PERSPECTIVES ON SCIENCE AND CHRISTIAN FAITH VOLUME 66, NUMBER 1 MARCH 2014

PERSPECTIVES on Science and Christian Faith

JOURNAL OF THE AMERICAN SCIENTIFIC AFFILIATION

In This Physics Theme Issue …

"The fear of the Lord is the beginning of Wisdom."
Psalm 111:10

VOLUME 66, NUMBER 1 **MARCH 2014**

(US ISSN 0892-2675) (CPM #40927506)

Perspectives on Science and Christian Faith (ISSN 0892-2675) is published quarterly for $50 per year by the American Scientific Affiliation, 55 Market Street, Ste. 202, PO Box 668, Ipswich, MA 01938-0668. Phone: 978-356-5656; Fax: 978-356-4375; asa@asa3.org; www.asa3.org

Periodicals postage paid at Ipswich, MA and at additional mailing offices. POSTMASTER: Send address changes to: American Scientific Affiliation, PO Box 668, Ipswich, MA 01938-0668.

Manuscript Guidelines

The pages of *Perspectives on Science and Christian Faith (PSCF)* are open to original, unpublished contributions that interact with science and Christian faith in a manner consistent with scientific and theological integrity. Published papers do not reflect any official position of the American Scientific Affiliation.

1. Submit all manuscripts to: **James C. Peterson, Editor, Roanoke College, 221 College Lane, Salem, VA 24153.** E-mail: jpeterson@roanoke.edu. Submissions are typically acknowledged within 10 days of their receipt.
2. Authors must submit **an electronic copy of the manuscript formatted in Word** as an email attachment. Typically 2–3 anonymous reviewers critique each manuscript considered for publication.
3. Use endnotes for all references. Each note must have a unique number. Follow *The Chicago Manual of Style* (16th ed., sections 14.1 to 14.317).
4. While figures and diagrams may be embedded within the Word text file of the manuscript, authors are required to also send them as individual electronic files (JPEG or TIFF format). Figure captions should be provided as a list at the end of the manuscript text. Authors are encouraged also to submit a sample of graphic art that can be used to illustrate their manuscript.

ARTICLES are major treatments of a particular subject relating science to a Christian position. Such papers should be at least 2,000 words but **not more than 8,000 words in length**, excluding endnotes. An abstract of 50–150 words is required. Publication for such papers normally takes 9–12 months from the time of acceptance.

COMMUNICATIONS are brief treatments of a wide range of subjects of interest to *PSCF* readers. Communications **must not be longer than 2700 words**, excluding endnotes. Communications are normally published 6–9 months from the time of acceptance.

BOOK REVIEWS serve both to alert readers to new books that appear significant and to engage these books in critical interaction. When a subject area editor selects a book for review, the book is then offered to a scholar with the best match in expertise. ASA/CSCA members who would like to be considered as potential reviewers are welcome to express interest to the book review coordinating editor for inclusion in the reviewer database. Publishers may also contact the book review coordinating editor if they are not sure which subject area reviewer would best consider a particular book.

- **Patrick Franklin** (patrick.franklin@prov.ca): book review coordinating editor; subject areas: ethics, philosophy, and theology.
- **Arie Leegwater** (leeg@calvin.edu): cosmology, engineering, history of science, mathematics, non-biotechnologies, and physical sciences.
- **Robin Rylaarsdam** (rrylaarsdam@ben.edu): biology, environment, genetics, and origins.
- **Angela Sabates** (a-sabates@bethel.edu): anthropology, psychology, and sociology.

The viewpoints expressed in the books reviewed, and in the reviews themselves, are those of the authors and reviewers respectively, and do not reflect an official position of the ASA.

LETTERS to the Editor concerning *PSCF* content may be published unless marked not for publication. Letters submitted for publication **must not be longer than 700 words** and will be subject to editorial review. Letters are to be submitted as electronic copies. Letters accepted for publication will be published within 6 months.

ADVERTISING is accepted in *PSCF*, subject to editorial approval. Please address inquiries for rates or further information to the Managing Editor. The ASA cannot take responsibility for any orders placed with advertisers in *PSCF*.

AUTHORIZATION TO PHOTOCOPY MATERIAL for internal, personal, or educational classroom use, or the internal or personal use of specific clients, is granted by ASA, ISSN: 0892-2675, provided that the appropriate fee is paid directly to Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923 USA for conventional use, or check CCC online at the following address: www.copyright.com/. No registration with CCC is needed: simply identify the article being copied, the number of copies, and the journal title (*Perspectives on Science and Christian Faith*). For those who wish to request permission for other kinds of copying or reprinting, kindly write to the Managing Editor.

Editorial

Have I Got a Job for You

James C. Peterson

Have I got a job for you. It demands high expertise in your field, openness to new ideas, discernment, time, and skilled communication. There is no pay and I will be the only person other than you who will know that you have done it. Ready to sign up?

The above is a partial description of doing blind peer review. The journal and its readers depend on it. It is a crucial task, but when I ask people to do anonymous peer review, I sometimes feel as if I am distantly echoing Churchill's call to the British people that "I have nothing to offer but blood, toil, tears, and sweat." And yet, scholars rise to the occasion. Each colleague that I ask so to serve almost always says yes, and does it with insight and alacrity.

They know that I send out for peer review, essays that have genuine potential. They are going to see something, maybe in raw form, that will probably be fresh and interesting. They know that being asked is recognition that they have the expertise to help shape their field, and that such service can be referenced on their resume. They know that they are providing a crucial service for the author, helping her or him to develop the work. They know that they are saving the journal readers' time and spurring their thought. They know that each discipline progresses when the best ideas are brought forward and that such both honors and extends the kingdom. And that last point, most of all, is enough.

Once a year we do publish an august list of peer reviewers who have expertly and generously given of their time in the previous year. A hearty thank-you to each one who so well served in this way in 2013.

James C. Peterson, *Editor*

Reviewers in 2013

We wish to thank the following scholars for their crucial service in anonymous peer review.

Robert Bishop
Hessel Bouma
Jeanne Bundens
Clayton Carlson
Jack Collins
David Delaney
Chris Dovolis
Harold Faw
Louise Freeman
Owen Gingerich
Brian Gruel
Douglas Harink
Allan Harvey
Noreen Herzfeld
Russ Howell
Randy Isaac
Michael Janzen
David Koetje
John Kok
E. C. Krupp
Arie Leegwater
Tremper Longman
Heather Looy
Robert Mann
April Maskiewicz
Keri McFarlane
Keith Miller
George Murphy
Philip M. Novack-Gottshall
Don Page
Christopher Peet
Alvin Plantinga
Peter Ramberg
Robin Rylaarsdam
Rick Schaeffer
Kevin Seybold
Arnold Sikkema
David Snoke
William Struthers
Judy Toronchuk
Bruce Waltke
Paul Wason
David Wilcox
Leanne Willson
Theresa Zolner

Robert B. Mann

Article

Physics at the Theological Frontiers

Robert B. Mann

The rapid pace of progress in physics in recent decades has brought not only significant changes in our technology and economy, but has also provided us with new perspectives on reality, perspectives that have implications for Christian faith. I discuss five major points of contact in the relationship between physics and Christian theology: typicality, plurality, reduction, quantization, and eternity. These ideas influence thinking at the forefront of physics today, and have interesting implications for Christian faith. I shall outline the meaning of these ideas, relevant recent experimental and theoretical developments, and some new questions for theological exploration and reflection. The goal is to generate further dialogue and research in the science/faith endeavor. The essays that follow in this theme issue helpfully begin to address some of these questions and raise yet more related ones.

One of the more exhilarating aspects of being a scientist is the continual novelty of discovery. This most commonly takes place in very specialized ways, with advances being made incrementally in a multitude of subdisciplines. Yet, from time to time, all scientists step back to take a broader look at progress made in their discipline as a whole, assessing its implications and directions for further work. This big-picture perspective is taken with increasing frequency, primarily because scientific progress in many fields is proceeding at such a rapid pace.

Robert Mann *has a BSc in physics from McMaster University and an MSc and PhD from the University of Toronto. Currently a professor of physics at the University of Waterloo, he has been a visiting researcher at Harvard University, Cambridge University, and the Kavli Institute for Theoretical Physics. He was president of the CSCA from 1996–2007 and chair of the Department of Physics and Astronomy at the University of Waterloo from 2001–2008. He is president of the Canadian Association of Physicists and was on the Advisory Board of the John Templeton Foundation. His research interests include black holes, cosmology, particle physics, quantum foundations, and quantum information. Married with one daughter, he is a member of the Waterloo-Kitchener United Mennonite Church in Waterloo, Ontario, where he regularly teaches Sunday School. For recreation he enjoys video making, cross-country skiing, cats, dogs, cycling, and acting in musicals.*

Such expansive overviews provide interesting points of contact with theology. New insights and new challenges for a theological perspective on the world are available for those willing to invest the time to reflect deeply on the broad meaning of existence. The mind-sciences, life-sciences, and physical sciences each provide their own particular forms of input for theological reflection.[1] Conversely, theology offers the prospect of enhancing one's worldview beyond the empirical and the quantitative in novel and refreshing ways.

This article is particularly concerned with physics, its latest developments, and how these might further enrich the science/theology dialogue. Rather than attempt to resolve the possible insights and questions, the purpose of this essay is to raise the issues in a context that encourages discussion. No attempt is made either to define the field or to claim mastery of it. Rather, the goal is to draw people who specialize in physics to think about the implications of some of the latest developments for the Christian faith and to pique interest from scientists in other disciplines to find out what is going on.

I shall proceed by discussing five major points of contact in the physics/theology interface—typicality, plurality, reduction, quantization, and eternity—that have been affected by recent experimental and theoretical developments. Each of the preceding five terms will be explained in context, describing the main issues at stake, the recent scientific developments pertinent to the topic, and the various theological questions and discussion points that emerge.

Typicality

One of the most fruitful advances in scientific thinking was the realization that our planet does not occupy a privileged place in the solar system. This idea, first proposed by Nicolaus Copernicus, asserted that the sun, instead of the earth, was at the center of the solar system.[2] Reasoning from this hypothesis provided a more coherent and technically satisfying explanation for the observed retrograde motion of the planets than did the Ptolemaic system.

The implications of this idea for both science and faith have redounded through the centuries, systematically revising our worldview.[3] So named by Hermann Bondi in the mid-twentieth century, the *Copernican principle* has had its greatest influence in cosmology, where it has been indispensable in providing a paradigm for interpreting observations concerning our universe.[4] For example, from the observation that our universe is isotropic (that it appears to have approximately the same large-scale structure in any direction), it is straightforward to reason, using the Copernican principle, that our universe is homogeneous at any given time, and so must be isotropic about any point in space (and not just our own earth-bound position). These conditions of homogeneity and isotropy are the primary testable consequences of the cosmological principle, which states that the properties of the universe, viewed on a sufficiently large scale, are the same for all observers.[5]

It is more or less folkloric that the Copernican principle is in conflict with Christian theology. While the high point of this conflict is generally regarded as being epitomized in the dispute between Galileo and the Catholic church,[6] the notion that the Copernican principle should be regarded as a demotion of humankind[7] (and by implication, undermining Christian theology[8]) was not asserted until a century after Copernicus's death by Cyrano de Bergerac, who associated (without citing evidence) the geocentric Aristotelian/Ptolemaic model with "the insupportable arrogance of Mankind, which fancies, that Nature was only created to serve it."[9] Bernard le Bovier de Fontenelle advanced this viewpoint further, praising Copernicus for demolishing "the Vanity of men who had thrust themselves into the chief place of the Universe."[10] By 1810 Goethe asserted, "No discovery or opinion ever created a greater effect on the human spirit than did the teaching of Copernicus, [since it required humankind] to relinquish the colossal privilege of being the center of the universe."[11] More recently, a classic textbook on general relativity by Hawking and Ellis asserts,

> Since the time of Copernicus we have been steadily demoted to a medium sized planet going round a medium sized star on the outer edge of a fairly average galaxy, which is itself simply one of a local group of galaxies. Indeed we are now so democratic that we would not claim that our position in space is specially distinguished in any way.[12]

Not only has this general perception persisted to the present day, but the Ptolemaic model is also still promoted in terms of representing humankind as "the pinnacle of God's creation," rhetorically linking monotheistic perspectives to backward scientific thinking.[13]

The Copernican principle is an irreducible philosophical assumption, one whose implications go well beyond cosmology. Indeed, many take it to mean that a core principle of science must be that of typicality, namely, that the outcome of any experiment must be interpreted using the assumption that we are typical observers.[14] This perspective motivates much modern work where details of its deployment in string theory, inflationary cosmology, and quantum physics are debated in the scientific literature.

Yet the Copernican principle evidently has limitations. Applying it temporally, Bondi and Gold used it to argue that the universe is homogeneous in time as well as space, the so-called "perfect" cosmological principle.[15] The steady-state cosmological model that is founded on this idea is in strong disagreement with observation, which indicates that our universe is undergoing cosmological evolution from markedly different conditions at a particular time (known as the Big Bang) to a future state whose conditions again differ radically from what we observe today. Is it time for a reassessment of the applicability of the Copernican principle and its theological implications?

There is a dynamic tension in Christian theology between typicality and uniqueness. The Savior who reminds us that it rains on the just and the unjust[16] also brings us the good news that the hairs on our heads are numbered by a loving God.[17] How do we effectively articulate a theology of God's love for each person in the light of the perceived secular "demotion" of humanity? To what extent should Christian theology humbly incorporate new scientific findings interpreted through the lens of typicality, and to what extent should a prophetic voice step forth to challenge the secular anthropological zeitgeist connected with modern cosmological thought? Can human significance be given a scientific basis? If not, then how can its refutation be founded on scientific findings? Is atypicality a testable concept? If so, what would be the implications for Christian faith? Conversely, is typicality falsifiable, or must we simply accept it as intrinsic to all of modern science? And if we do, whither is our understanding of God's relationship to humanity?

Dennis Danielson, who has pointed out that the Copernican principle does not carry the misanthropic interpretation that many modern scientists ascribe to it, has started some reassessment of this work.[18] Scientifically, there have been a few recent ideas suggesting how the Copernican principle could be subjected to new scientific tests, insofar as we might be able to discern more directly the extent to which the universe is indeed spatially homogeneous;[19] alternatively, if we are located at the center of a cosmic void, we would indeed be in a "privileged" location.[20] The outcome of such experiments and observations, should they be carried out, will surely have implications as profound as that of Copernicus's original insight. The ongoing implicit theological challenge of the Copernican principle is that of understanding our significance in a universe that can appear so harshly indifferent to human beings.

Plurality

The Copernican insight that our planet is one among several orbiting the sun inspired Giordano Bruno to propose that our universe is infinite, containing many suns and planets. The relative importance of this view (compared to other heresies Bruno held) as the rationale for the Roman Inquisition sentencing him to be burned at the stake, has been a point of historical debate.[21] Yet it is clear from the documentation of Bruno's trial that his cosmological ideas regarding the scope of the universe and the plurality of worlds were a nagging concern of his inquisitors.[22]

A number of cosmologists and particle physicists are reconsidering Bruno's idea in an extreme form, replacing the plurality of worlds with a plurality of universes. Known as multiverse cosmology, the idea that our observable universe is a small part of a much, much larger structure[23] raises new challenges for science, theology, and the relationship between them that go far beyond what Bruno and his inquisitors might have imagined.

Scientifically, the motivation for this idea emerges from the meta-observation that our cosmos is not a generic specimen from a warehouse of possible universes,[24] but instead has rather atypical features conducive to the existence of life and the cosmos as a whole.[25] Specifically, the physical laws, initial conditions, and particular structures of our universe are in a delicate state of balance: a small relative change in one parameter (e.g., the mass of the proton or the expansion rate of the universe[26]) results in a cosmos inhospitable to life,[27] looking nothing like the one we see.[28] A desire to ensure Copernican typicality has in recent years motivated an increasing number of scientists to consider the multiverse as the underlying scientific description of reality.[29] Its proponents generally rely further on string theory[30] and cosmic inflation,[31] regarded respectively by many as the best paradigms for uniting quantum theory with gravity and for describing our cosmos. String-theory calculations recently suggested that at least 10^{500} kinds of low-energy types of universes were possible (each with its own particular properties). Cosmic inflation, having indirect support from observations of the cosmic microwave background, is regarded by many as being most naturally described in a multiverse context.

This "super-Copernican" revolution merits a healthy dose of skepticism from both scientific and theological perspectives, as I have advocated elsewhere.[32] Scientifically, the necessary breadth of theoretical perspective, combined with the obvious empirical limitations of observing other universes, is implicitly redefining what is meant by science.[33] Theologically, it introduces a new question: why is there something instead of everything?[34]

These are interesting questions to pursue, to be sure. But one need not, and should not, accept at face value the ostensible merits of the multiverse without properly assessing its epistemic costs. From a scientific perspective, the relationship between observation and theory takes on a whole new character (since the idea relies on a wealth of empirically unverifiable precepts), and the distinction between potentiality and actuality becomes blurred, if not lost (since the ensemble of universes needs to be physically instantiated for our universe to have a chance of being a typical member). From a theological perspective, the theodicy problem becomes far more acute (since there can be unbounded replication of tragic events), and the possibility of ascribing any form of transcendent meaning or purpose in the context of a loving God becomes very remote (since existence itself actualizes otherwise exclusive possibilities).

There is a tension here between acknowledging God's sovereign ability to create in abundance with God's purposeful intentions for creation (as in Isaiah 46:9–10). A theory of everything is not the same as a theory of anything,[35] nor is a God that *can* create anything the same as a God that *does* creates everything.[36] A proper assessment of the merits of the multiverse will require a true blend of clear thinking in the overlap between science and theology.

If the multiverse is too speculative and extreme a realization of plurality, recent advances in astronomy are bringing Bruno's expectations much closer to home. Over one thousand extrasolar planets have been confirmed by observation, with more than 2,600 other objects as likely candidates. One hundred sixty-two different planetary systems analogous to our own solar system have been discovered so far. NASA's Kepler mission is making extraordinary advances, affirming the expectation that planetary systems are common in our galaxy (and presumably so in other galaxies).[37] At the end of 2011, discoveries of the earth-sized planets Kepler 20-e and Kepler 20-f were announced, along with the discovery of Kepler 22-b, a planet located in the habitable zone about its star. While these candidates fail other tests for habitability (20-e and 20-f being too close to their star, and 22-b being too large), it would seem only a matter of time—perhaps less than a few years—before a planet is found possessing all of Earth's habitable characteristics. As of this writing, there are twelve "superterran" exoplanets: considerably larger than Earth, though within what is thought to be the habitable zone about their star. There are no Earth-sized potentially habitable candidates at present.[38]

This would be the first empirical evidence that we may very well not be the sole inhabitants of our galaxy. Should evidence for life be found on such a world (or even perhaps elsewhere in our solar system), it would more strongly affirm the ubiquity of life throughout the universe. Such discoveries will have a profound impact on humanity's self-assessment of its place in the universe.[39]

While secularists will undoubtedly point to this as increasing evidence of a godless universe governed by blind evolutionary processes, such assertions miss the point that our quest for extra-solar life is of a deeply religious nature. There is an opportunity here for Christians to raise interesting ethical and theological questions, questions that go well beyond recognition of the generous creative power of God. How far can we extend the concept of the *Imago Dei*, that we are made in God's image? What proper social and ethical controls should be exerted over communication with alien species, should this be possible? What kinds of reinterpretations need to be made with regard to the creation/evolution dialogue? How do we interpret the plan of salvation in the context of life on other worlds?

While the exploration of alien life from a Christian theological perspective is not new,[40] the subject has, by and large, been left to secular writers and Hollywood filmmakers to shape our societal perspectives on this issue. The input of new information from the Kepler probe offers an opportunity to revisit the question of plurality afresh, seeing what genuine new insights and reliable truth the gospel might have to offer.

Reductionism

A key motivator underlying all scientific thought is unification: the notion that apparently disparate phenomena can be understood as different aspects of the same phenomenon at some deeper level. Historically, it has been scientifically quite fruitful to seek unification, particularly in physics, even though there is no proof that this strategy will work. Newton united terrestrial phenomena with celestial phenomena via his universal law of gravitation that governed the motion of both apples falling to earth and stars moving in the sky.[41] Maxwell united electricity and magnetism, once thought to be distinct phenomena, in a single theory describing them as a unified force that we now call "electromagnetism."[42] Four decades ago, weak interactions governing the phenomenon of radioactivity were united with electromagnetism in a single theory, "electroweak theory," that made a number of new predictions that have since been confirmed experimentally.[43]

We now have a Standard Model of particle physics,[44] a set of mathematical equations that describe all known subatomic particles (quarks and leptons) and their interactions due to the strong (or nuclear) force and electroweak forces.[45] High-energy accelerator and low-energy precision experiments have repeatedly confirmed this model. The last outstanding bit of information remaining was the Higgs particle, a particle whose interactions with all other known particles give rise to what we measure as their masses. In 2012, the Large Hadron Collider (LHC) announced the discovery of a particle with a mass 125 times heavier than the proton, a particle that has all of the expected properties of the Higgs particle.[46]

While further testing will need to be done to confirm that the interactions of this particle with other forms of matter agree with the predictions of the Standard Model, this finding is indeed a triumph for reductionistic science. Like a twenty-first-century version of the chemical periodic table, it leads, for the first time, to a fully comprehensive description of all known matter and forces. Nevertheless, particle physicists will remain much less than satisfied with this final confirmation of the Standard Model. For although the Standard Model self-consistently describes all that is known about particle physics, it depends on twenty-seven distinct parameters (twelve of which are the different masses of the twelve elementary subatomic particles, for example), each of which must be determined by experiment. No deeper principle explaining their values is known. Furthermore, cosmological observations of the orbital motions of galaxies in clusters and of the accelerating expansion of our universe have led to the view that only a little less than 5% of the mass-energy of the universe is composed of known (Standard Model) matter, most of which is gas and dust. The remaining portion is about 26.8% dark matter (matter that does not interact with light or electromagnetism and so cannot be directly observed by traditional astronomic means) and 68.3% dark energy (the name given to whatever diffuse energy source is causing the universe to accelerate).

For these reasons, most particle physicists believe that a deeper level of unification beyond the Standard Model is required. The search for a "Theory of Everything," a single theory describing all known (and currently undiscovered) particles and forces in a coherent unified whole, has occupied the attention of theoretical physicists for over three decades. The simplest model of a grand unification uniting the electroweak and strong forces predicted that the proton was not stable, decaying with a very long but feasibly observable lifetime.[47] No evidence for this decay was found in subsequent experimental searches. Instead, lower bounds were set on the proton lifetime.[48] Many more Grand Unified Theories (or GUTs as they are called) have since been constructed, each with its own predictions for low-energy (and sometimes early-universe) physics. Superstring theory was originally regarded as the most promising GUT,[49] as it held out the promise of also uniting gravitation with the other forces in a manner consistent with quantum mechanics.

To the frustration of the scientific community, no evidence whatsoever has thus far been found in their favor; instead, only various empirical bounds and limits on GUTs have been set. While many still pin their hopes on the final round of LHC experiments as revealing some new phenomenon, there is no guarantee that anything beyond the Standard Model will be found.

Reductionism elicits extreme responses within the scientific community. Nontheists generally regard this approach (affirmed at least by the success of the Standard Model) as closing off any last gaps in which hopeful believers might want to place evidence for a deity. Theists have generally regarded the deep mathematical intelligibility that has emerged from reductionistic physics as evidence in favor of a Creator, partially reflecting the mind of God for those willing to see.[50]

Must science and theology stand on opposite sides of such a wide intellectual chasm? Or is it possible to build a bridge of new understanding here? What, if any, are the limits of reductionism? How does science proceed in the face of such limitations? What metaphysical interpretations might be drawn in this case? Alternatively, is it possible to go beyond intelligibility in understanding a Creator who values mathematical elegance to One who loves creation sacrificially? How is the God of the Standard Model the God of Calvary?

Quantization

One of the central lessons of twentieth-century physics resulting from a reductionist paradigm was that the natural world is not fully atomized. Localized atoms, nuclei, and subatomic particles can behave as extended waves, and delocalized wavelike phenomena, such as light, can behave as particles. This schizophrenic wave/particle behavior is described by quantum mechanics.[51] The Standard Model is a quantum theory, more properly, a quantum field theory that regards point-like particles as quantum excitations of fields; the photon, for example, may be treated as a quantized excitation of electromagnetic field, or more simply, a tiny bundle of light.

Indeed, the foundational laws governing nature blur the distinction between individual things and their surroundings. This blurring of distinction between the subsystems of a system is called "entanglement," and the theory describing this is called "quantum mechanics." It has surprising implications for how we understand the natural world. It is so powerful that it alters the laws of probability from the everyday world as we know it. Consider two fair coins, one given to Alice and the other to Bob. Let each flip their respective coins repeatedly for many trials and then keep track of the results. If Alice gets heads, Bob has a 50/50 chance of getting heads or tails, no matter what Alice gets. And vice versa. Such is the normal behavior of random processes in the everyday world.

Now consider what would happen if it were possible to quantum mechanically entangle the coins. The results would be strikingly different. In one possible form of entanglement (there are many), Alice still has a 50/50 chance of getting heads—but whenever she gets heads, Bob also gets heads. And whenever she gets tails, Bob also gets tails. It is as though each coin "knows" what the other is doing, even though the coins send no signals to each other. Each coin maintains its individual integrity—for each coin, heads comes up as often as tails, with a 50/50 chance. Yet there is no chance of a head/tail or tail/head combination. The pair of entangled coins does not behave as two distinct coins, but rather as a system that exhibits "togetherness in separation." The whole truly is greater than the sum of the parts.

This holistic feature of quantum entanglement can be shown to imply a certain degree of ambiguity or indefiniteness to existence itself, overturning not only commonsense, but all conventional ways of thinking about science as well.[52] It troubled many physicists, most notably Albert Einstein, who refused to believe that nature could be like that.[53] Yet this spooky form of interconnectedness has been repeatedly verified in laboratories around the world, most commonly with polarized photons as the quantum coins, "heads" being a left-circularly polarized photon and "tails" being a right-circularly polarized one.[54] By shining light of a particular frequency through a nonlinear crystal, a pair of light rays of reduced frequency can emerge (a process known as spontaneous parametric down-conversion), and a percentage of the photons in these rays can have their polarizations entangled, affording a verification of the strange coin-flip scenario above.[55]

The implications of quantum entanglement are profound. At a practical level, it can be exploited to encode and transmit information in completely novel ways. This realization has given rise to a whole new research field known as "quantum computing," whose goal is to exploit the properties of quantum theory to transmit, encode, and process information. So far the field is still rather young, though rapid progress is being made. The stakes are high, with unbreakable security codes, teleportation, and solving otherwise unsolvable math problems as prospective outcomes of the endeavor.[56]

Quantum entanglement also has profound philosophical consequences, implying that interconnectedness is a central feature of existence. It is so central that the relationships between the bits and pieces of nature can produce effects that each bit or piece on its own cannot produce. Nature is intrinsically relational. Here the discussion can take a theological turn, insofar as this feature is what we might expect from a creation reflecting the character of its Creator, who, as Father, Son, and Holy Spirit, is most profoundly a personal and relational God.

Theologians for centuries have struggled with a problem similar to that faced by scientists confronted with quantum entanglement, namely, that of understanding the nature of the Trinity. Known as perichoresis, it is a dazzlingly paradoxical concept, and refers to the mutual indwelling and interpenetration of the Persons of the Trinity. The eighth-century Syrian Christian monk, John of Damascus, described it as a cleaving together in a fellowship of mutual love.[57] The Persons of the Trinity are not simply different aspects of one Person, a perspective that would not do justice in understanding, say, the baptism of Jesus. Nor are they so distinct as to be a sort of stripped-down polytheism, a committee of three gods. Perichoresis rather asserts both the individual integrity of Father, Son, and Spirit and the indivisibility of the one true God.

Here is new territory for science and Christian faith to explore.[58] Indeed, a fruitful and stimulating dialogue is taking place between scientists and theologians as to the consonant relationship between perichoresis and entanglement. Scientists such as Anton Zeilinger and Jeffrey Bub, and theologians such as Sarah Coakley and John Zizioulas, have gathered under the leadership of the Anglican physicist-turned-priest Sir John Polkinghorne to carry out research in these matters. A genuine theological and scientific dialogue is going on, one that is far removed from the more traditional conflict/apologetic stances.[59]

At a more prosaic level, the economic and societal impacts of quantum entanglement are novel and potentially far reaching. Quantum computation will radically change how we store, transmit, and process information. How we make use of this new technology is a question that necessarily goes beyond science. Insofar as we will be faced with new choices presented to us, we have new opportunities to be the salt of the earth and the light of the world. A science/faith dialogue on the proper uses of such new information technology is (as with any application of science) of perhaps even greater import than advancing our theological understanding.

Eternity

All attempts thus far to understand gravity in quantum mechanical terms have failed. While a majority of theoretical physicists still regard string theory as the most promising approach for addressing this problem, there are a number of competing ideas. Indeed, an understanding of quantum information in the context of gravitation has become a subdiscipline in its own right. Although at this point far removed from experiment, such ideas raise questions about the foundations of reality, a subject never far from a theological worldview. They suggest that the relationship between creation and the Creator is exceedingly subtle and complex.

Perhaps the most difficult conundrum here is that of time.[60] Every civilization throughout history has had to come to grips with how it marks the passing of the seasons and the advancement of years. However, it is at the birth of modern science that a debate takes place concerning the nature of time and its relevance to scientific understanding. One view, expressed by Newton, is that time is an external "thing" that clocks measure, flowing like an inexhaustible river.[61] The other view, articulated by Leibniz, is that time has no ontic reality of its own, but rather serves as an ordering parameter, with its sequencing of events bearing no more significance than the alphabetical ordering of names in a telephone book.[62] The Newtonian notion of time best corresponds to everyday intuition, and, for the most part, held sway in the practice of science. However, the twentieth-century revolutions of quantum physics and relativity have modified our understanding of time, both pragmatically and philosophically.

The key lesson of relativistic physics is that measurement of time is observer dependent, differing between observers having different relative speeds and/or different locations in a gravitational field. Time and space are woven together in a structure called "spacetime," whose properties and behavior are very accurately described by Einstein's theory of general relativity. Contrary to everyday experience (which is the way it is only because relativistic effects require high speeds and/or intense gravitational fields to be significant), both the duration of events and their simultaneity (the notion of "now") is not something universal. This is perhaps the hardest thing to understand about relativity.[63] Yet the Einsteinian theory that describes such effects has been repeatedly verified in many high-precision experiments, and today their proper incorporation into the rest of physics is required in order for the global positioning system to function properly.

The situation stands in stark contrast to the quantum-mechanical perspective, in which time is an ordering parameter demarcating the change of quantum systems (or states) from the past into the future. Quantum mechanics is highly compatible with a Newtonian nonrelativistic view of time. The paradoxical quantum effects of tunneling, wave-particle duality, and entanglement are all most straightforwardly explicated in this context. The union of quantum mechanics with special relativity took several decades to fully achieve, and led to what is now called "quantum field theory." Its early triumph was to successfully predict the existence of antimatter. Quantum field theory is the underlying mathematical structure of the Standard Model (discussed above). All particle physics experiments make use of it to interpret their data, and so far they have yet to contradict the Standard Model's predictions.

However, as noted above, all efforts to incorporate this same mathematical structure with general relativity have failed. This, in large part, is due to their very distinct conceptualizations of time. For example, quantum theory cannot be formulated without a clear and sharp distinction between past, present, and future. Yet one expects that a quantum gravity theory will yield a kind of wave/particle duality description of spacetime itself, blurring this distinction. To make matters worse, all predictions emerging from quantum field theory entail a systematic removal of infinite quantities that appear in calculations of various scattering processes (e.g., if an electron scatters off a muon), a procedure known as "renormalization." This troubling feature of quantum field theory is one its original practitioners were never happy with, though it did yield results that agreed with experiment. However, the same procedure applied to gravity fails miserably, yielding a theory with no predictive power. While there are many ideas as to how these problems can be addressed (string theory being the most popular), there is no clear resolution to this issue at present.[64]

A biblical picture of time yields a similar tension between dual concepts: we read of God being eternal, the Alpha and the Omega, transcending time in a manner that we can only dimly grasp.[65] Augustine proposed that time itself is created, something subservient to God as is the rest of creation.[66] Yet we also read of God lovingly interacting with the creation and its human inhabitants, conversing with them, challenging them, directing them, and providing them with a prophetic message. We puzzle at the notion of a God with foreknowledge who appears to change his mind.[67]

The active discussions in the theoretical physics community today on the nature of time can provide fertile ground for theological reflection. Properly treated, dialogue between theology and science can perhaps provide a deeper understanding or a more creative perspective on the nature of reality. In what follows, I shall sketch out some of the points of contact between science and theology on the nature of time.

The difficulties in obtaining a quantum description of gravity have led to the notion that time itself is perhaps "atomized." The idea here is that quantum gravitational effects will make it impossible to measure any time shorter than 10^{-43} seconds, a quantity known as the Planck time. Simply put, any clock attempting to measure time intervals shorter than this will be subject to gravitational effects so powerful that it will collapse into a black hole. A similar argument can be made for attempting to measure distances shorter than the Planck length of 10^{-35} meters (the Planck time multiplied by the speed of light). Perhaps it is simply not meaningful to consider time intervals shorter than the Planck time.

Yet, if this is accepted, what happens "in between" these intervals? Indeed, what sustains the existence of the universe in such intervals? Such an idea resonates with the notion of *creatio continua*, the ongoing activity of the initial creation out of nothing. The coherence of physical law over times (and distances) larger than this quantum limit is reflective of the integrity of nature and its ability to autonomously exercise its God-given causal powers, whereas the existence of such intervals perhaps speaks to the intimate moment-by-moment dependence of the creation on the Creator.

The directionality, or arrow, of time is another great puzzle at the roots of physics.[68] The laws of Newtonian physics are unchanged if the direction of time is reversed, so why does time "move forward"? In seeking to understand the arrow of time, physicists have identified seven different arrows—cosmological, thermodynamic, radiative, gravitational, metrological, subatomic, and psychological—whose deep explanations are still elusive. While we cannot rule out that they are all different aspects reflecting some underlying principle, each has its own distinctive manifestation in our world.

The cosmological arrow refers to the observation that the universe is expanding as time increases. That entropy, a measure of disorder, never decreases in any physical process constitutes the thermodynamic arrow. The radiative arrow refers to the observation that sound, light, and any other radiative phenomena always diverge outward (think of waves rippling outward after a pebble is dropped in water) and never converge inward, though the latter situation is permitted by the equations of physics. That black holes absorb all forms of matter and emit nothing but random thermal radiation is indicative of a gravitational arrow. The metrological arrow refers to measurement of any quantum system—once carried out, quantum superpositions irreversibly separate, a process whose ontic meaning is still an active subject of debate. The laboratory observation that subatomic particles known as kaons disintegrate more slowly than their antiparticle counterparts (a phenomenon also seen more recently for other subatomic particles) implies a subatomic arrow of time. And, of course, the most common temporal arrow is that of our own psychology: we remember the past and anticipate the future.

Temporal directionality is congruent with a theological notion of purpose—that history, writ large and small, is "going somewhere."[69] While the cyclic rituals of time—seasons, festivals, and high days—play an important role in all religions, the notion of ultimate purpose is one that is indispensable to Christianity. The Bible is replete with examples of a cosmic purpose, whose origin and culmination reside in God. From the Alpha, who formed the earth to be inhabited, to the Omega, who will make all things new, God's cosmic purpose unfolds along time's arrow for those having eyes to see. And this same testimony of faith also affirms that ultimately this cosmic purpose is one of love, in which God works all things together for good for the ones who love God, for each individual called according to his purpose.[70] There is certainly theological consonance between an arrow of time and the destiny of the cosmos. To the extent that scientific inquiry can provide information about interesting new connections between the various arrows of time, there is potential for deepening our theological understanding. Conversely, further theological reflection on the cosmic *telos* has the potential to broaden our appreciation and insight into the natural world and its directionality.

The notion that there is an ultimate destiny for the cosmos leads to the scientific question as to what the ultimate fate of the universe shall be. Here the picture from science over the past two decades has been considerably refined, amplified, and revised, pivoting around the observation that our cosmos is accelerating in its expansion. The source of this cosmic acceleration is referred to as "dark energy," whose structure and origin are currently under active investigation. Notwithstanding the outcome of such study, the long-term picture is one of puzzling gloom: puzzling because evolved carbon-based life can only exist in the earliest stages of the history of an accelerating cosmos, leading to the anti-Copernican implication that we live at a special time in cosmic history; and gloomy because no known laws of physics permit any other reasonable form of life to survive in an accelerating universe over any substantive fraction of its history—all sources of energy eventually become inaccessible. In the long run, we really are all dead.

Such notions require a considerable degree of unpacking, both scientifically[71] and theologically.[72]

It has already been noted that our scientific understanding of the destiny of the cosmos is considerably more threatening theologically than our corresponding understanding of its origins. How can we understand cosmic purpose in a universe condemned to dilute itself into virtual nothingness? What message of gospel hope can be proclaimed in such a context? In what manner might we expect a new heaven and a new earth?

Of course, any answers to such questions need to be quite tentative and speculative. However, I am optimistic enough to think that appropriate theological reflection on the nature of time might provide new approaches for sharing the light of the gospel for the scientifically—and perhaps not so scientifically—inclined.

Acknowledgments

I am grateful to James Peterson for his encouragement in this project, and for many discussions over the years with G. Cleaver, G. Ellis, M. Gedcke, D. Humphreys, N. Mann, D. McNally, D. Page, J. Toronchuk, and J. Wiseman on a number of ideas that influenced my perspective on these issues.

Notes

[1]For a broad overview of how these kinds of issues offer a broad range of science, see N. Murphy and G. F. R. Ellis, *On the Moral Nature of the Universe* (Minneapolis, MN: Fortress Press, 1996).

[2]N. Copernicus, *De Revolutionibus Orbium Coelestium* (1543).

[3]T. Kuhn, *The Copernican Revolution* (Cambridge, MA: Harvard University Press, 1957).

[4]H. Bondi, *Cosmology* (New York: Cambridge University Press, 1952), 13.

[5]W. Keel, *The Road to Galaxy Formation* (UK: Springer-Praxis, 2007).

[6]For a recent biography of Galileo, see J. Reston, *Galileo: A Life* (New York: Harper Perennial, 1994).

[7]D. Danielson, "The Bones of Copernicus," *American Scientist* 97 (2009): 50.

[8]C. Sagan, *The Varieties of Scientific Experience: A Personal View of the Search for God,* ed. A. Druyan (New York: Penguin Press, 2006).

[9]Quoted in D. Danielson, "That Copernicanism Demoted Humans from the Centre of the Cosmos," in *Galileo Goes to Jail and Other Myths about Science and Religion*, ed. R. L. Numbers (Cambridge, MA: Harvard University Press, 2009), 57.

[10]Ibid.

[11]Johann Wolfgang von Goethe, *Materialien zur Geschichte der Farbenlehre* (Hamburg: Christian Wegner Verlag, 1810).

[12]S. W. Hawking and G. F. R. Ellis, *The Large Scale Structure of Space-Time* (New York: Cambridge University Press, 1973), 134.

[13]P. C. W. Davies, *Cosmic Jackpot: Why Our Universe Is Just Right for Life* (Boston, MA: Houghton Mifflin, 2007), 129.

[14]For example, see R. Bousso, B. Freivogel, and I-Sheng Yang, "Boltzmann Babies in the Proper Time Measure," *Physical Review* D, vol. 77, no. 10 (2008): 103514.

[15]H. Bondi and T. Gold, "The Steady-State Theory of the Expanding Universe," *Monthly Notices of the Royal Astronomical Society* 108 (1948): 252.

[16]Matthew 5:45.

[17]Matthew 10:31.

[18]D. Danielson, "The Great Copernican Cliché," *American Journal of Physics* 69, no. 10 (2001): 1029.

[19]J. Uzan, C. Clarkson, and G. F. R. Ellis, "Time Drift of Cosmological Redshifts as a Test of the Copernican Principle," *Physical Review Letters* 100 (2008): 191303.

[20]R. Caldwell and A. Stebbins, "A Test of the Copernican Principle," *Physical Review Letters* 100 (2008): 191302.

[21]See, for example, R. L. Numbers, ed., *Galileo Goes to Jail and Other Myths about Science and Religion* (Cambridge, MA: Harvard University Press, 2010).

[22]L. Firpo, *Il Processo di Giordano Bruno,* Document 51 (Rome: Salerno Editrice, 1993), 247–304.

[23]A recent overview of this subject is given in B. J. Carr, ed., *Universe or Multiverse?* (New York: Cambridge University Press, 2007).

[24]For the first comprehensive discussion of this, see J. D. Barrow and F. Tipler, *The Anthropic Cosmological Principle* (New York: Oxford University Press, 1988).

[25]For a philosophical analysis of these issues, see J. Leslie, *Universes* (New York: Routledge, 1996).

[26]W. J. Kaufman III, *Universe*, 4th ed. (New York: W. H. Freeman, 1993); S. Weinberg, "The Cosmological Constant Problems," in *Sources and Detection of Dark Matter and Dark Energy in the Universe*, ed. D. B. Cline (New York: Springer-Verlag, 2001), 18–26.

[27]B. Carter, *IAU Symposium 63: Confrontation of Cosmological Theories with Observational Data* (Dordrecht: Reidel, 1974), 291–8.

[28]B. J. Carr and M. J. Rees, "The Anthropic Cosmological Principle and the Structure of the Physical World," *Nature* 278 (1979): 605–12; R. Collins, "A Scientific Argument for the Existence of God: The Fine-Tuning Design Argument," in *Reason for the Hope Within*, ed. Michael J. Murray (Grand Rapids, MI: Eerdmans, 1999), 47–75.

[29]Davies, *Cosmic Jackpot*.

[30]M. B. Green and J. Schwarz, "Anomaly Cancellation in Supersymmetric d=10 Gauge Theory Requires SO(32)," *Physics Letters B* 149 (1984): 117; for some readable introductions to string theory, pro and con, see respectively Brian Green, *The Fabric of the Cosmos: Space, Time, and the Texture of Reality* (New York: Vintage, 2005); and Lee Smolin, *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next* (New York: Spin Networks, 2006).

[31]A. H. Guth, "Inflationary Universe: A Possible Solution to the Horizon and Flatness Problems," *Physical Review D* 23, (1981): 347–56; A. Linde, "A New Inflationary Scenario: A Possible Solution of the Horizon, Flatness, Homogeneity, Isotropy, and Primoridal Monopole Problems," *Physics Letters B* 108 (1982): 389; see also, A. Guth, *The Inflationary Universe* (New York: Basic Books, 1998).

[32]R. B. Mann, "The Puzzle of Existence," *Perspectives on Science and Christian Faith* 61, no. 3 (2009): 139–50.

[33]For a recent critique, see G. F. R. Ellis, "Does the Multiverse Really Exist?," *Scientific American* 305 (2011): 38.

[34]R. B. Mann, "Inconstant Multiverse," *Perspectives on Science and Christian Faith* 57, no. 4 (2005): 302–10.

[35]Or as John Polkinghorne put it, "If you allow yourself to hypothesize an almost unlimited portfolio of different worlds, you can explain anything," quoted in an article by T. Folger, "Science's Alternative to an Intelligent Creator: The Multiverse Theory," *Discover Magazine* (December 2008): published online November 10, 2008, available at http://discovermagazine.com/2008/dec/10-sciences-alternative-to-an-intelligent-creator.

[36]R. B. Mann, "Thinking of Everything," *Irreconcilable Differences*, ed. Jason Robinson (Toronto, ON: University of Toronto Press; forthcoming).

[37]W. J. Borucki et al., "Kepler Planet-Detection Mission: Introduction and First Results," *Science* 327, no. 5968 (2010): 977–80.

[38]A variety of websites provide weekly updates on the search for extrasolar planets. See http://phl.upr.edu for up-to-date lists of habitable planets, and http://exoplanetarchive.ipac.caltech.edu for the complete archive of all extrasolar planets.

[39]Similar questions presented themselves (at least implicitly) in the sixteenth–eighteenth centuries when European explorers and colonists encountered people of different languages and cultures in the Americas, Africa, and Australia. In this case, the "alien" encounter was between different cultures, too often producing tragic results.

[40]C. S. Lewis, *The Seeing Eye* (Grand Rapids, MI: Eerdmans, 1995).

[41]S. Chandrasekhar, *Newton's Principia for the Common Reader* (New York: Oxford University Press, 2003).

[42]J. C. Maxwell, "A Dynamical Theory of the Electromagnetic Field," *Philosophical Transactions of the Royal Society of London* 155 (1865): 459–512.

[43]S. L. Glashow, "Partial Symmetries of Weak Interactions," *Nuclear Physics* 22 (1961): 579; S. Weinberg, "A Model of Leptons," *Physical Review Letters* 19 (1967): 1264–6; A. Salam, "Elementary Particle Theory," *Nobel Symposium* 8, ed. N. Svartholm (Stockholm: Almquist and Wiksell, 1968), 367.

[44]For a nontechnical introduction, see L. M. Lederman and D. Teresi, *The God Particle: If the Universe Is the Answer, What Is the Question?* (New York: Houghton Mifflin Harcourt, 2006).

[45]For an introduction at an undergraduate level, see R. Mann, *Introduction to Particle Physics and the Standard Model* (Boca Raton, FL: Taylor & Francis, 2009).

[46]Adrian Cho, "Higgs Boson Makes Its Debut after Decades-Long Search," *Science* 337, no. 6091 (13 July 2012): 141–3; Atlas Collaboration, "Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC," *Physics Letters B* 716 (2012): 1–29.

[47]H. Georgi and S. Glashow, "Unity of All Elementary-Particle Forces," *Physical Review Letters* 32 (1974): 438–41.

[48]C. Amsler et al., "2008 Review of Particle Physics," *Physics Letters* B 667, no. 1 (2008).

[49]J. Ellis, "The Superstring: Theory of Everything, or of Nothing?," *Nature* 323 (1986): 595–8.

[50]See, for example, J. Polkinghorne, *Reason and Reality: Relationship between Science and Theology* (London: SPCK, 1991).

[51]For an introduction at an undergraduate level, see D. J. Griffiths, *Introduction to Quantum Mechanics* (Harlow Gate, UK: Pearson Education, 2014).

[52]For a professional account of some of the interpretive issues, see B. d'Espagnat, *Conceptual Foundations of Quantum Mechanics*, 2nd ed. (Boulder, CO: Westview Press, 1999).

[53]For an account of these issues, see J. Bub, "The Entangled World: How Can It Be Like That?," in *The Trinity and an Entangled World: Relationality in Physical Science and Theology*, ed. J. C. Polkinghorne (Grand Rapids, MI: Eerdmans, 2010), 15–31.

[54]Polarization refers to the kind of vibrations an electric or magnetic field undergoes when a body emits light. Any form of light can always be decomposed into two distinct kinds of polarization, known as left- and right-circular.

[55]A. Aspect, P. Grangier, and G. Roger, "Experimental Tests of Realistic Local Theories via Bell's Theorem," *Physical Review Letters* 47 (1981): 460–3.

[56]For an introduction, see M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information* (New York: Cambridge University Press, 2004).

[57]See J. Zizioulas, "Relational Ontology: Insights from Patristic Thought," in *The Trinity and an Entangled World*, ed. Polkinghorne, 146–56.

[58]J. C. Polkinghorne, *Quantum Physics and Theology – An Unexpected Kinship* (New Haven, CT: Yale University Press, 2007).

[59]J. C. Polkinghorne, "The Demise of Democritus," in *The Trinity and an Entangled World*, ed. Polkinghorne, 1–14.

[60]For an introduction to some issues for nonspecialists, see P. C. W. Davies, *About Time: Einstein's Unfinished Revolution* (New York: Simon & Schuster, 1995).

[61]I. Newton, *Principia: Mathematical Principles of Natural Philosophy* (1687), 3rd ed. (1726), trans. I. B. Cohen and Anne Whitman (1999), "Definitions: Scholium," 408–9.

[62]G. W. Leibniz, "Third Letter to Samuel Clarke," February 25, 1716, http://www.phas.ubc.ca/~berciu/PHILIP/TEACHNG/PHYS340/EXTRA/FILES/Leibniz-ClarkeA.pdf.

[63]For a fairly nontechnical introduction at an undergraduate level, see J. B. Hartle, *Gravity: An Introduction to Einstein's General Relativity* (Reading, MA: Addison-Wesley, 2003).

[64]For an introduction to some of the issues, see L. Smolin, *Three Roads to Quantum Gravity* (New York: Basic Books, 2002).

[65]Revelation 1:8.

[66]St. Augustine, *Confessions*, bk. 11, chap. 13.

[67]Genesis 18:23–33.

[68]H. D. Zeh, *The Physical Basis of the Direction of Time* (Berlin: Springer-Verlag, 2001).

[69]J. Templeton, ed., *Evidence of Purpose* (New York: Continuum, 1994).

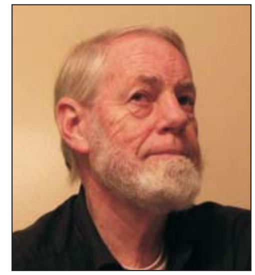
[70]Romans 8:28.

[71]G. F. R. Ellis, ed., *The Far-Future Universe: Eschatology from a Cosmic Perspective* (West Conshohocken, PA: Templeton Foundation Press, 2002).

[72]J. C. Polkinghorne, *The God of Hope and the End of the World* (New Haven, CT: Yale University Press, 2002).

ASA Members: Submit comments and questions on this communication at www.asa3.org → FORUMS → PSCF DISCUSSION.

Article



Dillard W. Faries

A Personal God, Chance, and Randomness in Quantum Physics

Dillard W. Faries

Using simple games of chance, we will see the challenge that chance and quantum physics present the theologians of physics. Our games avoid all higher mathematics and have experimental basis. They are not just Gedanken experiments. I hope they can leave us with "no excuse whatsoever,"[1] at least to deal with the issues. Unfortunately for all of us, physicists, metaphysicians, and theologians, we must think very carefully. I will tell you the story; you (or hopefully some good theologian) can do the careful thinking. Our two games of chance will be a million-dollar lottery and a revised game of Battleship™.

> One way or another, God has played us a nasty trick … Physicists may glory in the challenge of developing radically new theories in which non-locality and relativistic space-time can more happily co-exist. Metaphysicians may delight in the prospect of fundamentally new ontologies, and in the consequent testing and stretching of conceptual boundaries. But the real challenge falls to the theologians of physics, who must justify the ways of a Deity who is, if not evil, at least extremely mischievous.
>
> Tim Maudlin, at the end of his book *Quantum Non-Locality and Relativity*[2]

You will hear the whole range of reactions to chance. Within the last century, science, especially quantum mechanics, thinks that it has something to say about chance. I am sure that it does, and I am equally sure that a brief article cannot do it justice. Maybe we can at least stimulate some hard thinking.

Here is the rub: the general belief in quantum physics is that chance is absolutely fundamental and inextricable in nature and that we as knowers cannot penetrate that boundary. In philosophical terms, we might say that chance is not only epistemological but also deeply ontological. In theological terms, we might say that God turns some (or all?) of nature over to a chance mechanism and does not allow us to see its inner workings. If God is a person who maintains control of his universe, we might then be forced to accept this statement: God plays dice and he tosses them where we cannot see them. This is why an on-looking world may accuse God of evil, mischief, or deceit, as you will find in our opening quote by Tim Maudlin and our closing quote by David Albert. The sore spot of God and chance gets rubbed raw when one considers the following story (revised from an original Russian *anekdot*):

> In a state university city of Middle America, a restaurateur offers a chance for a free tattoo for every $25 purchase. You only have to guess the spot-count on his roll of two dice. Bubba and his buddy take the bait.

Dillard Faries *is Professor Emeritus of physics at Wheaton College and a long-time member of ASA, with degrees from Rice and Berkeley. His early research was in nonlinear optics; his present interests focus on foundations and history of quantum physics and its theological and philosophical ramifications. He and his wife Sally have three children and six grandchildren.*

> Restaurateur: What number do you choose?
>
> Bubba: Seven.
>
> The restaurateur turns his back, rattles the dice, throws them out of the customers' sight, picks them up and shows a 6 and a 2. "Sorry," he says. "Try again next time."
>
> Bubba's astute buddy is a skeptic. "That's fixed," he says. "Nobody can win against that guy."
>
> Bubba: No, you're wrong. Our quarterback won twice last week.

Any resemblance to real people, dead or alive, hired or fired, undiscovered or sanctioned by the NCAA, is purely coincidental.

The two most famous quantum physicists sparred or joked on the "theological" issue.

> Einstein: I cannot believe in a God who plays dice with the universe. *Der Herrgott würfelt nicht.*
>
> Bohr: Who are you to tell God how to run his universe?

Whether one hearkens to a Spinozan God (Einstein's view that God is Nature and Nature is God) or to a Creator, Sustainer, controlling God, the natural identification of the big questions with the Old One, with the One, or whatever we call him leads to cross-talk between fundamental physics and theology. Questions about reality, randomness, locality, and causality, all in the disguise of philosophy or physics, are about the ultimate nature of God and/or his creation, God's personhood, his control of nature, his omniscience, and his omnipotence. As Maudlin (quoted above) recognizes, the real challenge is theological, and it is no surprise that great physicists recognize that they are treading on holy ground. Einstein's concern about chance entering the world is clearly a worldview, theological objection; even though he probably did not remove his shoes, he was likely wearing no socks.

Although physicists may easily banter about God, theologians have generally been more circumspect in their pronouncements about physics. Even though he may think he sided with the great Albert Einstein, R. C. Sproul's venture into questions of chance may constitute rushing in where angels fear to tread. To give only one quote: "If chance exists in any size, shape, or form, God cannot exist. The two are mutually exclusive."[3] After seeing the challenges of quantum mechanics briefly here, you can be a better judge, at least of the complexity of the issue.

The Outer Chamber of God's Casino: A Lottery in Space and Time

Atomism brought a mild form of chance into physics. Newtonian physics developed such a thorough description of change as merely matter in motion that Laplace could envision a super-intelligence who could calculate and therefore know the complete history of the universe, backward and forward, with "no need of that hypothesis [God]."[4] A God of complete determinism becomes an impersonal God of complete law and order, one whose supposed connection to the universe becomes a moot question. Einstein understood and accepted this kind of God. The complexity of our world reduced to such simplicity left him in awe of the mysterious, subtle, yet nonmalicious God. Atomism, more specifically the very large number of little pieces of nature, meant that we, somewhat below the Laplacean super-intelligence, could not have that complete knowledge and/or control of even small portions of the universe. We had to rely on statistics, the calculations of apparent chance based on our ignorance and limitations. One of Einstein's papers of his *annus mirabilis* (1905) confirmed these atomistic statistics in calculations of Brownian motion, the jiggling of microscopic particles caused by the collisions of invisible submicroscopic molecules with the much larger visible chunks.

Radioactivity, discovered (by others) when Einstein was in his teens, introduced a deeper level of chance. Individual events could be seen because the energy was a million times that of atomic energies. We could not (and have not to this day) been able to predict when such an event will occur. We are still ignorant; statistics still allows calculations, but we cannot pretend to have any deterministic model. We can pretend that such a model exists and/or that God is in complete control on a level that is inaccessible to us. The causes, if there are causes, for an individual event appear to be internal and inaccessible because we cannot do anything to change the statistics. Chance, formerly introduced for intentional ignorance in games of chance or for practical ignorance in the case of the statistical mechanics of an impossibly large number of atoms, started to look as if it were hidden deep down inside the nucleus.

Another of Einstein's 1905 papers had introduced atomism into light, what we now call photons. The earliest quantum theory of atoms (Bohr, 1913) arose from the question of how atoms, with some kind of electron motion, produced light. Classical theory said that an orbiting electron in an atom of the known size would radiate light waves and collapse from loss of energy in about ten nanoseconds. Niels Bohr, astutely noting that our universe seemed to last a lot longer than such a predicted demise, postulated that specific states (such as certain exact orbits) were at least reasonably stable (called stationary states) and that light was emitted or absorbed only during jumps between states. There was a lowest state (lowest in energy and smallest in size) which could be a completely stable state (if no light came to kick it up to higher states) keeping the universe from total collapse. We call these various levels quantum states. Jumps between levels of many atoms produced a combined set of light waves, electromagnetic waves which had also become quite well understood.

At that time Bohr did not believe in photons, the atoms of light, so the full force of atomism did not strike him. Einstein, a sometimes lonely believer in the photon, saw something different and saw problems which were to come to fruition only later (mid-1920s) with a fuller development of a complete quantum theory. Bohr could envision the pay-out of energy from atoms in a continuous fashion, emitted throughout a transition. Einstein saw the grand jackpot: there is a full pay-out of a photon or there is no pay-out. Atomism has two sides: it explains semicontinuity by the large numbers involved in our ordinary macroscopic world, but when you get down to this size, it divides no further. An atom in transition does not dribble out small amounts of energy in all directions over some period of time. It gives up the whole transition energy to a *particle* of light which flies off in some direction at some instant of the jump between states. Einstein was seeing the conflict and consequences of what became wave-particle duality. Waves, a continuous transmission of energy, may be thought of as very many particles in some coherent pattern, but when you get down to one particle, it cannot reasonably behave like a wave. It is a clump; it is or it is not; it is indivisible.

Einstein saw that when you get to that indivisible level, it was going to act like a lottery. An exact complete result will occur, but we will not see the inner workings of the chance mechanism. As much as he struggled against the ad hoc style of Bohr's model of the atom, he found amazing confirmations by his own methods. In 1917, he worked out a formula for the thermodynamic equilibrium of atoms and light. To do so, he used the concept of spontaneous emission of light, basically granting that atomic emissions of visible light *might* follow the same seemingly random pattern of the apparently causeless radioactive emissions of nuclei. Combining this with stimulated emission[5] and absorption, Einstein reproduced the famous Planck formula[6] of 1900, which had been the basis for his 1905 paper on the quantization of light, the hypothesis of photons.[7] The atomic emission of light suddenly looked like nuclear radioactive emissions, at least in its statistical nature. He was forced to deal with chance up close and personal.

Chance is inevitable, simply a part of our experience when we have incomplete knowledge. We do not know, so our best understanding involves figuring the odds. Chance of this kind may be *choice* when the entity freely but inscrutably exerts its will, an internal unsearchable process for the outside observer. Chance of this kind could also be *grace*, the free and inscrutable choice of a controlling external agent. It could also be a *lawful* result, the end product of some recipe which remains hidden to us. It could also be *random*, as causeless and unpredictable as we can imagine. But if it is a singular undivided event—as the indivisible particle seems to require—the choice, or the gracious decision, or the lawful result, or the random deed is a done deal; the real particle of a certain kind goes off in a particular direction and makes itself available for detection by some observer. That is how Einstein saw it, a sharp reality for which we have only a fuzzy picture. Our camera, our knowledge, our theory is limited, but Nature (or God) is complete. Choice at a particle level (a nod toward panpsychism), grace (a nod toward a deity), law (a nod toward a hidden Newtonian/Laplacean determinism), or a random act (a nod toward chaotic anarchism) would remain a choice for the theorist, and Einstein would clearly lean toward deterministic law. We should note that a God who is vulnerable and willing to give up his high position, knowledge, and control is perfectly consistent with any of these.

Einstein's belief in the particle of light led him in the direction of determinism, but in the same paper (1917), he gave the impetus for a different direction, a direction in which quantum mechanics actually developed. He realized that the electromagnetic field value (squared, if you are willing to go to such higher mathematics) gave the probability of a photon at that location. With many photons, it gave a density of photons, but when you get down to the indivisible *one* photon, it gave probabilities. Places with larger electromagnetic fields had greater chances of having a photon. Rather than being a single probability decision which determines an event, probability could now go on the road. When quantum mechanics developed a wave equation for Ψ, a wave of inscrutable ontology (i.e., we do not know what it is), Max Born harked back to Einstein's understanding of electromagnetic fields as probability of the electromagnetic particles and interpreted Ψ as a probability wave.

God's Lottery

Imagine an atom in an upper energy level, ready and able to radiate energy which, in fact, is detectable as a single photon at some time at some place on a spherical surface surrounding the atom. The photon is detected at a certain point (on a sphere of radius R) at a certain time by a flash on the fluorescent screen. That is a reality we can all agree on. Einstein says that we can infer a reality of a decisive event called emission at an earlier time (earlier by R/c) for a photon traveling at speed c along the radial line. The decision may have been choice, grace, hidden law, or randomness, but it was a done deal back then. That is faith, a belief in a reality which can earn Einstein the claim (made by others) of representing a traditional monotheism (because Nature was God and God was Nature). The agnostic could have been represented by Bohr by means of a simple statement of ignorance: we know a flash occurred, but we do not know what happened before.

You can see how unsatisfying and how hopeless that feels; we think that we have to try to understand *something* and fill in the blanks. Thus a most fanciful story was invented. A wave Ψ propagated out from the atom. It is not just our knowledge (incomplete as it is in the representation of mere chance), but it is the photon in limbo, going by way of all possible paths from the atom outward. Every point in space has a traveling lottery passing through it, seeing which place and which time will be the winner, i.e., producing the flash of a decisive event. This scenario is also a matter of faith: a negative faith that the particle *does not exist* as Einstein envisions before the measurement, and a positive faith that it has some other form which we call superposition, a multiple identity in space and time. Ψ behaves lawfully as it propagates, but somehow collapses to a point in space and time. Because we can make no pictorial or lawful model of this collapse, we consider this to be a measurement problem. But it is an article of faith of the orthodox belief structure of quantum mechanics. For Bohr and the so-called Copenhagen interpretation, the flash tells you the immediate future and a starting Ψ for a lawfully determined evolution of Ψ in the future, but it does not tell the past. For Einstein, it was the real manifestation of a previous lottery which was the particle's creation.

I call this faith on Einstein's part, but it was not faith without reason. He had a reasoned argument against the existence of lotteries which can propagate but have indivisible prizes. If we have a million possible detectors out on the fluorescent screen at radius R, there is one chance in a million for each of them. In Einstein's picture, the atom hands out envelopes to one million recipients who carry them out to R. At the fluorescent screen, each of the one million envelopes is opened to see if it might be the *one and only* fluorescent flash, the indivisible $1,000,000 prize. The lottery was at the beginning, the winner was determined (though unknown), and it all propagated accordingly.

It was also faith on Bohr's part, and Einstein saw the problem. In Bohr's scenario, each of the million participants gets a full-fledged lottery machine which does not actuate until the measurement. Each one has a one-in-a-million chance when it gets to the screen. But what if two people win? That is no problem if we are turning in winning tickets and later determining that we can split the pot. But here there is *one* prize and it is instantaneous, a fluorescent flash now. Einstein saw that this is impossible because a win at one point must instantaneously exclude all possibilities of winning elsewhere. This required what he called spooky action-at-a-distance, *spukhafte Fernwirkung*. This was not just spooky; it violated his relativity principle, the finite speed limit of the universe, the speed of light. This was an absolute higher principle which claimed his faith.

If the decision is made at the start and reality ensues, the decision could have been choice, grace, law, or randomness. Randomness in the sense of independence from all external parameters is impossible to extend in space and time; it would have to be dependent on what occurred at other points, shutting off its chances if there was a winner elsewhere. Bohr convinced the physics community that it was one unified system which worked so as to give the result, but he gave no mechanism for the effective instantaneous connections.

We should be clear that quantum mechanics does not always claim a limbo state in every system. There are *pure* states which will give certain answers, in the simplest case a straightforward "yes" or "no." A pure state is what is produced by a measurement. Thus a nondestructive measurement converts a limbo state (uncertainty) into a pure state (certainty), and an immediate remeasurement will get the same result. The famous Heisenberg uncertainty principle specifies both qualitatively and quantitatively when limbo states must exist. *Incompatibility* of two measurements means that a pure state of one measurement (possible to prepare by making that measurement) is always a limbo state of the other measurement. The formalism of quantum mechanics makes it possible to describe mathematically which measurements are incompatible and to calculate the probabilities and statistics of the uncertain states. Einstein would agree that you and I may not know, but he insisted that when we measure and get a value that this is a real value of a pre-existing condition. They were arguing about an unmeasured past, and you cannot decide.

But Einstein fought for years and finally came up with a clincher, he thought. To get two independent measurements, you can use twins which are separated. Measurement on one gives 100% certainty on the other one, making that aspect as real as you can make it and yet independent of the act of measurement. Measuring property A on the right means the value of A is known on the left. The measurement of property B on the left gives the value of B on the left (and the right). There are thus real (100% certain) values of both A and B, real quantities which quantum mechanics does not give and does not know. Thus quantum mechanics is incomplete. The reality is not at fault; our theories and knowledge are just limited and fuzzy. Chance and randomness are our lack of knowledge. This paper of 1935 is so famous that it is known simply as EPR (Einstein, Podolsky, and Rosen, the authors).[8] The original paper dealt with the famous incompatible measurement of position and momentum; a simplified example using spins or polarization, called EPR-Bohm, is usually used because they are the simplest systems, being only two-valued. Thus the basic nature of such realities can be handled with a continuum of questions (directions along which polarizations or spins are measured), each of which has only two answers; a basically true/false exam is available for such a system.

Even though Einstein died first, the questions and lack of acceptance from his good friend haunted Bohr to his death in 1962. We have transcripts of an interview conducted by Thomas Kuhn the day before Bohr's death and drawings on his blackboard remained when he died. Einstein is not to be ignored lightly; Sproul, certainly lacking in scientific reasoning and arguments, chose a good running mate.

Into the Inner Sanctum of God's Casino

Independent of Sproul's hard-line theological argument (which I do not find appealing), Einstein's reality, our incomplete knowledge, and absolute speed limits in the universe are pretty convincing. Quantum mechanics' asymmetric time (a collapsing wave-function upon measurement) appealed to William Pollard. He thought that physics had finally discovered historical and personal time which is central in the Judeo-Christian tradition.[9] Many Eastern traditions maintain a cyclical time based, for example, on recurring phenomena such as seasons and reincarnation; physics had settled into an abstract directionless time represented by a simple one-dimensional line in Cartesian coordinates. The Judeo-Christian tradition affirms directional time given by a history of God's interaction with his people, coming from a beginning and going to a culmination. Asymmetric time may be nice, and it may be right, but my sense of symmetry in the abstract time of physics and my belief in a symmetry of causality and teleology draw me back. Whether we are Christian or not, Einstein's hard-rock reality is attractive to many of us, even if it might be a misguided throw-back to Newtonian-Laplacean determinism.

In a 1932 book on *The Mathematical Foundations of Quantum Mechanics*,[10] John von Neumann, a mathematician with an immense reputation, proved that a hidden-variables formulation (an underlying lawful determinism) was impossible. To keep us from taking mathematical proofs too seriously, it is fortunate that David Bohm, clearly under the spell of Einstein's questioning, proved von Neumann wrong by producing such an impossible formalism (1952).[11] Neither Bohm nor Einstein seemed to take it seriously as *the* way that reality was; it was "too cheap" a solution.[12] After his discovery of a deterministic formulation, Bohm still defended the occurrence of chance and the fall of classical causality in his 1957 book.[13] But the possibility of determinism kept Einstein's skepticism alive in the physics community. John Bell, appalled to find that a favorite book by Max Born[14] (from a set of lectures from 1948 but published later) had completely ignored the significant Bohm achievement, took up the challenge with clear sympathies with Einstein.[15] He produced a theorem[16] about the EPR-Bohm experiment which may prove to be the most significant theorem of twentieth-century physics. It is widely touted as proving that Einstein was wrong. Whether it is ultimately convincing or conclusive, I believe you will find it powerful. Hold your objections in abeyance please and try another level in God's casino, a variant of a good children's game.

Battleship™

The game of Battleship™ involves secret placement of an array of ships on a 2-D grid. Contestants alternately fire at particular squares seeing if they can destroy their opponent's ships. The game continues until only one person has some undemolished ship(s). Let me invent a quicker 1-D version suitable for gambling and for comparing our commonsense real world with the real quantum world. Our 1-D array contains the 60-minute markers around the circle of a clock face (fig. 1). Place 30 ships in the 60 places with two rules: (1) spaces 180° apart (30 minutes apart) must be the same (both occupied or both unoccupied), and (2) spaces 90° (or 270°) apart must be different (one occupied and one unoccupied). See figure 2 for one possible placement.

Figure 1. No ships placed.

Figure 2. Very poorly placed ships with many boundaries.

Now the purpose of the game is to find the unprotected flank, a boundary where one shot hits a ship and the adjacent shot finds only water. One person (the house for gambling purposes) prepares the array and the other chooses two adjacent spaces to try for a win. One double shot and the game is over, win or lose.

Analysis: The house/preparer would like to group ships as much as possible to limit the boundaries (although generous parents might place ships alternately around the circle to give their child 100% chance of winning). The house strategy is then to have 15 ships on one side, 15 on the other with four boundaries in the 60 possible choices (fig. 3). There is no strategy (short of cheating) for the player who shoots; you simply choose (randomly) among the 60 choices. You can choose to play or not based on the odds and the pay-out. The chance of winning is clearly limited to no less than 1 in 15 (4 in 60).[17] Anything better than $15 pay-out for $1 paid to play should be good, a money-maker in the long run.

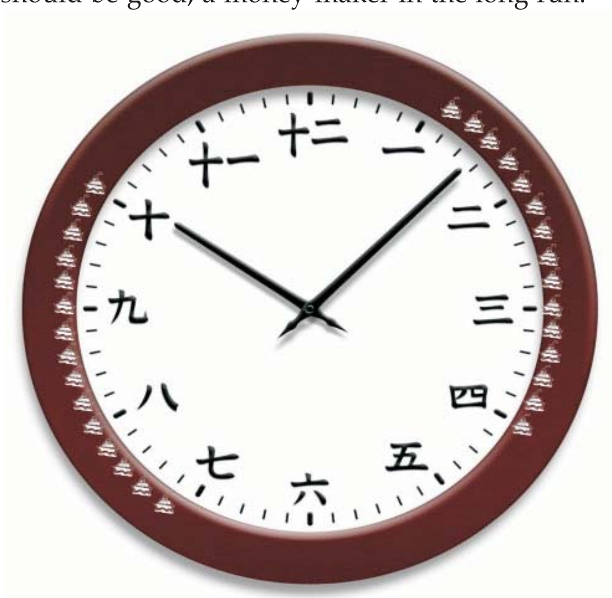


Figure 3. Good placement of ships with only four boundaries.

God's Quantum-Mechanical Battleship Machine

Let us see how God plays this game in the quantum world. Entering the casino we see a simple black box labeled BATTLESHIP with two dials (arrows that can be pointed to each of the 60 minutes around the face, a button, and a light for each dial which flashes *gray* (for striking a ship) or *blue* (for striking water). To play, set the dials to two adjacent positions, push the button, and see what the lights do. $1 to play, $25 pay-out for a win, i.e., different lights.

Good pay-out, but a committed choice first and a hidden machinery sounds too much like our restaurateur. The guardian angel sees our hesitation and offers to allow us to check that it abides by the rules for free. Try only one dial as much as you want; you find that it comes up 50-50, *blue* and *gray* like heads and tails on coin tosses. Try two dials with differences of 0°, 90°, 180°, and 270°, and you will always get the appropriate coincidences and anti-coincidences. Seems fair and it checks out.

OK, $225 gives us 225 plays and expectations of 15 wins and a pay-out of $25 x 15 = $375, a net gain of $150, not bad for one hour.

I know the quantum mechanical version and its answer so I simulated it on the computer. My first try, the results were as follows:

Blue-blue	*Gray-gray*	*Blue-gray*
113	110	2

Rather than making $150, I have lost $175. I feel cheated, and I feel bad that my first thoughts were of that restaurateur. It may be hard if you are a confirmed monergist or theistic determinist, but I, at this point, want to separate God the person from a god somehow running this machine. I want to preserve personhood and suppose that this machine has some independence, specifically some independent way of cheating me.

Since I had my computer simulation set up, I could play repeated sets of 225 games by merely punching a few buttons. I played many times and on a few occasions won six or seven times. Even with seven wins in 225 tries, I am losing $50. It was not a statistical fluke that I won only twice in my first 225 games. Any capable physicist should immediately recognize the quantum mechanical situation of polarizations of two twin photons. We say their polarizations are entangled. We should be able to tell you the formula for coincidences (and the left-over anti-coincidences); we should even be able to tell you that the win rate should be $\sin^2\theta = 1 - \cos^2\theta$; since I chose 6° (which is about 0.1 radian), we should be able to calculate in our heads that the win rate is about 1%, almost seven times smaller than our estimate.

Let us take an honest look at what we are saying. We are saying that if you or I or God prepares in any way the value (*gray* or *blue*, *ship* or *water*) for each of the 60 positions and we try our hand at finding a boundary, we will have *at least* 1 chance in 15. I mean that they can be chosen by the photon or atom, they can be given or simply known by God, they can be specified by some recipe which we call a law of nature, or they can be randomly generated. This prepared reality will always offer odds better than 1 in 15. Yet this quantum mechanical machine beats you, badly. Predetermined answers will not work. You can begin to see why the limbo state, a state which *does not* have the answers in advance, is looking as if it is necessary.

Let me be clear that we are not facing a problem with *only* a theory, or with *only* its interpretation. The theory gives us the answer readily, but it could be wrong. The interpretation may be wrong about some inner workings that are, in fact, inessential. But we are talking about what happens in quantum experiments which have been confirmed with a series of subtle refinements.[18] This is a statistical *reductio ad absurdum* argument. In mathematical proofs, we start with some givens, we make logical steps, we get to absurd results, and we know that the givens must be wrong. Here we start with givens (*any predetermined* answers to sixty 2-value questions), we calculate odds, and we go to nature and find that our odds are absurdly wrong; therefore we know that those sixty given answers *cannot be pregiven*. Period. Each and every question (Do I hit a *ship* or *water* with a shot at this position?) receives an answer if and when it is asked. But no one, not even God, could have predetermined or known *all* of the answers beforehand. Here is a simple case in which God simply does not have *all* the answers. He always gives a simple answer, *blue* or *gray*, *water* or *ship*, to the question we ask; he does not answer the questions we do not ask, simply not having the answer. This is strong talk, and I hope you will join me in being disturbed by it.

Let us go back to the machine because we have left God and the restaurateur plenty of opportunity to cheat us. Please let us see the dice rolling; let us have an auditing firm independently see the answers and our probing questions.

Step one: look in the machine and find two pathways from the back of the machine, each divided at the dial in the front: one branch producing a *gray* light, one a *blue* light in each case. We can surmise a real beam of particles but also check it by systematically blocking pathways. The beam takes some time to go from the back to the front. We can lengthen the time by putting the supposed twin source much further back, push the button first, and then make our choices. This is not easy because the velocity of light is large, but it does not matter. We still get the same results.

Step two: the beam from the back could just be a trigger and carry no information; the dials in front are close to each other and can be set to give distributions based on each other's settings. OK, separate the two dials by large distances, collude on the settings but do not set them until the source beam is on its way and no time is allowed for any signal to let the dials know about the other one. Good try, but no, it does not matter. The results are the same.

We are stuck. We have eliminated the possibilities of local collusion. We know that *any means* of having the answers prepared leads to contradiction. The only solution seems to be that something which lacked specificity in its *being* has some true *becoming* according to statistical odds, odds which are capable of having nonlocal links which are impossible to envision in our physical world. Except for the stretch to get a mechanism for the nonlocality, the orthodox quantum mechanician is happy and vindicated. The lack of specificity is the superposition of states, the ability to live a divided life, with various potentials of being which are actuated at the act of measurement. The nonlocality is just a manifestation of the inseparability of nature, the requirement to look at the whole system, puzzling as that may become. Theologically, this is also satisfying if you believe in a God who is vulnerable to chance, free-will, and even rejection; if you believe in a life of becoming, a historical arc; if you believe in a nonlocal nonconfined God; if you believe in a God who lets nature cooperate with him. However, if you believe in a God who has tied everything into a tightly deterministic system—what physicists would call a block universe—you cannot be very happy with this.

Let us say clearly that there is no argument against the concept that everything that was, that is, and that is to come was fully ordained and determined by a person we call God, even if the whole universe *was* total chaos, *is* totally random in appearance, and *is* totally lawless *to come*. It, the complete determination by God, is an explanation which explains nothing because it explains everything by the same single word. I can only say that, for me, it saps God of personhood and meaning. But if you find meaning in a strict determinism, let me loosen the noose for you, as a matter of honesty and with as clear thinking as I can muster.

Our argument focused on some things we call particles and their properties, answers to sixty *blue-gray* questions. We concluded that the properties were not fixed, that they came to being as chance events which were somehow guided in their relationship by nonlocal effects. We said nothing about their beginnings, or their ends, or—to say it in physics language—their detection before or after their creation and annihilation. We said that we push a button and something comes out; we put a discriminator in the path, dividing *blue* from *gray* and we get a detection, a *blue* or *gray* light flashes. If our argument holds, these detection processes are also chance processes which might have nonlocal influences. How many things, which we know nothing about, are coming from the source or to the detector, and what nonlocal effects or instruction sets determine which ones we will see? One can, of course, go further and include our eyes, our mind, *ad infinitum.* I suppose that, whatever your belief or disbelief, you may squirm into or out of any argument.

You will have to do your own clear thinking, but let me clarify two fine points:

1. I have said that *all* of the questions cannot have their answers predetermined; they cannot have that reality in any form. This does not mean that *none* of them can be real and determined. Because we can delay the choice of measurement until a particle is on its way, we think that all questions are equal. But we cannot deny the possibility of a determined reality before the measurement, of the result which is obtained by the measurement. This is clearly possible; it happens. The unmeasured are unmeasured, and we cannot argue about a hypothetical "what if?" But something which is measured, and thus determined, could have had that reality before.

2. Since all questions are open to us, predetermination or pre-paration must apply to all questions equally. Our sense of causality takes a simple form: when the dial set at nineteen produces a *blue* light flash, it was *because* there was no ship at position 19, we (and Einstein) think. The wholesale pre-paration is impossible, producing contradiction, but the specific post-paration for position 19 is possible. As hard as it is for us to consider teleology, i.e., causality of the future, going toward a *telos* rather than from a cause, it is a possibility. In terms of our relationship to God, we might say that "God does not answer *unless* we ask" is not the same as "God does not answer us *until* we ask." We may not know the reality of the answer until we ask, but the reality may have been on the way all along. God's foreknowledge and pre-paration may be accompanied by rear-knowledge and post-paration, and the nature he produces may participate in all of these.

There are no slam dunks in our understanding of nature and God, and even slam dunks are not 100% certain. Sproul puts God vs. chance as gambling stakes; to him, you either win God or chance, which is a complete loss. I am actually rather excited about a God who is vulnerable, playing the game of chance, who allows me, a chancy fellow, a chance with him, who is the Lord of becoming as well as being, a God who maintains a unitary universe, a God who draws us toward the future as well as sending us from our past, a God who can hold together the two ontologies of particle and wave, the workings of continuity and discontinuity, the deterministic lawfulness and chance occurrences, and the divinity and humanity of a man called Jesus. But I will not toss my God into any gambling pot based on how we understand the physical world.

A thoroughgoing physical determinism blossomed in the Newtonian mechanics and still holds appeal to both God-fearing and God-denying people. Bohm introduced a deterministic formalism of the otherwise standard quantum mechanics (with the nonlocality feature clearly in it). David Albert is a foremost proponent of Bohm's deterministic proposal, without having a theological ax to grind, to my knowledge. He says:

> [I]f this theory [Bohm's interpretation] is right (and this is one of the things about it that's cheap and unbeautiful, and that I like), then the fundamental laws of the world are cooked up in such a way as to systematically *mislead* us about themselves.

> [This becomes] an absolutely low-brow story about the world … that's about the *motions of material bodies*, the kind of story that contains nothing cryptic and nothing metaphysically novel and nothing ambiguous and nothing inexplicit and nothing evasive and nothing unintelligible and nothing inexact and nothing subtle … in which the whole universe always evolves *deterministically* and which recounts the unfolding of a perverse and gigantic conspiracy to make the world *appear* to be *quantum-mechanical*.[19] [Albert's emphases]

You pay your money and you take your choice, that is, if God is willing to take a chance and give you a choice.

Conclusion

Quantum mechanics gives chance and indeterminism a prominent place in the pantheon of science, changing the view that repeatability is a keystone of science. It thus has had a strong influence in our cultural worldview and therefore impinges on our theology with some strong evidences. It is quite appropriate that our theology should speak strongly back to physics, producing some legitimate "theologians of modern physics." In doing so, we cannot afford to offer easy answers out of our ignorance of physics. You will have to arrive at your own conclusions. Think hard; think carefully; help us all.

Acknowledgments

I am indebted both to an enormous literature and to individuals too numerous to list. The references below will lead you to most of them. My special thanks to students who provided the stimulus for me to make a continuing effort to understand what I can.

Notes

1With apologies to St. Paul (Romans 1).

2Tim Maudlin, *Quantum Non-Locality and Relativity: Metaphysical Intimations of Modern Physics* (Malden, MA: Wiley-Blackwell, 2011).

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

4Widely quoted, e.g., W. W. Rouse Ball, *A Short Account of the History of Mathematics* (London: Macmillan, 1924).

5Stimulated emission, the SE in LASER, is the basic idea for the laser, an idea which required more than three decades to gel and more than four decades (from 1917) to come to fruition.

6The formula for black-body radiation which was the start of the quantum revolution, introducing Planck's constant, h, as one of the universal constants.

7In spite of the dramatic success of relativity, it was this 1905 paper on the photoelectric effect which was cited by the Nobel committee for Einstein's Nobel Prize.

8A. Einstein, B. Podolsky, and N. Rosen, "Can Quantum Mechanical Description of Physical Reality Be Considered Complete?," *Physical Review* 47 (1935): 777–80.

9William G. Pollard, *Chance and Providence: God's Action in a World Governed by Scientific Law* (New York: Scribner, 1958).

10J. von Neumann, *Mathematical Foundations of Quantum Mechanics* (Princeton, NJ: Princeton University Press, 1955). The German original was published in 1932.

11D. Bohm, "A Suggested Interpretation of Quantum Theory in Terms of 'Hidden' Variables," *Physical Review* 85 (1952): 166–93.

12Einstein letter to Born of May 12, 1952: "That way [Bohm's deterministic reinterpretation of quantum mechanics] seems too cheap to me." Quoted by Jeremy Bernstein, *Quantum Profiles* (Princeton, NJ: Princeton University Press, 1991), 66.

13D. Bohm, *Causality and Chance in Modern Physics* (Princeton, NJ: Van Nostrand, 1957).

14M. Born, *Natural Philosophy of Cause and Chance* (New York: Dover, 1964), publication of the 1948 Waynflete lectures.

15"I feel that Einstein's intellectual superiority over Bohr, in this instance [EPR discussion of local reality and correlations in quantum mechanics], was enormous; a vast gulf between the man who saw clearly what was needed, and the obscurantist." John Bell, as quoted by Jeremy Bernstein, *Quantum Profiles* (Princeton, NJ: Princeton University Press, 1991), 84. Despite his sympathies, Bell continues, admitting "it is a pity that Einstein's idea doesn't work. The reasonable thing just doesn't work."

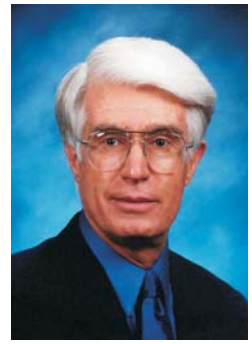
16J. S. Bell, "On the Einstein-Podolsky-Rosen Paradox," *Physics* 1 (1964): 195–200. His collected papers on quantum philosophy are published as *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987).

17It is unbelievable but these few lines of simple analysis get at the core of Bell's justly famous theorem. There are clearly some generalizations and more mathematical forms, but the core idea is simply that our simple local causal reality, what we call "common sense," has certain very well-defined limitations, expressed here as a limit on the odds. Many similar examples, expressed as mathematical inequalities, are referred to as Bell's inequalities. They do not need to make mention of quantum mechanics, but gain their significance by the fact that quantum mechanical systems do not obey these inequalities. They thus expose the "uncommon sense" of the real natural quantum world.

18For a reasonable set of references, see, e.g., G. Greenstein and A. G. Zajonc, *The Quantum Challenge* (Boston, MA: Jones and Bartlett, 2006), 289. Early experiments in the early 1970s by Clauser, Horne, Shimony, and Holt have been followed by more sophisticated tests by Aspect et al.

19David Z. Albert, *Quantum Mechanics and Experience* (Cambridge, MA: Harvard University Press, 1992), 169.

ASA Members: Submit comments and questions on this communication at www.asa3.org → FORUMS → PSCF DISCUSSION.



Richard F. Carlson

Two Interlocking Stories: Job and Natural Evil *and* Modern Science and Randomness

Richard F. Carlson and Jason N. Hine

Jason N. Hine

In the book of Job, we find a righteous and puzzled sufferer, a victim of evil brought on by other humans and by the forces of nature. Job demands answers to his suffering, screams at God for justice, and receives a surprising response: a Voice from the whirlwind challenges him to carefully consider certain aspects of the created order. Our thesis is that Job is wrong in his belief that creation reflects the retribution principle (RP). We maintain that the text indicates that God created through wisdom and power, but that the RP is not a promised part of God's excellent handiwork in the cosmos and our earth. We explore some consequences of there being no RP in creation, including natural evil, limited randomness in physical processes, the suffering of creation itself (including all living creatures), the ability of the living creation to adapt to environmental changes, and the opportunity for humans to emerge on Earth some 13.8 billion years after the Big Bang.

The biblical book of Job recounts a man described to be, as we read in the very first verse, "blameless—a man of complete integrity,"[1] and one who was very rich in every way—in possessions, family, and health. God allows the challenger (the satan) to test Job within limits (1:12, 2:6).[2] Calamity strikes quickly: Job's farmhands and animals are killed and stolen (1:14–15), a fire from heaven burns up Job's sheep and shepherds (1:16), Chaldean raiders steal his camels and kill his servants (1:17), a powerful wind sweeps in from the wilderness and collapses Job's house, killing his children (1:18–19), and later Job endures boils from head to foot (2:7). Job suffers grievously from both moral evil inflicted on him by people and physical (or natural) evil inflicted on him by creation.

Job's attitude progresses—at first he calmly accepts his losses (2:8–3:26), but later he insists that he has been treated unfairly, a conclusion he reaches after receiving unhelpful and inappropriate counsel from four friends (4:1–27:23 and 32:1–37:24).[3] Job then screams at God, demands a hearing, and asks for justice. Both Job's friends and Job strongly believe that the universe operates under

Richard F. Carlson *is a retired professor, now holding the position of Research Professor of Physics at the University of Redlands where he taught for thirty-four years. He also has a degree in theology and biblical studies, and has taught classes such as Issues in Philosophy, and Theology and Science at Fuller Theological Seminary. He has published two books with InterVarsity Press in the area of science and faith.*

Jason N. Hine *authors progressive geographic information systems (GIS) training solutions for Esri in Redlands, California. Jason holds an AS in Environmental Science and a BS in Natural Resource Management. He has served as webmaster and chair for the Southern California chapter of the ASA. During his bicycle commutes, Jason enjoys pondering the relationships between science, faith and fractals.*

the retribution principle (RP)—the idea that the righteous will prosper and the wicked will suffer.[4] Since Job has suffered greatly, these friends conclude that Job has sinned. Knowing that he has not sinned, Job rejects their conclusions and counsel. However, Job also believes in the RP, and surmises that God is exhibiting injustice by not acting consistently with the RP. Job declares his innocence and blames God for allowing undeserved suffering to befall him, claiming that he has been treated unjustly (28:1–31:40). Even though Job's monologue appears several chapters before the speeches by the Voice in the storm, it is thought by some that this section should directly precede the Voice's speeches in Job 38–41.[5] When we get to the Voice's speeches, we encounter two significant surprises: first, God (the Voice) responds to Job out of a storm; and second, God completely contradicts Job's working assumption of the validity of the RP.

God, as the Voice in the storm, opens his response to Job (38:1–3) by making a single criticism of Job: God says Job is ignorant and asks, "Who is this that questions my wisdom with such ignorant words?" (38:2). Commentator David Clines suggests that the Voice's tone is severe and not at all gracious, yet not offensive and not cruel.[6] John Walton writes that speaking from the storm signifies God's wrath directed at Job and indicates rebuke.[7] In the speeches, God's intention is to make his design plan for the universe (38:4–7) clear to Job, and God does this by teaching him aspects of creation, mainly through examples stated in terms of rhetorical questions.[8] By doing so, God wants to point out to Job the wisdom of the divine strategy in planning, creating, and overseeing the operation of the world. God does this by referring to the created order alone—to properties of the physical world (38:8–38) along with selected examples of animals and birds (38:39–41:34). From these references, God expects Job to deduce the principles by which he designed, created, and maintains the world, but God leaves those core principles unspoken. By describing his divine strategy in this way, God demonstrates patience and accommodation toward Job.[9]

This article consists of two parts. In the first part, we will explore Job's suffering, concentrating on the aspects of creation related to the natural evil that Job suffered, evil that has its origin in natural processes. Like Job we will ask, doesn't the RP apply to creation? Doesn't God's justice demand that a person like Job not suffer from natural causes? We will also ask a further question: How can God's justice exist alongside a world of suffering caused by natural processes such as earthquakes, floods, and storms of all kinds; devastating illnesses; birth defects; nature "red in tooth and claw"; and the physical death of living things throughout creation, including the death of humans? Understanding God's wise strategy for creation is a key step in dealing with natural evil. Job's understanding was limited and inadequate before the Voice addressed him, but for Job, and for us as twenty-first-century believers, the hope is that through the speeches God's strategy can be determined and his creation wisdom can be made clear.

Our thesis is that Job makes a faulty assumption when he assumes that creation reflects God's wisdom, power, and the RP. We maintain that the speeches indicate that God created through wisdom and power, but that the RP is not a promised part of God's excellent handiwork in the cosmos and on our earth. In the second part, we will focus on randomness as a key aspect of natural evil and the role that randomness plays in natural processes. We maintain that randomness plays a crucial role in carrying out God's creation strategy, but sometimes brings harm and suffering to parts of the created order—and in a somewhat indiscriminate way—both to humans and the rest of creation. Finally, we will suggest some implications for followers of Jesus as they seek to respond and minister to victims of natural evil.

Job 38–41: The Voice in the Storm

The Voice delivers two speeches to Job. After introductory remarks (38:1–7), the first speech (38:8–39:30) contains seventeen stanzas: the first ten refer to physical features of the world, and the next seven give short descriptions of nine animals and birds. The second speech (40–41) contains lengthy descriptions of the Behemoth and the Leviathan. The following is a summary of these four chapters, focusing on features of the speeches related to natural evil.

Following the Voice's initial statement to Job (38:1–3), God describes the structure of the world

(38:4–7), in which God claims high skill and competence in planning, constructing, and continuing to manage and nurture his creation in a consistent and wise way. God created everything with a purpose, but many of his purposes do not directly relate to humans. There is no evidence of anything unplanned in creation—no surprises for God—and no indication in the speeches that anything needs fixing. God knows his creation very well, for he has planned and measured it and has a purpose for each aspect. In short, God has displayed wisdom, competence,[10] power, and care in planning, carrying out, and continuing to uphold creation. God's wisdom in creation is seen in other places in the Bible (e.g., Prov. 3:19; 8:27–29; Pss. 104:24; 136:5; Jer. 10:12). It is informative to note the Jeremiah verse,

> But God made the earth by his power, and he preserves it by his wisdom.
> With his own understanding he stretched out the heavens.

Both Walton and Tremper Longman III conclude that God, in Job 38, expresses his control of creation, demonstrating power and wisdom, but not justice.[11] God does this not only with the creation processes themselves but also through establishing organization and order.[12]

An example of God's skillful management is related to the seas (38:8–11). The sea can be dangerous, stormy, unpredictable, chaotic, and destructive for anyone. But the text indicates that God set boundaries that the sea cannot normally cross, resulting in the establishment of dry land. The unpredictable, random behavior of the sea has limits set by God, who has the power to do so, and yet we know that the sea is still dangerous, for both the sinner and the righteous person. The world's seas claim many victims each year.

In Job 38:12–15, the Voice declares that creation is renewed by God as each new day is created. This signifies the continuation of the creation process in a way that exhibits regularity and consistency, and hence makes the study of creation (i.e., science) a possibility. Science has a job to do, for the Voice points out the existence of the underworld and the realms of light and darkness (38:16–21), implying that there is more to creation than the eye can see. In exploring both the vast reaches of the cosmos and the invisible realm of the subatomic, modern science has shown that much about creation is imperceptible to our senses.

Job's understanding of the operation of nature is flawed, for he assumes that because God is just, the operation of nature must likewise be just. The next five stanzas (38:22–38) discuss aspects of the weather. God has created an eco-system that nourishes the earth and its inhabitants with all forms of water—rain, dew, frost, ice, and snow. If justice always prevailed in the cosmos, the blessing of rain would consistently target the deserving. But we read here that rain falls on uninhabited lands. And then there are the destructive effects of the distribution of water—floods (associated with torrents), tornados, other storms of many kinds, lightning strikes, tsunamis, tidal waves, blizzards, and east winds (implying destructive winds) are scattered over the earth. These destructive effects are indiscriminate, acting on sinner and saint alike. Is this justice?

These destructive effects highlight another aspect of creation—the suffering of creation that results from the way it has been planned and executed, starting in the beginning and continuing to the present. This aspect of nature is called natural evil and is clearly an intentional part of creation. In his speech, God indicates the natural evil that results from the destructive distribution of wind and water over the earth.

These verses imply a random aspect to a number of physical processes occurring on the earth. Yet, throughout scripture, we read the affirmation that God created (and creates) very well (Gen. 1:31, Job 38:4–7, plus others) and that the cosmos is continuously being upheld by the Son (Col. 1:17 and Heb. 1:3). We recognize that God controls the forces of nature, but agree with Walton when he suggests that God does not "micromanage the system with justice in mind for each moment's activity."[13]

The remainder of the first speech and the entire second speech is given to descriptions of certain birds and animals, eleven in all. Some of the animals described hunt prey to get food for their young; these serve as examples of blood and suffering in the world of living things. God is indicating that there is an order to creation. The natural order includes a food chain and involves innocent creatures suffering, resulting in blood and death in the hierarchy of animals and birds.

Natural Evil

The speech opens with the Voice responding to Job's accusation by declaring that Job does not know enough—and apparently Job does not know enough about creation and God's strategy for creation, for that is what the entire speech is about. We should also listen to God's message to Job, lest we miss important theological implications by ignoring creation. Our understanding of creation may be the key to understanding God's plan for creation, which in turn may be a prerequisite for understanding natural evil and the place that natural evil has in the overall plan God has for the cosmos.

What do we learn about creation and natural evil from God's two speeches to Job? We have several suggestions.

1. There is no hint of anything wrong with the universe or our world. Creation, including the animals and birds, seems to have come out as planned. God has created everything with a purpose. There is no hint of nature having fallen into sin. Creation has been organized well[14] and reflects God's wisdom. God does not criticize creation.

2. Unfortunate things can happen to people, animals, and the environment because of the way the universe is, even though it is well planned and being upheld faithfully and wisely by God. God is powerful, wise, and just. But only his attributes of power and wisdom are exhibited in creation. Hence, it is possible that all people and all of creation may suffer because of the character of creation, suffering that is referred to as natural evil.

3. There are consequences of natural evil, primarily that creation suffers. Must creation feature natural evil, and hence suffering? Later in this article, we will explore the idea that our world would not have developed in the way it has, had the laws and physical parameters of the universe been anything other than what they actually are. Hence, natural evil may be a necessary aspect of creation.

4. There is lawful randomness in nature. This randomness is lawful because the universe operates under the laws of physics, chemistry, and biology. Weather, genetics, and disease are at least partly understood in terms of these laws, but there is also randomness at work, resulting in events that appear hit-and-miss because of our inability to predict their exact occurrences.

5. Nature has been given freedom to explore possibilities. This freedom is exhibited in the almost unfathomable diversity of life on our planet. Lawful randomness entrusts a degree of openness to natural systems and processes, enabling nature to develop novel forms and behavior that go beyond what one would expect from a strictly deterministic system. Some have said that God has given free will to humans to do good or evil, and that nature has also been given a certain dimension of freedom. In addition to lawful randomness, the possibility of miracles and answers to prayer are consistent with a universe that does not operate under completely deterministic principles. God shows his power not only by carrying out and upholding creation, but also by withholding his power in giving creation the freedom it enjoys. Kenosis is evident not only in the incarnation but also in these gifts of freedom.

6. God knows the universe and its life intimately.[15] God knows all of the details—nothing about the universe is a surprise to God or threatens his overall purpose for the universe. In contrast, Job's knowledge is defective and incomplete. Our knowledge today may be far greater, but it still falls infinitely short of the intimate knowledge God has about all the worlds and creatures throughout the universe.

7. God's attributes of wisdom and power, but not his justice, are exhibited in his creation. Recall Romans 1:20a,

> For ever since the world was created, people have seen the earth and the sky. Through everything God made, they can clearly see his invisible qualities—his eternal power and divine nature.

Throughout scripture, we see creation references to God's wisdom (Job 38:4–6, and others) and power (Rom. 1:20a, Isa. 40, and others), but there are no creation references to his justice in the Bible. Job was mistaken when he thought that creation should reflect God's justice, and he felt betrayed by God as a result of his mistake.

In summary, the Voice does not deny the existence of natural evil. Death, pain, and destruction play a prominent role in the two speeches. Natural evil and suffering are necessary consequences of God's carefully devised and very good plan for our universe and our world.

Randomness

We will next focus on the randomness apparent in the physical world, a feature routinely ignored when thinking theologically.[16] The Voice showed Job a number of examples in our physical world that imply an inherent randomness, including the action of the seas, the weather, and the distribution of water over the earth. Do Christians have a bias against the idea of randomness being a part of God's plan of creation? Is it theologically satisfying to claim that God has ordained each detail of every physical event? Let us explore the nature of randomness and how it is clearly present in our physical world, a world that the Voice declares has been and is being created and upheld by God in a very good fashion. Through examples, we will observe the crucial role randomness plays in a number of physical, biological, and cosmological processes.

Randomness or chance essentially means unpredictability, whether the randomness is inherent (in principle) or simply a result of incalculability (in practice). Our universe is not totally random because the laws of nature put bounds on the behavior of every physical system and biological entity. Randomness, as we understand it, is a relatively new feature of contemporary science. Quantum theory, chaos theory, evolutionary biology, and many other twentieth-century developments have identified randomness as a key ingredient in natural processes.

We will now look at several examples of randomness in nature. Our first example is the radioactive decay of matter. Radioactive decay is well understood in terms of nuclear and electromagnetic forces, and physicists can model decay events using the microscopic laws of motion as given by quantum theory. The decay constant for a given radioactive nucleus can be calculated by applying its nuclear properties to quantum theory, which in turn leads to a specification of the half-life for that nucleus. For example, the half-life of Cesium-137 has been measured to be almost exactly thirty years. If we monitor any single nucleus of Cs-137, there is a 50% probability that the nucleus will decay at some time in the next thirty years. The problem is that the half-life is only a probability—we can say how likely it is that a nucleus will decay in a given span of time, but we cannot say exactly when that particular nucleus will decay. However, if we have 100 grams of Cs-137 with approximately 4×10^{23} nuclei, statistical theory lets us say with a high degree of certainty that after thirty years have passed, about 2×10^{23} nuclei will remain in that sample, with the other half of the nuclei having undergone decay.

In one sense, this is a random process. There is no way of predicting which of the nuclei in the original sample will decay in any given interval of time. Each nucleus in the sample has a 50% chance of surviving the thirty-year period. We know *how many* will survive, but we do not know *which ones* will be the lucky ones to survive.

It is much the same way in the life insurance business. Given a large enough sample of 75-year-old men, an insurance company knows fairly precisely how many of these will survive the next 365 days. In fact, the insurance company knows this number so well that it can make money insuring the lives of these men. The company knows how many, but not which ones will die.

These are examples of what we have referred to as "lawful randomness." In the nuclear case, the half-life of an unstable nucleus can be calculated from the principles of quantum mechanics and nuclear physics, along with the general laws of nature such as the conservation laws for energy, momentum, and charge. The half-life does not give a deterministic measure of when any single nucleus will decay, but for a large enough sample, the half-life gives an accurate measure of how many of the nuclei in the sample will survive over a given time interval. This is lawful randomness and is an inherent physical property of our universe.

Another example of randomness in nature is in the occurrence of skin cancer. It is well known that skin cancer can be induced by ultraviolet radiation from the sun. Ultraviolet radiation consists of high energy photons, photons that are energetic enough to alter the molecules that comprise human skin. A very small percentage of the photons incident on the skin will induce a cancerous mutation. Just as with radioactive decay, our best scientific understanding of how often photons will induce cancer in skin molecules is in terms of calculated probabilities. We cannot be certain of the exact effects of a single photon on a single human skin cell, but we can accurately calculate the probability of skin cancer occurring when a sufficiently large number of photons (from sunlight) and skin cells (in people) are involved. Here we have another example of a random process that operates under well-understood physical laws. And, of course, we are fortunate that not every high energy photon with the potential of inducing skin cancer will actually do so.

Other examples of the importance of randomness in the life sciences abound. In an earlier article in *PSCF*, Craig M. Story pointed out the example of antibody gene rearrangement as an example of a biological process that relies on randomness to achieve important positive ends.[17]

Returning to physics, there is a simple classroom experiment that can deliver surprising and random results that we can see with our naked eyes. Figure 1a is a typical experimental set-up for observing interference fringes using a light source, a card with two narrow, closely spaced openings (slits), and a screen. Figure 1b is a photograph of the areas of light and dark observed on the screen. The interference pattern in Figure 1b is well understood in terms of classical wave optics, and arises from the constructive and destructive interference of wavelets of light as they emerge from the slits. The same basic experiment can be performed with electrons by replacing the light source with an electron emitter and the photo-sensitive detector with an electron detector. The same type of interference pattern results with electrons as was observed for light—a series of parallel regions of electron registration and regions of no electron arrival.

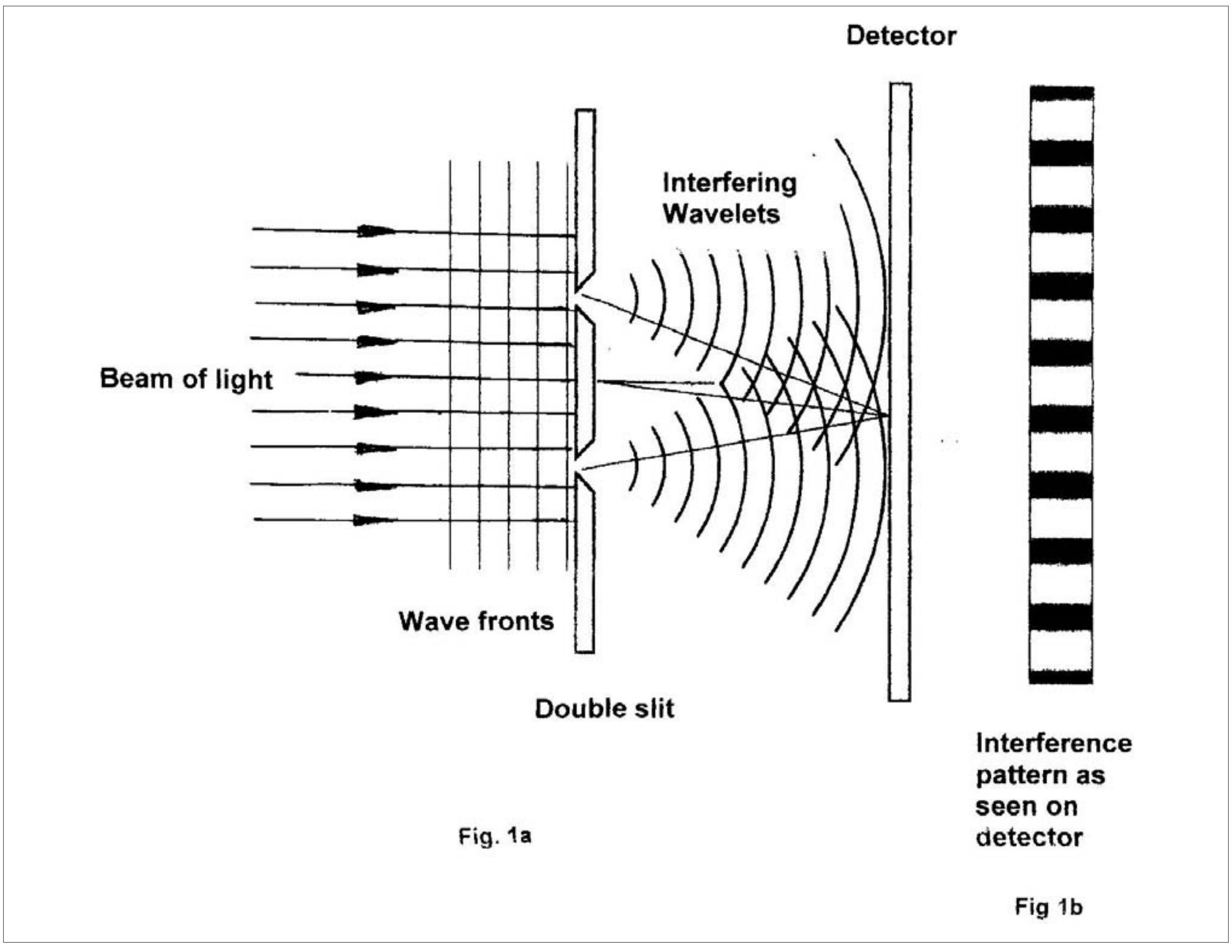


Figure 1. Double slit interference experiment schematic set-up (fig. 1a) and resulting interference pattern (fig. 1b).

Nature has a surprise for us. In the light-based experiment, let us reduce the intensity of the light beam until individual photons are travelling, one by one, from the light source, through the slits, and onto the screen. At this point, it is convenient to think (like Einstein and others) of the light beam as a beam of individual particles of light (photons) rather than as a wave phenomenon, the usual conception of light. We can even take measures to verify that only single photons are being produced, and, instead of a screen, we can use a light detector capable of registering the arrival and position of individual photons. We can also make similar adjustments to the electron experiment, using a single-electron emitter and a detector sensitive enough to record the arrival and position of single electrons.

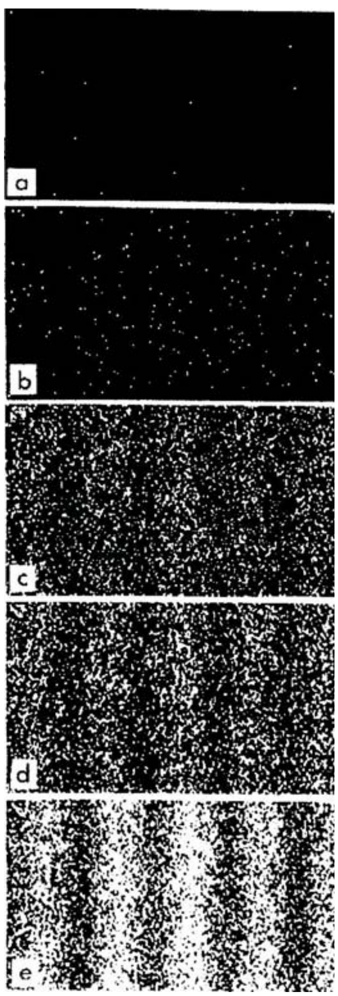


Figure 2. Results for a single-electron interference experiment. Photos of the registration patterns on the electron detector after (a) 11 electrons were recorded, (b) 200 electrons, (c) 6,000 electrons, (d) 40,000 electrons, and (e) 140,000 electrons.

The two experiments give similar results. Figure 2 is a photograph of the registrations on the electron detector.[18] Each dot in the photo represents the arrival of a single electron. In (a), 11 electrons have been recorded; in (b), 200 electrons; in (c), 6,000; in (d), 40,000; and in (e), 140,000. The pattern seen in the light experiment is quite similar. Figure 3 is a series of time lapse photographs of the arrival of photons at the light detector.[19] These figures show that when a sufficiently large number of particles have been emitted, the average behavior is the interference pattern expected by classical wave optics. However, notice that the behavior of individual particles is somewhat random, as seen in the photographs for small numbers of photon or electron arrivals. For example, across the entire area of the electron detector, we observe that electrons are less likely to be detected in the "dark" regions, and that electrons are more likely to be detected in the "lit"

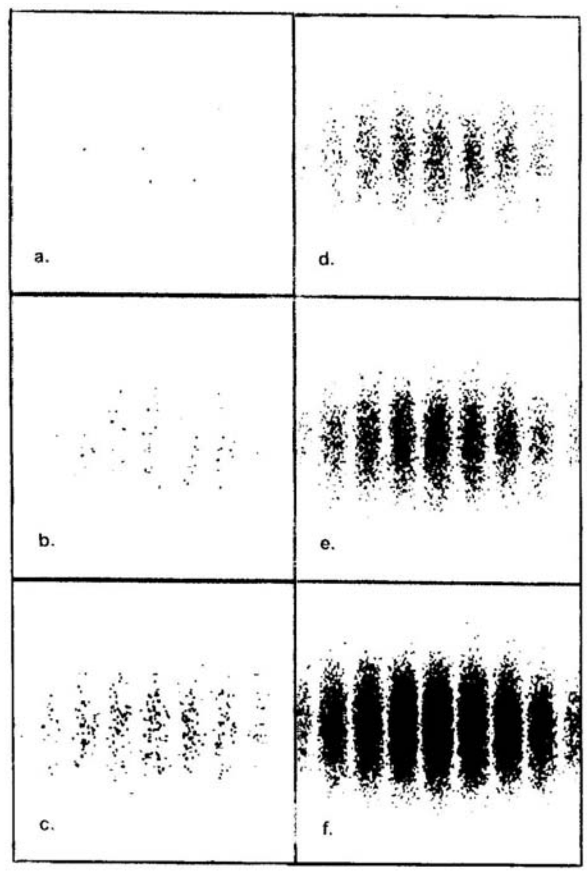


Figure 3. Results for the single photon experiment. Photos of the registration patterns on the photon detector over increasing time intervals from a. through f., respectively. From http://www.tnw.tudelft.nl/en/about-faculty/departments/imaging-science-and-technology/research/researchgroups/optics-research-group/education/experimental-projects/photons-in-an-optical-interference-experiment/.

regions, but we can predict nothing about the position of a given particle's arrival. The same can be observed for the individual photon experiment. These are also examples of lawful randomness, or randomness that is fenced in by physical principles.

Indeed, randomness seems to be woven into the very fabric of the universe. The 2012 Nobel Prize in physics was awarded to two physicists who, working independently, successfully observed individual particles exhibiting some bizarre quantum properties—properties of the superposition of quantum states. In one study, a single atom was found to be in two places simultaneously. In another experiment, an ion was put into a superposition state, which is the simultaneous existence of two distinctly different states. In both cases, the experiments confirmed that the most information we can have about a quantum superposition is the *probability* of getting outcome A versus outcome B. This is analogous to the Cs-137 nucleus decay, in which we can only know the *probability* that a given nucleus will decay in a given time interval. Quantum uncertainty produces random results, and this weird behavior appears to be a fundamental aspect of nature.

Nature may have more sources of lawful randomness than just quantum mechanics. The mechanisms of the development of life on our earth have been the topic of intense study over the past two centuries. Nearly all scientists now agree that the contemporary understanding of evolutionary processes is essentially correct, yet scientific work in this area of study continues. A number of evolutionary biologists (including Stephen Jay Gould) understand evolution to be a blind, random process. Simon Conway Morris moderates this position by suggesting that the "emphasis on randomness be replaced with an emphasis on deterministic outcomes that result largely from the role of ecological processes in speciation and extinction."[20] Conway Morris suggests a number of systems connected with the development of life as being convergent; for example, protein structures, skeletal structures, eyes, sensory nervous structure, intelligence, and social behavior, to name a few. The bottom line is that the evolutionary mechanism of adaptation and natural selection is a powerful method for searching among the myriad of random possibilities, and even though there is a random aspect here, evolution is progressive. Conway Morris maintains that we cannot predict the evolutionary future, but we can be confident that we are on a path to the future.[21] Once life began on earth, sentient life was inevitable, according to Conway Morris. Once again, we have encountered a situation of lawful randomness—randomness that is fenced here by higher principles that apply to the biological world.

The Voice did not discuss nuclear physics with Job, but the Voice did spend some time discussing weather, including the distribution of water over the surface of the earth. Today we understand that the earth's water cycle employs processes of evaporation, condensation, and precipitation to distribute water (in its various forms) over the earth. This distribution is partially lawful, depending on a number of well-understood factors such as surface temperature, prevailing wind directions, and ocean currents. In fact, weather patterns can be described very well by deterministic equations.

The reason we cannot predict the weather with great accuracy is because these deterministic equations require precise knowledge of the entire Earth's weather system at a given point in time (this is often referred to as knowledge of "initial conditions"). Unfortunately, it is not possible to collect the perfectly accurate information needed as input to the equations. Even if we could obtain the detailed information needed, all the classical computers in the world are not capable of processing the amount of information involved. We may receive some small consolation from the fact that our calculations would not give accurate predictions anyway, due to the many nonmeteorological events affecting the weather all the time (volcanic eruptions, butterflies in the Amazon, etc.). Epistemologically, we are prohibited from accurate weather predictions by chaos theory, another twentieth-century development. General patterns of weather can be predicted using the deterministic laws of meteorology, but precise predictions are impossible because of the chaotic nature of weather systems resulting from their exquisite sensitivity to initial conditions.

These examples are but a small sample of physical and biological processes that exhibit randomness constrained by physical law. Nature's operation includes a component of "lawful randomness."

Modern science takes chance seriously, for randomness occurs at all levels in nature. At the microscopic level, there is randomness in terms of nuclear processes, individual photon and electron phenomena, and the initiation of cancer. At the macroscopic level, we find randomness in patterns of disease, weather, and the outcomes of evolutionary processes. Many of these lawfully random phenomena have been observed throughout history, and some (such as the weather) would even have been within Job's experience.

Randomness and God's Nature

Is the idea of the existence of randomness in nature consistent with God's attributes? The concept of randomness does not usually jump into one's mind when thinking about God's attributes. We do not think of God intentionally creating the universe with the characteristic of ontological randomness—physical processes having a true, inherent random character.

Recall the very first thing God tells Job in chapter 38: Job does not know enough. What does Job not know? The two speeches of chapters 38–41 (which contain the greatest number of words by God in a speech in the entire Bible) make it starkly clear that Job does not know enough about God's strategy in creation or about how it operates.[22] In particular, Job does not know enough about those aspects of God's character as revealed in the created order. The Voice points to creation as being well planned and well constructed, and progressing in complete accordance with God's plans. This judgment echoes a short but elegant evaluation of creation by God in Genesis 1:31a: "God looked over all he had made, and he saw that it was very good!"

As Walton points out, "very good" here implies that creation is well planned, organized, and functions properly, according to God's pleasure. "Good" does not imply a standard of moral perfection here. Instead, God creates and governs by wisdom, and even though justice is one of his attributes, the cosmos (including our world) does not reflect that particular attribute.[23] The randomness that exists in nature implies that all of creation is subject to the effects of random events, and that the individual random events can be both beneficial and harmful to parts of creation, including humans. We can all contract cancer, and we can be a victim of a tornado or an earthquake. As Jesus said, referring to his Father in Matthew 5:45b,

> For he gives his sunlight to both the evil and the good, and he sends rain on the just and the unjust alike.

So, we should carefully consider the limits of our knowledge and understanding before making the claim that the randomness seen throughout nature is evidence that God is unjust in some ways. The question is, where does randomness fit into the good plan and wise management that the scriptures claim for God?

The Goodness of Creation (yes) and Natural Evil (really?)

The overwhelming majority of passages throughout the Bible declare creation to be good—and sometimes it is called very good or exceedingly good.

- Creation is associated with good planning and the ability to carry out creation (Isaiah 40).
- Creation is associated with wisdom (Proverbs 3 and 8).
- Creation is emphatically praised (Psalms 8, 19, 33, 74, 104, 145, 148).
- Creation is called "very good" (Genesis 1).
- Creation is the result of a wise and careful plan and skillful construction (Job 38).
- Creation is the work of God and the Second Person of the Trinity, the Word; the Word is revealed to be the one through whom God created and is the one who faithfully upholds creation (John 1, Colossians 1, and Hebrews 1).

Creation is never criticized in the Bible. There is nothing in the Bible that indicates that there is anything wrong with creation itself. However, creation groans and longs for the eschaton (Rom. 8). In the story of the Fall (Gen. 2 and 3), the human formed early on the day of creation is given responsibility to develop, preserve, and carefully watch over and protect creation (Gen. 2:15), this after the human was formed from the dust of the ground (Gen. 2:7). The disobedience of humanity results in an antagonistic relation between humanity and the ground, as human labor and toil is now required to work the ground, overcoming weeds and thorns to gain a harvest.

Yes, creation awaits the eschaton, we must work the land, and natural evil exists. But the overwhelming evaluation of creation by the Bible is that it is outstanding (nothing is wrong with it), and creation itself has not fallen (creation does not sin). In particular, the fact of natural evil is well displayed throughout the Bible without being criticized.

A relevant example is the pericope in John 9:1–3, where Jesus and his disciples come upon a man who had been blind from birth. The disciples ask Jesus, "Why was this man born blind? Was it because of his own sins or his parents' sins?" (John 9:2b). Jesus answers, "It was not because of his sins or his parents' sins" (John 9:3a). Here is an example of natural evil (a birth defect), and Jesus declares it is not the result of sin.

In summary, creation (nature) as presented in the Bible gets very good marks. And this evaluation, by implication, also falls on natural evil, and we would propose that this also applies to the natural evil that is associated with random natural events. Nowhere in the Voice's speeches from the storm do we find any criticism of creation. So we then need to ask, what possible good can come from natural evil and random natural events, and what should be our appropriate response, as followers of Jesus, to natural evil and to those who suffer the consequences of natural evil? In other words, why is natural evil, including random natural events, a part of a wisely planned and carried-out creation?

Nature's Freedom, Randomness, and Fine Tuning

Before further addressing natural evil, we need to recognize the crucial nature of (1) fine tuning and (2) the freedom of the natural world to explore new pathways. Both are at least partially related because of the random nature of certain natural events.

As a first example, consider the genome. The genome does not copy with 100% accuracy, and these copying mistakes (variations) can either be beneficial or harmful—many times the harmful ones die out because of differential reproductive competition or the early death of the creature because of the mistake. But the occasional beneficial variations allow the organism to gain reproductive advantages and to adapt to changing environments, resulting in a competitive edge, and hence an advantage for the continued existence and thriving of the organism. Randomness plays a crucial positive role here.[24]

Fine tuning has played a crucial role in the development of our cosmos and carbon-based life here on Earth. The discovery of the fine-tuning nature of physical constants and physical laws, plus the fortuitous characteristics of our solar system (including the relation of our earth to the sun), have played an important role in the development of life on our earth. In the latter part of the twentieth century, physicists discovered that there are roughly thirty characteristics of the universe that had to be just what they are, sometimes within unimaginably tight limits, or carbon-based life would not have developed on our earth, and humans would not exist.[25] These characteristics include the strengths of the fundamental forces; the mass and charge of the electron, proton, and other subatomic particles; the gravitational constant and other physical constants; the physical relationships between bodies in our solar system; and many others. The workings of our cosmos are reflected in the physical laws that make up the finely tuned array of required conditions for life to exist on Earth, and, as discussed earlier, randomness is a fundamental aspect of these laws. Randomness is required for humans and the rest of creation as we know it to exist. Randomness is the cost for the existence of carbon-based life here in the cosmos some 13.8 billion years after the Big Bang.

The physical characteristics of our universe/earth system—lawful randomness (the mix of chance and necessity) coupled with fine-tuning—continue to be crucial to the well-being of our planet and its living creatures. Hence, the existence of natural evil, including its random aspect, is crucial to the well-being of our entire earth's ecosystem. We need natural evil. I am not sure that I will praise God for the tornado that destroys my house or kills my family, but, in the overall scheme of things, that tornado is necessary.

God knows when the sparrow falls. God cares. But in spite of God's concern for the sparrow, nonetheless the sparrow indeed falls—God does not prevent the sparrow's demise (Matt. 10:29). If the sparrow did not fall—if there were no creaturely death in the world, we would be buried in sparrows and every previously living thing, and most likely the earth's life would be radically different, perhaps with no humanity.

So, creation is good and well planned; it came out as God planned (Job 38), no surprises. Like Job, we really do not know enough about creation. In particular, we need to understand natural evil. Our guess is that many Christians do not understand natural evil, its relationship with randomness, and how to react to it. In order to understand natural evil, we need to understand and appreciate randomness.

Theological Implications

Certain theological conclusions follow in a natural way. God's gift of freedom to nature implies that a fundamental characteristic of nature is its inherent randomness, and, hence, God withholds a portion of his omnipotence in normally choosing not to intervene in the day-to-day operation of the universe, including the earth. However, we do not want to say that, if the occasion calls for it, he will never intervene. Miracles have and will continue to occur, the principal miracles of the past being the incarnation and resurrection of Jesus. Miracles are truly unexpected providences associated with unprecedented situations that carry extraordinary religious significance. God will intervene, not so much by suspending the laws of nature in a given instance, but by bringing into play new aspects of nature that address a situation in an unprecedented way.[26] The result is that, in the normal course of weather events, tornados will develop and sometimes destroy cities and kill people. Could God have diverted the storm to an unpopulated area? Yes, he could, if he so chose.

But it seems that God will not stop a rattlesnake from doing what is natural to rattlesnakes—striking a nearby warm-blooded object such as a mouse or a person's leg. An eagle will feed her brood with a fish or a pet dog. A tick, carrying Lyme disease, will latch on to any nearby blood-carrying creature—dog, deer, or human, for example. Each can become ill, and even die, as a result of the tick's bite. An earthquake once destroyed a church filled with worshippers, killing hundreds. In many cases, people suffer. Is this suffering from natural evil the result of sin? We repeat Jesus's judgment in John 9 and God's judgment in Job 42 in declaring that the answer is a resounding NO!!! It is rather nature doing what nature was designed and given freedom to do in most cases—and *must* do for the ongoing health and existence of the cosmos and the world.

Natural evil has two diametrically opposed characteristics. Natural evil is associated with natural events that are (1) consistent with and necessary for the outworking of fine-tuning for the continuance of the development of the cosmos, the earth, and life on the earth and (2) random in nature but can be harmful to those who are victims of their outworking. Thus, they are ecologically beneficial, but, for an individual, they can be quite harmful. And these events fall on the just and the unjust—all people suffer.

Is natural evil a good descriptive name for such a phenomenon? We think not. But what should it be called? We invite the reader to consider and suggest alternatives.

As a result, we certainly will never say that a tornado that levels a city such as Joplin, Missouri, or Moore, Oklahoma, is evidence of God punishing these cities for sin. No. We say that those who suffer from tornados are making a sacrifice for the well-being of the world and the cosmos, and that their suffering, when it occurs, should be seen by Christians as sacrificial and an opportunity for compassion—recall Jesus's response to the natural evil suffered by the man born blind (John 9). As members of the human family, our response should always be to offer relief and help for those who suffer the consequences of natural evil. God is not punishing; God is not even directing the tornado at these cities. But God is allowing the natural world, the world that the Son sustains by the power of his command (Heb. 1:3), and the creation that he holds together (Col. 1:17), to carry out the processes that reflect how the universe was created and continues to be created.

No part of creation, including humans, is immune to suffering. Do we learn anything in Job about helpful responses to suffering? Longman suggests that Job's speeches prior to the Voice's speeches are not examples of a proper attitude toward God in the midst of suffering. Yet, later, Job becomes silent (40:4–5). This attitude toward suffering is also found in Lamentations.[27] In the end, Job's anger subsides, and he demonstrates that he will worship God even in the midst of suffering.[28]

In summary, we suggest that the message that God is sending in cases such as Job's, is that suffering from natural evil may be a cost of being part of a good creation. Creation continues, God reigns and upholds it faithfully, and the groaning of creation will end with the advent of the New Jerusalem. And for those who suffer, words from Exodus 33:14 (NIV) are relevant:

> The LORD replied, "My Presence will go with you, and I will give you rest."

Notes

1Job 1:1b, *Holy Bible – New Living Translation* (Carol Stream, IL: Tyndale House, 2007). All subsequent scripture quotations are also from the same version of the Bible.

2For a discussion of the use of "the challenger" rather than "Satan" here, see John H. Walton, *Job: The NIV Application Commentary* (Grand Rapids, MI: Zondervan, 2012), 64–7.

3Marvin H. Pope, *The* Anchor *Bible – Job* (Garden City, NY: Doubleday, 1965), xvii–xxii.

4Walton, *Job: The NIV Application Commentary*, 39–48.

5Ibid., 399.

6David J. A. Clines, *Word Biblical Commentary – Job*, vol. 18B (Nashville, TN: Thomas Nelson, 2011), 1088–9.

7Walton, *Job: The NIV Application Commentary*, 398.

8Clines, *Word Biblical Commentary – Job*, 1089.

9Ibid.

10Pope, *The* Anchor *Bible – Job*, xxii.

11Walton, *Job: The NIV Application Commentary*, 399; and Tremper Longman III, *Job*, Baker Commentary on the Old Testament: Wisdom and Psalms (Grand Rapids, MI: Baker Academic, 2012), 451.

12Walton, *Job: The NIV Application Commentary*, 400.

13Ibid., 401.

14Clines, *Word Biblical Commentary – Job*, 1089.

15Ibid., 1090.

16We want to point out that James Bradley, in a recent issue of this journal, did indeed consider some of the theological implications of randomness in his article, "Randomness and God's Nature," *Perspectives on Science and Christian Faith* 64, no. 2 (2012): 75–89.

17Craig M. Story, "The God of Christianity and the G.O.D. of Immunology: Chance, Complexity, and God's Action in Nature," *Perspectives on Science and Christian Faith* 61, no. 4 (2009): 221–32.

18A. Tonomura, J. Endo, T. Matsuda, T. Kawasaki, and H. Exawa, "Demonstration of Single-Electron Buildup of an Interference Pattern," *American Journal of Physics* 57 (1989): 117–20. The YouTube video, "Tonomura's electron double slit experiment without narration," shows the development of the two-slit interference pattern with electrons, http://www.youtube.com/watch?v=_oWRI-LwyC4.

19"Making Discrete Photon Effects Visible in an Optical Interference Experiment," accessed Dec. 23, 2013, at http://www.tnw.tudelft.nl/en/about-faculty/departments/imaging-science-and-technology/research/researchgroups/optics-research-group/education/experimental-projects/photons-in-an-optical-interference-experiment/.

20Simon Conway Morris, *Life's Solution: Inevitable Humans in a Lonely Universe* (Cambridge: Cambridge University Press, 2004), 236.

21Ibid., 307.

22Walton, *Job: The NIV Application Commentary*, 411.

23Ibid.

24Francis Collins, *The Language of God* (New York: Free Press, 2006), 189–90.

25John Polkinghorne, *Science and Creation* (Boston, MA: New Science Library, 1988), 22.

26John Polkinghorne, *Quarks, Chaos and Christianity* (London: Triangle, 1994), 79–89.

27Longman, *Job*, 453–4.

28Ibid., 456.

ASA Members: Submit comments and questions on this communication at www.asa3.org → FORUMS → PSCF DISCUSSION.

An Environmental Science Challenge

Science is constantly moving. **Dorothy Boorse**, professor and chair of biology at Gordon College and co-author of the textbook *Environmental Science* now in its twelfth edition, has written an intriguing description of the latest developments in environmental science along with insights and challenges it raises for Christian faith. The essay is provided at http://www.csca.ca/wp-content/uploads/2013/12/EnvironmentalScience2013.pdf.

This article is intended as an invitation. Readers are encouraged to take up one of the insights or challenges, or maybe a related one that was not mentioned, and draft an article (typically about 5,000–8,000 words) that contributes to the conversation. These can be sent to Boorse at Dorothy.Boorse@gordon.edu. She will send out the best essays to peer review, and then we will select from those for publication in an environmental science theme issue of *Perspectives on Science and Christian Faith*.

The lead editorial in the December 2013 issue of *PSCF* outlines what the journal looks for in article contributions. For full consideration for inclusion in the theme issue, manuscripts should be received electronically before March 30, 2014.

For those readers who prefer to take a literary approach in sharing their ideas, please submit essays (up to 3,000 words), poetry, fiction, or humor inspired by Boorse's invitational essay to emily@asa3.org for possible publication in *God and Nature* magazine.

Looking forward to hearing your perspectives,

James C. Peterson
Editor, *Perspectives on Science and Christian Faith*

Man Ho Chan

Can Natural Laws Create Our Universe?

Man Ho Chan

Stephen Hawking suggests that our universe can be created by natural laws without any supernatural explanation. In this article, I argue that it is not possible for natural laws or science to create our universe. Science can only illustrate how the universe evolves; it cannot explain why our universe exists. The existence of our universe can be addressed only by other disciplines such as religion or theology.

Modern astrophysics indicates that our universe has a beginning. We are living in a universe which was created 13 billion years ago.[1] A philosophical problem associated with this issue is why the universe comes into existence. A related issue is that the laws and parameters of our universe seem to be "fine-tuned" so that life can exist.[2] Can these provide the evidence to prove the existence of God?

In *The Grand Design*, Stephen Hawking and Leonard Mlodinow announced that modern science has found a way to address the problem of the beginning of the universe.[3] They deny that the existence of God should be taken into account and claim that the theories of gravitation and quantum mechanics are enough to provide a clear picture of how the universe begins. They suggest that our universe may not necessarily have a beginning, and suppose that the beginning of the universe was like the South Pole of Earth, with degrees of latitude playing the role of time. As one moves north, the circles of constant latitude, representing the size of the universe, would expand. The universe would start as a point at the South Pole. However, the South Pole is much like any other point. Technically speaking, Hawking and Mlodinow suggest that time at the very beginning is an imaginary number (e.g., $i^2 = -1$) rather than a real number, so that "t = 0" does not exist.[4] Therefore, our universe can be considered to have no boundary in space and time.[5]

Moreover, natural laws allow nearly infinitely many universes to exist, and they can explain why our universe seems to be fine tuned.[6] The extrapolation of string theory and inflation theory can provide a theoretical framework for the existence of nearly infinitely many universes. According to string theory, a particular Calabi-Yau manifold may represent a particular set of fundamental constants in nature. Mathematical estimation shows that there are 10^{500} possible types of Calabi-Yau manifold, and that the number of possible types should be finite.[7] In other words, if there really are many universes, and each universe is characterized by a particular Calabi-Yau manifold, there would be about 10^{500} possible universes existing in nature.[8] Hawking and Mlodinow suggest that all universes could be generated through this mechanism, and so we should not be surprised that our

Man Ho Chan *graduated from the Chinese University of Hong Kong in 2002. Later, he obtained his master's and doctoral degrees in physics in 2004 and 2009, respectively; Master of Arts in Christian studies in 2010; and postgraduate diploma in education in 2012 from the same university. Chan is now a lecturer in the physics department of the Chinese University of Hong Kong. His research interests include astrophysics, philosophy of science, and dialogue in science and religion.*

universe is fine tuned. Since there are so many universes with different fundamental constants, it is highly probable that the right set of fundamental constants that are life permitting will occur.

In this article, I claim that the problems of the beginning of the universe and its fine-tuning can never be explained by natural laws. These problems can be solved only with the help of other areas or disciplines, such as religion and theology.

What Can Science Explain?

Generally speaking, scientific laws are a set of laws that describe nature. Most of them are based on empirical studies, such as experiments and investigations. A scientific law can be established if numerous experiments are conducted and the results generated do not contradict that law. Therefore, most scientific laws, such as conservation of energy or Newton's law of gravitation, are based on countless repeatable experiments. These laws describe our universe and enable us to make predictions. For example, in physics, Newton's law of gravitation tells us how a particle moves under the action of gravity. We can also predict how the particle moves under given environmental constraints, or, in other words, under the initial conditions and under the forces acting on that particle. In this context, scientific laws are deterministic. What you need to provide are the necessary initial conditions. Otherwise, scientific laws cannot tell you the next step.

However, the rise of quantum mechanics tells us another story in modern science. In the small-scale regime, the wave nature of a particle becomes significant. The phenomenon of wave-particle duality makes an exact prediction impossible. The uncertainty principle tells us that you can never simultaneously measure the position and momentum of a particle precisely. Within the context of quantum physics, the particle's behavior becomes indeterminate. There may be many possible states that a particle can be in at a given time, but it will "fall into" only one of them when you measure it. The state of a particle can be described by a wave function, which is a superposition of (perhaps infinitely) many possible states. What you can do is calculate the probability that the particle will fall into a certain state; but you cannot guarantee this prediction for any particular instance of measurement.

Therefore, the combination of deterministic gravitation and indeterminate quantum physics is not that easy. Both the implicit natures of the theories themselves and the vastly different scales governed by these laws make it difficult. String theory is one of the theories tackling this problem in mathematical physics. Although no robust observations can prove the legitimacy of the theory, the picture of string theory is quite elegant and full of self-consistency. This theory invokes some extra dimensions and treats particles as strings instead of as points to reconcile both gravity and quantum mechanics, which, in turn, may provide a path to describe how our universe began. One of the implications of string theory is that there may be more than 10^{500} possible manifolds in the extra dimensions, and each manifold may correspond to one independent universe. Therefore, there may be more than 10^{500} different universes which have different physical laws and universal constants.[9]

Furthermore, the random nature of quantum physics enables our universe to start from nothing and come into existence. Hawking and Mlodinow used this idea to prove that we do not need the existence of God to explain either the beginning of the universe or the fine-tuning problem.[10] Since our universe is just one of many universes (or multiverse), we should not be surprised as to why our existence is so lucky. Can the above picture explain all that?

First of all, before I state my arguments, many scientists have already provided arguments to reject the idea of multiverse.[11] "Proof of parallel universes radically different from our own may still lie beyond the domain of science," Ellis said.[12] The existence of multiverse can be derived from string theory plus eternal inflation, but neither of them has been proven.[13] In addition, the existence of many universes does not necessarily mean that all of these universes can co-exist at any instant. Just as in quantum mechanics, there are infinitely many possible states for a particle to be in at a given time, but the particle can be found in only one state when we measure it. In other words, the existence of many universes in the mathematical model does not imply that they really exist simultaneously. Moreover, if a multiverse exists, it is highly probable that our universe would stay in a "dangerous region," in which the initial quantum fluctuation yielding our universe lies just at the edge of the life-permitting anthropic region. It is called the "principle of living dangerously." However, the observed value of the initial quantum fluctuation shows a negative result, weakening the theory of multiverse.[14] The assertion that the fine-tuning problem is already solved by science is far from being a consensus.

Science Cannot Explain Creation

For the beginning of the universe, I argue, in the following discussion, that science can never address this question. There are two ways to discuss this issue: (1) our universe has evolved from eternal existing energy, and (2) our universe is created from nothing. For the first case, science can never explain the assumption of eternal existing energy.

The second case is also beyond the scope of science. Some scientists think that matter and energy can be created from quantum fluctuations. It seems that quantum mechanics allows random physical processes in nature, and random fluctuations imply all possibilities. Therefore, matter and energy can be created in this oversimplified picture. However, although natural laws allow energy and matter to be created from quantum fluctuations, initial conditions and the existence of possible states also need to be taken into account. In quantum physics, "nothing" is not really nothing, but, rather, a state full of fluctuations. These fluctuations are essential conditions for creation and cannot be determined by natural laws. Therefore, natural laws can be regarded as necessary conditions for creation, but not as sufficient conditions.

C. S. Lewis had already pointed out that natural laws are more or less like the rule of addition.[15] Natural laws tell you that if you save $1,000 a month, you will have $3,000 after three months. Natural laws cannot guarantee that you will have $3,000 in the bank if you did not deposit any money. The actions (put money into the bank) together with the laws (addition rule) enable your money to accumulate correctly.[16] Similarly, initial conditions together with natural laws enable our universe to be created. Hawking suggests that our universe can be created based on existing scientific theories. However, these theories require initial conditions such as specifying the initial entropy, the initial (primordial) quantum fluctuations, and the initial inflation field.

Can natural laws create these quantum fluctuations and inflation field? The answer is no! If natural laws that govern the evolution of the universe are deterministic, as mentioned above, the initial conditions are essential. These conditions cannot be determined or described by natural laws. In fact, Hawking and Mlodinow are trying to develop "a law of initial conditions" through quantum gravity to address this problem. As noted above, they invoke the notion of imaginary time to blur the boundary at t = 0. It seems that we do not require initial conditions for creation.

However, there are a number of criticisms stating that the "imaginary time epoch" is ontologically unreal and unintelligible.[17] Strictly speaking, our universe is transformed from an ontologically *unreal* state to an ontologically *real* state. Our universe began to exist. Therefore, Hawking and Mlodinow's solution does not fully address the singularity problem but, rather, replaces it with another problem. If the natural laws that govern the evolution of the universe are fully indeterminate, then randomness is involved in creation, and probabilities should be taken into account. However, we can still ask, "Is the creation highly probable?" Whether the answer is yes or no, we need to further ask why.

Furthermore, logical difficulties will be encountered if we claim that natural laws could create the universe or multiverse. Since natural laws are derived from empirical studies in the existing natural world, how can they be used to describe a universe that is created from "nothing"? Is there a law that can describe "nothing" or that can transform "nothing" to "something"? If that is right, a law or logic should exist prior to space and time.[18] But we know that all physical laws are obtained from the real world (real space and time) and not from "nothing." The extrapolation of applying natural laws to creation (transforming "nothing" to "something") requires a leap of faith. Therefore, whether or not the law is deterministic, it is not possible to have "a law of initial conditions."

The theory of multiverse also states that there may be infinitely many universes that exist at the same time. Each universe may contain certain universal constants. As a result, different universes may have different natural laws. Since this theory is derived from existing scientific theories (string theory and inflation theory), do all universes satisfy a description based on string theory and inflation? If so, then how could these different universes have different universal constants and natural laws? If not, how could different natural laws in different universes be obtained from existing scientific theories? If string theory and inflation are the ultimate scientific theories that can apply to all universes, why are they so universal and so special? These questions are definitely beyond the scope of science.

Antony Flew thought that the existence of natural laws requires an explanation. The explanation cannot be addressed by natural law itself.[19] Therefore, science can only push the problems of creation to a more fundamental level, but it can never fully address this issue. In fact, it is quite easy for us to confuse the terms "cause" and "agency." Natural laws can tell you the cause of an event, given that all initial conditions are known. However, natural laws will not tell you who or what makes the laws (the agency). For example, natural laws can tell you how a steam engine works, but not who makes the steam engine.[20] Therefore, natural laws can only tell you "how" but not "who" or "why."[21] In other words, natural laws should be based on "methodological naturalism" rather than on "philosophical naturalism."

When Hawking and Penrose formulated their "Hawking-Penrose singularity theorem," this theorem suggested that our universe had a beginning. However, scientists still work hard to create different models to give solutions that avoid the existence of singularities. Mann suggests that the ideology of reductionism plays a crucial role. Nontheists generally regard the approach of reductionism as closing off any last gaps in which hopeful believers might want to place evidence for a deity.[22] However, none of the models suggested, including Hawking's "no boundary proposal," actually work.[23] Similarly, scientists also work on quantum gravity and string theories because they are not satisfied with the twenty-seven free parameters in the Standard Model of particle physics. Unfortunately, no successful results along these lines have yet been obtained by unifying quantum mechanics and general relativity. Mann comments that the failure of unifying quantum mechanics and general relativity is, in part, due to their very distinct conceptualizations of time.[24] All of these negative results may suggest that the Standard Model and the existence of singularities have already reached the limits of science.

What Can Explain Creation?

If science cannot explain the creation event, then which discipline can possibly do so? Intuitively speaking, the existence of a supernatural being may be a possible solution. Since all natural laws cannot explain the origin of natural objects, some supernatural forces should be taken into account. Therefore, the only way to address the origin of our universe is by seeking the supernatural source that creates the natural laws and initial conditions. This argument is known as the Kalam argument. The argument can be formulated as follows:[25]

P1: Whatever begins to exist has a cause of its coming to exist.

P2: The universe began to exist.

C: The universe has a cause of its coming to exist.

The conclusion, C, derived from the two premises, P1 and P2, needs an explanation. Natural laws support P1. However, natural laws cannot guarantee P2. Nevertheless, based on recent observations from cosmological microwave background, P2 is empirically true. Therefore, natural laws cannot be the cause of our universe. Generally, most philosophers believe that the existence of God is the ultimate cause or explanation. They advocate the doctrine of divine simplicity, which means that God is claimed to be absolutely simple without any internal complexity.[26] Therefore, God is the simplest being, and it is not necessary to transfer the existence of God to one higher level of simplicity.

Conclusion

To conclude, the two biggest problems in science and religion, the creation of the universe and the fine-tuning problem, can never be addressed by science. We should start from other disciplines such as religion to get the answers.

Notes

[1]D. N. Spergel et al., "Three-Year *Wilkinson Microwave Anisotropy Probe (WMAP)* Observations: Implications for Cosmology," *Astrophysical Journal Supplement* 170, no. 2 (2007): 377–408.

[2]M. J. Ree, *Just Six Numbers: The Deep Forces That Shape the Universe* (New York: Basic Books, 2000); A. E. McGrath, *A Fine-Tuned Universe: The Quest for God in Science and Theology* (Louisville, KY: Westminster John Knox Press, 2009).

[3]S. Hawking and L. Mlodinow, *The Grand Design* (New York: Bantam Books, 2010).

[4]An imaginary number is usually expressed as z = a + bi, where $i = \sqrt{-1}$ and a, b are real numbers.

[5]Hawking and Mlodinow, *The Grand Design*, 134–5.

[6]Ibid., 142.

[7]S.-T. Yau and S. Nadis, *The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions* (New York: Basic Books, 2010).

[8]Hawking and Mlodinow, *The Grand Design*, 118.

[9]Yau and Nadis, *The Shape of Inner Space*.

[10]Hawking and Mlodinow, *The Grand Design*.

[11]P. J. Steinhardt, "The Inflation Debate," *Scientific American* (April 2011): 38–43.

[12]G. F. R. Ellis, "Does the Multiverse Really Exist?" *Scientific American* 305 (July 2011): 38–43.

[13]D. F. Watson, "On the Anthropic Principle in the Multiverse: Addressing Provability and Tautology" (March 30, 2011): arXiv: 1103.6044.

[14]L. A. Barnes, "The Fine-Tuning of the Universe for Intelligent Life," *Publications of the Astronomical Society of Australia* 29 (2012): 529–64.

[15]C. S. Lewis, *Miracles* (London: Fontana, 1974).

[16]J. C. Lennox, *God and Stephen Hawking: Whose Design Is It Anyway?* (Oxford: Lion Books, 2011).

[17]W. L. Craig and J. D. Sinclair, "The Kalam Cosmological Argument," in *The Blackwell Companion to Natural Theology*, ed. W. L. Craig and J. P. Moreland (Oxford: Wiley-Blackwell, 2009), 179.

[18]Ibid.

[19]A. Flew, *There Is a God* (New York: HarperCollins, 2007).

[20]R. J. Asher, *Evolution and Belief* (Cambridge: Cambridge University Press, 2012), 5.

[21]Ibid., 14–15.

[22]R. B. Mann, "Physics at the Theological Frontiers," *Perspectives on Science and Christian Faith* 66, no. 1 (2014): 2–12.

[23]See the discussion from Craig and Sinclair, "The Kalam Cosmological Argument," 132–82.

[24]Mann, "Physics at the Theological Frontiers."

[25]M. J. Murray and M. Rea, *An Introduction to the Philosophy of Religion* (Cambridge: Cambridge University Press, 2008), 143.

[26]R. Collins, "The Teleological Argument," in *The Routledge Companion to Philosophy of Religion*, ed. C. Meister and P. Copan (New York: Routledge, 2007), 411–21.

ASA Members: Submit comments and questions on this communication at www.asa3.org → FORUMS → PSCF DISCUSSION.

Andy Crouch

Communication

Delight in Creation: The Life of a Scientist

Andy Crouch

I am married to a scientist—to be specific, an experimental physicist (which I would like to think is the very best kind). For more than fifteen years now, I have accompanied Catherine through a life in physics, a kind of *Pilgrim's Progress* that began in the Slough of Graduate School, continued through the Testing Fields of the Job Search and the harrowing of the Vale of Tenure, and is now wending its way through the Elysian Fields of Mid-Career Teaching, Research, and Administration. Along the way, just like Christian in Bunyan's classic, she has encountered plenty of both helpful and dangerous characters, some reassuringly metaphorical and others all too literal. And I, like Christian's friend Hopeful, have tried to be a faithful companion, though often I have been able to do little more than cheer or wince at the twists and turns of a life in science.

There is a serious point in my playful invocation of *Pilgrim's Progress*. Like many of the most complex human endeavors—parenting, farming, becoming a Christian—the life of a scientist is not just an "occupation," something that occupies us for a while and might then be followed by something entirely different. Being a scientist is as much about being as doing, as much about a particular way of being formed as a person as it is a set of activities or even skills. Training in science is induction not so much into a particular worldview (though it includes absorbing plenty of the kind of cognitive presuppositions that that word suggests) as it is a kind of posture or stance toward the world, toward one's work, and toward one's fellow human beings, both scientists and nonscientists. And the life of a scientist is a journey, one freighted with ultimate concerns and laden with values. It is a journey into a set of virtues, the habits and dispositions that make one a person of a particular kind of character.

When we talk about faith and science, we tend to focus on the cognitive content of both endeavors, the truth claims and worldviews that animate these two crucial dimensions of modern human life. These are important matters, and I do not at all mean to diminish them. At the same time, there are inevitable limits to what any pastor or church can do to constructively integrate the knowledge content of science—so vast and rapidly expanding that even scientists cannot pretend to be expert in anything but a tiny portion—with the content of Christian faith. But there is another way to approach faith and science which

Andy Crouch *(M.Div.), author of* Playing God: Redeeming the Gift of Power *(2013) and* Culture Making: Recovering Our Creative Calling *(2008), is the executive editor of* Christianity Today.

This communication was originally published in Deborah Haarsma and Scott Hoezee, eds., Delight in Creation: Scientists Share Their Work with the Church *(Grand Rapids, MI: Center for Excellence in Preaching, Calvin Theological Seminary, 2012), chap. 2. A product of The Ministry Theorem, http://ministrytheorem.calvinseminary.edu.*

I believe might well be more within reach of most pastors, and more essential to their job description than being deeply literate in the latest scientific discoveries and theories—and that is simply to attend to and prayerfully support and encourage the scientific life itself as a vocation that can reflect the image of God and be a place for working out one's own salvation.

So here is what I wish our fellow Christians knew about the life of a working scientist.

Delight and Wonder

If there is one personality characteristic of the vast majority of scientists I have met, it is delight. There is something about science that attracts people who are fascinated and thrilled by the world. To be sure, any given scientist is delighted by things that you and I may find odd or indeed incomprehensible—the intricacies of protein folding, the strata of Antarctic ice cores, or the properties of Lebesgue spaces (and no, I have no idea what that last phrase really means). But the specificity of their delights is one of delight's secrets: like love, delight is always most potent when it is particular. It is certainly possible to find lawyers who are delighted by law (I have one friend who can go on at great length, with enthusiasm, about corporate bankruptcies), dairy farmers who are delighted by cows, or lumberjacks who are delighted by trees—but I dare say your chances are much better that when you meet a scientist, you will find that they are delighted with the tiny part of the world they study day to day (at least when they are not frustrated with it, which frustrations we will examine below.)

In many scientists, delight is matched by wonder—a sense of astonishment at the beautiful, ingenious complexity to be found in the world. This is not the "wonder" that comes from ignorance—"I wonder how a light bulb really works?"—but a wonder that comes from understanding. Indeed, as we have progressed further into humanity's scientific era, we have been able to disabuse ourselves of a mistaken early-modern notion: that the more the world became comprehensible, the less it would be wonderful. That turns out not to be true at all. Ask a scientist: wonder grows as understanding grows. Indeed, wonder *only* grows if understanding grows. If we replace our childhood awe of lightning with an explanation such as, "It's nothing but a transfer of voltage across a highly resistive material" (an example of what G. K. Chesterton wittily called "nothing-buttery"), perhaps the world will seem like a less wonderful place. But those who actually pursue knowledge of lightning—of electromagnetism or cloud formation or weather systems or climate—end up being even more in awe of the world than they were as children. This is surely one of the remarkable features of our cosmos: the more we understand about it, the more we are in awe of its beautiful elegance and simplicity, and at the same time, its humbling complexity.

To be sure, many, if not most, scientists do not see this wonderful world in the way that most Christians would hope. For us, wonder is a stepping-stone to worship—ascribing our awe for the world to a Creator whose worth it reveals. For many scientists, wonder is less a stepping-stone than a substitute for worship. Yet they stop and wonder all the same.

Intellectual Humility

I doubt that humility is among the first traits most people think of when they think of scientists. And indeed, some scientists (like some academics and intellectuals generally) exhibit a combination of confidence in their own intellect and limitations in their social skills that make them seem abrasive if not arrogant. A few have made a public career of intellectual overreaching, not least in matters of science and faith. But in my experience (and certainly, let me stress, in the case of my own wife!), this is much more the exception than the rule. If intellectual humility is essentially a willingness to admit what you do not and cannot know, science cultivates humility like few other pursuits can, because in few other pursuits do you so often find out that you were wrong.

Even though we tell the story of science through its high points—the discoveries and confirmed theories that won Nobel Prizes and launched new eras in technology—the actual practice of science, for nearly every working scientist, involves far more failure than success. This is especially true for experimental science, the kind that requires the most direct interaction with recalcitrant reality. On most days, in most labs, the data do not add up, Matlab has an untraceable bug, the laser is on the fritz, and all the cultures become contaminated when the undergraduate research assistant sneezes. And while each of these everyday setbacks requires immense amounts of patience and persistence to overcome, they are only the quotidian version of the perplexity that begins early in the study of science. Every scientist, in the process of their training, has had to repeatedly discover that their intuitions about the world are simply wrong, or at least incomplete. Even great scientists have come up against the sheer oddity and unpredictability of the world. Albert Einstein, for example, never fully accepted the uncertainty at the heart of quantum mechanics, something that is now universally accepted by physicists.

This regular confrontation with the limits of one's own knowledge and skill is not to be taken for granted. The other divisions of the academy, the social sciences and the humanities, deal with matters of such variability and complexity that it is often difficult to say conclusively that anyone, or any theory, is entirely wrong. Marx's and Freud's grand theories may not seem nearly as plausible as they once were, but there are thousands of people following their lines of thought without losing the respect of their intellectual peers. But Ptolemaic cosmology or Lamarckian evolution now have, simply, no followers. They have been proven wrong beyond a reasonable doubt. Who is likely to be more intellectually humble: someone who, early in her training and daily in her work, learns that her assumptions have been wrong, or someone who can always argue his way out of any intellectual predicament? It is perhaps no accident that "grade inflation," in which undergraduates' grades ratchet ever upwards in a nod to the consumer realities of the modern university, is much less pervasive in the sciences, where you cannot cajole your way into an A. The honest and humbling truth is that there is likely more intellectual humility in the average physics laboratory than in the average theology classroom.

Frustration

To be sure, this humility is hard won. Not only is the work of science (and many technical fields) painstaking and frustrating, those pains are often taken for the sake of very small, incremental gains in knowledge. Every arena of human work involves difficulty, delay, and disappointment—"In the sweat of thy face shalt thou eat bread, till thou return unto the ground." Science, too, labors under the curse of a world that is not the way it is supposed to be. It is easy for us who are lay people regarding science to confuse science with technology. Technology is built on well-established knowledge, camouflaging tremendous amounts of human toil and sweat (not just scientific labor, of course, but also the labor of those who design and assemble our devices). Indeed, part of technology's attraction is its implicit promise to temporarily repeal the Curse, delivering an experience of godlike effortlessness to its end user. Those of us who benefit from the end product of the scientific–technological process can easily forget that at the beginning of every discovery, from the steam engine to the transistor, people were laboring at the uncharted edges of human knowledge, and that most days they left their workbench quite unsure whether they were making any progress at all. Scientists may or may not believe in the words of Genesis 3, but they know the burdens of work—even and especially delightful work—very well.

Collaboration

This may be the thing that nonscientists understand least about science. Science is done in community. Popular culture, perhaps inevitably, has a hard time portraying this accurately. Dr. Frankenstein, toiling alone in his lab long after midnight, has become our paradigm for the practice of science. Or maybe for a younger generation, it is "Doc" Emmett Brown from *Back to the Future*, tinkering with time in his garage. But Frankenstein and Doc are mad scientists, not real ones. Real—that is, sane—scientists collaborate. They work closely with one another—with peers, with advisors, with students. Nearly all scientific work today is intensely collaborative in a way that is foreign to nearly any other academic discipline, emphatically including theology. The most celebrated theologians (and pastors, too) write books with only their name on them, while the most celebrated scientists co-author papers with dozens of collaborators. It has been nineteen years since a single individual won the Nobel Prize in physics.

With the collaborative practice of science come the joys as well as the challenges of managing many people's priorities, expectations, egos, abilities, and limitations. Perhaps that is why, in a way that also confounds popular stereotypes, I so often find that highly successful scientists have strong social skills. They are not always the smoothest guests at the dinner party, but they have something more important—genuine interest in people, reserves of patience and generosity, and the ability to build and sustain teams that can survive the frustration of day-to-day research.

Let's see: a community of people who work side by side, motivated by delight and wonder, characterized by intellectual humility and a willingness to admit that they have been wrong and change direction, who together help one another bear the frustrations of work in a fallen world—does this sound like something the church ought to celebrate? Or perhaps even emulate? And yet I have never heard the world of science, the world my wife inhabits every day, held up even as a potential metaphorical reference point for the true beloved community toward which all of us are called. Perhaps it is closer than we think.

It is not, of course, the beloved community. The world of science has its shadow side, and this too forms the life and work of my wife and her fellow scientists. Among the features of this shadow side are competition, risk, isolation, and specialization.

Competition

Just as powerful and real as the cooperation within research groups is the competition between research groups to be first past the post with new discoveries. The currency of the academic scientific world is publication, and only the first group to submit its results can publish in the field's most prestigious journal. (Patents in industry have even higher stakes.) The history of science is replete with simultaneous in- dependent discoveries (Wikipedia has a fascinating, long list including Boyle's Law, the Möbius strip, and the polio vaccine), which suggests that "discovery" is as much a result of others' prior work, and mysteriously important social conditions, as any one person's or group's pure genius. In a better world, that insight might chasten ambitions to be unique and first. But in the world we have, if anything, it aggravates the competition, since it is likely that, whatever you are working on, some other group is probably also tantalizingly close to snatching the prize.

Competition can be healthy: most of us need it to reach the highest level of performance we are capable of, and when it is healthy, it is exhilarating, even for those who do not finish first. But competition is most healthy when it occurs in an environment of abundance, where everyone knows that they stand to gain by entering the race. For example, consider the joy, satisfaction, and camaraderie at both the beginning and end of a typical triathlon. Competition becomes stressful, if not toxic, when it takes place in an environment of diminishing resources and threats to survival. Unfortunately, that is more and more often the case in the practice of science today. The twentieth century, fueled both by economic growth and by a high-level competition between the Soviet Union and the West, was a time of abundant resources for scientific work. In many fields, the twenty-first century looks to be much more constrained. As in many sectors of our global economy, first-place finishers are winning a greater share of the available resources. As the pressure ratchets up, so do the risks to the emotional and spiritual health of those practicing the science (and, very possibly, to the long-term productivity and fruitfulness of the scientific enterprise itself).

Risk

The very essence of scientific research is to probe the edges of what is known, meaning that even the most talented scientists can only guess at the chances of success at the outset of any new research venture. What is true for individual experiments is true for whole research programs and whole lives in science. Some friends of ours from Catherine's graduate school years, all of whom worked with some of the most celebrated scientific mentors in the world at MIT and Harvard, have gone on to gain tenure and major funding after a handful of years, while others with equal talent and training have lost one job after another in the restructuring of the pharmaceutical industry. To choose a career as a scientist is to embark on a journey whose end cannot even be reasonably guessed at from the beginning, no matter how great your talents or fortunate your choice of mentors and advisors.

Delight in Creation: The Life of a Scientist

Few scientists are exempt from the psychological stress that comes with this kind of uncertainty. The best scientists, who tend to be both risk tolerant and optimistic by nature, harness it as energy for bold choices and unconventional experimental ventures; others can end up nearly paralyzed by the fear of making a wrong decision. Either way, their lives are shadowed by a degree of uncertainty that belies their relatively high professional status.

Isolation

It might seem odd that a highly collaborative endeavor could also be isolating. Indeed, scientists generally find great camaraderie in their research groups and within their disciplines. But to practice science is also to accept a certain amount of isolation from one's fellow human beings. Sometimes the isolation is emphatically physical—long lonely observing sessions at remote telescopes, all-nighters in a lab waiting for biological processes that take their own sweet time, or, in my wife's case, needing to work in a lab in the basement (to minimize vibration) with no windows (to minimize ambient light).

But the isolation is also intellectual. The high degree of specialization that science requires means that even most members of my wife's physics department cannot easily understand her current research, nor she theirs. Even more difficult is explaining one's work to neighbors or to fellow Christians, and this isolation is all too often compounded by intimidation. In school, most lay people found science, and especially the mathematics that is necessary for the physical sciences, perplexing and confusing, and were glad to be done with it as soon as they could. They are uneasy and inexperienced in talking about scientific research, so they quickly change the subject. This can make for very short conversations after church—or more likely, it means that scientists simply never get to share the joys and challenges of their work with most of the people with whom they worship and play.

Specialization

Another kind of isolation comes from one of the great achievements of Western society: the division of knowledge into ever more specialized subfields. There is no doubt that ever-increasing specialization has unleashed discovery, creativity, and indeed much of the prosperity that we enjoy. But specialization has intellectual and personal costs for at least some scientists, such as my wife, who went into physics for the love of physics as a whole. It was the beautiful and comprehensive elegance of physics that she was most eager to study and teach—and surely one of the great gifts of every field of science is the glorious symmetries and patterns that seem written into the fabric of our universe.

But sustaining a research career in physics requires attention to what can seem to the rest of us absurdly minute sub-sub-specialties, which have only become more tightly defined over time. Some, perhaps most, scientists thrive on these tiny areas of focus. But those of us who care about the way the world holds together, and believe that all things come together in Christ who is the wisdom and power of God, must insist that too much specialization is not good for anyone's soul. The sterility that is necessary for a successful biological experiment, or the austere vacuum essential to many experiments in physics, are not viable environments for flourishing life. Nor is intellectual specialization the highest form of knowledge—it is more likely to be the kind of knowledge that merely puffs up unless, after the fruits of specialization have been harvested, they are reintegrated with the complexity of fully human lives.

Ministering to Scientists

Such is the life of a scientist, at least the scientist I have known best. Some of these formative realities have been elements of intellectual careers for centuries (wonder, frustration, competition, the demand for novelty, perhaps the intimidation of nonspecialists). Others are particularly modern and not exclusive to science (specialization and isolation affect or afflict many careers in our age). Others are very specific to the vocation of a physicist and would be less true of a biologist or an ecologist. Since many scientists are also teachers, another essay's worth of commentary could be added on the challenges of teaching faithfully and well. And I have not mentioned the many complexities that come with being a woman, and more specifically a mother, in one of the few disciplines that still sees persistent underrepresentation of women as well as ethnic minorities. But I hope that at this point you are sensing that embracing the vocation of research puts one on a path that will ultimately require tremendous spiritual and emotional growth—or that will hinder such growth. As with so many professional callings, I have found that science makes such demands on its practitioners that those who succeed in it tend to be either strikingly mature and wise persons, or sadly foolish and stunted, with relatively few in the middle. The stakes in a scientific vocation are high.

And here is my concern: with Catherine by my side, I have sat through fifteen years' worth of sermons in churches that by and large have served our family very well with worship, teaching, fellowship, and opportunities for mission. There is much that I have been grateful for in those sermons. But I cannot help noticing that in all these years, unless I am forgetting something, I do not remember hearing one thing, in church or in a Christian Bible study or in another Christian context, that even acknowledged most of the dynamics she encounters in her vocation every day. Does the gospel really have nothing to say to our sense of wonder and delight in the world? Is it silent on how to manage competition and risk? Does it give us no guidance on the qualities that make for real, fruitful collaboration? To the contrary, all these are the soil where discipleship can grow, where grace can be discovered, and where real faith can be nourished. What other opportunities are we missing to name the ways that every vocation in our congregation points us toward, and indeed requires, the death to self and trust in God that are the essence of trust in Jesus?

Another way of putting this is that all these challenges and gifts are intensely personal. That is, they bear very directly on what kind of person Catherine is. They influence her as an embodied human being, affecting her sleep, her thoughts, her dreams, her heart rate, and her blood pressure. And they are not fundamentally about the theoretical content of physics. They are about the practice of physics. They are about the embodied patterns of life that have shaped the horizons of possibility and impossibility for Catherine and her colleagues.

None of these realities, incidentally, can be given an adequately meaningful account within the framework of science itself. Science itself cannot interpret the practice of science—not in a way that does justice to the whole experience of being a scientist, answering the questions of why it is a genuine human calling, why it is potentially full of temptation as well as potentially full of grace, why it can produce such delight and such difficulty. Those are theological questions, but more immediately they are ministry questions, requiring someone to come alongside scientists with resources from outside of science itself.

Many people who end up in academic vocations are comfortable with abstraction. There is real intellectual leverage that can be gained by abstracting away from particular persons, to talk about, for example, "personality"; to abstract away from a set of methods, practices, discoveries, and theories to talk about "science"; to abstract away from a set of beliefs and rituals to talk about "religion." Yet ministry is one human vocation that dare not be abstract. The most fruitful ministry always is engaged with very concrete communities and persons.

Indeed, when theologians and pastors neglect the personal component of science and engage it as if it did not have tremendous implications for the personal lives of scientists, the loss is asymmetric. Scientists do not do less valuable science if they set aside questions of theology. To the contrary: science is a discipline of specialized investigation. But this is precisely what theology and ministry are not. A friend of mine is fond of saying that most academic disciplines seek to know everything about something, but theology claims to know something about everything. Theologians owe the world as comprehensive an accounting as is possible given our human limits. Our theologizing, preaching, and pastoral care cannot afford to ignore whole fields of endeavor, especially ones that both deliver such salient information about the world and that impinge so directly on the lives of people who practice them.

And if there is one thing that Christians ought to insist on when we approach questions of science and religion, it seems to me that it is the primacy of persons—the persons who practice science, and the persons who are affected by its practice. Persons are, to borrow a word from nothing less than the intelligent design movement, irreducibly complex. I am not at all sure that, evolutionarily speaking, the bacterial flagellum is irreducibly complex. But I am quite sure that my wife is irreducibly complex. I am quite sure that you are irreducibly complex. And I am furthermore sure that such irreducible complexity demands from me a certain reverence.

I am also sure that the reverence you, my wife, and I myself command in our irreducible personhood is something that science cannot, using its own methods and practices, secure. In fact, neither can theology, nor religion, considered as theories alone, secure the reverence and respect that our personhood requires. Only embodied communities can cherish these strange and wonderful beings called persons—only communities that consciously examine the practices of the society around them, and cultivate distinctive practices of their own.

The practice of science, and the practices of the world of technology that emerge from science, is one of the determinative features of our world, for better and for worse. Those practices in some ways give life to the deepest hopes we could have for human flourishing in the Christian tradition. In other ways they put most profoundly at risk true human flourishing as best we understand it based on the revelation of God in Jesus Christ. If there is a meaning to the word ministry, it must have something to do with shepherding persons into practices that lead to true life. Some of the practices of science and a technologically shaped world do exactly that; others do exactly the opposite. Those of us who teach and preach, and those of us who befriend—and even marry!—scientists, can offer them an incalculable gift if we are willing to accompany them on their journey of formation as scientists and persons. We can help them understand that the very fabric of their vocation is potentially a means of grace.

And then, like Hopeful, we may encourage their progress toward the one truly worthwhile destination, the Heavenly City, where all our days will be, like science at its very best, full of wonder and delight.

ASA Members: Submit comments and questions on this article at www.asa3.org → FORUMS → PSCF DISCUSSION.

You are invited to draft an article related to

"The Matter of Mathematics"

Russell W. Howell, Kathleen Smith Professor of Natural and Behavioral Sciences, Westmont College, Santa Barbara, CA

Russell Howell has co-authored the textbook *Complex Analysis for Mathematics and Engineering* which is in its sixth edition, and is the co-editor of the HarperOne book *Mathematics through the Eyes of Faith*. He has provided an essay, now posted on the ASA and CSCA web sites, that gives an intriguing description of the latest developments in mathematics along with possible implications raised for Christian faith.

The essay is intended as an invitation. Readers are encouraged to take up one of the insights or challenges, or maybe a related one that was not mentioned, and draft an article (typically about 5,000–8,000 words) that contributes to the conversation. These can be sent to Howell at howell@westmont.edu. He will send the best essays on to peer review, and then we will select from those for publication in a mathematics theme issue of *Perspectives on Science and Christian Faith*.

The lead editorial in the December 2013 issue of *PSCF* outlines what the journal looks for in article contributions. For full consideration for inclusion in the theme issue, manuscripts should be received electronically before May 30, 2014.

For those readers who prefer to take a literary approach in sharing their ideas, please submit essays (up to 3,000 words), poetry, fiction, or humor inspired by the invitational essay to emily@asa3.org for possible publication in *God and Nature* magazine.

Looking forward to hearing your perspectives,

James C. Peterson
Editor, *Perspectives on Science and Christian Faith*

Environment

WASTED WORLD: How Our Consumption Challenges the Planet by Rob Hengeveld. Chicago, IL: University of Chicago Press, 2012. xviii + 337 pages. Hardcover; $30.00. ISBN: 9780226326993.

The present human population is doomed to collapse at any time, both in numbers and quality of life, because our overly complex society has wastefully used up Earth's resources—unless we immediately reduce our birth rate to nearly zero. This is the urgent message of *Wasted World* by Rob Hengeveld, author of two books on biogeography, formerly on staff in animal ecology at the Free University of Amsterdam, and now affiliated with the Centre for Ecosystem Studies of Alterra in the Netherlands. The book is directed to a general audience, and has a readable style enlivened by numerous anecdotes. There are nine line drawings without figure numbers [but some references to them, e.g., "figure 1 (see page 000)" have not been corrected].

The introduction tells how things are going wrong and what problems can be expected as a result. A brief Part 1 follows, with two chapters on natural processes, explaining how in nature the waste product of one part of an ecosystem becomes the input for another, so that matter goes through a continuing series of cycles, enabling life to continue indefinitely. In contrast, since human processes tend to be linear—mining or harvesting a resource and using it once, eventually producing waste that is degraded and unavailable—our civilization operating this way must come to an end once resources run out.

Hengeveld then develops his ideas in Part 2, "Ongoing processes in the human population," in twenty-two chapters. In the past, the problem of overpopulation led to the agricultural and industrial revolutions, but humanity lost the opportunity that these revolutions gave to solve the problem; instead we let our population grow much more. The small fraction of today's people who are actually engaged in producing food must bear the burden of supporting a much larger number who have established a complex structure of administration and commerce, an abstract kind of society that will disintegrate when mineral and environmental resources are exhausted after their present wasteful use. Energy, produced from fossil fuels that are being depleted, is largely wasted by conversion from one form to another, and its production is polluting the air with carbon dioxide, warming the climate. Earth's water is being contaminated by chemicals, and its land is becoming barren from deforestation, salinization, and dumping of refuse. The world's rich biodiversity, produced by evolution "all by chance, blind to the future, blind to the next day to come" (p. 166), is now being lost.

Next, attention turns to processes within the human population itself. Hengeveld challenges the generally accepted concept of a demographic transition, by which a modernizing country begins with a stable, low population with high birth and death rates, then has a lowered death rate and rising population, and finishes with a stable high population with low birth and death rates. Since nineteenth-century Europe, where this transition first occurred, differed greatly from the poor countries in today's world, any expectation that they will have a similar demographic transition is unduly optimistic. In the chapter "Bursting out of Eden," Hengeveld warns that a logistic model of human population, in which initial rapid growth slows down until the population reaches stability at the carrying capacity, is no more realistic than primitive beliefs that populations were "under the effective control of the gods or their representatives, such as kings or priests" (p. 213).

Chapters on urbanization, migration (e.g., from being "chased away, as may have happened to the Jews in biblical times" [p. 221]), and disease provide details on the influence of these factors. The final chapter suggests a way forward. We humans must find the most effective and least inhumane way to reduce our numbers, in spite of the moral and religious issues raised by any measures to do this. However, Hengeveld asks, "Under conditions of war, famine, thirst, or deadly pandemics, what will be left of our moral values or religious ideals?" (p. 302). His book ends with an epilogue summarizing its message, a note "about the author" in which he explains how his prior work prepared him to write this book, and acknowledgments. The selected bibliography contains over three hundred books, listed alphabetically for each chapter, including roughly equal numbers of academic works and popular writings, but without citations of primary scientific literature. There is no index.

Unfortunately, Hengeveld weakens his credibility by making numerous statements that are oversimplified, inadequately supported, or simply wrong. He asks, "[Could a runaway greenhouse effect] that once happened on Venus also happen here on Earth? Calculations show that this is indeed possible when we continue using fossil fuels the way we have so far" (p. 137). However, this actually "appears to have virtually no chance of being induced by anthropogenic activities," according to an IPCC Expert Meeting, Buenos Aires, Argentina, 18–20 May 2004, http://www.ipcc.ch/meetings/session31/inf3.pdf (p. 90).

Carbon dioxide emissions from use of concrete (pp. 140–1) are wrongly attributed to the hardening or setting of concrete, a reaction in which cement bonds chemically with water, rather than to the production of the cement, in which fuels are burned to heat limestone to drive off carbon dioxide. The reader is told that "we waste the air we breathe by expelling poisonous gases into the atmosphere" (p. 121) and that there is "heavy and large-scale pollution of surface and groundwater" (p. 133), whereas in the past half century there have been real improvements—in air quality due to requirements for abatement devices on both vehicles and stationary sources, and in water quality as a result of regulation of agricultural runoff and primary, secondary, and tertiary sewage treatment, which is indeed mentioned (p. 53).

Hengeveld is alarmed because a "large category of plastics containing the very poisonous phthalates (plastic softeners) occur in PVC and certain insecticides" (p. 181) and cause danger from pollution. In reality, the situation is being alleviated: use of phthalates as plasticizers and as solvents in pesticide formulations has been curtailed after sophisticated research (both epidemiological and with laboratory animals). Such research linked some adverse health effects to phthalates, originally used as solvents in pesticide formulations and as plasticizers for PVC in toys and medical tubing, because of their low toxicity. Nevertheless, Hengeveld's concerns need to be taken seriously, despite these and other inaccuracies in the case he makes.

Several environmental texts give a better treatment of these themes. Many ways of improving stewardship of resources and the environment, which should lead to stabilizing the world's population, are presented by Gordon College, Richard T. Wright and Dorothy F. Boorse, *Environmental Science: Toward A Sustainable Future*, 11th ed. (Boston, MA: Benjamin Cummings, 2011). The influence of processes within the human population is examined by two writers from colleges in Roman Catholic and Anglican traditions: Charles L. Harper and Thomas H. Fletcher, *Environment and Society: Human Perspectives on Environmental Issues* (Toronto: Pearson Education Canada, 2011). Hengeveld's book is also unattractive to a Christian reader because of its entirely materialistic world view. Although there is an attempt to simplify the scientific details for a general audience, the lack of concern for sound science makes the book unsuitable as a source of information for nonscientists. It does provide a comprehensive set of warning signs that our world is in trouble, but one should be cautious in suggesting to others that they read this book.

Reviewed by Charles E. Chaffey, Professor Emeritus, Chemical Engineering and Applied Chemistry, University of Toronto, Toronto, ON M5S 3E5.

ENERGY FOR FUTURE PRESIDENTS: The Science behind the Headlines by Richard A. Muller. New York: W. W. Norton, 2013. 368 pages. Paperback; $16.95. ISBN: 9780393345100.

I thoroughly enjoyed reading this excellent primer on energy—sources, utilization, distribution, and problems. If you had to make a decision to choose a technology that both provides for energy security and affects climate change, what would you do? Although the book will not give you an answer, it certainly helps to clarify what you thought you knew about energy. The book's balanced approach helps to remove some of the emotions that are so tied to the broader issues of energy.

I started the book with the attitude that the advice given to the president had better be the same advice I would give. After all, don't we all have a particular political persuasion? According to the political spectrum Muller provides on page 75, I consider myself to be a "warmist." I trust scientists who work on specific issues to know what they are talking about. I am not a climate scientist so I have to rely on the experts. Muller's goal was to educate the president about energy and not give advice. Good start. The book is very concentrated. I found myself reading a chapter or two and having to put it down and think a lot. When in the first chapter he said that the president did not need to know exactly what energy is and would defer defining it until the end of the book, I immediately found myself at the end of the book reading about how physicists think about energy. When he got to the four-dimensional energy-momentum vector, I knew I was in trouble and immediately returned to the beginning chapter and followed his advice. I already liked him.

I have had many discussions with scientists over the years, and when we talk about the research they are doing, I am always impressed with those who can explain what they are doing in terms that I can understand. I like it when someone takes a napkin and begins to draw pictures or does order-of-magnitude calculations that get me beyond what occurs in a test tube. Muller has accomplished this with his writing. I can imagine that we are talking in a diner, and he excitedly confronts my feel-good scientific reasons why we should be driving electric cars with global calculations of the impact of the gasoline-powered cars in the United States on global temperature change—and all on the back of a napkin.

Muller discusses pros and cons of the various energy choices we have for the next two or three decades. The choices were described, not as I have read in short newspaper articles or heard that politicians or extremists on either end of the climate debate would want me to believe, but as logical explanations, based on physics, and importantly, scaled-up engineering principles. His discussion went from acting and thinking locally, to the effects these acts would have globally.

I am all for local environmental change. But I also have to face the reality that any president has to contend with energy security and economic stability. Even these words “security” and “economics” have political color. How can a president be worried about our sources of liquid energy and economics when the world is heating up? Sometimes I lose track of this balance-of-thinking as well. I generally would raise an eyebrow when someone would talk about nuclear power or fracking instead of solar power or geothermal energy. The discussions would get polarized and listening would start to close down. Presidents cannot afford to do this; we cannot either.

Muller uses more of an engineering approach than a physicist’s approach in describing energy productivity. He describes the 5,000 wells being drilled at a cost to oil companies of $25 billion, or the 20 million barrels of oil that are used by the United States each day for energy production. He compares the costs of the various sources of energy in constant terms, such as kilowatt-hour, so they can be compared across the board. The scale of the world energy problem is mind-boggling, and he is not afraid to use big numbers and is very capable of making you feel comfortable with them.

The chapters on energy storage were excellent in describing the waste products associated with energy production and use. We need to decrease our production of carbon dioxide where it will have the greatest effect. Using natural gas as an energy source decreases carbon dioxide production by 50% over coal utilization. Changing an energy economy from fossil fuel to something else takes decades, if not longer. Muller argues that we need to make good choices in what research we invest in for both the intermediate and long term. What our world energy economy will be in one hundred years no one really knows, but what we invest our research dollars in now greatly influences that outcome. Understanding energy technology will help us make better choices in the direction we go.

I liked the book. If I were president, I still would not know the answers to the very difficult choices among the issues tying energy, security, and economics together. There are serious issues related to energy that will affect all of our lives. Climate change continues at a rate such that many climate scientists now believe the efforts to reduce emissions will be inadequate to meet the limit of a 2°C global warming by 2050. These scientists now feel that we need to talk more about adapting to a warmer world than about preventing its occurrence.

The Fukushima nuclear plant disaster of 2011 continues to have worldwide implications. Each day three hundred tons of radioactive water from the damaged plant enters the Pacific Ocean, and radioactive material is steadily building up in the ocean food chain. With increased global temperatures, the Arctic Ocean sea ice has decreased to a level that opens this ocean to navigable sea-lanes and deep-water oil drilling. An oil spill in Arctic waters, similar to what occurred in the Gulf of Mexico, would result in oil collecting under sheets of ice. Oil does not decompose readily in freezing water! The Keystone Pipeline proposal to transport synthetic crude oil from the oil sands of Alberta to the gulf coast of Texas has been a politically and environmentally debated issue since it was proposed in 2005. Recently, because of the open Arctic Ocean sea-lanes, the provincial government of Alberta conducted research to find out if an Arctic Ocean shipping plan would make more sense than moving its oil through the proposed Keystone XL pipeline or pipelines west or east through Canada. If you were president, what actions would you take regarding climate change? Is nuclear power an option to be considered as a continuing energy source in the United States? Would you prefer that oil sands production be transported by means of a pipeline crossing the United States, or be shipped by tankers in the Arctic Ocean?

In the “land of the Benedictines” where I come from, we have been taught that Benedictine monks held environmental stewardship as an essential defining value. It is an explicit policy of most Benedictine monasteries and communities worldwide to apply environmental stewardship principles to their land, buildings, and work. They treat stewardship as the careful and responsible management of something entrusted to one's care (natural resources) and sustainability as meeting current needs without sacrificing the ability of future generations to meet their own needs, by balancing environmental, economic, and social concerns.

Energy transformations and usage touch both stewardship and sustainability. In an article written in this journal in 2006, Fred VanDyke wrote that we should approach the required interventions of stewardship with humility, and that such interventions require diligent scientific study, guided by the determination to work toward God's revealed purpose for nature.[1] This book provides an approachable guideline in our understanding of the science of energy. Our present and future presidents need not only to understand energy, but also to be sensitive to stewardship and sustainability for future generations. I think that, having read this book, I am more open to the ideas of others and less tied to the emotions of the issues. If everyone were to read the book, we would have more fruitful discussions.

[1]Fred VanDyke, "Cultural Transformation and Conservation: Growth, Influence, and Challenges for the Judeo-Christian Stewardship Environmental Ethic," *PSCF* 58, no. 1 (2006): 48–63.

Reviewed by John Mickus, Professor Emeritus, Benedictine University, Department of Biological Sciences, Lisle, IL 60532.

Engineering

TO FORGIVE DESIGN: Understanding Failure by Henry Petroski. Cambridge, MA: The Belknap Press of Harvard University Press, 2012. 410 pages. Hardcover; $27.95. ISBN: 9780674065840.

A couple of months ago I participated in a highly technical discussion about engineering materials with a fellow professional. The material in question was a ceramic-particulate-filled ultraviolet-curable polymer resin, and the issue of interest was a tradeoff between the properties of stiffness, strength, and longevity. While a discussion of this type is commonplace among mechanical engineers like me, this particular conversation was unexpected because it occurred while I was tilted almost flat on my back in a padded chair, between periods of being required to "open wide." The fellow professional, if you have not already guessed, was my dentist. At the time, I considered this interaction to be unusual. But based on Henry Petroski's latest book, *To Forgive Design: Understanding Failure*, maybe I should not have been so surprised. As the author points out in the first chapter, dentistry and engineering have many concerns in common. Both disciplines are involved in carefully placing and maintaining materials to avoid structural failure including, in my case, the consideration of how long my filling might last before breaking down and needing to be replaced with a crown.

I became a fan of Henry Petroski long before reading this particular book. Since the publication in 1982 of the seminal volume *To Engineer Is Human*, Petroski has been considered a sage of engineering design practice. I have cited his work in my papers, shown the video version of *To Engineer Is Human* in my introductory engineering classes, and relied on his explication of the relationship between failure and the engineering design process to mold my understanding of how and why technological projects sometimes go horribly awry. His historical approach not only applies to engineers, but also opens a window for non-engineers into what engineers do every day, bringing to light the creative activities that often result in modern marvels but also occasionally in unanticipated disasters. So, I had high expectations for this book, which were exceeded for the most part, with one exception which will be revealed later on in this review.

Obviously, a correct understanding of the character of past engineering failures is required in order to avoid future disasters. In this book, Petroski contends that society is too quick to blame poor technical design, when, in fact, most disasters are caused by interacting failures that, in many cases, could not have been foreseen by the designers. These failures can occur not only during the design process, in the implementation of the design (construction or manufacturing), but also while the designed technology is used (perhaps abused) over time. The many examples that he describes in satisfying detail support this contention and emphasize the limitations that economic and cultural contexts place on engineering design activity.

While Petroski claims that the "knee-jerk reaction, especially among the mass media, to look for the culprit" of a highly visible failure results too often in blaming "the design and its designers," not all experts would agree with this sentiment. Charles Perrow, another highly respected engineering failure analyst, claims in his book, *Normal Accidents*, that the blame for engineering disasters is too often placed on human error, particularly on individuals who make mistakes when trying to manage time-dependent, complex technological systems. While the two authors might differ as to where the media and legal system get it wrong, both Perrow and Petroski, especially in *To Forgive Design*, highlight the unanticipated interaction of multiple small failures within complex engineered systems, not all of them technical, as the rationale for large-scale disasters. This recognition of multiple causes is necessary for a truly robust understanding of engineering catastrophes.

A Christian framework of reference can distinguish several categories of these small failures that have the potential to combine and induce a disaster. The first is our own human finitude, including the limitations of our predictive models and the unanticipated variations in physical materials that affect designed structures. The phenomenon of crack propagation and its contribution to brittle fracture, very effectively elucidated by the author in chapter 5, provides an example of this type of engineering failure.

Petroski also mentions failures related to a second category: societal fallenness. The political and economic contexts within which modern technology operates can emphasize, for example, cost-cutting, which can increase risk, as it appears to have done in the case of several construction crane failures detailed in chapter 13.

A third category of causes relates to individual sinfulness, including the unethical choices sometimes made by system participants. This category is highlighted in Petroski's revelation of a contractor falsifying concrete-mixing records in the run-up to a severe water leak problem in Boston's "big dig" tunnels. Recognition of risks posed by our finite and fallen human nature, at both the personal and cultural levels, supports Petroski's conclusion that all innovation necessarily involves risk. Despite the inevitability of future failures, the author maintains a reasonable balance between disappointment in the number and scope of past disasters and celebration of the many real benefits of past large-scale engineering projects.

I appreciated the clear analysis of a wide variety of engineering failures. Many of the heavy hitters of the engineering disasters line-up are presented for scrutiny in this book, for example, the Tacoma Narrows bridge collapse, both space shuttle disasters, and the Deepwater Horizon oil spill. The book also includes many relevant cases that may not have made news headlines at the time of their occurrence. When engineering and technology have become so strongly associated with computers and digital entertainment, often more antiquated infrastructure and transportation systems take a backseat. I enjoyed the focus of this book on the structures that we depend on every day but mainly take for granted. The writing is engaging and even suspenseful. Forensic accident investigation, just like crime investigation, requires great attention to detail, and Petroski provides this as he integrates physical evidence into evolving failure theories in the aftermath of a technological failure. The interjection of personal experiences into the narrative also helps the reader to relate to the technical material.

Although other reviews have pointed out some of the features described above, I find it interesting that none have seen fit to question or explore the book's intriguing title. My primary disappointment with the book is not so much with the actual message and content as it is with what I felt was missing based on that title: *To Forgive Design*. Who needs to be forgiven, and who needs to do the forgiving, in the context of engineering failures? As I progressed chapter by chapter through the book, I eagerly waited for this subject to be addressed. Unfortunately, it never was.

Petroski is a virtuoso of detached explanation of disasters and their outcomes. He deliberately assumes the role of unbiased reporter. His apparent lack of ulterior motive enhances the credibility of his historical analysis. However, forgiveness depends on justly assigning blame for wrongs. The author's refusal to make any moral judgments as to the justice of conclusions reached following engineering disasters does not shed light on the place of forgiveness. Christian admonishments to forgive usually refer to a personal decision to excuse a blameworthy person. This makes sense only when blame is individual and the wrong was intentional. The meaning of forgiveness is less clear in a situation in which a person has unintentionally caused harm, which is the case for the vast majority of failures described in the book. Blame is not as easily allocated when an action is considered an accident or a mistake, at least as long as due diligence was pursued. Common wisdom might interpret forgiveness as forgetting and moving on, putting the past behind us, but this does not fit Petroski's supposition that engineers need to be informed by a historical understanding of disasters. His perspective would seem to require remembering rather than forgetting.

Technology development and engineering design are clearly human cultural activities. Therefore, any forgiveness needed for failures must recognize that bad consequences are often caused by aggregate systemic effects, as well as by blameworthy individual actions. Petroski's focus on external factors that constrain the design process could be interpreted as a plea for society to forgive the design and designers. However, this appears to let engineers too easily off the hook, when they should, in fact, be encouraged to assume more, not less, responsibility for attending to the possible risks of designed systems. Failures may be to some extent unavoidable given the nature of reality, but Petroski wants to emphasize that more attention needs to be paid by engineers to anticipating failure modes. The message to engineers should be one of caution, but also one of encouragement to broaden the scope of their engineering analysis in order to contend with political and economic impacts.

The few photos included in the text were very helpful in illuminating the engineering failures described. I wish there were more. While Petroski does a masterful job of explaining complex geometries and technical design features in the text, interpretation of his conclusions would have been easier with more graphics, particularly sketches and diagrams. For engineers, a picture can be worth a thousand words, or at least make the thousand words a lot more intelligible. As a remedy for this lack, my suggestion would be to employ web searches strategically as you read. For example, when I came to the section on early construction cranes, I googled "Petruvius" and "medieval crane." This resulted in a plethora of images from which I could pick out a few that matched the text description, thus clarifying the terminology.

As Petroski wisely notes in his final chapter, there is a natural propensity among engineers to see technology as continuously advancing and to view older, supposedly obsolete systems as having nothing important to teach regarding future designs. *To Forgive Design* refutes this, and will be an especially worthwhile read for engineering students, practicing engineers, and anyone else with a healthy curiosity about the limitations of contemporary technological systems. I also strongly recommend the book for the influence it provides in countering a tendency in engineering to devalue scholarly work that focuses on the context of engineering practice, rather than on the equations and experiments that constitute the more technical aspects of scientific engineering analysis. This book is a noteworthy example of successful integration of the hard and soft sides of engineering, which should allow engineers, scientists, and policy makers to better appreciate the cultural embeddedness of engineering work, and therefore better negotiate the risks of living in our modern technological society.

Reviewed by Gayle Ermer, Professor of Engineering, Calvin College, Grand Rapids, MI 49548.

ETHICS

THE UNDEAD: Organ Harvesting, the Ice-Water Test, Beating-Heart Cadavers—How Medicine Is Blurring the Line Between Life and Death by Dick Teresi. New York: Vintage Books, 2013. 291 pages, endnotes, bibliography, index. Paperback; $16.00. ISBN: 9781400096114.

In our age of ever-increasing breakthroughs in medical technology, it is possible to forget the amazing healing power of solid organ transplants, and the very real ethical issues raised by these well-accepted procedures. While issues of justice in access to donor organs surface occasionally in the press, it has been many years since I read a discussion of the ethics of brain death and the complicated factors that must surround the donation of organs in a usable form for the recipient. In *The Undead*, journalist Dick Teresi investigates organ transplantation largely from the point of view of the donor. He develops a historical path through societal definitions of "death," beginning in ancient Egypt and continuing through the present day. An interesting section in chapter 3 analyzes the "Harvard criteria" for brain death, the significant results of the 1968 "Ad Hoc Committee of the Harvard Medical School to Examine the Definition of Brain Death." These standards consist of four criteria to indicate a permanently nonfunctioning brain: unreceptive/unresponsive patient, lack of movement or breathing, no reflexes, and a flat EEG. Teresi points out that these criteria were based on theory, not studies on patients who met the criteria and did or did not recover. However, the criteria have become the standard for declaring death in the US following the 1981 Uniform Determination of Death Act.

Teresi observes that in practice, the EEG is rarely used in declaring a patient brain dead. He declares this a serious omission, most notably because three years after publication of the Harvard Criteria in the *Journal of the American Medical Association*, University of Minnesota physicians measured positive EEG readings in five of nine patients for whom the first three Harvard criteria—today's standard for brain death—applied. The disconnect between the criteria for brain death and the actual medical practices used in declaring brain death are the focus of the rest of the book. Teresi describes other populations of patients who could be potential organ donors: anencephalic infants and patients in persistent vegetative states (PVS). A large section of the book addresses how new advances in brain imaging have shown that at least for PVS patients higher brain function is not infrequently maintained; giving the patient the ability to communicate his or her higher brain functions is what is difficult in some cases of stroke or other brain damage. The measurable physiological responses of organ donors to the stresses of their final surgery, organ harvesting, is also discussed in an attempt to ask if these individuals are truly dead or not at the time of harvest.

Teresi raises many questions about whether our definition of "brain dead" is physiologically accurate, and thus whether our current practices for organ donation are ethical. The movement toward implied consent for organ donation in many countries makes this issue more urgent to address, as personal choice for donating organs in these situations may be eroding. Unfortunately, Teresi provides no suggestions for solutions to these thorny issues. He does, however, expose enough situations in which families have been pressured into organ donation, or corners have been cut in declaring brain death, to make the reader wonder why the medical community is not developing better protocols or reliably using those that are in place. Teresi posits that the financial benefit to the individual healthcare providers and their institutions is great enough to highly motivate them to make the donations happen.

The Undead is a thought-provoking book. It is written in an engaging style, and organized into small vignettes that make the reading easy, although occasionally disjointed. Case studies of real patients are sprinkled throughout, which draw the reader into the topic at a more personal level. There is little to no religious reasoning in the ethical analysis, or even standard philosophical treatments of the ethics, but as a starting point for a discussion of the thorny and often overlooked issues associated with organ transplantation, this book is an excellent resource and compelling read.

The book would be more useful for discussion in church education sessions, small groups, or classrooms in Christian education settings if it were paired with readings that reflected on Christian responsibilities to the terminally ill and/or injured, or simply Christian responses in the face of death. Making heartbreaking choices about continuation of treatment versus organ donation is aided by accurate information about the biology—even acknowledging the murkiness in our current biological definition of death. However, making those decisions with the help of one's faith, faith community, and the thoughts of Christian theologians and ethicists is a better road for believers.

Reviewed by Robin Pals Rylaarsdam, Professor of Biology, Benedictine University, Lisle, IL 60532.

General Sciences

SHAPING A DIGITAL WORLD: Faith, Culture, and Computer Technology by Derek C. Schuurman. Downers Grove, IL: InterVarsity Press, 2013. 138 pages with index. Paperback; $18.00. ISBN: 9780830827138.

"What does Silicon Valley have to do with Jerusalem?" With that play on Tertullian's ancient remark about Athens and Jerusalem, Derek Schuurman begins his discussion of the relationship between Christian faith and computer technology. It turns out that the answer is "quite a lot." The book presents a broad but thorough overview of issues a Christian in the computer field ought to consider.

Schuurman teaches at a Christian college in the Reformed tradition (Redeemer University College in Ancaster, Ontario) and approaches his subject from that perspective, drawing heavily on writers in the Kuyperian tradition. Four of the six chapters focus on the relationship between computer technology and the four great themes that compose a Reformed worldview: Creation, the Fall, Redemption, and Restoration. An introductory and concluding chapter round out the book.

The author sees technology as part of the latent potential of creation, and the doing of technology as a form of obedience to the cultural mandate (Gen. 1:28). The creativity involved in doing technology flows from our having been made in the image of God. Schuurman here cites Frederick Brooks, a believer who is well known in the field of software engineering:

> Why is programming fun? What delights may its practitioner expect as his reward? First is the sheer joy of making things. As the child delights in his mud pie, so the adult enjoys building things, especially things of his own design. I think that this delight must be an image of God's delight in making things, a delight shown in the distinctiveness and newness of each leaf and each snowflake. (p. 37, cited from Brooks, *The Mythical Man-Month,* p. 7).

Thus, the creativity of technological work is something that we share with all of humanity. As Schuurman puts it, "regardless of the faith commitments of those who discover new technologies, we are all working with the bounty of God's creation" (p. 57).

But technology, like all of creation, has been damaged by the Fall, though the author explicitly rejects the thesis that technology is a result of the Fall, seeing it instead as "part of the latent potential in creation" (p. 64). At the same time, he notes that "computer technology is not neutral; it can either be directed in ways that comport well with God's intentions for his world or in rebellious ways" (p. 65). Schuurman cites as examples of rebellious use of computer technology such phenomena as compulsive computer use, technology driven by efficiency at the expense of other considerations, failure to recognize the value of people as human beings, and reliance upon technology to produce *shalom*. (Responsible use of technology is discussed in-depth in the next chapter.) One fascinating question he discusses in this chapter is whether the phenomenon of "bugs" can be regarded as part of the consequences of the Fall, some of the "thorns and thistles" of the curse. While regarding the inherent complexity of computer programming as part of the creation, he asserts, "the drudgery and harmful consequences of bugs and failed computer projects are certainly a result of the fall" (p. 69).

The next chapter, entitled "Redemption and Responsible Technology," is the longest and perhaps the central chapter in the book. Schuurman rejects the notion that there is such a thing as a distinctively Christian sort of computer technology. Nonetheless, faith does make a difference in how we approach our work. He writes, "Our faith can motivate us to do our technical work well as a way to be faithful stewards and to show love for our neighbors" (p. 74). He then lists a number of norms that should govern the way a Christian approaches computer technology. Most of the norms he lists, while comporting with biblical teaching, are also ones that many secular practitioners would embrace. While I found myself agreeing almost entirely with the norms he espoused, I also found myself wishing that more was said about how these norms follow from biblical principles, especially in areas where there are differences of opinion among secular practitioners.

In his fifth chapter, dealing with the future, the author discusses optimistic and pessimistic views of the future of technology. He rejects utopian views as a form of postmillennialism, and despairing views as incompatible with the understanding that the potential for technology is part of a world which God both created good and is now redeeming through the work of Christ. Here again, I wish that he had developed biblical teaching more fully. For example, while I agree with his rejection of the singularity views espoused by writers like Ray Kurzweil, I know Christian students who are fascinated by this emphasis, and I wish that Schuurman had more fully developed just how the singularity view is incompatible with biblical faith.

The book ends with a short, concluding chapter and then a series of discussion questions that could be used in a Bible study or college classroom. Summing up, this is a well-written book that fills an important gap. I know of no other book that is like it.

Reviewed by Russell C. Bjork, Professor of Computer Science, Gordon College, Wenhan, MA 01984.

THE UNIVERSE WITHIN: Discovering the Common History of Rocks, Planets, and People by Neil Shubin. New York: Pantheon Books, 2013. 225 pages. Hardcover; $25.95. ISBN: 9780307378439.

The rocks are speaking to you! These words, spoken by a geology professor on the first day of class, inspired a colleague to study the environment. While reading Neil Shubin's latest book, *The Universe Within,* I could not help but be reminded of my friend's tale during a summer workshop that we attended. In her story, she related her fascination in understanding the stories that rocks tell. "The rocks are speaking to you" could easily be the title of this book. Shubin does a good job demonstrating the significant clues to the past that rocks hold—fossils being one of many types of clues. The book shows that ignoring these clues is foolish to anyone who desires to understand how life evolved on this planet.

Readers with a weak science background may have some difficulty grasping the scientific concepts as Shubin moves from one concept to the next. His descriptions are good, accurate, and most appropriate for readers with a well-rounded science background. There is not a great deal of detail provided by the author when discussing concepts such as the big bang, the creation of elements within stars, plate tectonics, and the formation of solar systems, to name a few. However, teaching science concepts and theories is not the main goal of the book. Shubin is more interested in presenting the connections that led scientists into postulating current theories about the origins of life based on data collected from rocks, which are hundreds of millions of years old. He does a good job illustrating how rocks carry information about events long since passed. Those readers that are not well versed in the sciences may not understand completely, but they will understand the big picture and be able to follow where his stories lead.

The book shows the reader that evolution is truly an interdisciplinary field, and it provides examples of the valuable input from various fields in piecing together the story of life on this planet. Throughout the book, significant contributions by biologists, chemists, physicists, and geologists are highlighted to demonstrate how difficult it is to discern evolution of life and how small details and discoveries, which many would consider having little value, provide insight and give rise to great discoveries or new avenues of research. Shubin succeeds in demonstrating these connections through the stories that he includes. By relating personal tales from his years of field experience, he illustrates the difficulties and hardships that go into collecting data from rocks and the perseverance of dedicated scientists. He also discusses the lucky breaks that led to some amazing scientific discoveries.

The anecdotes that he weaves into his chapters are amusing. The stories make the jump from one concept to the next more enjoyable. They dismiss the notion that science is boring and help readers realize that there is a lot of excitement, and interesting stories, behind the scenes of scientific discoveries. Everyone will appreciate the anecdotes and, in some ways, relate to the struggles in scientific research. Obviously, I do not want to spoil any surprises, but my favorites in this book are Shubin's personal stories about his first trip to a Greenland field site, Camp Century, and the string of tales related to the theory of plate tectonics. I feel these stories will encourage readers to delve deeper into the history of science, where they will find that even scientists struggle with accepting new ideas and shifting paradigms. In addition, I appreciated that the titles of the chapter did not reveal the content. They were very appropriate and gave me a chuckle at the end of each chapter.

Shubin's writing style is concise and straightforward. The flow of information is linear and the connections are clear. Readers will not have difficulty finishing the book. His "Further Reading and Notes" are very beneficial. For those who desire to learn more, the section is organized, using the book's chapters as a reference. It includes relevant articles, YouTube links, supplementary explanations for concepts, and recipes for dehydrated meals to use in fieldwork. I appreciated that he includes some context instead of a simple list of information, because it strengthens the reader's desire to seek out the information.

While this book is not written from a religious viewpoint, it exemplifies an interesting idea that could play a more prominent role in Christian discussions of evolution, namely, the important links between environment and the history of life on Earth. Many Christians advocate a philosophy of global stewardship, which has been the theme of several addresses and declarations by Christian leaders along with articles in *PSCF*. The connections between the lifeless and living components of the planet discussed by Shubin reinforce the view that humans are part of this planet, not a separate entity. We should be more responsible in our use of global resources, because we may lose more than just its beauty. We may lose important clues to understand ourselves and to help us carry out our mandate for caring for the earth.

After reading this book, I can honestly say that I appreciate a little more the journey of life on this planet as told from the rocks' point of view.

Reviewed by Jerry H. Kavouras, Associate Professor of Biology, Lewis University, Romeoville, IL 60446.

History of Science

I DIED FOR BEAUTY: Dorothy Wrinch and the Cultures of Science by Marjorie Senechal. New York: Oxford University Press, 2013. ix + 300 pages. Hardcover; $34.95. ISBN: 9780199732593.

What role should beauty play in the formulation of scientific hypotheses? The title, and this book itself, allude to both Dickinson's poem on the kinship of beauty and truth as well as C. P. Snow's works on the culture clash between science and the humanities. Relying heavily on Wrinch's private papers and letters, the dominant themes include the role of aesthetics in science and the role of obsession in the life of scientists. Marjorie Senechal is professor emerita of mathematics at Smith College where, as a new faculty member in 1968, she began collaboration with the polymathic Dorothy Wrinch. Senechal presents Wrinch's journey from mathematics to protein chemistry, accompanied by excursions through philosophy of science, theoretical biology, seismography, crystallography and x-ray diffraction. Wrinch contributed almost two hundred articles and books in these diverse fields. We learn along the way almost as much about Senechal's own ambivalence about beauty, symmetry, and order as we do about Wrinch's obsession with geometry and pattern. Like her mentor, Senechal has published on a diversity of topics including crystallography, symmetry, tiling, Escher, the cultures of science, silk, and Albania.

Wrinch (1894–1976) attained first-class honors in math at Cambridge where she fell under the influence of Bertrand Russell's philosophy, logic, and political ideas. She was an early member of the Heretics Club, which formed specifically to question authority and religion. When Russell lost his position at Cambridge she accompanied him to London, where he privately tutored a small group of exceptional postgrads, and she arranged the publication of Wittgenstein's *Tractatus* while Russell was in prison. Much gossip on the lives and loves of Russell's coterie lies scattered among the more mundane academic details.

While teaching in London she completed her MSc and DSc with mathematician John Nicholson, whom she married. They moved to Oxford where Dorothy taught and received the first DSc awarded to a woman at Oxford on the basis of fifteen more publications. Soon after their daughter's birth, John became institutionalized due to alcoholism and mental instability, and they divorced. During this period, she published prolifically in math, probability, and philosophy of science. *The Retreat From Parenthood,* published in1930 under the pseudonym Jean Ayling, elaborated on the plight of professional women forced to choose between a successful career and successful "breeding." Her book, written in the heyday of J. B. Watson's behaviorism, includes a chapter entitled "Homes are Hell," and proposed a national service to redesign homes and provide services for families and centers for unlimited daily or longer-term childcare. Although the British academic scene in the early twentieth century was undoubtedly a difficult place for women, especially single mothers, Senechal glosses over the sources and implications of Wrinch's views on parenting and fails to make the obvious contrast with the emphasis on beauty and symmetry in science.

In the 30s, with her daughter in boarding school, Wrinch visited labs across Europe reinventing herself academically in molecular biology through the application of mathematical theory to chromosomes and then to protein structure. On the basis of this work, Wrinch was awarded a five-year Rockefeller grant, moved to the US, and became well known for her work on X-ray diffraction in crystals and her proposed model of protein structure based on a fabric of interconnected six-sided rings that she called cyclols. Eventually, she proposed that the rings folded into a hollow cage with a hydrophobic interior. This was the high point of her career and Irving Langmuir nominated her for a Nobel Prize. Other friends and supporters included Michael Polanyi, C. H. Waddington, Niels Bohr, and John von Neumann. It was about this time that she wrote to a friend admitting anger at her daughter's participation in church events, which she suspected had to do with filling the loneliness caused by maternal neglect.

In spite of the initial excitement over her proposed model, it was criticized most severely by Linus Pauling who claimed that the cyclol structure was too unstable to exist. He advocated collecting evidence by the breakdown of whole structures into parts rather than making mathematical deductions from geometry and symmetry of the whole. This bottom-up versus top-down approach pitted the culture of chemistry against the culture of mathematics. Pauling began a prolonged campaign against Wrinch, whom he accused of "affinity for the media" (p. 161) and dishonesty (p. 165, 281, notes 3–5). Senechal presents Pauling's obsession with debunking cyclols as a major reason why Wrinch's grant was not renewed, and she failed to find an appropriate position. In the end, both Wrinch and Pauling were wrong. Cyclols have never been found in proteins, but, in the 1950s, they were found to exist naturally in thousands of alkaloids. Pauling's own obsessive preoccupation with vitamin C suffered a similar demise.

After losing her grant, Wrinch married biologist Otto Glaser of Amherst and was appointed research professor of physics at Smith. During this period she wrote on the use of Fourier transforms in determining the structure of crystals. At the outset of her thirty years at Smith, she confided to an English friend that she was unhappy with the isolation and lack of adult students there; nevertheless, after Glaser's death, she lived in residence at Smith for over twenty years. She continued until retirement to write prolifically in defense of her protein theory.

One take-home message of this book is that science is ultimately not built on preconceived Platonic notions of beauty and order. You have to take the data as is. Beauty may be a useful criterion but only when competing hypotheses are equally supported. Wrinch was unable to give up her hypothesis and became isolated and resentful about her lack of success. The lives Senechal portrays remind us of the human frailty of great men and women and that, although math and geometric symmetry may be beautiful, real life is invariably messy.

Readers interested in history, methodology, and philosophy of science are likely to find the book of general interest, and in particular a useful source of material on the treatment of women in early twentieth-century academia. Most readers outside the area of molecular biology will, however, find the research details obscure. The narrative jumps about and sometimes seems disjointed, but overall provides an interesting portrait of a brilliant woman. Even though the book reads like a Who's Who in math and science, Senechal thankfully provides an appendix listing the major characters and their roles in both science and Wrinch's life. There is also an index and fifteen pages of notes, many of which derive from private letters and notes organized by Senechal after Wrinch's death.

Reviewed by Judith Toronchuk, Trinity Western University, Langley, BC V2Y 1Y1.

Philosophy & Theology

CLEANSING THE COSMOS: A Biblical Model for Conceptualizing and Counteracting Evil by E. Janet Warren. Eugene, OR: Pickwick, 2012. 336 pages. Paperback; $37.00. ISBN: 9781620324035.

In her book, *Cleansing the Cosmos: A Biblical Model for Conceptualizing and Counteracting Evil*, Janet Warren constructs a model for understanding and responding to evil that is anchored in scripture's spatial/boundary metaphors and that is intended to serve as an alternative to the warfare model that has become quite popular today. Rather than conceiving of God and all who align with him "battling" forces of evil to free humanity and the cosmos from their grip, Warren's spatial model construes forces of evil more along the lines of dirt that needs to be swept out of the cosmos in order for it to become the all-encompassing "sacred space" that God has always wanted it to be (e.g., p. 157).

I found much of value in Warren's informative work. One of the book's greatest strengths is the masterful way Warren integrates a broad range of scholarship in the process of recasting central components of the biblical story with the use of spatial and boundary metaphors (pp. 80–250). The breadth of scholarship Warren employs reflects the fact that this book is a reworking of her doctoral dissertation (University of Birmingham, UK). Yet, this book is relatively free of technical jargon and is thus accessible to most lay readers. Another particularly strong aspect of this book is chapter 2 in which Warren sagaciously brings readers up to speed on the current discussion on the nature of metaphors in defense of her "critical realist" epistemology (pp. 29–52).

Yet a third feature of this book that is particularly strong is the highly creative manner in which Warren elucidates theological concepts by drawing on analogies from contemporary science. For example, chaos and complexity theory are used to articulate the way demonic forces self-organize and create emergent properties that impact the world in chaotic, nonliner, indeterministic ways (e.g., pp. 72–6, 79, 83, 171, 218, 223, 230, 271–2). So, too, while I will later argue that Warren's ontology of evil is highly problematic, I cannot help but appreciate the creative manner in which she attempts to capture its "nothingness" by drawing analogies with such things as "dark matter," "dark energy," "virtual particles," and "quantum fields" (e.g., pp. 70, 77–8, 124, 163, 252, 269, 271).

While I think that the strengths of this book rendered it worth reading, there are, unfortunately, a number of things that weakened it considerably. For the purposes of this review, I will restrict myself to two sets of criticisms.

First, it seems to me that Warren at times misunderstands and/or misrepresents the warfare models she critiques. For example, Warren repeatedly states that the warfare approach implies that God and Satan are "equal and opposing forces" (e.g., pp. 125, 172, 173–4, 210). She neither cites any advocate of the warfare model who expresses this conviction, nor provides any line of argumentation in its defense. I can only assume that Warren considers this strong claim to be self-evident.

If anything is self-evident, it seems to me it is that Warren's assumption is mistaken. Every earthly war that has ever been eventually won by one of the opposing sides was a battle between forces that were obviously *not* equal. Yet, I doubt anyone would hesitate to call them genuine "wars" on this account. So, too, the fact that all orthodox Christian advocates of the warfare model hold that God is guaranteed eventually to defeat Satan demonstrates that they do *not* hold that spiritual warfare is between "equal" forces. Unfortunately, this aspect of Warren's critique of the warfare model is hardly peripheral to her overall thesis, for it factors strongly into other negative evaluations of the warfare model (e.g., as undermining God's sovereignty [pp. 125, 213], as "dualistic" [pp. 125, 213, 250, 271], and as ascribing "excessive reality" to Satan [pp. 62, 71, 270]).

Judging from the way Warren interacted with my work in particular, I suspect that some of her misunderstandings of warfare worldview may be due to a less than careful treatment of her sources. For example, as her only illustration of her frequent claim that advocates of the warfare model fail to appreciate the metaphorical nature of much of the Bible's language about forces of evil, Warren contends that "Boyd … insists that demons and cosmic forces are 'real' spiritual beings, and not 'mere metaphors'" (citing page 91 of my *God at War*). After her citation, Warren goes on to state that Boyd "appears to think that 'spiritual warfare' is not a metaphor or model" (p. 51), while elsewhere she contends that I do not seem "to recognize that metaphors can depict reality" (p. 113).

If you check out the context of Warren's quote, you will find that I am speaking about the Old Testament's depiction of malevolent cosmic forces as "the deep," "the hostile sea," and the "raging waters." I state that, given the original cultural context of the biblical writers, these concepts "cannot be taken as mere poetic flourishes" (*not* "mere metaphors"). I then contend that "the very meaning of such expressions in ancient culture was predicated on the belief that such demonic realities actually existed." Following this, I go on to argue that "[w]hile believers today cannot affirm as literal the mythological portrayals of the cosmic forces that the biblical authors give," we should nevertheless "affirm the reality to which these mythological portrayals point" (*God at War*, pp. 91–2). In short, I am arguing that the mythic metaphors in Scripture *point to a reality*—the very "critical realist" position that Warren defends and accuses me and other advocates of the warfare model of overlooking.

A second set of considerations that I believe weakens Warren's thesis concerns a number of claims and concepts that struck me as highly ambiguous, and possibly incoherent. The most serious example of this, and the only one that space allows me to address, concerns Warren's conceptualization of evil—a point that is of some consequence inasmuch as clarifying our understanding of evil is one of the central claims Warren makes for her spatial model (e.g., pp. 27, 286). To arrive at her conception, Warren applies her spatial model to ontology (without announcing that this is what she is doing). The metaphor of "center" to "periphery" is thus transformed into a way of speaking about *degrees of reality*. The result is that, though Warren claims her approach is rooted in "metaphorical" rather than "propositional or metaphysical truth" (p. 269), the discussion about the nature of evil that runs throughout her book is steeped in propositional and metaphysical truth claims. And I, for one, frankly found many of these claims to be highly ambiguous, if not incoherent.

To illustrate, throughout her book we find descriptions of evil as rooted in "nothingness" (from Barth) which, she claims, is "not allowed ontological status" (p. 117), has "reduced existence" (p. 175), "reduced ontology" (pp. 210, 270), and "diminished ontological status" (p. 186). Nothingness is thus "less real" (pp. 142, 186, 230, 248, 271) and "quasi-real" (pp. 90, 269, 287). Similarly, "evil," "Satan," and other "forces of evil" are variously described as "non-ontological" (p. 55), "unreal" (pp. 186, 230), "semi-real" (p. 272), possessing "little substance" (p. 210) and a "reduced ontology" (p. 285), while lacking "true reality" (p. 268).

I confess that I cannot get clear what these descriptors mean or how they can be coherently related to one another. How can anything "exist," in *any* sense, without being given "ontological status"? Isn't having "ontological status" simply *what it means* to "exist," in *any* sense of the word? Nor is it clear how something can lack "ontological status" and yet possess "diminished" or a "reduced ontological status" (whatever these terms might mean). One would have thought that not being "allowed ontological status" would be *less than* having "*diminished* ontological status," yet both are applied to "nothingness" (which, in any event, I have trouble calling "nothingness" if it has *any* "ontological status," however "diminished"). Nor is it clear what it means for something to lack "true reality" (is there a "*false* reality"?), just as it is not clear how one and the same thing can be "unreal" and "quasi-real."

As I noted earlier, Warren utilizes a host of scientific concepts to give this graded ontological language some meaning, but for all her ingenuity, I think the analogies fail. For example, when scientists such as Paul Davies speak of particles prior to their measurement (i.e., in a state of "superposition") as being "in a shadowy world of half-existence" (p. 77), they are speaking *phenomenologically*, namely, relative to our ordinary experience of the world as composed of stable objects. It is a way of metaphorically capturing the distinct *mode of existence* of a quantum particle prior to its measurement (e.g., the "collapse of the wave packet"). But there is nothing "quasi-real" (p. 272) about a quantum particle in this state if we are speaking *metaphysically*. The subatomic particle exists—as "fully" as anything else exists, otherwise it would make no sense to refer to any *particular* particle in this state or to contrast it with any other existing thing or even with non-existence. It is just that the particle in this state exists in a *distinct mode* that distinguishes it from the mode of existence that characterizes our phenomenological world. I would argue along the same lines for all the analogies Warren uses, as I would argue regarding the ontological status of possibilities, potentialities, dreams, imaginary animals, and so forth.

I would therefore contend that Warren has confused *modes* of existence with *degrees* of existence while assuming (without argumentation) that certain modes of existence (e.g., God, holiness, sacred space) should be considered *more real* while other modes of existence (sub-atomic particles, demons) should be considered *less* real. This ontological privileging of one mode over others strikes me as arbitrary, and I struggle to ascribe any coherent meaning to this "more" and "less" scaling of reality. As I have argued elsewhere (*Satan and the Problem of Evil*), I believe Barth's concept of "nothingness" can be salvaged as a way of expressing that which conflicts with God's will for creation, but only if it is conceived of as a domain of *possibilities* that becomes *actualized* only when free agents, human or angelic, choose to do so against God's will.

According to the warfare model, the choosing of these negated possibilities constitutes the origin of evil, and it is expressed in Scripture's allusions to an angelic fall and its account of the human fall. To my way of thinking, this is the only plausible account of the origin of evil, and the fact that Warren instead favors the concept of "nothingness" as an uncreated quasi-reality (e.g., pp. 86, 257) lies at the foundation of her problematic ontology of evil and constitutes one of the primary reasons why I remain unconvinced that her spatial/boundary model is superior to the warfare model.

Reviewed by Gregory A. Boyd, PhD, Senior Pastor of Woodland Hills Church and President of ReKnew, St. Paul, MN 55109.

Religion & Science

COLD-CASE CHRISTIANITY: A Homicide Detective Investigates the Claims of the Gospels by J. Warner Wallace. Colorado Springs, CO: David C. Cook, 2013. 288 pages. Paperback; $16.99. ISBN: 9781434704696.

This book offers a unique perspective on the claims of the Gospels, that of a trained homicide detective. As such Wallace approaches the reliability of Christian truth claims with a detective's skill and perspective. Using the same forensic skills he uses when solving a cold-case crime, he looks at the evidence available in the Gospels to determine their reliability and truth claims. Wallace was a vocal atheist for the first thirty-five years of his life. He eventually became a Christian because he discovered the reliability of the Gospel's truth claims using the same forensic techniques that he had employed successfully to solve many cold-case crimes during his career.

The book is divided into two sections followed by an Appendix of Case Files. Section 1 has ten chapters, each dealing with "one of the 10 important principles every aspiring detective needs to master." He proceeds to apply each of these principles to an actual crime scene he had to solve while he was a homicide detective. On the basis of these principles, he then cautions skeptics not to fall into the trap of rejecting Christian truth claims outright.

His ten principles are (1) resisting the influence of dangerous presuppositions, (2) understanding the role of abductive reasoning, (3) respecting the role of circumstantial evidence, (4) evaluating the reliability of the witnesses, (5) examining the choice and meaning of the language, (6) determining what is important evidentially, (7) recognizing the rarity of true conspiracies, (8) establishing reliability by tracing the evidence, (9) getting comfortable with one's conclusions, and (10) distinguishing between possible alternatives and reasonable refutation. These principles then become his "call-out bag and checklist."

Section 2 consists of four chapters and is devoted to applying the above principles to the claims made about the reliability of the New Testament. This section will be very familiar to the ASA reader, but still contains some surprises that only the sharp eye of a detective could bring forth. For example, he observes that if the gospels were written late, they should have mentioned the siege of Jerusalem and the destruction of the temple predicted by Jesus. Why did Luke not mention the death of Peter or Paul? He claims Mark avoids mentioning important names in his gospel (unlike a later rendition by the Apostle John) to protect key players!

It will not be possible to discuss each chapter separately. But they all follow the same forensic approach that Wallace uses. An outline of a couple of chapters will illustrate this uncommon approach that only a detective would use as an apologetic tool.

Wallace starts with chapter 1, entitled "Don't Be a Know-It-All." He describes how he solved his first assignment, a homicide case. The approach he took in solving the mystery was avoiding the temptation of *relying on his initial presupposition* as to who seemed to be the most logical culprit. Only after thinking "outside the box" (unlike his co-investigators) was he able to find the real culprit. He uses this experience to caution others of the dangers of "presuppositional belief," so common among atheists, that is, that only natural laws and forces operate in the world. He identifies mental blocks that would keep someone from accepting the supernatural and encourages the reader to enter the scene "with empty hands" and thus distinguish between what is natural and what is not.

In chapter 2, entitled "Learn How to Infer," Wallace describes how he solved a very difficult homicide case by distinguishing between two answers: the possible and the reasonable. Contrary to what his co-workers surmised, Wallace used an abductive approach to show that the most *reasonable* answer to the crime was that the death was not a suicide, but murder. Then he brings his expertise as a cold-case detective to bear on the forensic aspects of the events surrounding the first Easter, concluding that the most reasonable answer had to be that Christ rose from the dead.

The ASA member trained in apologetics will find many of the tools Wallace uses to defend the truth claims of Christianity to be familiar. His arguments are not as rigorous as those of trained apologists such as William Lane Craig or Alvin Plantinga. The novelty lies in the ingenious ways he weaves his experiences in solving difficult murder cases with how one can use those same methods to defend the faith. In fact, he claims that it was this "empty hand, unbiased approach" that eventually brought him to faith from atheism. This makes reading the book entertaining as well as educational. (For example, the ten homicide cases that he has solved, some against all odds, are alone worth reading.)

Wallace ends the book with three case files. The first case file consists of a list of known experts in the field of apologetics, one or more experts per chapter. These experts are called on to support the arguments used by the author in each of his chapters (e.g., William Craig, Gary Habermas, Paul Copan). The second case file lists names of assisting officers, police, detectives, and others who used their expertise to come to the same conclusion as the author regarding the reliability of the Gospel accounts. The third case file is the list of references used by the author to write his book. I thoroughly enjoyed this novel way of defending the truth claims of Christianity and strongly recommend it to others.

Reviewed by Kenell Touryan, ASA Fellow, Visiting Professor, American University of Armenia (an Affiliate of UC Berkeley), Indian Hills, CO 80454.

Social Science

THEOLOGY FOR BETTER COUNSELING: Trinitarian Reflections for Healing and Formation by Virginia Todd Holeman. Downers Grove, IL: IVP Academic, 2012. 205 pages. Paperback; $20.00. ISBN: 9780830839728.

Can theology actually impact how a Christian counselor works? This is the central question that Virginia Holeman tackles in her book *Theology for Better Counseling*. Holeman does not just attempt to answer this question; she demonstrates the answer, by presenting a metamodel of *theologically reflective counseling* utilizing a Wesleyan perspective. This book, which falls into the *Integration* genre (i.e., integrating psychology and Christian faith), is not a book solely for Wesleyan oriented counselors, but rather Holeman uses her own particular theological sensibility as an example and invitation for Christian counselors from other traditions to do the same.

The literature in Christian counseling has often relied on vague rhetoric, treating Christianity as universal, monolithic, and encyclopedic. Holeman argues that when this happens theological particularity is lost and Christian counseling becomes theologically thin. This may then lead to what she calls weak-sense theological thinking, hallmarked by theological ethnocentrism and discomfort with ambiguity. Most importantly, weak-sense thinking can lead to counselors failing to recognize their theological position, and subsequently it becomes a hidden bias which may negatively impact their work.

In chapter 1, Holeman sets out the argument for why Christian counselors should incorporate strong-sense theology, hallmarked by personal theological awareness, curiosity, and respect for alternative perspectives, awareness of theological ethnocentrism, and comfort with theological ambiguity. Strong-sense theological reflection assists clinicians in evaluating the clinical systems of therapy from which they work, establishes professional competency to work with religious issues, enables clinicians to employ theological empathy toward clients, and helps clinicians to engage in theological discernment (teasing out constructive and destructive forms of religiosity).

A metamodel for a theologically reflective counseling is advanced in chapter 2, but Holeman notes that this must first be embodied in the personal, spiritual, and professional formation of clinicians. This formation includes theological preparation of the therapist, development of their Christian character, growing in awareness of the Holy Spirit, and the actual practice of the counselor in the room. There are four movements in the metamodel that therapists must engage to be effective: *attending* to theological echoes; *addressing* salient theological themes; *aligning* areas of life to be more theologically congruent; and *attaining* a deepening Christian character in their clients. Holeman then provides helpful examples of what each one of these movements looks like in clinical work. Holeman rightly points out that counselors and clients will not always share the same theological tradition. Because of this challenge, Holeman highlights that theologically reflective counseling does not happen just because a clinician is Christian. It must entail supervision with theologically reflective mentors and ethical commitments to clinical competency (is the therapist really competent to deliver the type of therapy he or she is providing?) and to informed consent (what has the client agreed to in terms of utilizing Christian resources at the outset of therapy?).

Chapter 3 is a hinge chapter in which Holeman employs contemporary understandings of the Trinity as a hermeneutical lens through which to conceptualize counseling theologically. Describing the Trinity as divine persons-in-relations provides a means for also understanding the *therapeutic community* of client, therapist, and God. Since God is already in the room, clients can experience God's love through the therapeutic interchange. The "dance" of the therapeutic community begins to resemble the mutual loving, respecting, and recognizing dance of the Trinity (i.e., *perichoresis*).

In chapters 4 through 7, Holeman demonstrates a theologically reflective counseling utilizing her Wesleyan tradition. Chapter 4 takes up the issue of holiness or responsible living. While many theological traditions speak of personal holiness, Holeman moves the discussion to the realm of *relational holiness* and borrows John Wesley's description of holiness as the enactment of God's love within the church and to the world, in the here-and-now. Therefore, therapists who help clients develop their capacity for loving and relating rightly to others promote holiness. Holeman then engages in practical clinical integration as she puts the idea of relational holiness into conversation with Bowenian family therapy, and describes what she calls *differentiating holiness*. Differentiating holiness includes three important aspects: being able to have a clear "I" position because one is centered on Christ; being able to self-soothe without fusion or emotional cutoff because of the peace of God; and being able to take personal responsibility for one's impact on others through the grace of God. Holeman then demonstrates what this looks like through the use of a case vignette.

In the last three chapters, Holeman takes theology so seriously that she allows it to set the agenda for counseling rather than the other way around. This is *theology-directed* integration, which can be unusual in a genre of literature that is often guilty of privileging psychology's methodology and epistemology. In these creative chapters, she tackles social holiness and social justice (chapter 5), atonement and forgiveness (chapter 6), and finally eschatology (chapter 7). Each of these chapters is deeply rooted in her Wesleyan sensibility, but again, as a challenge to readers to follow her example and dig into their own theological traditions. Chapter 5 is perhaps the most provocative, for it challenges Christian clinicians to move out of an individualistic understanding of disorder toward a social and cultural conceptualization. This is a call for Christian clinicians to become agents of social change, to get out of their offices, to rethink fee for services and to give psychology away.

Holeman has written a unique book in the integration literature. Her theologically reflective practice model is neither treatment-model-specific (she does utilize clinical research on *common factors* that influence therapeutic effectiveness) nor is it generically thin Christianity. It is not psychology with a "side of Jesus" but is a genuine and successful attempt to allow theology (specific, thick, and strong) to have real impact. This book will be very useful for Christian clinical graduate training as well as pastoral care and counseling.

Reviewed by Brad D. Strawn, Evelyn and Frank Freed Professor of the Integration of Psychology and Theology, Fuller Theological Seminary, Graduate School of Psychology, Pasadena, CA 91182.

MINDS, BRAINS, SOULS AND GODS: A Conversation on Faith, Psychology and Neuroscience by Malcolm Jeeves. Downers Grove, IL: InterVarsity Press, 2013. 219 pages. Paperback; $20.00. ISBN: 9780830839988.

Pascal wrote, "It is dangerous to show a man too clearly how much he resembles the beast, without at the same time showing him his greatness. It is also dangerous to allow him too clear a vision of his greatness without his baseness. It is even more dangerous to leave him in ignorance of both." This quote articulates both the reason and the goal of Malcolm Jeeves's most recent book, *Minds, Brains, Souls and Gods: A Conversation on Faith, Psychology and Neuroscience*.

The *raison d'être* of the book and its central questions revolve around the uncertainty and fear that Christians express as they wade into scientific research on brains and behavior. Jeeves's goal is to articulate recent scientific findings that indicate how much humans resemble beasts while, as Pascal recommends, simultaneously reassuring the reader of his or her own greatness and importance. The greatness and importance of humans within the sphere of brain and behavior are centered on whether humans have free will, souls, and features that separate us from other animals. Such features, many believe, give us special status in the animal kingdom. And these special features include our moral intuitions and, particularly for Christians and other religious believers, a belief in God.

Jeeves maintains that "a fuzzy boundary between humans and animals is not something that should bother Christians and those holding a religious outlook on life," and then immediately states that, "for many of those who do not believe in God, there is a tacit acceptance that humans are clearly unique in terms of the explosive development of learning, philosophy, literature, music, art, science, religion, and so on" (p. 117). Jeeves is onto something here. He suggests that these grounds—learning, philosophy, literature, music, art, and science—are sufficient for the nonbeliever's tacit acceptance of human uniqueness and greatness. If such endeavors contribute to humans' belief in their own uniqueness and greatness in the animal kingdom, it is little wonder that some Christians believe that their uniqueness and greatness is in question. The atrophy of these intellectual pursuits has left many Christians vigorously defending their intrinsic worth based on religion alone. Within such an atrophied intellectual context, it is easy to believe that any intellectual pursuits outside religion may very well erode both humanity's intrinsic uniqueness and worth. These beliefs frequently haunt believers who venture into the sciences, and particularly those in psychology, biology, and neuroscience. And while Jeeves leaves it to others to describe the causes and development of these implicitly fear-filled contexts, it is within such contexts that he writes.

The book is organized as an email correspondence between Jeeves and an imaginary undergraduate Christian student studying biology and psychology at a secular university. The imaginary student is the synthesis of questions Jeeves has received from students attempting to integrate their faith with findings from neuroscience and the psychological sciences. The product of this synthesis is a student who is at once incredibly bright and oddly naïve. Although the format is, at times, contrived and awkward, it offers Jeeves an opportunity to articulate a warmth and sincere compassion for believers wading into the area and to demonstrate a quiet confidence in his faith in the midst of scientific findings that potentially raise significant questions for believers.

Jeeves addresses these significant questions from perspectives inside and outside the Christian faith tradition. For general questions such as whether humans have free will, he highlights how other cognitive scientists and neuroscientists unaffiliated with a particular faith tradition counter reductionist interpretations of neuroscientific data from within the field of neuroscience. For example, Jeeves quotes Michael Gazzaniga, a Dartmouth College neuroscientist whose experimental work has shaped cognitive neuroscience and whose textbooks have defined the field. Gazzaniga offers several pointed criticisms of standard reductionist interpretations against the existence of free will. For more specific questions regarding Christian faith, Jeeves leans on the perspectives of well-known writers such as N. T. Wright, Mark Noll, Peter Enns, Nancey Murphy, and Justin Barrett.

Jeeves's treatment of theological questions and those related to biblical interpretation and history are engaging but noncommittal. He frequently articulates multiple views, often citing books from the "Four views on …" series, and then offers a qualified nod toward one. More interestingly and potentially uncomfortable for some, he suggests that there are reasonable grounds for reinterpreting scripture in light of scientific findings while simultaneously emphasizing the authority of God as the inspiration of the scriptures. This view is one of the main reasons that Jeeves's writings work: they explore and maintain an active dialogue between Christian faith and psychology/neuroscience rather than simply allowing one side to dictate to the other. His treatment of questions regarding Christian faith in the light of the rise of evolutionary psychology, social neuroscience, moral psychology, Benjamin Libet's experiments on free will, recent work on "god-spots" in the brain, and more, draws from a wealth of scientific and theological knowledge collected over more than five decades of active research and writing in these areas.

Despite this wealth of experience, Jeeves draws on a few odd sources. For example, he cites Jonah Lehrer, a popular science writer and former neuroscientist, whom Jeeves mistakenly refers to as a psychologist. Lehrer was dismissed from his post at *The New Yorker* in 2012 for plagiarism, fabricating quotes, and factual inaccuracies.

Early in the book, Jeeves writes that his view about the relationship between the mind and brain "may change tomorrow" (p. 30). What will not change is Jeeves's commitment to showing us, simultaneously, how much humans resemble the other beasts of God's creation—both in brain and behavior—and the greatness God offers these fascinating human creations.

Reviewed by Adam Johnson, Department of Psychology, Bethel University, St. Paul, MN 55112.

ANATOMY OF THE SOUL: Surprising Connections between Neuroscience and Spiritual Practices That Can Transform Your Life and Relationships by Curt Thompson. Wheaton, IL: Tyndale Momentum, 2010. 282 pages. Paperback; $15.99. ISBN: 978414334158.

Psychology, neuroscience, and issues of faith have become increasingly connected. In 2010, this journal published a special issue on that theme: *Psychology, Neuroscience, and Issues of Faith* (62:2). The attempt to integrate these disciplines rather than contrast them is ambitious and promising, leading us toward new hermeneutics and new applications. Curt Thompson's *Anatomy of the Soul* exemplifies this trend. His book is a thought-provoking attempt to link Christian spiritual practice and clinical strategy/outcomes to the way the brain is wired, re-wired, functions, and develops.

This book is the result of the author's personal experience. Reflecting upon a neurobiology workshop conducted by Daniel Siegel that he had just taken, Thompson—who had been called to his dying mother's bedside—came to see his mother, himself, and their relationship with very different eyes, free of regret and condemnation. He became able to truly listen to her, and thus saw her narrative from a new perspective, integrating past experience and its effect on the brain. Thompson notes that such an experience also has an effect on one's spirituality, leading to more undivided heart and mind. Thus the author hopes that the book may "show you how your life, too, can be transformed by the renewal of your mind that leads to the wholeness that God intends for you" (p. xvi). The postulate at the basis of his integration is that "God has designed our minds, part of his good creation, to invite us into a deeper, more secure, more courageous relationship with God and with one another."

Neuroscience, says Thompson, points to God. The findings of neuroscience, attachment, and storytelling offer new language to reintroduce us to God and his work with and within us (p. xviii). Though science is an important grounding for this book, this is not a strictly scientific book. The author uses science both as a factual basis and as a transformative tool, offering new strategies to think and act, and to transform one's spiritual life as well. The audience for this text is very wide, ranging from the lay person to the professional. This can be a problem. As I looked at some of the many online reviews, it was evident that the reading was too demanding for some of the lay audience, too "loose" for the scientifically minded, and yet "just right," intriguing and eye-opening, for a substantial part of the audience as well.

Being of a more scientific sort, I was curious, looking for definite applications, but the first two chapters deal in more general concepts, and the third chapter is a basic explanation of the brain, stressing the left brain–right brain concepts, and the triune organization. I almost gave up in frustration at that point, finding the science too general and a bit dated. Then I came to chapter 4, *Are You Paying Attention?* It is an excellent chapter containing clear applications of clinical cases and interesting correlations with biblical text. This is not text-proofing, but a more narrative, sometimes analogical, use of scripture. It finds echoes, resonances, images, and stories that open one's soul to dimensions of one's relationship with God that might have been overlooked before. Similarly, chapter 5 on memory (implicit and explicit memory, the construction of narratives), and chapter 6 on emotion are also quite well done. In my view, chapters 4, 5 and 6 are the strongest chapters of this text.

The next section, chapters 7 and 8, deal with attachment theory (Bowlby; Ainsworth's "strange situation"), and the varieties of attachment that result (secure, avoidant, ambivalent, disorganized) and can influence the development of attachment in adults. There is no specific connection there with neurobiology (except in terms of memory). What is novel though is how the author applies these attachment styles to the manner in which we relate to God. Through the use of biblical narrative and poetry, and through meditative exercises, he helps his clients develop a more stable, secure, loving relationship with God, which can change their perception of reality, hence the title of chapter 8: *Earned Secure Attachment: Pointing to the New Creation.*

Chapter 9, with the engaging title *The Prefrontal Cortex and the Mind of Christ,* presents the synthesizing, reflecting, and moderating function of the prefrontal cortex. It connects spiritual disciplines such as meditation, prayer, fasting, study, and confession to its better functioning, which Thompson connects with "having the mind of Christ." The last few chapters connect Christian themes such as sin and redemption, sin and rapture, resurrection, and living in community with the material developed in the preceding chapter, interwoven with new case studies.

Overall, this is a didactic book (as opposed to a more open, exploratory or descriptive one) organized around a set of topics interwoven with stories and exercises. This would work well with a college-level lay audience, or with students preparing themselves to be therapists. Like Daniel Siegel, who influenced him, Thompson connects his clinical approach to neurobiology findings, stressing neuroplasticity. In addition, the way the author finds echoes of our brain's ways of learning, unlearning, and mislearning in biblical narratives, poem, and themes points to a deeper transformation through prayer and spiritual disciplines, as well as through therapy.

Reviewed by Lucie R. Johnson, Department of Psychology, Bethel University, St. Paul, MN 55112.

Letter

A Correction to the Review of Russell, *Time in Eternity*

I appreciate the editors' granting me a chance to correct my review of Bob Russell's *Time in Eternity* (*PSCF* 65, no. 2 [2013]: 135–7). It appears that I confuse light cones with inertial frames of reference in the review at the bottom of p. 136 and top of p. 137, an error Russell was kind enough to point out. In fact, in shortening the word-count of an earlier draft, I deleted a key point necessary to understand the paragraph in question. Here is that point, which, I emphasize, is my interpretation of Russell's view.

His argument for an ontological and inhomogeneous past-present-future structure ("ppf") within a light cone logically entails that, mutatis mutandis, *more than that single light cone has the same ppf structure*. Call the event at the center of the given light cone "Q." When Q is present, any event which is simultaneous *within Q's inertial frame of reference*, will also be at the center of a light cone with the same or very similar ppf. (This assumes a standard simplification in general relativity, viz. that for an inertial frame of reference one ignores the negligible curvature of space-time within the frame.) Events in the same inertial frame will have approximately the same temporal metric, and so also ppf relations. And this would spread Q's ppf structure beyond one light cone to those in its frame.

This proposed interpretation is missing from the text, and it explains the way I wrote the offending paragraph. I do own the error in the draft I submitted, and apologize to the author, and to the readers and editors of *PCSF*, for making it.

Alan Padgett
Luther Seminary
2481 Como Ave.
St. Paul, MN 55108

American Scientific Affiliation

The American Scientific Affiliation (ASA) is a fellowship of Christians in science and related disciplines, who share a common fidelity to the Word of God and a commitment to integrity in the practice of science. Founded in 1941, the purpose of the ASA is to explore any and every area relating Christian faith and science. *Perspectives on Science and Christian Faith* is one of the means by which the results of such exploration are made known for the benefit and criticism of the Christian community and of the scientific community. The ASA Statement of Faith is at www.asa3.org → HOME/ABOUT → ASA BELIEFS.

American Scientific Affiliation Forums

We encourage members to submit comments and questions on the articles published in this journal on the ASA **PSCF Discussion Forum** at www.asa3.org → FORUMS → PSCF DISCUSSION.

The ASA home page/forums also contains links to four other members-only discussion groups. The **General Discussion** is for thoughtful discussion of various issues in science and faith. **Books** hosts a series of discussions on seminal books on science and faith. There are also forums for discussion about the **Annual Meeting** and **Education**.

An **Open Forum** is open to the public for dialogue on topics of science and faith at www.asa3.org → FORUMS → OPEN FORUM.

Canadian Scientific & Christian Affiliation

A closely affiliated organization, the Canadian Scientific and Christian Affiliation, was formed in 1973 with a distinctively Canadian orientation. The CSCA and the ASA share publications (*Perspectives on Science and Christian Faith* and the upcoming news and views *God and Nature* magazine). The CSCA subscribes to the same statement of faith as the ASA, and has the same general structure; however, it has its own governing body with a separate annual meeting in Canada.

Canadian Scientific and Christian Affiliation, PO Box 63082, University Plaza, Dundas, ON L9H 4H0. Website: www.csca.ca.

How Do I Join the ASA?

Anyone interested in the objectives of the Affiliation may have a part in the ASA. Membership and subscription applications are available at www.asa3.org → HOME/ABOUT → WHO CAN JOIN?

Full membership is open to all persons with at least a bachelor's degree in science who can give assent to our statement of faith. Science is interpreted broadly to include anthropology, archeology, economics, engineering, history, mathematics, medicine, political science, psychology, and sociology as well as the generally recognized science disciplines. Philosophers and theologians who are interested in science are very welcome. Full members have voting privileges and can hold office.

Associate membership is available to interested nonscientists who can give assent to our statement of faith. Associates receive all member benefits and publications and take part in all the affairs of the ASA except voting and holding office.

Full-time students may join as **Student Members** (science majors) with voting privileges or as **Student Associates** (nonscience majors) with no voting privileges.

Spouses and **retirees** may qualify for a reduced rate. **Full-time overseas missionaries** are entitled to a complimentary membership.

An individual wishing to participate in the ASA without joining as a member or giving assent to our statement of faith may become a **Friend** of the ASA. Friends receive all member benefits and publications and take part in all the affairs of the ASA except voting and holding office.

Subscriptions to *Perspectives on Science & Christian Faith (PSCF),* are available at $50/year (individuals), $85/year (institutions) and $20/year (student premiers).

How Do I Find Published *PSCF* Articles?

Articles appearing in *Perspectives on Science and Christian Faith* are abstracted and indexed in the *Christian Periodical Index; Religion Index One: Periodicals; Religious & Theological Abstracts*, and *Guide to Social Science and Religion in Periodical Literature*. Book Reviews are indexed in *Index to Book Reviews in Religion*. Present and past issues of *PSCF* are available in microfilm form at a nominal cost. For information, write to NA Publishing, Inc. PO Box 998, Ann Arbor, MI 48106-0998 or go to www.napubco.com.

Contents of past issues of *PSCF* are available at www.asa3.org → PUBLICATIONS → PSCF.

American Scientific Affiliation
55 Market Street, Suite 202
PO Box 668
Ipswich, MA 01938-0668

Phone: (978) 356-5656
FAX: (978) 356-4375
E-mail: asa@asa3.org
Website: www.asa3.org

ECFA MEMBER
A higher standard. A higher purpose.

"Upholding the Universe by His Word of Power" *Hebrews 1:3*

Editorial

2013 Reviewers

Articles

Communication

Book Reviews

Letter

Volume 66, Number 1 **March 2014**