dimensions? The answer presumably lies in the need to economize on information, that is, in the tradeoff between the value of the information and the cost of obtaining it. For our ancestors, 3D models efficiently captured what was relevant to their lives.9 But quantum entanglement is perhaps becoming relevant to our lives, and our conceptual models may need to evolve accordingly. Indeed, quantum computers in some applications arguably do or will “see”, and model in, many dimensions of the wave function.10

 The conclusion here is narrow but fundamental: the absence of a separate 3D ontology beyond a wave function evolving in configuration space does not make wave function realism untenable. As a model, it accounts for our perception of a 3D world while preserving locality and pure Schrodinger evolution. It does face other challenges; for example, a configuration space with a fixed number of dimensions tied to particles cannot account for the variable number of particles encountered in relativistic quantum field theory and high-energy physics, whose tracks or arrivals at detectors are apparently observed in experiments. Can the model be successfully generalized, or is a completely different approach required? We shall see.

**7 Conclusion**

The Giere-Teller model view places the construction and use of models at the center of scientific theorizing—at the center, indeed, of how we perceive and interact with the world generally. I have argued here that Giere’s characterizing the model-world relationship as one of “similarity” founders on the problem of direct model-world comparison. We can avoid this difficulty by refining the concept of a “model” and placing additional emphasis on the purposes and judgment of the modeler. On my view, the service of purposes is central. Individual judgment of individual satisfaction is absolute. Science as a process is mainly the conscious continuation of a biologically evolved propensity to generate mental models of the world, an outgrowth of processes that begin beneath our conscious awareness. The model view can accommodate a modest scientific realism: there is a world external to and operating independently of our thought, which behaves in certain respects and degrees as though a given model is true and the entities it posits are real. Nevertheless, the model view is itself only a model. We noted examples of non-model theorizing in physics, although we also noted efforts to ground these in models, suggesting that theoretical principles lacking underlying models tend to be regarded as unsatisfying.

 From this perspective, Everettian quantum mechanics with wave function realism is a *model*, one which consists in its entirety of a wave function evolving via a Hamiltonian in a high-dimensional space. This model is not rendered untenable for lack of a separate 3D ontology. Our perception of a 3D world is itself a deeply ingrained model that evolved to enhance the survival of our distant ancestors, whatever their (or our) ultimate nature. In the wave function realist model, that nature is of complex patterns in the wave function. If we ourselves cannot directly perceive more than three dimensions, it is possible that some of our creations can or will be able to do so.

 We do not know the underlying reality. Nevertheless, we have developed, and continue to develop, many models that serve our purposes. That they do so is--thus far, at least--the truth of science.

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**Notes**

1Teller (2001, 395) uses the term “model view.”

2Leonard Mlodinow, private communication.

3Giere (2004, 744) takes Newton’s laws to be “model-building principles.” I take them to constitute a model. Particles exert equal and opposite forces on each other and undergo acceleration according to **F** = m**a**. That is a model of how things happen in nature.

4A physicist employing the textbook recipe will of course have a model in mind, such as an electron traveling through an inhomogeneous magnetic field (Stern-Gerlach apparatus) and reaching a screen where it causes a flash. But if the quantum formalism leads to a superposition of different locations, the recipe simply asserts that the electron will be detected at one location with probability given by the square amplitude of the wavefunction at that location. There is no underlying model for how it is that the electron is detected at one spot rather than another.

5Richard Feynman (1967, 172), for example: “The age in which we live is the age in which we are discovering the fundamental laws of nature, and that day will never come again.” Or Steven Weinberg (2001, 126): “I think that physical theories are like fixed points, toward which we are attracted…It [the fixed point] is something toward which any physical theory moves, and when we get there we know it, and then we stop.” Setting aside the incoherence of Weinberg’s two sentences (physical theory = fixed point versus physical theory moving toward a fixed point), the sentiment is clear.

6The subjective understanding of value arrived with the marginal revolution in economics. See e.g. Menger ([1871] 2007, ch. 3).

7A vision of science as an economic process—a market process, even—is proposed in Walstad (2002). See also Walstad (2001). In what follows, I adopt some wording from those works.

8Or both might be flawed, but that suffices for the point.

9Thus, our perception of a 3D world is not an illusion, not an error, not a fiction; it is simply the way our physical systems, whatever their ultimate nature, package the information by which we pursue our goals and purposes (which, for our evolutionary ancestors, were dominated by survival and procreation).

10As argued, for example, by Deutsch (1997, ch. 9).

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