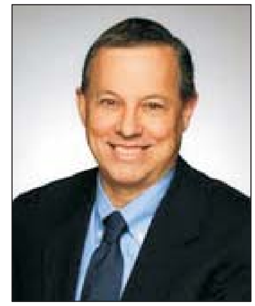
James Bradley

Randomness and God's Nature

James Bradley

Observations of apparently random phenomena are commonplace in science. However, randomness and Christian belief are often seen as incompatible, both by naturalists and by theists. This article argues that the scientific concept of randomness and the historic Christian understanding of God's nature are compatible. It argues that the existence of randomness cannot be settled scientifically; nevertheless, it clarifies randomness as a mathematical concept, argues that it provides a plausible interpretation of scientific data, and argues that its existence is consistent with God's nature as it is commonly understood by systematic theologians.

1. The Problem

Observations of apparently random phenomena are commonplace in the natural sciences. But randomness is often seen as incompatible with the historic Christian understanding of God's nature both by naturalists and theists.

Some naturalists accept the existence of chance but deny God; for example,

> The more we understand of the workings of nature, the more we realize that the forces that shape it are those of blind, purposeless chance. Across a universe encompassing billions of light years, through scales of magnitude extending from subnuclear particles to immense galaxies colliding like a clash of cymbals, there is no hint of plan or purpose.[1]

Some theologians affirm God's existence but deny chance; R. C. Sproul writes,

> The mere existence of chance is enough to rip God from his cosmic throne. Chance does not need to rule; it does not need to be sovereign. If it exists as a mere, impotent humble servant, it leaves God not only out of date but out of a job. If chance exists in its frailest possible form, God is finished.[2]

In this article, I argue that the scientific concept of randomness and the historic Christian understanding of God's nature are compatible. I will not provide a conclusive demonstration of the existence of randomness—in fact, I will argue that its existence cannot be settled scientifically; rather I will argue that it provides a plausible interpretation of scientific data and its existence is consistent with God's attributes.

The argument proceeds as follows. In Section 2, I examine several exemplars of randomness. This is to place the subsequent philosophical and theological discussion of randomness within the actual practice of probability, statistics, and the natural sciences. Section 3 explores the concepts these exemplars are used to convey and presents two interpretations of nondeterministic models—instrumentalism and realism. I argue that it is impossible to choose between them on scientific grounds alone; hence the study

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of randomness necessarily involves metaphysical and/or theological reflection. Section 4 explains how randomness can plausibly be viewed as a key feature of the physical world. Section 5 presents the classical perspective on God's attributes as studied in systematic theology. It argues that most of God's attributes do not pose a consistency problem with realism about randomness; nevertheless, four issues—purpose, control, foreknowledge, and causality—do pose potential conflicts. Sections 6 through 9 address each of these, showing how the apparent conflict can be resolved. Section 10 discusses how a realist interpretation of randomness might influence our understanding of God's relational attributes.

2. Exemplars of Randomness

A popular conceptualization of randomness is not having a governing design, method, or purpose; unsystematic; without cause. But this concept is not how randomness is actually used in mathematics, statistics, and the sciences. In *The Structure of Scientific Revolutions,* Thomas Kuhn drew on the notion of *exemplar,* those examples in a discipline that transmit its key concepts from one generation to the next. He wrote,

> By [exemplar] I mean, initially, the concrete problem-solutions that students encounter from the start of their scientific education, whether in laboratories, on examinations, or at the ends of chapters in science texts … All physicists, for example, begin by learning the same exemplars: problems such as the inclined plane, the conical pendulum, and Keplerian orbits; instruments such as the vernier, the calorimeter, and the Wheatstone bridge.[3]

I begin with nine exemplars of randomness that show how the term is used in mathematics, statistics, and the sciences; they will illustrate key ideas later in this article.

Exemplar 1: Games of chance

"Games of chance" employ playing cards, dice, coin flips, and roulette wheels; frequently, these introduce probability to students.[4] Textbooks pack many concepts into the discussion of these games. Each involves a small, finite number of equally probable outcomes; for coin flips, if the coin is "fair," the outcomes are equally likely. The probabilities of all outcomes must total one, so each has probability ½. Thus the fairness assumption introduces a method to calculate probabilities. The frequentist interpretation of probability is also introduced here—that the ½ should be understood in terms of the law of large numbers[5]—that with many flips the relative frequency of each outcome will approach ½. A flipped coin could land on edge or fall into a drain. The assumption that there are only two outcomes (heads and tails) introduces the idea that probabilistic representations are *models*, simplifying and idealizing a more complex reality.

Exemplar 2: Pseudorandom numbers

Computer games and simulations often depend on pseudorandom numbers. These are generated by an algorithm but appear random in that they are uniformly distributed over some range (say 0 to 1) if the algorithm works as intended; this provides a kind of "fairness" in games and simulations. Typically such algorithms start by selecting a number (called a *seed*), entering it into a formula that generates a next number, then using that as the seed for the next, and so forth. If one knew the initial seed and the formula, one could compute all the numbers. But the seed is often chosen so as to make the numbers unpredictable in practice, such as selecting digits from the time given by the computer clock at the instant the number is requested. Nevertheless, John von Neumann once joked, "Anyone who considers arithmetical methods [as] producing random digits is, of course, in a state of sin."[6]

Exemplar 3: Random sampling

This is the basis of statistical investigations. It is typically done by numbering the members of a population, then using a computer or a table to generate pseudorandom numbers that are used to select a sample of the population. Statisticians view such samples as having the best chance of being unbiased—that is, being representative of the population. Random sampling is so widespread that it provides a particularly familiar example of how randomness can be used purposefully.

Exemplar 4: Radioactive decay

If we take a sample of Carbon-14, for example, it will gradually decay into Nitrogen-14 through emission of beta particles—electrons or positrons. The rate of emission is constant, making it possible to calculate a half-life—the time it takes for half of the radioactive material in a sample to decay; in Carbon-14's case, the half-life is 5,730±40 years. Nevertheless, there is no known way to predict when any particular atom in the sample will emit such a particle. Thus the time of emission serves as an exemplar of a continuous random variable (in contrast to the discrete random variables of the previous three examples); our inability to identify a determinate process that would enable prediction of the time of a particular emission is often used to introduce the notion that indeterminacy may be an inherent property of processes and not simply a matter of our ignorance.

Exemplar 5: Poisson processes

Time-dependent events such as the arrivals of customers at a check-out counter in a store, of cosmic rays at a detector, or of telephone calls at a hub are often modeled using Poisson processes. In such processes, arrivals occur randomly at a constant rate over a time interval and are equally likely to occur at any time in that interval. These assumptions guarantee that inter-arrival times will follow an exponential pattern; if the frequency of arrivals in a fixed time interval is counted for many such intervals (all having the same arrival rate), the frequencies will follow a pattern known as a Poisson distribution. Poisson processes illustrate the fact that randomness may arise by aggregating events that are individually not random—the coincidence of large numbers of independent events, each determined by its own (possibly deterministic) causes, produces behavior consistent with an assumption of randomness.

Exemplar 6: Quantum uncertainty

We cannot see electrons but we can represent them mathematically. "Spin" is a property of electrons even though (as far as we know) electrons do not spin in the same sense as large objects such as baseballs and planets. Electron spin can occur in one of two states: spin-up or spin-down. But this does not mean that electrons exist in one state or the other; rather, they are mathematically represented as a probability distribution over the possible spin states (and other properties). However, when electrons pass through a device called a *beam splitter*, a transition (called the *collapse of the wave function*) occurs in such a way that the path of the electron shows it to be in either the up or down state with each state having probability one-half. In the *Copenhagen interpretation* of this phenomenon,[7] the collapse is precisely what it appears to be—nondeterministic; the Copenhagen interpretation is held by most physicists and is commonly taught. In the *Bohmian interpretation*,[8] the collapse is viewed as deterministic and depends on the existence of currently undiscovered *hidden variables.* The hope of finding such variables received a major setback in 1964, however, with the publication of Bell's Theorem. This provides an empirical test for whether quantum uncertainty can be accounted for by local hidden variables (ones that respect the velocity of light as a maximum velocity); such testing has demonstrated that the answer is no.[9] Nevertheless, the issue of how to interpret the collapse of the wave function is far from settled; two other interpretations are *decoherence,* focusing on the interaction of the electron with its environment, and *many-worlds.* In the latter, the collapse is deterministic—the waveform representation of the electron is seen as real but its collapse is denied. Rather, reality is seen as a multibranched tree in which all possible alternative histories of the electron and all possible future states are real.

Exemplar 7: Mendel's peas

Gregor Mendel (1822–1884), an Austrian Augustinian monk, is known as the "father of modern genetics." Working with peas grown in his monastery's experimental garden, he discovered the laws of inheritance that govern the transmission of traits from parents to children. For instance, some traits of peas (color, texture, etc.) occur in two genetic forms (or *alleles*) that can be denoted "A" for the dominant form and "a" for the recessive form. The genotypes governing the expression of such a trait occur as pairs—AA, Aa, or aa. Using careful records, Mendel demonstrated that the offspring of hybrids (those with the form Aa) occur randomly with ¼ taking the form AA, ½ Aa, and ¼ aa. Mendel's work preceded the discovery of genes; however, their subsequent discovery provided an understanding of the mechanisms underlying Mendel's laws. Random transmission of genetic information to offspring is a key component of the theoretical framework of modern evolutionary theory.

Exemplar 8: Diffusion

Consider a cell in the human body. It needs nutrients and oxygen delivered to it from its exterior and has waste products in its interior of which it needs to dispose. Water can pass through the semipermeable cell membrane taking dissolved substances with it and balancing the concentration of these substances on either side of the membrane. This process is called *osmosis* and is a form of *diffusion*, the random movement of particles from regions of higher concentration to those of lower concentration. This random motion is the result of the heat energy of molecules, each moving independently, and occurs continually in all liquids and gases. Life as we know it would not be sustainable without osmosis.

Exemplar 9: Chaos theory

"Chaos" is the popular name of *deterministic non-periodicity*.[10] It characterizes nonlinear systems such as global atmospheric pressure. Such systems are extremely sensitive to their initial conditions. They are deterministic in the sense that if one knew their governing equations and initial state precisely, their entire future behavior would be predictable. However, it is impossible to measure their initial state with full precision; furthermore, the system amplifies tiny variations in the initial state so that two systems that start out close together become farther apart over time. Thus, future states are, in practice, unpredictable even though in principle they are predictable. These systems are deterministic but their long-term behavior appears random.

3. Randomness

The popular conception of randomness mentioned earlier—not having a governing design, method, or purpose; unsystematic; without cause—is misleading. For example, rolling a fair die produces six possible outcomes, each with probability 1/6. Both scientists and lay people regard that outcome as random, but the die is carefully designed and purposeful, is far from being unsystematic, and its outcome has a clear (arguably nondeterministic) cause.

Nevertheless, even among specialists, "random" does not enjoy a widely agreed upon univocal definition. The nine exemplars involve indeterminate processes—characterized by multiple possible outcomes and the impossibility of predicting which will occur. However, the term "indeterminate" is ambiguous. Physicists, for example, often think of randomness in terms of causation or lack thereof. Thus an event is determinate if it is "determined," i.e., caused; it is indeterminate if it is uncaused. Mathematicians and statisticians typically avoid the causality question by focusing on unpredictability.

"Random" can also refer to outcomes as well as processes.[11] An idealized process (assuming perfect repeatability) can produce an arbitrarily long sequence of outcomes. *Algorithmic information theory* (AIT) studies infinite strings of bits; these provide a mathematical model of sequences of outcomes. AIT has introduced several concepts of randomness. For example, for *Martin-Löf randomness* a string of bits is random if it passes all reasonable statistical tests for randomness. Another approach uses incompressibility—a string is compressible if it can be described by a string shorter than itself;[12] random strings are incompressible. These concepts have yielded powerful results such as methods to decide whether one string is more random than another. The underlying intuition linking all of AIT's formulations of randomness is that a random string lacks a discernible pattern. But AIT makes the notion of "lacking a pattern" precise by giving it the meaning of incomputable—there is no algorithm that can take the first n bits of a random string and compute the $(n+1)^{st}$.[13]

The process definition (in terms of unpredictability) and product definition (the absence of pattern in lists of outcomes) are similar but not equivalent—an infinite bit string that lacks a pattern represents multiple outcomes and its terms are unpredictable. However, a real world process is never perfectly repeatable, nor can it produce an infinite sequence of outputs. Also, its outputs may truly be unpredictable but for any finite set of outputs there is a nonzero probability that they possess a discernible pattern. Furthermore, AIT offers several nonequivalent definitions. So randomness can be viewed as a collection of concepts that bear a "family resemblance" incorporating the notions of multiple outcomes, unpredictability, and the absence of pattern in idealized sequences of outputs. I will simply use "indeterminacy" and "indeterminate" to refer to this family. This will suffice for the consistency argument given here.

An *epistemically random* sequence is one that appears random but, in fact, possesses a pattern that can be computed by an algorithm. An *ontologically random* sequence has no algorithm that can compute its members. Thus these represent two very different types of randomness; ontological randomness (if it exists in the natural world) is a property of the very nature of things; epistemic randomness is apparent randomness—it is a function of human perception of things but not their nature.[14] *Determinism* is the philosophical position that ontological randomness does not exist in the physical world; *nondeterminism* is the assertion that it does exist. There are two principal interpretations of models that include randomness. For *instrumentalism*, randomness is a useful tool when we have limited knowledge; for *realism*, it corresponds to a deeper nondeterministic reality.

Some Christian thinkers have argued for realism regarding randomness; some against it. John Byl rejects ontological randomness in physics; he argues that a preference for nondeterministic interpretations of quantum mechanics "… is motivated largely by philosophical and theological commitments."[15] R. C. Sproul, quoted earlier, also denies that randomness could be real. Hans Gregersen sees all natural laws including any that involve randomness, as human expressions of patterns. He writes,

> … laws of nature simply pick out the regularities of nature in so far as these can be identified by empirical investigations. Laws of nature, on this account, are a metaphor or shorthand for general descriptions of regularities; ontological assumptions are deemed unnecessary.[16]

Other Christian writers argue that the apparent nondeterminacy in quantum mechanics indicates a more fundamental nondeterminate reality. John Polkinghorne justifies this inference on grounds he calls *critical realism*. He starts from realism, the idea that things are the way they appear to be; critical realism, however, acknowledges that our perceptions can be fooled by things such as optical illusions. It also acknowledges that very small things (at the quantum level) and very large things (at the galactic level) are outside our normal experience. So while realism is basically sound, we need to apply it cautiously. Polkinghorne argues for the Copenhagen interpretation on grounds that when something such as quantum uncertainty has been studied by a large number of people over many years producing powerful and consistent results, a move from "x appears this way" to "x is this way" is warranted.[17]

Keith Ward argues that nondeterministic laws allow creative freedom room to exist and to operate.[18] David Bartholomew argues that God uses chance.[19] His book is subtitled "Can God Have It Both Ways?," referring to the existence of both randomness and order; he answers yes.

I claim that it is impossible to decide on scientific grounds alone whether ontological randomness exists (although I will argue in the next section that evidence in favor of it is stronger than evidence against it). Either claim would require complete knowledge of the universe. That is, suppose Professor A is a nondeterminist. Consider any particular example he believes to be nondeterministic. Professor A can never exclude the possibility that some future discovery will show it to be deterministic. Now suppose Professor B is a determinist. In lieu of complete knowledge of the universe, she can never show that deterministic causes can be found for all physical events. So neither position can be scientifically established; metaphysical and/or theological reflections are necessary if we are to explore the concept of randomness. Randomness is a scientific concept that cannot be completely investigated by science.

There is no inconsistency with historic Christian theology if we adopt the instrumental interpretation—this interpretation makes no ontological claims. However, the realist interpretation is controversial. In the remaining sections of this article, I will argue for the consistency of the realist interpretation with classical Christian views of God's nature.

4. Arguments for the Existence of Ontological Randomness

Even if we could construct a sound argument for the consistency of the realist interpretation of randomness and God's attributes, it would be of little importance without a plausible case for ontological randomness.

On one hand, a theist could argue for the consistency of randomness and God's attributes on the grounds of God's infinitude—algorithms are necessarily finite, human understanding is limited; thus, unpredictability and the creation of patterns that cannot be detected by finitistic means are consistent with God's infinitude. On the other hand, a different theist could assert that the physical world is finite and hence be skeptical that any physical process could produce outcomes that lack a discernible pattern even though God created that process. This section presents three arguments based on observations of the natural world that support the plausibility of ontological randomness.

1. Recent work on "quantum coin tossing" uses quantum indeterminacy to generate sequences of bits that exhibit strong evidence of being random.[20] AIT has shown that there are random numbers; however, this could simply be an abstract mathematical curiosity. Quantum coin tossing demonstrates that it is plausible that such numbers correspond in a meaningful way to entities in the physical world. Through both the long-standing durability of the Copenhagen interpretation and this recent work on quantum coin tossing, quantum indeterminacy provides a powerful argument for ontological randomness; it does not prove its existence, but it shifts the burden of proof to those who deny its existence.

   Some physicists have used quantum indeterminacy to argue for indeterminacy in the natural world well beyond the quantum level. In this argument, quantum indeterminacy feeds indeterminate initial states into chaotic systems, and that indeterminacy is subsequently amplified many fold. The argument, however, possesses a serious weakness: differential equations that exhibit chaotic behavior (such as those describing global weather) approximate states of the macro world; they may not be applicable at the quantum level.[21] Of course, the cumulative effect of the enormous number of small particle interactions may be sufficiently large that it affects macro systems. But the argument is weaker than is sometimes assumed.

2. A different argument for widespread randomness begins with Poisson processes. These illustrate that the coincidence of multiple independent events, each of which may be deterministic, can produce a composite effect consistent with an assumption of randomness. Furthermore, the natural world is extremely complex—the number of elementary particles has been estimated as on the order of 10^{89}, almost all of which are constantly interacting with other particles. Also, the differential equations used to model many natural systems exhibit extreme sensitivity to initial conditions.[22] Considering these three factors together—independence, complexity, and chaos—it is easy to see how the world could appear random on a broad scale.

   A determinist could argue that the world appears random to finite human beings but need not to an infinite, omniscient God. However, this assertion does not seem consistent with God's omniscience, although it is easy to reconcile it with his omnipotence. Consider this thought experiment: an engineer is designing a system to keep a ball in place. He could place it on the peak of a mountain, and with sufficient resources and vigilance, he could maintain it there. Or he could put it in a valley. In the first case, he might be called omnipotent, but he would not be called omniscient. Managing this world given its nonlinearity, complexity, and sensitivity to initial conditions in a deterministic manner would be like placing the ball at the top of the hill; managing it via indeterminacy would be like placing it in the valley. That is, an omniscient engineer would know that a deterministic system that incorporates such a high degree of instability is not an optimal design.

   This argument is an application of inference to the best explanation and depends on an analogy between God's thoughts and those of an engineer. Since the existence of ontological randomness cannot be settled scientifically, such arguments are our only option. Nevertheless, this argument does not address the origin of randomness in the physical world. This is a mystery which is probably impenetrable. The presence of mystery should not be surprising, however; if God is infinite, we would expect that much of his nature and actions will remain mysterious to finite creatures.

3. A third argument starts from free will. If a person's decision is a function of many inputs, including genetic and environmental factors, is such a function deterministic? There are two principal perspectives. *Compatibilism* consists of the assertions that it is deterministic and that such a position can be reconciled with the intuition that we have free will. *Incompatibilism* is the assertion that such decisions are not deterministic. The free will argument for randomness assumes incompatibilism.

   Incompatibilist free will implies that ontological randomness exists, but the converse need not hold. Consider, for example, flipping a coin. Conceivably an engineer could design a "coin flip predictor," a machine that detects the initial position of the coin, its initial upward and rotational velocities, and the position where it will land, and predicts its outcome. Thus once the coin is released, the outcome is deterministic. But if the flipper has incompatibilist free will, the exact moment and the manner of that release are inherently unpredictable; in fact, they are not fully under the flipper's control. So before the coin is released, the outcome is ontologically indeterminate. Since incompatibilist free will necessitates ontological randomness, denying ontological randomness necessitates compatibilism.

Some scientists have argued that the Copenhagen interpretation of quantum indeterminacy, if correct, allows for an account of incompatibilist free will. They argue the plausibility of the converse—that ontological randomness can account for free will. However, it is difficult to see how to carry out such an argument. For example, one form of this argument starts from quantum indeterminacy of elementary particles in a person's brain. However, to account for free will, the argument needs to "connect the dots" between that indeterminacy and particular free choices. It is far from clear that that can be done.[23]

Note that if incompatibilist free will exists, games of chance can exhibit ontological randomness since they are under the control of an agent acting indeterminately. Furthermore, so do pseudorandom numbers and random sampling—an ontologically indeterminate choice can start the random number generator.

The arguments from physical processes make a stronger claim about randomness than the argument from free will—the former locate randomness in the structure of the physical world, giving it a time frame of billions of years and independence from human activity.

An assertion that the physical world is extensively indeterminate may seem incredible given the orderliness and predictability of the physical world. Furthermore, to many people, such an assertion seems inconsistent with God's nature. Sections five through ten address this issue.

5. God's Nature

To say whether randomness is consistent with God's nature, we need to understand that nature. Systematic theologians have written extensively about it; some scholars have balked on grounds that finite human beings cannot understand a transcendent, infinite God. However, the consensus of historic Christian thought is that we can make accurate, if necessarily incomplete, statements about God's nature because God has revealed himself in scripture.

The prototypical approach presents a list of divine attributes and then expands on each. For example, Thomas Oden presents sets of divine attributes organized around four themes:

- The divine being (primary and essential attributes of God: sufficiency, underived existence, unity, infinity, immeasurability, eternity, life)
- The divine majesty (the relational attributes of God: all-present, all-knowing, almighty)
- The divine person (free, congruent, interactive Spirit)
- The divine goodness (holy, constant, compassionate)[24]

"Congruent" means that God acts in ways consistent with his being and character—he "cannot deny himself"; "relational" refers to God's relationship with the entirety of creation.

Herman Bavinck discusses God's attributes using the names of God revealed in scripture.[25] His list is similar to Oden's; he also presents a thorough discussion of the history of Christian thought about the attributes. Many other theologians, notably Thomas Aquinas in his *Summa Theologica* and John Calvin with his *Institutes of the Christian Religion* have presented systematic treatments of God's attributes. Oden's four sets of attributes provide a representative summary.

The essential attributes have no relationship with randomness since they deal with what God is apart from creation.[26] Also, attributes of the divine person and of the divine goodness do not involve God's relationship with physical processes. Hence, in terms of Oden's list, the potential problems reconciling randomness with God's nature all arise with the relational attributes—omnipotence, omniscience, and omnipresence.

Omnipotence

Oden offers a succinct definition of omnipotence: God's "perfect ability to do all things that are consistent with the divine character." Bavinck explains omnipotence in several ways. The most explicit are the following:

- "He has absolute power over all things so that nothing can resist him."

- "Nothing is too hard for God: for him all things are possible."
- "He does whatever he pleases and no one can call him to account."
- "This power of God, finally, is also the source of all power and authority, ability and strength, in creatures."[27]

In discussing nominalism, Bavinck also explains what omnipotence does *not* mean.

> … the nominalists defined the omnipotence of God not only as his power to do whatever he wills, but also as his power to will anything. Differentiating between God's "absolute" and his "ordained" power, they judged that in accordance with the former God could also sin, err, suffer, die, become a stone or an animal, change bread into the body of Christ, do contradictory things, undo the past, make false what was true and true what was false, and so forth. According to his absolute power, therefore, God is pure arbitrariness, absolute potency without any content, which *is* nothing but can *become* anything.[28]

Nevertheless, Bavinck does not limit God's omnipotence beyond excluding things that are contradictory or inconsistent with his nature. He adds, "What is possible extends much further than what is real." That is, he rejects the position of Abelard that God cannot do anything beyond that which he does. Bavinck also adds,

> Calvin did not deny that God can do more than he actually did, but only opposed a concept of "absolute power" that was not bound to his nature and therefore could do all sorts of contradictory things. Conceived along the lines of Augustine and Thomas, this distinction was generally endorsed by Reformed theologians, and so understood, it is worthy of endorsement.[29]

Bavinck exposes one potential problem in reconciling randomness with God's nature: While randomness is not inconsistent with God's character, it appears to involve processes outside of God's control—without pattern or predictability, there seems to be no control—so it seems inconsistent with divine omnipotence. This issue will be addressed in Section 7.

Omniscience

Oden defines divine omniscience as "God's complete knowledge of the world and time."[30] One biblical source is Heb. 4:13, "Nothing in all creation is hidden from God's sight. Everything is uncovered and laid bare before the eyes of him to whom we must give account." Oden says,

> God's knowing is said to be (a) eternally actual, not merely possible; (b) eternally perfect, as distinguished from a knowledge that begins, increases, decreases, or ends; (c) complete instead of partial; and (d) both direct and immediate, instead of indirectly reflected or mediated.[31]

For Oden, omniscience is wisdom as well as factual knowledge:

> The wisdom of God is God's incomparable ability to order all things in the light of good, to adjust causes to effects, and means to ends; so that the divine purposes are firm and never thwarted.[32]

Two issues arise from omniscience. The first problem is that, in the popular concept, chance has no governing design, method, or purpose. The existence of chance, then, would contradict the position that God has a purpose for all of creation and orders all things in light of that purpose. For example, Isaiah presents God as saying, "I will accomplish that I please" (Isa. 46:10b, NEB).

Section 6 addresses our second problem—reconciling randomness with God's purposefulness. One could argue that even if a process appears random, God knows what will happen, so the outcomes are predictable to God. If predictable to God, then perhaps they are predictable to human beings. This contradicts the unpredictability that characterizes randomness. Bavinck supports this position, quoting Cicero: "… if he [God] knows it, it will certainly take place, but if it is bound to take place, no such thing as chance exists."[33] Section 8 addresses this issue.

Omnipresence

Oden defines omnipresence as "God's mode of being present to all aspects of both space and time. Although God is present in all space and time, God is not locally limited to any particular time or space."[34]

Aquinas writes,

> God is in all things by his power, insofar as all are subject to his power. God is in all things by his presence, insofar as everything is naked and open to his eyes. God is in all things by his essence, insofar as God stands to all things as the cause of their being …[35]

The *Stanford Encyclopedia of Philosophy* raises a philosophical question about omnipresence: "How can an immaterial being be present at or located in space?" It explains Aquinas' answer:

> This way of understanding God's presence by reference to his power and his knowledge treats the predicate 'is present' as applied to God as *analogical* with its application to ordinary physical things. It is neither univocal (used with the same meaning as in ordinary contexts) nor equivocal (used with an unrelated meaning). Rather, its meaning can be explained by reference to its ordinary sense: God is present at a place just in case there is a physical object that is at that place and God has power over that object, knows what is going on in that object, and God is the cause of that object's existence.[36]

Omnipresence in the sense of being present to all things in space and time is not inconsistent with randomness. However, God's presence at every act of causality raises a fourth problem: In *deterministic causation*, if A occurs, B necessarily follows and either A is the mechanism producing B or it triggers such a mechanism.[37] In *probabilistic causation*, if A occurs, the probability of B increases. For instance, smoking causes lung cancer, but not everyone who smokes gets lung cancer; neither is every lung cancer sufferer a smoker. But smoking increases the probability of lung cancer. Deterministically caused processes (such as discussed in Exemplar 9) can exhibit epistemological randomness, but probabilistically caused processes (if they are more than simply an expression of human limitations) can exhibit ontological randomness. However, because God is omniscient, he completely understands the mechanisms by which all physical processes operate. This casts doubt on the existence of probabilistic causation, thereby casting doubt on randomness. Section 9 addresses this issue.

6. Purpose

People use randomness purposefully in many ways, for example, games of chance, pseudorandom numbers, and random sampling. In this section, I argue that God uses randomness to fulfill his purposes, and thus objections to randomness based on God's purposefulness are unfounded. I assume the examples of randomness discussed in this section are ontological and argue for the consistency of that assumption with God's nature.

Robert Bishop articulates several of God's purposes for creation: (1) to exhibit his glory, (2) to serve as his temple, (3) "to become uniquely what it is called to be in Christ," (4) to populate creation with life, and (5) "to be an arena for comprehensive redemption."[38] Randomness contributes to achieving (at least) the first and fourth of these by maintaining dynamic equilibria in complex systems. Consider these examples.

- Every cell in living organisms needs to transport nutrients to its interior and to dispose of waste. These operations are carried out by osmosis that involves the random motion of molecules as discussed in Section 2.
- More generally, diffusion is an ubiquitous phenomenon that operates to equalize temperature and air pressure distributions. For instance, diffusion makes the uniform shape of a balloon possible in spite of the random motion of air molecules within it.
- Genetic diversity allows populations to adapt to changing environmental conditions.[39] For example, based on skeletal remains, ornithologists have estimated that before Polynesians migrated to Hawaii sometime in the first millennium AD, over one hundred species of honeycreeper inhabited the Hawaiian Islands. Ornithologists consider them a subfamily, *Drepanidinae*, of *Fringillidae*, the finch family. Finches are seed eaters. Hawaiian honeycreepers include not only seed eaters but also insectivores, nectivores, fruit eaters, and even snail eaters, as well as birds that probe decaying wood for insects. Ornithologists account for the uniqueness and diversity of Hawaiian honeycreepers by positing that at one time, a pair (or more) of finches was blown onto the islands. Given the lack of competition they encountered, Hawaiian honeycreepers evolved to exploit the rich resources available in ecological niches that finches do not normally inhabit. Genetic randomness enabled this diversity to arise. It provided for good use of resources, but it also produced an amazing variety of beautiful birds.[40]

Further examples of purposeful roles for randomness from artificial intelligence, hierarchy theory, game theory, and quantum mechanics could be cited, but these will suffice. Thus randomness, often seen as synonymous with disorder and instability, is the mechanism that brings about order, stability, and diversity in physical situations on which life depends. So we can reason like this: God is Creator of all things, and we have articulated some of his purposes for that creation. We see how randomness supports the achievement of these purposes. Therefore we can reason analogically from how purposes function for us, to how they might function for God, and conclude that God has created randomness to accomplish his ends.

While the above examples are well understood, some authors have advanced additional speculative ideas as to how God might use randomness.

- In his chapter, *Order out of Chaos*, David Bartholomew cites examples of how unanticipated orderly structures arise out of chaotic arrangements of entities such as light bulbs and buttons. He writes, "Randomness achieves easily that which, by design, might have been very difficult."[41] Bartholomew uses this as an analogy for how God can have both randomness and order.
- Speaking of scientific law, John Polkinghorne writes, "Chance … is the means for the exploration and realization of inherent possibility, through continually changing (and therefore at any time contingent) individual circumstances."[42] That is, Polkinghorne views God as endowing the creation with possibilities; randomness provides the means for exploring them, thereby enabling creativity in the physical world.
- William Pollard, a well-known physicist and an Episcopal priest, argued for quantum indeterminacy. But he also argued that macrolevel randomness provides room for providential action not easily recognizable as extraordinary.[43] Thus, Pollard suggests, the world is not deterministic, and continual divine action takes place in the form of God's providential care. However, randomness makes it possible for God to hide such actions. Hence, God ensures that the interpretation of events as providential depends on faith; it is not forced on anyone.

So randomness need not contradict God's purposefulness.

7. Sovereignty

Our second potential problem is that randomness appears to involve processes outside of God's control, so randomness appears to conflict with divine omnipotence. Oden writes,

> God's power is not bound always to exercise every conceivable form of power in every situation … God even allows wills contrary to the divine will to act and express influence within fleeting temporal limits.[44]

Aquinas regarded God as empowering and sustaining nature rather than controlling it; creatures can be causative agents in and of themselves.[45] For Aquinas, God is not just another cause or being in the universe but endows all else with being, order, and the capacity to be a secondary cause. This section will explore the perspective that Aquinas and Oden represent in more detail.

First, randomness can involve order. If one rolls a fair die, apart from a drastically unusual event such as the family dog swallowing the die, there are only six possible outcomes and each has probability 1/6. The situation is closer to deterministic order than to complete chaos. But all order originates in God and that includes the order in randomness. As Michael Heller points out, the laws of probability are still laws.[46]

David Bartholomew argues that God "can have it both ways"—have both randomness and order—by introducing the concept of level. At the level of individual entities, a situation can be random, but at an aggregate level, it can be orderly.[47] For example,

- Globally, about 106 male children are born for each 100 female children. However, males have a slightly higher rate of childhood mortality, so that when both genders reach adulthood, the numbers of males and females are almost equal. Thus the gender of an individual birth can be nondeterminate while the aggregate produces a simple order.
- The ideal gas law was first stated by Émile Clapeyron in 1834. For gas in a closed container, $PV = NRT$ where P denotes pressure; V, volume; N, the amount of gas present; R, the gas constant; and T, temperature. A gas consists of enormous numbers of molecules moving randomly in the container; the gas law describes its aggregate behavior in a simple, orderly way.

Figure 1 presents a probability distribution. Note its erratic, uneven quality. Using a computer, I selected

10,000 random samples of size 30 from a population so distributed. Figure 2 presents the distribution of the means of these samples. It is similar to the familiar bell-shaped curve. The central limit theorem tells us that for any probability distribution, if we take independent random samples of size n from that population, the distribution of means of those samples approaches a normal distribution as n gets larger. Processes that average together large number of similar items are common. For example, temperature is the average motion of molecules. Thus, the central limit theorem provides a powerful explanation for why normal distributions arise so frequently in nature. It demonstrates how aggregation transforms disorder at one level to order at a higher level.

Bartholomew argues that God's sovereignty operates differently at different levels. A believer can easily affirm that the order and structure at aggregate levels expresses God's orderliness and goodness.

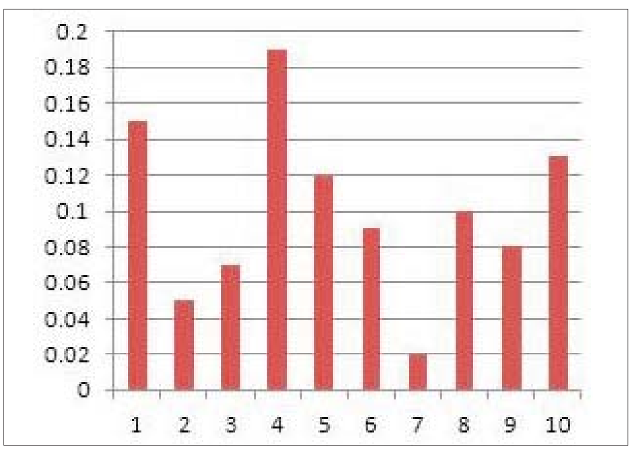

Figure 1. A Probability Distribution

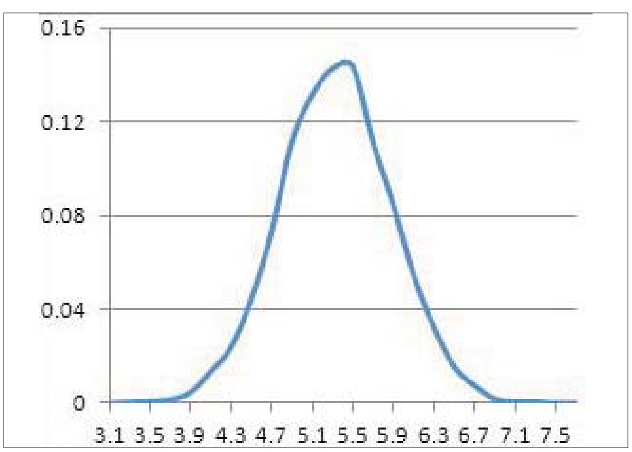

Figure 2. The Distribution of Averages of Random Samples from Figure 1.

But, says Bartholomew, randomness at low levels also expresses God's sovereignty. Nevertheless, while Bartholomew's discussion of levels is helpful in seeing how "God can have it both ways," viewed in isolation, it can oversimplify the complexities of reality. Creation cannot be neatly divided into two levels—a lower one where God operates via randomness and an upper one where deterministic laws prevail.

Robert Bishop's notion of contingent rationality—the order and structure that God has freely given creation—helps here. He writes, "… creation has its own rationality, its own particular order, structure and functionality, which are at least partially intelligible to us."[48] God works through that rationality and that includes the laws of probability and the orderliness of random processes. Randomness does not mean arbitrariness. Rather, random phenomena are constrained to act within boundaries according to their nature. Molecules can vibrate in any direction in three-dimensional space, but that is all they can do; a smooth-skinned pea may nondeterministically produce offspring that are smooth or rough, but it cannot produce a gorilla. God's sovereign control over randomness is expressed in both types of probabilistic laws—those that operate at the level of the individual entity and those that govern aggregation.

8. Foreknowledge

Reconciling randomness with divine foreknowledge is a generalization of the classical problem of reconciling human free will with divine foreknowledge—all of the same questions arise. In *On Free Choice of the Will*, Augustine formulates the problem in the words of his interlocutor, Evodius:

> I very much wonder how God can have foreknowledge of everything in the future and yet we do not sin by necessity. It would be an irreligious and completely insane attack on God's foreknowledge to say that something could happen otherwise than as God foreknew. So suppose that God foreknew that the first human being was going to sin. Anyone who admits, as I do, that God foreknows everything in the future will have to grant me that. Now … since God foreknew that he was going to sin, his sin necessarily had to happen. How then is the will free when such inescapable necessity is found in it?[49]

Replace sinning by random events and free will by processes that produced them and we have the problem of reconciling randomness with God's foreknowledge. Three ways to reconcile God's foreknowledge and human free will apply to randomness in the natural world as well.[50]

1. *Open theists* assert that the future does not exist. They affirm that God has knowledge of many future events—he knows his plans for the future; he knows the laws of nature fully, so he can predict the future evolution of all objects under the control of those laws. He also knows the aggregate behaviors of nondeterministic systems. But he does not have knowledge obtainable by observing a future event—if I plan to flip a coin in the next five minutes, open theists would argue, God cannot say whether that coin will come up heads or tails. Advocates of this approach argue that it does not violate God's omniscience—God knows all that is knowable, but because indeterminate future events do not exist, they are not knowable. They also present numerous biblical texts referring to God regretting actions, changing his mind, and so forth, that they interpret as providing support for an open future.
2. Another approach is *simple foreknowledge*—God's complete and infallible knowledge of the future "… uncomplicated by exceptions, additions, qualifications, et cetera …"[51] Arguments for simple foreknowledge argue that foreknowledge does not constrain events. Consider any particular event that one might want to regard as random—say observing the measurement of the spin of a particular electron. Imagine that God, in spite of his omniscience, chooses to ignore this particular event. (Perhaps he cannot, but let's accept it as a hypothesis for the sake of this argument.) God has no foreknowledge of whether this electron will be measured as spin-up or spin-down, and so the randomness of that outcome does not conflict with his foreknowledge. But the event is exactly the same whether God knows about it or not. So the randomness of the event is independent of God's foreknowledge.
3. A third approach is *Molinism,* after the Jesuit scholar Luis de Molina of the late sixteenth century. Imagine God contemplating all possible worlds he could create. Molinists call the knowledge of these worlds *God's natural knowledge*. Now imagine God after he has chosen the one we live in ("after" is used here in a logical rather than a temporal sense); his knowledge of this is his *free knowledge* (since he has freely chosen which one to create). In between these, Molinists argue, is God's *middle knowledge*, knowledge of events (which may be random) in each possible world. Molinists argue that in choosing the particular world God chose to create, he took this middle knowledge into account. Thus he is able to create randomness, to foreknow its outcomes, and to ensure that his will is accomplished—not in spite of randomness, but as we saw in Section 6, because randomness is one of the means of accomplishing his will.

Scholars are far from a consensus on which of these accounts is the most compelling. Open theism contradicts classical Christian theology's affirmation that God's omniscience includes knowledge of the future; given the extent of classical unity on this question, it would require a very compelling case to reject it. To my mind, the case for open theism, however, does not seem that compelling. Simple foreknowledge affirms free will (and by inference randomness), but it has not provided a clear account of the relationship between God's knowledge and that freedom. Molinism has been critiqued on various grounds, notably the question of why God, knowing his creatures' free choices in advance, would create souls that are lost.

I lean toward Molinism—it provides a powerful account of how God's foreknowledge and ontological randomness can be reconciled; it also seems that God's omniscience would include middle knowledge and that God would use that knowledge in creation. The matter is far from settled, but the three approaches demonstrate that compelling arguments can be presented to reconcile randomness and God's foreknowledge.

9. Causality

Oden writes that God's omnipresence means (among other things) that God is present in every act of causation. Historically, Christian thinkers identify God as the first cause of all actions, although observed events may have secondary causes. Physicists who endorse the Copenhagen interpretation of quantum mechanics typically associate quantum indeterminacy with causelessness; many Christian thinkers object. For example, John Byl argues against quantum randomness:

> Indeed, a basic principle of rational enquiry is that everything has a sufficient reason. The Principle of Sufficient Reason implies the Principle of Causality, which affirms that every event has a sufficient cause. To say that a quantum choice is made by chance is to say that "nothing" makes and actuates the choice. This contradicts the Principle of Sufficient Reason. To say that an event has no cause is to give up on science and to invoke magic, in this case magic without even a magician.[52]

In contrast, Robert Kane distinguishes the principle of sufficient reason and the axiom of sufficient reason. The first says that if p, then there is a sufficient reason for p. The second is its converse; it says that if there is a sufficient reason for p, then p. Kane writes,

> … it will be logically possible that something be the case (e.g., a chance event) which does not have a sufficient cause or explanation for its existence.
>
> … We may say that the axiom of sufficient reason defines the *sufficiency* of a sufficient reason. By contrast, it does not seem that one can derive from the definition of a sufficient reason that everything existing must have one, which is what the principle of sufficient reason requires.[53]

Byl seems to raise the principle of sufficient reason to the level of an axiom. The principle assumes determinism; an argument against chance based on it begs the question.

Consider this thought experiment. A male bear walks through the woods in mating season to liaison with a female. A deer steps on a stick which snaps. The bear stops, listens, and moves on. During that hesitation, his sperm swim around so that the genetic material he passes on differs from what it would have been. In explaining his cub's genetic makeup, the stick would not appear in a causative explanation. Now suppose the deer had stepped a half inch further and missed the stick. That non-event would also not appear in the explanation. That is, one could construct a causative explanation for the cub's DNA makeup and yet, indeterminacy would still be present. In fact, arbitrarily many such counterfactuals could alter the cub's DNA. But none would appear in a causative account. As another example, a puff of wind could cause a bee in Mendel's garden to move slightly; the pollen grains on its back would differ and his peas would receive different genetic material than they would have received without the wind.

By considering counterfactuals, we can see how probabilistic causation can exist without violating God's presence to the causation.

10. Conclusions

How might the existence of ontological randomness in the physical world influence how we see God?

First, the apostle Paul writes,

> *Oh, the depths of the riches of the wisdom and knowledge of God!*
> *How unsearchable his judgments,*
> *And his paths beyond tracing out!* (Rom. 11:33, NIV)

Randomness can be viewed as a subtle expression of God's wisdom—numbers consist of bits that cannot be generated by any algorithmic process, enormously complex systems have components that act independently according to their own laws yet aggregate to produce a simple order, dynamically stable systems depend on randomness for their stability, God's sovereignty is expressed in dramatically different ways at different levels, and probabilistic laws define how order can exist in the midst of apparent disorder. Such factors expand our understanding of Paul's words and can lead to richer worship.

Secondly, Calvin writes,

> Suppose a man falls among thieves, or wild beasts; is shipwrecked at sea by a sudden gale; is killed by a falling house or tree. Suppose another man wandering through the desert finds help in his straits; having been tossed by the waves, reaches harbor; miraculously escapes death by a finger's breadth. Carnal reason ascribes all such happenings, whether prosperous or adverse, to fortune. But anyone who has been taught by Christ's lips that all the hairs of his head are numbered [Matt. 10:30] will look further afield for a cause, and will consider that all events are governed by God's secret plan.[54]

The view of randomness presented here can nuance Calvin's statement. We need not set "fortune" against Christ by associating it with "carnal reason." Rather, randomness suggests we should look at the events

Calvin cites systemically—God has ordained that such events occur but, rather than seeing each event as God's particular will, we see the broad system in which such events occur randomly as God's will. A nondeterministic world provides an arena in which God can demonstrate providential care.[55]

Thirdly, Isaac Newton saw his theory of gravitation as explaining God's work in the physical universe. But subsequent scholars used his laws to undergird deism. The use of nondeterministic processes to account for events in the physical world could also lead to deism. But it need not. Rather, along the lines that Aquinas suggests, nondeterminism can enhance respect for the freedom God gives his creation and recognition of God's providential care.

And lastly, randomness offers the potential of a more nuanced theodicy than does determinism. But this will require development beyond this article. ⁂

Acknowledgments

I would like to thank Kenneth Constantine, Russell Howell, Roger Konyndyk, and Mary Vanden Berg for comments on the first draft of this article. I would also like to thank three anonymous referees for their very helpful comments.

Notes

[1]David Stover and Erika Erdmann, *A Mind for Tomorrow: Facts, Values, and the Future* (Westport, CT: Praeger Publishers, 2000), 37.

[2]R. C. Sproul, *Not a Chance: The Myth of Chance in Modern Science and Cosmology* (Grand Rapids, MI: Baker Books, 1994), 3.

[3]This quotation appears in a postscript to the second edition of Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago, IL: University of Chicago Press, 1970).

[4]The modern concept of probability was formulated by Andrey Nikolaevich Kolmogorov in the 1930s. The earliest widely used textbooks were written in 1950 by William Feller in the United States and Boris Gnedenko in the Soviet Union. Feller mentions all of the games of chance discussed here as well as other examples in chapter 1. Gnedenko uses dice and cards as his principal examples.

[5]In the *Bayesian interpretation*, probabilities refer to subjective degrees of belief.

[6]John von Neumann, "Various Techniques Used in Connection with Random Digits," *Applied Mathematics Series,* no. 12 (1951): 36–8.

[7]Developed by Niels Bohr and Werner Heisenberg in 1924–1927.

[8]Articulated by Louis de Broglie in 1927 and rediscovered by David Bohm in 1952.

[9]Nancey Murphy argues that God is such a nonlocal variable in "Divine Action in the Natural Order: Buridan's Ass and Schrödinger's Cat," in *Chaos and Complexity*: *Scientific Perspectives on Divine Action*, 2nd ed., ed. Robert John Russell et al. (Rome: Vatican Observatory Publications, 2000), 325–58.

[10]The name was popularized in James Gleick, *Chaos: Making a New Science* (New York: Viking Penguin, 1987).

[11]In the *Stanford Encyclopedia of Philosophy* article on chance, Antony Eagle applies *chance* to processes and *random* to data.

[12]For instance, the string 010101010 … can be finitely described as an infinite repetition of 01 even though the string itself is infinite.

[13]AIT removes any remaining ambiguity in the idea of computability by defining it with Turing machines—an abstract model of computation that serves as the theoretical foundation for computer science.

[14]Ontological randomness, as defined here, is not merely a limitation in human knowledge. If there is no algorithm for computing a pattern, God cannot compute it either. Of course, it is conceivable that God could know the list of outcomes in another way, for example, by possessing timeless knowledge that encompasses all past, present, and future outcomes of a process. Whether such knowledge can exist is controversial; I will return to this question in Section 8.

[15]John Byl, "Indeterminacy, Divine Action and Human Freedom," *Science and Christian Belief* 15, no. 2 (October 2003).

[16]Niels Henrik Gregersen, "Laws of Physics, Principles of Self-Organization, and Natural Capacities: On Explaining a Self-Organizing World," in *Creation: Law and Probability*, ed. Fraser Watts (Minneapolis, MN: Fortress Press, 2008), 81.

[17]John Polkinghorne, "The Metaphysics of Divine Action," in *Chaos and Complexity: Scientific Perspectives on Divine Action,* ed. Robert John Russell, Nancey Murphy, and Arthur R. Peacocke (Berkeley, CA: The Center for Theology and the Natural Sciences, 1996).

[18]Keith Ward, "Why God Must Exist," *Science and Christian Belief* 11, no. 1 (April 1999): 5–13.

[19]David Bartholomew, *God, Chance, and Purpose: Can God Have It Both Ways?* (Cambridge: Cambridge University Press, 2008).

[20]See, for example, "Random Numbers Certified by Bell's Theorem," *Nature* 464 (April 15, 2010): 1021–4. Also see Cristian S. Calude, Michael J. Dinneen, Monica Dumitrescu, and Karl Svozil, "Experimental Evidence of Quantum Randomness Incomputability," *Physical Review* A 82, 022102 (2010), http://tph.tuwien.ac.at/~svozil/publ/2010-qrat-j.pdf.

[21]John Polkinghorne, *Science and Providence: God's Interaction with the World*, 2nd ed. (West Conshohocken, PA: Templeton Foundation Press, 2005), xii.

[22]There are several excellent articles on this phenomenon in Russell et al., *Chaos and Complexity*. Crutchfield et al. in an article simply titled "Chaos," pp. 35–48, mention several natural systems including the atmosphere, dripping faucets, turbulence in fluid mechanics, and the heart.

[23]See Harald Atmanspacher, "Quantum Approaches to Consciousness," *Stanford Encyclopedia of Philosophy,* ed. Edward N. Zalta (Summer 2011), http://plato.stanford.edu/archives/sum2011/entries/qt-consciousness/.
[24]Thomas C. Oden, *Classic Christianity: A Systematic Theology* (New York: HarperOne, 1992), 35ff.
[25]Herman Bavinck, *Reformed Dogmatics, Volume 2: God and Creation* (Grand Rapids, MI: Baker Academic, 2004).
[26]Some writers speak of God's attributes "prior to" creation. But time, too, is usually seen as part of the created order. So "prior to creation," in the sense of time, has no meaning. Nevertheless, these writers use the term not in a temporal way but in the sense of creation being dependent on God and not the reverse. I prefer to avoid the ambiguity by using "apart from" to refer to those attributes that would characterize God even if there had been no creation.
[27]Bavinck, *God and Creation,* 246.
[28]Ibid., 247.
[29]Ibid., 249.
[30]Oden, *Classic Christianity*, 46.
[31]Ibid., 49.
[32]Ibid.
[33]Bavinck, *God and Creation,* 202.
[34]Oden, *Classic Christianity*, 43.
[35]Thomas Aquinas, *The Treatise on the Divine Nature, Summa Theologiae* 1, trans. Brian Shanley (Indianapolis, IN: O.P. Hackett Publishing, 2006), 1–13.
[36]Edward Wierenga, "Omnipresence," *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2009), http://plato.stanford.edu/entries/omnipresence/.
[37]The clause about mechanism is essential. For instance, if A is the fact that the air pressure in a certain location drops and B is the fact that a storm occurs, B necessarily follows A, but A does not cause B.
[38]Robert C. Bishop, "Recovering the Doctrine of Creation: A Theological View of Science," http://biologos.org/uploads/static-content/bishop_white_paper.pdf.
[39]This bulleted item also appears in James Bradley and Russell Howell, *Mathematics through the Eyes of Faith* (New York: HarperOne, 2011), 108. Copyright 2011 by the Council for Christian Colleges and Universities. Reprinted by permission of HarperOne.
[40]Another clear example of this phenomenon can be found in Jonathan Weiner, *The Beak of the Finch: A Story of Evolution in Our Time* (New York: Alfred A. Knopf, 1994).
[41]Bartholomew, *God, Chance, and Purpose*, 49.
[42]Polkinghorne, *Science and Providence*, 46.
[43]William Pollard, *Chance and Providence: God's Action in a World Governed by Scientific Law* (New York: Scribner, 1958).
[44]Oden, *Classic Christianity*, 53.
[45]I am grateful to William Stoeger, S.J. for explaining Aquinas's thought on this matter to me.
[46]Michael Heller, *Creative Tension: Essays on Science and Religion* (West Conshohocken, PA: John Templeton Foundation Press, 2003), chap. 11.
[47]Much of the material in this section also appears in Bradley and Howell, *Mathematics through the Eyes of Faith*, 105–6.
[48]Bishop, "Recovering the Doctrine of Creation."
[49]Augustine, *On Free Choice of the Will*, trans. Thomas Williams (Indianapolis, IN: Hackett, 1993), 73.
[50]All three are clearly presented in *Divine Foreknowledge: Four Views*, ed. James K. Beilby and Paul R. Eddy (Downers Grove, IL: InterVarsity Press, 2001). It also presents the case for determinism; because my goal here is to show that ontological randomness is consistent with historic views of God's nature, I will not address that case.
[51]David Hunt in *Divine Foreknowledge: Four Views*, 67.
[52]Byl, "Indeterminacy, Divine Action and Human Freedom," 102–3.
[53]Robert Kane, "Principles of Reason," *Erkenntnis* 24 (1986): 117.
[54]*Institutes*, I, XVI, 2.
[55]For a further exploration of these ideas, see Paul Ewart, "The Necessity of Chance: Randomness, Purpose, and the Sovereignty of God," *Science and Christian Belief* 21, no. 2 (October 2009).

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