

“Of All the Gin Joints . . .” Causality, Science, Chance, and God

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Introduction

IN ONE OF THE CLASSIC LINES from the film *Casablanca*, Humphrey Bogart muses: “Of all the gin joints in all the towns in all the world . . . she walks into mine.” If the implied question is “why?,” the answer is “chance.”

The world is rife with chance. You find it everywhere—from the star crossed lovers in *Casablanca* to the probabilistic particles of quantum mechanics.¹ Sometimes it is just the good luck of getting a parking place or the bad luck of missing a traffic light. We talk about chance all the time, but when we try to say exactly what it is, it eludes us. Statistician David Hand says: “Be warned! Chance is a slippery concept. It can wriggle and twist even when we think we have a sound grasp of it.”²

In this article, we will try to grab hold of chance and see how it is related to science and God. We will start with the way people

¹ Toby Handfield, *A Philosophical Guide to Chance* (Cambridge, UK: Cambridge University Press, 2012), 126: “Chance claims are part and parcel of our ordinary dealings with the world. Doctors recommend surgical procedures or medications on the basis of their estimates of the chances. Professional gamblers get rich or poor to the extent that they are able to choose to play games where the chances of winning are greater than are those of losing. Quantum physicists build exquisitely sensitive experimental apparatus to test chance hypotheses, and often find that their theories are well confirmed.”

² David J. Hand, *The Improbability Principle: Why Coincidences, Miracles, and Rare Events Happen Every Day* (New York: Scientific American, 2014), 56.

talk about chance. Then we will look at how the notion has been employed in science—especially the way its “job description” changed in the transition from Newtonian to contemporary science. Finally, we will see how the understanding of chance in science has influenced the discussion of divine action and how the philosophy of Aristotle and Thomas Aquinas can help us in that discussion.

How We Talk about Chance

Chance As Cause and Chance As Probability

In ordinary talk, we often treat chance as a cause: chance makes things happen.³ A gambler chalks up his winning streak to “Lady Luck”—chance. The police try to decide whether an apparently accidental death was due to foul play or just to chance. In other contexts, however, chance is not treated as a cause—especially when it is associated with notions like “probability,” “propensity,” or “risk.” If a weather report predicts a forty-percent “chance” of rain, for instance, no one thinks the “chance” given in the report actually causes the rain.⁴

Chance As Objective and Chance As Subjective

Chance can also be treated as objective or subjective. Objectively, chance is considered a real part of nature. It makes things happen. Subjectively, chance is thought of as just a name for our ignorance. When we do not know the real causes behind an event, we attribute it to chance.⁵

³ “‘Chance’ is not a technical term, but is rather an ordinary concept deployed in fairly familiar situations (games of chance, complicated and unpredictable scenarios, large ensembles of similar events, etc.). There is widespread agreement amongst native speakers of English over when ‘chance’ applies to a particular case, and this agreement at least indicates that there is a considerable body of ordinary belief about chance. One needn’t take the deliverances of folk intuition as sacrosanct to recognize that this ordinary belief provides the starting point for philosophical accounts of chance” (“Chance versus Randomness,” in *Stanford Encyclopedia of Philosophy*, at <http://plato.stanford.edu/entries/chance-randomness>).

⁴ See Hand, *The Improbability Principle*, 45–46.

⁵ Ibid., 45 and 56–60; Michael Heller, *Philosophy of Chance: A Cosmic Fugue with a Prelude and a Coda* (Krakow, PL: Copernicus Center Press, 2013), 114–118 and 147–151; and Toby Hanfield, *Philosophical Guide*, vii, 2, and 127.

Chance and Science

Philosophical discussions of chance go back to Greek thinkers like Democritus. Aristotle gave the first extensive, philosophical account of chance, and Aquinas followed his views.⁶ Both saw chance as a real feature of the natural world.⁷ With the coming of modern Newtonian science, however, the reality of chance was denied.

Chance and Modern Newtonian Science

Chance dropped out because the mathematical method of modern science left no room for it. Gerd Gigerenzer explains: “Natural philosophers like Galileo assumed that if nature spoke the language of mathematics, this was because nature was fully determined: . . . the glue that connected causes and effects must be as strong as that which connected premises and conclusions in a mathematical argument. Determinism thus became a precondition for the mathematical description of nature.”⁸

Even as science shut the door on chance as a real feature of the natural world, it also (rather paradoxically) opened the way for a science of chance as such. Certain mathematicians (especially some with a penchant for gambling) began to think that, just as science had quantified nature, so it might also quantify chance.⁹ Gigerenzer

⁶ John Dudley, *Aristotle's Concept of Chance: Accidents, Cause, Necessity, and Determinism* (Albany: SUNY Press, 2012), 5n13: “Aristotle (with the possible exception of Democritus) . . . was the first thinker to give a philosophical account of chance.”

⁷ Aristotle, *Physics* 2.5.196b14: “It is plain that there is such a thing as chance”; *ibid.* 2.4.195b310: “Many things are said both to be and to come to be as a result of chance and spontaneity”; see *The Basic Works of Aristotle*, trans. Richard McKeon (New York: Random House, 1941; unless otherwise noted, all quotations from the works of Aristotle will be from this edition). Thomas Aquinas, *Summa contra gentiles* (hereafter, SCG) III, ch. 74, no. 2: “It would be contrary to the character of divine providence if nothing were to be fortuitous and a matter of chance in things”; see *On the Truth of the Catholic Faith: Summa Contra Gentiles*, 4 vols., trans. Anton Pegis et al. (Garden City, NY: Image Books, 1955–1957; all quotations of SCG are from this edition).

⁸ Gerd Gigerenzer, Zeno Swijtink, Theodore Porter, Lorraine Daston, John Beatty, and Lorenz Krüger, *The Empire of Chance: How Probability Changed Science and Everyday Life* (Cambridge, UK: Cambridge University Press, 1989), 11.

⁹ Hand, *The Improbability Principle*, 48–49: “It is notable that the idea that chance could be quantified arose at the same time as the view that the universe was intrinsically deterministic. . . . The period just after the middle of the seventeenth century represents a turning point in the understanding of probability.

explains how the determinism of modern science paved the way for a science of chance:

Classical probability theory arrived when luck was banished; it required a climate of determinism. . . . Determinism made a “geometry of chance” conceivable by anchoring variable events to constant probabilities, . . . so that even fortuitous events met what were then the standards for applying mathematics to experience. Those standards were not compatible with older notions of chance as real, or with what we might call genuine randomness in the world.¹⁰

Events in the natural world were seen as the effects of absolutely deterministic causes, and chance was simply a name for our ignorance of those causes. Scientists discovered, however, that, although they could not calculate all the causes, they could still predict certain outcomes statistically by using probability theory. In the kinetic theory of gasses, for instance, the macroscopic properties of a gas, such as temperature and pressure, could be described and predicted statistically, despite our ignorance of the precise movements of the microscopic molecules of the gas.¹¹ In this way, as Gigerenzer points out, “Probability, understood as a measure of ignorance, harmonized with the most uncompromising form of determinism.”¹²

Chance and Contemporary Science

The fortunes of chance changed with the advent of contemporary science. New scientific theories and philosophical interpretations of them established chance, once again, as an ontological feature of the natural world.¹³ Max Born has said: “We . . . admit chance into the realm of exact science.”¹⁴ Among contemporary sciences that have

It was around this time that the earliest books on the subject appeared, often motivated by gambling.” Max Born, *Natural Philosophy of Cause and Chance* (Oxford: Clarendon Press, 1949), 46: “The theory of probability itself, which expresses these laws, is much older; it sprang not from the needs of natural science but from gambling and other, more or less disreputable, human activities.”

¹⁰ Gigerenzer, et al., *The Empire of Chance*, 12.

¹¹ On the development of statistical mechanics, see Heller, *Philosophy of Chance*, 96–100.

¹² Gigerenzer, et al., *The Empire of Chance*, 276.

¹³ See Hand, *The Improbability Principle*, 40.

¹⁴ Born, *Natural Philosophy*, 3.

made a place for chance, we will look especially at biology and quantum mechanics.¹⁵

Biology

In biology, Charles Darwin suggested that chance might be the source of spontaneous variations among offspring that could then, through natural selection, result in the evolution of new species. He remained ambiguous, however, as to how large a role might be attributed to chance in this process and saw chance fundamentally as a name for our ignorance of actual causes.¹⁶ In view of Darwin's work, the philosopher Charles Sanders Peirce declared that chance was a real aspect of nature and not just a name for our ignorance.¹⁷ Today, biologists continue to attribute spontaneous genetic mutations simply to chance.¹⁸

Quantum Mechanics

If chance has now found a home in biology, it is even more firmly ensconced in quantum mechanics. As David Hand says: "The shift from the clockwork universe to the probabilistic universe began a century ago and is now virtually complete. We live in a universe dominated by chance and uncertainty."¹⁹

¹⁵ In addition, one might also consider chaos theory and cosmology, with its "anthropic principle." Hand, *The Improbability Principle*, 72–73: "A chaotic system appears to move between its states completely at random—and yet it is not random in the sense that its next state is unpredictable, because an explicit deterministic equation can be given to link successive states. It is just that the starting point can never be exactly known, and slight differences in that starting point can lead to vast differences further down the line."

¹⁶ Charles Darwin, *The Origin of Species* (New York: Modern Library, 1998), 172: "I have hitherto sometimes spoken as if the variations . . . were due to chance. This, of course, is a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation."

¹⁷ See Gigerenzer, et al, *The Empire of Chance*, 67–68 and 152.

¹⁸ See Charles Birch, "Chance, Necessity and Purpose," in *Studies in the Philosophy of Biology: Reduction and Related Problems*, ed. Francisco Jose Ayala and Theodosius Grigorievich Dobzhansky (Berkeley, CA: University of California Press, 1974), 225–226; Stephen Barr, "Chance by Design," *First Things* 228 (December, 2012): 28; and Manfred Eigen and Ruthild Winkler, *Laws of the Game: How the Principles of Nature Govern Chance* (New York: Knopf, 1981). More recent developments in biology, however, may leave less room for chance in the process of evolution. See C. H. Waddington, "How Much Is Evolution Affected by Chance and Necessity?" in *Beyond Chance and Necessity: A Critical Inquiry into Professor Jacques Monod's Chance and Necessity*, ed. John Lewis (London: Garnstone Press, 1974), 98.

¹⁹ David J. Hand, *The Improbability Principle*, 74; Karl R. Popper, *The Open*

In Newtonian science, chance was merely a name for our ignorance. In contemporary physics, it seems to have a secure, ontological niche.²⁰ Its security, however, depends on the interpretation of the science. The two most famous interpreters of that science were Neils Bohr and Albert Einstein.²¹ Bohr saw indeterminism as a real aspect of nature in what has been called the “Copenhagen interpretation” of quantum mechanics.²² Einstein, however, considered indeterminism as simply a name for our ignorance. In a famous letter to Max Born, Einstein says: “You believe in the God who plays dice, and I in complete law and order in a world that objectively exists. . . . Even the great initial success of the quantum theory does not make me believe in the fundamental dice-game.”²³

Universe: an Argument for Indeterminism (Totowa, NJ: Rowman and Littlefield, 1982), 41, 124: “I personally believe that the doctrine of indeterminism is true, and that determinism is completely baseless. . . . The new indeterminism was introduced by quantum mechanics, which assumes the possibility of elementary chance events that are causally irreducible.” See also Ian Stewart, *Does God Play Dice? The Mathematics of Chaos* (Cambridge, MA: Blackwell, 1989), xi; Handfield, *Philosophical Guide*, 2; Charles Ruhla, *The Physics of Chance: From Blaise Pascal to Niels Bohr* (Oxford: Oxford University Press, 1992), 213.

²⁰ See Gigerenzer, et al., *The Empire of Chance*, 276.

²¹ See Manjit Kumar, *Quantum: Einstein, Bohr, and the Great Debate about the Nature of Reality* (New York: W. W. Norton, 2009).

²² On Bohr’s position, see Ruhla, *The Physics of Chance*, 2–3 and 189–90. Following Bohr’s interpretation, Popper maintains that quantum mechanics has introduced a new kind of chance in the natural world: “There are, it appears, two kinds of chance events. One kind is due to the independence of two causal chains which happen, accidentally, to interfere at some place and time, and so combine in bringing about the chance event. A typical example consists of two causal chains, one of which loosens a brick while the other independent causal chain makes a man take up a position where he will be hit by the brick. This kind of chance event (whose theory was developed by Laplace himself, in his work on probability) is perfectly compatible with Laplacean determinism: anybody furnished in advance with sufficiently full information about the relevant events could have predicted what was bound to happen. It was only the incompleteness of our knowledge which gave rise to this kind of chance. Quantum mechanics, however, introduced chance events of a second, and much more radical kind: absolute chance. According to quantum mechanics, there are elementary physical processes which are not further analyzable in terms of causal chains, but which consist of so-called ‘quantum jumps’; and a quantum jump is supposed to be an absolutely unpredictable event which is controlled neither by causal laws nor by the coincidence of causal laws, but by probabilistic laws alone” (*Open Universe*, 125).

²³ Albert Einstein, “Letter to Max Born, November 7, 1944,” as translated in

On whether Einstein or Bohr is correct, it seems the jury is still out. Ian Stewart argues for Einstein:

It must be admitted at the outset that the vast majority of physicists see no reason to make changes to the current framework of quantum mechanics, in which quantum events have an irreducibly probabilistic character. Their view is: "If it ain't broke, do not fix it." However, hardly any philosophers of science are at ease with the conventional interpretation of quantum mechanics, on the grounds that it is philosophically incoherent. . . . Moreover, some of the world's foremost physicists agree with the philosophers. They think that something is broke, and therefore needs fixing.²⁴

Charles Ruhla, on the other hand, argues for Bohr's position:

Is it not time . . . at long last, to accept chance as fundamentally characteristic of Nature? On this last point the physics community remains divided. . . . It would of course be very difficult to demonstrate conclusively that . . . Nature is basically deterministic, or basically random: philosophers have tried it and have failed. But, today, physics is progressing much faster by the use of random than of deterministic models: so much so that chance is bound to become more and more part of the language and eventually of the paradigms of physics.²⁵

Science, Chance, and Divine Action

Now that we have traced the fortunes of chance in empirical science, we can consider its influence on the discussion of divine action.²⁶

Stewart, *Does God Play Dice?* xi. See Max Born, *Natural Philosophy*, 122.

²⁴ Stewart, *Does God Play Dice?* 330. See also Mario Bunge, *Causality and Modern Science* (New York: Dover, 1979), 14–17 and 326–330.

²⁵ Ruhla, *The Physics of Chance*, 214. Born agrees: "Though I am very much aware of the shortcomings of quantum mechanics, I think that its indeterministic foundations will be permanent" (*Natural Philosophy*, 109).

²⁶ Given the limits of its method, science as such, of course, has nothing to say about divine action. Here, I am using the term "science" in a broad sense to include certain philosophical and theological positions that often accompany it but are not part of science itself. Such positions might prove valid if properly grounded philosophically or theologically. Often, however, they remain ungrounded, though they sometimes attempt to claim the authority of science as such for their foundation. In such cases, we should be careful to see them

Divine Action and Newtonian Science

Deterministic Newtonian science gave rise to two inferences. The first was that determinism excludes any possibility of chance events in the natural world. The second was that determinism excludes all divine action in the world, since such action would violate the deterministic laws of science.

Determinism Excludes Chance

Regarding the first inference, the scientific elimination of chance from the natural world coincided conveniently with a theology of divine omnipotence that was equally eager to eliminate chance and to view all events as necessary parts of the immutable plan of divine providence.²⁷ Any whiff of chance seemed to imply “an absence of divine planning and control.”²⁸ Both science and theology saw chance as opposed to determinism. For science, chance was opposed to

not as tenets of science, but as an essentially unfounded ideology that is better labeled “scientism.” So, when I speak here of a conflict between “theology and science,” we should recognize that the true conflict is between theology and scientism, not between theology and science as such. Similarly, I am using the term “theology” in a broad sense for which the phrase “certain theologians” would be more precise.

²⁷ Hand, *The Improbability Principle*, 27, 60: “If we believe there is a single intelligence directing the universe, we ascribe events to chance only because we do not know their cause. Chance is then a matter of ignorance of fundamental cause rather than a fundamental cause in itself. This shift leads us to the notion of a deterministic universe, which is following the steps of a master plan, as set up by the one God. . . . So epistemological probability fits in well with the heavily monotheistic religious context in which the foundations of probability were laid in the mid-seventeenth century, where a chance event was regarded merely as one for which we didn’t understand how God caused it to happen.” See also Gigerenzer, et al., *The Empire of Chance*, 12–13: “[In the eighteenth century] the natural theologians and their probabilist allies like De Moivre made much [of] the opposition of chance and purpose, particularly divine purpose. . . . Almost any symmetry or stability unlikely to have come about by ‘mere chance’—the intricate construction of the human eye, the regular mortality rate, etc.—became an argument ‘from design’ for the existence of an intelligent and beneficent deity. . . . [T]he natural theologians persisted until Darwin in seeing chance refuted everywhere by the traces of divine handiwork. . . . [F]or the classical probabilists ‘chance’ and ‘luck’ that stood outside the causal order were superstitions. If we could see the world as it really was, penetrating to the ‘hidden springs’ and principles of things, we would discover only necessary causes. Probabilities were merely provisional, a figment of human ignorance and therefore subjective.”

²⁸ Gigerenzer, et al., *The Empire of Chance*, 60.

deterministic natural causes. For theology, chance was opposed divine providence, which was considered deterministic, omniscient, and unchanging. For both, chance was simply a name for our ignorance: for scientists, an ignorance of the real, natural, and deterministic causes at work in the world; for theologians, an ignorance of the determined and immutable, but unknowable, plan of divine providence.²⁹

Determinism Excludes Divine Action

If science and theology could agree on the first inference, the second—that the deterministic laws of science left no room for God to act in the world—held the seeds of conflict. Some theologians avoided the conflict by adapting their theology to the determinism of science. Deists, for instance, affirmed God's act of creation, but posited no further action of God in the world. If God's providential plans were perfectly expressed in the original design of nature, now discovered and described by the laws of science, any further intervention on God's part would contradict not only science, but the very wisdom of the original plan of providence. Other theologians, while subscribing to the premise that the laws of science left no room for God's action in nature, still allowed that God might act within the subjectivity of human experience, where his action would not interfere with the laws of science. They accordingly reinterpreted biblical miracles as metaphors for subjective human experiences.³⁰ To theologians who

²⁹ Heller, *Philosophy of Chance*, 76: "Random events, understood as breaches in rationality, can exist only from the human vantage point by virtue of his imperfect understanding (or rather boundless ignorance) of God's intentions."

³⁰ Thomas F. Tracy, "Creation, Providence, and Quantum Chance," in *Quantum Mechanics: Scientific Perspectives on Divine Action*, ed. Robert John Russell, Philip Clayton, Kirk Wegter-Mcnelly, and John C. Polkinghorne (Vatican City: Vatican Observatory; Berkeley, CA: Center for Theology and the Natural Sciences, 2001), 237: "It is a mistake to conclude that modern human beings have adopted, in general, a 'scientific way of knowing' and/or a 'scientific worldview' that rules out talk of divine agency developed within a theological interpretation of the world. The theologians who have made these claims, and used them as the basis for far-reaching theological revision, have almost always uncritically presupposed a deterministic picture of the natural world. We can see this in a long line of religious thinkers, from deists in the eighteenth century to Schleiermacher at the founding of liberal Protestant theology in the early nineteenth century to contemporary theologians like Rudolph Bultmann and Gordon Kaufman. For these thinkers, a general metaphysical picture of the world as a closed causal continuum came to be invested with the authority of science by being treated either as a methodological given of scientific inquiry or as a well-established empirical result."

considered divine action, including miracles, to be an essential element of Christian faith, however, the exclusion of miracles by deterministic science constituted a fundamental ground for conflict between science and religion.

Divine Action and Contemporary Science

Both evolutionary biology and quantum mechanics now assign a role to chance in their account of the natural world. The presence of chance in these two branches of science, however, has elicited quite different theological responses. While the presence of chance in quantum mechanics has precipitated a fruitful dialogue with theology, its presence in biological evolution has been an occasion for conflict.

Divine Action, Chance, and Evolutionary Biology

Theological reactions to the presence of chance in contemporary biology harken back to the first inference that arose from the determinism of Newtonian science—namely, the opposition between chance and divine providence. It is remarkable how many theologians and atheistic biologists alike share the premise that there is a fundamental opposition between chance and providence. Sharing that premise, they reach the same conclusion: that the presence of chance in evolution must exclude the providential influence of God. Faced with such an either/or proposition, the atheists accordingly reject God, while the theologians either reject evolution or limit God's power to preserve the presence of chance in evolution.

For atheistic biologists, there is no place for divine providence in evolution, particularly in the instantiation of human life. All is the result of blind chance. As Jacques Monod says: “[M]an knows at last that he is alone in the universe's unfeeling immensity, out of which he emerged only by chance.”³¹ Creationist theologians also think that the presence of chance in evolution excludes divine providence, and they accordingly reject the theory of evolution.³² Other theologians,

³¹ Jacques Monod, *Chance and Necessity: an Essay on the Natural Philosophy of Modern Biology* (New York: Alfred A. Knopf, 1972), 180.

³² Heller, *Philosophy of Chance*, 25, 168: “[There is] an even today widespread belief that the biological theory of evolution cannot be reconciled with religious faith because the theory of evolution attributes a crucial role in the genealogy of life to chance, and chance constitutes a breach in the rationality of the plan of creation. . . . The supporters of creation science quite often contrast God with ‘pure chance.’ Was the Universe created by God or did it emerge on the strength of pure chance?”

however, while subscribing to the same premise that chance and providence are incompatible, are still unwilling to reject evolution. Instead, they simply set limits on providence. They do this by limiting God's knowledge or power or both. When God's knowledge is diminished, God's plan for the world becomes a bit vague and so is better able to accommodate the vagaries of chance. God might have a general plan for creation, but must leave the specifics to chance. God might, for instance, know that the process of evolution may lead to intelligent life, but must leave the details to evolutionary chance.³³ When God's power is diminished, God is seen as "stepping back" or limiting himself in some way in order to make room for chance and contingency in the world.³⁴ Again, the details of the chance outcomes of nature lie beyond the reach of divine providence.

Divine Action, Chance, and Quantum Mechanics

In contrast to the conflicts occasioned by the presence of chance in biology, broad avenues for dialogue between theology and science have been opened by the introduction of chance into quantum

³³ This seems to reflect Darwin's own views on the subject: "I am inclined to look at everything as resulting from designed laws, with the details, whether good or bad, left to the working out of what we may call chance. Not that this notion at all satisfies me. I feel most deeply that the whole subject is too profound for the human intellect"; see Charles Darwin, "Letter to Asa Gray, May 22, 1860"; in *The Life and Letters of Charles Darwin*, ed. Francis Darwin (New York: D. Appleton and Co., 1897), 2:104. David Bartholomew seems to agree: "So we return to my opening question: 'Is God a risk taker?' In the light of my discussion, this question has to be worded more carefully because we have to distinguish between ultimate goals and short-term deviations. We have seen that determinate ends may be achieved as the result of averaging many random effects or by the interactions within the process. This means that the end of the process may be virtually certain, even though the path to that end is not determined. Is it sufficient to preserve our understanding of God's greatness that he, as it were, gets there in the end—or that he must never put a foot wrong? It seems to me that it is the end that matters and if deviations toward that end deliver side benefits, the net result may be gain"; see his *God, Chance and Purpose* (New York: Cambridge University Press, 2008), 235–236.

³⁴ Nancey Murphy argues that God limits himself in order "to respect the innate characteristics with which he has endowed his creatures"; see her "Divine Action in the Natural Order: Buridan's Ass and Schrödinger's Cat," in *Chaos and Complexity: Scientific Perspectives on Divine Action*, ed. Robert John Russell et al. (Vatican City: Vatican Observatory; Berkeley, CA: Center for Theology and the Natural Sciences, 1995), 355.

mechanics.³⁵ The openness of quantum indeterminacy is seen as a new and welcome locus for God to act in the world.

It is curious, however, that the very welcomeness of the new locus hearkens back to the second inference that seemed to follow from Newtonian science—that the deterministic laws of science exclude divine action. On that supposition, the new locus of quantum indeterminacy is especially welcome, since it provides a place for God to act in the world without intervening in, interfering with, or violating the established laws of science.³⁶ For some theologians, such as Thomas Tracy and Robert Russell, quantum indeterminacy is simply a newly discovered feature of the world in and through which God might act.³⁷ For others such as Nancey Murphy, however, quantum indeterminacy is viewed as the *only* place for God to act, since the laws of science exclude God's action in the natural world at any other level.³⁸

³⁵ One might consider, for instance, the many years of fruitful conversations between scientists and theologians resulting in the series of distinguished volumes published by the Vatican Observatory and the Center for Theology and the Natural Sciences at the Graduate Theological Union in Berkeley. See the summary volume *Scientific Perspectives on Divine Action: Twenty Years of Challenge and Progress*, ed. Robert John Russell, Nancey Murphy, and William R. Stoeger (Vatican City: Vatican Observatory; Berkeley, CA: Center for Theology and the Natural Sciences, 2008).

³⁶ Ian Barbour, *Nature, Human Nature, and God* (Minneapolis: Fortress Press, 2002), 104–105: “Several recent authors have said that their accounts of divine action do not involve violations of the laws of nature or divine intervention in gaps in the scientific account. . . . Instead they have tried to show how new scientific concepts either permit divine action or suggest analogies for it. . . . In all these cases God is seen as working subtly in cooperation with the structures of nature rather than by intervening discontinuously.” For other examples, see Michael J. Dodds, *Unlocking Divine Action: Contemporary Science and Thomas Aquinas* (Washington, DC: Catholic University of America Press, 2012), 153–155.

³⁷ See Thomas F. Tracy, “Theologies of Divine Action,” in *The Oxford Handbook of Religion and Science*, ed. Philip Clayton and Zachary Simpson (Oxford: Oxford University Press, 2006), 609. Robert Russell argues that “we can view God as acting in particular quantum events to produce, indirectly, a specific event at the macroscopic level, one which we call an event of special providence. . . . [Q]uantum mechanics allows us to think of special divine action without God overriding or intervening in the structures of nature”; see his “Does the ‘God Who Acts’ Really Act in Nature?” in *Science and Theology: The New Consonance*, ed. Ted Peters (Boulder, CO: Westview Press, 1998), 89 and 94. Like Thomas Tracy, he sees quantum indeterminacy not as the exclusive theater of divine action, but as “one location or domain where that action may have an effect on the course of nature” (*ibid.*, 92).

³⁸ “My proposal is that God’s governance at the quantum level consists in acti-

Implications of the Diverse Consequences for Divine Action Arising from the Presence of Chance in Evolutionary Biology and Quantum Mechanics

The presence of chance in contemporary science seems to pose a challenge to divine action in evolutionary biology, while opening an opportunity for it in quantum mechanics. This puzzling situation is compounded when we consider that both the new challenge and the new opportunity appear to be founded on inferences that followed from the now antiquated world view that accompanied Newtonian science, according to which chance was contrary to divine providence and the established laws of science excluded divine action.

The question then arises: if the supposed oppositions between chance and divine providence and between the laws of science and divine action are no longer imposed by the deterministic world view of Newtonian science, why does that supposed opposition continue to influence theological accounts of divine action?

Perhaps the source of the supposed oppositions between chance and providence and between the laws of science and divine action lies deeper than the now obsolete determinism of Newtonian science. Perhaps it is grounded (and has always been grounded) more fundamentally in the way that the causality of God has been conceived in relation to the causality of creatures.

Since contemporary science views chance as a kind of ontological cause, it may be helpful to consider the nature of the causality of chance as such before considering the relationship between the causality of chance and the causality of God. As a resource for these considerations, we turn to the philosophy of Aristotle and Aquinas.

Retrieving the Philosophy of Chance in Aristotle and Aquinas

Aristotle's reason for treating chance as a cause is, as he says, because that is the way people talk. They treat it as a cause, but a special kind of cause.³⁹ It causes some things, but not others. Necessary things that

vating or actualizing one or another of the quantum entity's innate powers at particular instants, and that these events are not possible without God's action. This is the manner and extent of God's government at this level of reality" (Murphy, "Divine Action in the Natural Order," 342).

³⁹ *Physics* 2.4.195b31–32: "But chance also and spontaneity are reckoned among causes: many things are said both to be and to come to be as a result of chance and spontaneity." Dudley, *Aristotle's Concept of Chance*, 19: "Chance must be examined in a treatise on causality, since people speak of things happening 'by chance,' as if chance were a cause."

always happen in just the same way (like taxes) are not attributed to chance. Nor are contingent things that happen the same way most of the time, but not always (like goose bumps). Only things that happen rarely are chalked up to chance.⁴⁰

Even rare events are attributed to chance only when they look like they were planned or intended but, in reality, were not.⁴¹ Some things, like birthday parties, are planned by human beings and do not happen by chance. Other things, like acorns growing into oak trees, are intended by nature, and so are not by chance.

Such planned or intended outcomes have the nature of an end. They have some intrinsic quality of goodness that makes them desirable, either consciously by human beings or unconsciously as built-in tendencies of nature. Aristotle thinks that goodness is really present in nature and that every natural agent (whether consciously or not) acts to attain some good. He calls this quest for goodness “final causality” and sees it as an intrinsic aspect of nature. Goodness and the quest for it are not things that humans impose on nature, but that they simply find there.⁴²

⁴⁰ *Physics* 2.5.196b 10–15. Even things that Aristotle calls “necessary” are not exceptionless, as Richard Sorabji observes: “In connexion with other events, Aristotle sometimes recognises two kinds of necessity: necessity in accordance with and necessity contrary to nature. In neither case does it occur to him to suggest that there must be an exceptionless law at work. Necessity in accordance with nature is illustrated by the case of a stone’s falling down. The downward motion is in accordance with its nature, and Aristotle thinks of nature as something which may produce its results either invariably or only for the most part. Thus a stone does not invariably fall through the air: it may get thrown upwards. There is no attempt to argue that, in the cases where natural necessity is in play, nature behaves invariably. . . . For the idea that absolutely everything happens in conformity with regularity, we have to wait till the Stoics. Their innovation was to associate exceptionless regularity with cause. Since every event, in their view, had a cause, this linked every event with exceptionless regularity”; see his *Necessity, Cause, and Blame: Perspectives on Aristotle’s Theory* (Ithaca, NY: Cornell University Press, 1980), 61 and 64.

⁴¹ Sorabji, *Necessity, Cause, and Blame*, 175n1: “Aristotle insists that we do not talk of chance or spontaneity . . . unless we are talking of something which might well have been brought about on purpose or by nature, and hence for the sake of an end (196b22, b34, 197a35, 198a6). At the same time, he insists that chance events are not in fact brought about for the sake of an end (197a35, b18–19, 198b29). And so he treats chance as opposed to final cause (e.g. 199a3–5).”

⁴² Dudley, *Aristotle’s Concept of Chance*, 25–26: “For Aristotle [human] intellect is not a prerequisite of purpose, but subsequent to it. The outcome of thought is not merely parallel to the working of Nature, but posterior to it.” Lindsay

Chance events can also have an intrinsic quality of goodness and, so, appear to be something that would be intended or aimed at, either by human choice or by some intrinsic tendency of nature.⁴³ In this way, they have the character of an end or a goal.⁴⁴ What is peculiar about them is that they occur apart from any direct human choice or intrinsic tendency of nature.

Judson, "Chance and 'Always or for the Most Part' in Aristotle," in *Aristotle's Physics: A Collection of Essays*, ed. Lindsay Judson (Oxford: Oxford University Press, 1991), 73–100, at 92: "What marks out chance outcomes is that they are beneficial events which are not reliably connected with the natural workings or the choices of the subject who benefits from them."

⁴³ See Vincenzo Cioffari, *Fortune and Fate from Democritus to St. Thomas Aquinas* (New York: [s.n.], 1935), 17–18: "[The finding of gold by a farmer who is ploughing] will be a fortunate result in that gold is such that it would have been sought after, had its existence been known (*Physics* II. v [196b35]). That is: this rare occurrence, in order to be the effect of Fortune, must also be finalistic; its object must have value—positive or negative. Of course it is not purposed; but without being intended, it must be capable of being desired." Of course, not all chance outcomes are good. There is "bad luck" as well as "good luck," as Aristotle recognized in *Physics* 2.5.197a25–30: "Chance or fortune is called 'good' when the result is good, 'evil' when it is evil. The terms 'good fortune' and 'ill fortune' are used when either result is of considerable magnitude. Thus one who comes within an ace of some great evil or great good is said to be fortunate or unfortunate." Dudley explains how "bad luck" can be understood under the rubric of that which has the character of an end or belongs to the realm of purpose (even though it is itself undesirable): "[T]he inclusion of purpose or meaningfulness in the definition of chance has nothing to do with the choice of the outcome by the person who undergoes bad luck (or indeed good luck), but rather with the fact that the outcome strikes the human mind, because it is the kind of thing that recalls purpose (i.e., it belongs to the area of purpose), regardless of whether it is lucky or unlucky" (*Aristotle's Concept of Chance*, 43–44). The good outcome would have been purposefully chosen; the bad outcome would have been purposefully avoided.

⁴⁴ Cioffari, *Fortune and Fate*, 5–6: "This relation, however, of Chance to finality, cannot be described as a *negation* but rather as a *privation*. For the chance result indeed came about without being intended by Nature or Will. But it must yet be such as to constitute a possible object of natural or volitional purposiveness—it must have value for some one. Moreover the chance effect (of Aristotle) cannot merely be styled as what does not proceed from a purposeful action . . . for we must add the limitations which Aristotle so carefully introduces (*Physics* II, v), that it must be of those things that have teleological significance. . . . The chance effect is unintended, to be sure, but it must be such as to be worthy to be sought after. It is, therefore, a privation rather than a negation, and Aristotle looks upon Chance not merely as the absence of purposiveness, but as a conditioned privation of it."

Their intrinsic goodness suggests that they should be chosen or naturally intended. Yet no human chooses them, and no natural thing intends them. But if they are neither chosen nor intended, what makes them happen? The answer is “chance.” Since the events are real, and since their intrinsic goodness is real, chance, as their source or cause, must also somehow be real. But how?

Chance involves an interplay of causes that results in some good effect that none of the causes directly intends. A classic example of chance is the man who, busy digging a grave, happens to find a treasure.⁴⁵ He certainly intends to produce a hole in the ground. And the one who first buried the treasure certainly intended to stash his loot. Yet no human agency or impulse of nature intended that the man find the treasure. Still, the event, because of its very goodness, looks like something that would be intended.

The digger intended only to make a hole, and finding the treasure is incidental to his action. The one who buried the treasure intended only to hide it—and not that it be found by another. Each is in some way incidentally, but not directly, the cause of the event. For this reason, Aristotle says that chance involves incidental causality—it entails an effect that is incidentally connected to a certain cause.⁴⁶

It is clear that the event would not have happened without the action of such incidental causes. But we are still left with a question: Why did the grave digger happen to make his hole just there, where the treasure happened to be buried? And why did the one who buried the treasure leave it just there, where the grave digger would be working? What brings the two together? What unites these two happenstances, without which uniting the event itself would not have happened? For this, there is no proper cause.⁴⁷ In this sense, Aquinas

⁴⁵ Thomas Aquinas, *Commentary on Aristotle's Physics*, trans. Richard J. Blackwell, et al. (New Haven, CT: Yale University Press, 1963), II, lect. 8, no. 214: “In this sense fortune is said to be a *per accidens* cause when something is accidentally joined to the effect, for example, if the discovery of a treasure is accidentally joined to the digging of a grave.”

⁴⁶ *Physics* 2.5.197a 5–13: “It is clear then that chance is an incidental cause in the sphere of those actions for the sake of something which involves purpose. . . . Things do, in a way, occur by chance, for they occur incidentally and chance is an incidental cause.”

⁴⁷ SCG III, ch. 92, no. 12: “In fact, an event does not lose its fortuitous character unless it may be referred back to a direct cause. . . . Now, it is proper for a nature to tend to one objective. So, if an effect is not simply one result, then its direct cause cannot be a natural power. But, when two things are combined with each other accidentally, they are not truly one, but only acci-

nas says that the chance event has no cause,⁴⁸ and Aristotle says that “chance is not the cause, without qualification, of anything.”⁴⁹ Yet the outcome (in view of its very goodness) seems to demand a cause, and so we attribute it to the causality of chance—a peculiar kind of causality that is also in some ways a “non-causality.”⁵⁰

How can we say that chance is both a cause and not a cause?⁵¹ Perhaps we might say that chance is our name for that complex structure of nature in which a proper cause can, in the midst of pursuing its

dentally so. Hence, there can be no direct, natural cause for this union. . . . Now, the grave and the location of the treasure are one only accidentally, for they have no relation to each other.”

⁴⁸ Thomas Aquinas, *Summa theologiae* (hereafter, *ST*) II-II, q. 95, a. 5, resp.: “An accidental being has no cause [*non habet causam*], least of all a natural cause . . . because what occurs accidentally, neither is a being properly speaking, nor is one. For instance, that an earthquake occur when a stone falls, or that a treasure be discovered when a man digs a grave—for these and like occurrences are not one thing, but are simply several things. Whereas the operation of nature has always some one thing for its term, just as it proceeds from some one principle, which is the form of the natural thing.” Unless otherwise noted, all citations of *ST* come from St. Thomas Aquinas, *Summa Theologiae*, trans. Fathers of the English Dominican Province (New York: Benziger Brothers, 1947). For other texts from Aquinas, see Dodds, *Unlocking Divine Action*, 39n84.

⁴⁹ *Physics* 2.5.197a14: “But strictly it [chance] is not the cause—without qualification—of anything.”

⁵⁰ Aristotle, *Metaphysics* 12.3.1070a6–9: “For things come into being either by art or by nature or by luck or by spontaneity. Now art is a principle of movement in something other than the thing moved, nature is a principle in the thing itself (for man begets man), and the other causes are privations of these two.” Cioffari explains this quotation: “That is: hazard (*automaton*) is a privation of Nature, and Fortune (*Tyche*) is a privation of *techne* (of Mind). It is a privation which is a result of indeterminateness, for, as Aristotle tells us (*Physics* 201b26): ‘the principles . . . are regarded as indefinite because of their privative character. . . . Now as Mind and Nature are surely efficient causes, a privation of them is a lack of causality’” (Cioffari, *Fortune and Fate*, 21). See also Pascal Massie, “The Irony of Chance: On Aristotle’s *Physics* B, 4–6,” *International Philosophical Quarterly* 43 (2003): 25 and 28; and Bunge, *Causality and Modern Science*, 99–100.

⁵¹ Judson, “Chance and ‘Always or for the Most Part’ in Aristotle,” 75: “[Aristotle’s] main purpose is the characteristic one of seeking a middle way which will show how most of the *endoxa* are partially true. In effect, his aim is to do justice to the idea that chance is something and to the idea that it is nothing. He does this by denying that chance is a causal force in its own right (or a fifth type of cause coordinate with the other four), while maintaining that there is nonetheless a sense in which events do happen by chance.”

proper effect, also produce some good effect beyond its intentionality and outside the whole intentionality of nature. The very goodness of the effect demands a cause, but it has no proper cause. We attribute it to the causality of chance. Chance is therefore mysterious. We cannot fathom why or when an individual chance event might happen.⁵² But if chance is mysterious, it is a natural mystery—a part of the very structure of the natural world.⁵³ As such, chance is not just a product of human ignorance or wishful thinking. It is, rather, a real feature of the very complexity of the structure of the natural world that humans simply recognize.⁵⁴

Chance and Divine Action

How should we understand the causality of God in relation to the peculiar causality of chance? The first thing to notice is that chance cannot be opposed to divine causality. If chance is an ontological feature of the natural world and the world is the product of divine creation, then chance can hardly be viewed as contrary to God's creative and sustaining action in the world.

If chance is a mode of creaturely causality, and if there can be no contradiction between the causality of creatures and the causality of God, then chance cannot be contrary to divine providence. So, we lay to rest the first troublesome inference that seemed to arise from the determinism of Newtonian science and the theology that accompanied it, that chance is contrary to divine providence. Far from contradicting divine providence, chance should rather be seen as one of its instruments.

In considering the causality of God in relation to creatures, Aquinas uses the analogy of instrumental and secondary causality.⁵⁵ In instrumental causality, a principal cause employs an instrument to produce

⁵² Hand, *The Improbability Principle*, 48–49: “[C]hance events can’t be predicted. . . . [I]t’s completely unknown which of heads or tails will come up on any individual toss of a coin.”

⁵³ For Aristotle’s summation of chance as an aspect of nature, see *Physics* 2.6.198a1–13.

⁵⁴ *Physics* 2.5.196b14: “It is plain that there is such a thing as chance and spontaneity; for we know that things of this kind are due to chance and that things due to chance are of this kind.” SCG III, ch. 74, no. 2: “[I]t would be contrary to the character of divine providence if nothing were to be fortuitous and a matter of chance in things.”

⁵⁵ On the distinction between these modes of causality, see Dodds, *Unlocking Divine Action*, 29–30.

an effect that is beyond the capacity of the instrument. So a writer might use a pen to make intelligible marks on a page, an act that is beyond the capacity of the pen by itself.⁵⁶ Yet, the effect belongs entirely to both causes. There is no mark that the pen did not produce and none that the writer did not cause.

In secondary causality, a primary cause uses a secondary cause to produce an effect that is proportionate to the nature of the secondary cause, but which it can produce only under the influence of the primary cause.⁵⁷ So, the musicians in an orchestra, as secondary causes, might each produce a quality of music that is entirely proportionate to his or her skill and training, but they could not produce the sounds of the symphony without the influence of the conductor, acting as primary cause. Again, the effect is attributed entirely to both the primary and the secondary cause.

Only in cases where one cause in some way transcends the other can the effect belong wholly to both. If the causes belong to the same order or are of the same type, the effect will simply be divided between them. If, for instance, a writer uses two pencils to make marks on the page, some marks will be due to one pencil and some to the other. They cannot all belong equally to both. Similarly, if two people push a car, the movement of the car will belong to both but be divided between them, and the more strongly one pushes, the less there will be for the other to do. Since the two causes belong to the same order, the effect cannot belong wholly to both. Because they belong to the same order, they are called univocal causes.

Since God utterly transcends the realm of creaturely causality, creatures are always secondary or instrumental causes with respect to God. For this reason, their effects—to the extent that they have being and actuality—must be attributed wholly to God and wholly to creatures.⁵⁸

⁵⁶ See Thomas Aquinas, *Truth [Quaestiones disputatae de veritate]*, trans. R. Mulligan et al. (Chicago: Regnery, 1952–1954), q. 27, a. 4, resp.

⁵⁷ David Burrell, *Freedom and Creation in Three Traditions* (Notre Dame, IN: University of Notre Dame Press, 1993), 97: “The terms ‘primary’ and ‘secondary’ come into play when we are faced with the situation where one thing is what it is by virtue of the other. So each can be said properly to be a cause, yet what makes one secondary is its intrinsic dependence on the one which is primary. This stipulation clearly distinguishes a secondary cause from an instrument, which is *not* a cause in its own right: it is not the hammer which drives the nails but the carpenter using it.”

⁵⁸ Since evil is a privation of being and actuality, to the extent that creaturely actions are evil, they are not to be traced back to the divine cause as the principle of being and actuality.

There can be no competition between divine action and creaturely action (or between divine action and the laws of science that describe creaturely action). So, we lay to rest the second troublesome inference apparently proceeding from Newtonian science, that the deterministic laws of science leave no room for God's action in the world.

It is only when God and creatures are mistaken for univocal causes that any competition can be posited between them. Only then can their mutual causality be viewed as a kind of zero sum game in which the more the effect is attributed to God, the less it can be attributed to the creature.

If chance is a mode of creaturely causality, it must also be a secondary or instrumental cause in relation to divine causality. We therefore cannot say that chance is beyond the reach of divine providence, nor that it requires any diminishment of God's knowledge or power.⁵⁹ We should rather say that God acts through chance, just as God acts through any secondary creaturely cause.⁶⁰ In this sense, there can be

⁵⁹ SCG III, ch. 92, no. 6: "The power of the human soul, or also of an angel, is particularized in comparison with divine power which, in fact, is universal in regard to all beings. Thus, then, some good thing may happen to a man which is apart from his own intention, and apart from the inclination given by celestial bodies, and apart from the enlightenment coming from the angels—but not apart from divine providence, which is regulative, just as it is productive, of being as such, and, consequently, which must include all things under it. Thus, some good or evil may happen to man that is fortuitous in relation to himself, and in relation to the celestial bodies, and in relation to the angels, but not in relation to God. Indeed, in relation to Him, nothing can be a matter of chance and unforeseen, either in the sphere of human affairs or in any matter." God is not himself subject to chance, so "in relation to him, nothing is a matter of chance." Rather, God is the ultimate cause of chance events, not depriving them of their character of chance and contingency, but rather being the very source of it.

⁶⁰ Thomas Aquinas, *Commentary on Aristotle's On Interpretation* I, lect 14, no. 22: "There is a difference to be noted on the part of the divine will, for the divine will must be understood as existing outside of the order of beings, as a cause producing the whole of being and all its differences. Now the possible and the necessary are differences of being, and therefore necessity and contingency in things and the distinction of each according to the nature of their proximate causes originate from the divine will itself, for he disposes necessary causes for the effects that he wills to be necessary, and he ordains causes acting contingently (i.e., able to fail) for the effects that he wills to be contingent. And according to the condition of these causes, effects are called either necessary or contingent, although all depend on the divine will as on a first cause, which transcends the order of necessity and contingency. This, however, cannot be said of the human will, nor of any other cause, for every

no competition or opposition between the causality of chance and the causality of God. Even God's miraculous action in the natural world cannot be viewed as a violation of nature or of the natural tendencies of creatures (or even of the laws of science that describe those tendencies), since the most fundamental tendency of nature and of all creatures is toward the transcendent goodness of God.⁶¹

In this context, we can say that God acts through chance both in biological evolution and in quantum events. Elizabeth Johnson explains how secondary causality, as Aquinas understands it, can be applied to evolution:

[God, the] Absolute Holy Mystery dwells within, encompasses, empowers the evolutionary process, making the world through the process of things being themselves, thus making the world through chance and its genuinely irregular character. If God works through chance, then the natural creativity of chance itself can be thought of as a mode of divine creativity in which it participates. And the gracious mystery of God can be glimpsed as the Source not only of deep regularities in the universe, but also of novelty. The future remains genuinely open: God does not act like a bigger and better secondary cause to determine chance atomic events or initial conditions of chaotic systems. Randomness is real, for God respects the structure of creation while at the same time weaving events into providential patterns toward the realization of the whole. Divine sovereignty and creaturely freedom, of which chance is one instance, do not compete.⁶²

other cause already falls under the order of necessity or contingency; hence, either the cause itself must be able to fail or, if not, its effect is not contingent, but necessary. The divine will, on the other hand, is unfailing; yet not all its effects are necessary, but some are contingent"; in *Aristotle: On Interpretation. Commentary by St. Thomas and Cajetan*, trans. Jean T. Oesterle (Milwaukee, WI: Marquette University Press, 1962).

⁶¹ See *ST* I, q. 6, a. 1. See also *ST* III, q. 11, a. 1, resp.: "Now it must be borne in mind that in the human soul, as in every creature, there is a double passive power: one in comparison with a natural agent; the other in comparison with the first agent, which can reduce any creature to a higher act than a natural agent can reduce it, and this is usually called the obediential power of a creature."

⁶² Elizabeth Johnson, "Does God Play Dice? Divine Providence and Chance," *Theological Studies* 57 (1996): 15–16.

Similarly, we can say that God acts through chance in quantum mechanics, whether we follow the interpretation of Einstein or Bohr. Should we follow Einstein's account (where the quantum event is attributed to chance as a name for our ignorance of the as yet unknown hidden variables that are its real source), we would say that God acts through the hidden variables (as secondary causes) in the production of the effect. As with any case of secondary causality, the effect would be attributed wholly to God and wholly to the secondary causes (the hidden variables). Should we follow Bohr's account (where the quantum event is attributed to chance as a real, ontological feature of the natural world), we would say that God acts through the causality of chance itself (as a secondary cause) in the production of the effect. Again, the effect would be attributed wholly to God as primary cause and wholly to quantum chance as secondary cause.

Conclusion

The moral of our musings on the fortunes of chance in empirical science and its implications for the discussion of divine action seems to be that the discussion can be rightly grounded only if, at the start, we recognize the transcendent causality of God in relation to the secondary causality of creatures. From that vantage point, there can be no contradiction between chance (conceived as a mode of creaturely causality) and God.

The presence of chance in the natural world is not contrary to divine action, and God's action in the world is neither contrary to the natural actions of creatures nor excluded by the laws of science that describe them. Stewart captures something of the compatibility of chance and divine action when he writes:

Whether Einstein was right about quantum mechanics remains to be seen. But we do know that the world of classical mechanics is more mysterious than even Einstein imagined. The very distinction he was trying to emphasize between the randomness of chance and the determinism of law is called in question. Perhaps God can play dice, and create a universe of complete law and order, in the same breath.⁶³

We can, in any case, be sure that the presence of chance in contemporary science should cause no conflict between theology and science.

⁶³ Stewart, *Does God Play Dice?* xii.

Rather, the presence of chance, when rightly understood, opens a new avenue for dialogue between the two disciplines. As Bogart might say: “I think this is the beginning of a beautiful friendship.” **N&V**