GOD’S PROVIDENCE
AND
RANDOMNESS
IN NATURE
GOD’S PROVIDENCE
AND
RANDOMNESS
IN NATURE
Scientific and Theological Perspectives

Edited by Robert John Russell and Joshua M. Moritz

TEMPLETON PRESS
CONTENTS

Introduction
Robert John Russell 3

Part I: Scientific Warrants for Indeterminism throughout Nature

1. Necessity, Purpose, and Chance
   George F. R. Ellis 21

2. The Universal Laws of Physics
   Robert E. Ulanowicz 69

3. Multiverse
   Gerald B. Cleaver 85

Part II: Philosophical and Theological Perspectives on Indeterminism in Nature

4. Are Randomness and Divine Providence Inconsistent?
   James Bradley 117

5. What We’ve Learned from Quantum Mechanics about Noninterventionist Objective Divine Action in Nature—and Its Remaining Challenges
   Robert John Russell 133

6. Context-Sensitive Constraints, Types, Emergent Properties, and Top-Down Causality
   Alicia Juarrero 173
CONTENTS

7. Is Classical Science in Conflict with Belief in Miracles? Some Bridge-Building between Philosophical and Theological Positions
   Erkki Vesa Rope Kojonen 205

8. Necessity, Chance, and Indeterminism
   Veli-Matti Kärkkäinen 235

9. Contingency and Freedom in Brains and Selves
   Ted Peters 261

10. Contingency, Convergence, Constraints, and the Challenge from Theodicy in Creation’s Evolution
    Joshua M. Moritz 289

    About the Contributors 329

    Index 333
GOD’S PROVIDENCE
AND
RANDOMNESS
IN NATURE
INTRODUCTION

Robert John Russell

Introduction and Purpose of the Volume

This book is the output of project SATURN, a two-year interdisciplinary research program dedicated to studying the “Scientific and Theological Understandings of Randomness in Nature.” SATURN was created by the Center for Theology and the Natural Sciences (CTNS) through generous funding from a grant from Calvin College, administered by Jim Bradley. It included over a dozen scholars in mathematics, physics, biology, ecology, the philosophy of science, and Christian theology. In October 2014, CTNS convened an international research conference at the Graduate Theological Union, Berkeley, California, to focus on the results of this research. Final versions of papers are published here. But what are the philosophical and theological implications of the randomness that characterizes so many natural phenomena?

To date, scholars in the theology and science community have made a strong case for four closely related claims in relation to such phenomena: (1) that God acts at every level of nature as her creator ex nihilo (creation out of nothing), giving existence and rational lawfulness to the universe as a whole and to all its natural processes; (2) that God continuously acts in nature to bring about the dynamic evolutionary processes that produce the variety of species of life on earth and probably elsewhere in the universe (i.e., general providence); (3) that God acts in particular ways at the atomic and subatomic levels of nature (i.e., one form of special providence) and that
such special divine action often makes objective differences in the course of
time, and (4) that God does so without violating or suspending natural
processes, that is, that such divine action is “non-miraculous” or, equiva-
ently, “noninterventionist.” Divine action as named in (3) and (4) is often
referred to as NIODA or “noninterventionist objective divine action.” The
key to making this claim is a compelling philosophical interpretation, based
on the relevant sciences, that nature is genuinely or ontologically random at
some, or many, levels of complexity. A prime instance is quantum mechanics
(QM) in which atomic and subatomic processes are taken to be indetermin-
istic. Of special significance here would be the claim that God’s action at the
quantum level makes specific differences in the biological evolution of life, a
view defending one form of theistic evolution. If this claim gains widespread
support, it would provide a robust counter to atheistic interpretations of evo-
lution, and it could render Intelligent Design as superfluous. The SATURN
program builds on the accomplishments of the collaborative research pro-
gram of the Vatican Observatory and CTNS during the 1990s and 2000s.

Analytic Overview of the Chapters

The three chapters of Part I of the volume address questions that are both
preliminary and foundational to those of Part II. These eight chapters ask
in detail about the scientific warrants for randomness and indeterminism in
nature, and they begin the wider philosophical and theological discussions
whose focus is in Part II.

In the “Necessity, Purpose, and Chance: The Role of Randomness and
Indeterminism in Nature from Complex Macroscopic Systems to Relativis-
tic Cosmology,” cosmologist and mathematician George F. R. Ellis explores
the presence of chance, purpose, and necessity while moving from the realm
of the subatomic to the universe as a whole. He argues that quantum ran-
domness in cosmology ensures that present events on earth cannot possibly
have been written into the initial data in the early universe. Rather com-
plex current entities such as human beings must have come into being via
a process of emergence whereby higher levels in the hierarchy of structure
have their own causal powers in accordance with the dynamics operative at
that level and act to affect lower levels in accordance with those purposes.
This process of emergence is enabled by the randomness of lower levels relative to the next higher levels on the other. This randomness enables adaptive selection in evolution to continually find better solutions to higher-level needs of organisms. The selection process works as nature deletes undesired entities in the random ensemble, leaving behind a more ordered set of entities; in this way, useful information is acquired and structures are created that did not exist before.

For Ellis, the term chance includes the three types delineated in the VO/CTNS research: (a) chance as epistemic ignorance of underlying deterministic processes (the roulette wheel type of chance); (b) chance as the unpredictable juxtaposition of fully deterministic but uncorrelated causal trajectories (the car crash type of chance); and (c) chance as ontological indeterminism (as found in the Copenhagen interpretation of QM). Ellis claims that all three types of chance occur in nature. Rather than connoting meaninglessness, randomness is “the gateway to variety and possibility.” Randomness together with necessity “opens up the possibilities of mental and spiritual life . . . because it allows adaptive selection to take place in accord with higher level purposes.”

Ellis starts with the exponentially rapid expansion of the extremely early universe, referred to as inflation. After some 300,000 years after the big bang, the universe was bathed in what we now call the cosmic microwave background radiation. Tiny fluctuations in it eventually led to the structure of the universe as we now know it, including clusters of galaxies, with their stars and planets. The key point here is that these fluctuations arose during the process of inflation and were quantum mechanical in nature; “they were not determined uniquely by the state of the universe at the start of inflation. . . . Hence the existence of our specific galaxy, and the sun and earth in it, are also not so determined. They are the outcome of unpredictable random events.” Ellis then discusses the evolution of life on earth and makes a case for the unpredictability of the present state of nature. He cites the fact that quantum events affect life’s genetic inheritance and thus influence the specific course of Darwinian evolution. “The specific evolutionary outcomes of life on earth . . . cannot even in principle be uniquely determined by causal evolution from conditions in the early universe. . . . Quantum uncertainty prevents this, because it significantly affected the occurrence of radiation-induced mutations in this evolutionary history.” Thus, the fluctuations in the very early
universe “encode the possibility of today developing” but not the unique and determinate landscape of the universe today.

This in turn leads Ellis to a careful discussion of the emergence of physical and biological complexity. Here he makes a detailed argument in support of top-down causality, including feedback control and adaptive selection. He then turns to randomness in the processes of the brain and mind. He concludes by reiterating the thesis of his chapter:

The occurrence of chance and randomness in the universe in addition to physical necessity does not mean that what happens is simply random. It opens up the space for higher levels of meaning to have real causal powers, and to embody abstract types of causation representing higher levels of meaning not written into the physical initial conditions in the universe.

“The Universal Laws of Physics: Inflated Ontologies?” is the provocative title of biologist and ecologist Robert E. Ulanowicz’s chapter. His purpose is to defend the claim that the chemical and biological processes of living systems offer room for noninterventionist divine action. Ulanowicz begins by pointing to scholars who place their ultimate trust in the universal laws of physics and who argue that these laws determine all that transpires in the natural world. But is it true that all other forms of natural causality are ultimately derivable from them? Such faith in the universality of these laws likely derives from the fact that no violations of these laws have been observed. But as Ulanowicz points out, Newton’s laws of mechanics owe much to Leibniz and Euler and their assumption that the coordinates and properties of physical systems can be represented mathematically by continuous variables. This in turn gave rise to a neo-Parmenidean conception of nature in which the laws assume the status of neoplatonic essences. No real predictions, however, can be resolved by appealing to the laws alone. It is always necessary to supplement these laws by boundary and initial conditions, and these, in turn, must be exact if deterministic outcomes are to follow. The overwhelming combinatorics inherent in a heterogeneous world, however, implies that most boundary descriptions will remain incomplete. This residual indeterminacy means that real systems are free to develop along multifarious pathways, none of which violate the underlying universal laws. Furthermore, those conditions that cannot be predicated explicitly range beyond what is often called blind chance, sensu Jacque Monod. Possible indeterminate boundary conditions
span a spectrum that runs from unique events to blind chance to conditional chance to near certainties. Furthermore, the order inherent in these latter categories arises out of feedback processes, namely, the constraints that reflect upon themselves in mereological or part-to-whole fashion. Of particular importance are autocatalytic, or self-stimulating, configurations of mutually supporting processes. These processes may give rise to endogenous, or internal, selection from among constituent entities and mechanisms in processes that draw resources into their own orbits in centripetal fashion. While these nonrandom configurations do not violate any universal law, they are not fully determined by them. Contingency plays a necessary role in the history of each one. Even the laws of thermodynamics are often accorded an inflated ontological depth. The first law, the conservation of energy, seems to be constructivist by nature in that units of measure were explicitly defined so that no exceptions would ensue. Many interpret the second law, the increase of entropy in a closed system, as implying an eschatological heat death for the universe, although in a heterogeneous world such as ours, that endpoint is no longer unique.

Ulanowicz concludes with the view that the metaphor of nature as a clock has been seriously compromised. Perceived order appears rather to be the outcome of a natural dialectic: In the large, homogeneous sense, all behaviors must conform to the universal laws of physics, which include entropic decay. In the immediate heterogeneous realm, however, order is generated and maintained by contingent and circumscribed proximate laws, such as those that emerge from among living phenomena. Whereas the prevailing consensus is that the universal laws constitute an ultimate ontology that allows no gaps for divine intervention, it is now possible to entertain a rational view of the heterogeneous world that offers ample room for natural, human, or even divine freedom of action. One difference between Robert Russell’s argument for such divine action is that his approach, NIODA, is based on QM, whereas Ulanowicz bases his argument on natural processes at all physical scales in the macroworld.

In “Multiverse: God’s Indeterminacy in Action,” physicist Gerald B. Cleaver examines the concept of multiverse in relation to God, as Creator, interacting with creation. He argues that a multiverse is the likely natural mechanism through which the God of infinitudes grants inherent freedom to a spatially and/or temporally infinite creation. The multiverse is thus
God’s means of indeterminacy in action. The freedom inherent to a multiverse is perhaps the greatest gift God grants to creation. This proposal is explored in terms of both general and specific concepts of the multiverse as well as the philosophical and theological implications for sentient life within the multiverse.

Cleaver first discusses the views of many Americans regarding God’s engagement with creation. Then he considers the role that the theology of nature can play in developing these views. Past and present paradigms of creation have led to larger, more beautiful, vast, and complex, theologies as well as more unified and complete understanding of creation and its physical laws. Cleaver argues that the observed properties of our universe give scientific credence to the existence of the multiverse in which our universe is but one of many universes.

Cleaver proposes a taxonomy of multiverses. He then summarizes key scientific, philosophical, and theological controversies of the multiverse proposal with a focus on what a multiverse may imply regarding God’s interactions with creation. The free will of sentient life is evaluated with regard to divine will, from deist to interventionist views of God. He also considers process theology within the multiverse framework versus the multiverse as an extension of St. Augustine’s block universe. Cleaver concludes his chapter with a contemplation of what it might mean for a multiverse to receive God’s “Seal of Approval.”

With the preliminary and foundational questions addressed in Part I, we now move to Part II, the heart of the volume, titled “Philosophical and Theological Perspectives on Indeterminism in Nature.” These deal with the philosophical and theological implications emerging from the writings of Part I while developing new insights into the implications of the natural science.

In “Are Randomness and Divine Providence Inconsistent?” mathematician James Bradley notes that many scientists stress the randomness in the natural world. However, for many people—not just scientists—such randomness seems inconsistent with the existence of a divine being who is omniscient, omnipotent, and sovereign and who acts with providential care. Bradley’s chapter offers a response to this theological anxiety about randomness by carefully examining the concept of randomness, its presence in various phenomena, and its role in problems of theodicy.
Bradley begins by examining a number of phenomena that display randomness in the physical world—dynamic systems that are highly sensitive to initial conditions, quantum uncertainty, Poisson processes, diffusion, mutations, the human immune system, unicellular organisms, and the distribution of labor among social insects. He then examines a popular definition of randomness—“Not having a governing design, method, or purpose; without order; without cause”—and shows the similarity of this concept to the notion of chance as it was used in classical Greece. Bradley contrasts this popular concept with definitions of the word random as it is used in different sciences: For mathematicians, it means unpredictability; for statisticians, it arises in sample selection process; for computer scientists, it means the binary representation of numbers; for physicists, it can mean both mathematical unpredictability and without cause; biologists use it to suggest that mutations are independent of their environment. Bradley then suggests that much of the anxiety surrounding randomness in science is the result of confusing it with chance.

Next, Bradley examines two quite different sources of randomness. The first is its origin in physical phenomena, notably its presence as a necessary property of complex systems. The second arises in algorithmic information theory (AIT) and treats randomness as a property of natural numbers that exhibit properties of irreducibility, absence of pattern, and unpredictability. Randomness in this sense can be seen as originating in the divine nature, and it suggests that randomness in the physical world should be seen neither as a surprise nor as a threat to religious belief. Nevertheless, randomness in evolutionary biology does give rise to the problem of theodicy.

Bradley concludes that in many ways randomness can be understood as a complex, subtle, and beautiful way by which God has developed and sustained much of creation. Nevertheless, randomness is ambiguous and can be destructive—it is part of such undesirable phenomena as harmful mutations that can contribute to suffering and early death. Although much of the theological anxiety associated with randomness can be relieved by a better understanding of what randomness means and its role in the natural world, not all of it can. A religious skeptic may look at the negative phenomena associated with randomness and be reinforced in his or her skepticism. However, some believers have provided plausible responses to such skepticism. Bradley discusses three—Stephen Wykstra’s affirmation that God could have
good reasons to allow suffering even if we are unable to see them, John Hick’s soul-making, and Bruce Reichenbach’s necessity of harmful side effects.

Physicist and theologian Robert John Russell entitles his chapter “What We’ve Learned from Quantum Mechanics about Noninterventionist Objective Divine Action in Nature—and Its Remaining Challenges” In the Introduction, Russell lays out several of his theological presuppositions about the acts of God as Creator and Redeemer. These presuppositions display the diversity of what the generic term divine action means: God as Creator ex nihilo, including general and special providence, and God as Redeemer, including divine miracles. In the section “NIODA,” Russell describes QM as offering a new interpretation of divine action in which God’s action makes an objective, counterfactual difference in the course of nature without intervening in nature, that is, without violating or suspending natural processes. He calls this “NIODA,” an acronym for noninterventionist objective divine action. For NIODA to be viable, it must be based on an interpretation of one of the theories of the natural sciences in which nature can be viewed as indeterministic, that is, the underlying physical processes must at some (or many) level of complexity lack sufficient efficient natural causes. In these processes, divine action can produce counterfactual results without being interventionist. The quest is thus launched for suitable domains in nature, as depicted by the theories of science, in which NIODA might apply. Russell argues that QM is well suited for the task, offering what he dubs “QM–NIODA.” The project of SATURN is, in part, to find many other such levels in nature.

In the section “QM–NIODA: A Very Brief Summary,” Russell argues that QM gives rise to the general physics of the macroscopic world as well as specific effects in that world. He then claims it offers a robust defense of theistic evolution against both atheistic evolution and Intelligent Design. Are there other areas in nature that are open to the noninterventionist influence of divine action? In the section “QM–NIODA Gives Rise to the General Physics of the Macroscopic World as Well as Some Kinds of Specific Effects in That World,” Russell points out that QM supports libertarian free will in leading to the possibility that mental states, which supervene on brain states, can indeed change the body’s somatic disposition if brain states are vulnerable to quantum processes. In the section “The Extent of the Amplification of Quantum Events to Specific Effects in the Macroscopic Level: An Open
Question,” Russell addresses two important critiques of NIODA. He first takes on a criticism common among neo-Thomists that NIODA makes God into a secondary, univocal cause as found in recent work by the Dominican theologian Michael Dodds. In the process, he employs specific texts from Aquinas in hopes of finding new areas of mediation and potential agreement with Dodds. Next, Russell addresses recent work by Alvin Plantinga who is widely critical of the “Divine Action Project” in the CTNS/Vatican Observatory volumes. Instead, Plantinga proposes that divine action at the quantum level is best considered in terms of a “sudden collapse theory” that proposes to account for the collapse of the wave function in strictly natural terms. Russell offers a careful read of Plantinga’s arguments and seeks common ground while acknowledging remaining differences. In the section “QM–NIODA: A Robust Defense of Theistic Evolution against Both Atheistic Evolution and Intelligent Design,” Conclusions, Russell cites seven “remaining challenges” that point toward future research in theology and science related to divine action.

Philosopher Alicia Juarrero titles her chapter: “Context-Sensitive Constraints, Types, Emergent Properties, and Top-Down Causality” Juarrero begins with a bold claim: “The long night of eliminative materialism is over. . . . I am not claiming the hard problems of consciousness have been solved, only that assertions that subjective experiences are real and not epiphenomenal no longer elicit snide snickers and eye rolling.” To support this claim, Juarrero examines the intentional causality of selves and agents, a form of causality without which there can be no autonomy or agency. Fundamental assumptions of modern science concerning causality bar any meaningful discussion of these issues. According to these assumptions, only primary qualities of fundamental atomic particles are real, wholes are reducible to aggregates, seemingly emergent properties are mere epiphenomena, and causality is restricted to billiard-ball-type impact of external forces while at the same time forbidding self-cause. If nothing can cause or move itself, then causes such as long-term plans of behavior, or the way an agent’s character affects his or her behavior, are illusory. Substance dualism and the various forms of materialism ineffectively attempt to legitimize autonomy and agency. The former founders on the problem of conservation laws; the latter cannot make sense of emergent properties such as meaning, much less their ability to cause behavior.
According to Juarrero, Kant was among the first to recognize that unexamined presuppositions pertaining to causality were insurmountable obstacles for explaining purposiveness. What is needed is a kind of mereological causality where parts interact to produce a novel whole that in turn produces components of a larger whole. Polanyi understood that patterns could be causally efficacious, but he could not conceptualize how a pattern could bring itself into existence. It took far from equilibrium dynamics to provide us with a scientifically respectable way of accounting for cohesive wholeness. Dissipative structures such as Bénard cells, in which recursive feedback and boundary conditions lead to a new level of self-organization in which the components’ behavior is determined by the whole into which they are entrained.

The last section of the chapter is an argument for the reality of such top-down causation. The closure of temporal and spatial context-dependent constraints is both what brings dynamic wholes into being and also makes them exquisitely sensitive to initial conditions. In consequence, each trajectory is unique. Different configurations can embody the *same* emergent property; and the same configuration (in different organisms, or in the same organism at different times) can embody different properties. In each of these cases, however, the global systemic level harnesses and modulates its components, their rates of interaction, and so on, so as to promote and maintain the emergent property it embodies at that moment in time. The top-down harnessing and modulating is performed *in the service of* the emergent property. If such causal influence by emergent properties on their constituents is real, then so is the emergent property. This means that in humans, comparable emergent properties of meaning, value, and morals can likewise affect behavior and are thus real. Fully human autonomy and agency can thus be naturalized.

Theologian Erkki Vesa Rope Kojonen asks a crucial question for this volume: “Is classical science in conflict with belief in miracles?” Kojonen starts by noting that while different reasons have been raised against belief in miracles, arguments based on classical deterministic physics are perhaps the most popular. In the theology and science literature, this argument has been challenged primarily by appealing to the indeterminism of physics based on new scientific discoveries. But some recent discussion has instead been focused on criticizing the premises of the argument from classical science
against miracles. The purpose of Kojonen’s chapter is to explore these new arguments and build bridges between the theology and science community and analytic philosophers of religion such as Alvin Plantinga and William Alston.

Much depends on the definition of miracle: Are miracles understood as violations of the laws of nature or merely as events that go beyond the capacities of nature but do not violate the laws as such? Defining the laws of nature is also crucial: Does understanding the laws of nature allow us to predict everything that happens in nature? Philosophical defenders of the compatibility of deterministic science and theological miracle-claims argue that science itself does not settle such questions. Rather, defending a deterministic worldview is always a philosophical and theological, rather than merely a scientific, position.

There are significant analogies in the theology and science discussion with the arguments presented by Plantinga and Alston. For instance, the hierarchical model of the relationship of the natural sciences, humanities, and theology assumes that no disciplines study all of reality. This fits in with the claim that the natural sciences are descriptively incomplete. Kojonen also argues that in discussing eschatology, Robert Russell’s defense of the possibility of Christian eschatology has some similarities to the Alston/Plantinga defense of miracles. The natural sciences predict that the cosmos will end in heat death; this appears to be in contradiction to Christian claims about the eschatological resurrection. Russell’s defense is based on identifying the philosophical nature of such claims, just as Alston/Plantinga do in their defense of miracles. But this is not to understate the existence of differences between Russell and Alston/Plantinga.

As Kojonen points out, purely theological arguments for the possibility of miracles have also been made. It can be argued that the question "are miracles possible" is a metaphysical and theological, not primarily a scientific, question. If we believe that the whole of nature is ultimately dependent on God, then it becomes difficult to argue that the laws of nature as such limit God. If God chooses not to act miraculously, then it arguably must be for theological and metaphysical reasons, such as honoring the integrity of nature and making human freedom possible. So the reasons for the possibility or impossibility of miracles ultimately lie in the metaphysical God–world relation and must be a consequence of free divine choice, rather than in limitations
imposed on God by the laws of nature themselves. The philosophical argument from descriptive incompleteness can at most demonstrate that natural science does not contradict belief in special divine action or human freedom. The new physics goes beyond this. It may be able to show that belief in divine and human freedom actually finds support in the scientific understanding of indeterminacy. Some ontologies of nature may be more congenial to theological understanding than others, and scientific theories clearly have much bearing on such questions.

Next, theologian Veli-Matti Kärkkäinen turns to one of the central topics in this volume: “Necessity, Chance, and Indeterminism: A Theological Account of Freedom of Will in a Regulated World.” Kärkkäinen notes at the outset that there are several forms of determinism that seek to defeat the freedom of will. The most important forms derive from physics, neo-Darwinism, genetics, and neurosciences. His primary aim in this chapter is to seek to defeat such forms of neuroscientific reductionisms and establish a robust account of freedom of will. Before engaging with neuroscientific determinism, Kärkkäinen locates the discussion of free will in the wider context of neo-Darwinian and genetic determinisms.

In order for the theologian to defeat forms of determinism that reject freedom of will, it is necessary to establish not only indeterminacy but also the possibility of teleology and purpose in nature, or else pure randomness results. With this goal in mind, this chapter sets forth a modest theological proposal for the possibility of the freedom of will in a world that, while basically deterministic in its processes, is not so to the exclusion of the limited but true exercise of human free will. Indeed, determinism per se is not the problem. It is reductionism—the view that everything about human behavior and intentions can be reduced to their physical basis. Instead, while we live in a determined world, it is not an absolutely determined one.

In this chapter, Kärkkäinen takes for granted human rationality and responsibility. The necessity of free will, at least in some relative and modest sense, is so obvious and is such a deep human intuition that even the deniers of freedom, luckily, do not live according to their belief. Kärkkäinen first seeks to clarify the meaning of chance and determinism in human evolution. Next he critiques genetic determinism, which is closely allied with the neo-Darwinian paradigm. The third part of the chapter gets to Kärkkäinen’s main point, which has to do with the contemporary neuroscientific- and
philosophy-of-mind–driven paradigm: the lack of the freedom of will. Here he engages critically the research done by Benjamin Libet, which suggests that “the brain acts before the mind decides!” Kärkkäinen shows that for both methodological and philosophical reasons that implication does not follow. He concludes with some theological reflections on the possibility and source of human freedom.

In his chapter on “Contingency and Freedom in Brains and Selves,” theologian Ted Peters reviews the latest findings in neuroscience and neurophilosophy along with the debate among physicists regarding contingency at the quantum level in order to ask two connected questions: (1) Does human free will exist? And, (2) is human free will connected to contingency in the physical realm? He replies that human free will does exist and that what we mean by free will is self-determination, namely the self engaged in deliberation, decision, and action. While this understanding of free will might be compatible with Newtonian mechanics, free will is more coherently understood within the context of indeterminism and contingency at the subatomic level, which is a necessary, even if not sufficient, condition for free will at the human level. Contingency in the physical domain as well as the human domain is due to the dialectic between necessity and randomness at the level of subatomic QM. Human freedom is an indirect by-product of this underlying structure of physical interaction.

Once both physical indeterminism and human free will have been established, we then confront a caveat: From the point of view of the Christian theologian, what we call free will is in fact the bound will. It is a will that is bound to self-expression and not at liberty to represent fully the needs or interests of someone else's self. According to the Augustinian tradition, the natural self is *incurvatus in se*, curved in upon itself. The self cannot but express itself on behalf of its own self-interest. What in the wider culture is celebrated as free will is nothing more than subjective arbitrariness, the unavoidable choosing of what would be in a person's own self-interest. In sum, subjective arbitrariness can be satisfactorily accounted for when drawing upon neuroscience and quantum physics, but Christian freedom, in its deepest sense in regard to the bound will, remains unaddressed and unexamined in current discussions in theology and science.

Theological discussions of divine action inevitably bring up the staggering challenge of God’s relation to apparent purposelessness in biological evolution.
and the reality of suffering in nature (i.e., natural evil). Philosopher, theologian, and evolutionary biologist Joshua M. Moritz addresses this thorny issue of natural theodicy in his chapter “Contingency, Convergence, Constraints, and the Challenge from Theodicy in Creation’s Evolution.” Moritz summarizes the philosophical and theological challenge by asking how the central role of chance within natural selection, the predominance of stochasticity within the neutral theory of molecular evolution, and the pervasiveness of contingency within the overall history of life relate to the problem of theodicy. What challenges does evolutionary randomness pose for theologians endeavoring to fully affirm theistic evolution within the Christian doctrine of creation? In this chapter, Moritz first examines the role of chance in evolutionary theory in order to explore some possible directions of response. Considering the place of stochasticity within genetic mutations, Moritz points out that Robert Russell and, recently, Elliot Sober have argued “that evolutionary theory, properly understood, does not rule out God’s causing some mutations.” Findings in evolutionary symbiosis, evolutionary convergence, and evolutionary-developmental constraints have also been interpreted as reducing the overall role of randomness in the evolutionary history of life.

Beyond this, certain types of randomness can be seen as contributing a positive value to a theological understanding of creation that employs a balance of both contingency and evolution. If God’s goals in creating the cosmos include making beings with the capacity for incompatibilist freedom, rationality, community, and morality, then accomplishing such goals appears to require a regular structure as expressed in natural law, combined with a significant degree of physical indeterminism. In a similar way, the divine goal that creatures develop a high degree of independence and relational love is best achieved through a means by which creatures are created with the capacity to create themselves. An evolutionary understanding of creation allows for distinct beings who, having played a key part in their own particular histories of emergence, can then independently love God for who God is as Himself, and in turn be loved for who they are as themselves. An evolutionary creation seems to be required for God to create independent, moral, and rational creatures who can—on their own terms—enter into relational love and community with their Creator. The natural evils that arise from contingency within the creative process are indirect consequences of the values and goals that God aims to achieve in creating beings, through natural processes, who can know and love God.
Notes

1. Calvin College, in turn, received funds for this and other related projects from the John Templeton Foundation.

2. SATURN is an appropriate acronym for this research because the rings of the planet Saturn exhibit the kind of self-organization that can come about in nature through random processes and gravitational interactions.

3. The Humean sense of “miraculous” as “noninterventionist” and its relation to broader meanings of “miracle” will be explored in several of the chapters in this volume.

4. Note: Although few, if any, of the authors in this volume deny that God may also act in miraculous/interventionist ways, particularly as witnessed to in Scripture, this is a subject for another research program.
SCIENTIFIC WARRANTS FOR INDETERMINISM THROUGHOUT NATURE
1

NECESSITY, PURPOSE, AND CHANCE

The Role of Randomness and Indeterminism in Nature from Complex Macroscopic Systems to Relativistic Cosmology

George F. R. Ellis

Causation and Randomness in Nature

Various kinds of causation occur in nature. Famously, Jacques Monod (1972) characterized them only as chance and necessity. He missed a key further kind of causation that certainly occurs in the real universe: purpose or goal seeking (Ellis 2005), and specifically libertarian free will, when we include sentience, and in particular, human self-consciousness. With the omission of this key causal category—which inter alia explained why he wrote his book—his analysis was prevented from relating adequately to deep philosophical questions, even though he claimed to answer them. The same comment applies to more recent books by Susskind, Hawking and Mlodinow, Krauss, and others.

This chapter will consider a broader context: The interplay between necessity, purpose, and chance. The first has an inexorable impersonal quality. It is the heart of physics and chemistry. It can be successfully described by mathematical equations. The second is the core of human beings, indeed of all life. All living entities embody some kind of purpose or function in their structure and actions (Campbell and Reece 2005); this is a particular form of top-down causation. The third embodies the idea of randomness, implying a lack of purpose or meaning. Things just happen that way, not because it’s inevitable, but because it’s possible, and maybe probable.
It is prevalent in the real universe because of the large number of unrelated causes that influence events, and in particular, because of the vast numbers of micro-events that underlie all macroscopic outcomes. All three kinds of causation occur in an intricate interplay in the real universe.

Bob Russell points out that the classification of chance that surfaced repeatedly in the Vatican Observatory/The Center for Theology and the Natural Sciences (CTNS) volumes edited by Russell, Murphy, and Stoeger was as follows:

1. Chance events along a system’s trajectory as epistemic ignorance of underlying deterministic processes (roulette wheel): *the large number of unrelated causes that influence events*
2. Chance as the unpredictable juxtaposition of fully deterministic but apparently uncorrelated causal trajectories (car crash): *the vast numbers of micro-events that underlie all macroscopic outcomes*
3. Chance as ontological indeterminism (Copenhagen interpretation of quantum mechanics or QM)

In the viewpoint I take, all three will occur. Randomness is, in effective terms, basic to quantum physics, and I will adopt the view that this is an irreducible ontological indeterminism: If this is not true, the practical effects are unaltered (otherwise, there would be an experiment showing this to be wrong.) Bose–Einstein and Fermi–Dirac statistics, while they reduce to Boltzmann statistics at the classical level, account for many practical properties of the classical world (like the hardness of a table or the coherence of laser light) in ways that Boltzmann statistics do not. Proposing that quantum physics is not based in ontological indeterminism makes no difference to this assertion. All three relate to causality in complex systems and the existence of life. There is, in effect, an intermediate between chance and necessity—*probabilistic causation*, such as “Smoking causes lung cancer.” This is when chance at the lower level leads to high probability but not uniquely predictable events at the macro-level. But then in a specific case, this is either 1 or 2 of the aforementioned types of chance. For the purposes of this chapter, though, I do not need to distinguish these variants of chance.

Essentially, quantum phenomena such as self-interference, superposition, and nonlocality were, until recently, thought to have no effect on life because decoherence would destroy superpositions and entanglement on very rapid
timescales. However, the rapidly developing subject of quantum biology now shows this is not always the case: It seems that such quantum effects play a key role in some processes needed for the existence of life (Al-Khalili and McFadden 2014).

When one has social or engineering systems, randomness is often a problem to be handled, and as far as possible, to be limited by careful design, so that the desired outcome will be attained despite random events intervening in the dynamics. This is not always successful. In particular, digital computers are notoriously susceptible to the smallest error: A single wrong full stop can bring an immensely complex program to a crashing halt. However, social systems, such as the economic and legal systems, and technological artifacts, such as modern aircraft, are generally more robust: They are designed to handle reasonable classes of random events without disaster occurring. Feedback control in cybernetic or homeostatic systems is specifically designed to tame randomness, but it often remains an enemy to be handled with care. It has the potential to derail everything and prevent attainment of the desired goal. However, in some contexts, such as randomized medical trials, it can be useful, and with the right design, randomness in mechanical systems can increase stability by inhibiting resonance. So it can sometimes be used to advantage.

At the micro-level, biological systems do not live in a carefully controlled environment: They face rampant randomness all the time. It turns out that they take advantage of the storm of randomness encountered at the molecular level—there is much evidence that molecular machinery in biology is designed to use that randomness to attain desired results (Hoffmann 2012). This is true also in terms of macro-levels of behavior, and in particular, as regards how the brain functions (Deco, Rolls, and Romo 2009; Glimcher 2005; Rolls and Deco 2010). Randomness is harnessed through the process of adaptive selection, which allows higher levels of order and meaning to emerge. It is then a virtue, not a vice. It allows purpose to be an active agent by selecting the desired outcomes from a range of possibilities.

Effectively, irreducible randomness occurs in physics at the quantum level, thereby influencing cosmology and the existence of life on earth. Whether it is due to ontological indeterminism or not, what is experienced in the real world at the quantum level is unpredictable.

If it were not for this effective randomness, we would be stuck in the vice of determinism and outcomes would be limited and uninteresting. But it
is there, as part of the design of the universe. It is a key feature in enabling autonomous higher levels of order to come into being. It is remarkable that many writings on quantum physics (e.g., regarding the black hole information paradox) claim its dynamics are deterministic: Only unitary transformations can occur. These texts, which explicitly or implicitly deny that state vector reduction takes place, give no way whereby superpositions reduce to an eigenstate, so in effect they deny that specific classical outcomes occur, and hence also give no way whereby the Born rule—the key relation that predicts probabilities of different classical outcomes to experiments—can be realized. They simply do not reflect the nature of the paradigmatic two-slit experiment where the quantum mechanical interference pattern is built up photon by photon as individual photons arrive at a detector in an indeterministic way.

This chapter, by contrast, takes that experiment seriously as genuine evidence regarding the nature of the universe. Our experience is that irreversible unpredictable quantum effects do indeed take place in the real universe. This indeterminism—whether ontological or not—is a key aspect of the nature of physical reality. Its existence is based in deeper levels of being—the possibility spaces that determine what is and what is not possible in the physical universe. It is part of the design of the things—one of the features one has to explain, if one claims to explain on any basis whatever the nature of the physical universe.

Why do both chance and necessity occur? Who or what ordered them both? And how does purpose fit in?

An element of randomness at the bottom does not mean all that happens is just pure chance—rather it is one of the foundations that, together with necessity, opens up the possibilities of mental and spiritual life, realized through physical existence, because it enables adaptive selection to take place in accord with higher-level purposes. It does not have to have the connotation of meaningless so often ascribed to it. It is the gateway to variety and possibility. That is what will be explored in this chapter.

**Randomness in Quantum Physics**

The standard view is that quantum physics, which introduced the quantum principle that only discrete energy states occur, particle–wave duality, the uncertainty principle, quantum tunneling, superposition of states, and
entanglement, involves a foundationally indeterminate dynamics: Probabilities can be predicted, but not specific outcomes.

The Standard View

The basic postulate of quantum mechanics (Greenstein and Zajonc 2006; Isham 1995; Morrison 1990; Rae 1994) is that before a measurement is made, the vector $|\psi\rangle$ describing the quantum state of the system can be written as a linear combination of unit orthogonal basis vectors representing different possible measurement outcomes:

$$|\psi_1\rangle = \sum_n c_n |u_n(x)\rangle,$$

(1)

where $|u_n(x)\rangle$ is an eigenstate of some observable $\hat{A}$. The evolution of the system can be completely described by a unitary operator $\hat{u}(t_2, t_1)$, and so the state vector evolves as

$$|\psi_2\rangle = \hat{u}(t_2, t_1) |\psi_1\rangle.$$

(2)

Here $\hat{u}(t_2, t_1)$ is determined by the evolution equation

$$ih \frac{d|\psi_t\rangle}{dt} = H |\psi_t\rangle,$$

(3)

where $H$ is the Hamiltonian (substitute (2) into (3) to see how $H$ determines $\hat{u}$). This is a unitary evolution: No surprises occur; the initial state uniquely determines the final state at all later times. Physics is determinate—necessity rules.

Immediately after a measurement is made at a time $t = t^*$, however, the relevant part of the wave function is found to be in one of the eigenstates representing a specific measurement outcome:

$$|\psi_2\rangle = c_N |u_N(x)\rangle$$

(4)

for some specific index $N$. This is where the quantization of entities and energy comes from (the discreteness principle): Only discrete eigenstates can result from a measurement. The eigenvalue $c_N$—the outcome of the measurement—is unrelated to the initial wave function (1). It cannot be a unitary evolution (2). The data for $t < t^*$ do not determine either $N$ or $c_N$; they merely determine a probability for each possible outcome (4), labeled by $N$, through the fundamental equation

$$p_N = c^2_N = <e_N|\psi_i|^2.$$

(5)