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How to Complete Quantum Mechanics, *or*, What It's Like to Be a Naturally Creative Bohmian Beable

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Abstract

In another essay, I've argued by means of a formal analogy between (i) the incompleteness of *Principia Mathematica*-style systems of mathematical logic (logico-mathematical incompleteness) and (ii) the incompleteness of the Standard Models in contemporary physics (physico-mechanical incompleteness), that (iii) just as the fact of logico-mathematical incompleteness entails the existence of mathematical creativity, so too the fact of physico-mechanical incompleteness entails the existence of natural creativity. Building on that line of thought, in this essay I present a new and empirically-testable strategy for completing quantum mechanics. More precisely, I argue that if we assume that the Standard Models in contemporary physics are incomplete, and if we also assume that all rational human animals are primitive sources of natural creativity via their free agency, then, by means of an appeal to Bohmian mechanics, together with the thesis that all rational human animals are primitive sources of natural creativity via their free agency, we can complete quantum mechanics.

Keywords: Physics, quantum mechanics, Bohmian mechanics, physico-mechanical incompleteness, natural creativity, free agency

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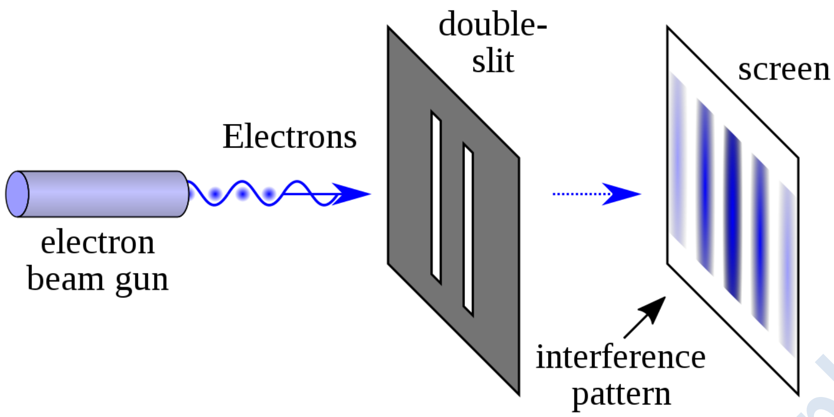
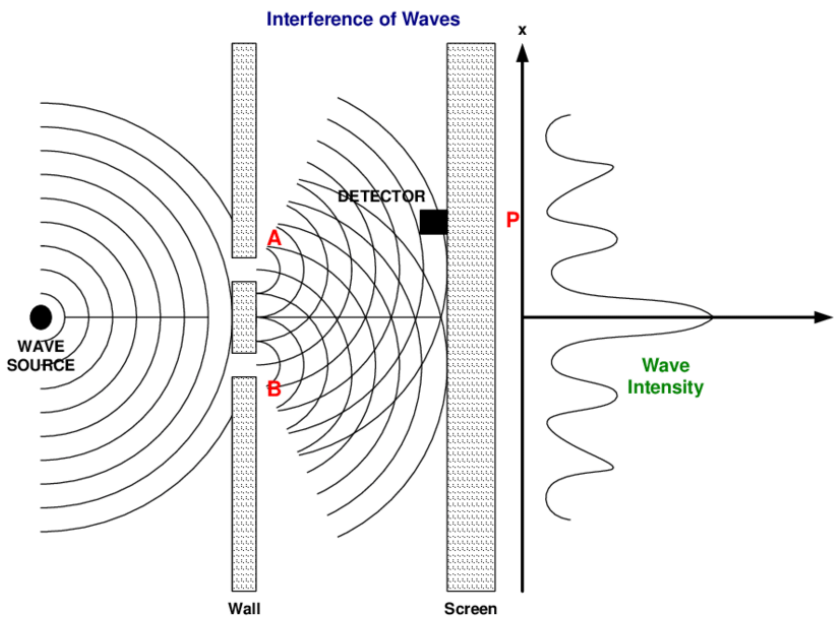




I. Introduction

In a recent essay (Hanna, 2021), I argued by means of a formal analogy between (i) the incompleteness of *Principia Mathematica*-style systems of mathematical logic (Whitehead and Russell, 1962) that are rich enough to contain the Peano axioms for arithmetic and the primitive recursive functions over the natural numbers (logico-mathematical incompleteness), and (ii) the incompleteness of the Standard Models in contemporary physics (physico-mechanical incompleteness), that (iii) just as the fact of logico-mathematical incompleteness entails *the existence of mathematical creativity*, so too the fact of physico-mechanical incompleteness entails *the existence of natural creativity*, and that (iv) all rational human animals are not only primitive sources of mathematical creativity, as *mathematical a priori knowers* of mathematical axioms and mathematical truths, arguably by means of *mathematical intuition* (Hanna, 2015: chs. 6-8), but also primitive sources of natural creativity, as *rational human free agents*, arguably by means of *deep freedom of the will and non-instrumental practical agency* (Hanna, 2018).

I won't repeat the argument-from-incompleteness-to-our-primitive-sourcehood here, but will simply assume its soundness for the purposes of developing, in this essay, a further line of thinking that importantly elaborates and extends that argument. More precisely, what I want to argue in this essay is that if we assume that the Standard Models in contemporary physics are incomplete, and if we also assume that all rational human animals are primitive sources of natural creativity via their free agency, then, by means of an appeal to Bohmian mechanics, together with the thesis that all rational human animals are primitive sources of natural creativity via their free agency, *we can complete quantum mechanics*.

II. Some Terminology Defined

For the sake of clarity and distinctness, I'll define some terminology.

By *the Standard Models in contemporary physics*, I mean the current Standard Model of Cosmology (SMC), together with a proper sub-part of SMC, the current Standard Model of Particle Physics (SMPP), as per the following non-technical description by B.A. Robson (Robson, 2021):

> The current Standard Model of Cosmology (SMC), also called the "Concordance Cosmological Model" or the "ΛCDM Model," assumes that the universe was created in the "Big Bang" from pure energy, and is now composed of about 5% ordinary matter, 27% dark matter, and 68% dark energy.[1]
>
> [T]he SMC is based primarily upon two theoretical models: (1) the Standard Model of Particle Physics (SMPP),[2] which describes the physics of the very small in terms of quantum mechanics and (2) the General Theory of Relativity (GTR),[3] which describes the physics of the very large in terms of classical mechanics; it also depends upon several additional assumptions.
>
> The main additional assumptions of the SMC are: (1) the universe was created in the Big Bang from pure energy; (2) the mass energy content of the universe is given by 5% ordinary matter, 27% dark matter, and 68% dark energy; (3) the gravitational interactions between the above three components of the mass energy content of the universe are described by the GTR; and (4) the universe is homogeneous and isotropic on sufficiently large (cosmic) scales.
>
> Unfortunately, both the SMPP and the GTR are considered to be *incomplete* in the sense that they do not provide any understanding of several empirical observations. The SMPP does not provide any understanding of the existence of three families or generations of leptons and quarks, the mass hierarchy of these elementary particles, the nature of gravity, the nature of dark matter, etc.[4] The GTR does not provide any

> understanding of the Big Bang cosmology, inflation, the matter-antimatter asymmetry in the universe, the nature of dark energy, etc.
>
> Furthermore, the latest version of the SMC, the ΛCDM Model is essentially a parameterization of the Big Bang cosmological model in which the GTR contains a cosmological constant, Λ, which is associated with dark energy, and the universe contains sufficiently massive dark matter particles, i.e., "cold dark matter." However, both dark energy and dark matter are simply names describing unknown entities.

Correspondingly, by *Bohmian mechanics*, I mean a certain version of quantum mechanics, as per this non-technical description by Sheldon Goldstein:

> Bohmian mechanics, which is also called the de Broglie-Bohm theory, the pilot-wave model, and the causal interpretation of quantum mechanics, is a version of quantum theory discovered by Louis de Broglie in 1927 and rediscovered by David Bohm in 1952. It is the simplest example of what is often called a hidden variables interpretation of quantum mechanics. In Bohmian mechanics a system of particles is described in part by its wave function, evolving, as usual, according to Schrödinger's equation. However, the wave function provides only a partial description of the system. This description is completed by the specification of the actual positions of the particles. The latter evolve according to the "guiding equation,"[۵] which expresses the velocities of the particles in terms of the wave function. Thus, in Bohmian mechanics the configuration of a system of particles evolves via a deterministic motion choreographed by the wave function. In particular, when a particle is sent into a two-slit apparatus, the slit through which it passes and its location upon arrival on the photographic plate are completely determined by its initial position and wave function.
>
> Bohmian mechanics inherits and makes explicit the nonlocality implicit in the notion, common to just about all formulations and interpretations of quantum theory, of a wave function on the configuration space of a many-particle system. It accounts for all of the phenomena governed by nonrelativistic quantum mechanics, from spectral lines and scattering theory to superconductivity, the quantum Hall effect and quantum computing. In particular, the usual measurement postulates of quantum theory, including collapse of the wave function and probabilities given by the absolute square of probability amplitudes, emerge from an analysis of the two equations of motion: Schrödinger's equation and the guiding equation. No invocation of a special, and somewhat obscure, status for observation is required. (Goldstein, 2017)

And finally, by *a better scientific theory*, I mean what's spelled out in this non-technical description by Ethan Siegel:

Every once in a while, a revolutionary idea comes along that has the potential to supersede our best scientific ideas of the day. This happened numerous times in theoretical physics during the 20th century, as Einstein's General Relativity replaced Newtonian gravity, quantum physics replaced our classical view of the Universe, and the quantum field theory-based Standard Model superseded the early-20th century version of our quantum Universe.

Over the past half-century, many novel ideas have sought to surpass the current limitations plaguing theoretical physics, from supersymmetry to extra dimensions to grand unification to quantum gravity to string theory. The ultimate idea of many is to arrive at one unified theory of everything: where one framework elegantly encompasses the entirety of nature's laws….

When we use the word "theory" in a conventional sense, we talk about it the same way we'd talk about the word "idea" or "hypothesis." We mean that sure, we have our conventional way of thinking about things that we generally accept, but maybe things are actually this other way instead.

To a scientist, though, a theory is a far more powerful thing than that. It's a self-consistent framework that has the quantitative power to predict the outcomes (or sets of probable outcomes) of a large set of systems under a wide variety of conditions.

A successful, established theory goes even farther. It contains a large suite of predictions that agree with established experiments and/or observations. It's been tested in a large number of independent ways, and has passed every test thus far. It has a range of validity that's well-understood, and it's also understood that the theory may not be valid outside of that particular range.

Which means, if you want to surpass that theory in a scientific sense, you have a tall order ahead of you. You have to do better than the old theory that you're seeking to replace with your new idea, and that means you have to take these three very difficult steps.

1. You have to reproduce all the successes of the currently prevailing theory; your new idea must succeed in all the places where the prior one succeeds.

2. You need to explain at least one existing observation or measurement that the current theory struggles with; you have to demonstrate why this new idea is more compelling than the one it's seeking to replace.

3. You need to make at least one new prediction that differs from the leading theory's predictions that you can then go out and measure; if your new idea is right, there must be a way to validate or refute it.

This is asking a lot, and most new ideas never make it this far. (Siegel, 2020)

III. A New Idea About Quantum Mechanics In Eleven Steps

Now, here's an eleven-step line of thought that puts forward a "new idea" by conjoining Bohmian mechanics and the thesis that all rational human animals are primitive sources of natural creativity via their free agency.

1. I'll start off by distinguishing between three fundamentally different kinds of natural process: (i) a *deterministic* process, i.e., a process that's time-reversible, aka "block-world,"and its basic quantities are Turing-computable from initial conditions/facts about the past together with the Conservation Laws, the 1^{st} and 2^{nd} Laws of Thermodynamics, and specific non-probabilistic/non-stochastic laws of nature), (ii) an *indeterministic* process, i.e., a process that's time-reversible/block-world, and its basic quantities are Turing-computable from initial conditions/facts about the past together with the Conservation Laws, the 1^{st} and 2^{nd} Laws of Thermodynamics, and specific probabilistic/stochastic laws of nature), and (iii) a *non*-deterministic and *non*-indeterministic process, aka a *naturally creative* process, i.e., a process that's time-*ir*reversible, *anti*-block-world, non-equilibrium thermodynamic, and its basic quantities are *not* Turing-computable from initial conditions/facts about the past together with the Conservation Laws, the 1^{st} and 2^{nd} Laws of Thermodynamics, and either specific non-probabilistic/stochastic laws or specific probabilistic/stochastic laws, due to complexity and self-organization.

2. Then I'll define *a mechanical process* as a natural process that's either deterministic or indeterministic, hence it's time-reversible/block-world and its basic quantities are Turing-computable from initial conditions, the Conservation Laws, the 1^{st} and 2^{nd} Laws of Thermodynamics, and other specific natural laws.

3. In order to avoid possible misunderstandings, I note that the definitions of deterministic and indeterministic natural processes I've used here are somewhat stronger than would be needed to define *universal natural determinism* and *universal natural indeterminism* in the free will debate, since there can also be time-irreversible/ anti-block world determinism and indeterminism alike. But in this context it's not the free will debate per se that's my primary target—rather, my primary target is the debate about the Bohmian hidden variables interpretation of quantum mechanics, and how Bohmian mechanics could be combined with the thesis that all rational human animals are primitive sources of natural creativity via their free agency.

4. As per step **1**, I'm defining a *naturally creative process* as a complex, self-organizing, time-irreversible, Turing-incomputable thermodynamic process that also obeys the

Conservation Laws, including the 1st Law of Thermodynamics—so, no new matter/energy is created, and none that already exists is lost—but *also* systematically creates negentropy (i.e., it's dissipative) by spontaneously structuring/restructuring or shaping/reshaping the dynamic patterns of matter/energy flow, hence it's not entailed or necessitated by the 2nd Law of Thermodynamics.

5. Furthermore, an *organism* is a certain special kind of naturally creative process, namely, an "autopoietic" one in Varela, Maturana, and Uribe's terminology (Varela, Maturana, and Uribe, 1974), that self-organizes in such a way that it produces a membrane separating its inner or endogenous states and its interpendependent proper parts, from its outer or exogenous interactions and relationships with the environment, and strives to maintain a homeostatic balance between its endogenous states and its exogenous interactions and relationships. Obviously, rational human animals are *also* organisms, hence they are *also* themselves naturally creative processes, *in addition* to being, by hypothesis, primitive sources of natural creativity via their free agency.

6. Now let's consider Bohmian mechanics, and also, relatedly, Ilya Prigogine's time-irreversible/anti-block-world attempt to create a unified formulation of quantum mechanics using non-equilibrium thermodynamics (Prigogine, 1997: ch. 6). More specifically, let's consider Bohmian mechanics and the hidden variables interpretation as a way of avoiding (i) the mysterious intervention of the observer in producing the "collapse of the wave function," and correspondingly also (ii) the Copenhagen interpretation of quantum mechanics.

7. I'm generally in agreement with the hidden variables interpretation. But it seems to me that Bohm was mistaken in thinking that every version of the hidden variables theory reintroduces *deterministic* natural processes. Indeed, it also seems to me more generally that a characteristic feature of philosophical and natural-scientific debates about mechanistic physics and about the free will problem *alike*, is a basic confusion between at least two different senses of "deterministic process":

> (i) *deterministic process*$_1$, which means a time-reversible/block-world natural process that precisely fixes a causal outcome across a set of alternative relevant possible future worlds, as entailed or nesessitated by the Conservation Laws, the 1st and 2nd Laws of Thermodynamics, and specific non-probabilistic/non-stochastic laws of nature together with initial conditions/facts about the past, and

(ii) *deterministic process*$_2$, which means a time-irreversible/non-block-world natural process that precisely fixes a causal outcome in the actual-world-sequence *only*.

But a time-irreversible/non-block-world natural process that precisely fixes an outcome in the actual-world-sequence *only*, i.e., a deterministic process$_2$, can be (a) a naturally creative process, therefore (b) *not* a deterministic$_1$ process, and *also* (c) exemplify deeply responsible rational human free agency: such processes are what I'll call *self-determining*.

This is shown by (Harry) Frankfurt-style counterexamples to The Principle of Alternative Possibilities, aka PAP, about responsibility (PAP: necessarily, responsibility requires alternative possibilities of choice and action) (Frankfurt, 1988b), together with a broadly Frankfurt-style hierarchical-desire conception of the will and freedom of the will (Frankfurt, 1987c, 1987d, 2004), but without compatibility with determinism at the source of agency, aka *source-incompatibilism*. So I'm talking about a broadly Frankfurt-style conception of rational human free agency (i.e., free will + practical agency, including deep responsibility, not just free will) that's also source-incompatibilist.

The distinction between the two importantly different senses of "deterministic process" can be usefully redescribed as the distinction between natural processes that exhibit either (i) *classical determinism* or (ii) *naturally creative non-determinism, including self-determination*. Naturally creative non-deterministic processes, including self-determination, precisely fix quantitative (and qualitative) outcomes in nature *in the actual-world-sequence only*, without those outcomes either being *entailed or necessitated by*, or *Turing-computable by virtue of*, the Conservation Laws, the 1st and 2nd Laws of Thermodynamics, and specific non-probabilistic/non-stochastic of nature together with initial conditions/facts about the past, although naturally creative non-determinism, including self-determination, is still *consistent with and not in violation of* any natural laws there are—apart, of course, from the 2nd Law of Thermodynamics, which is *not* universally true if (as I'm supposing) non-equilibrium dynamics *is* universally true Again: *consistency with and non-violation of* the natural laws is sharply distinct from *entailment or necessitation by* the natural laws. Then I can say that according to the broadly Frankfurt-style source-incompatibilist conception of deeply responsible free agency that I'm talking about, rational human free agency *inherently involves naturally creative self-determination*, and thereby is characterized by neither classical determinism nor indeterminism.

8. Bell's Theorem, I think, is often or even usually taken to undermine *all* hidden variables theories; but in my opinion, actually what it undermines is only *local* hidden variables theories. So for the purposes of my present argument, let's assume *that* to be so (i.e., that Bell's Theorem undermines only local hidden variables theories). Then, if one is prepared to accept non-locality/entanglement/complementarity, it follows that one can still accept *non-local* hidden variables; and if the non-local hidden variables are *naturally creative processes*, especially including living organisms, amongst which are rational human animals and their *naturally creative self-determining processes*, it also follows that all the quantum facts can be explained using Bohmian mechanics and non-deterministic$_1$/non-indeterministic processes, and an irreversible time/anti-block world approach.

9. Relatedly, The Kochen-Specker Theorem, I think, is also often or even usually taken to undermine *all* hidden variable theories; but in my opinion, actually what it undermines is *only* those hidden variable theories that accept these three assumptions:

> **Value Realism (VR):** If there is an operationally defined real number α, associated with a self-adjoint operator **A** and if, for a given state, the statistical algorithm of QM for **A** yields a real number β with β = prob(*v*(**A**)=α), then there exists an observable *A* with value α.
> **Value Definiteness (VD):** All observables defined for a QM system have definite values at all times.
> **Noncontextuality (NC):** If a QM system possesses a property (value of an observable), then it does so independently of any measurement context. (Held, 2018: section 4)

But if one postulates, as I do, non-local hidden variables that are naturally creative processes, especially including living organisms, amongst which are rational human animals and their naturally creative self-determining processes, then since these sorts of naturally creative processes *inherently belong to, and are therefore inherently sensitive to, the measurement context of any quantum mechanical system*, then I can deny **Noncontextuality** and also assert a special, naturally creative kind of **Contextuality**, *consistently with* The Kochen-Specker Theorem.

10. The structure of quantum *superposition*—aka the "collapse" of Schrödinger's wave function—is essentially analogous to Frankfurt-style thought-experimental counterexamples to PAP, with the actual world of the scientific experimental situation *apart from* the experimenter/observer playing the role of Black (the counterfactual intervener who never actually has to intervene, but if he *did* have to intervene, *would have* collapsed/shut down the relevant alternative) and the experimenter/observer playing the role of Jones$_4$ (the free chooser who never needs the relevant but counterfactually collapsed/shut-down alternative, because he has already selected the outcome Black wants). The moral of the Frankfurt cases, as I see it, is that PAP is *not* required for deep responsibility by way of the naturally creative self-determination of free agency; and the essentially analogous moral of quantum superposition is that what precisely fixes the experimental/observational outcome is a set of naturally creative (including, in the case of rational human animals, self-determining) processes operating as non-local hidden variables for the Schrödinger wave function equation. Since there's always an actual experimenter/observer involved, they would be *a proper part* of the relevant naturally creative processes operating as non-local, measurement-context-sensitive hidden variables, but not *solely* responsible for what precisely fixes the experimental/observational outcome.

This in turn would reconcile the "pared-down truth" of the Copenhagen interpretation (the experimenter/observer indeed *necessarily belongs to* what is doing the physical and metaphysical work, *but without either intervention or requiring indeterminism*) and also the "pared-down truth" of the Bohmian hidden variables interpretation (hidden variables are indeed doing the physical and metaphysical work, *yet not only are they non-local, they also don't require classical determinism and they're measurement-context-sensitive*). To be sure, you *still* have pervasive complementarity/entanglement/non-locality, but it also seems to me that complementarity/entanglement/non-locality is simply a pervasive feature of the natural cosmos insofar as it contains non-mechanical physical processes and systems.

Q: Where does relativity fit into all this? **A:** You get the relativity view by narrowing formal and natural scientific attention to deterministic_1 natural processes and light-constrained causality, supplemented by gravitation, and also by imposing a 4-D non-Euclidean/Riemannian block-world picture that turns real dynamic/processual time into something that's fully "spatialized" and reversible. So, just as classical Newtonian mechanics (NM) shows up as a restricted or special case under relativity, so too relativistic Einsteinian mechanics (EM) shows up as a restricted or special case under the Bohmian-mechanics-plus-natural-creativity (BMPNC) transformation of classical Schrödinger (et al.)-style quantum mechanics plus quantum field theory (CQM + QFT): hence the transformative theoretical progression is NM→EM→(CQM + QFT)→BMPNC, and each right-facing arrow also implies proper containment of every theory to the left of it.

11. Now The Big Bang Singularity happened 9 billion years before unicellular organismic life emerged on Earth, roughly 4 billion years ago. But it's at least logically, metaphysically, and nomologically possible that unicellular organismic life could have emerged elsewhere in the universe quite a while before that. So I'm proposing (i) that all the non-local hidden variables for supplementing the Schrödinger equation are *either non-living or living naturally creative (including, in the case of rational human animals, self-determining) processes*, and (ii) that the non-living naturally creative processes were immediately produced by The Big Bang Singularity during the period of cosmic expansion, which then later gradually evolved into *living* processes, i.e., *organismic*, naturally creative processes, at least 4 billion years ago, and then later they evolved into *minded* organismic naturally creative processes, including the self-determining processes of rational human animals, who, as primitive sources of natural creativity, are capable of broadly Frankfurt-style source-incompatiblist deeply responsible rational human free will and practical agency, less than a billion years ago.

IV. An Experimental Argument That Implements The New Idea

Now, building on that eleven-step line of thought, I want to work out *an experimental argument* that implements the "new idea" expressed by that line of thought. Here's a non-technical description of the famous "two-slit experiment," framed against the backdrop of Bohmian mechanics:[۶]

> In modern physics, the [two]-slit experiment is a demonstration that light and matter can display characteristics of both classically defined waves and particles; moreover, it displays the fundamentally probabilistic nature of quantum mechanical phenomena. This type of experiment was first performed, using light, by Thomas Young in 1801, as a demonstration of the wave behavior of light. At that time it was thought that light consisted of either waves or particles. With the beginning of modern physics, about a hundred years later, it was realized that light could in fact show behavior characteristic of both waves and particles. In 1927, Davisson and Germer demonstrated that electrons show the same behavior, which was later extended to atoms and molecules…. Thomas Young's experiment with light was part of classical physics well before quantum mechanics, and the concept of wave-particle duality. He believed it demonstrated that the wave theory of light was correct, and his experiment is sometimes referred to as Young's experiment or Young's slits.
>
> The experiment belongs to a general class of "double path" experiments, in which a wave is split into two separate waves that later combine into a single wave. Changes in the path lengths of both waves result in a phase shift, creating an interference pattern. Another version is the Mach–Zehnder interferometer, which splits the beam with a mirror.
>
> In the basic version of this experiment, a coherent light source, such as a laser beam, illuminates a plate pierced by two parallel slits, and the light passing through the slits is observed on a screen behind the plate…. The wave nature of light causes the light waves passing through the two slits to interfere, producing bright and dark bands on the screen—a result that would not be expected if light consisted of classical particles…. However, the light is always found to be absorbed at the screen at discrete points, as individual particles (not waves); the interference pattern appears via the varying density of these particle hits on the screen…. Furthermore, versions of the experiment that include detectors at the slits find that each detected photon passes through one slit (as would a classical particle), and not through both slits (as would a wave)…. However, such experiments demonstrate that particles do not form the

interference pattern if one detects which slit they pass through. These results demonstrate the principle of wave–particle duality….

Other atomic-scale entities, such as electrons, are found to exhibit the same behavior when fired towards a double slit…. Additionally, the detection of individual discrete impacts is observed to be inherently probabilistic, which is inexplicable using classical mechanics…..

The experiment can be done with entities much larger than electrons and photons, although it becomes more difficult as size increases. The largest entities for which the double-slit experiment has been performed were molecules that each comprised 810 atoms (whose total mass was over 10,000 atomic mass units)….

The [two]-slit experiment (and its variations) has become a classic thought experiment, for its clarity in expressing the central puzzles of quantum mechanics. [According to Richard Feynman, b]ecause it demonstrates the fundamental limitation of the ability of the observer to predict experimental results, the two-slit experiment for electrons is

> a phenomenon which is impossible, *absolutely* impossible, to explain in any classical way, and which has in it the heart of quantum mechanics. In reality it contains the *only* mystery.[۷]
>
> This experiment has been designed to contain all of the mystery of quantum mechanics, to put you up against the paradoxes and mysteries and peculiarities of nature one hundred per cent.[۸]

As to the question,

> How does it really work? What machinery is actually producing this thing? Nobody knows any machinery. Nobody can give you a deeper explanation of this phenomenon than I have given; that is, a description of it.[۹]

But Bohmian mechanics is just such a deeper explanation. It resolves in a rather straightforward manner the dilemma of the appearance of both particle and wave properties in one and the same phenomenon: Bohmian mechanics is a theory of motion describing a particle (or particles) guided by a wave. Here we have a family of Bohmian trajectories for the two-slit experiment.

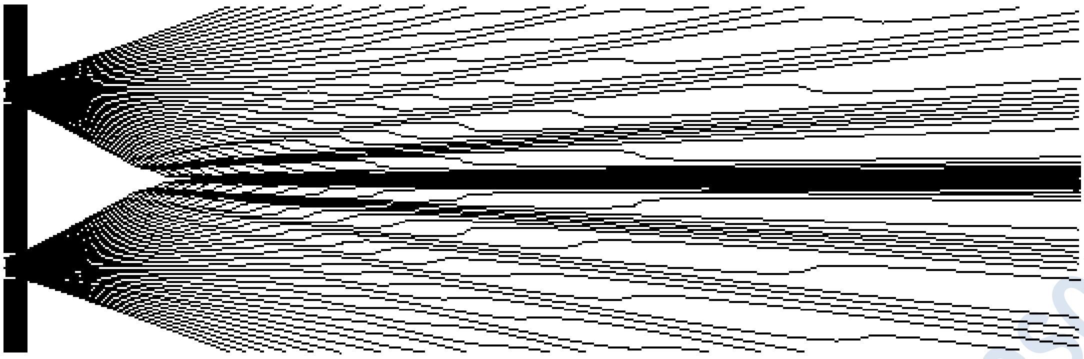


Figure 1: An ensemble of trajectories for the two-slit experiment, uniform in the slits. (…)

> While each trajectory passes through only one slit, the wave passes through both; the interference profile that therefore develops in the wave generates a similar pattern in the trajectories guided by the wave.
>
> Compare Feynman's presentation with Bell's:
>
> > Is it not clear from the smallness of the scintillation on the screen that we have to do with a particle? And is it not clear, from the diffraction and interference patterns, that the motion of the particle is directed by a wave? De Broglie showed in detail how the motion of a particle, passing through just one of two holes in screen, could be influenced by waves propagating through both holes. And so influenced that the particle does not go where the waves cancel out, but is attracted to where they cooperate. This idea seems to me so natural and simple, to resolve the wave-particle dilemma in such a clear and ordinary way, that it is a great mystery to me that it was so generally ignored.[10]
>
> Perhaps the most puzzling aspect of the two-slit experiment is the following: If, by any means whatsoever, it is possible to determine the slit through which the particle passes, the interference pattern will be destroyed. This dramatic effect of observation is, in fact, a simple consequence of Bohmian mechanics. To see this, one must consider the meaning of determining the slit through which the particle passes. This must involve interaction with another system that the Bohmian mechanical analysis must include. The destruction of interference is related, naturally enough, to the Bohmian mechanical analysis of quantum measurement.[11] It occurs via the mechanism that in Bohmian mechanics leads to the "collapse of the wave function."[12]

So much for the two-slit experiment.

Now, I want to describe an experiment designed to be *essentially analogous to the two-slit experiment*, that I call *the two-mirror experiment*. **First**, construct a double-mirror by attaching two identical square mirrors to one another at one of their edges, so that

that they form a right angle, and then place the double-mirror on a flat table in a well-lit room. **Second**, place a Dale's Pale Ale (or any other ordinary aluminum) beer can in the corner of the double-mirror, thereby creating two enantiomorphic (i.e., point-for-point and qualitative-property-for-qualitative-property identical, but topologically reversed in "handedness," and therefore incongruent) images of the beer can on the surfaces of the two mirrors. **Third**, place a healthy, mature rational human animal—let's call them "Freddy"—directly in front of the beer can, equidistant from both mirrors, such that, without having to change their location or extend either of their arms beyond a simple relaxed pointing gesture, Freddy is equally able to touch the right hand mirror at the location of the right hand beer can image with the index finger of their right hand, or the left hand mirror at the location of the left hand beer can image with the index finger of their left hand. **Fourth**, Freddy is instructed to *either* (i) utter "right" and then touch the corresponding right hand beer can image with their right index finger *or* (ii) utter "left" and then touch the corresponding left hand beer can image with their left index finger. **Fifth**, Freddy spontaneously and freely carries out the instructions.

In this essential analogy to the two-slit experiment, Freddy together with Freddy's intentional act correspond to *the Bohmian wavicle*, and the enantiomorphic mirror images—which, by hypothesis, are physically identical *except for* their topologically reversed handedness—correspond to *the double path*. As per the two-slit experiment and the Standard Models, it's impossible to predict which beer can image will be touched. As per Bohmian mechanics, however, *the hidden variables* determine which beer can image will be touched. But as per Bohmian mechanics *plus* the thesis that all rational human animals are primitive sources of natural creativity via their free agency, then Freddy together with Freddy's intentional act just *are* the relevant (non-local, measurement-context-sensitive) hidden variables. And Freddy, the rational human animal, can *always* predict *exactly which image will be touched*, simply by spontaneously and freely uttering "right" or "left" and then reaching out with their right arm and hand, or with their left arm and hand, respectively, and touching the right hand beer can image or left hand beer can image with their right or left index finger, respectively.

Let's now recall the three independently necessary and collectively sufficient criteria of what makes a new scientific theory **T2** count as *a better scientific theory* than a currently prevailing theory **T1**:

1. You have to reproduce all the successes of the currently prevailing theory; your new idea must succeed in all the places where the prior one succeeds.
2. You need to explain at least one existing observation or measurement that the current theory struggles with; you have to demonstrate why this new idea is more compelling than the one it's seeking to replace.

3. You need to make at least one new prediction that differs from the leading theory's predictions that you can then go out and measure; if your new idea is right, there must be a way to validate or refute it.

Some or another version of Bohmian mechanics satisfies criterion 1. And Bohmian-mechanics-plus-the-thesis-that-all-rational-human-animals-are-primitive sources-of-natural-creativity-via-their-free-agency satisfies criterion 2 and criterion 3. Therefore, according to the generally-accepted criteria of what counts as a better scientific theory, Bohmian-mechanics-plus-the-thesis-that-all-rational-human-animals-are-primitive sources-of-natural-creativity-via-their-free-agency *is a better scientific theory than the Standard Models*.

Q: If, by using explanatory methods based on mechanical principles alone, you've explained everything about physical nature that you can possibly explain, but this explanation is still *incomplete*, then what's left over? **A:** In the actual world, in addition to all mechanical physical systems, there's *also* a multiplicity of primitive sources of naturally creative processes that include, but are not restricted to, all living organisms, including rational human animals. Such actual-sequence, naturally creative self-determining processes *cannot* be explained *mechanically* by means of the Standard Models in contemporary physics; but they *can* be scientifically explained *non*-mechanically, by means of Bohmian mechanics together with the thesis that all rational human animals are primitive sources of natural creativity via their free agency.

Let me now briefly explain how this can *be*—pun fully intended.

John S. Bell's conception of physical theories, especially including quantum mechanics, prominently features the notion of a *beable*: [۱۳]

> "Beable" is Bell's term for those elements of a theory which are "to be taken seriously, as corresponding to something real."[۱۴]
>
> The beables of a theory have values that (according to the theory) are supposed to exist independently of any observation or experiment. In this regard Bell contrasts the notion of beable with the notion of "observable" which features prominently in orthodox quantum theory:
>
>> The concept of "observable" lends itself to very precise *mathematics* when identified with "self-adjoint operator." But physically, it is a rather woolly concept. It is not easy to identify precisely which physical processes are to be given the status of "observations" and which are to be relegated to the limbo between one observation and another. So it could be hoped that some increase in precision might

> be possible by concentration on the *be*ables, which can be described in "classical terms," because they are there.[15]

Correspondingly, my proposal for scientifically explaining actual-sequence, absolutely unique naturally creative processes, whether organismic or non-organismic, is for the physicist to imagine *what it's like to be* a naturally creative Bohmian beable, i.e., one or another of the naturally creative Bohmian non-local, measurement-context-sensitive hidden variables, and then experimentally measure whatever can be experimentally measured.

This idea of "what-it's-like-to-be," of course, draws directly on Thomas Nagel's famous essay, "What Is It Like To Be a Bat?"[16] But it also significantly extends Nagel's seminal idea of an actual or imagined first-person point-of-view (what-it's-like-to-be an *X*) from *minded* living organisms, whether non-rational or rational, to *non-minded* living organisms, to *non-minded, non-living* naturally creative processes and systems. In other words, what I'm proposing is that in order to explain actual-sequence, absolutely unique naturally creative processes and systems, the quantum physicist must either

(i) by an act of imaginative projection, place themselves *inside* the naturally creative Bohmian non-local hidden variables, construed as beables, thereby empathically mirroring their "Bohmian-beable wavicle's-eye point of view" (in the non-organismic case) or their "Bohmian-beable organism's-eye point of view" (in the case of non-minded or minded but non-rational living organisms) and ask themselves *precisely how* the beable itself creatively manages the delicate (non-organismic or organismic) homeostatic balance—thereby creating negentropy—between its inner states and its outer environment, via the causal powers of its (non-organismic or organismic) bodily membrane, and then experimentally measure whatever can be experimentally measured, or (ii) like Freddy, one can simply *be* that (macroscopic) naturally creative Bohmian beable, engage in successful/true predictions via rational human free agency, and then experimentally measure whatever can be experimentally measured.

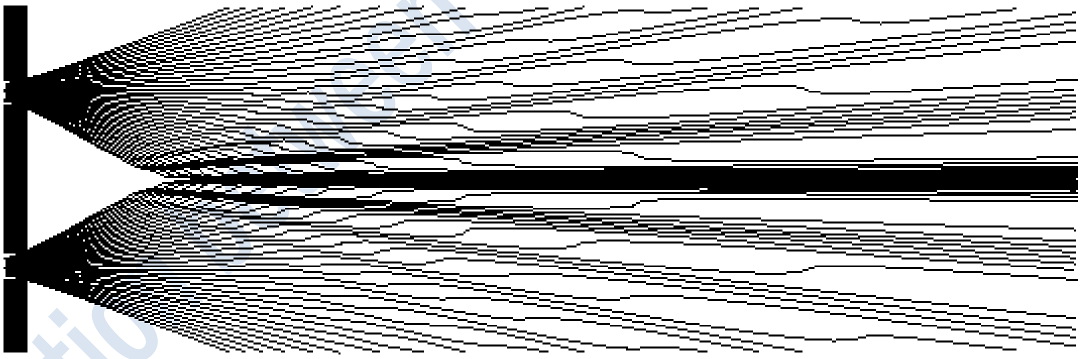
Let's call the first sub-method *empathic mirroring*, and the second sub-method *consciousness* (aka, "subjective experience"). In this sense, anyone's spontaneously freely-willed intentional bodily performance (say, Freddy's uttering "right" and then touching the right hand beer can image with their right index finger) is *the paradigm of a successful/true prediction*, precisely because what is *imagined* in the empathic mirroring sub-method (for example, what-it's-like-to-be a naturally creative Bohmian beable, i.e., one or another of the non-local, measurement-context-sensitive hidden variables that precisely determine$_2$ the evolution of the wave function according to Schrödinger's equation) is actually *realized* in the sub-method consisting in one's own consciousness or subjective experience of free agency.

In 1905, Einstein remembered himself, at age 16, imagining himself *chasing* a beam of light, which in turn directly led to his discovery of the basic idea of special relativity:

How could we be anything but charmed by the delightful story Einstein tells in his *Autobiographical Notes* of a striking thought he had at the age of 16? While recounting the efforts that led to the special theory of relativity, he recalled

> a paradox upon which I had already hit at the age of sixteen: If I pursue a beam of light with the velocity c (velocity of light in a vacuum), I should observe such a beam of light as an electromagnetic field at rest though spatially oscillating. There seems to be no such thing, however, neither on the basis of experience nor according to Maxwell's equations. From the very beginning it appeared to me intuitively clear that, judged from the standpoint of such an observer, everything would have to happen according to the same laws as for an observer who, relative to the earth, was at rest. For how should the first observer know or be able to determine, that he is in a state of fast uniform motion? One sees in this paradox the germ of the special relativity theory is already contained. (Norton, 2013: p. 123)

Similarly, as a post-Einsteinian, post-Standard-Models, non-mechanistic Bohmian quantum physicist, you can imagine yourself *being* one or another of the naturally creative non-local, measurement-context-sensitive hidden variables that satisfy the Schrödinger equation for the evolution of the wave function, which, by means of "your"/its naturally self-determining non-equilibrium thermodynamic activity, *body-surfs the Bohmian wavicle* as it flows through the two-slit device in the two-slit experiment, as per the diagram originally displayed above, i.e.,



thereby fixing all the relevant measurable quantities in nature, all the way down to their maximum level of finegrainedness.

V. Conclusion

In short, and to conclude, my new idea about quantum mechanics is that the Bohmian-beables, i.e., the naturally creative non-local, measurement-context-sensitive hidden variables—including, but not restricted to organisms and their activities, including rational human free agency—successfully/truly *predict* the evolution of the wave function by just *being themselves*, followed by experimental measurement of whatever can be experimentally measured, and *that* (and that *alone*) completes quantum mechanics.

Notes:

1 Ade PAR et al. (Planck Collaboration). Planck 2013 results. I *Overview of products and scientific results*. Astronomy and Astrophysics. 2014;571:A1, 48pp. (Robson, 2021: footnote 1).
2 Gottfried K, Weisskopf VF. *Concepts of Particle Physics*. Vol. 1. New York: Oxford University Press; 1984. 189pp. (Robson, 2021: footnote 2).
3 Einstein A. *The basics of general relativity theory*. Annals of Physics. 1916;49:769-822. (Robson, 2021: footnote 3).
4 Robson BA. *The generation model of particle physics*. In: Kennedy E, editor. Particle Physics. Rijeka: InTech; 2012. pp. 1-28. (Robson, 2021: footnote 4).
5 See (Goldstein, 2017: section 4).
6 This description combines material from (i) (Wikipedia, 2021)and (ii) (Goldstein, 2017: section 6). I've also moved some of Goldstein's references into my footnotes.
7 (Feynman, Leighton, and Sands, 1963: p. 37).
8 (Feynman, 1967: p. 130).
9 (Feynman, 1967: p. 145).
10 (Bell, 1987c: p. 191).
11 (Bohm, 1952).
12 (Goldstein, 2017: section 8).
13 (Goldstein, Norsen, Tausk, and Zanghi, 2011). I've also moved some of Goldstein et al.'s notes into my footnotes.
14 (Bell, 1987d: p. 239).
15 (Bell, 1987b: p. 52, italics in the original).
16 (Nagel, 1979).

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