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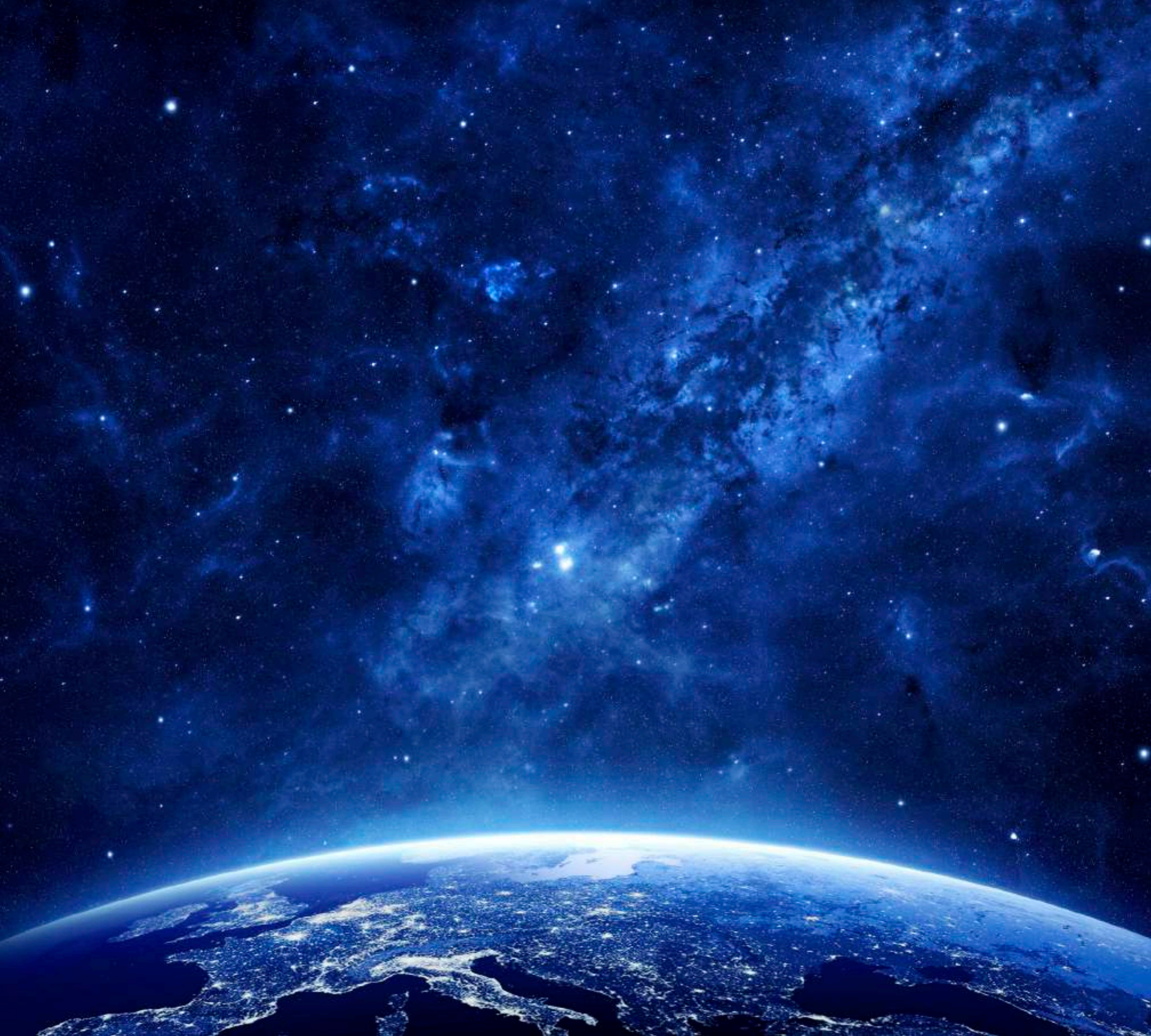

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Divine Action and the World of Science: What Cosmology and Quantum Physics Teach Us about the Role of Providence in Nature[1]

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Abstract: Modern science has revealed a world far more exotic and wonder-provoking than our wildest imaginings could have anticipated. It is the purpose of this essay to introduce the reader to the empirical discoveries and scientific concepts that limn our understanding of how reality is structured and interconnected—from the incomprehensibly large to the inconceivably small—and to draw out the metaphysical implications of this picture. What is unveiled is a universe in which Mind plays an indispensable role: from the uncanny life-giving precision inscribed in its initial conditions, mathematical regularities, and natural constants in the distant past, to its material insubstantiality and absolute dependence on transcendent causation for causal closure and phenomenological coherence in the present, the reality we inhabit is one in which divine action is before all things, in all things, and constitutes the very basis on which all things hold together (Colossians 1:17).

§1. Introduction: The Intelligible Cosmos

For science to be possible there has to be order present in nature and it has to be discoverable by the human mind. But why should either of these conditions be met? Albert Einstein (1879-1955) famously remarked that "the eternal mystery of the world is its comprehensibility. . . . [t]he fact that it is comprehensible is a miracle."[2] If there were no sufficient cause explaining why the universe exists, if it were taken as a brute fact, there would indeed be no reason to expect the universe to be ordered, let

1. This essay is a synthesis of ideas I have discussed more extensively in other places; I thank the anonymous reviewers for comments that have improved the cohesion of the narrative. For a more complete treatment of various concepts discussed here, please see various articles of mine mentioned in subsequent footnotes.

2. Albert Einstein, "Physics and Reality," *Ideas and Opinions* (New York: Crown Publishers, 1954), 292. Originally published in *The Journal of the Franklin Institute* 221, no. 3 (1936).

alone for that order to be amenable to the human mind.[3] Of course, if the universe we inhabit is the product of the mind of God, there need be no mystery here. In the Judeo-Christian worldview, nature exists and is regular not because it is closed to divine activity, but because (and *only* because) *it is the operative product of divine causality*. It is only because nature is a creation and thus *not* a closed system of causes and effects that it exists in the first place and exhibits the regular order that makes science possible. And this order is amenable to the human mind because we are created in the image of God with the capacity to understand. God's existence and action are not, therefore, an obstacle to science; rather, they provide the very basis of its possibility.[4]

It is all very well to state this, but it is hardly compelling if there is no evidence that our universe has originated and operates by the action of a particular providence. So *does* the reality we inhabit bear the hallmarks of transcendent intelligent causation, and *does* scientific investigation lead us to its discovery? In a word, yes. It is the purpose of this essay to show how the evidence from cosmology and quantum physics

3. These themes are explored ably in the following works: James Beilby, ed., *Naturalism Defeated? Essays on Plantinga's Evolutionary Argument Against Naturalism* (Ithaca: Cornell University Press, 2002); William Lane Craig and J. P. Moreland, *Naturalism: A Critical Analysis* (New York: Routledge, 2000); Stewart Goetz and Charles Taliaferro, *Naturalism* (Grand Rapids, MI: Eerdmans, 2008); Bruce L. Gordon, "The Rise of Naturalism and Its Problematic Role in Science and Culture" *The Nature of Nature: Examining the Role of Naturalism in Science*, Bruce L. Gordon and William A. Dembski, eds. (Wilmington: ISI Books, 2011), 3-61; Bruce L. Gordon, "In Defense of Uniformitarianism," *Perspectives on Science and Christian Faith* 65, no.2 (2013): 79-86; C. S. Lewis, *Miracles: A Preliminary Study* (New York: Macmillan, 1947, repr. 1960); Ronald Nash, "Miracles and Conceptual Systems," in *In Defense of Miracles: A Comprehensive Case for God's Action in History*, ed. R. Douglas Geivett and Gary Habermas (Downers Grove, IL: IVP Academic), 115-31; Alvin Plantinga, *Warrant and Proper Function* (New York: Oxford University Press, 1993); Alvin Plantinga, "Against Materialism," *Faith and Philosophy* 23, no. 1 (2006): 3-32; Alvin Plantinga, "Evolution versus Naturalism," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce L. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 137-51; Alvin Plantinga, *Where the Conflict Really Lies: Science, Religion, and Naturalism* (New York: Oxford University Press, 2011); Michael Rea, *World Without Design: The Ontological Consequences of Naturalism* (New York: Oxford University Press, 2002); and Mark Steiner, *The Applicability of Mathematics as a Philosophical Problem* (Cambridge: Harvard University Press, 1998).

4. Gordon, "Rise of Naturalism," 3-61; Gordon, "Uniformitarianism," 79-86; Bruce L. Gordon, "Intelligibility of the Universe," in *Dictionary of Christianity and Science*, ed. Paul Copan *et al* (Grand Rapids, MI: Zondervan), 387-89; Bruce L. Gordon, "The Necessity of Sufficiency: The Argument from the Incompleteness of Nature," in *Two Dozen (or so) Arguments for God: The Plantinga Project* (Oxford: Oxford University Press, forthcoming 2017); Alvin Plantinga, *Where the Conflict Really Lies: Science, Religion, and Naturalism* (Oxford: Oxford University Press, 2011).

enables us to infer it.[5] Our discussion of cosmology will start with the Big Bang and the implications of the universe having an absolute beginning in the finite past, then consider the efforts of quantum cosmologists to mitigate this conclusion, why these efforts fail, and the parallel evidence for design inherent in their proposals. This will lead into a brief discussion of the ways in which the fine-tuning of the universe for life—inclusive of its initial conditions, law-like regularities, and natural constants—is reflective of intelligent causation and how further efforts by theoretical cosmologists to obviate this fine-tuning both fail and undermine scientific rationality in the process. In short, current attempts to obviate the conclusion that the universe had an absolute beginning and is intelligently fine-tuned for the existence of life create conditions under which probabilistic reasoning falters and *anything* that could happen does happen—infinitely many times.[6] The third section of the essay will move from the physics of the very large to that of the very small, considering quantum theory and its description of the behavior of reality at the atomic and subatomic levels. We will find that quantum phenomena—which encompass physically incompatible states in superposition, the nonlocalizability of single quanta, and instantaneous correlations that, on pain of experimental contradiction, have no physical explanation—are incompatible with the reality of material substances[7] and, furthermore, that there is an objective indeterminacy in the operation of the physical universe that is indicative of its causal incompleteness. It is not quantum mechanics that is incomplete, as Einstein once argued, but rather what we call "physical reality" itself. We will also see that the metaphysical incompleteness of "physical reality" entails two things, namely

5. A similar discussion may be had in biology, but it lies beyond the scope of this essay. For readers interested in this subject, I recommend the following works: Douglas Axe, *Undeniable: How Biology Confirms Our Intuition that Life is Designed* (San Francisco: HarperOne, 2016); William A. Dembski, *The Design Revolution: Answering the Toughest Questions about Intelligent Design* (Downers Grove, IL: InterVarsity, 2004); William A. Dembski and Jonathan Wells, *The Design of Life: Discovering Signs of Intelligence in Biological Systems* (Dallas: The Foundation for Thought and Ethics, 2008); Bruce L. Gordon and William A. Dembski, eds., *The Nature of Nature: Examining the Role of Naturalism in Science* (Wilmington: ISI Books, 2011); Stephen C. Meyer, *Signature in the Cell: DNA and the Evidence for Intelligent Design* (San Francisco: HarperOne, 2009); Stephen C. Meyer, *Darwin's Doubt: The Explosive Origin of Animal Life and the Case for Intelligent Design* (San Francisco: HarperOne, 2013); Jonathan Wells, *The Myth of Junk DNA* (Seattle: Discovery Institute Press, 2011); Thomas Woodward and James Gills, *The Mysterious Epigenome: What Lies Beyond DNA* (Grand Rapids, MI: Kregel, 2012).

6. Max Tegmark, "Infinity is a Beautiful Concept—And It's Ruining Physics," in *This Idea Must Die: Scientific Theories that are Blocking Progress*, ed. John Brockman (New York: Harper Perennial, 2015), 48-51.

7. There is a weaselly kind of materialism that tries to adjust the content of the thesis that "all is matter" again and again when a once-favored account of what it means for something to be a material object is rendered untenable by the progress of physical theory. The disingenuous character of this retrenchment strategy is made plain in materialism's confrontation with quantum physics, however, since there are no sufficient criteria by which to identify and individuate the fundamental constituents of "material" reality in quantum theory, and no sustainable notion of material substance. See Bruce L. Gordon, "A Quantum-Theoretic Argument against Naturalism," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce L. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 179-214.

that: (1) the regularity of nature, while mathematically describable, has no physical explanation; and (2) since the principle of sufficient reason—the requirement that every contingent event must have an explanation—is foundational to the practice of science and necessary for both metaphysical coherence and the avoidance of an extreme skepticism, when no physical explanation is possible for why one event rather than another occurred, a metaphysical explanation must be forthcoming. This metaphysical explanation comes in the form of God's active providential governance of the universe's day-to-day operation: the quantum-mechanical probabilities for observing certain outcomes are neither more nor less than *ceteris paribus* counterfactuals of divine freedom, that is, objective expressions of the probability that God will act in a certain way to produce the natural phenomena we observe, all other things being equal.[8] In short, there is no such thing as secondary causation providing order to a world of created material *substances*: quantum mechanics reveals the Thomistic view of divine providence to be untenable. The inanimate natural world is not now, nor has it ever been, metaphysically substantial in a way that would provide a foothold for secondary causation; it is wholly and completely, at every instant of its being, a free phenomenological construct of divine causality that incorporates, accommodates, and provides the metaphysical background for the free

8. It is worthwhile noting that Lydia Jaeger, drawing on the work of Peter Mittelstaedt, has argued that the objective indeterminacy of quantum outcomes is such that "not even an omniscient Being can know it, nor can an omnipotent Being (or anybody else) influence or change it. The indeterminacy is objective and does not provide any room for divine action without violating the quantum mechanical laws" (Lydia Jaeger, "Against Physicalism-Plus-God: How Creation Accounts for Divine Action in Nature's World," *Faith and Philosophy* 29, no. 3 (2012): 298; see also Lydia Jaeger, *What the Heavens Declare: Science in the Light of Creation* [Eugene, OR: Cascade Books, 2012], 90-93; J. B. Stump has repeated and popularized this claim in his *Science and Christianity: An Introduction to the Issues* [Malden: Wiley-Blackwell, 2017], 128). While it is true that quantum indeterminacy is *physically* objective and so there is no local fact of the matter to be known about quantum outcomes before they are observed—and supposing there is leads to Bell inequalities that the relevant quantum system will then violate—this does *not* entail that it is *metaphysically* impossible for God to create quantum outcomes *as they happen* in a way that maintains the validity of quantum-mechanical descriptions. Jaeger's mistake—inherited from those she is criticizing—is to assume that quantum mechanics describes the indeterministic behavior of a *substantial* material reality created by God to function in accordance with *secondary causation*, God himself being the primary cause (see Jaeger, *What the Heavens Declare*, 93). But God is *not* acting in the causal gaps of a secondary-causal structure; rather, divine causality *constitutes* the moment-by-moment reality of any and all quantum phenomena, *tout court*. And it could not be otherwise, for as we shall see in what follows, there is no substantial material reality compatible with quantum-mechanical description that could instantiate and sustain secondary causality, and Jaeger's view would also require God to create a universe in which the principle of sufficient reason was false, which leads to metaphysical absurdity as well as science-destroying skepticism. In particular, if it were possible for contingent events to happen without any explanation, i.e., without a sufficient cause, then the contingent event constitutive of the universe as a whole might be one of those things, and God would not be necessary to explain its existence. It seems strange at best to think that God could, let alone would, create conditions that imply his existence is optional. And of course, if it can be the case that there is no sufficient reason why one thing happens rather than another, your current perception of reality and its accompanying memories may be happening for no reason at all, so the world you think you are experiencing may not even exist. How would you know?

choices and actions of the finite minds God places within it. If that does not grab your attention, nothing will. I trust these claims have whet your appetite for the details and arguments to follow, so let us begin.

§2. Cosmology and the Evidence of Divine Action

Contemporary scientific cosmology begins with Albert Einstein, whose 1915 theory of general relativity replaced the theory of gravity developed by Isaac Newton (1642-1727). Gravitational forces affect the structure of the universe on scales both small and large, and one of the things that bothered Einstein about Newton's theory was that gravitational force, for Newton, acted *instantaneously* across any distance, no matter how great. For example, in Newton's theory, the motion of the planets around the Sun in our solar system has an immediate (though very weak) gravitational effect on the opposite side of the universe. Such action-at-a-distance had always been controversial, but in 1905 Einstein had shown in his special theory of relativity that the speed of light was the limiting velocity in the universe at which any physical cause could have an effect, so he knew that Newton's theory needed to be modified. General relativity fixed the problem. In Einstein's theory, the presence of matter had gravitational effects that change the structure of spacetime around it as gravitational waves ripple outward from massive objects at the speed of light. The physicist John Wheeler succinctly summarized the situation by saying that, in general relativity, matter tells spacetime how to curve and spacetime tells matter how to move.[9] In this way, Einstein succeeded in eliminating the instantaneous action-at-a-distance that was part and parcel of Newton's theory, and the modern study of the universe was born.

Big Bang Cosmology and the Origin of the Universe

Big Bang cosmology—the currently accepted model for the beginning of the universe—has its theoretical basis in general relativity, which predicts that space itself is expanding and therefore, if we were to reverse the direction of time, would be contracting. In both special and general relativity space and time are not separate entities, but rather mathematically fused into a four-dimensional structure: spacetime. As Roger Penrose and Stephen Hawking showed in the late 1960s, no matter which general-relativistic model of our universe is chosen, every temporal path backward through spacetime leads to a beginning point in the finite past—a singularity, to use the technical term—from which not just matter and energy, but spacetime itself, emerged. This coming into existence of the universe from *nothing* (no space, no time, no matter, no energy, and hence no physical laws either) is, as the agnostic astronomer

9. John Archibald Wheeler, *Geons, Black Holes, and Quantum Foam* (New York: Norton & Company, 2000), 235.

Robert Jastrow once observed, startling evidence for the doctrine of creation *ex nihilo*. He famously put it this way

> For the scientist who has lived by his faith in the power of reason,[10] the story ends like a bad dream. He has scaled the mountain of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries.[11]

Having grasped that Big Bang cosmology implies a cause for physical reality that transcends the universe, the natural question to ask is what evidence there is for its truth.[12] The first evidence for it came in the late 1920s when the American astronomer, Edwin Hubble, discovered that there were countless galaxies outside our own Milky Way and the light we receive from them is stretched toward the red end of the light spectrum. What is more, the farther away these galaxies are, the greater the shift in wavelength toward the red. This means that these galaxies are moving away from us at great speed and the farther away they are, the faster they are receding from us. But if the universe is flying apart as time moves forward, then if time were moving backward, the universe would be coalescing back into the singularity from which it emerged. The observed expansion rate of the universe allows us to calculate how much time has elapsed since the Big Bang: the currently accepted figure is that the universe is 13.7 billion years old. This is not the only evidence for the Big Bang, however. As the physicist George Gamow demonstrated in 1948, one of the predictions of the theory is the existence of gravitational ripples and cosmic microwave background (CMB) radiation that are "echoes of Creation", as it were, permeating the whole universe. The CMB was discovered in 1965 by Robert Wilson and Arno Penzias, earning them a Nobel Prize. Gravitational waves are much subtler and have just recently been reported to have been detected—though this result is still being subjected to critical scrutiny—but their existence is not doubted. A final prediction of the Big Bang, calculated by Gamow's graduate student, Ralph Alpher, was the relative abundance of the lightest elements (hydrogen and helium) in the universe. The existence of the heavier elements is explained by their formation through nuclear fusion in stars and their subsequent dispersion when those stars explode as supernovae. But the existence of the lightest elements has no explanation beyond the Big Bang itself, which predicts their relative abundance quite accurately. In short, Big Bang cosmology is well-confirmed, justifiably believed, and points to a moment of creation that implies a Creator.

10. Jastrow might better have said "faith in the sufficiency of material explanations" because the inference from the *ex nihilo* generation of the universe to a transcendent intelligent cause is eminently reasonable.

11. Robert Jastrow, *God and the Astronomers* (New York: Norton & Company, 1978), 116.

12. For an account of the controversy that once surrounded the model, see Helge Kragh, *Cosmology and Controversy: The Historical Development of Two Theories of the Universe* (Princeton: Princeton University Press, 1996).

This triumph of evidence and explanation gives us a good understanding of the universe back to the time right after the strong force, which holds the nucleus of the atom together, separated from the electroweak force (between 10^{-32} and 10^{-12} seconds after the Big Bang), but physics before this point is *highly speculative*. All physics breaks down at a singularity, and since quantum effects in the gravitational field should manifest at sizes smaller than the Planck length (10^{-35} meters)—which was the size of the observable universe *prior* to the Planck time of 10^{-43} seconds—this era in universal history (from 0 to 10^{-43} seconds) is known as the *Planck Epoch*. Speculations pertaining to this epoch form a branch of theoretical physics known as *quantum cosmology*, work in which is largely pursued by theoreticians uncomfortable with the idea that the universe had a beginning that physics cannot explain, a situation they attempt to obviate by applying quantum descriptions to the earliest stage of the universe under the assumption that a coherent quantum treatment of the gravitational field (i.e., a theory of quantum gravity) will someday be discovered.

Before we discuss the severe limitations and fine-tuning inherent in quantum cosmological models, let me round out the discussion of universal origins by outlining the origin of the four fundamental forces of nature (strong, weak, electromagnetic, and gravitational). Immediately following the Planck Epoch is the *Grand Unification Epoch*, which extends from about 10^{-43} seconds to 10^{-36} seconds. In this epoch, the symmetries that unified the four fundamental forces spontaneously started to break as energy levels dropped, and gravity separated from the other three forces. It is then conjectured that the separation of the strong nuclear force from the electroweak unification of the two remaining forces (electromagnetism and the weak force, which accounts for radioactive decay) catalyzed a period of exponential cosmic expansion (the subject of inflationary cosmology) that lasted from around 10^{-36} to 10^{-32} seconds and distributed radiation and matter (the latter in the form of a quark-gluon plasma) relatively uniformly throughout the size of the observable universe (which at this point was a volume ranging in size from 10 centimeters to a meter in diameter, depending on the parameters of the inflationary model). It is from this point in the history of the universe that the well-understood physics of the Standard Model and Big Bang cosmology takes over. In other words, *prior* to 10^{-32} seconds after the actual beginning of the universe, speculative models abound and testable assumptions are few and far between. We begin our discussion of these speculative models with a brief examination of quantum cosmology before moving on to discuss the assumptions used to extend the observational basis of cosmology to the global structure of the universe, the fine-tuning it exemplifies, and the problematic ways in which theoretical cosmologists have tried to eliminate this fine-tuning.

Quantum Cosmology

The most famous quantum cosmologist is Stephen Hawking, who popularized his approach to the subject in the best-selling book *A Brief History of Time*.[13] In this book, he gave a popular account of the "no-boundary proposal" he developed with another physicist, James Hartle. We cannot go into detail here,[14] but let me briefly list some problems with the model in light of its intended goal of erasing a beginning to time. *First*, it presumes we have a consistent quantum theory of gravity. We do not, and if someday we do, it may not fit with the Hartle-Hawking approach. *Second*, the proposal makes essential use of the many-worlds interpretation of quantum theory (something we will discuss in section three below), a highly contentious viewpoint with the bizarre implication that there are countless realities parallel to our own with exponentially more coming into existence every second. *Third*, the proposal involves using a mathematical transformation that changes the structure of spacetime to make the equations solvable. While the transformation eliminates the singularity at the beginning of time—one of the goals of quantum cosmology—this singularity reappears when the mathematical trick is reversed so that the model describes the spacetime of our universe. So Hawking's famous question "What place, then, for a Creator?",[15] predicated on a universe with no beginning, falls completely flat on two counts: first, when the transformation is reversed, as it must be if the solution is to describe our reality, the universe *does* have a beginning; and secondly, even if, mathematically speaking, the universe did *not* have a beginning, it would still be something *with highly contingent properties* and so would require an explanation for its existence. In such case, the best explanation would seem to be God himself as the timeless and necessarily existent transcendent cause of a contingent universe with no temporal beginning.[16]

A *fourth* problem, as quantum cosmologist Alexander Vilenkin has rightly observed, is that "an observational test of quantum cosmology does not seem possible. Thus . . . quantum cosmology is not likely to become an observational science."[17] The

13. Stephen W. Hawking, *A Brief History of Time: From the Big Bang to Black Holes* (New York: Bantam, 1988).

14. For a technical critique, see Bruce L. Gordon, "Balloons on a String: A Critique of Multiverse Cosmology," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce L. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 558-601, especially pages 563-69. For a more accessible discussion, see Bruce L. Gordon, "Cosmology, Contemporary," in *Dictionary of Christianity and Science*, ed. Paul Copan *et al* (Grand Rapids, MI: Zondervan), 124-27 and John Lennox, *God and Stephen Hawking: Whose Design Is It Anyway?* (Oxford: Lion Hudson, 2011).

15. Hawking, *Brief History of Time*, 141.

16. Robert C. Koons, "A New Look at the Cosmological Argument," *American Philosophical Quarterly* 34 (1997): 171-92; Alexander Pruss, "Leibnizian Cosmological Arguments," in *The Blackwell Companion to Natural Theology*, ed. William L. Craig and J. P. Moreland (Oxford: Blackwell, 2009), 24-100.

17. Alexander Vilenkin, "Quantum Cosmology and Eternal Inflation" (2002), accessed June 29, 2017, https://arxiv.org/pdf/gr-qc/0204061v1. pdf.

idea of a “scientific” conjecture being forever beyond observational testing should give us pause. *Fifthly*, given that one of the purposes of quantum cosmology is to avoid finely-tuned physical models describing the beginning of the universe, it fails spectacularly. The no-boundary proposal requires an infinite winnowing (fine-tuning) of mathematical structures to get its technical machinery off the ground, establish the right relationship between matter variables and the curvature of space, and render the geometry of our universe probable (typical) within its description. In short, the reality we inhabit turns out to be very special indeed, which brings us, *sixthly* and lastly, to Hawking’s most lucid question: “What is it that breathes fire into the equations and makes a universe for them to describe?”[18] The fact that one can write down a mathematical equation does not mean that any physical reality corresponds to it, and abstract entities like mathematical equations have no causal powers of their own. So even if quantum cosmological descriptions were correct—and there is no accessible physical evidence that could ever indicate they are—the reality they describe would *still* require a transcendent explanation, and the model itself would *still* embody finely-tuned parameters that point to a transcendent intelligent cause.

Observational Astronomy and Extrapolations to the Global Structure of the Universe

Before considering other aspects of cosmology suggestive of an intelligent cause and the efforts by various contemporary cosmologists to avoid this implication, we need to reflect for a moment on how what we *can* see (the observable universe) is used to make inferences about what we *cannot* see (the global structure of the whole universe). The equations of general relativity have a perplexing variety of solutions, each representative of different spacetime geometries with different global properties. Since the speed of light is the limiting signal speed in the universe, we only ever have access to information about our *local* part of spacetime—the “past light cone” within which light has had time to reach us since the beginning of the universe—and, while the equations of general relativity decree a specific *local* relationship between spacetime geometry and the distribution of matter and energy, there are no *global* constraints that would warrant an inference, on the basis of our local observations, to a “best” model for the global structure of the universe.[19] Furthermore, even within our local environment, the current wisdom is that explaining what we see using general relativity requires attributing ninety-six percent of the mass-energy density of the universe to new entities that cannot be seen directly (“dark matter” and “dark energy”), the existence of which is inferred from its alleged gravitational effects. This inference is based, however, on assumptions and extensions in accepted theories that can be questioned, raising the possibility that some alternative gravitational theory

18. Hawking, *Brief History of Time*, 174.

19. John Manchak, “Can We Know the Global Structure of Spacetime?” *Studies in History and Philosophy of Modern Physics* 40 (2008): 53-56.

could explain what we can see *without* invoking new kinds of matter and energy that we cannot see.[20]

In regard to the nature of the universe beyond our horizon of observability, is there any basis on which claims regarding its global structure can be made? In order to apply general relativity to the universe as a whole, Einstein assumed something called the *cosmological principle*: on large scales, spacetime geometry is homogeneous (mass-energy is evenly distributed) and isotropic (the universe looks basically the same in every direction from every location). While not an unreasonable assumption, adopting this principle means that calculations of global structure that are justified on this basis can be challenged. Even cosmic inflation,[21] invoked to explain the homogeneity and isotropy of the *observable* universe, only succeeds, if correct, in pushing potential inhomogeneities beyond the horizon of what we can see. Arguments for the cosmological principle range from its utility as a simplifying assumption to its being a necessary condition for global theorizing in cosmology,[22] but quite apart from such pragmatic considerations, its status as a *metaphysical* assumption used to extend cosmological research into arenas beyond the observable, however reasonable, should be recognized.

Furthermore, as Guillermo Gonzalez and Jay Richards[23] have noted by way of ideological progression, the relatively innocuous cosmological principle has come to be identified with another more general idea known variously as the *Copernican Principle*, or the *Principle of Mediocrity*, or the *Principle of Indifference*. The principle of mediocrity proclaims that there is nothing exceptional about the time or place of the Earth in the universe, or more pointedly, it proclaims that "the universe is not organized for our benefit and we are not uniquely privileged observers."[24] In other words, the universe is not designed with us in mind, we are not here for any transcendent purpose, and we are about as metaphysically insignificant as our astronomical location would seem to indicate (which is to say, we matter not one whit). In this latter guise, the principle of mediocrity is an extension of scientific materialism, the view that material reality is all there is, ever was, and ever will be, and we live in a universe that is indifferent to our existence. Against this background, science is frequently praised as our only "candle in the dark," our only means to truth

20. Christopher Smeenk, "Cosmology," in *The Routledge Companion to the Philosophy of Science*, 2nd ed., ed. Martin Curd and Stathis Psillos (New York: Routledge, 2014), 609-20.

21. See the discussion below and the account in Alan Guth, *The Inflationary Universe: The Quest for a New Theory of Cosmic Origins* (Reading: Perseus Books, 1997).

22. Claus Beisbart, "Can We Justifiably Assume the Cosmological Principle in Order to Break Underdetermination in Cosmology?" *Journal for General Philosophy of Science* 40 (2009): 175-205.

23. Guillermo Gonzalez and Jay Richards, *The Privileged Planet: How Our Place in the Cosmos is Designed for Discovery* (Washington, D.C.: Regnery, 2004), 247-74.

24. Jim Baggott, *Farewell to Reality: How Modern Physics Has Betrayed the Search for Scientific Truth* (New York: Pegasus Books, 2013), 23.

in an implacable universe, so scientific materialism often has scientism as a close companion.

The principle of mediocrity can be challenged in a variety of ways, not just by considering the singular properties of the Earth and its local environment,[25] but also on the basis of what physics dictates the cosmological conditions must be for the universe to be habitable.[26] One of the key discoveries of contemporary cosmology is that we live in a "Goldilocks universe" that is "just right" in the sense of being fine-tuned for the existence of embodied conscious beings such as ourselves.[27] Most of us intuitively grasp that the precise correlation of the properties necessary for the universe to be habitable with the extraordinarily fine-tuned initial conditions, law—like natural regularities, and values for the constants of nature is an overwhelming coincidence which—when the demonstrable inadequacy of undirected material mechanisms to produce it and the obvious causal sufficiency of intelligent agency to explain it are appreciated–warrants an inference to intelligent design. Nonetheless, there has been a debate among philosophers of science and mathematicians as to how the probability of such fine-tuning can be measured and evaluated in a way that would

25. Guillermo Gonzalez, "Habitable Zones and Fine-Tuning," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce L. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 602-38; Gonzalez and Richards, *Privileged Planet*; and Hugh Ross, "Probability for Life on Earth" (2004), accessed June 29, 2017, www.reasons.org/articles/probability-for-life-on-earth.

26. Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life" (2012), accessed June 29, 2017, https://arxiv.org/pdf/1112.4647.pdf; John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986); Robin Collins, "A Scientific Argument for the Existence of God: The Fine-Tuning Design Argument," *Reason for the Hope Within*, ed. Michael J. Murray (Grand Rapids, MI: Eerdmans), 47-75; Robin Collins, "Evidence for Fine-Tuning," in *God and Design: The Teleological Argument and Modern Science*, ed. Neil A. Monson (New York: Routledge, 2003), 178-99; Robin Collins, "The Teleological Argument: An Exploration of the Fine-Tuning of the Universe," in *The Blackwell Companion to Natural Theology*, ed. William L. Craig and J. P. Moreland (Oxford: Blackwell, 2009), 202-81; Robin Collins, "The Fine-Tuning Evidence is Convincing," in *Debating Christian Theism*, ed. J. P. Moreland, Chad Meister, and Khaldoun A Sweis (New York: Oxford University Press, 2013), 35-46; Paul Copan and William Lane Craig, *Creation out of Nothing: A Biblical, Philosophical, and Scientific Exploration* (Grand Rapids, MI: Baker Academic, 2004); P. C. W. Davies, *The Accidental Universe* (Cambridge: Cambridge University Press, 1982); Bruce L. Gordon, "Inflationary Cosmology and the String Multiverse," *New Proofs for the Existence of God: Contributions of Contemporary Physics and Philosophy*, ed. Robert J. Spitzer (Grand Rapids, MI: Eerdmans, 2010), 75-103; Gordon, "Balloons on a String," 558-601; Rodney D. Holder, *God, the Universe, and Everything: Modern Cosmology and the Argument from Design* (Burlington: Ashgate, 2004).

27. Barnes, "Fine-Tuning;" Barrow and Tipler, *Anthropic Cosmological Principle*; Collins, "Scientific Argument;" Collins, "Evidence for Fine-Tuning;" Collins, "Teleological Argument;" Collins, "Fine-Tuning Evidence is Convincing;" Holder, *God, the Multiverse, and Everything*.

warrant such a design inference.[28] A sophisticated and broadly accepted approach has been developed by Robin Collins, but we cannot examine its details here.[29] Instead, we will take a look at how the fine-tuning of our universe manifests itself on three levels–the initial conditions governing the Big Bang, the mathematical form of the laws of nature, and the precise values of many of the constants of nature[30]–and indicate why the undirected mechanisms of a speculative "multiverse cosmology" can never provide a sufficient basis for its explanation.

The Fine-Tuning of the Regularities of Nature

One aspect of cosmological fine-tuning is the mathematical form taken by the regularities of nature. There is an uncountable infinity of possible mathematical forms. How is it that nature exhibits mathematical regularities of a form requisite to a universe that is *habitable*? Many of the law-like regularities of nature have a general form necessary to the existence of embodied conscious agents like ourselves since, if such laws were not operative, it would be impossible for an environment to exist that could sustain such life:

1. Gravity

What would happen if there were no long-range attractive force between material objects while all the other forces of nature, as far as possible, remained the same? In such case, there would be no stars and hence no long-term energy sources to sustain life. Planets, if there were such, would exist merely by cohesion, would almost certainly lack any atmosphere, and would not provide a stable platform for the development or persistence of life, which even if it did exist, could easily float off into space with no means of return.

2. The Strong Force

The strong force binds the nucleons together in the nucleus of the atom. If there were no such force, the nucleons would not cohere and both electromagnetic repulsion among protons and quantum energy fluctuations in the nucleon fields would drive the constituents of the nucleus apart. Furthermore, because of electromagnetic repulsion, the strong force must be considerably stronger than the electromagnetic force, but to keep atoms of limited size, it must also only operate over a very short

28. See Robin Collins, "Fine-Tuning Arguments and the Problem of the Comparison Range," *Philosophia Christi* 7, no.2 (2005): 385-404; Timothy McGrew, Lydia McGrew, and Eric Vestrup, "Probabilities and the Fine-Tuning Argument: A Skeptical View," in *God and Design: The Teleological Argument and Modern Science* (New York: Routledge, 2003), 200-8; Timothy McGrew and Lydia McGrew, "On the Rational Reconstruction of the Fine-Tuning Argument," *Philosophia Christi* 7, no.2 (2005): 425-443; Alexander Pruss, "Fine- and Coarse-Tuning, Normalizability, and Probabilistic Reasoning," *Philosophia Christi* 7, no.2 (2005): 405-23; and Jay Richards, "Some Preliminary Questions to Any Future Fine-Tuning Argument," *Philosophia Christi* 7, no.2 (2005): 369-81.

29. See Collins, "Fine-Tuning Arguments and the Problem of the Comparison Range" and "Teleological Argument."

30. See Collins, "Fine-Tuning Arguments and the Problem of the Comparison Range;" "Teleological Argument;" and "Fine-Tuning Evidence is Convincing."

range. If it operated at an unlimited range like gravity, then given its current strength of about forty orders of magnitude *greater* than gravity, it would turn the universe into a giant black hole.

3. The Electromagnetic Force

Without electromagnetism there would be nothing to hold electrons in orbit around the nucleus of an atom and no chemistry to speak of, including, of course, the chemistry that forms the basis of life. Furthermore, there would be no means of energy transmission for nuclear processes in stars to support the existence of life on planets.

4. Quantization of Energy

If we view the atom from the classical Newtonian perspective, an electron should be able to orbit at any distance from the nucleus of an atom just as a planet can orbit at any distance from the sun. However, Maxwell's laws of electromagnetism dictate that any accelerating charged particle will emit radiation, and, as Newton's laws imply, electrons orbiting the nucleus of an atom are accelerating because their direction of motion is constantly changing. By emitting radiation, however, the electrons are losing energy, and this loss of energy would cause the electron's orbit to decay so quickly that an atom could not exist for more than a minute or so. This was the problem faced by Rutherford's model of the atom, which was resolved in 1913 by Bohr's (at the time) *ad hoc* proposal of a quantization rule that required electronic orbital shells of fixed energies. Without such a quantization rule, however, atoms could not exist and neither could life.

5. The Exclusion Principle

Finally, consider Pauli's Exclusion Principle, which dictates that no two fermions (particles with half-integral spin) can occupy the same quantum state. The exclusion principle limits the number of electrons in each quantized orbital shell, thereby allowing the complex chemistry necessary for life, for otherwise all electrons would end up in the lowest orbital. Furthermore, Pauli's principle also applies to the nucleus of the atom, thus preventing an indefinite number of neutrons from falling into the lowest nuclear shell, and thereby putting a limit on atomic weight, another condition that seems necessary for life.

The Fine-Tuning of the Initial Conditions of the Universe

Other aspects of fine-tuning relate to the initial conditions of the universe. An *initial condition* specifies the state of a physical system at a particular time such that, for all subsequent times, the equations of motion and their associated constraints will describe all future states. In speaking of the initial conditions of the universe, one can focus on a variety of cosmic parameters—the mass-density of the early universe, the strength of the big bang explosion, the strength of the density perturbations leading to star formation, the ratio of radiation density to the density of normal matter—and so on. Various arguments for the fine-tuning of these parameters have been made. I want to focus on a related condition, the initial entropy of the universe, which on analysis has to be *exceedingly low* and thus *incredibly fine-tuned* to produce a universe resembling the one in which we live.

To get at this number, we need the concept of statistical entropy developed by the nineteenth-century physicist, Ludwig Boltzmann. In statistical mechanics, entropy is essentially a measure of the number of ways in which a system may be arranged and is often taken as a measure of "disorder" (the higher the entropy, the higher the disorder, with maximum entropy being present in the equilibrium state). To be specific, the statistical entropy, denoted by S, is proportional to the natural logarithm of the number of possible microscopic configurations of the individual atoms and molecules of the physical system (this number of microstates being denoted by W) which could give rise to the observed macroscopic state (macrostate) of the system as a whole. The constant of proportionality is known the Boltzmann constant, k_B, yielding Boltzmann's well-known formula for statistical entropy: $S = k_B \ln(W)$.

Roger Penrose (1931-) calculated how fine-tuned the initial entropy of our universe had to be by comparing the statistical entropy of the observable universe with the entropy it could have had emerging from the Big Bang singularity.[31] The statistical entropy *per* baryon (protons and neutrons, for all practical purposes) for the observable universe can be estimated by supposing that it consists of galaxies mostly populated by ordinary stars, where each galaxy has a million-solar-mass black hole at its center. Under such conditions, the statistical entropy *per* baryon (a dimensionless number) is calculated to be 10^{21}, which, given the fact that there are about 10^{80} baryons in the observable universe, yields an *observed statistical entropy for our Universe* as a whole *on the order of* $10^{80} \times 10^{21} = 10^{101}$. The fine-tuning of universal entropy is essentially the ratio of the volume of the phase-space (that is, the position-momentum space) of the observed statistical entropy in the universe to the volume of the phase-space for the statistical entropy it *could have had* emerging from a singularity whose entropy is calculated using the Bekenstein-Hawking formula for black-hole entropy (think of time-reversed movie that runs the Universe backward until it collapses into the singularity from which it emerged). Since 10^{123} is the natural logarithm of the volume of the position-momentum (phase) space associated with initial universal entropy when calculated using the Bekenstein-Hawking formula, the phase-volume itself is given by the exponential: $V = e^{10\exp(123)}$; similarly, the *observed* total entropy is $W = e^{10\exp(101)}$. For numbers this size, it makes really no difference to the order of magnitude of our answer if we substitute base 10 for the base of the natural logarithm, which Penrose does. Taking the ratio, the required precision in the

31. Roger Penrose, "Time-asymmetry and quantum gravity," in *Quantum Gravity 2*, ed. C. Isham, R. Penrose, and D. Sciama (Oxford: Clarendon, 1981), 245-72; see also Roger Penrose, *The Road to Reality: A Complete Guide to the Laws of the Universe* (New York: Alfred A. Knopf, 2005), 757-65.

Big Bang to produce a habitable universe with the statistical entropy ours is observed to have is therefore (observed entropy W / possible entropy V):

$$W/V \approx 10^{10\exp(101)}/10^{10\exp(123)} = 10\exp(10^{101} - 10^{123}) \approx 10^{-10\exp(123)}.$$

In other words, to satisfy the observed entropy of *our* universe, the Big Bang singularity had to be fine-tuned to one part in $10^{10\exp(123)}$, that is, 1 / $10^{10\exp(123)}$. If it were written out, there are ten million trillion-trillion-trillion more zeros in the denominator of this number than there are particles in the observable universe! This level of fine-tuning is staggering and not reasonably attributed to chance.[32]

The Fine-Tuning of the Constants of Nature

But the fine-tuning of the universe does not stop with its law-structure and its initial conditions; it also includes many of the fundamental constants of nature and their relationships to each other.[33] Space prohibits canvassing the full extent of the fine-tuning of natural constants, so we will focus on just a few:[34]

1. Newton's Gravitational Constant Relative to the Other Fundamental Forces

The strength of the force of gravity, represented by Newton's constant, is forty orders of magnitude weaker than that of the strong force holding the nucleus of the atom together, the latter representing the strongest of the four fundamental forces. Given that the strengths of the forces of nature are *measured* quantities that are not derived from the theories that represent them, they could presumably have been different from what they are, and the observed range of strengths helps us to set a scale on which they might have varied. Currently gravity is one ten thousand

32. Two proposals have been suggested by way of trying to mitigate this entropic fine-tuning: (1) the inflationary multiverse overcomes the probabilistic obstacles; and (2) there is some special law that requires a perfectly uniform gravitational field at the beginning of time, thus giving rise to maximally low entropy. As we shall see presently, the inflationary multiverse proposal has massive fine-tuning problems of its own, as well as creating conditions that undermine the very possibility of scientific rationality. The second proposal, that there is a special law requiring a perfectly uniform gravitational field (in technical language, a gravitational field with zero Weyl curvature), merely shifts the locus of fine-tuning from the Big Bang itself to the gravitational field associated with it. In other words, it merely displaces the fine-tuning problem to another area without resolving it. The Weyl Curvature Hypothesis also has been unpopular among naturalistically-minded physicists for a different reason: it requires a genuine singularity at the beginning of time at which all the laws of physics break down.

33. See Barnes, "Fine-Tuning;" Barrow and Tipler, *Anthropic Cosmological Principle*; Collins, "Scientific Argument;" Collins, "Evidence for Fine-Tuning;" Collins, "Teleological Argument;" Collins, "Fine-Tuning Evidence is Convincing;" Davies, *Accidental Universe*; G. F. R. Ellis, "Issues in the Philosophy of Cosmology," in *Handbook of the Philosophy of* Physics, *Part B*, ed. John Earman and Jeremy Butterfield (Amsterdam: Elsevier, 2007), 1183-1286; Gordon, "Inflationary Cosmology and the String Multiverse," 75-103; Gordon, "Balloons on a String," 558-601; and Holder, *God, the Multiverse, and Everything*.

34. See Collins, "Evidence for Fine-Tuning" for more details.

trillion-trillion-trillionth the strength of the strong force. Suppose we changed it so that it was still very small in comparison, say ten thousand trillion trillionths the strength of the strong force. Small though this fraction is, it still represents a trillion-fold increase in the strength of the gravitational force, which would have the effect of crushing virtually all life out of existence—or more accurately, preventing it from existing in the first place. This sensitivity is exacerbated by the consequences of tweaking the strength of the gravitational force while maintaining the same mass density, radiation to matter ratio, and cosmological constant in the very early universe. As Paul Davies calculates,[35] if the strength of gravity were larger or smaller by one part in 10^{60} of its current value, the universe would either have exploded too quickly for stars and galaxies to form, or collapsed back on itself too quickly for life to have developed. As is clear from this example, the fine-tunings in nature often involve the relative values of more than one quantity instead of the stand-alone fine-tuning of a single quantity.

2. The Cosmological Constant

The cosmological constant, Λ, is a term in Einstein's field equations for general relativity that, when positive, acts as a repulsive force driving the expansion of space and, when negative, acts as an attractive force causing space to contract. Einstein's equations imply that if the vacuum—spacetime devoid of normal matter—has an energy density, then that energy will play the mathematical and hence physical role of a cosmological constant. The need for the fine-tuning of this cosmological constant, understood as the vacuum energy, arises from the fact that almost all real or hypothesized fields in contemporary physics—the electromagnetic field, the fields associated with various elementary particles, the Higgs field, the inflaton field in inflationary cosmology, the dilaton field in superstring theory, and so on—contribute to the vacuum energy so as to drive it far, far beyond the maximum life-permitting limit. If this cosmological constant were larger than some positive value or smaller than some negative value, then again, the universe would have expanded too quickly (if positive) or collapsed too quickly (if negative) for stars and galaxies to have formed, thus also prohibiting the existence of living organisms.

Let us define the *effective cosmological constant* as the sum of all of the contributions of factors that function in the same way as Einstein's cosmological constant in respect of causing space to expand or contract. The fine-tuning of the effective cosmological constant can now be stated this way: unless some new principle of physics is discovered, without being fine-tuned, the effective cosmological constant is expected from calculations in quantum field theory to be about 10^{120} larger than the maximum life-permitting value, meaning that its actual value is fine-tuned to one part in 10^{120}, that is, fine-tuned to 120 decimal places.

35. Davies, *Accidental Universe*, 89.

3. Supersymmetry and the Mass of the Higgs Boson

Some physicists have suggested that supersymmetry, if correct, would obviate the fine-tuning of the cosmological constant. Supersymmetry postulates a symmetry between fermions (half-integer-spin matter particles) and bosons (integer-spin force/radiation or "messenger" particles) in which all the known particles of the Standard Model have "superpartners" of the opposing type. It further requires that the positive vacuum energy associated with each bosonic field is exactly cancelled by the negative vacuum energy of the corresponding fermionic field, yielding a net contribution of zero to the cosmological constant. Nonetheless, this solution faces a major difficulty in that, even if supersymmetry were correct, it is a broken symmetry at present-day energies, and there is no natural way of implementing symmetry breaking while retaining this cancellation of contributions to the cosmological constant. Beyond this, with the failure to observe supersymmetric particles at the new energies achieved by the Large Hadron Collider (LHC) in Geneva, Switzerland, many theoretical physicists are concluding that supersymmetry is *false* and new approaches need to be tried, in which case no obviation of the fine-tuning of the cosmological constant is achieved.

More specifically, in respect of the contributions of the Higgs field to this fine-tuning, with the recent discovery of the Higgs boson within its predicted range, we note that it has been shown that if the Higgs boson were even 5 times more massive than its measured value, it would suppress the formation of all atoms other than hydrogen, effectively rendering the universe lifeless.[36] In the absence of supersymmetric cancellations between fermions and bosons, then, the Higgs field *alone* has to be fine-tuned to about one part in 10^{18} for the Higgs boson to have its observed mass.[37]

4. Neutron Mass

The neutron is marginally heavier than the proton by a factor of around 1.293 MeV. We won't go into the details, but if the neutron's mass were increased by another 1.4 MeV, i.e., by one part in 700 of its actual mass of 938 MeV, then one of the key steps in the fusion process by which stars burn their hydrogen into helium could not occur.[38] This one-sided fine-tuning of the neutron mass can be translated into a two-sided fine-tuning parameter for the down-quark mass of about one part in 18,000 of the range of quark masses.

5. The Weak Force Coupling Constant

Because of the high temperature and mass-energy density in the first few seconds after the Big Bang, neutrons and protons readily interconverted via the weak

36. V. Agrawal, Stephen M. Barr, John F. Donoghue, and D. Seckel, "The anthropic principle and the mass scale of the Standard Model," *Physical Review* D57 (1998): 5480-5492, accessed June 29, 2017, https://arxiv.org/pdf/hep-ph/9707380.pdf.

37. See the helpful discussion of this instance of fine-tuning in Geraint Lewis and Luke Barnes, *A Fortunate Universe: Life in a Finely Tuned Cosmos* (Cambridge: Cambridge University Press, 2016), 58-63.

38. See Collins, "Evidence for Fine-Tuning," 186ff.

force through interactions also involving electrons, positrons, neutrinos and anti-neutrinos. The rate of this interconversion was dependent upon the temperature, the mass-energy density, the mass difference between the proton and the neutron, and the strength of the weak force. Because the neutron is more massive than the proton, at thermal equilibrium, the ratio of neutrons to protons will always be less than one, but the higher the temperature is, the closer the ratio will be to one. As the universe expands, however, the density of the particles relevant to interconversion rapidly decreases, and at some point the interconversion effectively stops. This "freeze-out" temperature ultimately determines the ratio of neutrons to protons, and the higher it is, the closer the ratio will be to one. Furthermore, since the interconversion proceeds via the weak force, it is highly dependent on the strength of this force. The stronger the weak force, the greater the rate of interconversion at any temperature and density, lowering the freeze-out temperature, but if the weak force were decreased, the opposite would happen, raising the freeze-out temperature. Since the freeze-out temperature is proportional to the weak-force coupling constant in this way, one can calculate that decreasing the weak force relative to the range of strengths of the physical forces by one part in a billion would have the effect of raising the freeze-out temperature to a point where most of the protons would combine with neutrons to produce deuterium and tritium, which would fuse to form ^{4}He during the early stages of the Big Bang. As a consequence, stars would burn helium rather than hydrogen and have life spans of only 300 million years rather than several billion years, severely limiting the prospects for the appearance of life. So the one-sided fine-tuning of the weak force relative to the range of strengths of the fundamental forces is about one part in a billion.

An Excursus on "Naturalness" and Mediocrity as a Prelude to the Multiverse

As the false narrative of the history of science goes, ever since Copernicus displaced the Earth from the center of the cosmos, humanity and its physical surroundings have been on a downward path to utter mediocrity.[39] As succinctly and colorfully stated by Douglas Adams in *The Hitchhiker's Guide to the Galaxy*:

> Far out in the uncharted backwaters of the unfashionable end of the western spiral arm of the galaxy lies a small unregarded yellow sun. Orbiting it at a distance of roughly 93 million miles is an utterly insignificant little blue-green planet whose ape-descended life forms are so amazingly primitive that they still think digital watches are a pretty neat idea.[40]

39. Never mind that displacing Earth from the center in medieval cosmology would be doing humanity a favor: hell was at the very center of the center of the cosmos, and heaven, the most exceptional realm, was as far away from the center as you could get. Any move away from the center was a promotion.

40. Douglas Adams, *The Hitchhiker's Guide to the Galaxy* (New York: Del Rey 1995 [1979]), 1.

This rush to mediocrity gives us *one* sense of what scientists often mean by "naturalness": something is *natural* because it's *unexceptional*. The discovery of cosmological fine-tuning represents a trend in the opposite direction, however, since, with mediocrity as the gold standard, it's highly *unnatural*. Scientists who want the issue of fine-tuning to go away are concerned that the startling exceptionality indicated by cosmological fine-tuning might, God forbid, even provide evidence for *intelligent design*. Stanford theoretical physicist Leonard Susskind, staunch advocate of the inflationary string landscape hypothesis as a multiverse remedy for fine-tuning, expressed the worry this way:

> If, for some unforeseen reason, the landscape turns out to be inconsistent—maybe for mathematical reasons, or because it disagrees with observation... [then] as things stand now we will be in a very awkward position. Without any explanation of nature's fine-tunings we will be hard pressed to answer the ID critics.[41]

Appeal to a multiverse is currently the preferred strategy for restoring an appropriate sense of mediocrity. If our universe can somehow be seen as a very typical example of the sort of universes one finds in a multiverse, we can still revel in the naturalness of being ever-so-average and not be troubled by exceptionality. But even if multiverse theories should fail to confirm our mediocrity, we might at least find a material explanation of our exceptionality through appeal to observer-selection effects: we have to live in a corner of the multiverse that is compatible with our existence as observers, so even if observer-supporting patches of the multiverse are exceptional, our presence in one of them is not, because we could not exist anywhere else. By means of such anthropic selection, then, we can at least appreciate that it would be unseemly to take pride in our exceptionality because we weren't intended to exist; we were merely the lucky byproduct of a random process. In this respect, multiverse explanations have a lot in common with neo-Darwinian explanations.

The second strategy for preserving a sense of "naturalness" actually came first historically among physicists, but it has fallen on hard times as of late. Naturalistically minded physicists who nonetheless despise speculative multiverse explanations of fine-tuning have hope that this strategy might even yet be restored. The sense of "naturalness" it embodies is best described as one of *inevitability*. This viewpoint was very clearly articulated by Einstein and is represented by his remark that what really interested him was whether God had a choice in creating the world. In his autobiographical notes in the Schilpp collection, Einstein put the thought this way:

> I would like to state a theorem which at present cannot be based upon anything more than a faith in the simplicity, i.e., intelligibility, of nature . . . nature is so

41. This quote comes from an interview with Leonard Susskind conducted by Amanda Gefter, "Is String Theory in Trouble?" *New Scientist Magazine*, December 14, 2005, accessed June 29, 2017, https://www.newscientist.com/article/mg18825305-800-is-string-theory-in-trouble/

> constituted that it is possible logically to lay down such strongly determined laws that within these laws only rationally completely determined constants occur (not constants, therefore, whose numerical value could be changed without destroying the theory).[42]

The naturalness of inevitability in this sense can be related to the naturalness of unexceptionality in this way: what is inevitable is not special because it *could not be otherwise*. If it is going to be, it has to be *this* way. Of course, it might still be special if it did not have to exist at all, yet, nonetheless, there it is, and since its laws, say, have the *only* form they could have and they completely *determine* their associated constants, we marvel at the fact that the only thing that *could* exist, does in fact exist—for its *actual* existence, logically and metaphysically speaking, seems a very contingent affair. The radical contingency of there being a universe at all brings us to the doorstep of the theistic point of view. So it is not hard to see that, from the perspective of classical monotheism, the universe can be expected to have *both normal and exceptional aspects*.

Given that the universe is understood to be the *free* creation of a rational God, it is natural to suppose that one should have to *look* at the creation to see what God in fact has done, for in his freedom, he might have done many things and it is quite proper that some of them should follow by necessity (inevitability) from certain of his choices and others be startlingly exceptional. The theist thus expects *law-like regularity in nature* and for this reason is unsurprised, to paraphrase Galileo (1564-1642), that the book of nature is written by God in the language of mathematics. The universe is subject to selective regular mathematical description because such order is (a) necessary to the very existence of embodied beings; and (b) indispensable to reliable belief formation among such beings. But, from a theistic perspective, *exceptionalities in nature* are also be expected because, as a divine creation, *nature is not self-sufficient* in either its *origin* or its *operational parameters*. Its *ontological non-self-sufficiency* is evident in its *contingent character* (it did not have to exist, it has not always existed, and certain of its properties might have been other than those it actually has). Furthermore, it can be argued that its *operational non-self-sufficiency* is manifested in the fine-tuning of multiple parameters for the existence of life and, arguably, in the fact that a principle of sufficient *physical* causality fails in the quantum realm (see the discussion in §3). From a theistic perspective, this operational *non*-self-sufficiency is another expression of the *freedom* of divine creativity, and it speaks of ongoing divine intimacy and involvement with created reality—we are, after all, talking about *theism*, not *deism*. In short, the theist is troubled neither by what appears normal nor by what appears exceptional, and is content to follow the evidence wherever it may lead.

42. Albert Einstein, "Autobiographical Notes," in *Albert Einstein: Philosopher-Scientist*, ed. Philip Schilpp (LaSalle: Open Court, 1949), 63.

With these things in mind, let's take a look at the idea that a multiverse could explain away the fine-tuning of our universe as an observer selection effect. We begin by considering the hypothesis of cosmic inflation.

Inflationary Cosmology

The idea of cosmic inflation is that, a split-second after the Big Bang, the universe underwent a short period of hyper-accelerated expansion that "smoothed out" our local cosmic environment by pushing any inhomogeneities beyond the boundary of what can be seen. Specifically, Alan Guth invented cosmic inflation in 1980 to explain why the temperature of the cosmic background radiation was the same throughout the observable universe to one part in a hundred thousand, and why the density of mass-energy resulting from the Big Bang yielded a universe that was flat to at least one part in a quadrillion (explanatory demands known respectively as the "horizon" and "flatness" problems). As it turned out, the most viable theoretical model of the inflationary process, chaotic eternal inflation, requires that once inflation starts it never ceases. Inflation thus produces a potentially infinite number of "bubble universes," each with *different* initial conditions, which suggests that a bubble universe with initial conditions as fine-tuned as our own is bound to occur sooner or later.

The irony of this proposal, at least in regard to the principle of mediocrity as an expression of scientific materialist philosophy, is that inflationary processes actually *increase* rather than decrease the fine-tuning of its initial conditions. For instance, the energy of the inflationary field has to be shut off with tremendous precision in order for a universe like ours to exist, with inflationary models requiring shut-off accuracies ranging from one part in 10^{53} to as much as one part in 10^{123}, depending on the particular inflationary model in view. Furthermore, achieving thermodynamic equilibrium in the cosmic microwave background radiation through inflation is an *entropy-increasing process* (it increases the thermodynamic disorder of the cosmos), yet even without it, as we have seen, our universe's initial entropy was fine-tuned to one part in 10 to the 10 to the 123rd power. In other words, adding exponential inflationary growth to the *already* hyper-exponentially fine-tuned entropy required by the Big Bang has the effect of *exponentially increasing* its already hyper-exponential fine-tuning! But there is more. Theoretical cosmologists Sean Carroll and Heywood Tam have shown that the chance of inflation actually occurring as part of any *realistic* cosmological history is only one in 10 to the 66,000,000th power.[43] Of course, the fact that chaotic eternal inflation—if it ever happens—generates an unending and rapid succession of bubble universes with different initial conditions (a "multiverse"), gives scientific materialists what they say they want: a scenario in which the staggering improbabilities just mentioned do not matter because *every* initial condition is

43. Sean Carroll and Heywood Tam, "Unitary Evolution and Cosmological Fine-Tuning" (2010), accessed June 29, 2017, https://arxiv.org /pdf/1007.1417v1.pdf

realized sooner or later (in fact, it is realized infinitely many times)! As we shall soon see, however, this ontological profligacy comes at a price.

The Anthropic String Landscape

Before we offer further critique of multiverse cosmology, we need to consider two more aspects of fine-tuning that cosmic inflation—which focuses solely on initial conditions—does not address: the form of the *laws of nature* and the values of the *constants of nature*. There is only one cosmological theory—the anthropic string landscape—that offers mechanisms aimed at explaining away the fine-tuning evident in the mathematical form of natural laws and the values of natural constants.

The only way for a scientific materialist to avoid the conclusion that our universe exemplifies transcendent intelligent design is to propose there is a blind universe-creating mechanism that produces universes with an endless variety of different properties (laws, constants, and initial conditions) and that our universe is the chance outcome of such a mechanism. The reason *we* observe our universe to have the life-permitting properties it does is the result of an "observer selection effect": given that we exist, it must be in a region of the multiverse that has conditions compatible with our existence. This is the essence of the "anthropic string landscape"[44] proposal as a "solution" to the scientific materialist's fine-tuning problem.

To see how this blind universe-creating mechanism is supposed to work, we need a conceptual grasp of certain details about string theory. String theory is a branch of theoretical physics that has received a lot of attention in the last forty years as a potential "theory of everything" that could unite the four fundamental forces of nature (gravity, electromagnetism, the weak force, and the strong force) under one mathematical umbrella as the manifestation of a single fundamental force: *gravity*. It postulates that the fundamental constituents of nature are one-dimensional filaments instead of particles. These filaments are either open-ended or closed into loops and they vibrate in different ways to produce all the different kinds of "particles" we observe. For string theory to allow for the existence of both radiation and matter while satisfying the rules of quantum mechanics, two things have to be the case: a theoretical constraint called "supersymmetry" must be satisfied and the strings must

44. Leonard Susskind, "The Anthropic Landscape of String Theory," accessed June 29, 2017, https://arxiv.org/pdf/hep-th/0302219.pdf; Leonard Susskind, *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design* (New York: Little, Brown, and Company, 2006); Steven Weinberg, "Living in the Multiverse," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce L. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 547-57. See also the interesting discussion of the historical background to all of these developments in Helge Kragh, *Higher Speculations: Grand Theories and Failed Revolutions in Physics and Cosmology* (Oxford: Oxford University Press, 2011).

move in a spacetime having ten dimensions.[45] The extra six spatial dimensions in string theory must be curled up or "compactified" at each point of spacetime into a structure so small it cannot be observed since, quite obviously, the universe we inhabit only has three large spatial dimensions. The problem is that there are *infinitely many ways* of folding these extra spatial dimensions into unobservable structures. Nonetheless, the *shape* of each such compact structure dictates the *form* of the laws of nature in the three dimensions we can see, and the relative *sizes* of the curled dimensions in these structures dictates the *strength* of the natural constants. Consequently, each of the infinitely many compactifications represents a universe with different natural laws and constants that, taken collectively, form an infinite *landscape* of universes having different properties: every one of the infinitely many solutions of string theory thus represents a different physics.

The trick for anthropic string landscape theorists is turning the *vice* of a theory with infinitely many solutions capable of describing almost any reality you please into a *virtue* that explains away the fine-tunings of our universe. In the early 2000s it was discovered that there are somewhere between 10^{500} and 10^{1000} compactifications that have a positive cosmological constant and might therefore be able to describe our universe. In light of this discovery, the just-so story detailing how the universe got its spots[46] runs like this: The branch of the multiverse that contains our universe started in the highest possible energy state for the effective cosmological constant (because it must for the model to work) and, through the random quantum decay of various features of the initial compactification, cascaded in different directions down the energy scale of the landscape, each sequential decay launching an eternally inflating bubble representative of a particular combination of laws and constants, then chaotically decaying itself into smaller bubble universes with yet different combinations of laws and constants. By such means, it is postulated (without any justification save that it is needed if the model is to serve its explanatory purpose) that the *whole* landscape of compactifications representing different laws and constants will be explored. The fact that our universe, which must inevitably arise in the course of a random exploration stipulated to be exhaustive, has properties fine-tuned for the existence of life, can then be explained as an observer selection effect: while there are infinitely many universes in the landscape that have different properties, most of which are incompatible with the existence of life, we must exist in a region of the multiverse that is compatible with our existence. The fact that we live in a universe with the finely-tuned conditions necessary to our existence is therefore not a cause for surprise.

45. In 1994, ongoing research into the mathematical relationship among the five anomaly-free classes of string theories led to discovery of an eleventh unifying dimension, resulting in a new theoretical construct that physicists call "M-theory" ("M" for "membrane", or "mystery", or even "mother-of-all-theories").

46. See Casey Luskin, "Just-So Stories," in *Dictionary of Christianity and Science*, ed. Paul Copan *et al*. (Grand Rapids, MI: Zondervan, 2017), 396.

We may legitimately ask whether Susskind and other landscape theorists are justified in pinning their hopes on such theories. Addressing the full range of fine-tuning (initial conditions, laws, and constants) requires *fusing* inflationary cosmology with string theory, compounding the difficulties and improbabilities associated with each. Close examination not only reveals the deep implausibility and deleterious consequences of such "explanations" of fine-tuning, it also demonstrates, on pain of infinite regress, the impossibility of resolving fine-tuning issues with the explanatory resources available to scientific materialism. We have seen that inflationary cosmology requires fine-tuning that goes far beyond the fine-tuning it was invoked to explain (though, as mentioned, advocates regard all possible initial conditions, no matter how finely-tuned, as inevitably exemplified countless times because of the infinite variation generated by inflation). We now highlight further difficulties with cosmic inflationary explanations before detailing the implausibilities of string theory and showing the in-principle impossibility of multiverse cosmology ever resolving the fine-tuning "problems" generated by materialist constraints on scientific explanation:

(1) Arvind Borde, Alan Guth, and Alexander Vilenkin have shown that any inflationary multiverse has a beginning in the finite past.[47] In other words, while inflationary models can be eternal into the future, it is mathematically impossible for them to be eternal into the past. This means that inflation entails creation *ex nihilo* in much the same way as standard Big Bang cosmology. The inflationary string landscape, by way of the inflationary mechanism, also satisfies this constraint. But if everything that begins to exist has a cause and the multiverse began to exist, then the multiverse has cause which, as logically prior to everything physical, cannot itself be physical (but see point 5, below).

(2) One of the touted strengths of generic inflationary models is their prediction that the CMB will display a normal distribution of energy density fluctuations having the same spectrum at all scales, a prediction largely confirmed by observation. From the standpoint of confirming the theory, however, the difficulty is that this prediction *is not unique to inflation*. The existence of a normal distribution also follows as a straightforward consequence of the Central Limit Theorem in statistics, which states that the mean of a sufficiently large iteration of random variables with well-defined means and variances will have a near-normal distribution.[48] Furthermore, a scale-invariant spectrum of energy fluctuations was also proposed for independent reasons by Harrison[49] and Zel'dovich,[50] *prior* to the advent of inflationary cosmology.

47. Arvind Borde, Alan Guth, and Alexander Vilenkin, "Inflationary spacetimes are not past-complete," in *Physical Review Letters* 90 (2003), accessed June 29, 2017, https://arxiv.org/pdf/gr-qc/0110012.pdf.

48. J. A. Peacock, *Cosmological Physics* (Cambridge: Cambridge University Press, 1999).

49. E. R. Harrison, "Fluctuations at the Threshold of Classical Cosmology," *Physical Review* D1, no.10 (1970): 2726-2730.

50. Y. B. Zel'dovich, "A hypothesis, unifying the structure and the entropy of the Universe," in *Monthly Notices of the Royal Astronomical Society* 160 (1972), 7-8.

(3) Swamping the fine-tuned improbabilities intrinsic to inflation by multiplying the number of universes generated so as to render all possible combinations inevitable has consequences that undermine scientific rationality. In a materialist multiverse resting on the hypothesis of an undirected and irreducibly probabilistic quantum inflationary mechanism lacking any principle of sufficient causality, *anything* quantum-mechanically possible can happen for *no* reason at all (see point 5 below). What is more, anything that *can* happen, no matter how improbable, *does* happen with unlimited frequency, generating something that physicists call the "measure problem." In such an environment we can have no confidence that the future will resemble the past in a way that legitimates the very inductive inferences that make science possible. In short, taken seriously, the inflationary multiverse proposal *undermines* the very possibility of scientific rationality. MIT theoretical physicist Max Tegmark expresses the problem this way:

> [B]y predicting that space isn't just big but truly infinite, inflation has also brought about the so-called measure problem, which I view as the greatest crisis facing modern physics. Physics is all about predicting the future from the past, but inflation seems to sabotage this. When we try to predict the probability that something particular will happen, inflation always gives the same useless answer: infinity divided by infinity. The problem is that whatever experiment you make, inflation predicts there will be infinitely many copies of you, far away in our infinite space, obtaining each physically possible outcome; and despite years of teeth-grinding in the cosmology community, no consensus has emerged on how to extract sensible answers from these infinities. So, strictly speaking, we physicists can no longer predict anything at all! This means that today's best theories need a major shakeup by retiring an incorrect assumption. Which one? Here's my prime suspect: ∞.[51]

(4) Viewed from another angle, two paradoxes resulting from the inflationary multiverse suggest that our place in such a reality must be very special: the "Boltzmann Brain Paradox"[52] and the "Youngness Paradox."[53] In brief, if the inflationary mechanism operates in an undirected and self-sufficient way that generates an infinite multiverse, then with probability indistinguishable from one (i.e., virtual necessity) the typical observer in such a multiverse will be a spontaneous

51. Max Tegmark "Infinity is a Beautiful Concept," 48-51.

52. L. Dyson, M. Kleban, and L. Susskind, "Disturbing Implications of a Cosmological Constant," *Journal of High Energy Physics* 0210 (2002): 011, accessed June 30, 2017, https://arxiv.org/pdf/hep-th/0208013v3.pdf; R. Bousso and B. Freivogel, "A Paradox in the Global Description of the Multiverse," *Journal of High-Energy Physics* 0706 (2007), 018, accessed June 30, 2017, https://arxiv.org/pdf/hep-th/0610132.pdf; Andrei Linde, "Sinks in the Landscape, Boltzmann Brains, and the Cosmological Constant Problem," *Journal of Cosmology and Astroparticle Physics* 0701 (2007): 022, accessed June 30, 2017, https://arxiv.org/pdf/hep-th/0611043.pdf.

53. Alan Guth, "Eternal Inflation and Its Implications," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce l. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 487-505.

thermal fluctuation with memories of a past that never existed (a Boltzmann brain) rather than an observer of the sort we take ourselves to be. Alternatively, by a second measure, post-inflationary universes overwhelmingly will have *just* been formed, which means that our existence in a universe as old as our own has a probability that is effectively zero. So either way, if our universe existed as part of an inflationary multiverse, it would not be at all typical, but rather infinitely improbable with respect to its age and compatibility with stable life-forms. Needless to say, the fact that we are not Boltzmann brains and we live in a stable universe that is 13.7 billion years old does not comport well with the principle of mediocrity that motivates inflationary cosmology.

(5) Must every contingent event have a cause? Some have argued that quantum mechanics provides a counter-example to this claim because it describes physical events that, on pain of experimental contradiction, have no *physical* cause. So maybe the multiverse could exist for no reason at all (see point 1 above) and anything that has a non-zero quantum probability, no matter how small, could happen countless times (see point 3 above). Two considerations render this viewpoint inadvisable: First of all, maintaining that events which lack a *physical* cause therefore have *no* cause begs the question against transcendent (non-physical) causation. Absence of a physical cause does not entail the absence of causality altogether unless you have a prior commitment to materialism. Secondly, to maintain that there can be physical states of affairs that have no cause (physical or otherwise) and therefore no explanation at all undermines the possibility of explaining *any* physical state of affairs. The reason for this is that the possibility that there is *no explanation* becomes a competing "explanation" for everything that occurs, and there is no objective basis on which its likelihood can be assessed[54] and thus no way of telling whether the best "explanation" for something is that it has no explanation! In short, the integrity of scientific explanations rests on the assumption that every physical state of affairs has a causal explanation of *some* sort, regardless of whether that explanation is itself physical.

(6) Turning to string theory as the second pillar in the inflationary string landscape hypothesis, we observe that while evidence for the truth of inflationary cosmology is contentious at best,[55] evidence for the truth of string theory is

54. See Alexander Pruss, *The Principle of Sufficient Reason: A Reassessment* (Cambridge: Cambridge University Press, 2006); Pruss, "Leibnizian Cosmological Arguments," 24-100; see also Jonathan Loose, "Sufficient Reason, Principle of," in *Dictionary of Christianity and Science*, ed. Paul Copan *et al*. (Grand Rapids, MI: Zondervan, 2017), 649-50.

55. For further critique see Gordon, "Inflationary Cosmology and the String Multiverse," 75-103; Gordon, "Balloons on a String," 558-601; Roger Penrose, *The Road to Reality: A Complete Guide to the Laws of the Universe* (New York: Alfred A. Knopf, 2005), 746-57; Paul Steinhardt, "The Inflation Debate," *Scientific American* 34, no. 4 (2011): 36-43.

non-existent.[56] String theory does not make any *unique* predictions testable by any currently conceivable experiments and its mathematical structure is so rich and all-encompassing that, if supersymmetry proves tenable (see point 7 below), there is virtually no experimental result it cannot accommodate. But a theory compatible with everything *explains nothing*.

(7) String theory presupposes supersymmetry, the postulation of a fundamental symmetry between matter particles (fermions) and radiation particles (bosons), such that these two kinds of particles can transform into each other. If supersymmetry turns out to be false, then string theory will also be false and the inflationary string landscape hypothesis will come to nothing. As things now stand, the energy scale at which supersymmetry was expected to be discovered has been revised multiple times and it still has not been observed. Its failure to manifest in experiments at the Large Hadron Collider (LHC) in Geneva, Switzerland, has contributed to the growing consensus that supersymmetry *is* false[57] and that, if further progress is to be made, theoretical physics needs some new ideas.

(8) The string multiverse was invented to explain away the fine-tuning of natural laws by producing regions with every conceivable form of natural law. But string theory incorporates the mathematical structures of quantum theory (in fact, the landscape is explored through spontaneous quantum transitions), thus requiring both the quantization of energy and the exclusion principle, constraints we earlier noted were necessary for life-supporting universes. As should be obvious, the string landscape does *not* explain away those law structures necessary to life that it must presuppose for its own function.

(9) Lastly, any mechanism that generates universes *ad infinitum* must have stable characteristics that constrain its operation if it is to avoid breaking down and sputtering to a halt. This means that any "universe-generator" will have *design parameters* that themselves *require explanation*. So postulating a random universe-generator to explain away the appearance of first-order design in a single universe *does not obviate the inference to design*, it merely bumps it up to the next level. Avoiding an infinite regress of explanatory demands requires a termination point in *actual* design by an Intelligence that transcends spacetime, matter and energy, and which, existing *timelessly* and logically prior to any universe or multiverse, also *exists necessarily* and therefore requires no further explanation of its own existence.

56. Baggott, *Farewell to Reality*; Gordon, "Inflationary Cosmology and the String Multiverse," 75-103; Gordon, "Balloons on a String," 558-601; Lee Smolin, *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next* (New York: Houghton Mifflin Company, 2006); Alexander Unzicker and Sheilla Jones. *Bankrupting Physics: How Today's Top Scientists Are Gambling Away Their Credibility* (New York: Palgrave Macmillan, 2013); Peter Woit, *Not Even Wrong: The Failure of String Theory and the Search for Unity in Physical Law* (New York: Basic Books, 2006).

57. Natalie Wolchover, "Supersymmetry Fails Test, Forcing Physics to Seek New Ideas," *Scientific American Online*, accessed June 30, 2017, https://www.scientificamerican.com/article/supersymmetry-fails-test-forcing-physics-seek-new-idea/; Lewis and Barnes, *A Fortunate Universe*, 63.

In short, multiverse cosmologies only make sense within the context of theism,[58] but this very theistic context renders multiverse theories *unnecessary* for understanding the design parameters of our universe.

To conclude this part of our discussion, it is fair to say that Christians may take considerable encouragement from contemporary cosmology—the implausible machinations of materialist research programs notwithstanding—since it points to a universe that has a beginning requiring a transcendent cause, and it manifests multiple properties that are fine-tuned for life and ultimately require intelligent design for their explanation.

§3. Quantum Physics and the Necessity of Divine Action[59]

We have had reason to mention at a number of junctures so far that quantum physics is sometimes portrayed as giving evidence that the principle of sufficient reason/causality—the requirement that every contingent event have an explanation—is false. We have also remarked that drawing this conclusion is inadvisable. It is now time to take a closer look at how quantum physics captures the causal incompleteness of the material realm and at the implications of providing causal closure and restoring metaphysical coherence to the universe by the only reasonable means available: continuously operative transcendent causation. But to set the stage for this argument, we need to learn a little bit about the historical development of quantum mechanics.

A Quantum of History

Quantum theory—which is a pillar of modern physics that includes quantum mechanics and various quantum field theories—is the mathematical theory describing the behavior of reality at the atomic and sub-atomic level. At dimensions this small, the world behaves very differently than the world of our ordinary experience. This peculiarity is a consequence of the basic quantum hypothesis: energy does not have a continuous range of values but is absorbed and radiated *discontinuously* in units

58. See, most trenchantly, Robin Collins, "The Multiverse Hypothesis: A Theistic Perspective," in *Universe or Multiverse?*, ed. Bernard Carr (Cambridge: Cambridge University Press, 2007), 459-80; a more idiosyncratic view is offered by Don N. Page, "Does God So Love the Multiverse?" (2008), accessed June 30, 2017, https://arxiv.org/pdf/0801.0246.pdf.

59. This section draws heavily on Bruce L. Gordon, "A Quantum-Theoretic Argument against Naturalism," in *The Nature of Nature: Examining the Role of Naturalism in Science*, ed. Bruce L. Gordon and William A. Dembski (Wilmington: ISI Books, 2011), 179-214; Bruce L. Gordon, "Quantum Theory, Interpretations of," in *Dictionary of Christianity and Science*, ed. Copan, Paul *et al*. (Grand Rapids, MI: Zondervan, 2017), 551-54; and *especially* Gordon, "The Necessity of Sufficiency." See also Bruce L. Gordon, "Maxwell-Boltzmann Statistics and the Metaphysics of Modality," *Synthese* 133 (2002): 393-417; Bruce L. Gordon, "Ontology *Schmontology*? Identity, Individuation, and Fock Space," *Philosophy of Science* 70 (2003): 1343-56; Bruce L. Gordon, "Idealism," *Dictionary of Christianity and Science*, ed. Copan, Paul *et al*. (Grand Rapids, MI: Zondervan, 2017), 372-73; and Bruce L. Gordon, "Occasionalism," *Dictionary of Christianity and Science*, ed. Paul Copan *et al*. (Grand Rapids, MI: Zondervan, 2017), 491-93.

(*quanta*) that are multiples of Planck's constant. While this quantum hypothesis was put forward by Max Planck (1858-1947) in 1900 to explain black body radiation (energy emitted by a non-reflecting body due to its own heat), the work of Albert Einstein (1879-1955), Niels Bohr (1885-1962), and others soon showed it was foundational to the whole of physics.[60]

The peculiarity of the quantum realm is evident in the classic *double-slit experiment* demonstrating the *wave-particle duality* of light.[61] To visualize the situation, consider two waves of the same size (amplitude) traveling through water in opposite directions. Each wave has a crest (its highest point) and a trough (its lowest point). When they meet, they move through each other in various phases of *superposition*. Since they have the same size, when a crest meets a crest or a trough meets a trough, it will amplify respectively to twice its height or depth, and when a crest meets a trough, each cancels the other and the water is level. The former behavior is called *constructive interference* and the latter *destructive interference*. Light exhibits these kinds of interference—manifested as closely spaced light and dark bands on a projection screen—when passed through two narrow parallel slits. So light has a wave nature. But light also knocks electrons out of a variety of metals and therefore, as Einstein's 1905 explanation of this "photoelectric effect" demonstrated, exists as packets of energy called *photons* that behave like particles. This strange quantum-mechanical wave-particle duality is displayed in the double-slit experiment. When *very* low-intensity light is directed through narrow parallel slits, an interference pattern builds up on a photographic plate one spot at a time, manifesting the wave nature of light in the emerging interference pattern and the particle nature of light in its spotty accumulation. The pattern emerges if only one photon is in the apparatus at a given time and it disappears if one of the slits is covered. So *each* photon behaves as though it passes through *both* slits and *interferes with itself*, something that, from the standpoint of classical (non-quantum) physics and our ordinary experience of the world, is impossible. What is more, matter particles display this same wave-particle

60. Jim Baggott, *The Meaning of Quantum Theory* (Oxford: Oxford University Press, 1992), 1-74; Robert P. Crease and Charles C. Mann, *The Second Creation: Makers of the Revolution in 20th Century Physics* (New York: Macmillan Publishing Company, 1986); W. Michael Dickson, "Non-Relativistic Quantum Mechanics," in *Handbook of the Philosophy of Physics*, *Part A*, ed. Jeremy Butterfield and John Earman (Amsterdam: Elsevier, 2007), 275-415; Bruce L. Gordon, *Quantum Statistical Mechanics and the Ghosts of Modality* (Evanston: Northwestern University, Ph.D. Dissertation, 1998), 17-249; Helge Kragh, *Quantum Generations: A History of Physics in the Twentieth Century* (Princeton: Princeton University Press, 1999); Thomas S. Kuhn, *Black-Body Theory and the Quantum Discontinuity, 1894-1912* (Chicago: University of Chicago Press, 1978); Jagdish Mehra and Helmut Rechenberg, *The Historical Development of Quantum Theory*, vols. 1-5 (New York: Springer-Verlag, 1982-1987); Abraham Pais, *Inward Bound: Of Matter and Forces in the Physical World* (Oxford: Clarendon Press, 1986); Andrew Whitaker, *Einstein, Bohr, and the Quantum Dilemma* (Cambridge: Cambridge University Press, 1996).

61. Richard P. Feynman, "Probability and Uncertainty: The Quantum-Mechanical View of Nature," *The Character of Physical Law* (Cambridge: MIT Press, 1965), 127-48; Richard P. Feynman, *The Feynman Lectures on Physics*, *Vol. 3: Quantum Mechanics* (Reading: Addison-Wesley Publishing Company, 1971).

duality under similar experimental conditions, as the Davisson-Germer experiment demonstrated for electrons.[62]

The way that quantum mechanics deals with such things is to set aside classical conceptions of motion and the interaction of bodies and to introduce acts of measurement and probabilities for observational outcomes in an *irreducible* way, that is, in a way that *cannot* be resolved by an appeal to our inability to observe what is actually happening (in fact, quantum theory shows this peculiarity is *intrinsic* to reality rather than an artifact of our limited knowledge). In classical mechanics, the state of a physical system at a particular time is completely specified by giving the precise position and momentum of all its constituent particles, after which the equations of motion determine the state of the system at all later times. In this sense, classical mechanics is *deterministic*. But quantum mechanics does *not* describe systems by states in which particle position and momentum, for example, have simultaneously defined values. Instead, the state of the system is described by an abstract mathematical object called a *wavefunction*.[63] As long as the system is *not* being measured, the wavefunction develops deterministically through time, but it only specifies the *probability* that various *observables* (like position or momentum) will, when measured, have a particular value. Furthermore, not *all* such probabilities can equal zero or one (be absolutely determinate). This fact is expressed in *Heisenberg's indeterminacy/uncertainty principle*: no mathematical description of the state of a quantum system assigns probability 1 (determinateness) to the simultaneous existence of exact values for certain "complementary" pairs of observables. The particular value resulting from the measurement of a quantum observable is therefore *irreducibly probabilistic* in the sense that no sufficient condition is provided for *this* value being observed rather than another that is permitted by the wavefunction. This is *one* sense in which quantum theory is *indeterministic*. Also, since *all* the information about a quantum system is contained in its wavefunction, no measurement of the *current* state of a system suffices to determine the value that a *later* measurement of an observable will reveal. This is *another* (related) sense in which quantum theory is *indeterministic*. Applied to the double-slit experiment, the quantum wavefunction gives a probability distribution for measurement outcomes associated with a photon being observed to hit the photographic plate in a certain region when a measurement is made. This probability distribution describes the interference pattern on the plate that results when both slits are open, even if just one photon is sent through at a time.

This way of describing physical systems has further paradoxical consequences that conform to experimental observations. Albert Einstein, Boris Podolsky

62. C. J. Davisson, "Are Electrons Waves?" *Journal of the Franklin Institute* 205, no.5 (1928): 597-623.

63. Alyssa Ney and David Z. Albert, eds. *The Wave Function: Essays on the Metaphysics of Quantum Mechanics* (Oxford: Oxford University Press, 2013).

(1896-1966), and Nathan Rosen (1909-1995) pointed out one of these paradoxes in 1935, arguing that the quantum description of physical systems must be incomplete because there are elements of reality that quantum theory does not recognize. To make this case, they considered a situation in which two quantum particles interact so as to "entangle" their spatial coordinates with each other and their linear momenta with each other.[64] As a result of this wavefunction entanglement, measuring either the position or the momentum for one particle instantaneously fixes the value for that same observable for the other particle, no matter how far apart they are. If one then assumes, as the 1935 paper did, that what counts as an element of reality for the second particle is independent of which measurement is performed on the first particle, then reality can be attributed to both the position *and* the momentum of the second particle since measuring the position or the momentum of the first fixes the position or the momentum of the second without disturbing it and without any signal (subject to the limiting velocity of light) having passed between them. As Einstein, Podolsky, and Rosen (EPR) put it, "[i]f, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity."[65] Since quantum theory does not allow the second particle to have both position and momentum simultaneously, it is incomplete.

By way of response, Bohr argued that EPR missed the point of quantum-mechanical descriptions by ignoring the *different contexts of measurement*.[66] He agreed that measuring *either* the position *or* the momentum of one particle would render *either* the position *or* the momentum of the other particle an element of reality, but *denied* that the results from these different experimental contexts could be *combined*. In other words, if we try to make context-independent claims about what is real in a distant system, we will violate quantum-mechanical predictions and run afoul of experiment. This amounts to the claim that *measurement* of the first particle *can constitute what is real* about the second particle, even when they are separated by a distance that would prohibit any signal (subject to the limiting velocity of light) from passing between them.

64. Albert Einstein, Boris Podolsky, and Nathan Rosen, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review* 47 (1935): 777-80; Arthur Fine, "The Einstein-Podolsky-Rosen Argument in Quantum Theory," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2013), accessed June 30, 2017, http://plato.stanford. .edu/entries/qt-epr/.

65. Einstein, Podolsky, and Rosen, "Can Quantum-Mechanical Description," 777.

66. Niels Bohr, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review* 48 (1935): 696-702.

While Bohr's attempt to justify these claims generated much confusion,[67] John Bell's (1928-1990) work on the EPR argument and missing elements of reality,[68] along with subsequent experimental tests,[69] have shown that Bohr was essentially correct and Einstein wrong about the completeness of quantum mechanics. As we have noted, the wavefunctions of interacting quantum systems can become entangled in such a way that what happens to one of them instantaneously affects the other, no matter how far apart they have separated. Since local effects obey the constraints of special relativity and propagate at speeds less than or equal to that of light, such instantaneous correlations are called *nonlocal*, and the quantum systems manifesting them are said to exhibit *nonlocality*. What John Bell showed is that, if quantum theory is correct, no hidden variables (empirically undetectable elements of reality) can be added to the description of quantum systems exhibiting *nonlocal* behavior that would explain these instantaneous correlations on the basis of local considerations. As indicated, subsequent experiment showed that quantum theory is correct and complete as it stands. But since all *physical* cause-and-effect relations are local, the completeness of quantum theory implies the *physical incompleteness* of reality: the universe is shot through with mathematically predictable nonlocal correlations that, on pain of experimental contradiction, have *no* physical cause.[70]

67. For a helpful clarification, see Hans Halvorson and Robert Clifton, "Reconsidering Bohr's Reply to EPR," in *Non-locality and Modality*," ed. J. Butterfield and T. Placek (Dordrecht: Kluwer Academic, 2002), 3-18.

68. See John S. Bell, "On the Einstein-Podolsky-Rosen Paradox," in *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University, 1987 [1964]), 14-21; and John S. Bell, "On the Problem of Hidden Variables in Quantum Mechanics," in *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987 [1966]), 1-13.

69. A. Aspect, P. Grangier and G. Roger, "Experimental Tests of Realistic Theories via Bell's Theorem," *Physical Review Letters* 47 (1981): 460-67; A. Aspect, P. Grangier and G. Roger, "Experimental Realization of Einstein-Podolsky-Rosen-Bohm *Gedanken-experiment*: A New Violation of Bell's Inequalities," *Physical Review Letters* 48 (1982): 91-94; A. Aspect, J. Dalibard and G. Roger, "Experimental Tests of Bell's Inequalities Using Time-Varying Analyzers," *Physical Review Letters* 49 (1982): 1804-7; M. A. Rowe, D. Kielpinski, V. Meyer, C. A. Sackett, W. M. Itano, C. Monroe, and D. J. Wineland, "Experimental violation of a Bell's inequality with efficient detection." *Nature* 409 (2001): 791-94.

70. John S. Bell, "Bertlmann's Socks and the Nature of Reality," in *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987 [1981]), 139-58; Jeffrey Bub, *Interpreting the Quantum World* (Cambridge: Cambridge University Press, 1997); Robert Clifton, ed., *Perspectives on Quantum Reality: Non-Relativistic, Relativistic, and Field-Theoretic* (Dordrecht: Kluwer Academic, 1996); James T. Cushing and Ernan McMullin, eds., *Philosophical Consequences of Quantum Theory: Reflections on Bell's Theorem* (Notre Dame: University of Notre Dame Press, 1989); Gordon, "A Quantum-Theoretic Argument against Naturalism," 179-214; Hans Halvorson, "Reeh-Schlieder Defeats Newton-Wigner: On Alternative Localization Schemes in Relativistic Quantum Field Theory," *Philosophy of Science* 68 (2001): 111-33; Tim Maudlin, *Quantum Non-Locality and Relativity*, 2nd ed. (Oxford: Blackwell Publishers, 2002); Alistair Rae, *Quantum Physics: Illusion or Reality?,* 2nd ed. (Cambridge: Cambridge University Press, 2004); Michael Redhead, *Incompleteness, Nonlocality, and Realism: A Prolegomenon to the Philosophy of Quantum Mechanics* (Oxford: Clarendon Press, 1987); John A. Wheeler, "Law without Law," in *Quantum Theory and Measurement*, ed. John A. Wheeler and Wojciech H. Zurek (Princeton: Princeton University Press, 1983), 182-213.

The radicalness of nonlocality is actually deeper than this because it extends to isolated quanta as well. Stated roughly, it has been shown that if one makes the reasonable assumptions that an individual quantum can neither serve as an infinite source of energy nor be in two places at once, then that particle has *zero* probability of being found in any bounded spatial region, no matter *how* large.[71] In short, unobserved quanta do not exist *anywhere* in space, and so, to be honest, have no existence at all apart from measurement![72] Hans Halvorson and Robert Clifton closed some minor loopholes and extended this argument by demonstrating that the Hegerfeldt-Malament result holds under even more general conditions—including when the standard relativistic assumption that there is *no* privileged reference frame is dropped.[73] The proper conclusion seems to be that there is no intelligible notion of microscopic material objects: particle talk has pragmatic utility in relation to measurement results and macroscopic appearances, but *no* basis in an unobserved and independent microphysical reality.

So how should we understand the relationship and transition between the microscopic and the macroscopic world? This question leads to the second famous paradox of quantum theory, *the measurement problem*, which was first described in Erwin Schrödinger's (1887-1961) famous "cat paradox" paper.[74] In Schrödinger's iconic example, a radioactive atom with an even chance of decaying in the next hour is enclosed in a chamber containing a cat and a glass vial of poison. If a Geiger-counter detects the radioactive decay of the atom in that hour, it triggers a relay that causes a hammer to smash the vial and release the poison, thus killing the cat; otherwise, the cat survives. After an hour, the quantum wavefunction for the whole system (atom + counter + relay + hammer + vial + cat) is in an unresolved superposition that involves the cat being neither dead nor alive. The question of *where* and *how* the superpositions in the wavefunction "collapse" into a determinate result is the essence of the measurement problem. Is the determinate result a consequence of some special random process? Is it due to the quantum system's interaction with a macroscopic measurement device? Is it somehow connected to the *act* of observation itself? Is determinateness perhaps not manifested until the result is recognized by a *conscious*

71. G. C. Hegerfeldt, "Remark on Causality and Particle Localization," *Physical Review D* 10 (1974): 3320-21; David Malament, "In Defense of Dogma: Why There Cannot Be a Relativistic Quantum Mechanics of (Localizable) Particles," in *Perspectives on Quantum Reality: Non-Relativistic, Relativistic, and Field-Theoretic*, ed. Robert Clifton (Dordrecht: Kluwer Academic Publishers, 1996), 1-9.

72. Maria Fuwa, Shuntaro Takeda, Marcin Zwierz, Howard Wiseman, and Akira Furusawa, "Experimental Proof of Nonlocal Wavefunction Collapse for a Single Particle Using Homodyne Measurement," in *Frontiers in Optics* (Tuscon: *Optical Society of America Technical Digest*, paper FW2C.3, 2014), accessed June 30, 2017, https://arxiv.org/pdf/1412.7790v1.pdf.

73. Hans Halvorson and Robert Clifton, "No place for particles in relativistic quantum theories?" *Philosophy of Science* 69 (2002): 1-28.

74. Erwin Schrödinger, "Die gegenwärtige Situation in der Quantenmechanik." *Naturwissenschaften* 23 (1935): 807-12, 823-28, and 844-49.

observer? This issue arises because every quantum wavefunction is expressible as a superposition of different states in which the thing it describes, say an alpha particle that could be ejected from an atomic nucleus, fails to *possess* the properties specified by those states. At any given time, then, some features of a quantum object occupy an ethereal realm between existence and non-existence. Nothing subject to a quantum description *ever* has simultaneously determinate values for *all* its associated properties. And these ethereal superpositions percolate upward into the macroscopic realm because anything composed of quanta is always also intrinsically in a superposition of states, even though destructive interference (what physicists call *environmental decoherence*) may give the appearance that the wavefunction has "collapsed" into the single reality we observe.[75] What is more, under special conditions in the laboratory, we can create *macroscopic* superpositions. A clear example is provided by Superconducting Quantum Interference Devices (SQUIDs). SQUID states have been combined in which over a billion electrons move in a clockwise direction around a small superconducting ring, while another billion or more electrons simultaneously move around the ring in an anti-clockwise direction, meaning that *the two incompatible currents are in superposition*.[76] With respect to this macroscopic quantum realization superposing classically incompatible states, the pressing question is: in what direction are the electrons *supposed* to be moving*?* Which of these classically incompatible macroscopic states is supposed to be the *real* one?

So it is that quantum theory raises fundamental questions about the coherence of material identity, individuality, and causality that pose a *prima facie* problem for naturalistic metaphysics: if material reality is sufficient unto itself, as metaphysical naturalists insist, then, provided that quantum theory is correct, in *what* does the *intrinsic* substantial nature of material reality consist? What is more, given the irreducibly probabilistic nature of quantum outcomes and their demonstrable nonlocality, and given relativistic constraints on material causality, in *what* does the *causal integrity* and *sufficiency* of material reality consist? Why, in naturalistic metaphysics, if quantum outcomes lack any material explanation, does the physical universe cohere at all, let alone in a way that makes science possible? Efforts abound

75. Guido Bacciagaluppi, "The Role of Decoherence in Quantum Mechanics," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2012), accessed June 30, 2017, https://plato.stanford.edu/entries/qm-decoherence/; E. Joos, H. D. Zeh, C. Kiefer, D. Giulini, J. Kupsch, and I. O. Stametescu, eds., *Decoherence and the Appearance of a Classical World in Quantum Theory*, 2nd ed. (Berlin: Springer, 2003); N. O. Landsman, "Between Classical and Quantum," in *Handbook of the Philosophy of Physics, Part A*, ed. Jeremy Butterfield and John Earman (Amsterdam: Elsevier, 2007), 417-553; Maximilian Schlosshauer, *Decoherence and the Quantum-to-Classical Transition* (Berlin: Springer-Verlag, 2007); W. H. Zurek, "Decoherence and the Transition from Quantum to Classical – *Revisited*," *Los Alamos Science* 27 (2002): 2-25, accessed June 30, 2017, https://arxiv.org/ftp/quant-ph/papers/0306/0306072.pdf.

76. Joey Lambert, "The Physics of Superconducting Quantum Interference Devices" (2008), accessed June 30, 2017, http://www.physics. drexel.edu/~bob/Term_Reports/Joe_Lambert_3.pdf; see also Baggott, *Farewell to Reality*, 55.

to interpret quantum phenomena in a way consistent with a naturalistic worldview, so we turn now to a consideration of the primary strategies and their inadequacies.

Several Quanta of Discontent: The Failure of Naturalistic Interpretive Strategies

Various solutions have been and continue to be offered to the fundamental puzzle these quantum paradoxes pose: how is it even *possible* for the world to be the way that quantum theory describes? These solutions constitute different *interpretations* of quantum theory that cannot often be distinguished from each other on experimental grounds because they usually do not have decisively distinct experimental consequences. We will briefly consider six such interpretations —the Copenhagen interpretation, the de Broglie-Bohm nonlocal hidden variable interpretation, the many worlds interpretation, the Ghirardi-Rimini-Weber spontaneous collapse interpretation, the quantum logical interpretation, and instrumentalism—and, by noting their conceptual shortcomings, show how a theistic variant of the Copenhagen interpretation brings metaphysical completion to quantum theory so as to resolve the fundamental puzzle.

The Copenhagen interpretation of quantum mechanics (so-called because of its association with Niels Bohr's Institute for Theoretical Physics at the University of Copenhagen) has been regarded as the "official" or "orthodox" interpretation since the late 1920s when the consensus formed that Einstein had lost the debate with Bohr.[77] This interpretation is hardly uniform—it includes the initial concepts hashed out by Niels Bohr (1885-1962), Werner Heisenberg (1901-1976), Max Born (1882-1970), Wolfgang Pauli (1900-1958), John von Neumann (1903-1957), Paul Dirac (1902-1984), and others along with their positivistic reconstruals;[78] it includes the observer-centered and consciousness-related interpretations of von Neumann, Wigner, and Wheeler;[79] and it also includes the more recent "modal" interpretations

77. For an overview see Bub, *Interpreting the Quantum World*, 189-211; Jan Faye, "Copenhagen Interpretation of Quantum Mechanics," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, accessed June 30, 2017, https://plato.stanford.edu/entries/ qm-copenhagen/; Dugald Murdoch, *Niels Bohr's Philosophy of Physics* (Cambridge: Cambridge University Press, 1987).

78. Niels Bohr, *Atomic Theory and the Description of Nature* (Cambridge: Cambridge University Press, 1934); Niels Bohr, *Essays 1932-1957 on Atomic Physics and Human Knowledge* (Woodbridge: Ox Bow, 1958); Werner Heisenberg, *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper & Row, 1958); Werner Heisenberg, "Quantum Theory and Its Interpretation," in *Niels Bohr: His Life and Work as Seen by his Friends and Colleagues*, ed. S. Rozental (New York: Wiley Interscience, 1967), 94-108.

79. John Von Neumann, *Mathematische Grundlagen der Quantenmechanik* (Berlin: Springer, 1932), trans. R. T. Beyer as *Mathematical Foundations of Quantum Mechanics* (Princeton: Princeton University Press, 1955); Eugene Wigner, "Remarks on the Mind-Body Question," in *The Scientist Speculates*, ed. I. J. Good (London: Heinemann, 1961), 284-301; Wheeler, "Law without Law," 182-213.

of Healey and van Fraassen.[80] More often than not, however, its advocates adhere to variations on a set of core ideas: (1) quantum theory provides a *complete* description of physical systems (or what we can know about them) at the atomic and sub-atomic level, thus making nature (or our knowledge of it) irremediably causally *incomplete* and therefore irreducibly indeterministic; (2) the square of the amplitude of the wavefunction gives the probability of associated measurement outcomes (the Born Rule); (3) obtaining measurement results presupposes the existence of a classical (non-quantum) world of measurement devices; (4) quantum mechanics should recover the predictions of classical mechanics in the limit where increasingly large numbers of quanta are involved[81]—a modified version of the "correspondence principle" advocated by Bohr;[82] (5) for quantum properties like position and momentum that do not have simultaneous values,[83] the measurement process is *contextual* since the classical world of measuring devices requires mutually exclusive (*complementary*) experimental arrangements (this is Bohr's "principle of complementarity"); and (6) while every physical system can in principle be treated as quantum-mechanical, since quantum measurement requires a classical frame of reference provided by the measurement apparatus, not all systems can be treated as quantum-mechanical *simultaneously*.

The Copenhagen interpretation, taken as a realistic and *purely physical explanation* of quantum phenomena, has an intractable difficulty. The completeness of quantum theory entails the causal incompleteness and indeterministic character of physical reality—as evidenced by nonlocality and the irreducibly probabilistic results of quantum measurements—and if the physical world is all that is recognized to exist, then the absence of a physical explanation for nonlocal correlations and for irreducibly probabilistic quantum outcomes forces us to conclude that innumerable events in the physical realm happen without a sufficient cause and thus for no reason at all. But then by some miracle, individual events without a cause occur with a frequency that conforms to a probability distribution. By a similar miracle, events that cannot be causally connected nonetheless exhibit predictable correlated behavior, functioning as *random devices in harmony*. We are thus confronted with a situation in which the causal structure of the physical world is metaphysically incomplete and insufficient to explain quantum phenomena, but in virtue of a prior metaphysical commitment to naturalism, no non-naturalistic (transcendent) explanation is permitted. In short,

80. Richard Healey, *The Philosophy of Quantum Mechanics* (Cambridge: Cambridge University Press, 1989); Bas C. Van Fraassen, *Quantum Mechanics: An Empiricist View* (Oxford: Clarendon Press, 1991).

81. David Bohm, *Quantum Theory* (New York: Prentice-Hall, 1951), 31.

82. Alisa Bokulich, "Bohr's Correspondence Principle," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2010), accessed June 30, 2017, https://plato.stanford.edu/entries/bohr-correspondence/.

83. Hans Halvorson, "Complementarity of Representations in Quantum Mechanics," *Studies in History and Philosophy of Modern Physics* 35 (2004): 45-56.

Copenhagen orthodoxy, framed in a purely physical context, entails a denial of the *principle of sufficient reason* (PSR) understood as the general maxim that *every contingent event has an explanation*.

But denying the PSR, so understood, has consequences that undermine the very possibility of doing science.[84] Why? Suppose, among all of the events that happen in the universe, there are countless many that happen without cause or reason. If this were true, we would have no principled way of telling which events were caused and which were not, for events that *appeared* to have a cause might, in fact, lack one. Our current perceptual states, for example, might have no explanation, in which case they would bear no reliable connection to the way the world is. So if the PSR were false, we could never have any confidence in our cognitive states. In short, we would be saddled with an *intractable skepticism*. Furthermore, if the PSR failed for some event, there would be no objective probability for the occurrence of that event, because there would be no basis on which to make a calculation of probability. But without an evaluative basis, we could not even claim that violations of the PSR were improbable. Since we decide on the credentials of scientific explanations by comparing them with their competitors, and "no explanation" would then be an inscrutable competitor for *every* proposed explanation, we would be unable to decide whether there is a scientific explanation for *anything* that happens![85] So denial of the PSR is a science-killer that opens the door to an irremediable skepticism. If we were to accept a version of Copenhagen orthodoxy, then, the absence of a physical explanation for nonlocal correlations and individual quantum outcomes, especially in light of their occurrence in seemingly miraculous conformity to a probability distribution, would point to the rational necessity of a *non-physical explanation* for quantum phenomena. We will return to this theme momentarily.

84. See Pruss, *The Principle of Sufficient Reason*; Pruss, "Leibnizian Cosmological Arguments."

85. This consequence cannot be mitigated by suggesting that testing can distinguish between those cases where there is no explanation and those where there is. No test can distinguish between the case in which an event *appears* to have been caused when in fact it just happened and the case in which it *actually* was caused, for the *appearance* that something was actually caused may itself be something that lacks explanation. This metaphysical situation is further complicated, if the PSR is false, by the skeptical possibility that our perception that an event has occurred that has such-and-such a cause might itself lack a cause, and our beliefs about the world may therefore have no basis in reality. The PSR is a necessary metaphysical truth that we know *a priori*; it is a precondition of all knowledge and of the intelligibility of the world.

A second interpretation of quantum theory is the de Broglie-Bohm nonlocal hidden variable theory, sometimes simply called "Bohmian mechanics."[86] Bohmian mechanics attempts to restore causality to quantum phenomena by privileging position as an observable and introducing either a "guidance equation" or a "quantum potential field" that gives determinate trajectories to all of the constituents of a quantum system. While this sounds good in theory, there are intractable problems with the proposal. First of all, even though the proposal solves the measurement problem in ordinary (non-relativistic) quantum mechanics, neither the quantum potential field nor the guidance equation carry energy-momentum, so they act in a way that is both *undetectable* and *non-mechanical* and hence cannot, in principle, provide a *causal* explanation of interactions among particle locations. Nonlocal correlations among spatiotemporally located particles are *described*, but not *explained*. Furthermore, when the attempt is made, as it must be, to extend Bohmian mechanics to incorporate relativity theory and quantum field theory, fatal theoretical inadequacies arise:[87] (1) the quanta associated with relativistic pilot waves can travel faster than light and backwards in time; (2) the numbers of quanta do not vary in field interactions as experiment demands and standard quantum field theory describes; (3) unlike standard quantum field theory, Bohmian field theory does not predict or explain the existence of antimatter; and (4) relativistic Bohmian field theory reintroduces the measurement problem and makes it unsolvable. All things considered, therefore, the interpretation must be judged a failure.

86. John S. Bell, "Beables for Quantum Field Theory," in *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987 [1984]), 173-80; David Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables, I and II," *Physical Review* 85 (1952): 166-193 (reprinted in *Quantum Theory and Measurement*, ed. John A. Wheeler and Wojciech H. Zurek [Princeton: Princeton University Press, 1983], 369-396); David Bohm, *Wholeness and the Implicate Order* (London: Routledge, 1980); David Bohm and Basil Hiley, *The Undivided Universe: An Ontological Interpretation of Quantum Theory* (London: Routledge, 1993); James T. Cushing, *Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony* (Chicago: University of Chicago Press, 1994); James T. Cushing, Arthur I. Fine, and Sheldon Goldstein, eds., *Bohmian Mechanics and Quantum Theory: An Appraisal* (Dordrecht: Kluwer Academic Publishers, 1996); Sheldon Goldstein, "Bohmian Mechanics," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2013), accessed June 30, 2017, https://plato.stanford.edu/entries/qm-bohm/; Simon Saunders, "The 'Beables' of Relativistic Pilot Wave Theory," in *From Physics to Philosophy*, ed. Jeremy Butterfield and Constantine Pagonis (Cambridge: Cambridge University Press, 1999), 71-89.

87. Saunders, "The 'Beables' of Relativistic Pilot Wave Theory," 71-89.

A third approach is known as the "many worlds interpretation" (MWI) of quantum theory.[88] Its solution to the measurement problem pursues a drastic course by denying wavefunction collapse and asserting instead that *every* possible quantum outcome in the entire history of the universe *has been realized* in a *different branch* of the "universal wavefunction" that defines an ultimate and exhaustive collection of parallel realities. Everything that could happen, quantum-mechanically speaking, has happened and will happen, but since each of us splits into multiple parallel selves with every branching of the universe catalyzed by different quantum outcome possibilities, we each only ever observe those outcomes in branches of the universal wavefunction that are part of the personal history of that version of ourselves.

Aside from its implausibility and, from a Christian perspective, the perfect bollix it makes of human identity and moral responsibility, of the doctrines of the incarnation and the atonement, and of both individual and corporate eschatology (to name just a few things), the MWI also faces intractable theoretical problems. The first difficulty is that there are infinitely many ways to express the universal wavefunction as a superposition of component waves and the branching that takes place in the universal wavefunction depends on which expression (basis) is chosen. So which way of building the universal wavefunction is to be preferred? This difficulty, known as the "preferred basis problem", reveals that the branching process itself is completely arbitrary from a mathematical standpoint and therefore, from the abstracted point of view presupposed by the MWI, not reflective of any physical reality. The second difficulty lies in its treatment of quantum probabilities. Suppose that a quantum event has two possible outcomes with unequal probabilities, say 1/3 and 2/3. Since, according to the MWI, *both outcomes occur* in different branches of the universal wavefunction, how can their probabilities be different? In fact, does not *everything* happen with absolute certainty (probability one)? If we follow the suggestion of Deutsch[89] and Wallace[90] and say that quantum probabilities reflect how we should decide to bet about which universe we will find ourselves in, then, as

88. David Z. Albert, *Quantum Mechanics and Experience* (Cambridge: Harvard University Press, 1992); Baggott, *Farewell to Reality*, 211-21; David Deutsch, "Quantum theory of probability and decisions," *Proceedings of the Royal Society of London A* 455 (1999): 3129-37; Bryce S. DeWitt and Neil Graham, eds., *The Many-Worlds Interpretation of Quantum Mechanics* (Princeton: Princeton University Press, 1973); Hugh Everett III, "'Relative State' Formulation of Quantum Mechanics," *Reviews of Modern Physics* 29 (1957): 454-62; Simon Saunders, "Physics," in *The Routledge Companion to Philosophy of Science*, 2nd ed., ed. Martin Curd and Stathis Psillos (New York: Routledge, 2014), 645-58; S. Saunders, J. Barrett, A. Kent, and D. Wallace, eds., *Many Worlds? Everett, Quantum Theory, & Reality* (Oxford: Oxford University Press, 2010); Lev Vaidman, "Many Worlds Interpretation of Quantum Mechanics," in *Stanford Encyclopedia of* Philosophy, ed. Edward N. Zalta (2014), accessed June 30, 2017, https://plato.stanford.edu/entries/qm-manyworlds/; David Wallace, "Everettian Rationality," *Studies in History and Philosophy of Modern Physics* 34 (2003): 87-105.

89. Deutsch, "Quantum theory of probability and decisions," 3129-37.

90. Wallace, "Everettian Rationality," 87-105.

David Baker[91] has argued, we land in vicious circularity, for talk of probabilities in the many worlds scenario assumes the existence of a preferred basis that *only* comes about through decoherence of the wavefunction, which is *itself* an irreducibly probabilistic phenomenon. Furthermore, to paraphrase David Albert,[92] what needs to be explained about quantum theory is the empirical frequency of the outcomes we actually experience, *not* why, if we held radically different convictions about the nature of the world than we actually do, we would still place bets in accordance with the Born Rule. And to this observation we may add that since there are no unrealized outcomes, in innumerable branches of the universal wavefunction we will come to reject the Born Rule (or never formulate it) as a betting strategy because what it proclaims to be the most probable outcome *never* happens! The MWI thus fails for multiple reasons.[93]

A fourth interpretation that has been growing in popularity is the spontaneous collapse theory of Ghirardi, Rimini, and Weber, often simply called GRW theory.[94] The basic idea is that quantum-mechanical descriptions should be supplemented by random, infinitesimally small fluctuations which, with extremely high probability, localize the wavefunction to a specific region. While this postulation is *ad hoc*, Ghirardi's approach is nonetheless similar to Bohm's in emphasizing the density of matter to make the theory as "physical" as possible. The problem is that it cannot be rendered compatible with relativity theory or extended to the treatment of quantum fields in this form. When the effort is made to extend GRW theory to relativistic quantum fields by replacing matter (mass-density) with "flash events,"[95] the theory remains radically non-local and has the additional drawback of eliminating the possibility of particle interactions and thus any physics of interest.[96] Finally, there

91. David Baker, "Measurement Outcomes and Probability in Everettian Quantum Mechanics," *Studies in History and Philosophy of Modern Physics* 38 (2007): 153-69.

92. David Albert, "Probability in the Everett Picture," in *Many Worlds? Everett, Quantum Theory, & Reality*, ed. Simon Saunders, Jonathan Barrett, Adrian Kent, and David Wallace (Oxford: Oxford University Press, 2010), 355-68.

93. But see Simon Saunders *et al*, *Many Worlds?* (2010) for extensive polemics.

94. See John S. Bell "Are There Quantum Jumps?" in *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987), 201-12; A. Cordero, "Are GRW tails as bad as they say?" *Philosophy of Science* S66 (1999): S59-S71; Dickson, "Non-Relativistic Quantum Mechanics," 376-81; G. C. Ghirardi, "Collapse Theories," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2016), accessed June 30, 2017, https://plato. stanford.edu/entries/qm-collapse/; G. C. Ghirardi, A. Rimini, and T. Weber, "Unified Dynamics for Microscopic and Macroscopic Systems," *Physical Review D* 34 (1986): 470-91; Simon Saunders, "Physics," 645-58; Roderich Tumulka, "A Relativistic Version of the Ghirardi-Rimini-Weber Model," *Journal of Statistical Physics* 125 (2006): 821-40; Roderich Tumulka, "On spontaneous wave function collapse and quantum field theory," *Proceedings of the Royal Society of London A* 462 (2006): 1897-1908.

95. Tumulka, "A Relativistic Version," 821-40; Tumulka, "On spontaneous wave function collapse," 1897-1908.

96. Thomas Ryckman, "Review of William Lane Craig and Quentin Smith, eds., *Einstein, Relativity and Absolute Simultaneity*," *Notre Dame Philosophical Reviews: An Electronic Journal* (2010.09.20), accessed June 30, 2017, http://ndpr.nd.edu/news/24498-einstein-relativity-and-absolute-simultaneity/.

are no versions of the theory in which the collapse is complete, with the consequence that all "material" objects have low-density copies at multiple locations, the presence and effect of which linger forever in the GRW wavefunction.[97] In short, GRW theory does not succeed in restoring material causality (locality), physical substantiality, or spatiotemporal uniqueness to quantum phenomena, and thus makes no real progress toward resolving the "paradoxes" of quantum theory.[98]

The quantum-logical interpretation[99] is the fifth attempt to provide realistic interpretation of quantum theory we will consider. Its fundamental premise is that the paradoxes of quantum theory are resolved if we change the logic we use to analyze the world, for example, by modifying the formal structure of classical logic to conform to the algebra of observables in quantum mechanics, or by introducing a third truth-value that is neither true nor false. Of this proposal only two things need be said. The first is that one does not obviate the paradoxes of quantum mechanics by shifting the venue of discussion from the strangeness of the world to a logical structure that embodies that very strangeness. This is not a solution to the problem; it is a redescription of the problem in a different mathematical vocabulary. The second point that needs to be made is that, even if one were to adopt a non-classical logic to analyze propositions about quantum-mechanical reality, the systemic properties of that non-classical logic could only be explored using the tools of classical logic. And as regards its application, in any given situation, either you use quantum logic or you don't, and if you do, you are either correct or incorrect to do so, and the conclusions you reach will be either true or false. In short, quantum logic can never replace classical logic and, while a useful tool for exploring the logical structure of quantum theory, it is yet another description of the quantum paradoxes, not an explanation of them.

Given the difficulties of interpreting quantum theory realistically, perhaps, as a last resort, we would be better off taking an anti-realist and instrumentalist attitude toward it. This approach treats the theory as a tool for generating predictions about experimental outcomes while denying it tells us anything about the nature of reality. On this view, quantum theory is a mathematical "black box" for successful

97. Cordero, "Are GRW tails as bad as they say?" S59-S71; Dickson, "Non-Relativistic Quantum Mechanics," 376-81.

98. Unfortunately, Alvin Plantinga indicates some sympathy for GRW theory in *Where the Conflict Really Lies*, 95-97, 115-17; needless to say, I think he is mistaken to do so.

99. G. Birkhoff, and J. von Neumann, "The Logic of Quantum Mechanics," *Annals of Mathematics* 37 (1936): 823-43; W. Michael Dickson, "Quantum Logic is Alive $\wedge$ (It is True $\vee$ It is False)," *Philosophy of Science* 68 (2001): S274-S287; Peter Gibbins, *Particles and Paradoxes: The Limits of Quantum Logic* (Cambridge: Cambridge University Press, 1987), 126-67; Clifford Hooker, ed., *The Logico-Algebraic Approach to Quantum Mechanics*, vols. I and II (Dordrecht: D. Reidel, 1975 and 1979); Hilary Putnam, "How to Think Quantum-Logically," *Synthese* 29 (1974): 55-61; Hilary Putnam, "The Logic of Quantum Mechanics," in *Matter and Method: Philosophical Papers, Volume 1* (Cambridge: Cambridge University Press, 1979), 174-97; Willard V. O. Quine, "Two Dogmas of Empiricism," *The Philosophical Review* 60 (1951): 20-43; Hans Reichenbach, *Philosophic Foundations of Quantum Mechanics* (Berkeley: University of California Press, 1944), 144-66.

predictions, but is devoid of any explanatory value. Is this a tenable approach? It is true that, without an interpretation of some sort, the mathematics of quantum theory just describes the behavior of the micro-world without any suggestion of explaining it. But to prescind from the task of interpretation simply because the phenomena the mathematics describes are resistant to a coherent *physical* explanation seems mere avoidance behavior. The *facts* of quantum behavior are not and cannot be disputed by instrumentalists: the quantum world exhibits measurable nonlocal correlations and individual outcomes that lack sufficient physical causes. These facts beg explanation and the instrumentalist strategy is simply to embrace antirealism and reject explanatory demand rather than deal with the intractability of physical explanations for such phenomena.

On pain of denying the principle of sufficient reason and putting all of science and human knowledge in jeopardy, *some* explanation for these phenomena must exist in spite of the increasingly clear recognition that no physical explanation, in principle, is possible. To review and expand on the bases for this conclusion we note that: (1) no physical explanation of nonlocal quantum correlations is possible under relativistic constraints; (2) the non-localizability of individual particles apart from measurement is incompatible with them having intrinsic substantial existence; (3) quantum fields exhibit states of superposition of contradictory numbers of quanta that make the individual substantiality of these quanta impossible;[100] (4) the stability of macroscopic appearances is an artifact of destructive interference (environmental decoherence) in which still extant yet phenomenologically suppressed macroscopic superpositions persist and for which, given the metaphysical *unity* of reality in contrast to the many worlds hypothesis, has material *in*substantiality as a necessary condition; (5) macroscopic superpositions have been and can be created under

100. Aside from the intractability (nay, *impossibility*) of constructing substantial identity conditions on the basis of a quantum field ontology, there is good reason to think that field ontologies are as inadequate as particle ontologies for interpreting QFT: see David Baker, "Against Field Interpretations of Quantum Field Theory," *British Journal for the Philosophy of Science* 60, no.3 (2009): 585-609, accessed June 30, 2017, http://philsci-archive.pitt.edu/4350/1/AgainstFields.pdf. Nonetheless, considering various approaches to constructing ontological interpretations of QFT helps us appreciate the unworkability of materialist metaphysics in this context. In this regard, the essays in Meinard Kuhlmann, Holger Lyre, and Andrew Wayne, eds., *Ontological Aspects of Quantum Field Theory* (Singapore: World Scientific, 2002) are instructive. Even so, an astute reader might think that an event ontology in the context of process metaphysics could hold promise as an interpretive strategy for QFT; with some very important provisos, I would acknowledge this possibility. The most important proviso, however, is that event ontologies are parasitic on substance ontologies since there can be no events without substantial participants *in* those events. If *nothing* participates in an event, there is no event. In the absence of material substances, however, what remains are mental events, more specifically, mental events within the perceptual world of *immaterial mental substances*. But making ontological sense of this requires placing any process-metaphysical event ontology for QFT in the context of an occasionalist quantum idealism of the sort I will soon outline. I dealt with this question more fully in an unpublished paper presented at the Pacific Division of the *American Philosophical Association* in 2005 ("Quantum Field Theory and Process Metaphysics: An Unnecessary and Problematic Union"), though I would emphasize different aspects of the discussion now.

laboratory conditions,[101] thus allowing the aforementioned insubstantiality to be observed directly; (6) mass, which is resistance to acceleration, is not itself intrinsic to matter and indicative of its substantiality, but rather an *artifact* of ongoing interactions between matter fields and the quantum Higgs field; and (7) in every quantum state, whether for microscopic or macroscopic systems, there will always be some elements that *fail* to have a determinate value, in other words, there will always be some elements that *fail to exist*.[102]

To employ an imprecise metaphor, the reality that quantum theory gives us is rather like a Hollywood set where all the buildings are façades and only one side of a structure is visible at any given time; then, when you try to open a door on the side currently visible in order to see inside the structure, you find that there's *nothing* behind it! In short, what both quantum theory and the observational evidence that gives rise to it tell us is that what we take to be the "material universe" is radically incomplete, both with respect to a material explanation of the constitution of the objects we perceive and with respect to the causal interactions of such objects with each other. The fact that *some* explanation is necessary and *no* material explanation is sufficient shows that the physical universe is *neither* a self-contained *nor* a self-sustaining entity. Rather, the universe we experience is dependent on a form of causality that *transcends* what we take to be physical and *completes* it, giving integrity to its causal structure.

More than a Quantum of Divine Action: The Ontological Basis for the Phenomenological Regularity of Nature

Given the ubiquitous insufficiency of physical causation and the metaphysical and epistemic necessity of sufficient causality, how is causal closure achieved, and what does the answer to this question tell us about the nature of those things we commonly call physical "laws"? Could we, for instance, usefully explain macroscopic regularities as *emergent* properties of quantum interactions in a way that would ground material identity and physical law? It is true that we can understand such emergence in terms of the limit behavior of physical systems in two ways—the classical mechanical (CM) limit, and the classical statistical (CS) limit. While these limits are useful in seeing how quantum descriptions can give rise to classical appearances, they are

101. J. A. Dunningham, K. Burnett, R. Roth, and W. D. Phillips, "Creation of Macroscopic Superposition States from Arrays of Bose-Einstein Condensates," *New Journal of Physics* 8 (2006): 182-88, accessed June 30, 2017, http://iopscience.iop.org/article/10.1088/1367-2630/8/9/182/pdf; Joey Lambert, "The Physics of Superconducting Quantum Interference Devices" (2008), accessed June 30, 2017, http://www.physics. drexel.edu/~bob/Term_Reports/Joe_Lambert_3.pdf.

102. In this latter regard, see also Hans Halvorson, "The Measure of All Things: Quantum Mechanics and the Soul," in *The Soul Hypothesis: Investigations into the Existence of the Soul*, ed. Mark C. Baker and Stewart Goetz (New York: Continuum, 2011), 145-46.

metaphysically unenlightening where relevant, and irrelevant in the case of nonlocal behavior.[103] Consider first the classical limit in which Maxwell-Boltzmann statistical behavior emerges from quantum (Bose-Einstein or Fermi-Dirac) statistics. With the standard definitions of the Poisson and commutator brackets, the CM limit of a quantum system is defined to be:

$$\lim_{\hbar \to 0} \frac{1}{i\hbar}\left[\hat{A}, \hat{B}\right] = \{A, B\}.$$

This limit is fictional, of course, because ħ is a physical constant; nonetheless, it represents the transition between the quantum and classical descriptions of a system since classical behavior "emerges" when quantum effects are dampened to the point of negligibility. It is important to note, however, that there are still residual effects (dependent on Planck's constant) even after the classical mechanical limit is taken, and that the underlying reality is still quantum-mechanical in character. In the second case, that of the CS limit, statistical mechanics mathematically relates the thermodynamic properties of macroscopic objects to the motion of their microscopic constituents. Since the microscopic constituents obey quantum dynamics, the correct description must in principle lie within the domain of quantum statistical mechanics. Under thermodynamic conditions of high temperature (T) and low density (n), however, classical statistical mechanics serves as a useful approximation. With this in mind, the CS limit may be defined as the situation represented by:

$$T \to \infty \text{ and } n \to 0.$$

These are the same conditions as those governing the applicability of the ideal gas law ($pV = nRT$), so the CS limit could equally well be called the ideal gas limit. Unlike the CM limit, the conditions governing the CS limit are subject to experimental control. In respect of quantum statistical behavior, both the CM and the CS limits are continuous, so the indistinguishability arising from the permutation symmetry of the quanta is not removed, even though it is dampened. Quantum "particles" retain their indistinguishability even when their aggregate behavior can be approximated by a classical (Maxwell-Boltzmann) distribution. These observations reveal why any emergentist account of the dependence or supervenience of the macroscopic realm on the microscopic realm, while perhaps descriptively interesting, will be unenlightening as a metaphysical explanation. It is environmental decoherence (essentially, statistical damping through wave-function orthogonalization) that gives quantum-mechanical ephemera a cloak of macroscopic stability, but decoherence is *not* a real solution to the measurement problem. The apparent solidity of the world of our experience is a mere epiphenomenon of quantum statistics; the underlying

103. Gordon, "Maxwell-Boltzmann Statistics and the Metaphysics of Modality," 393-417.

noumena retain their quantum-theoretic ephemerality while sustaining a classical macroscopic phenomenology.[104]

So where does this leave us in respect of an analysis of what are commonly called physical "laws"? Alvin Plantinga provides a very cogent philosophical critique of the role of necessity in accounts of physical law.[105] Though some philosophers have argued that natural laws are broad logical necessities similar to statements like *no equine mammals are mathematical propositions*,[106] there seems little to no basis for this claim. If we take Coulomb's Law of electric charges, for instance, the fact that two like (or different) charges repel (or attract) each other with a force proportional to the magnitude of the charges and inversely proportional to the square of the distance between them gives no hint of being metaphysically necessary. We can easily conceive of a different mathematical relationship holding between the charges. This has led other philosophers to assert that the laws of nature are *contingently* necessary and to develop an account of natural laws based on this assumption.[107] But quite apart from the oxymoronic appearance of such a claim, no coherent account of its substance has ever been put forward. One cannot just call natural laws "contingent necessities" and expect it to be true "any more than one can have mighty biceps just by being called 'Armstrong'," as David Lewis famously quipped.[108] Finally, other advocates of natural laws as physical necessities have proposed an account of physical laws deriving from innate causal powers:[109] laws of nature are grounded in the essential natures of things inherent in their material substance and manifested through forces or fields that express necessary capacities or emanations from these natures and mediate or constrain physical interactions in a way that also is necessary. But again, it is difficult to see why *this* causal power must necessarily flow from the essential nature of *that* material substance. Calling it necessary or essential doesn't make it so; we could imagine it otherwise.

104. See Gordon, "A Quantum-Theoretic Argument against Naturalism," 190-95 for a more complete discussion of the explanatory vacuity of the concepts of supervenience and emergence in relation to the transition between the microscopic and macroscopic realms.

105. Alvin Plantinga, "Law, Cause, and Occasionalism," in *Reason and Faith: Themes from Swinburne*, ed. Michael Bergmann and Jeffrey E. Brower (Oxford: Oxford University Press, 2016), 126-44.

106. For example, Sydney Shoemaker, "Causality and Properties," in *Time and Cause*, ed. Peter van Inwagen (Dordrecht: D. Reidel, 1980), 109-35; Chris Swoyer, "The Nature of Natural Laws," *Australian Journal of Philosophy* 60 (1982): 203-23; Evan Fales, *Causation and Universals* (London: Routledge, 1990); and Alexander Bird, "The Dispositionalist Conception of Law," *Foundations of Science* 10, no. 4 (2005): 353-70.

107. For example, David Armstrong, *What is a Law of Nature?* (Cambridge: Cambridge University Press, 1983); Fred Dretske, "Laws of Nature," *Philosophy of Science* 44 (1977): 248-68; Michael Tooley, *Causation: A Realist Approach* (Oxford: Clarendon Press, 1987).

108. David Lewis, "New Work for a Theory of Universals," *Australasian Journal of Philosophy* 61 (1983): 166.

109. For example, R. Harré and E. H. Madden, *Causal Powers: A Theory of Natural Necessity* (Oxford: Basil Blackwell, 1975); J. Bigelow and R. Pargetter. *Science and Necessity* (Cambridge: Cambridge University Press, 1990).

Even if necessitarian accounts of physical law were not philosophically intractable, however, they would still be empirically false on quantum-mechanical grounds. All of them require that physical systems and material objects objectively possess properties that are capable of being connected together in a law-like fashion. At a minimum, necessitarian theorists have to maintain that quantum systems, or their components, objectively possess properties prior to measurement, whether these properties are determinate or indeterminate (probabilified dispositions), and that it is the *objective possession* of these properties that necessitates (or renders probable) their specific behavior. But Bell's theorem demonstrates that this assumption leads to empirically false consequences in the case of both locally deterministic and locally stochastic models.[110] Furthermore, this assumption either leads to an ontological contradiction in the nonlocal stochastic case,[111] or if an undetectable privileged reference frame is invoked, succumbs to the nonlocalizability and insubstantiality of the intended possessors of the requisite properties.[112] What we are left with, therefore, is a situation in which there are no objective physical properties at the quantum level in which to ground necessitarian relations, and no emergentist or supervenience account of material identity that would provide a *substantial* foundation for macroscopic necessitarianism. So necessitarian theories of natural law cannot gain a foothold in fundamental physical theory and must be set aside. All that remains are so-called *regularist* accounts of natural law, which assert that while there are regularities present in the phenomenology of the world on a universal scale, there are no real *laws* of nature, that is, there is *no necessity* that inheres in the natural relationships among things or in the natural processes involving them. In short, nature behaves in ways we can count on, but it does so for no discernible *physical* reason. How do we make sense of this situation?

In dealing with this conundrum, we must first address the metaphysical coherence of regularist accounts of physical law in the context of naturalistic metaphysics. The

110. John S. Bell, "On the Einstein-Podolsky-Rosen Paradox," 14-21; John S. Bell, "On the Problem of Hidden Variables in Quantum Mechanics," 1-13; Arthur I. Fine, "Correlations and Physical Locality," in *PSA 1980,* vol. 2, ed. P. Asquith and R. Giere (East Lansing, MI: Philosophy of Science Association, 1981), 535-62; Arthur I. Fine, "Hidden variables, joint probability, and the Bell inequalities," *Physical Review Letters* 48 (1982): 291-95; Arthur I. Fine, "Joint distributions, quantum correlations, and commuting observables," *Journal of Mathematical Physics* 23 (1982): 1306-10; Michael Redhead, *Incompleteness, Nonlocality, and Realism: A Prolegomenon to the Philosophy of Quantum Mechanics* (Oxford: Clarendon Press, 1987), 71-118; Cushing and McMullin, eds., *Philosophical Consequences of Quantum Theory*; R. Clifton, D. V. Feldman, H. Halvorson, M. L. G. Redhead, and A. Wilce, "Superentangled states," *Physical Review A* 58, no. 1 (1998): 135-45.

111. Gordon, *Quantum Statistical Mechanics and the Ghosts of Modality*, 444-51; Gordon, "A Quantum-Theoretic Argument against Naturalism," 194-95; Tim Maudlin, *Quantum Non-Locality and Relativity*, 204-12.

112. Gordon, *Quantum Statistical Mechanics and the Ghosts of Modality*, 452-53; Gordon, "A Quantum-Theoretic Argument against Naturalism," 198-201; Halvorson, "Reeh-Schlieder Defeats Newton-Wigner," 111-33; Halvorson and Clifton, "No Place for Particles," 1-28; Malament, "In Defense of Dogma," 1-9.

patron saint of this approach is David Hume and the most sophisticated modern articulation of it is given by David Lewis.[113] In describing the regularities of our world, Lewis's theory takes the fundamental relations to be spatiotemporal: relativistic distance relations that are both space-like and time-like, and occupancy relations between point-sized things and spacetime points. Fundamental properties are then local qualities—perfectly natural intrinsic properties of points, or of point-sized occupants of points. Everything else supervenes on the spatiotemporal arrangement of local qualities throughout all of history—past, present, and future—hence "Humean supervenience." On this view, natural regularities are simply the theorems of axiomatic deductive systems, and the best system is the one that strikes the optimal balance between simplicity and strength (informativeness). Lewis postulates this "best system" to exist as a brute fact whether we know anything about it or not. As Plantinga points out,[114] we have little conception of what Lewis's "best system" might look like and even less reason to think that there is a uniquely "best" such system as opposed to "a multitude of such systems each unsurpassed by any other." We may add that Lewis's approach, as it stands, is inadequate to deal with quantal nonlocalizability, physical indeterminism, and the undoing of the causal metric of spacetime in quantum gravitational theories. Furthermore, quantum-theoretic Bell correlations, while nonlocally and instantaneously coincident, would have to be understood in Lewis's theory in terms of *local* properties manifesting *random values in harmony at space-like separation* without *any* ontological connection or explanation, everything functioning as part of an overarching system of regularities that is in some sense optimal, but which also lacks any explanation for the ongoing order it displays. In short, embracing Lewis's approach requires rejecting the PSR on a colossal scale, which, as we have seen, has among its consequences both self-defeating skepticism and the utter futility of scientific explanation. When its implications are grasped, Lewis's Humean supervenience serves as a *reductio* of itself.

Having seen that necessitarianism is untenable for quantum-theoretic reasons and that the regularist account of laws is rationally unsustainable in a naturalistic context, let's begin anew with the eminently reasonable assumption that there is a way that the world is, that we can get it right or wrong, and that science is a useful tool in helping us to get it right. In particular, when physical theory backed by experiment demonstrates that the world of our experience must satisfy certain formal structural constraints—for example, quantizability, nonlocality as encapsulated in the Bell theorems, nonlocalizability as indicated by the Hegerfeldt-Malament and Reeh-Schlieder theorems, Lorentz symmetries in spacetime, internal symmetries like isospin, various conserved quantities as implied by Noether's theorem, and so

113. David K. Lewis, *Counterfactuals* (Cambridge: Harvard University Press, 1973); Lewis, "New Work for a Theory of Universals," 343-77; David K. Lewis, "Humean Supervenience Debugged," *Mind* 103 (1994): 473-90.

114. Plantinga, "Law, Cause, and Occasionalism," 130.

on—then these *formal* features of the world may be taken as strong evidence for a certain metaphysical state of affairs. At a minimum, such states of affairs entail that the *structural* constraints empirically observed to hold and represented by a given theory will be preserved (though perhaps in a different representation) in any future theoretical development. This gives expression to a generic *structural realism*.

Whether this structural realism has further ontological consequences pertaining to the actual furniture of the world (entity realism) is a matter of debate among structural realists. The *epistemic structural realist* believes that there are epistemically inaccessible material objects forever hidden behind the structures of physical theory and that all we can know are the structures.[115] The *ontic structural realist* eliminates material objects completely—it is not just that we only know structures, but rather that all that exists to be known are the structures.[116] Both versions of structural realism are deficient, though in different ways.

We have argued that quantum theory is incompatible with the existence of material substances. Given this conclusion, the epistemic structural realist is just wrong that there is a world of inaccessible material individuals hidden behind the structures that quantum theory imposes upon the world. The situation would therefore seem to default to ontic structural realism. But while the ontic structural realist is correct that there are no material objects behind the structures, his position is deficient too because there can be no structures *simpliciter* without an underlying reality that is enstructured; we cannot build castles in the air. It would seem, then, that we are in a Catch-22 situation. The challenge to making sense of quantum physics is to give an account of what the world is like when it has an objective structure that does *not*

115. John Worrall, "Structural Realism: The Best of Both Worlds?" *Dialectica* 43 (1989): 99-124; Michael Redhead, *From Physics to Metaphysics* (Cambridge: Cambridge University Press, 1995); Tian Yu Cao, *Conceptual Developments of 20th Century Field Theories* (Cambridge: Cambridge University Press, 1997); Tian Yu Cao, "Structural Realism and the Interpretation of Quantum Field Theory," *Synthese* 136 (2003): 3-24; Tian Yu Cao, "Appendix: Ontological Relativity and Fundamentality—Is QFT the Fundamental Theory?" *Synthese* 136 (2003): 25-30; Tian Yu Cao, "Can We Dissolve Physical Entities into Mathematical Structures?" *Synthese* 136 (2003): 57-71.

116. James Ladyman, "What is Structural Realism?" *Studies in the History and Philosophy of Science* 29 (1998): 409-24; Steven French, "Models and Mathematics in Physics: The Role of Group Theory," in *From Physics to Philosophy*, ed. J. Butterfield and C. Pagonis (Cambridge: Cambridge University Press, 1999), 187-207; Steven French, "The Reasonable Effectiveness of Mathematics: Partial Structures and the Application of Group Theory to Physics," *Synthese* 125 (2000): 103-20; Steven French, "A Model-Theoretic Account of Representation (Or, I Don't Know Much About Art . . . But I Know It Involves Isomorphism," *Philosophy of Science* 70 (2003): 1472-83; Steven French, "Scribbling on the blank sheet: Eddington's structuralist conception of objects," *Studies in History and Philosophy of Modern Physics* 34 (2003): 227-59; Steven French, "Symmetry, Structure and the Constitution of Objects," accessed June 30, 2017, http://philsci-archive.pitt.edu/327/1/Symmetry%26Objects_doc.pdf; Steven French and Decio Krause, *Identity* in *Physics: A Historical, Philosophical, and Formal Analysis* (Oxford: Clarendon Press, 2006); Steven French and James Ladyman, "The Dissolution of Objects: Between Platonism and Phenomenalism," *Synthese* 136 (2003): 73-77; Steven French and James Ladyman, "Remodeling Structural Realism: Quantum Physics and the Metaphysics of Structure," *Synthese* 136 (2003): 31-56; James Ladyman and Don Ross, *Everything Must Go: Metaphysics Naturalized* (Oxford: Oxford University Press, 2007).

depend on material substances. What investigations of the completeness of quantum theory have taught us, therefore, is rather than quantum theory being incomplete, it is material reality (so-called) that is incomplete. The realm that we call the "physical" or "material" or "natural" is not self-sufficient, but dependent upon something more basic that transcends it and gives reality to it.

In light of this realization, the rather startling picture that begins to seem plausible is that preserving and explaining the objective structure of appearances in light of quantum theory requires reviving a type of phenomenalism in which our perception of the physical universe is constituted by sense-data conforming to certain structural constraints, but in which there is no substantial material reality causing these sensory perceptions. This leaves us with an ontology of minds (as immaterial substances) experiencing and generating mental events and processes that, when sensory in nature, have a *formal* character limned by the fundamental symmetries and structures revealed in "physical" theory. That these structured sensory perceptions are *not* mostly of our own individual or collective human making points to the falsity of any solipsistic or social constructivist conclusion, but it also implies the need for a transcendent source and ground of our experience. As Robert Adams points out, mere formal structure is ontologically incomplete:

> [A] system of spatiotemporal relationships constituted by sizes, shapes, positions, and changes thereof, is too incomplete, too hollow, as it were, to constitute an ultimately real thing or substance. It is a framework that, by its very nature, needs to be filled in by something less purely formal. It can only be a structure *of* something of some not merely structural sort. Formally, rich as such a structure may be, it lacks too much of the reality of material thinghood. By itself, it participates in the incompleteness of abstractions. . . . [T]he reality of a substance must include something intrinsic and *qualitative* over and above any formal or structural features it may possess.[117]

When we consider the fact that the *structure* of reality in fundamental physical theory is merely phenomenological and that this structure itself is hollow and non-qualitative, whereas our experience is not, the metaphysical objectivity and epistemic intersubjectivity of the enstructured qualitative reality of our experience can be seen to be best explained by an occasionalist idealism of the sort advocated by George Berkeley (1685-1753) or Jonathan Edwards (1703-1758). In the metaphysical context of this kind of theistic immaterialism, the *vera causa* that brings coherent closure to the phenomenological reality we inhabit is always and only *agent* causation. The necessity of causal sufficiency is met by divine action, for as Plantinga emphasizes:

> [T]he connection between God's willing that there be light and there being light is necessary in the broadly logical sense: it is necessary in that sense that

117. Robert Adams, "Idealism Vindicated," in *Persons: Human and Divine*, ed. Peter van Inwagen and Dean Zimmerman (Oxford: Oxford University Press, 2007), 40.

> if God wills that *p*, *p* occurs. Insofar as we have a grasp of necessity (and we do have a grasp of necessity), we also have a grasp of causality when it is divine causality that is at issue. I take it this is a point in favor of occasionalism, and in fact it constitutes a very powerful advantage of occasionalism.[118]

Plantinga is right to emphasize the virtues of occasionalism, but he does not take his argument in the idealist direction that the quantum-theoretic evidence we have considered seems to warrant. Clearly, the philosophical and quantum-theoretic problems for necessitarianism also prohibit a secondary causation account of divine action as the metaphysical basis for natural regularities. Secondary causation requires God to have created material substances to possess and exercise, actively or passively, their own intrinsic causal powers. God acts in the *ordinary* course of nature only as a universal or primary cause that sustains the existence of material substances and their properties as secondary causes. On this view, material substances mediate God's ordinary activity in the world and function as secondarily efficient causes in their own right. Plantinga recognizes that secondary causation inherits many of the philosophical problems associated with necessitarian accounts. Beyond this, however, it also inherits the quantum-theoretic problems that render necessitarianism untenable: the inherent *insubstantiality* of fundamental quantum entities, the *inability* of emergentist accounts of macroscopic objecthood to generate substantial material individuality and identity, and the *operative incompleteness* of this reality in respect of sufficient causation. In the absence of coherent material substances and physical causality, therefore, secondary causation lacks a purchase point in fundamental physical theory. So regardless of whether God *could* have created a world in which there were secondary material causes, it is evident that *he did not do so*. This leaves us with an occasionalist account of natural regularities, which in its "weak" form, as Plantinga is at pains to argue, fares no worse than secondary causation in respect of allowing for libertarian freedom and a resolution of the problem of evil. In fact, if we take advantage of Alfred Freddoso's approach to occasionalism,[119] we can build libertarian freedom into its definition:

> God is the sole efficient cause of every state of affairs in the universe that is not subject to the influence of freely acting creatures.

In other words, God is the only *vera causa* of every state of affairs occurring in "pure" nature, namely, that segment of the universe *not* subject to the causal influence of creatures with libertarian freedom.

In giving an account of the ontological basis for natural regularities under occasionalist idealism, then, the regularities of nature may be formulated as

118. Plantinga, "Law, Cause, and Occasionalism," 137.

119. Alfred Freddoso, "Medieval Aristotelianism and the Case against Secondary Causation in Nature," in *Divine and Human Action: Essays in the Metaphysics of Theism*, ed. Thomas V. Morris (Ithaca: Cornell University Press, 1988), 79-83.

counterfactuals of divine freedom.[120] Rather than understanding God's activity in terms of the divine production of certain behavior in substantial material objects, however, with the perception of the same divinely induced in our material brains, we must instead conceptualize the creaturely experience of mental phenomena as directly communicated to finite immaterial minds by God. So the natural regularities we interpret as "laws of nature" are just specifications of how God would act to produce the phenomena we experience under different complexes of conditions. More precisely, nature's nomological behavior should be understood in the following way: *if collective phenomenological conditions C were realized, all other things being equal, God would cause us to experience the phenomenological state of affairs S*. On this view, then, what we take to be material objects are mere phenomenological structures that we are caused to perceive by God and which have no non-mental reality. They exist and are given being in the mind of God, who creates them, and they are perceived by our minds as God "speaks" their reality to us. What we perceive as causal activity in nature is always and only God *communicating* to us—as immaterial substantial minds whose bodies are also phenomenological constructs—the appropriate formally structured qualitative sensory perceptions.

§4. Conclusion: "In Him We Live and Move and Have Our Being"

A careful consideration of the progress of physics since 1900 reveals that the harder we have looked at the universe's material constitution, the more ephemeral it has gotten, until in the final analysis we are left with a phenomenological reality that does not emanate from a material substratum, for material substances are shown to have no place in fundamental physical theory. The irony for the scientific materialist is palpable. In seeking an explanation for how the universe works, he turns to science and marshals his resources, restricted as they are to material objects and processes and what can be derived from them. But as he journeys deeper and deeper into the heart of matter, he finds that it dissolves and his whole worldview lacks a metaphysical foundation. Yet the phenomenological universe that constitutes his experience and ours remains, is ever so regular, and is ever so evidently not of human making, for we do not will the experiences we have—they come to us unbidden, sometimes welcome and sometimes not. As we have extracted this metaphysical picture from quantum physics and examined its implications, we have found an explanation of this surprising state of affairs—for it *requires* an explanation—in an occasionalist quantum idealism

120. Del Ratzsch, "Nomo(theo)logical Necessity," *Faith and Philosophy* 4, no. 4 (1987): 383-402; Plantinga, "Law, Cause, and Occasionalism," 126-44.

that has a strong affinity with Berkeley's occasionalist idealism.[121] In summary, not only is divine action *detectable* in the origin of the universe and the fine-tuning of its initial conditions, regularities, and constants, quantum physics reveals it to be *necessary* for the causal integrity and phenomenological coherence of the universe from moment to moment. Fundamental physical theory does not just reveal the mind of God to us, it reveals to us that *we live in the mind of God*. In his speech at the Areopagus (Acts 17:22-31), the Apostle Paul appropriates and recontextualizes the words of Epimenides, stating of God that "in him we live and move and have our being" (Acts 17:28a). As it turns out, this is quite *literally* true.

121. I arrived at an earlier version of this occasionalist quantum idealism about twenty years ago (Gordon, *Quantum Statistical Mechanics and the Ghosts of Modality*, 488-97), but it is encouraging to see a burgeoning interest in and advocacy of Berkeleyan occasionalist idealism by a variety of Christian philosophers and theologians. See, for example, Joshua Farris, S. Mark Hamilton, and James S. Speigel, eds., *Idealism and Christianity, Volume 1: Idealism and Christian Theology* (New York: Bloomsbury Academic, 2016); and Stephen B. Cowan and James S. Spiegel, eds., *Idealism and Christianity, Volume 2: Idealism and Christian Philosophy* (New York: Bloomsbury Academic, 2016).