ARGUMENTS FROM NOTHING: GOD AND QUANTUM COSMOLOGY

by Lawrence Cahoone

Abstract. This essay explores a simple argument for a Ground of Being, objections to it, and limitations on it. It is nonsensical to refer to Nothing in the sense of utter absence, hence nothing can be claimed to come from Nothing. If, as it seems, the universe, or any physical ensemble containing it, is past-finite, it must be caused by an uncaused Ground. Speculative many-worlds, pocket universes and multiverses do not affect this argument, but the quantum cosmologies of Alex Vilenkin, and J. B. Hartle and Stephen Hawking, which claim that the universe came from literally nothing, would. I argue that their novel project cannot work for reasons both physical (their "nothing" is actually a vacuum state governed by eternal physical laws) and methodological (physical theory cannot explain the emergence of the physical per se). Thus my argument stands. However, as David Hume showed, a posteriori arguments like mine infer a creation, and Creator, of a certain character, namely, a stochastic concept of creation and a panentheistic, partly physical Creator lacking omniscience and omnipotence. Rather than undermining the cosmological argument, as Hume intended, these limitations liberate the concept of the Ground from unnecessary problems, as Hartshorne suggested.

Keywords: Big Bang; cosmological argument; cosmology; creation; Creator; God; Hartle-Hawking; David Hume; inflation; no-boundary proposal; Nothing; origin of universe; past-eternal; past-finite; quantum cosmology; quantum gravity; teleological argument; universe; Alex Vilenkin

---

Parmenides offered a possible answer to a question unasked in Greek thought: "Why is there something rather than nothing?" For if it is true that, as he held, it makes no sense to refer to "Nothing," we must follow Lucretius in holding that nothing comes from Nothing. In the first part of this essay I argue that if this is so, and if the universe had a beginning, as physics claims, there must be an uncaused Ground of Being from which

Lawrence Cahoone is Associate Professor of Philosophy at the College of the Holy Cross, Worcester, MA 01610; e-mail lcahoone@holycross.edu.

[*Zygon*, vol. 44, no. 4 (December 2009)]
 ISSN 0591-2385 *www.zygonjournal.org*

the universe comes. However, a family of recent physical theories under the name of quantum cosmology claims that the universe *did* come from Nothing. My second task is to show that this family, however fascinating, is dysfunctional, perhaps not in the family home but at least on its metaphysical junkets. Hence my argument for the Ground goes through. However, if a theistic argument gains its traction a posteriori from the physical world, it must accept the attendant limitations, diagnosed in the eighteenth century by David Hume. In the last part I suggest that although Hume's criticisms do not, as he hoped, reduce the cosmological argument to absurdity, they serve to posit a Ground with no more than finite powers. The Ground inferred from the universe is neither omniscient nor omnipotent.[1]

Parmenides, Lucretius, and Nothing

All that follows is based in what I call the neo-Parmenidean principle: It makes no sense in inquiry to refer to *Non-Being* or *Nothing* in the sense of utter absence. Not that such a usage is meaningless; it does have meaning in the sense of holding a place in our system of signs as the negation of anything else we can say. But it can have no reference, and its lack of reference is extreme. The term *witch* presumably has no reference in our world, but it could pick out a reference in a different possible world. *Nothing*, on the other hand, could pick out no reference in any possible world. Nor can we make sense of Nothing phenomenologically or psychologically. Utter absence can never be experienced or imagined. Experience and imagination are mental acts with objects, however diffuse, vague, or indeterminate. Experience or imagination of Nothing would have to mean utterly contentless mentation. But this would simply be the absence of experiencing or imagining, rather than experiencing or imagining Nothing.

Most relevant for the current essay, from the standpoint of basic physics, absence of matter is not Nothing. Most of the content of the universe seems to be energy, the so-called dark energy (Kirschner 2004). For the reigning theory of the microscopic world, quantum field theory, reality *is* fields and their excitations. The quantum vacuum, where no material particles are present, is a state of nonzero energy from which particles continually emerge and into which they are annihilated. Absence of material particles is not utter absence. Neither is space, for even if there were no cosmological constant ascribing energy to space itself—and recent research suggests that there may be—space is three aspects of a four-aspect system called spacetime with its own metric structure that causally interacts with mass-energy. So, even that which we typically intuit in trying to imagine Nothing—a black empty space—is *not* Nothing in the sense of utter absence.

Note that my claim does not refer to "nothing" in the sense of what lacks the degree and type of determinateness characteristic of individual objects, what might be called a state of "no-thing." Paul Tillich distinguished two concepts of nothing in Greek philosophy, *ouk on* and *me on*, the former being total absence and the latter undifferentiated potential reality waiting to be formed (Tillich 1951, 188). My argument applies only to *ouk on*. We may say that *determinate* means "having traits." Things can vary in their degree of determinateness; electrons and photons are less determinate than baseballs because, lacking simultaneous, arbitrarily precise momentum and position, they cannot be said to have trajectories. If "nothing" is understood as relative rather than utter indeterminateness, it can have reference.

The neo-Parmenidean principle leads to what we can call the Lucretian principle, "*ex nihilo nihil [fit]*," "from nothing, nothing comes" (Lucretius 1921, Book 1). For if Nothing can never be affirmed, we cannot say that something came from it. It is thus a guiding principle of inquiry not to accept that something comes into being out of nothing, for if that is allowable all bets are off for rational explanation.

We must be clear what these principles do not say. They do not accept Parmenides' conclusion that because all talk of change or motion implies reference to some property or state that either no longer exists or does not yet exist, change and motion are impossible. Given any distinction between substance and accident, actuality and possibility, or conservation laws, the recognition that something endures through any transition or change can avoid violating Lucretius. Nor does the argument prohibit creativity, as long as we do not conceive creativity as the uncaused arising of something from Nothing. Nor does it deny chance or indeterminism. Once there is something, there can be no requirement that it be absolutely determinate; beings, and Being itself, need only be partly determinate. Finally, the Lucretian principle is a partial, not full, endorsement of Leibniz's Principle of Sufficient Reason. To hold that every thing asserted, every being or state of affairs, must have a reason, goes beyond it.

I mention in passing that this proposal suggests a straightforward answer to the question of why there is something rather than nothing. There is something rather than nothing because there cannot be Nothing. Whether on the basis of a phenomenological account of our first-person experience, a physicalist account of the universe, or a logical parsing of our terms, utter absence is unavailable. There is no alternative to Being; there are alternatives to any particular, determinate being or arrangement of beings. If this seems unappealingly deflationary, we can say that my claim merely shifts the question to another domain, for "Why does *this* world exist?"—why our particular universe with its specific character exists—remains a live issue.

A Past-Finite Universe

In the Western tradition the universe as a whole has been commonly thought to be static, that is, nonevolutionary, even if engaged in some periodic or cyclic motion, whether it existed eternally, as Aristotle held, or was created. Only in 1929 did Erwin Hubble discover that this appears to be incorrect because the universe is in the process of expansion, meaning that galaxies are moving away from each other. The 1965 discovery by Arno Penzias and Robert Wilson of the background microwave radiation that fills the universe in every direction made that conclusion very likely. According to the standard Hot Big Bang theory, the universe began in an explosion from a state of highly concentrated mass-energy. The explosion must have been preceded by a state of infinite mass-energy density, a singularity in which the equations of general relativity break down because of infinite spatial curvature, where we cannot speak of spacetime reality at all. But knowable physical reality begins with the Bang itself, a process of expansion and cooling punctuated by stages of symmetry breaking (about which more later), in which unified forces and single types of particle split into diverse kinds. In the first 10^{-43} of the first second, the Planck era, presumably energies were so high that microscopic particles exerted gravitational force, yielding a chaotic spacetime foam, but such energies are far beyond our experimental snooping. Also speculative, but widely accepted, is the belief in a brief period of massive expansion around 10^{-35} seconds, called inflation. We are more confident that at 10^{-12} seconds a unified electroweak force broke into electromagnetism and the weak nuclear force. At 10^{-6} quarks were "confined" into protons and neutrons, and sufficient cooling eventually allowed nuclei and then atoms to form so that electromagnetic and gravitational radiation could pass through them. Thus what we call matter began its uneven but impressive buildup of complexity.

The point is that the universe had a beginning and a history. Current physics claims that the ensemble of matter, physical energy, force fields, waves, particles, and spacetime, characterized by physical constants and governed by laws, *started*.

This claim is buttressed by a thermodynamic argument (Davies 1983, 11). According to the Second Law of Thermodynamics, closed systems move toward, not away from, a condition of highest randomness or entropy, that macrostate composed by the highest number of possible microstates, or its most probable macroscopic arrangement. Like any closed system, the universe is presumably proceeding toward thermal equilibrium or maximum entropy. Whether it will reach it is uncertain, but recent research suggests that it will, meaning galaxies will continue to recede as their stars increasingly burn out in a heat death of the universe. If the universe were eternal it would already have had infinite time to reach equilibrium. But it has not reached it. As Alex Vilenkin writes, "one thing is clear: the universe as we know it could not have existed forever" (2006, 210 n. 4).

If the universe began, what caused it? If it makes no sense to say that particular events or things come from Nothing, what sense can it make to say that the universe came from Nothing?[2] This justifies the inference that there must be, or have been, a Ground of the universe, which is to say, with Thomas Aquinas, an uncaused cause of the universe (*Summa Theologiae*, Part I, Ques. 2, Art. 3). The qualifier *uncaused* has seemed suspicious to some. Unlike Aquinas, I argue that an infinite regress of past causes is not irrational, only apparently false. *Caused* causes of the universe would be other universes that are either eternal or past-finite. If *they* began, the origin question returns, unless one resorts to a series of polytheistic demiurges, which have their own conceptual and evidentiary difficulties. So, if the universe began and did not come from Nothing, there must be something that could exist without it, something without a beginning, that caused it. Either the largest physical ensemble containing our universe as a part or phase is eternal, or there is an uncaused first cause. In short: Aristotle or Aquinas.

The most sensible philosophical (as opposed to physical) objection to this argument would criticize my extension of the Principle of Sufficient Reason to the universe as a whole. One might say, as Hume did, that it is legitimate to search for causes or reasons *in* the world but not *of* the world. A contemporary might answer me: "We all must accept that, as Wittgenstein said, 'Explanations have to end somewhere.' You yourself say that they end with the Ground. But that is an explanation too far. Rational inquiry must stop with the Big Bang, or perhaps the singularity that may have been its source. If we probe further, we end up with a mysterious Ground insusceptible to physical inquiry."

Here looms a potentially unending debate about the aims of inquiry. My only short-term defense is that the censorship of that extra step can make no obvious claim to rational superiority. The question is whether it is legitimate to inquire into the cause of the universe's initial state. If it is legitimate to inquire into all states of the reality we inhabit, including the first, it seems natural and rational, for a philosopher at least, to inquire one more step, and somewhat unnatural and irrational to post an intellectual No Trespassing sign. In taking that step, we are indeed confronted by the mysterious nature of the Ground, and the techniques of physical inquiry used up to that point must falter. But the recalcitrance of the Ground to inquiry is, I think, the inevitable price of admission, not a sufficient reason to refuse the step, especially if we accept that the boundaries of inquiry exist to guide the discovery of truth rather than insulate extant views from challenge. We must choose our poison here: either a likely although unverifiable model of the initial physical state that leaves it unexplained, or a further explanation that steps into territory inaccessible to physical inquiry. I find the latter more rational; I would at least argue that it is not less so.

Cosmological Alternatives

It is a remarkable fact that some contemporary physicists take that same further step, and are guided by a similarly philosophical motive, although they land in a different spot. It is overwhelmingly likely that the Big Bang should have produced either a collapsing Black Hole or a universe empty of stars, thus of all complex matter. That it did not is because the physical constants of our universe, which are not determined by known laws but are contingent facts or possibly initial conditions of the universe, occupy extremely narrow, improbable values. That these parameters could have arisen by chance is extremely unlikely. Lee Smolin calculates the likelihood that the Planck mass, cosmological constant, the masses of the proton, electron, and neutron, and the strengths and ranges of the four forces would occupy their current values as one in 10^{229} (Smolin 1997, 401–2). It is naturally the goal of physicists to explain this improbable universe without reference to something outside the bounds of physical inquiry. In effect, their goal is to avoid a teleological argument for a Designer. Some aim to do so also without reference to contingent initial conditions, partly because those conditions are likely unknowable but also in hopes of determining them by law, rendering them necessary rather than contingent. This task has led cosmologists to try not merely to explain physical facts in terms of other physical facts but to explain the existence of physical facts per se. They are trying to answer the metaphysical question, Why is there something rather than nothing? Their relevance to the present discussion is that such accounts would seem to derail my argument. In what follows I take them in order of the least to the most relevant (hence, least to most troublesome).

Megaverses, Multiverses, and the Anthropic Principle. One factor sometimes invoked as an explanation of our universe's improbability is the anthropic principle. Its original function was to recognize a "selection effect" or bias in our interpretation of evidence. Trying to explain some striking observations, particularly of the size of the universe, in 1957 Robert Dicke pointed out that such observations could occur only after stellar formation, explosion, and seeding of the universe with elements such as carbon had led to the evolution of intelligent observers. In short, the only universe that *could* be observed is one that had been expanding for at least ten billion years, so one accordingly large (Barrow and Tipler 1986, 246).

In recent decades the anthropic principle often has been used and stated in confusing ways, such as "The universe must have traits *x*, *y*, or *z* because of the presence of intelligent life." This is misleading. The anthropic principle directly concerns not facts but our observations of facts. The Dicke example explains not *why* the universe is cold, dark, and empty but why all our observations of the universe *should be expected to find it* cold, dark, and empty. To say that the universe "must" be *x*, *y*, or *z* "because of" intelligent life cannot mean that the presence of intelligent life *causes* the universe to be *x*, *y*, or *z*, only that intelligent life justifies our inference that the universe is *x*, *y*, or *z*. Further, the anthropic principle is relevant to explaining the improbability of our universe as a whole only if there are or were other universes with other constants but that could not be observed because their constants precluded intelligent life. The force of the principle is that our observational sample (our universe at this time) is unrepresentative of the population from which it is selected (all universes). That requires a population larger than the sample, that is, more universes than just ours.

Such is asserted by a number of theories. The least complex holds that if matter and energy are finite and space is infinite, the observable universe—that portion near enough that its light signals could reach us during the time the universe has existed—may be only one of many "island universes" in an infinite megaverse (Tegmark 2003). This would still be our one current universe, under one set of laws and with one set of physical constants, but with regions too distant to influence each other. A very different physical theory that plays the same role in our discussion is Hugh Everett's many-worlds interpretation of quantum mechanics. The indeterminacy of each event at the quantum level means that when, for example, photons and electrons interact, the wave equation permits many possible alternative outcomes, only one of which we observe in our experimental apparatus. This reduction of many possibilities to one actuality by observational intervention is the so-called collapse of the wave function. It lies at the heart of the measurement problem, a genuine mystery about quantum behavior. Everett's resolution of this mystery is to suggest that each possibility does in fact happen in its own reality separate from ours, that at every microsecond reality is branching into an endless number of universes composing one multiverse. Last is the possibility that if cosmic expansion reaches a limit and contracts, eventually to initiate another Big Bang—the oscillating or bouncing universe proposed by Richard Tolman in 1934—ours could be one phase in an eternally recycled universe.

Regarding the first and second theories, whether this universe is an island in a bigger sea or a momentary branch, if it is part of an ensemble that developed according to one initial set of laws from the one Big Bang, my argument is simply shifted to the larger ensemble. As long as there is a Big Bang origin of the largest physical ensemble containing our universe, my argument goes through. Regarding the oscillating universe, if it were true it would derail my argument. But as of now there is no evidence to recommend this dynamic version of Aristotle's eternal universe. Aside from questions of how the "bounce" would avoid violating the Second Law, and what, if anything, would remain constant or be communicated from one universe to its successor, current data lean toward an endless expansion to heat death rather than collapse or bounce.

Eternal Inflation. More relevant proposals presume the theory of inflation, first proposed by Alexei Starobinsky in 1979, then independently by Alan Guth, later revised by Andrei Linde and by Andreas Albrecht and Paul Steinhardt. Inflation is the claim that the early universe's expansion underwent a brief but enormous acceleration very soon after the Big Bang, at around 10^{-35} seconds, followed by regular Hubble expansion. The theory holds that the vacuum space of the early universe was filled with very dense energy fields, which Guth ascribed to Higgs particles and others to scalar fields today simply called the inflaton. Immediately after the initial expansion, these fields occupied a false-vacuum state, meaning a metastable state far from true equilibrium, which decayed or supercooled toward a true lowest-energy vacuum state. During this brief supercooling the fields released massive numbers of expanding true-vacuum bubbles that inflated at the speed of light. (Because the scalar or Higgs fields' mass density is fixed, they do not lose energy density as they expand; otherwise inflation would shut down immediately.) Like a temporary cosmological constant, they provide a negative gravitational pressure, or tension, to vacuum space. Inflation addresses the problem of the improbability of our universe by explaining its size while allowing the preinflationary universe to expand slowly enough that spatial regions could be causally connected, thereby explaining certain improbable traits such as the universe's uniformity in all directions and nearly flat curvature. Its predictions are consistent with the recent discovery of the universe's acceleration and unobservable dark energy.

By itself such inflation does not affect my argument because it concerns only what happens after the universe's initial state. But Vilenkin and especially Linde (1994) took the theory further. Seeing that a reconceived inflation could replace the Hot Big Bang itself, they understood its expanding vacuum bubbles as separate island universes, ours being one. This would seem to make inflation an eternal physical process of universe creation, but problems have been raised with that possibility. Vilenkin, Guth, and Arvind Borde argue that in any inflationary universe where the average Hubble expansion rate is greater than zero, past-tending world-lines slow because of relativistic effects, yielding a finite past (Borde, Guth, and Vilenkin 2003). Vilenkin writes, "past-eternal inflation without a beginning is impossible" (Vilenkin 2006, 175). Today, neither Linde nor Vilenkin claims the multiverse to be past-eternal. Thus the hope that eternal inflation would avoid a finite past, and with it my argument for the Ground, seems dim at present.

Universes from Nothing. This brings us to the most famous physical alternative, first proposed in 1973, before the inflation theory, by Edward Tryon (1973). As noted, the quantum vacuum is the scene of continuous emergence and disappearance of particles. Tryon suggested that the universe may have begun as such a fluctuation. This might seem impossible because the mass-energy of fluctuation-emergent particles is inversely related to their longevity, so for any such universe to avoid violating conservation of energy it would have to be extremely short-lived. However, Tryon noted that gravitational fields have *negative* potential energy that in a closed universe precisely matches, and cancels, their mass-energy.[3] So a closed universe in effect has zero energy. It then becomes conceivable that vacuum fluctuations could produce a long-lived universe.

Guth summarized Tryon's idea this way: "*everything* can be created from nothing" (Guth 1998, 15). Now, that is an overstatement, because Tryon's theory presumed a quantum field vacuum and spacetime, neither of which is Nothing. Nevertheless, it inspired others to press his idea further. To do so required not just inflation but also quantum gravity. It is well known that no one has successfully integrated the two major theories of the force interactions that make our world: quantum field theory of the electromagnetic, weak and strong interactions, which dominate the microscopic world and the construction of macroscopic bodies, and general relativity, which describes the gravitation responsible for the spacetime structure of the universe. For most purposes an overarching theory that integrates the two is unnecessary. But not so in understanding the universe before the Planck time of 10^{-43} seconds, when the thermal energy of quantum particles would be theoretically high enough to generate gravitational effects by Albert Einstein's $E=mc^2$. Although such a theory has not been achieved, some parameters that it must satisfy have been worked out. John Wheeler and Bryce DeWitt independently derived an equation that stipulated how different spacetimes could evolve under the quantum wavefunction in "superspace," a conceptual space where each point represents a three-dimensional space and any path represents a spacetime.

This result, coupled with inflation and Tryon's idea, led to two proposals for how it is that the universe could emerge from, as one put it, literally nothing. In 1982 Vilenkin analogized the creation of the universe to *quantum tunneling* (Vilenkin 1982; 1984). Unlike a classical particle, in quantum mechanics there is a nonzero chance for a particle to arrive at a state for which it did not have the requisite energy. If we graph the potential energy required to achieve that state, the quantum particle tunnels through the potential barrier (in Figure 1, B from A) instead of bouncing off (like C).

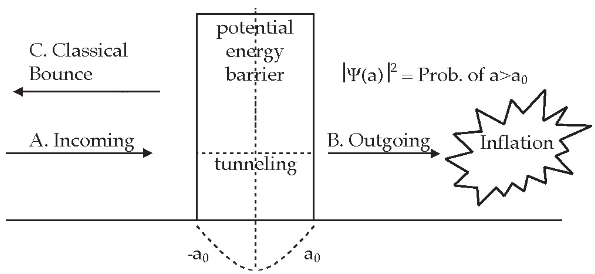

Fig. 1. Vilenkin's creation via quantum tunnelling.

If *a* is the universe's radius, and the wavefunction $\Psi(a)$, Figure 1 gives the probability for universe *a* to appear on the positive side of a potential energy barrier, in existence. The portion of the process where $a < a_o$ is regarded as "nothing."

Then in 1983 J. B. Hartle and Stephen Hawking published another argument, their "no boundary" proposal. Using the "path integral" or "sum over histories" approach that Richard Feynman developed for quantum electrodynamics, they summed all possible relevant spacetime paths by which a universe could evolve to find the path with the highest wave amplitude, hence highest probability to occur. That path is represented by a Euclideanized or three-dimensional sphere in which time has become a spatial axis with imaginary values.[4] We may imagine it as a sphere (Figure 2) whose North pole, where t=0, would be the initial state of the universe or Big Bang (P), and whose South pole is the Big Crunch at the end of the universe, if there is one (Q). We now have a representation of the universe without a singularity or boundary, the first and last states of the universe being just two points on the sphere.[5] As the authors wrote, "This means that the Universe does not have any boundaries," or, more famously, "the boundary conditions of the Universe are that it has no boundary" (Hartle and Hawking 1983, 2961, 2965). As Hawking later summarized, "the universe would be self-contained and not affected by anything outside itself. It would neither be created nor destroyed. It would just Be" (Hawking 1998, 13).

Some physical questions are raised by these proposals. First, as others have wondered, just what does it mean to say that "the ground state [of the wavefunction] is the amplitude for the Universe to appear from nothing"? (Isham 1993). This would seem to be an unconditional probability, a probability dependent on no existential conditions, as if someone were to ask "What is the probability of red?" Whether such makes sense is unclear, although some argue that it does (Smith 1998). Even if it does, it must signify the probability of this universe relative to the other universes that

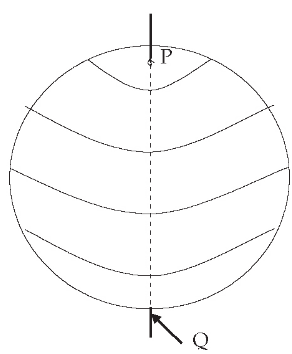

Fig. 2. Hartle and Hawking's no-boundary proposal.

could have arisen. The probability attached to *our* universe does not give the likelihood of its existence compared to Nothing but rather the likelihood of its existence compared to all other possible universes, whose sum must be one. It answers the question, "Given the certainty of some universe coming into being, how likely was it to be ours?" *Nothing* does not appear in the equation; the equation can only assign likelihoods of being observed to possible universes. One can interpret its result as the probability of a universe coming from Nothing only if the wavefunction includes *everything*, all the information necessary for the construction of our universe. In fact it specifies only the universe's spacetime metric and radius, leaving out quite a lot.[6]

Certainly real time is left out. There is nothing mathematically wrong in treating time as an imaginary value, but this means either accepting the physical meaning of such treatment—that time is running backward—or denying the physical reality of time.[7] It is true that a movie of a simple energy-conserving system could be run backward without violating physical law. Such processes are reversible, given their abstraction from other conditions. And it is true that change can be spatially represented in such a way that our usual physical *t* drops out of the representation. But to deny the reality of physical time is to deny the Second Law of Thermodynamics, which dictates that closed systems must proceed toward greater entropy. Irreversibility is the physical reality of a time-direction. This is objective, physical time, entirely independent of our subjective sense of time's flow. To banish time is to banish the Second Law. Some investigations can legitimately ignore the Second Law, but how can a claimed description of the universe as a whole ignore it?[8]

Philosophically, however, the most glaring question regarding these theories remains: Is their "nothing" really Nothing? Philosopher of physics Tianyu Cao makes the point that quantum events "require a background space whose specific properties make fluctuations possible" (Cao 2004, 192–93). Physicist John Polkinghorne notes that to speak of quantum tunneling requires the quantum vacuum (1989, 59ff.). Indeed, the language of Vilenkin and Hartle-Hawking proponents suggests a rather substantive Nothing. Physicist Frank Wilczek wrote, "Our answer to Leibniz's great question 'Why is there something rather than nothing?' then becomes '"Nothing" is unstable'" (Wilczek and Divine 1989, 275). Quantum geometer David Atkatz remarks that the universe "nucleat[ed] from the *eternally existing nothing*" (Atkatz 1994, 625; emphasis added). Philosopher Victor Stenger (2006) supports Vilenkin and Hartle-Hawking, arguing that it is "natural" for nature to come to exist: "The transition nothing-to-something is a natural one."

Here the philosopher must object. Nothing is *not* simple, complex, stable, unstable, temporal or eternal, natural or unnatural. It just *is not*. Either we are speaking of a state with properties and a causal role, so speaking of something, or we are not speaking about anything.[9] It seems inevitable that, as Cao goes on to say, the theories in question must posit a "quantum nothing," an extant quantum vacuum or some other physical state that precedes t=0, which is *not* Nothing in the sense of utter absence. If *that* state is past-eternal, we would have returned to the Aristotelian option.

Indeed, it is made clear by Quentin Smith, a supporter of Vilenkin and Hartle-Hawking, that their cosmologies "require a Platonic-realist theory of the laws of nature" (Smith 1998, 82). Now, perhaps most cosmologies could say that the laws are real but not independent of what they govern, that they came into existence at the same instant as spacetime and mass-energy, and leave it at that. However, to claim that there is a transition from Nothing to something requires that the transition be rule-governed, so the laws must hold when the universe is not yet. Vilenkin himself admits, "The Laws of physics must have existed even though there was no Universe" (2006, 181).

This gives the game away entirely. The laws of physics are not Nothing. Indeed, the whole thrust of the new cosmology is to build structure into the laws so as to leave nothing to initial conditions. As Guth writes, "If someday this program can be completed, it would mean that . . . the laws of physics would imply the existence of the universe" (1998, 276). Its existence would be necessary. But how could changeless eternal laws initiate and fund the mass-energy of a past-finite universe that they preexist? If the laws not only structure but also initiate the universe and fund its content, while remaining sufficiently distinct from it so that they can obtain when it does not, they begin to sound suspiciously like a Creator.

Whatever the physical achievements of the proposals in question, they have not shown that the universe could come from Nothing. The problem is not that they seek a physical theory with no reference to an "outside." Such is already available, if one is willing to stop one's explanatory regress with the initial state of the physical universe, which is to say, to explain physical states in terms of other physical states. But this traditional goal of physics inevitably leaves something unexplained. If our local, past-finite universe is the only universe, physics is left with no explanation for its existence or for the nature of its initial state and governing laws; there will always be parameters and laws regarding which we can say what they are but not *why* they are what they are. The new cosmologists have raised the bar for physical explanation so that they find this unacceptable. Guth recognizes that "the attempts to describe the materialization of the universe from nothing . . . represent an exciting enlargement of the boundaries of science" (Guth 1998, 276). In suggesting that, absent his no-boundary proposal, physics cannot show why this particular universe was selected, Hawking writes, "Was it all just a lucky chance? That would seem a counsel of despair, a negation of all our hopes of understanding the underlying order of the universe" (Hawking 1998, 133).

Such "despair" results from holding two contradictory hopes: to explain everything about the largest physical ensemble, including its fundamental laws and constants, leaving nothing to unexplained contingency (for example, initial conditions), and to keep physics closed, with no reference to an "outside." One cannot do both. Physics can rightly eschew reference to an agency independent of the universe, but in doing so it must leave some physical conditions unexplained. Even an encompassing past-eternal multiverse, while, like Aristotle's universe, avoiding any need for a cause, still must have some unexplained eternal laws and constraints.[10] Quantum cosmologists have sought to explain the emergence of the physical per se. Without reference to an outside, that is impossible. One cannot explain how *X* comes into being without reference to not-*X*. Nature can govern itself, but it cannot govern its own creation.

The Ground

The argument from Nothing leads to this: If the universe, or whatever physical ensemble contains or caused the universe, is past-finite, it must have been caused by an uncaused Ground that exists or existed independent of it. A past-eternal multiverse would avoid this argument, but emergence out of Nothing cannot. That is as far as my argument takes us in a strict sense. But I will go farther, for two reasons. First, my argument is inevitably entangled with theological and antitheological discussions that will affect its reception, so some clarification of the inferred Ground is advisable. The second is an acceptance of responsibility, for if an a posteriori argument supports theism it must also color the theism supported. What follows is speculative in the sense of making presumptions that go beyond the argument from Nothing and hence are not as inescapable.

Hume made two insightful criticisms of a posteriori arguments for God (Hume 1910; 1998). He criticized attempts to extend the concept of causality to the origin of the world. We argue merely by analogy, and a tenuous one at that, he wrote, if we extend the notion of causality that holds among parts of the world to the world as a whole. He also pointed out that if a Designer is inferred from the harmony or orderliness of the universe, given that the universe is *not* perfectly harmonious or orderly but mixes disorder with order, that inference could justify only a limited God. His cautionary lesson is that if one argues from the nature of the universe to God as its cause, one's conclusion must be faithful to the context of that inference.

So, what can we hypothesize about an uncaused Ground initiating, funding, and fixing the rules and perhaps the constants of our or any more encompassing (or previous) universe? In what follows I describe a minimalist conception of such a Ground and its creation.

If we are to extend the intraworldly notion of causation to the world, it must look at least something like causation of things *in* the world. Thus, although the Ground must be sufficiently independent of the physical universe so as to exist when it does not, it must be sufficiently continuous with the physical universe to have a causal relation to it. To cause a physical world the Ground must act physically. At the same time, our Lucretian principle suggests that there can be no creation *ex nihilo*. My denial is not aimed at the classical function of that doctrine in Christian theology as a guarantee of the complete dependence of the Creation on the Creator. Rather, I suggest that the universe must not only be initiated by the Ground but must *come from* the Ground; its content must be funded by the Ground. Thus, if there is nothing coeval with yet distinct from the Ground prior to the creation, the Ground must create the universe *out of itself*.

These considerations point, not inescapably but readily, to the doctrine of panentheism, which holds that the universe is in or of the Ground, even if the Ground is more than the universe. This arguably was the view of Baruch Spinoza, as clarified later by Friedrich W. J. Schelling, and recently advanced by Philip Clayton (1997).[11] The universe, or at least its initial state, must be made out of the Ground. This means that the Ground must be at least partly physical. I am thereby joining Spinoza in claiming that at least one of the attributes of the Ground is physicality.

Just what this means is admittedly speculative. Students of quantum gravity, the yet incomplete theory of the source of spacetime and quantum fields somewhere near the Planck scale, assume that spacetime is an emergent phenomenon (Smolin 2001). Perhaps then the physical aspect of the Ground is energy not located or extended in spacetime but nevertheless obeying a law of conservation of energy internal to the Ground. This may mean that the Ground has some immediate connection to either, or both, the quantum vacuum and spacetime singularities, that it was and is metaphysically continuous with the physical universe while not exhibiting spacetime or the determinations that generate the fields of quantum field theory and the general theory of relativity. The option that springs to mind is that the Ground is partly vacuum physical energy.

This would be congenial to a related conception. Nothing, or Non-Being, has been the historical antithesis of Being in Western philosophy. If the former is rejected as nonreferential, so is our common imagination of beings and existence as filling up sheer absence. We can replace the conceptual opposition of Being and Nothingness with the opposition of Determinate Being and Indeterminate Being, the distinction being relative. Put more suggestively, *to exist* would mean to maintain a state, the state of a relatively determinate something against an indeterminate, or less determinate, background or environment. We may then imagine the Ground as, whatever else it is, predifferentiated Being, Being that is not constituted by the kind of determinations characteristic of the physical beings of the universe, including but not limited to spacetime location, extension, boundedness, exclusiveness, hierarchic composition out of parts, or individuation. This does not mean that the Ground is entirely indeterminate or without properties; that would make the Ground Nothing. While presumably determinate in some respects, the Ground may be neither one nor many, because those terms require a level of determinateness that the Ground lacks. The suggestion is that, independent of creation, the Ground exists in a nonspatiotemporal state of minimal determination akin to Anaximander's Boundless, Schelling's Absolute, Tillich's Power of Being, or Robert Neville's Indeterminate Being-itself (Anaximander 1988; Schelling 1936; Tillich 1952; Neville 1968).

Although speculative, this notion harmonizes with a program of recent physical thought. Conservation laws were in the twentieth century discovered by Amy Noether to be symmetry transformations, that is, spacetime transformations under which the phenomena remain invariant. Some physical processes "break" symmetries. For example, water molecules that in the liquid state can occupy any angle with respect to another—a state of high symmetry—in the process of freezing suddenly line up at fixed angles—a state of lower symmetry. The differentiation of the weak nuclear from the electromagnetic force in the early universe was discovered to be another case of symmetry breaking. This approach can be qualitatively generalized. In the words of Pierre Curie, "*C'est las dissymetrie qui cree le phenomene*"—Dissymmetry creates the phenomenon (Curie 1894, 393). A phenomenon can be distinguished from local background states by its lesser symmetry. One might imagine creation, then, as the partly physical-energetic Ground breaking its own symmetry. The idea is that the Ground is so constituted that the physical attribute of its Being was in the state of greatest symmetry, a symmetry it broke in such a way as to initiate a complex ensemble eventually distributed in spacetime with certain constraints (the basic laws and constants).

Unlike historical versions of the teleological argument, the contemporary question of *design* focuses not on order but on improbability. We must ascribe to the Ground the capacity not only to cause, but to cause in a finely tuned way, to arrange laws and constants that would eventually yield our improbable universe. Making the laws and/or constants independent of the universe's cause would, given that laws cannot fund or initiate the universe, postulate both eternal laws and an eternal funding-initiating Ground. Nor can the laws evolve during the universe's existence.[12] It would seem that the Ground must have the capacity to select and fix a unique set of laws and constants, and so to anticipate their likely results.

Hume argued that the universe is only partly, not perfectly, ordered. The understanding of order and disorder would require a long discussion, but we can at least say that he was certainly correct, for our universe includes objective chance and a tendency to disorder. By "objective chance" I mean unpredictability that results not from our lack of knowledge but from intrinsically indeterministic phenomena, most famously recognized in quantum mechanics. By "a tendency to disorder" I mean the Second Law. Our universe thus exhibits both disorder and order: on the one hand quantum indeterminism, atomic and molecular disorder, and the tendency of all macroscopic order to decay, and on the other, pockets of self-maintaining complex organizations such as galaxies, stars, diverse heavy elements, and, in at least one case, a planet with liquid water and an astounding biosphere.

The degree of design a modern theism requires is only this: that the original ensemble of spacetime energy was constrained by the Ground, particularly in its constants and laws, so that the likelihood of the eventual development of complex forms of order was sufficiently higher than their otherwise enormous unlikelihood—to what number between zero and one I do not propose to say. It need not claim that the evolution of complex order, life, and mind was certain. Splitting the difference between quantum uncertainty and Einstein's dismissive claim against it that God does not play dice with the universe, the naturalist and environmental philosopher Holmes Rolston puts it this way: "There is dice throwing, but the dice are loaded" (Rolston 1988, 186). There is no theological need to assume that the development of our universe was deterministic.[13]

This suggests one last point about the kind of Ground herein implied. Hume used the incompleteness of worldly order to argue that the teleological argument infers a limited God. Indeed, the cosmological argument above justifies the concept of a Ground adequate only to initiate, fund, and fix the rules and fundamental constants for the universe as we know it, not a Ground infinite in power or ability. Of course, Hume hoped to reduce the teleological argument to absurdity, not in a logical sense—the idea of a limited God is not self-contradictory—but in a practical sense by showing that it could not sustain the kind of God its proponents sought. Nevertheless, following Charles Hartshorne, I suggest that the traits of omniscience and omnipotence are dubious in themselves, difficult to reconcile with natural science, and more theological trouble than they are theistically worth (Hartshorne 1984). My argument from Nothing only needs to infer a Ground that is finite or limited in knowledge and power.

Hartshorne's view is motivated by theological concerns that I cannot adjudicate here, particularly his notion that a good God who is related to the creation must be mutable, not static, hence only the greatest of beings, not infinite or complete in every respect. He holds that God is the preeminent or greatest conceivable being, but not perfect, which would preclude change. God is unsurpassable by any other being, but not by Itself. God is the most perfect *becoming*. This requires not only mutability, and that God include possibility as well as actuality, but, as Daniel Dombrowski points out (1996, 58–65), receptivity or the capacity to be altered by creation, without which God could not be related to creation. God is the most powerful being, but only as powerful as is compatible with the power granted the beings of creation, hence not *all* powerful. God knows all past and present actualities but knows the future only as possibility—which, for Hartshorne, is all the future is. God does not know the unknowable, namely, which possibilities will become actual.[14] Such a notion allows us to avoid the many difficulties of imagining a classically omniscient and omnipotent God, including the reality of chance and risk, the ascription of agency or power to beings, the existence of human free will, and the problem of evil. For with regard to any evil in the world, if God both knew it was going to take place and could have arranged things so as to accomplish all relevant divine purposes without the evil in question—as an omniscient and omnipotent Being must have known and could have done—yet chose not to do so, the Ground could not be completely good.

Without endorsing Hartshorne's theology more generally, I concur with his denial of classical omnipotence and omniscience.[15] To put the point starkly, the Ground inferred by the argument from Nothing does not know and cannot control all the particular details of the vast interactions of the system it generated out of itself. Even if there is a divine purpose, presumably only some events accord with it; it may well be that a complex universe exhibiting objective chance, stochastic order, and the Second Law can achieve or embody such purpose only in some of its features or events, not in all, just as only a fraction of a plant's seeds germinate and grow. I see no reason why such a Ground would be incompatible with a physics that expects no more than to explain interactions among physical realities, or with a philosophical theology that accepts the approximate validity of modern inquiry's most reliable product, science.

Notes

This essay has benefited from the criticisms of Robert Garvey, Matthew Koss, Andrew Hwang, and Tian-yu Cao. They bear no responsibility, of course, for the finished product.

1. The attempt to formulate a modern version of the cosmological argument for God on the basis of physics is not new. See for example Craig and Smith 2003; Russell, Murphy, and Isham 1993; Clayton 1997.

2. I am not assuming that every event must have a cause in the narrow sense of a discrete material or efficient event that deterministically generates it. The emission of, say, an alpha particle from an atomic nucleus in radioactive decay is random or indeterministic; hence it fails to have a deterministic cause. But the emission *is* caused in that it is the stochastically predictable consequence of a system's properties; the alpha particle does not come from nothing. I thank Matthew Koss for raising this issue.

3. If the Moon were removed far enough so that Earth's pull, and the Moon's velocity toward the Earth, were near zero, the Moon's gravitational potential energy could not be positive. The same would be true if the Moon rested on the Earth's surface. At points in between, where the Moon is being pulled toward the Earth, it must have positive kinetic energy. But potential energy plus kinetic energy must add to zero to be conserved, so the gravitational potential energy must be negative.

4. Our real world is characterized by the four-dimensional Minkowski spacetime metric in which time is negative ($ds^2 = dx^2 + dy^2 + dz^2 - dt^2$). Using the method of Wick rotation, t is taken to be a complex number, multiplied by the imaginary number i (square root of -1) so that the time factor becomes positive, yielding a Euclidean metric ($ds^2 = dx^2 + dy^2 + dz^2 + dt^2$) of three "real" dimensions and one "imaginary" dimension.

5. This can be related to the Vilenkin tunneling model (see Figure 1). The Hartle-Hawking wavefunction retains the incoming particle-waves (A) as well as the outgoing (B), the former now interpreted as the Big Crunch of a collapsing universe. Where $-a_0<a<a_o$, inside the potential barrier, is the "Nothing" from which a universe tunnels out.

6. We may set aside one popular understanding of Hartle-Hawking, that the universe cannot have had a beginning because time is internal to the universe. True, but we did not need quantum gravity for that. As Vilenkin recognizes, Augustine made the same point. We cannot conceive the universe being created *at a time* (Vilenkin 2006).

7. Hawking admits that his "imaginary time" is not the "real time" of the world. As Roger Penrose notes, having removed time to Euclideanize the universe Hawking must later put it back so we can get our real Minkowski spacetime (Penrose 2005, 769–78).

8. Arthur Eddington once wrote, "the second law of thermodynamics holds, I think, the supreme position among the laws of Nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations—then so much the worse for Maxwell's equations. If it is found to be contradicted by observation—well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation" (Eddington 1933, 74–75).

9. Regarding Ludwig Wittgenstein's early claim that beliefs that could not be logically "said" could nevertheless be "shown," philosopher Frank Ramsey once remarked, "If we can't say it, we can't say it, and we can't whistle it either" (Ramsey 1990, 146). *Nothing* can't be whistled either.

10. Even Smolin's series of "naturally selected," evolving universes (Smolin 1997) must be constrained by background laws that make the cosmic evolution possible.

11. This is distinct from pantheism, the claim that the universe and the Ground are identical. Panentheism was Spinoza's view, because he held that the mental and physical aspects of the universe are only two of God's infinite number of attributes. Schelling (1936) took pains to deny that Spinozism meant identifying God and world.

12. The evolution of laws and/or constants was suggested by Charles S. Peirce and more recently by Smolin. Most physicists reject it because we must assume unchanging laws and constants in order to investigate the early universe. In fact, Smolin claims that only certain parameters evolved, for he must assume eternal laws to govern the process of evolution or what he calls "cosmological natural selection" (Smolin 1997).

13. Some who accept a stochastic universe take heart from the ultimate paragraph of Ilya Prigogine's widely read *Order out of Chaos: Man's New Dialogue with Nature* (Prigogine and Stengers 1984, 313), which closes with the following passage from Andre Neher's discussion of the Midrashic commentary on the Book of Genesis (Neher 1975, 179): "Twenty-six attempts preceded the present genesis, all of which were destined to fail. . . 'Let's hope it works.' *Halway Sheyaamod*, exclaimed God as he created the World, and this hope . . . has emphasized right from the outset that this history is branded with the mark of radical uncertainty." Unfortunately, Neher's rendition is questionable at best. The claim of twenty-six attempts comes from the medieval French commentator Rashi and has no justification in Genesis. Moreover, "*Halway sheyaamod*" does not appear in the passage Neher cites (*Bereshit Rabbah* 9:4). The closest passage containing *halevai*, "Let's hope" or "May it," is rendered by the volume's translator, Jacob Neusner, "May you [the world] always charm me." We might read it, "May it continue to please me." Either is a far cry from Neusner's stochastic reading. I thank Professors Neusner and Alan Avery-Peck for their help in finding and analyzing the original reference.

14. Hartshorne also accepts panentheism, holding that all is "in" God, or, better, that the God-creation relationship is itself internal to God. His favorite metaphor for this relation is that God stands to the world as an organism stands to its cells, his version of Plato's notion of God as the world-soul in relation to the world-body. At the same time, this is only part of Hartshorne's dipolar conception of God, under which the actual world-soul or embodied God is, like Alfred North Whitehead's notion of the consequent nature of God, combined with the notion of God as eternal, as more than the universe, or primordial in Whitehead's sense (see Hartshorne 1984, 75–80).

15. It is not my concern in this essay to discuss theology generally, or process theology in particular. Even with the particulars of his denial of omniscience and omnipotence I would probably have some differences with Hartshorne. For example, the main justification of his

denial of omniscience is his Socinian view that God's knowledge of the future is indefinite because the future itself is indefinite. I would go further and doubt that it makes sense to say that God knows all present and past actualities. That we must imagine the Ground to be the greatest in knowledge, to surpass all other beings cognitively, may be true, but that does not require that God know everything that is knowable.

References

Atkatz, David. 1994. "Quantum Cosmology for Pedestrians." *American Journal of Physics* 62:619–27.

Anaximander of Miletus. 1988. Chapter 3 of G. S. Kirk, J. E. Raven, and M. Schofield, *The Presocratic Philosophers.* Cambridge: Cambridge Univ. Press.

Barrow, John, and Frank Tipler. 1986. *The Anthropic Cosmological Principle*. Oxford: Oxford Univ. Press.

Bereshit Rabbah. 1985. *The Judaic Commentary to the Book of Genesis: A New American Translation. Vol. I: Parashiyyot One through Thirty-Three on Genesis 1:1 to 8:14.* Trans. Jacob Neusner. Providence, R.I.: Brown Univ. Press.

Borde, Arvind, Alan H. Guth, and Alex Vilenkin. 2003. "Inflationary spacetimes are not past-complete." *Physical Review Letters* 90 (15) (April 18):151301-1 to 151301-4.

Cao, Tian-yu. 2004. "Ontology and Scientific Explanation." In John Cornwell, *Explanations: Styles of Explanation in Science*. Oxford: Oxford Univ. Press.

Clayton, Philip. 1997. *God and Contemporary Science*. Grand Rapids, Mich.: Eerdmans.

Craig, William Lane, and Quentin Smith. 2003. *Theism, Atheism, and Big Bang Cosmology*. New York: Oxford Univ. Press.

Curie, Pierre. 1894. "*Sur la symétrie dans les phénomènes physiques. Symétrie d'un champ électrique et d'un champ magnétique*." *Journal de Physique*, 3d series, vol. 3:393–415.

Davies, Paul. 1983. *God and the New Physics*. New York: Simon and Schuster.

Dombrowski, Daniel. 1996. *Analytic Theism, Hartshorne, and the Concept of God*. Albany: State Univ. of New York Press.

Eddington, Arthur S. 1933. *The Nature of the Physical World.* Cambridge: Cambridge Univ. Press.

Guth, Alan. 1998. *The Inflationary Universe: The Quest for a New Theory of Cosmic Origins*. New York: Perseus.

Hartle, J. B., and S. W. Hawking. 1983. "Wave Function of the Universe." *Physical Review D* 28:2960–75.

Hartshorne, Charles. 1984. *Omnipotence and Other Theological Mistakes.* Albany: State Univ. of New York Press.

Hawking, Stephen. 1998. *A Brief History of Time*. New York: Bantam.

Hume, David. 1910. "Of Providence and a Future State." In *An Enquiry into Human Understanding*, Section XI. New York: Collier.

———. 1998. *Dialogues concerning Natural Religion*. Indianapolis: Hackett.

Isham, Christopher J. 1993. "Quantum Theories of the Creation of the Universe." In *Quantum Cosmology and the Laws of Nature: Scientific Perspectives on Divine Action*, ed. Robert John Russell, Nancey Murphy, and Christopher J. Isham, 49–89. Vatican City State: Vatican Observatory Publications.

Kirschner, Robert P. 2004. *The Extravagant Universe: Exploding Stars, Dark Energy, and the Accelerating Cosmos*. Princeton: Princeton Univ. Press.

Linde, Andre. 1994. "The Self-Reproducing Inflationary Universe." *Scientific American* (November): 48–55.

Lucretius. 1921. *On the Nature of Things*. Trans. William Ellery Leonard. New York: E. P. Dutton.

Neher, Andre. 1975. "*Visions du temps et l'histoire dans la culture juive*." In Paul Ricoeur, *Les cultures et le temps*, 171–91. Paris: Payot.

Neville, Robert C. 1968. *God the Creator: On the Transcendence and Presence of God*. Chicago: Univ. of Chicago Press.

Penrose, Roger. 2005. *The Road to Reality: A Complete Guide to the Laws of the Universe.* New York: Knopf.

Polkinghorne, John. 1989. *Science and Creation*. Boston: Shambala.
Prigogine, Ilya, and Isabelle Stengers. 1984. *Order out of Chaos: Man's New Dialogue with Nature*. New York: Bantam.
Ramsey, Frank. 1990. "Law and Causality B: General Propositions and Causality." *Philosophical Papers*, ed. D. H. Mellor. Cambridge: Cambridge Univ. Press.
Rolston, Holmes III. 1988. *Environmental Ethics: Duties to and Values in the Natural World.* Philadelphia: Temple Univ. Press.
Russell, Robert John. 1993. "Finite Creation without a Beginning: The Doctrine of Creation in Relation to Big Bang and Quantum Cosmologies." In *Quantum Cosmology and the Laws of Nature: Scientific Perspectives on Divine Action*, ed. Robert John Russell, Nancey Murphy, and Christopher J. Isham, 293–330. Vatican City State: Vatican Observatory Publications.
Russell, Robert John, Nancey Murphy, and Christopher J. Isham. 1993. *Quantum Cosmology and the Laws of Nature: Scientific Perspectives on Divine Action.* Vatican City State: Vatican Observatory Publications.
Schelling, Friedrich Wilhelm Joseph Von. 1936. *Philosophical Inquiries into the Nature of Human Freedom*. Trans. J. Guttman. New York: Open Court.
Smith, Quentin. 1998. "Why Stephen Hawking's Cosmology Precludes a Creator." *Philo: A Journal of Philosophy* 1 (1): 75–94.
Smolin, Lee. 1997. *The Life of the Cosmos.* Oxford: Oxford Univ. Press.
———. 2001. *Three Roads to Quantum Gravity*. New York: Basic Books.
Stenger, Victor. 2006. "Why Is There Something Rather Than Nothing?" *Skeptical Briefs Newsletter*, Vol. 16 (June). Committee for Skeptical Inquiry. *http://www.csicop.org/sb/show/why_is_there_something_rather_than_nothing.*
Tegmark, Max. 2003. "Parallel Universes." *Scientific American* (May): 41–51.
Tryon, Edward. 1973. "Is the Universe a Vacuum Fluctuation?" *Nature* 246:396–97.
Tillich, Paul. 1951. *Systematic Theology.* Vol. 1. New York: Harper and Row.
———. 1952. *The Courage to Be.* New Haven: Yale Univ. Press.
Vilenkin, Alex. 1982. "Creation of Universes from Nothing." *Physical Letters* 117B:25–28.
———. 1984. "Quantum Creation of Universes." *Physical Review D* 30 (2) (July 15): 509–11.
———. 2006. *Many Worlds in One: The Search for Other Universes*. New York: Hill and Wang.
Wilczek, Frank, and Betsy Devine. 1989. *Longing for the Harmonies: Themes and Variations from Modern Physics.* New York: Norton.