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In This Issue …

"The fear of the Lord is the beginning of Wisdom."

Psalm 111:10

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James C. Peterson

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Big, Indeed Epic, History

While this is not specifically a theme issue, all the articles in this issue address how to read aspects of what is sometimes called "Big History." In my last editorial, I noted that there are two trillion galaxies in our universe. Considering such and Big History, rather dramatically raises the question of why there is something, rather than nothing. It seems to me that every material thing has a cause. We see no popping into existence, no spontaneous generation. Consistent with that, it appears as well that the material universe had a beginning. We call it the Big Bang. We can measure its wave effects still propagating. We can see it unfolding as we look back further and further in time by catching light that has been traveling since that beginning. If the cause of the material universe were material, that cause would need a cause, and we would have an infinite regression (a problem in itself) that ignores entropy. It seems that there must have been a cause: one that was not material, that has always been, and that was incredibly powerful. The material universe cannot explain its own existence. Something else, immensely powerful, is out there.

It seems to me as well from looking at the material universe, that the something else is purposeful, smart, and generous. The material universe is expanding at precisely the rate of speed required for us to exist. If the expansion were a billionth faster, stars and planets would never coalesce. If the expansion were a billionth slower, gravity would pull everything together to a big and final crunch with no stars or planets. The material universe is expanding at precisely the right rate to make personal life possible. That looks purposeful, smart, and generous. Paul Davies, Arizona State University astrophysicist, in *Super Force: The Search for a Grand Unified Theory of Nature* (New York: Simon and Schuster, 1984), put it this way:

> The laws which enable the universe to come into being spontaneously, seem themselves to be the product of exceedingly ingenious design. If physics is the product of design, the universe must have a purpose, and the evidence of modern physics suggests strongly to me that the purpose includes us. (p. 243)

How generous for the source to choose to make a space for new beings who could live, and themselves choose how to shape their lives. A place where new conscious beings might come to know the creator, but would not have to. The most central reality is present, but intentionally and sufficiently hidden, such that knowledge of and relationship with that reality can be a free response to its invitation.

There is evidence and reason enough, without being overwhelming. One might survive for seventy, eighty years, without acknowledging any source or purpose to this surprising universe. Yet I marvel at the long list of constants in physics, in addition to expansion rate, remarkable for how essential and precise they are to support life. Walter L Bradley enumerates examples in "The Fine Tuning of the Universe," in this journal, vol. 70, no. 3 (2018): 147–60, https://www.asa3.org/ASA/PSCF/2018/PSCF9-18Bradley.pdf.

So if the physical universe we can observe indicates that there is something not-material which is powerful enough to create the material; that is purposeful, smart, and generous enough to make it happen in a way that supports the development of conscious life; it might be expected that such a creator would have an interest in the resulting conscious life.

Acknowledgment

If that were to happen in regard to Earth, where would be the best location to reach the sentient life on that planet? Maybe centrally, where Asia, Europe, and Africa meet, and therefore not favoring any one ethnic group or region. If we look more closely at that area, there was a people group that claimed that the creator was speaking to them and that the creator promised to come to Earth as a male child who would be himself the almighty God (Isa. 9:6), born specifically in an obscure little village called Bethlehem (Micah 5:2), a descendant of their King David (2 Sam. 7), yet be associated with a despised region called Galilee (Isa. 9:1–2).

There is one who more than fulfilled these markers. His life transformed his followers (N.T. Wright, *The Resurrection of the Son of God* [Minneapolis, MN: Fortress Press, 2003]). Acts 4:13 puts it this way (in my translation): "Seeing these uneducated, common people act and talk this way, they were astonished and could tell that these people had been with Jesus."

Not only individuals, but communities and whole societies were changed; not yet perfected, but set on a better course that we should not take for granted. Tom Holland traces some of these points of transformation in *Dominion: How the Christian Revolution Remade the World* (Basic Books, 2019). Now 2.5 billion people claim to follow Jesus of Nazareth, Jesus the Christ, as part of the world's largest, and still growing, global movement. In our current year, we find more Anglicans in church each Sunday morning in Nigeria, than in England. Brazil has 166 million Christians as the largest Catholic country in the world, alongside 43 million Brazilian Protestants. In the last one hundred years, South Korea has gone from about one percent Christian, to now actively 25% Christian …

This is Big, Indeed Epic, History.

James C. Peterson
Editor-in-Chief

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The Irreducible Novelty of Chemistry in Natural History

Benjamin J. McFarland

The central metaphor of nature as a watch has colored the debate about natural theology since Paley and Darwin. However, a chemical interpretation of natural history will differ because chemical systems do not work like watches. Here, a natural history of chemical constraints proposed by R. J. P. Williams is interpreted through Joseph Earley's two modes of "chemical becoming" with classical realism and the philosophy of emergence. This interpretation shifts attention from a system's irreducible complexity to its irreducible novelty, focusing on its novel existence and its transcendental truth, goodness, and beauty. A view of natural history in which irreducible novelty evolves through chemistry has several advantages: it accommodates continuous change (giving direction to a gradual mechanism of evolution) and irreversible change (providing an important yet limited role for chance rather than denying its existence or overemphasizing its power). A chemical perspective perceives the inherent "makeability" and manifest order of the universe.

Keywords: natural history, natural theology, science and faith, emergent evolution, biochemistry, antecedent order, chance

Questioning the Watchmaker

Darwin described his intellectual journey with a sort of conversion narrative. Once, Darwin was delighted by William Paley's argument that nature was complex like a watch, and therefore, nature required a maker as does a watch. But in his autobiography, Darwin wrote,

> The old argument of design in nature, as given by Paley, which formerly seemed to me so conclusive, fails, now that the law of natural selection has been discovered. We can no longer argue that, for instance, the beautiful hinge of a bivalve shell must have been made by an intelligent being, like the hinge of a door by man.[1]

Darwin found a mechanism of variation and natural selection that could make functional biological structures ranging from bivalve shells to complex eyes. Both Darwin and Paley assumed that the universe is like a watch and that God is fundamentally a watchmaker. They disagreed only on whether this God is blind.

Darwin and his followers have imported most of Paley's theological assumptions. According to Michael Hanby:

> Paley's conflation of nature and artifice "sets the agenda" for Darwinian biology, supplying the latter's defining problem, its view of the organism, the concept of creation which it seeks to overcome, and the "God" it refuses to believe in. … Darwin brings Paley's natural theology and his conflation of nature and art to their logical conclusions.[2]

This article was written in response to an invitation essay written for *PSCF* by Stephen Contakes, who has also guided the peer-review evaluation and development.

Benjamin J. McFarland *(PhD, University of Washington) teaches and researches immunoprotein biochemistry at Seattle Pacific University. He writes monthly about science and faith for the* Christian Scholar's Review Blog, *and Oxford University Press published his book,* A World from Dust: How the Periodic Table Shaped Life *(2016).*

Hanby offers an alternative to these nineteenth-century theological analogies of nature as a watch by looking to the classical realism of Augustine and Aquinas, focusing on being and essence rather than mechanism, asking "what is life?" rather than "how did life come to be?" Hanby writes,

> There can only be mechanism because there are first things, *beings*, which are irreducible to mechanism, and no mechanical description of, say, a bird in flight, ever suffices as a complete account of *how* a bird flies.[3]

The mechanism itself may be reduced to its parts and its history, but that does not completely account for the existence of that mechanism, which still displays an emergent, irreducible novelty. The mechanism of natural selection may, or may not, be sufficient to account for the many novelties of life, but when Paley, Darwin, and their followers ask only that question, they neglect others more fundamental: what life is, and what it means.

The theories of intelligent design and "irreducible complexity" argue that known evolutionary mechanisms are insufficient to account for the most complex biological structures, such as the flagella, or periods of evolutionary change, such as the Cambrian explosion.[4] These arguments tend to focus on the most complex phenomena, which inherently require complex mechanisms and detailed arguments, so that the dialogue becomes a sort of "numbers game" with dueling probabilities and parameters, an exercise in which the novelty and purpose of the change itself is decentered.[5]

We can reframe the dialogue by asking instead, "What is irreducible about these new things?" which can include their complexity, but also other aspects. To use Paley's metaphor, if we ask only how the watch was made, we neglect the question of what the watch is for in the first place, or what it is doing in a grassy field. If nature is more than an intricate watch, then God is more than a distant watchmaker.

Theologies from before the invention of the watch, communicating ancient and medieval views of God, can refresh our twenty-first-century understanding of creation. In many of these older views, God is not seen as a hands-on artisan who makes the world like a watch. According to theologian Katherine Sonderegger:

> The act of creation is in truth not like an artist who realizes her concept or plan in a painting, emerging in dazzling color from bare canvas and board. Though Christians are surely right to speak of Personal Agency in the doctrine of creation, we are warned against assimilating such Agency to the artistry and design of creatures. Scripture's silence on this analogy is eloquent … its preoccupation in the opening chapters of Genesis is goodness, moral reality, not material objects as such.[6]

In ancient and classical creation theology, novelty is a more fundamental category than complexity. In scripture, God's creativity is literally a "new creation" (2 Cor. 5:17; Gal. 6:15) or presented in conjunction with the idea of things beginning, when all was new (Mark 10:6; 13:19). Colossians 1:15–20 is a psalm of praise to the irreducible novelty of the incarnation and resurrection of Jesus, firstborn of creation. History culminates in God creating a new heaven and a new earth in continuity and discontinuity with the old (Isa. 65:17; Rev. 21:1). God is not creating all things complex, but has created things as *good* and is creating all things *new* (Rev. 21:5). When Genesis 1 repeatedly calls creation "good," the text is asking us many questions, not first and foremost "how did God make this?" but rather, "what does God mean when he calls all this 'good'?" As Jesus said, "No one is good but God" (Mark 10:18), so we look to God's unchanging nature to define goodness. Classical theologies discussed these matters in terms of transcendentals such as truth, beauty, and goodness, in which created things can participate.

At the end of an essay about the relationship of science to the theology of creation, Hanby defines "irreducible novelty" in terms of these transcendentals, not in terms of complexity:

> Creation, in other words, is the condition of possibility for anything being genuinely *new*, and this irreducible novelty is visible in, and indeed is, the irreducible goodness, beauty, and truth of every concrete act of existence. This power of making new, as Paul says in Romans, is already visible in and as the world, had we only the eyes to see and the ears to hear it, and yet since we cannot help but see and hear it, we are "without excuse."[7]

In this definition, irreducible novelty is a theological gift to be received with wonder, not a quantitative measure or gap in understanding. What is irreducible

is the unique way in which the created system participates in goodness, beauty, and truth.

The metaphor of nature as a watch has limited our discussion of creation to mere complexity and bracketed out its goodness and beauty. As a chemist who makes proteins (not watches), I nevertheless see in nature many chemicals bright and beautiful, which are irreducibly novel even if reducibly complex. In *A World from Dust: How the Periodic Table Shaped Life,* I described how chemicals in natural history have dissolved, mixed, melted, and precipitated throughout the narrative of evolution.[8] Here I give a theological interpretation to that story by identifying its moments of irreducible novelty, looking at creation not as a watch in a field of grass but as chemical structures and systems, on a planet in a field of stars.[9]

Chemical Perspectives on Emergence and Irreducible Novelty

In *A System of Logic,* one of the first texts defining emergence of novelty,[10] John Stuart Mill described emergent behavior as coming from chemistry, not watch-like mechanics. He explains that, in chemistry, two substances combine to make a third

> with properties entirely different … Unlike mechanics, chemistry is not a deductive but an *experimental science* … Once the new property has emerged, however, it presents itself as an entirely independent value, even though it has been discovered to be the complex result of the combination of simpler parts.[11]

Mill's new properties exhibit irreducible novelty despite their reducible complexity.

Later, the philosopher Chauncey Wright, a friend of both Darwin and Charles S. Peirce, "was able to transfer the idea of emergent novelty from the static conceptual framework of associationism to the much more dynamic Darwinian evolutionary thought."[12] Both Wright and Peirce were pragmatist philosophers who emphasized thinking about novel effects ("last things, fruits, consequences, facts" in William James's words) rather than the origins of those effects.

Wright discussed the biological emergence of the novel effects of flight and consciousness. Of these, the emergence of flight is more obviously related to chemical causation. The gradual variation and selection of limb structures resulting in a wing is like the variation and selection of biochemical structures within the wing. Once a wing evolves, the new flying creature can inhabit an expanded space, allowing greater chances for survival. Evolution of novel chemical structures and reactions likewise allows the organism to survive in more places and under more conditions.

The pragmatists' emphasis on future effects requires teleological, goal-driven "final causation" that is not obviously compatible with the undirected, "efficient causation" of Darwinian natural selection. Peirce addressed this conflict by proposing that "final causes are basically habits … not static 'entities,'"[13] and according to Menno Hulswit, they complement efficient causes "inasmuch as each act of causation has both an efficient and a teleological component."[14] Each act of causation incorporates "an aspect of irreducible novelty, which coincides with objective chance" and which is also irreversible. Emergence of new forms of self-organization, including new chemical structures, reactions, and processes in natural history, "may be seen as a teleological or quasi-teleological concept in the Peircean sense."[15]

Some prominent chemists agree: "Irreversible processes are the source of order"[16] in nature, according to Ilya Prigogine, who won the 1977 Nobel Prize in Chemistry, writing with Isabelle Stengers. They give examples such as the physical-chemical "transition from laminar flow to turbulence [which] is a process of self-organization,"[17] clock reactions, and a biochemical "catalytic loop."[18] Order emerges from chance, as when "a random fluctuation in the external flux, often termed 'noise,' far from being a nuisance, produces new types of behavior … [including] more complex reaction schemes."[19] Prigogine and Stengers approvingly cite Peirce's statement that "Force is in the long run dissipative; chance is in the long run concentrative"[20] as a source of novel chemical forms of self-organization.

Self-organization is also a major theme of Jacob Klapwijk's philosophical definition of emergent evolution across "five ontological or explanatory levels: the physical, the chemical, the biotic, the mental, and the social level."[21] Klapwijk relates the earlier of these levels to the later:

> Then we may discover in the baffling world of minerals and microbes, of plants and animals,

> a pathway of meaning: a development that may be considered meaningful because it is not devoid of ends and purposes and appears to be a precursor to the human search for meaning."[22]

The chemist John Satherley applies Klapwijk's definition of emergent evolution especially at the first two of the five levels of natural history. Satherley describes the inner structural layers of the earth, the unusual boiling point of water, and the self-organizing lipid bilayers as

> *vital* ingredients that make this planet a *habitat* for living creatures … The evolution of the inanimate things of the universe must be considered alongside of, and integrally connected with, any type of biological evolutionary hypothesis.[23]

If something like Klapwijk's "pathway of meaning" can be discovered in geochemical and biochemical structures and processes, this path implies a common goal and therefore a unity.[24] This chemical perspective on natural history breaks down dualisms and unites concepts. Peirce insisted on continuity of all things over dualism, so that "all phenomena are of one character … present[ing] that mixture of freedom and constraint, which allows them to be, nay, makes them to be teleological, or purposive."[25] Rather than extending purposelessness "upward" from the physical and chemical levels to the biotic, mental, and social levels, we can interpret the world in such a way that we perceive purposefulness "downward" when we find the natural laws, habits, and tendencies toward particular ends at the so-called "lower" levels. Our unity with nature can elevate its purpose, rather than reducing our purpose.

We can also extend our search for transcendentals downwards, asking the question "how does this new physical, chemical, or biological thing manifest and participate in the true, beautiful, and good?" rather than merely "how could this complexity have come about?"[26] A focus on irreducible novelty unites efficient, formal, and final cause; chance and constraint; chemistry, physics, and biology; and even natural being and becoming.[27]

There is no necessary conflict between appreciating something's irreducible novelty and reducing its complexity into understandable steps of development or evolution. A created thing can be caused by other, secondary, agents, but all of them remain created by God as the primary Agent. Understanding the components or causes of a novel object or system, or the mechanism that created novelty, in no way diminishes its irreducible novelty. However it came about, the genuinely new thing still makes the world better, truer, and more beautiful, even after its path into the world is traced. The human task is to experience, understand, and describe it, and the chemist's task is to do all this at the elemental and molecular level.

R. J. P. Williams and the Recognition of Chemotypes

Both Paley and Darwin began with a moment of recognition at the level of the organism, with Darwin especially focusing his thought on the evolution of species, which are groups of organisms. Eventually this led to a problem: how exactly should a species be defined? For Thomas Pfau, this "species problem" comes from assumptions made prior to scientific investigation, involving how to perceive the "form" of the species:

> Darwin had struggled to articulate what exactly he meant by "species," since at every step of his far-flung empirical research the reality of species appeared to have been already presupposed. … [S]cientific cognition [remains] haunted by the ontological commitments associated above all with classical Aristotelian-Thomist realism and its origins in Plato's doctrine of ideas.[28]

Recognizing a species or "kind" of animal is not as simple as recognizing a watch in a field, yet it is essential to understanding how species transmute. Irreducible novelty, with its emphasis on the Platonic transcendentals of the true, beautiful, and good, grounds the scientific act of classification by supposing that the mind's ability to recognize the form of the species and its fitness to its environment (which is part of the goodness of creation) reflects truth, not accidents.[29]

Hanby argues that recognition of form played an implicit but unacknowledged role in Richard Dawkins's characterization of genes as "survival machines" driving evolution. When Dawkins states that a "DNA molecule could theoretically live on in the *form* of copies of itself for a hundred million years," he "performs the covert work of granting to DNA an 'essence,' denied to organisms themselves, transcending its particular material instances."[30] By

vitalizing the "form" of replicating DNA, Dawkins endorses a kind of formal causation, which Peirce says also imports final causation and goal-directed behavior.

A focus on classical realism and transcendentals, rather than on complexity, accounts for Darwin's and Dawkins's moments of recognition. These ancient and medieval traditions say we can recognize species and genes because

> If we reflect on our grasp of any being, we perceive *that* we grasp it, and so each being is true (*verum*), intelligible, capable of being cognitively grasped. We also grasp that it is good (*bonum*), valuable or worthwhile, capable of being desired or loved, at least at an end for acts of knowing. At this point, we reach the experience of divine beauty.[31]

Robert Joseph Paton Williams was a renowned chemist who classified living organisms by chemistry, rather than by biological homology.[32] His "chemotypes" are groups of species based on chemical processes of their cells, which he defined as "controlled energized chemistry essentially in physically confined and organized flow systems."[33]

In *The Chemistry of Evolution,* Williams and João José Rodiles Fraústo da Silva state,

> The complexity of flow systems does not allow us to treat each and every observed case, species, individually, but we can describe in general terms the classes of species, "chemotypes," and their evolution which, as we shall explain, are systematic, causative, and not random in their relationships.[34]

In particular, three "thermodynamic characteristics of chemotypes … have evolved systematically and inevitably following the equally inevitable changes of the environment."[35] These chemical definitions give Williams a different view of evolution:

> Evolution may be blind in its diversification of similar organisms (species) but it expands within a directed time cone of physical and chemical opportunity in an ecosystem, increasing and improving the retention and use of elements and energy.[36]

The adverbs "systematically" and "inevitably" are not often found in descriptions of Darwinian evolution but come directly from Williams's chemical perspective and classification of species into chemotypes.

Williams himself speaks without reference to transcendence, but others interpret his work in this light. Notably, Alister McGrath cites Williams's work as a narrative that "resonates with the core themes of the Christian vision of reality"[37] in *The Open Secret: A New Vision for Natural Theology,* of which part of the renewal is "discerning the transcendent in nature"[38] in terms of "abduction to the best explanation" (McGrath quoting Peirce's common phrase).[39] McGrath could cite Williams as an example of "natural theology's capacity to make sense of things"[40] because Williams did not argue for irreducible complexity, but rather gave examples of a good and even beautiful chemistry sequence leading to complex life, which McGrath could interpret in the transcendental framework of irreducible novelty.

At a crucial point in *The Chemistry of Evolution,* Williams and Fraústo da Silva followed a Peircean path of abductive reasoning by juxtaposing the shapes (forms) of two graphs and linking levels together. In this book, figure 4.3 (p. 135) shows the concentrations of the free metallome and the caption states, "Note how closely the sequence follows the inverse of the Irving-Williams binding constant sequence," which is shown in figure 2.8 (p. 67). Formal recognition of the similarities between the two graphs led the authors to state, "Note how we have linked biochemical and geochemical features together."[41] In addition, they made accurate predictions: the chemical sequence predicted by Williams and Fraústo da Silva was later supported by genetic analysis.[42] This led the authors to propose that both biological and geological evolution followed a chemical sequence "systematically and inevitably"; their proposal is a statement of final causation and goal-directed behavior. More than efficient cause is at play here!

Joseph Earley's Two Modes of Chemical Becoming

What exactly is novelty to a chemist? Joseph E. Earley, a philosopher of chemistry, described two distinct ways in which new things come to be in chemistry, in an essay titled "Modes of Chemical Becoming."[43] Earley's examples of the generation of new chemical structures and systems can be considered "irreducible" in their goodness, truth, and beauty, and therefore in their novelty.

First Earley described how scientists determined the structure of a molecule of argon dichloride. This molecule does not form naturally, but small quantities can be made fleetingly in a laboratory, with a lifetime around 10^{-12} s. Scientists observed the spectrum predicted by theory for a molecule of argon dichloride in a particular shape. Earley writes, "Not only can we say that a new chemical entity has come into existence, but we can also tell what the shape of that entity is!"[44]

Earley's exclamation point shows his excitement at this new thing. The argon and chlorine existed before, but the arrangement of the components is novel. (This is similar to Mill's associative conception of novelty.) This molecule has a particular shape and lifetime. If it relates to other molecules in useful ways, we can say it has gained a particular function. Even if it does not, it still truly exists. As for whether it is beautiful and good, Earley thinks it is. Irreducible novelty can be thought of as the exclamation point we put on our observations of the surprising new things we observe.[45]

Earley's second example is that of a new, dynamic chemical system. In a continuously stirred tank reactor, chemicals are put in and out at different rates, often producing chaotic readings on the sensors that monitor the reactions. Sometimes the rates of input and output can be changed carefully to simplify the chaotic readings into a simple oscillation. (This is similar to Wright's evolutionary conception of novelty.) This gradual simplification produces a well-defined and stable system that cannot be ascribed to any single component. Out of chaos, from a location that cannot be precisely predicted in advance, comes predictable recurrence, distributed throughout the system. Earley wrote,

> The networks of chemical changes that give rise to this kind of organization can be regarded as composed of several parts—several sets of processes, each of which partially controls the others. When these diverse parts of a reaction-network achieve a kind of balance, harmonious oscillation results, and the system *as a whole* serves as a center of agency.[46]

In Klapwijk's terms, an intelligible, dynamic form would self-organize and affect other levels of existence, including the mental perception of the system's observers.[47]

These novel coherent centers of agency have complexity that can be reduced to components and understood using the rules and laws of chemistry. However, the precise atomic location and moment of self-organization is driven by chance, so it is irreducible in Prigogine's and Peirce's terminology. When the molecule or system is broken or decomposed, so is its present elegance, harmony, and agency, and its irreducible novelty is lost.

The Antecedent Order of Natural History

Earley's definitions of "chemical becoming" can be expanded to chemistry in other contexts. We are people in the act of becoming, alive in a universe that is itself in the act of becoming. When new things occur in nature as part of this becoming, brought about by atoms reacting, they can be understood through the discipline of chemistry. The arc of natural history can be told as a story of chemical becoming, composed of a sequence of chemical reactions from the Big Bang to the present day.

In another essay, Earley argued that chemistry should itself be taught with this narrative arc, which he called (somewhat grandly) the "Evolutionary Epic":

> Logically, perhaps one should start with the vacuum—an excitable medium. New classes of entities—quarks, atoms, molecules, stars, organisms, societies—could then be introduced as arising in evolutionary (historical, in Collingwood's sense) transitions from prior entities.[48]

All true elements of the triumvirate of irreducible novelty are found in Earley's argument for this "new philosophical basis" of teaching chemistry: certainly the story contains *truth*, and he also states that it is "*good* preparation for professional work" and motivates students with the "*beauties* of nature."[49]

But the classical realist tradition would add that Earley's scientific story, however epic, is insufficient in itself, because it is founded on a pre-existent order, or *Logos*. Hanby writes:

> Nature is more than simply whatever happens and is irreducible to a dynamic historical process, however "creative." It will have to apprehend and articulate an "all-at-once" unity and completeness in things that precedes their

> temporal development and the realization of historical possibilities and thus an antecedent order, that is true and good prior to our activity upon it, a givenness that precedes our activity as its condition of possibility. All this, in turn, will require the rediscovery of a truth that is irreducible to function, that is more than mere possibility, a truth that is not of our own making though we may be its midwife.[50]

This "antecedent order" is summed up for chemists by the periodic table of the elements, which represents the limits and laws of our discipline. Universal physical laws led to a universal periodic table of relationships among the elements that hold true for the stars, for the earth's core, for evolution, for natural history, and for our human flesh.

Hanby suggests that scientists should assess the beauty of nature as a gift to be appreciated, not a puzzle to solve. He wrote, "Were biologists to approach their subjects as one approaches a painting, it would no doubt transform the very meaning of science, restoring it to *theoria* in the traditional sense."[51] Chemists can approach natural subjects as one approaches a painting as well.

The beauty of nature revealed by chemistry includes the order of the periodic table's rows and columns. All matter on this planet has been ordered into fewer than one hundred natural elements at the atomic level, themselves ordered by the chemical patterns captured by the periodic table of the elements. As those atoms reacted over billions of years, more-reactive chemicals reacted before less-reactive chemicals, and more-stable compounds persisted longer than less-stable compounds. Chemistry allows us to understand why natural geochemical or biochemical events happened in a certain order, and it can place those events in the context of the central symbol of chemistry: the periodic table.[52]

Irreducible Novelty in *A World from Dust*

The editor of a group of essays responding to Klapwijk's *Purpose in the Living World?* wrote, "Why should the task of critically immersing oneself in evolutionary thought and thinking it through, step by step, not be received as a divinely mandated creaturely task with its own integrity *coram Deo*?"[53] Under this same mandate, we can think through Williams's view of the chemical constraints of natural history, step by step, in terms of Earley's two modes of becoming, looking for the moments of irreducible novelty.[54]

In 2016, I wrote an overview of natural history based on Williams's chemical sequence, titled *A World from Dust: How the Periodic Table Shaped Life*.[55] A theology of creation is implicit in this book, as it is in every natural history, although I translated theological into philosophical terms for a general audience, as is customary for popular science books. Here I attempt to bring new things out from the old, by revealing the original theology that motivated the writing of the book and delineating the events where something irreducibly novel came about, step by step. The major events in this chemical narrative of natural history are acts of order, goodness, and beauty, which made genuinely new systems or structures, each demonstrating irreducible novelty even in the presence of reducible complexity.

1. Stellar Nucleogenesis

In the beginning, the periodic table was (mostly) void.[56] The Big Bang, the premier event of irreducible novelty, was an event of physics rather than chemistry. The initial expansion of the universe produced hydrogen and helium, with only traces of heavier elements. The force of gravity gathered hydrogen and helium into stars so massive that atoms in the center were crushed together. This overcame atomic repulsion so that nuclei joined and fused into new elements. This process drove forward to bigger nuclei with larger atomic numbers, which are more stable (with iron the most stable). Even today, more than ten billion years later, the lighter elements predominate in the universe, and the heavier an element is, in general, the harder it is to find.[57] The new, heavier elements provided new structures and reactions, like carbon's four bonds, oxygen's powerful electronegativity, and metals' unusually shaped electronic orbitals, all of which can serve as recognizable chemical forms and centers of agency. The existence of each new element allowed new chemical movements of electrons and new structural forms of molecules, so that each is irreducibly novel. These new atomic structures are like Earley's example of the new structure of argon dichloride, applied at the atomic, rather than at the molecular, level.

2. From Atoms to Molecules and Liquids

As heavier elements formed, they were spread across the universe by supernovae; then some were collected again into objects smaller and more dense than stars: planets.[58] This was the birth of geology. One consequence of electronic energy levels established by the periodic table's trends was that metals lost electrons while non-metals gained them. Bonds formed, allowing the binary combination of metals with abundant oxygen, and then with less-abundant sulfur; then more complex chemical combinations followed. Solid rocks formed from these, rocks that included much of the oxygen available due to its potential to form strong bonds. Meanwhile, oxygen and hydrogen formed water that, with its combination of small atoms and strong hydrogen bonds, formed a liquid phase.[59] Most places in the universe were either too cold or too hot for large liquid oceans to form, but the earth was located in the right place on the phase diagram of pressure versus temperature, close to water's triple point.[60] The liquid phase and water cycle provided by oceans is essential to chemistry because it allows molecules to move while in constant contact, facilitating the formation of complex assemblies more easily than could occur in solid or gas (or plasma) phases. It is no accident that the continuously stirred tank reactor in Earley's second example is in the liquid phase. A liquid phase allowed irreducibly novel systems, similar to Earley's reactor, to form in nature.

3. Mineral Evolution

At some point, life began to multiply and evolve. But the first kind of "evolution" facilitated by the liquid phases on and inside young Earth may have been mineral. After planetary accretion 4.5 billion years ago, mere hundreds of different minerals existed on the earth—today there are more than four thousand.[61] Robert Hazen and colleagues list ten stages of mineral evolution, including igneous rock formation, granite formation, and plate tectonics driven by the liquid phase of the earth's mantle allowing minerals to mix, flow, and (in their term) evolve. This is evolution in a chemical, rather than a biological, sense of the word. The authors wrote,

> Mineral evolution is not analogous to biological evolution through Darwinian natural selection … Minimization of Gibbs free energy simply leads to nucleation and growth of quartz, but not olivine. The driving force for mineral evolution, rather, is the evolving diversity of prebiotic and biologically mediated temperature-pressure-composition environments.[62]

The generation of mineral diversity is another example of irreducible novelty. Most of these new minerals contain novel crystalline structures that may be unique to our planet, each with new chemical properties, perhaps even serving as templates for the origin of life.[63] Each new mineral serves as an example of irreducible novelty, extending to the new colors of gems hidden in the depths to be revealed to human miners billions of years later.

4. From Solubility to Three Biochemical Roles

Chemical cycles of dissolution and precipitation connected the crust to the ocean. Both dissolving and precipitating are chemical actions described by chemical equilibrium constants and kinetic rate constants, themselves set by the strength of bonds and stabilities of chemicals in the solid phase versus dissolved in water, themselves rooted in the trends of the periodic table. These chemical solubilities affect biology and determine the biochemical roles each chemical can adopt:[64]

1. Concentrations below nanomolar (gold, tin, and lead) = not abundant enough to be used;
2. Concentrations below micromolar (manganese, iron, and zinc) = trace amounts for biochemical catalysis;
3. Concentrations below millimolar (carbon, nitrogen, and oxygen) = build novel covalent structures;[65] and
4. Concentrations above millimolar (sodium, potassium, and chloride ions) = adjust osmotic and electrochemical ionic balance.

In each of these categories, life selected some elements with the proper solubility but, for chemical reasons, not others: for example, the lighter element may have been selected because it was more abundant. Williams wrote extensively about these biogeochemical rules and selections, making predictions of the chemical sequence over time from classifications such as these four chemical categories.[66] Williams predicted that redox-sensitive ions would change categories according to their redox potentials as the earth oxidized over billions of years,

and later we observed these trends in new genomic analyses around the turn of the century.[67] Each of the three active biochemical roles (catalysis/metabolism, structure, and ionic balance) can be considered an instance of irreducible novelty, in which each element fulfills a new role for life in a particular way specific to that element's chemistry.

The novel structures made by life from carbon, nitrogen, oxygen, etc., are similar to Earley's novel argon dichloride structure, while the novel dynamic processes of dynamic catalysis, metabolism, and ionic balance are similar to Earley's dynamic flow reactor example. The dynamic stability of the flow reactor is similar to biological homeostasis. Both the novel structures and the novel systems work together to produce the living organism, or they are produced by the living organism in its process of living. Each new chemotype is an example of irreducible novelty.[68]

5. Photosynthesis

Another category of novelty came about when life harnessed light for making and maintaining chemical structures and systems. Like mineral evolution, biological evolution can also make colored molecules that interact with the visible wavelengths of light from the sun, absorbing solar energy from far beyond the earth. This energy would often dissipate, heating the environment, but over time, life directed some of that energy productively, moving electrons to form new bonds in photosynthesis. At first, sunlight helped move less-stable, more-mobile electrons from iron ions and hydrogen sulfide, but a combination of manganese and calcium in a rock-like crystalline structure eventually cracked the toughest molecule open, prying electrons off stable, but abundant, water molecules.[69] Thus sunlight was made into new bonds among carbon atoms, building up sugars that the living microbe stored until their energy was needed. The chemical reaction of water-oxidizing photosynthesis produced a byproduct that at first was more dangerous than useful: diatomic O_2, which is oxygen gas. But as photosynthetic organisms multiplied, this gas would cover the world and lead to new things never seen before on this planet. The sugars, as fuel for rapidly reproducing life, were the firstfruits of the irreducible novelty of photosynthesis, but in a billion years or so, the oxygen that was rejected became the cornerstone of animal life.

6. The First Great Oxidation Event and the Ordered Sequence of Prehistorical Metals

The chemical composition of the atmosphere changed as life carried out photosynthesis and produced oxygen. Oxygen in the atmospheric gas phase increased and came into contact with the liquid ocean and solid land, reacting with the entire surface of the planet. A bit more than two billion years ago, this atmospheric change created new banded-iron formations in oceans across the globe as iron (II) oxidized to iron (III) and immediately precipitated due to iron (III)'s low solubility.[70] This new solid material was just the most obvious consequence of the shifting of the planetary redox potential toward increased oxidation. A more oxidized atmosphere shifts redox-sensitive metals to a higher oxidation state, making some metal ions more soluble and some less, and therefore shifting the metals that could fulfill the biochemical roles of metabolism and catalysis. Binding sites for metals such as nickel and cobalt were removed from genomes, while those for metals such as molybdenum and copper appeared more.[71] Metabolisms shifted from using reduced molecules such as hydrogen sulfide and ammonia to sulfate and nitrate. Combined, these trends mean that biochemistry itself developed new reactions, new structures, and new biological species (or, better yet, Williams's new "chemotypes"), each an example of irreducible novelty that can be traced back to the chemical properties of oxygen.

7. The Second Great Oxidation Event and the Cambrian Explosion

The most important chemical novelty happened later, when enough oxygen accumulated in the atmosphere that it could be reliably used as a reactant rather than a product for biochemical re-actions.[72] Oxygen levels rose as geological processes such as glaciation eroded the planet's surface, leaving behind a global geological gap called the "Great Unconformity." Chemically, the eroded rocks dissolved in the oceans, increasing calcium, molybdenum, and phosphate levels, all of which are important ingredients for life.[73] In fact, calcium and phosphorus are two of the three dual-role elements (in terms of the four roles listed in section 4),[74] which can support multiple kinds of novel reactions at once.

Then, around 600 million years ago, new life forms appeared relatively suddenly in the fossil record, in

an event called the "Cambrian explosion." The dramatic numbers and forms of these Cambrian fossils have sparked debate about whether this event is irreducibly complex.[75] Yet the "Great Unconformity" shows that geology was changing dramatically before the Cambrian explosion, which would have provided crucial chemicals used by life. In addition, the rate of speciation is estimated to be about 5–10 times faster than normal—a significant increase that is still continuous with typical, if accelerated, mechanisms of evolutionary chance.[76] If chemistry did cause the Cambrian explosion, irreducible novelty is supported and enhanced for those who find a beauty in chemistry and in the connections it can make across disciplines. If chemistry's role was less important, then the irreducible novelty would be attributed to the other source.

8. The Ordered Sequence of Historical Metals

The order provided by chemistry extended to human history, because the sequence in which metals could be mined from the earth and used by civilizations was ordered by the chemical parameter of redox potential. Gold has a high, positive redox potential, meaning that it accepts electrons readily and can be easily reduced to a neutral state, so it is commonly found in the neutral, metallic state in the earth. Silver and copper also have high positive redox potentials, meaning they could be mined and used for coinage by early humans. The other metals known to the ancients (mercury, lead, and tin) likewise have positive or near-neutral redox potentials, but nickel, cobalt, chromium, zinc, and aluminum have more negative potentials, meaning they bind oxygen and other elements more tightly (i.e., are oxidized) so are not found naturally in the metallic state.[77] For these metals, civilizations must discover more powerful chemical methods such as electrochemistry to reduce the metals to a neutral state. We spend huge amounts of energy to do this to make aluminum's irreducible novelty.

Once the irreducible novelty of chromium in the form of chromate was unlocked by chemistry, it was combined with lead in a laboratory to make a bright yellow, insoluble pigment named chrome yellow. The beautiful brightness of chrome yellow is an irreducibly novel color. It was a favorite of nineteenth-century artists such as Vincent van Gogh, and it allowed him to create his paintings of sunflowers, which are themselves artistic examples of irreducible novelty. Even if we can analyze Van Gogh's chrome yellow and determine which laboratory it came from and exactly how it was made, it remains a unique and beautiful part of creation, no less irreducibly novel for our understanding of its mechanism of origin.[78] In fact, our participation in its mechanism of origin and increased understanding of it may allow us to appreciate its beauty and novelty that much more.

Implications for Meaning, "Makeability," and Chance

The visual motif of *A World from Dust* is an arrow. Arrows are predominant in most of the figures referenced in this article, and time or redox potential (which increased with time) is commonly on the x-axis of graphs. In these figures, chemistry ordered the arrows, but the arrows point beyond chemistry.

Klapwijk wrote, "The deepest mystery of evolution is not the emergence of new realities; it is time."[79] A watch tells time, but its mechanism is solid and cyclical: a watch never grows or evolves. A chemical system that unfolds over time, and a geobiochemical system that evolves, is integrated more deeply with time. The irreversible changes of increasing entropy cannot be turned back, as Prigogine noted, so that the physical world experiences directional change, like the mental world of experience rather than the cyclical, mechanical change of a watch.

The question is whether these arrows of becoming, both within and without, are truly aligned with each other, and whether together they point toward something specific, which would be some final cause such as Peirce posited. C. Stephen Evans makes a case that sequences of becoming, which can include Williams's chemical sequence, are signs pointing to God's activity as Creator: "God has instituted the signs so as to make it possible for people to become aware of his reality. And there is a 'hard-wired' natural tendency to 'read' the sign in this way, to see it as pointing to God."[80] Yet these signs can always be discounted or denied. Irreducible novelty is not irresistible.

If there is more than efficient cause, then thinking about formal and final causes reveals the truth about the world. As David Bentley Hart wrote, "[Goal-directed behavior] is an intrinsic rational determination in a complex system, not … intrinsically imposed by some detached designing

intelligence."[81] If so, truth is integral to the system and these arrows point to

> an ultimate reality where existence and perfect intelligibility are convertible with one another because both subsist in a single unrestricted act of spiritual intelligence. This, in theological terms, is one of the paths of the mind's journey into God.[82]

Hart, Pfau, Peirce, McGrath, Hanby, and others, coming from their own philosophical perspectives, align and point to the conclusion that the mind, through the sciences, reveals truth because God made it to do so. The scientific goal-directed behavior and emergence described by Williams, Earley, and Prigogine seem to me to point in the same direction. These irreducible novelties are truly good and beautiful.

If chemistry brought these about in nature, then we can repeat and isolate those chemical reactions in the laboratory for our own purposes, using them to make new things for our own purposes: knowing through making.[83] When our artificial laboratories and workshops first copied, then expanded, the chemical structures and systems that could be made, we produced irreducible novelty. The novel chrome yellow pigment led to Van Gogh's novel *Sunflowers*. Even an artist as great as Van Gogh depended on others and on nature itself, so that his creative achievement was an act of co-creation within the larger gift of Creation.

Learning about these overlapping and integrated processes demonstrates the "makeability" of knowledge itself. The act of retracing the events, chemical and otherwise, that led to the creation of *Sunflowers* is itself an act of comprehending irreducible novelty. Unlike irreducible complexity, one can trace this path without reducing the novelty of Van Gogh's creation.

A chemist's work is as important as that of a watchmaker, and both types of makers operate underneath the transcendent act of original and ongoing creation that is from God alone. Klapwijk wrote, "To create out of nothing is one thing. To cause something to originate out of existing material is another."[84] But these acts of subcreation, within their limits, can clearly be good, beautiful, and truly novel. Hanby wrote, "The advent of meaning in the world and the realization of these various possibilities are surely *ex nihilo* events; they mark the appearance of genuine novelties, irreducible to their antecedents."[85]

Theologian John Milbank writes that this "makeability" of the universe is so important that it can be elevated to the status of a new transcendental![86] One need not go that far to emphasize it as important, and to correlate it with acts within the discipline of chemistry could also align with Milbank's transcendental "makeability." Given chemistry's emphasis on synthesizing and making new structures, "makeability" seems particularly apt.

A chemist who makes a new tool for separating phases or molecules is like Nicholas of Cusa's toolmaking spoonmaker, whom Milbank cites in his writing on the theological significance of making and therefore of "makeability." Nicholas of Cusa wrote that the spoon is formed and named by the spoonmaker, and yet is a reflection of divine creativity, because "all human arts are 'images' of the Infinite Divine Art."[87] But the spoonmaker insists he is no mere mimic: "So my artistry involves the perfecting, rather than the imitating, of created visible forms, and in this respect it is more similar to the Infinite Art."[88]

According to Milbank, Nicholas "regards 'makeability' as the criterion for theoretical understanding, thereby reversing, as we also saw, the inherited assumption that the only criterion for the possibility of making something was previously to have understood it with theoretical adequacy."[89] This combinatorial, empirical approach is common in chemistry, and is also an effective way to teach, as when students in a multi-institutional effort mix chemicals, each student trying a different combination, to test for catalytic efficiency in the "Solar Army" effort.[90] These chemists do not know how effective their combination of chemicals will be until they run the experiment; they know by making.

In the book *Making Good,* Trevor Hart seeks "to reckon with the nature of God's creative action vis-à-vis the world … in his capacity as 'Maker of the heavens and earth.'"[91] Hart describes "God's determination 'to create creators'"[92] using the analogy of the artist as creator, showing that artistry at both the divine and human levels leads to "the establishment of a world in which God and the creature dwell together 'at one' in peace and mutual enjoyment."[93] In Hart's account, creative acts in the past reveal that God is near: "Faith in God as Creator also discerns God's dynamic presence in history's midst, 'opening

it up for the possible and the new in unexpected and unforeseeable ways.'"[94]

As every chemist knows, making new molecules or systems is difficult, and experiments are not always (or often) successful.[95] Chance may favor the prepared mind, but it is always at work in the lab. Any view of nature that emphasizes "makeability" must also accommodate a significant role for chance events. The chemical perspective has been shown to do this, in Prigogine's and Peirce's emphasis on irreversible events (which are driven by chance) being a source of irreducible novelty. In this, they align with medieval thinkers like Boethius and Dante, and recent thinkers published in this journal,[96] who also found a place for chance or fortune in their philosophies. This is in contrast to proponents of irreducible complexity, who insist that nature happened "Not by Chance."[97]

Williams, speaking from the perspective of chemistry, incorporates chance mutations as causative agents in his chemical sequence to explain how destructive chemicals can produce a sequence of responses from an organism: first protective, then opportunistic:

> The suggested principle to explain "directed" evolution is then that mutation is not random over the whole genome but that its intensity is related to the harmful effect of a new environmental energy source or any new damaging substance. Several such substances were released in turn in time due to the oxygen increase in the atmosphere and so new chemotypes of organisms evolved in a sequence as new groups of genotypes were better able to handle the damaging environment.[98]

Klapwijk also finds a place for chance in his view of emergent evolution:

> Random events have unchained orderings that are anything but random. Contingency catalyzes functionality and purpose; it has elicited, again and again, higher and more complex levels of meaning. Thus believing people have good reason to say that God called the physical nature into being and that He, at the same time, incorporated all higher levels of ordering into His creation as potentials from the beginning. Thus they are also justified in saying that humans are, at the same time, a product of evolution and created according to God's image.[99]

If irreducible novelty has a place for meaning, for making, and for chance, it also has a place for us. Klapwijk remarks on the way nature seems to have anticipated life:

> Can we say: Evolution takes advantage of emergence? No matter how incomprehensible this may be, it appears at times—I express myself carefully—that the process of becoming on Earth, despite its capricious and unpredictable course, did indeed anticipate the biological forms that were forth-coming.[100]

The Periodic Table of the Elements was an antecedent, rational structure imprinted in the laws of nature at the beginning of time, and it provided every *thing* life needed (with emphasis on the word "thing"). It established chemical rules and trends that unfolded through an interplay of necessity and chance. Most of these unfolding events were continuous with what went before and can be understood by analogy to things we can make ourselves, but we are far from understanding it all.

All events do not occur by clockwork necessity, but neither do all occur by unformed and unguided chance. I understand the events creating chemotypes as emphasizing predictable necessity, while, on the other hand, those creating species as emphasizing unpredictable chance. However we understand this interplay, we can copy these events and make new things with this confidence: God made us, from the world, to understand and participate in the world through our disciplinary foci, including through chemistry.

Notes

[1]Quoted in George Johnson, "Raw Data: A Creationist's Influence on Darwin," *New York Times*, May 23, 2014, https://www.nytimes.com/2014/05/23/science/a-creationists-influence-on-darwin.html.

[2]Michael Hanby, *No God, No Science: Theology, Cosmology, Biology* (Hoboken, NJ: Wiley-Blackwell, 2013), 188.

[3]Ibid., 204.

[4]My specific responses to intelligent design arguments can be found in Benjamin J. McFarland, "Mixed Metaphors: Intelligent Design and Michael Polanyi in *From Darwin to Eden*," *Perspectives on Science and Christian Faith* 73, no. 4 (2021): 228–32, https://www.asa3.org/ASA/PSCF/2021/PSCF12-21McFarland.pdf.

[5]An example of this is the dialogue between Michael Behe and Kenneth R. Miller regarding the blood clotting cascade and the bacterial flagellum. Both authors wrote chapters in *Debating Design: From Darwin to DNA*, ed. William A. Dembski and Michael Ruse (Cambridge, UK: Cambridge University Press, 2004).

Michael Hanby wrote that the questions of intelligent design when debated do not resolve because they become focused on minutiae: "Accounting for novelty, then, becomes, quite literally, a matter of accounting, not of explaining what makes a thing or its states genuinely and irreducibly *new*" (Hanby, *No God, No Science,* 221).

Irreducible novelty represents a response to the incomprehensible diversity of creation that is more than arguments about accounting and probabilities.

[6]Katherine Sonderegger, *Systematic Theology: The Doctrine of God, Volume 1* (Minneapolis, MN: Fortress Press, 2015), 369. Exceptions may include times when God is described as a potter, but even then, the clay being molded tends to be metaphorical rather than material, resulting in the creation of something spiritual or social, rather than a natural object in the universe.

[7]Michael Hanby, "Saving the Appearances: Creation's Gift to the Sciences," *Pro Ecclesia* 22, no. 1 (2013): 29–54, https://doi.org/10.1177/106385121302200102.

[8]Benjamin J. McFarland, *A World from Dust: How the Periodic Table Shaped Life* (Oxford, UK: Oxford University Press, 2016).

[9]Asking "how did God act through chemistry?" may be no less limited of a perspective than asking "how did God act like a watchmaker?" Regardless, it is a novel perspective that God might accommodate and illuminate like the others.

[10]Elly Vintiadis, "Emergence," in *Internet Encyclopedia of Philosophy* (2012), https://iep.utm.edu/emergence/.

[11]Andrea Parravicini, "Pragmatism and Emergentism. In Chauncey Wright's Evolutionary Philosophy," *European Journal of Pragmatism and American Philosophy* 11, no. XI-2 (2019), https://doi.org/10.4000/ejpap.1623.

[12]Ibid.

[13]Charles S. Peirce, quoted in Menno Hulswit, "Teleology," in *The Commens Encyclopedia: The Digital Encyclopedia of Peirce Studies. New Edition*, ed. Mats Bergman and João Queiroz (2014): 120320-1519a, http://www.commens.org/encyclopedia/article/hulswit-menno-teleology.

[14]Ibid.

[15]Ibid.

[16]Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue with Nature* (New York: Bantam Books, 1984), xxi.

[17]Ibid., 141–42.

[18]Ibid., 145.

[19]Ibid., 166.

[20]Ibid., 302.

[21]Jacob Klapwijk, *Purpose in the Living World? Creation and Emergent Evolution* (Cambridge, UK: Cambridge University Press, 2008), 99. For example, "Idionomy and self-organization thus understood are two sides of the same coin. They are an unmistakable indication of emergence" (p. 121).

[22]Ibid., 6. Elsewhere Klapwijk defines the bonding of oxygen and hydrogen to make water as non-supervenient because "they can be explained by the structural traits of the underlying atoms. The supervenient properties of emergent life forms, on the contrary, are characteristics that cannot be completely explained from the structural properties of more elementary constellations and that are, therefore, to be recognized as non-reductive in nature" (p. 120). Klapwijk's distinction is difficult to maintain (what about viruses or lipid bilayers?), and in my opinion, unnecessary. If we define irreducibility in terms of goodness, truth, and beauty, then the emergent structure of the H_2O molecule with the advantages described by Satherley can be considered an example of irreducible novelty, even though the molecule can be reduced to atoms. Even the water molecule is not "completely explained" to us by its structure, and it may never be.

[23]John Satherley, "Emergence in the Inorganic World," *Philosophia Reformata* 76, no. 1 (2011): 47, https://doi.org/10.1163/22116117-90000501.

[24]Robert Spaemann remarked that an "authentic teleology" is "an emerging property, non-reducible to its conditions of origin," distinguished as a "fundamental 'tending-towards,' as tendency and fulfilling." Robert Spaemann, "The Unrelinquishability of Teleology," in *Contemporary Perspectives on Natural Law*, ed. Ana Marta González (Abingdon, UK: Routledge, 2016) 281–96. Spaemann connects physical-chemical tendencies with the "unity of the person over time [that] presupposes that being, existing, has a vectorial meaning," stating "There is only teleology in human action because and insofar as there is a direction in natural tendency" (p. 293).

[25]Hulswit, "Teleology," quoting Peirce, CP 7.570 (1892). I take Peirce's application of his synechism (anti-dualism) to apply to all "things" literally; since God is not a "thing," Peirce's reasoning may not apply to all areas of theology.

[26]The latter question should be seen as a subset of the former.

[27]Prigogine and Stengers, *Order Out of Chaos,* 256: "We are now entering a new era in the history of time, an era in which both being and becoming can be incorporated into a single noncontradictory vision." This scientific unity refers to the lack of a natural distinction, and it is different from Klapwijk's distinction between creation and becoming, in that Klapwijk's is a theological distinction consistent with classical realism. Prigogine's lack of distinction is valid for nature and objects, while Klapwijk's is valid for God and nature.

[28]Thomas Pfau, *Incomprehensible Certainty: Metaphysics and Hermeneutics of the Image* (South Bend, IN: University of Notre Dame Press, 2022), 511. Later, Pfau continues this thought:

> For where (scientific) knowledge should eventuate, the event of seeing must have already taken place; and what allows a phenomenon to stand out against a background of visual miscellany and sheer "noise" of disjointed optical data is its very reality and specificity, that is, its conspicuously textured and distinctive *form* (p. 520).

[29]Other thoughts on the theology of naming and classification can be found in Beth Stovell and Matthew Morris, "Taxonomic Theology: An Interdisciplinary Approach to a Biblical and Biological Theology of Naming," *Perspectives on Science and Christian Faith* 74, no. 4 (2022): 194–211, https://www.asa3.org/ASA/PSCF/2022/PSCF12-22Stovell.pdf.

[30]Hanby, *No God, No Science*, 222, first sentence quoting Richard Dawkins, *The Selfish Gene* (Oxford, UK: Oxford University Press, 1976), 35.

[31]Mark K. Spencer, "Classical Theism, Divine Beauty, and the Doctrine of the Trinity," chapter 15 of *Classical Theism: New Essays on the Metaphysics of God*, ed. Jonathan Fuqua and Robert C. Koons (New York: Routledge, 2023), 288.

[32]Andrew J. Thomson, "The Science of RJP Williams," *Journal of Biological Inorganic Chemistry* 21, no. 1 (2016): 1–3, https://doi.org/10.1007/s00775-015-1328-5.

[33]Robert Joseph Paton Williams and João José Rodiles Fraústo da Silva, *The Chemistry of Evolution: The Develop-*

ment of Our Ecosystem (Amsterdam, The Netherlands: Elsevier, 2005), 127. The authors define chemotypes as "broad groups of organisms that have major distinctive chemical, energetic, spatial or organizational features" (p. 443).

[34]Ibid., 119–20.

[35]Ibid., 442.

[36]Ibid., 442.

[37]Alister E. McGrath, *The Open Secret: A New Vision for Natural Theology* (Hoboken, NJ: John Wiley & Sons, 2011), 243. Williams is cited on p. 242.

[38]Ibid., 73.

[39]Ibid., 244.

[40]Ibid.

[41]Williams and Fraústo da Silva, *The Chemistry of Evolution*, 134–35.

[42]McFarland, *A World from Dust,* 170–73.

[43]Joseph E. Earley, "Modes of Chemical Becoming," *Hyle* 4, no. 2 (1998): 105–15, https://hyle.org/journal/issues/4/earley.pdf.

[44]Ibid., 108.

[45]In one sense, an exclamation point does not change the content of the sentence, but in another sense, it changes everything. We relate to the novelty with gratitude for its creation, and our understanding of the world is made new.

[46]Earley, "Modes of Chemical Becoming," 111.

[47]If the structural novelty of argon dichloride is elegant, the systemic novelty of a continuously stirred tank reactor is musical, "harmonious" like an instrument in tune. Both of these cases of irreducible novelty are not only beautiful, but they may also be functional and could be "good" for something; as Earley wrote, "Since both of these cases generate coherences that are centers of agency, they should be considered to produce new chemical entities."

[48]Joseph E. Earley, "Would Introductory Chemistry Courses Work Better with a New Philosophical Basis?," *Foundations of Chemistry* 6, no. 2 (2004): 137–60, https://doi.org/10.1023/B:FOCH.0000034992.42777.95.

[49]Ibid., 139.

[50]Michael Hanby, "Questioning the Science and Religion Question," in *After Science and Religion: Fresh Perspectives from Philosophy and Theology*, ed. Peter Harrison and John Milbank (Cambridge, UK: Cambridge University Press, 2022), 170.

[51]Hanby, "Saving the Appearances," 42.

[52]The periodic table is not only an exemplar of order: in most chemists' opinion, it is beautiful as well, although that may be in the eye of the beholder. Order and beauty have often been associated in theology and philosophy. For example, John Haught described Alfred North Whitehead's definition of beauty as "the 'harmony of contrasts' or the 'ordering of novelty' … Beauty arouses our appreciation by turning what would otherwise be contradictions or clashes into aesthetic patterns that preserve both nuance and coherence." (John Haught, "What Is the Purpose of Existence?," *Engelsberg Ideas*, August 11, 2020, https://engelsbergideas.com/essays/what-is-the-purpose-of-existence/.) So, if the story of natural history is told as an ordered sequence of chemical reactions producing new things, then that telling will emphasize its beauty, and therefore its irreducible novelty.

[53]Bruce C. Wearne, "Jacob Klapwijk's Invitation: Come to the Party!," with Introduction by Guest Editor," *Philosophia Reformata* 76, no. 1 (2011): 1–10, https://doi.org/10.1163/22116117-90000499.

[54]Klapwijk wrote that in cases of emergence, "a scientific explanation is excluded" (*Purpose in the Living World?,* 94), which seems to contradict my assertion that irreducible novelty can be scientifically reducible; however, throughout the book, Klapwijk accommodates scientific explanation (i.e., efficient causation) with other levels of causation and with theological meaning, so that the truth, goodness, and beauty of an organism do not compete with its natural history. Throughout the book, Klapwijk depends on the recognition of these different levels through formal reasoning, while referring to efficient explanations for the separation or definition of the levels. For example, on p. 96, plants are recognized as a novel form of life in the same way as Williams's chemotypes, using the language of "nested bowls" which echoes Williams's cone illustration on the cover of *The Chemistry of Evolution*; on p. 105, Klapwijk states that "we *recognize* that there are various kinds of reality" [emphasis mine]; on p. 104, he wrote that "continuity and discontinuity are intertwined" and therefore compatible; and on p. 136, he specifically argues against irreducible complexity in terms appropriate to irreducible novelty.

[55]McFarland, *A World from Dust.* I identified as a Christian in the introductory Author's Note, although the book was written for an audience without a theological background.

[56]Ibid., 46–50.

[57]Ibid., figure 3.3, 47.

[58]Ibid., 60–61.

[59]For more on the special properties of water for life, see Ruth M. Lynden-Bell et al., eds., *Water and Life: The Unique Properties of H_2O* (Boca Raton, FL: CRC Press, 2010).

[60]McFarland, *A World from Dust,* figure 4.4, 75.

[61]Robert M. Hazen et al., "Mineral Evolution," *American Mineralogist* 93, no. 11-12 (2008): 1693–720, https://doi.org/10.2138/am.2008.2955.

[62]Ibid., 1712.

[63]The origin of life is not included in this article, although it is addressed in *A World from Dust,* chapter 5, as "hints." This event may be continuous with geochemistry if a proper mineral template interacts with dissolved solutes, or it may have been a discontinuous, emergent miracle as Klapwijk allows for. Either way, the life produced is irreducibly novel. Helpful discussion of this topic can be found in the "Rethinking Abiogenesis" series published in this journal: see Emily Boring, J. B. Stump, and Stephen Freeland, "Rethinking Abiogenesis: Part 1, Continuity of Life through Time," *Perspectives on Science and Christian Faith* 72, no. 1 (2020): 25–35, https://www.asa3.org/ASA/PSCF/2020/PSCF3-20BoringStumpFreeland.pdf; and Sy Garte, "Continuity, Simplification, and Paradigm Shifting in Biological Evolution," *Perspectives on Science and Christian Faith* 74, no. 3 (2022): 149–55, https://www.asa3.org/ASA/PSCF/2022/PSCF9-22Garte.pdf.

[64]McFarland, *A World from Dust,* figure 4.5, 84.

[65]Phosphate, with a solubility between millimolar and micromolar, adopts both metabolic and limited structural roles.

[66]For an overview, see Robert Joseph Paton Williams, "The Bakerian Lecture, 1981. Natural Selection of the Chemical Elements," *Proceedings of the Royal Society of London. Series B. Biological Sciences* 213, no. 1193 (1981): 361–97.

[67]McFarland, *A World from Dust,* 32 and 129–31.

[68]Several types of cells, ordered by their redox potentials like the chemical sequence, can be seen in ibid., figure 6.3, 125.

[69]Ibid., figure 7.2, 152. Much of this power is located in the element: magnesium-containing materials can catalyze photosynthetic-adjacent reactions in inorganic laboratory environments.

[70]Ibid., figure 8.1, 161.

[71]Ibid., figure 4.5, 84 and figure 8.4, 172.

[72]One interesting puzzle is that oxygen levels were very high for brief periods before and during the first great oxidation event, so oxygen is not the only factor, but other factors such as genetic complexity and multicellularity/specialization must be present in life to take advantage of oxygen's chemical power.

[73]McFarland, *A World from Dust,* 186–89.

[74]Calcium can both build and balance, while phosphate can both build and participate in metabolism/catalysis. The third dual-role element is sulfur.

[75]McFarland, *A World from Dust,* chap. 9, especially 184–90, addresses these claims in more detail, as well as in McFarland, "Mixed Metaphors."

[76]McFarland, *A World from Dust,* 185.

[77]Ibid., figure 11.2, 251. There are exceptions to the historical trend of decreasing redox potentials in the mining of metals—iron is a notable one—but as an overarching explanation, it serves well to put the historical events in good order. The irreducible novelty of gold was accessible without chemical methods, but the irreducible novelty of aluminum requires chemical methods to access. The novelty of the properties produced by these metals is still "irreducible" even if metals themselves must literally be "reduced" by the addition of electrons to be experienced by human senses.

[78]For example, see Muriel Geldof, Inez Dorothé van der Werf, and Ralph Haswell, "The Examination of Van Gogh's Chrome Yellow Pigments in 'Field with Irises near Arles' Using Quantitative SEM–WDX," *Heritage Science* 7 (2019): 1–11, https://doi.org/10.1186/s40494-019-0341-3.

[79]Klapwijk, *Purpose in the Living World?,* 209.

[80]C. Stephen Evans, *Natural Signs and Knowledge of God: A New Look at Theistic Arguments* (Oxford, UK: Oxford University Press, 2010), 154.

[81]David Bentley Hart, "Science and Theology: Where the Consonance Really Lies" in *After Science and Religion: Fresh Perspectives from Philosophy and Theology,* ed. Peter Harrison and John Milbank (Cambridge, UK: Cambridge University Press, 2022), 70.

[82]Ibid., 74.

[83]This approach means that chemical experiments in the laboratory are an act of subcreation, while the theological origin of creation itself remains with God. Consistent with Hanby's argument, nature is not an artifact, but we can isolate and make artifacts mimicking nature because of natural integrity and chemical laws.

[84]Klapwijk, *Purpose in the Living World?,* 192. See also Pfau, *Incomprehensible Certainty,* where he states that for Ruskin, truth is "not a correlate of finite 'making' (*facere*) but, instead, manifests an anterior, transcendent 'creating' (*creare*). An intrinsic property of being that can never be secured in propositional form, truth is attainable only qua participation" (p. 527).

[85]Hanby, "Questioning the Science and Religion Question," 168.

[86]Ibid. Hanby writes:

> Milbank proposes to elevate "makeability" to the status of a transcendental. The "poetic" unity of knowing and making then appears as an expression and approximation of, and indeed a participation in, what is most uniquely Christian in the history of ontology: creation *ex nihilo* as the ontological structure of reality, grounded in the self-differentiating unity of the Trinity. (pp. 166–67)

Hanby's "*ex nihilo*" language seems deliberately provocative, but it does underscore both the irreducibility and the novelty of these events from his perspective. Even though these events are precedented, Hanby considers their novelty to be in a sense *ex nihilo*.

[87]Nicholas of Cusa, *Idiota de Mente,* trans. by Jasper Hopkins, in *Nicholas of Cusa on Wisdom and Knowledge* (Minneapolis, MN: Arthur J. Banning Press, 1996), https://www.jasper-hopkins.info/DeMente12-2000.pdf, 59. See also:

> Now, the wood receives a name from the advent of a form, so that when there arises the proportion in which spoonness shines forth, the wood is called by the name 'spoon'; and so, in this way, the name is united to the form. Nevertheless, the imposition of the name is made at will, since another name could have been imposed. (p. 64)

[88]Ibid., 62.

[89]John Milbank, "Religion, Science, and Magic: Rewriting the Agenda," in *After Science and Religion: Fresh Perspectives from Philosophy and Theology*, ed. Peter Harrison and John Milbank (Cambridge, UK: Cambridge University Press, 2022), 158.

[90]Paige N. Anunson et al., "Involving Students in a Collaborative Project to Help Discover Inexpensive, Stable Materials for Solar Photoelectrolysis," *Journal of Chemical Education* 90, no. 10 (2013): 1333–40; Sarah E. Shaner et al., "Discovering Inexpensive, Effective Catalysts for Solar Energy Conversion: An Authentic Research Laboratory Experience," *Journal of Chemical Education* 93, no. 4 (2016): 650–57, https://doi.org/10.1021/acs.jchemed.5b00591.

[91]Trevor Hart, *Making Good: Creation, Creativity, and Artistry* (Waco, TX: Baylor University Press, 2014), 85.

[92]Ibid., 98, quoting H. H. Farmer.

[93]Ibid., 85. Hart later writes that "artistry may usefully serve as a paradigm case for reckoning with that wider set of 'poetic' actions and outputs in which, I shall argue, *Homo faber* is always and everywhere implicated and complicit" (p. 90).

[94]Ibid., 96–97, quoting Ingolf U. Dalferth.

[95]For example, I do not believe the "Solar Army" discovered a significant new catalyst. However, the education of the students, which is the primary point, was certainly accomplished.

[96]Consider how the poetic technique of the book of Job "seems unnervingly to place God in considerable sympathy with the emblems of the chaotic." John R. Schneider, "Recent Genetic Science and Christian Theology on Human Origins: An 'Aesthetic Supralapsarianism,'" *Perspectives on Science and Christian Faith* 62 no. 3(2010): 206, https://www.asa3.org/ASA/PSCF/2010/PSCF9-10Schneider.pdf.

[97]Stephen C. Meyer, "Not by Chance: From Bacterial Propulsion Systems to Human DNA, Evidence of Intelligent Design is Everywhere," *National Post of Canada*, December 1, 2005, https://www.discovery.org/a/3059/.

[98]Williams and Fraústo da Silva, *The Chemistry of Evolution*, 446.

[99]Klapwijk, *Purpose in the Living World?,* 209–10.

[100]Ibid., 214.

Arie Leegwater

Article

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Dead Chemists Do Tell Tales: The Religious Shaping of Chemical Knowledge

Arie Leegwater

This article offers an analysis of the science-religion relationship in the thought and practice of two influential chemists: F. Wilhelm Ostwald and Charles A. Coulson, who lived during the formative period of modern chemistry (1870s–1950s). I examine Ostwald's program for an "allgemeine Chemie" and Coulson's program for quantum chemistry, explore the deeper implications/basic beliefs at stake in these developments, and suggest why the "received" interpretation of the relation of science and religion may be inadequate for an understanding of their work.

Keywords: Religion and cognitive beliefs, Wilhelm Ostwald, energetics (an "allgemeine Chemie"), Charles A. Coulson, quantum chemistry, history of science, religion and science.

What bearing do religious beliefs have on the development of chemical theories and practice? Does Wilhelm Ostwald's proposal of a chemical energeticism reflect in some way his positivistic outlook and his eventual elaboration of an atheistic monism? Does the "phasen-leer" (phase theory) as promoted by H. W. B. Roozeboom display his Dutch Reformed background? Was Linus Pauling's development of structural chemistry related at all to his western American devil-may-care attitude toward religion and his support of liberal causes? Does Charles Coulson's framework for quantum chemistry reflect his English Methodism? Posing the question in this way: how religion influences cognitive beliefs and affects practices in modern science such as late nineteenth-century and mid-twentieth-century chemistry makes us, as moderns, feel uncomfortable.

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Martin Rudwick, a historian of science, once perceptively commented,

> … the strength of the historian's empathy for religious beliefs often seems to be directly proportional to the space of time that separates him from them, fading away as one approaches the present day.[1]

However, over the past four decades or more, historians of science have paid increasing attention to religion and religious beliefs. These beliefs have even been allowed to play a role as one among many factors affecting the development of science.[2]

A historian may more easily detect the influence of religious beliefs when investigating a powerful and influential individual. One can then hopefully find the person (actor) reflected in their scientific work. One must look to the

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problems the scientist chooses to work on, the kind of mathematical argument that they bring to bear, the experimental evidence they marshal and the conceptual experiments they devise, to what they take as basic and what subsidiary, to what they find easy or evident and what they find difficult and in need of discussion, to what they perceive as the range and scope of the theory, both with respect to the subject proper and to its impingement on other areas. In short, such studies need to be sensitive to various traditions in which each individual finds their place—either by spirited reaction or quiet acceptance.

These questions will be further explored using two historical examples: the chemical practice of the German Nobel prize-winning chemist Wilhelm Ostwald (1853–1932) and the work of Charles Alfred Coulson (1910–1974), an English-Methodist quantum chemist and Rouse Ball Professor of Mathematics at Oxford University. More specifically, this article will

(1) examine Ostwald's program for an "allgemeine Chemie" (general chemistry) and Coulson's program for quantum chemistry,

(2) explore the deeper implications/basic beliefs at stake in these developments, and

(3) suggest why the "received" interpretation of the relationship of science and religion may be inadequate for an analysis of their work.

My aim will be to understand the scientists in action: their effort to religiously shape *chemical* knowledge. I do not aim to provide an historically detailed account of their subsequent cultural engagement and influence. Rather, I wish to pay attention to their contribution in a specific area of *chemical* science.

Wilhelm Ostwald and Energetics (*Energetik*)

Until recently, little attention has been paid to the daring assumptions and consequences of Wilhelm Ostwald's program of energetics (*Energetik*).[3] Ostwald, a German physical chemist, who was awarded the Nobel Prize in Chemistry in 1909 for his "works on catalysis as well as for fundamental investigations of chemical equilibrium and reaction velocities,"[4] was one of the most celebrated German scientists at the turn of the twentieth century. As a student in Dorpat (University of Tartu) and professor at the Riga Polytechnikum, he did extensive studies in chemical affinity (*Verwantdschaftslehre*). Of note were two lengthy series: "*Studien zur chemischen Dynamik*" (1884–1888) and "*Elektrochemischen Studien*" (1884–1888). He had also written a two-volume *Lehrbuch der allgemeinen Chemie* (1885/1887). In 1887, he founded (and co-edited with J. H. van't Hoff) the first physical chemistry journal, *Zeitschrift für physikalische Chemie, Stöchiometrie und Verwantdschaftslehre*. Clearly, Ostwald was a man of considerable talent: a skillful experimenter, an adept organizer, an excellent teacher, and a persuasive expositor.

In 1887, Ostwald was appointed to the only German university chair in physical chemistry in Leipzig. In his inaugural address, Ostwald drew a parallel between the Law of Mass Action "which rests on the persistence of matter, and chemical affinity laws, which rest on the persistence of chemical energy."[5] But, Ostwald was determined to go beyond simple parallel comparisons. He insisted that chemistry required extensive reform. It lacked the simple and general laws of mechanics that Heinrich Hertz claimed characterized much of physics.[6] Ostwald wanted to develop a general chemistry (an "*allgemeine Chemie*"), which would undergird all the subspecialties of chemistry. His aim was to be constructive, to reconstruct and reformulate the principles of chemistry along more general and intuitive lines. He considered a good chemical theory to be one that satisfied two requirements: (1) it should consist of functional relations among measurable quantities; and (2) it must provide a main or general law from which special laws referring to particular systems could be derived.[7] Chemistry should be cleansed of as many hypotheses as possible.[8]

Ostwald proposed a research program called *Energetik* (energetics) which drew its inspiration from the success of thermodynamics in describing the principal relationships in physical chemistry without resorting to atomic and molecular models. Ostwald held that the ills of late nineteenth-century physics and chemistry could be addressed by the simple expedient of discarding the model—and indeed all models—and reducing physics and chemistry to an account of the conservation and transformation of energy. The unification of chemistry and the establishment of an "*allgemeine Chemie*" could not depend on mechanics as the integrating and foundational theory, but rather requires generalized

thermodynamics (or energetics) which appeals to observables and empirical data such as temperature, pressure, active mass (concentration), etc. Ostwald longed to give expression to his energetic vision so vividly described in his "conversion experience" in 1890:

> In the earliest morning hour I walked from my hotel to the zoological garden [Tiergarten], where I experienced in the sunshine of a marvelous spring morning a true Pentecost, an outpouring of the spirit over me … Everything regarded me with new unaccustomed eyes, and I felt as if I were experiencing all of these blisses and splendors for the first time … The thought process required for the general formation of the energetic conception of the world then took place without any effort—indeed, with positive feelings of bliss. All things looked at me as if I had just been placed in Eden, in accordance with the Biblical account of creation, and was now giving each thing its true name.[9]

This description, forty years after the event, could easily be an embellished account, particularly with all its biblical imagery. But this account, embellished or not, does indicate how serious Ostwald was in being an apostle of energy and how zealous he was in propagating his gospel of energy. The ontological key to understanding reality was at hand. Energy had received its "true name."[10]

Ostwald's focus on energy as the explanatory principle and final constituent of reality developed through various phases during 1887–1905: sequentially (1) a challenge to physical atomism (kinetic molecular theory), (2) a particular interpretation of thermodynamics and method of energy analysis, (3) a search for an alternative to chemical atomic theory, and finally (4) the formulation of "*eine Chemie ohne Stoffe*" (a chemistry without matter/substances).[11]

Initially, in Oswald's self-described period of "*Unbewusste* [unconscious] *Energetik*" (1887–1892), energy and matter had ontological parity. But soon thereafter (1893–1902), energy gained priority and supremacy—conceptually, methodologically, and ontologically. Matter, he argued, "is nothing but a complex of energy factors."[12] Energy has a right (besides space, time, and an intensity or capacity factor of energy) to be the central concept, since everything that happens is in the final instance nothing but a change of energy.[13]

It would take me too far afield to describe all the details of this energy doctrine. In brief, Ostwald formulated two laws of energetics: (1) "*Die Gesamtmenge* [total quantity] *der Energie ist konstant*," and (2) "*Zwei Gebilde, die einzelnen mit einem dritten in Energiegleichgewicht sind, sind auch einander gleich*" (Two systems that are in energy equilibrium with a third are also equal to each other—one of several formulations Ostwald used).[14] The first law was a restatement of the law of energy conservation. The second law of energetics attempted to answer the question as to when a transformation would occur.

One suggested solution incorporated the concept of intensity. Each form of energy—heat, chemical, electrical, volume, etc.—was assigned an intensity. If the intensities of a particular form of energy are equal in two different regions, no energy transfer will occur between these regions. If, on the other hand, the intensities are unequal, a state of non-equilibrium prevails, and thus the energy will flow from a region of higher intensity to a region of lower intensity until equilibrium is once again established. In addition to the intensity factor (i), Ostwald also assigned a capacity factor (c) to each energy form. The product of these two factors represents a given quantity of energy: E = ci. Ostwald identified five "*Arten* [kinds] *der Energie*": (1) mechanical energy, (2) heat, (3) electrical and magnetic energy, (4) chemical and internal energy, and (5) radiant energy. Ten paired combinations are possible, three of which Ostwald claimed were particularly important for chemical energetics: thermochemistry, electrochemistry, and photochemistry. The total energy of a system [*Gebilde*] is equal to the arithmetic sum of the individual energies.[15] Each system contains (*or is*) a definite amount of energy of one form or another.

The most penetrating criticisms of Ostwald's energetic interpretation and derivation of thermodynamic relationships came from Ludwig Boltzmann and Max Planck. Ostwald had kept them apprised of his approach well before the fateful 1895 Lübeck meeting of the Gesellschaft Deutscher Naturforscher und Ärzte. At the meeting, the confrères debated the energetics program at length. On the last day, Ostwald delivered his famous lecture, "*Die Überwindung des wissenschaftlichen Materialismus*" ("The Conquest of Scientific Materialism"),[16] proclaiming atoms to be nothing but "graven images" and atomic models to be, at best, heuristic devices.

> The job of science is to determine the relationships between aspects of reality, in the form of demonstrable and quantifiable parameters, so that when some of the parameters are known the others can be calculated. This goal cannot be achieved by setting up a hypothetical picture of the world but only by demonstrating the relationship between quantifiable parameters.[17]

After Lübeck, the leading physicists of the day (such as Ludwig Boltzmann and Max Planck) were quick to publish their concerns.[18] Their criticism can be summarized as follows: (1) energetics displays a poor, if not deplorable, mathematical development of arguments; (2) energetics as defended by Ostwald, (and Georg Helm) argues to extant thermodynamic relationships rather than providing their foundation; (3) energetics has no adequate concept of irreversibility (most irreversible processes were subsumed under radiant energy); and (4) energetics employs an ad hoc construal of volume energy (Volume Energy = Volume [capacity] x Pressure [intensity]). For example, the critics charged that the energeticists juggled mathematical formulae to "derive" results known in advance or employed formulae which made no sense when describing irreversible processes.

But Ostwald did not stop promoting energetics in chemistry, even after support for physical *Energetik* waned after Lübeck. He advanced studies directed toward finding an alternative to chemical atomic theory, and eventually "*eine Chemie ohne Stoffe*" (a chemistry without matter/substances).[19] Even when Ostwald "recanted" in 1905, admitting the existence of atoms based on the X-ray investigations in 1896 by W.C. Röntgen, he could still comment, "Energetics is not affected by these developments because, since it is the more general concept, it is not affected by whether atoms exist or not."[20]

After a year as an exchange professor at Harvard, Ostwald resigned his Leipzig chair in physical chemistry in 1906 and retired to his retreat, Landhaus Energie, in Grossbothen. He actively began to employ a much broader range of arguments: not only scientific and methodological, but also philosophical, and most centrally, religious. This latter characteristic is manifest in Ostwald's commitment to an energy principle of cosmic proportions. To understand this development of "cultural" energetics, some historical background is needed. Ostwald did not follow a humanistic curriculum in his gymnasium (high school) and University of Tartu education, but once he moved to Leipzig he began to participate in interdisciplinary dialogue with fellow academics. In the mid-1890s, he joined the Leipziger Positivisten-Kränzchen, a small group of positivists such as the historian Karl Lamprecht, the geographer Friedrich Ratzel, the psychologist Wilhelm Wundt, and the economist Karl Bücher.[21] As Matthias Neuber has argued,

> What these scholars had in common was the conviction that it should be possible to establish a unified field of natural and cultural sciences in the sense of some sort of *Gesamtwissenschaft* [a unified science].[22]

They rejected any form of Cartesian dualism in favor of a monistic conception of reality. Ostwald's application of energetics to cultural phenomena, particularly after his experience at the Lübeck meeting, entailed a monism (an ontology of energy), a naturalism, and in historical terms, an appeal to Auguste Comte's law of three stages of historical development: theological, to metaphysical, to positive (scientific). Energetics, as a positive science and an all-embracing worldview, philosophy, or secular religion would, in his view, ultimately replace Christianity.[23]

Already foreshadowed in his 1902 *Vorlesungen über Naturphilosophie* [*Philosophy of Nature Lectures*], Ostwald minced no words about the universal scope of his energetics: it would be an energetics complete with a theory of happiness, an encyclopedia of the sciences, a theory of spirituality, an energetic understanding of consciousness, an argument for Esperanto, supplemented by numerous monistic Sunday sermons, many of which exhorted listeners to conserve energy.[24] In 1911, Ostwald assumed leadership of the Monist League, founded by the biologist Ernst Haeckel in 1906. Ostwald, to his mind, had fulfilled his vision so vividly described in his conversion experience in 1890 to pure energetics: he considered to have given energy its *true* name.

Ostwald and Religious Belief

> "[O]ne must come to the conclusion that energy—and only energy—is real."[25]

If one holds that religion is a way of life that people always engage in with their full existence (while faith is only one of a number of fundamental modes of being religious), a different way of understanding

the relationship of science and religion may follow. As Robert Sweetman proposes in his holist account of the relationship of religion and scholarship: "… it acknowledges that socio-cultural endeavor can be religious; indeed, it denies that socio-cultural endeavor can ever be *irreligious*."[26] Then the question becomes, what religion or religions does Ostwald's scientific activity and practice bear witness to?

That question can be addressed in two different, but related, ways: an analysis of Ostwald's religious belief in his formulation of energy theory, and a critique of his reductionism in chemistry. First, Ostwald claims far more than that his energy doctrine is only a hypothesis, open to testing and potential verification. For Ostwald, "… one must come to the conclusion that energy—and only energy—is real. This is because energy is the only thing that must be part of every act and affects both the acted-upon as well as the actor."[27] This belief also funded his later monistic understanding of the mind/body problem:

> … the problem of the relationship between mind and body, which scientific materialism had left unsolved, … lost in the light of energetics its unapproachable character since both mind and body were subsumed in the higher-level concept of energy and hence the two must be intimately bound up with each other.[28]

This energy doctrine also undergirds Ostwald's reductive view of chemistry. The strength of Ostwald's energeticist account in chemistry, energy as a singular quantitative measure of physical interaction, is simultaneously its major weakness. The abstract mathematical description of energy and its various exchanges required the isolation, either theoretically or experimentally, of a physical system and a conscious purging of its typical properties and structure.[29] This neglect, or explicit *reduction*, that is, of subsuming typical properties as instantiations of a general energy law, ran counter to the major thrust of nineteenth-century chemistry, namely organic chemistry with its structural and stereochemical assumptions,[30] and later in the early twentieth century: valence theory, chemical bonding, and structure-reactivity relationships. For Ostwald, physical entities and their interactions are projected to be quantitatively measurable *energy* factors.

But in what sense is this view of energy a religious belief? In his book *Knowing with the Heart: Religious Experience and Belief in God,* Roy Clouser advances the idea that a belief is a religious belief when "it is (1) a belief in something as divine or (2) a belief about how to stand in proper relation to the divine, where (3) something is believed to be divine provided it is held to be unconditionally nondependent."[31] This third sense entails replacing God with a nondependent reality on which all else depends, that is, as scripture proclaims, "to call anything a god or an idol if it in *any* way replaces God"[32] Granted this understanding, Clouser concludes a materialist has a religious belief. Ostwald's core belief in energy certainly functions in a comparable manner.

In the end, Ostwald's energy considerations, both in theory and practice, served as a religion, as a substitute source of meaning and revelation. His "graven images" may not have been atoms, but rather they became energy and its many manifestations. Energy was something within creation which everything else depended on for its existence. St. Paul's confession of creation frames the context for any discussion of these matters:

> For in him all things were created in heaven and on earth, visible and invisible, whether thrones or dominions or principalities or authorities; all things were created through him and for him. He is before all things, and in him all things hold together. (Colossians 1:16–17, NIV)

By 1893, Ostwald regarded energy as a self-existent substance; he accords it divine status, and it is therefore a core religious belief whether this is acknowledged or not. As he stated: "… there is nothing more 'real,' that is more effective than energy. And, indeed, in this sense it could be defined as the only thing that is 'real' in the physical world."[33]

Charles A. Coulson as Student, Quantum Chemist, and Religion-Science Spokesperson

Charles A. Coulson (1910–1974) was an early participant in the English school of quantum chemistry who, after World War II, was also one of the leading English spokespersons for understanding science and religion.[34] During Coulson's lifetime, quantum chemistry went through a revolutionary process of development. Coulson played a significant role in bringing quantum approaches—in particular, the molecular orbital interpretation of the chemical bond—to the broader chemical community. But

academic research in quantum chemistry is only one component of Coulson's work. Crucial to understanding Coulson's career was his missionary zeal in promoting an understanding of the chemical bond that wed the pictorial representation of bonds—so dear to structural chemists—to the increasingly complex mathematical descriptions of the chemical bond, while simultaneously advancing a view of the relationship of science and religion which placed the person as historical actor at the center of responsible engagement.

Recent scholarship has done little to examine how these two leading interests of Coulson were related.[35] As J. W. Linnett noted in a brief 1975 memorial notice in *Chemistry in Britain,*

> Many scientists thought of Coulson as a "double person"—a theoretical chemist and a man of the church; and they thought of these two as two immiscible and separate persons. This was not so, because, had it been, then his life would have been a dishonest one, and would have been totally incompatible with all the rest of our experiences.[36]

That Coulson's life displayed a unity of belief and action was displayed in a variety of ways. First, Coulson's belief in a personal religious experience, the role of a group's fellowship in confirming that experience, and a call to holiness affected Coulson's approach to his scientific coworkers, his research group and their activities, and his general promotion of science to a wider public. Secondly, when Coulson employed and presented his optimistic style of attacking scientific problems in quantum chemistry, replete with approximations and models, he displayed a concern for others, particularly chemists, who often displayed a prejudice against the utility of quantum mechanics. Thirdly, his emphasis on the wholeness or unity of personal experience shaped his view of the science/religion connection.

Coulson as Student:

"I came up … a mystic,
I went down a missionary."[37]

Coulson's style and approach in quantum chemistry, as well as in his view of life, involves the theme of giving and receiving which first arose from his student experiences. During the Easter term of 1930, his second year at Cambridge, Coulson received an invitation to attend group meetings organized by W. Harold Beales, minister of Wesley Methodist Church. Beales encouraged Cambridge student groups, of roughly ten students, to explore how best to communicate the Christian faith. He presented feeling, knowing, choosing (personal choice), doing, and belonging as essential marks of a Christian's experience.[38] The impact of this small intimate group on Coulson was indeed life changing. After a group retreat held in June 1930, he wrote:

> I learnt from the value of corporate action. You all remember Beales' description of the anthropological view of the group idea. It impressed me most marvelously … I began to see that Christianity for me must be something broader than my own self … I began to see that religion was something that got beyond you and God, it included everybody … I came up this term a mystic—I went down a missionary.[39]

Coulson wished to "come down" from himself to the "world of others."[40] In fact, soon afterward, Coulson became a Methodist lay preacher who often did the circuit with other group members on weekends at churches and chapels in the vicinity of Cambridge. His sermons and letters from this initial period in his life display a Wesleyan-Methodist concern with holiness (perfection), a need for fellowship, and a desire for social action. A call for social action was not so much driven by a sense of duty, but rather seen as a way of developing spirituality.

One would surmise there must have been a tension between Coulson's academic interests and his interest in social action. A glimpse of how Coulson resolved this tension is revealing:

> I was reading mathematics myself, and puzzled to know to what extent I should allow my love for the subject to dominate my future life. The two chief competing possibilities were represented in my mind by two people. One was a most distinguished mathematician [G. Hardy], with a worldwide reputation: he was a symbol of the life so wholly devoted to academic study that it merited the epitaph: "this man decided to know and not to live." The other was Alex Wood [Quaker physicist at Emmanuel College, Cambridge], symbol for me then, as now, of the life of a man whose service to God lies not only through his learning, but no less through his social conscience, his power among people,

> his simple Christian affection. If, in the end, my puzzle was solved, it was because this second man was so attractive that I felt I wanted to be a bit like him.[41]

Coulson as Quantum Chemist and Group Leader:

"Feet on the solid earth …
head … in the clouds."[42]

In her book, *From Chemical Philosophy to Theoretical Chemistry,* Mary Jo Nye traces the tenuous relation between the disciplines of chemistry and physics and the eventual rise of quantum chemistry.[43] She argues that chemistry, over the nineteenth century, became a distinct and separate discipline from physics. But by century's end, a convergence took place that resulted in the creation of a new subdiscipline—physical chemistry, and by 1933, the creation of another—chemical physics. Discipline boundary demarcation inevitably led to debates about where the boundaries should be drawn, which proper methodology to invoke, what ontological commitments were proper to make, and what the character of theory should be like.

Quantum chemistry (1927–1940s) arose as a subdiscipline emerging from the introduction and employment of wave mechanics (from physics) to solve classical chemical valence problems. As this occurred, certain national styles developed. Often the German and American approaches to quantum chemistry have been pitted against each other.[44] Friedrich Hund, Walter Heitler, and Fritz London represent the German *gründlich* approach, replete with mathematical sophistication, concerted efforts to reduce chemistry to physics, and deep, even pessimistic, philosophical concerns about the nature of causality, wave-particle duality, visualizability, etc., but a step or two removed from the practicing experimental chemist.

Linus Pauling, Robert Mulliken, John Slater, and John Van Vleck represent the so-called American approach, more pragmatic and optimistic, more pictorial in its representation of molecules, cozy with the operationalism of the American physicist Percy W. Bridgman (Bridgman considered the meaning of a concept dependent on a set of operations or a method of measurement). For the Americans, especially the chemist Linus Pauling, the formulation of a rule-governed methodology replete with predictive power was considered far superior to any deep understanding of the physics of the chemical bond.

In contrast to either of these approaches, the English school of which Coulson was a leading figure consisted of applied mathematicians who wished "to enlarge the domain of applied mathematics so as to include quantum chemistry."[45] The qualitative work of Nevil Sidgwick (1927) on the concept of valency was followed in the 1930s by the more mathematically sophisticated approaches of John Lennard-Jones, Douglas Hartree, and Coulson. As Lennard-Jones's student from 1932–1936, Coulson wrote the first quantum chemistry thesis in the UK. It dealt with molecular-orbital theory. Rather than viewing molecules as aggregates of individual atoms, each linked to its nearest neighbor by bonds formed by electrons localized between two atomic nuclei, molecular orbital theory considers molecules as atomic nuclei with binding electrons. These electrons spread throughout the whole molecule in orbitals.

Coulson's stated wish of living for others is seen in how he presented quantum chemistry and its results to others. As an applied mathematician, Coulson was interested in making sure that his conceptual, mathematical, and pictorial expressions were translatable and understandable to the chemist. The true applied mathematician is someone with "his feet on solid earth, but his head must be in the clouds."[46] He stated as much in his famous 1952 textbook *Valence*:

> Contrary to what is sometimes supposed, the theoretical chemist is not a mathematician, thinking mathematically, but a chemist thinking chemically. That is why almost everything in this book should be understandable to a chemist with no mathematical attainment … Almost everything necessary can be put in pictorial terms.[47]

Accuracy was not the strength of the new quantum mechanics. Its strength lay in the understanding it gave of chemical processes. At times, chemistry appeared to be solving the applied mathematicians' problems rather than the other way around. *Valence* presented the molecular-orbital approach to bonding, which it favored, as well as the valence-bond theory. Its pages are replete with pictorial diagrams of molecular orbitals.[48]

Several elements in Coulson's approach to quantum chemistry reflected his stated wish of living for others:

1. Non-reductive emphasis: Coulson would not render his descriptions of molecules in pure mathematical terms. Rather he stressed the role and bridge function of applied mathematics. Although holding a chair in mathematics (and in theoretical chemistry during 1972–1974), he was determined to respect the given patterns and structures of creation, even when described mathematically, in terms that others, particularly chemists, could understand.

2. Personal element: Coulson was keen on recognizing and emphasizing the personal element involved in science. What are our models? For Coulson, they are all "products of our imagination" that are displayed and described by applied mathematics. He employed strategies which highlighted visual representation and metaphors in his effort to advance mathematics in a formerly non-mathematical science—chemistry. Coulson was fearful that computational chemistry, which employed computers for its sophisticated calculations would both minimize and mask the personal element involved.

3. Fairness in presentation: While promoting his own molecular-orbital approach in an early 1941 publication, Coulson strove to be fair in representing other approaches:

> [W]e meet two different main avenues of approximation, known as the molecular orbital and electron-pair [valence bond] methods respectively. We confine ourselves here to the former of these … not because it is the better (neither is satisfactory, and the existence of the two complementary approximations is an indication of our partial failure to solve the problem).[49]

Although quantum chemists continued to

> discuss the relative merits and disadvantages of the valence bond and molecular orbital theory, mostly with the aim of choosing one of the two, Coulson argued for their *complementarity* and their mathematical equivalence when each method is adequately extended.[50]

> When Linus Pauling first reviewed *Valence,* he was hostile to Coulson's treatment even though the book presented Pauling's valence bond theory, but only after first discussing molecular orbital theory. Coulson went out of his way to mollify Pauling. After an exchange of letters between the two, an amicable understanding was reached. In the second edition of *Valence* (1962), Coulson, in fact, incorporated a number of Pauling's comments.[51]

In a 1950 BBC radio broadcast, "I Speak for Myself," Coulson reflected on his life's experiences: "To receive, and not to give, that would be to deny the common humanity that we all share. This is why, for me, it is such a high privilege to carry scientific research a stage further."[52] For Coulson, this theme of giving and receiving marked his life's path. He thought it applied even more intensely to interpersonal relationships for it reflects the sacrificial giving of Christ who says: "If man shall try to save his life, he shall lose it. But if he loses his life for my sake, he shall find it" (Matthew 10:39).[53]

Coulson's style of leading a research group demonstrates his desire to live for others. He was determined to create a sense of fellowship in his research group and department. Coulson held Tuesday morning coffee parties and also organized outings and picnics, all designed to entertain his students as well as the constant stream of foreign scientists who attended his lectures. He stayed connected with past students for years, "mainly by organizing reunion parties which he called 'centenaries' where several generations of students met to celebrate the publication of each new lot of a hundred pages by him and his associates."[54]

Another way that Coulson "lived for others" was through his summer schools in theoretical chemistry held in Oxford from 1955–1972. They became famous and a powerful influence in the worldwide dissemination of current scientific ideas and the further development of theoretical chemistry. In fact, Coulson insisted that one-half of the participants be from the Third World.[55]

Coulson on Science-Religion: "On the Mountain"

When delivering his 1951 Tilden Lecture, "The Contributions of Wave Mechanics to Chemistry," Coulson concluded his lecture with these words:

> You must surely have been struck by the way in which, all along, modern wave mechanics has taken up ideas of the past and refurbished them. How astonishingly fruitful have been those semi-formulated concepts of the classical chemists: and how necessary, in a sense, it has been for wave mechanics to give flesh and blood to the spirit which it has inherited … At every turn we have seen how wave mechanics has taken their work and has added to it the quality of a deeper understanding. That of course is always how science proceeds, building the past into the present and enriching it thereby.[56]

At first reading, it strikes one as a wonderful, literate summary of the development of wave mechanics in chemistry from 1926 to 1951. And yet, if we look more closely at the statement, particularly at the phrase, "give flesh and blood to the spirit which [wave mechanics] has inherited," a whole new vista is open to our view. Another horizon of experience and interpretation funds this description. Does it reflect Coulson's reading or narrative of nature? In this case, does it describe a Christian incarnational view? nature not read as organism, as magical, as mechanism, as an economy, or as an entangled bank, but as God's incarnational involvement with the earth. For Coulson, the scientific investigation of nature was considered to be a religious activity.[57]

When Coulson examined the relation of science and religion, he introduced an analogy of a mountain, Ben Nevis, as a basis for extending and clarifying his arguments. The artist, the poet, the historian—they each have their own perspective. Each person attempts to describe his encounter with the mountain in terms that make sense. To say, "Ben Nevis is a grassy slope," or to say, "Ben Nevis is a rocky mountain," may seem at variance, but it is equivalent to saying: "An electron is a wave and a particle." Which model or description you prefer depends on the problem you wish to solve. In a telling statement, illuminating the primacy of experience, Coulson remarked: "There is no conflict, nor can there be, since both descriptions start from the same basic origin—our experiences—and experience can never contradict itself."[58]

Science and religion, for Coulson, may exhibit complementary views and features of reality. But what does this imply for the position of Christianity? Is it just one among a variety of viewpoints, each equally valid, each equally true? Here Coulson admitted the analogy of the mountain broke down and displayed its limitations. Much of religion, taken as theology, he argues, can be considered as a view corresponding to art or science.[59] But, Coulson maintained, there are other elements of religion that cannot be thought of at all as "views."[60] He identified a non-discursive element that he was convinced could never be explained or adequately described, similar to Pascal's phrase: "The heart has her reasons, of which reason by itself knows nothing." As Coulson expressed it:

> To accept Nature as, in some senses, given: to receive the gift, and behave in a creaturely fashion towards it; to believe that it carries with it meaning and significance; and to seek, in reflection, what that meaning is—this surely is to act religiously. But in that event, religion is not merely one view of the mountain. It is some attitude which colors all the separate views, and gives them a depth which otherwise they would lack, more or less as a yellow filter reveals a pattern of clouds in a sky that without it appears pure blue.[61]

What then did Coulson mean by religion? For him, "Religion is the total response of man to all his environment."[62] The word *total* is crucial for Coulson's understanding of religion. By it, he meant to convey the whole person: thoughts, emotions, and human relationships. Similarly, the term environment includes everything, echoing the words of St. Paul, "all things in heaven and on earth." Coulson's favorite text was "The earth is the Lord's and all that is in it, the world, and all who live in it" (Psalm 24:1, NIV). The basic theme of his last sermon gave expression to this: God not only directs the play of our lives. He also built the theater in which they take place.[63] Let me conclude with a quotation by Coulson which, I think, captures his spirit and vision:

> Not until the power conferred by our knowledge has been recognized as God's gift, enabling his children to grow up into fully developed men and women; not until man's new independence is seen to be but the liberty of the children of God; not until man's patient observation of the world around has led him on to awe and then to worship; not until our science has shown us with what rich luster the heavens declare the glory of God, and the firmament shows His handiwork; not until then can human faith be as it was meant to be, nor human life fulfil its

> proper destiny. Nor shall we see how all things are summed up in Christ, both things on earth and things in Heaven; and our hearts be so astonished at the splendor of God's creation that they grasp eternity in a moment of time, and are lost in wonder, love and praise.[64]

Concluding Reflections

What can we learn from this brief excursion into the life and work of two widely diverging chemists? One, that the view of the complementarity of science and religion, though enriching our purview, will not capture all the constitutive relationships between science and religion. In fact, it often does not take seriously enough the depth dimension of religion, its defining nature as to what it means to be human. We may "engage" science as active participants in its investigative regimen or as casual observers and commentators of its grand theories, but religion is not something we "engage." As Christians, we may participate in religious practices and worship services, but life lived before the face of God is religion for everyone. We need to assume a stance which allows us to get beyond viewing a person as a Christian and as a scientist. Only then will we do justice to a person such as Charles Coulson who desired to live as a Christian scientist.

This brief historical analysis also raises a more interesting question: must religion involve a form of theism? If we insist on this definition, we will miss the religious dynamic in thinkers like Ostwald. For the atheist Ostwald, at least, we can see a concerted effort to eradicate traditional religion by a substitute scientific religion, an *Ersatzreligion* as he himself called it. Religion, for him, is not irrelevant. It does not function as a factor or merely provide a context. It is the very ground for scientific practice and life in its totality with presuppositions that have a religious character.

Both scientists concentrated on existing features and modes of reality: for Ostwald, physical interaction was fundamentally energy exchange; for Coulson, molecular models, imaginatively generated by scientists, were best described in applied mathematical language, not hidden in pure mathematical terms. For Ostwald, reality was equivalent or reduced to energy and its manifestations. He desired to remake a monistic energetic world. For Coulson, the reality of the givenness of God's incarnational involvement with creation ruled, even while designing intricate mathematical descriptions.

Each responded in their own way to creational revelation. Each translated that revelation in ways that were markedly different. For Ostwald, science rules as a secular religion giving meaning and purpose to life; for Coulson, science is a form of worship, a religious activity deeply empowered by personal acts of giving and receiving.

Notes

[1]Martin J. S. Rudwick, "Senses of the Natural World and Senses of God: Another Look at the Historical Relation of Science and Religion," in *The Sciences and Theology in the Twentieth Century,* ed. Arthur R. Peacocke (Notre Dame, IN: University of Notre Dame Press, 1981), 245.

[2]As examples, see John Brooke and Geoffrey Cantor, "Biographical Narratives," in *Reconstructing Nature: The Engagement of Science and Religion* (Edinburgh, UK: T&T Clark, 1998), 247–81; and Steven Shapin, *Never Pure: Historical Studies of Science as if It Was Produced by People with Bodies, Situated in Time, Space, Culture, and Society, and Struggling for Credibility and Authority* (Baltimore, MD: Johns Hopkins University Press, 2010).

[3]See the three papers by Robert J. Deltete, "Wilhelm Ostwald's Energetics 1: Origins and Motivations," *Foundations of Chemistry* 9 (2007): 3–56, https://doi.org/10.1007/s10698-005-6707-5; "Wilhelm Ostwald's Energetics 2: Energetic Theory and Applications, Part I," *Foundations of Chemistry* 9 (2007): 265–316, https://doi.org/10.1007/s10698-006-9025-7; and "Wilhelm Ostwald's Energetics 3: Energetic Theory and Applications, Part II," *Foundations of Chemistry* 10 (2008): 187–221, https://doi.org/10.1007/s10698-008-9053-6.

[4]Deltete, "Wilhelm Ostwald's Energetics 1," 6.

[5]Wilhelm Ostwald, "*Die Energie und ihre Wandlungen*," in *Abhandlungen und Vorträge* (Leipzig, Germany: Veit & Company, 1904), 205.

[6]Heinrich Hertz, "All physicists agree that the problem of physics consists in tracing the phenomena of nature back to simple laws of mechanics," *Die Prinzipien der Mechanik in neuem Zusammenhange Dargestellt* (Leipzig, Germany: J. A. Barth, 1894), vii.

[7]See Arie Leegwater, "The Development of Wilhelm Ostwald's Chemical Energetics," *Centaurus* 29 (1986): 314–37; and Arie Leegwater, "The Chemical Audience for Wilhelm Ostwald's *Energetik*," paper presented at the XVIIIth International Congress of the History of Science, August 1–9, 1989, Hamburg and Munich, Germany.

[8]One of Ostwald's American students, Joseph E. Trevor, who studied at Ostwald's Leipzig Institute in 1890–1892, echoes this thought:

> … in this matter we stand for conservatism. We must not countenance the wild hypotheses which have so often disfigured chemistry. Facts are the things with which we must deal, and we must deal with them rigorously. Hypotheses are to be used with the utmost caution and discarded whenever possible. ["The Fundaments of Chemical Theory," in *Journal of the American Chemical Society* 15 (1893): 430]

[9]Wilhem Ostwald, *Lebenslinien: Eine Selbstbiographie,* vol. 2 (Berlin, Germany: Klassing & Co., 1926), 160. For another translation, see Robert Smail Jack and Fritz Scholz, eds., *Wilhelm Ostwald*, Springer Biographies (Cham, Switzerland: Springer International Publishing AG, 2017), 232, https://doi.org/10.1007/978-3-319-46955-3_21.

[10]There is a tension in Ostwald's view of the relation of matter to energy. Do material objects *contain* energy or are they ontologically *nothing more than* energy complexes? For an excellent analysis see Deltete, "Wilhelm Ostwald's Energetics 2," 267–68.

[11]Leegwater, "The Chemical Audience for Wilhelm Ostwald's *Energetik*." A point of clarification: The development of Ostwald's thought about energy makes it imperative to say that the historiographic tradition which regards energetics as being equivalent to (or by definition, equivalent to) anti-atomism needs to be challenged.

[12]Wilhem Ostwald, "Studien zur Energetik (I)," *Berichte über die Verhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig. Mathematische-Physische Klasse* 43 (1891): 275.

[13]Ostwald's disenchantment with the kinetic molecular theory (viewing it only as a heuristic device) alarmed George F. Fitzgerald, an Irish physicist. He was genuinely concerned about Ostwald's influence: "There is considerable risk that others, chemists especially, may be carried away by the arguments of one whom they rightly value as a leader in their domain when he descants positively about the realm of mechanics" (Fitzgerald, "Ostwald's Energetics," *Nature* 53, no. 1376 [1896]: 441, https://doi.org/10.1038/053487c0).

[14]Wilhem Ostwald, "Studien zur Energetik [I]," *Berichte über die Verhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig. Mathematische-Physische Klasse*, 43 (1891): 271–88 [Reprinted in *Zeitschrift für physikalische Chemie* 9 (1892): 563–78]; and Ostwald, "Studien zur Energetik [II], Grundlinien in der allgemeinen Energetik," *Berichte über die Verhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig. Mathematische-Physische Klasse,* 44 (1892): 211–37. See 211 and 214. [Reprinted in *Zeitschrift für physikalische Chemie* 10 (1892): 363–86].

[15]Ostwald, "Studien zur Energetik [I]," *Berichte über die Verhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig. Mathematische-Physische Klasse* 43 (1891): 279–80.

[16]Wilhem Ostwald, "*Die Überwindung des wissenschaftlichen Materialismus*," in *Abhandlungen und Vorträge* (Leipzig, Germany: Veit & Company, 1904), 220–40.

[17]Jack and Scholz, eds., *Wilhelm Ostwald*, 242.

[18]Robert Deltete, "Helm and Boltzmann: Energetics at the Lübeck Naturforscherversammlung," *Synthese* 119, no. 1/2 (1999): 45–68, https://doi.org/10.1023/A:1005287003138.

[19]Leegwater, "The Chemical Audience for Ostwald's *Energetik*."

[20]Jack and Scholz, eds., *Wilhelm Ostwald*, 244.

[21]Roger Chickering, "Der 'Leipziger Postivismus,'" *Comparativ* 5, no. 3 (1995): 20–31, https://www.comparativ.net/v2/article/view/1442.

[22]Matthias Neuber, "Monism, Naturalism, and the 'Pyramid of the Sciences': Wilhelm Ostwald's Energetic Theory of Culture," *Historia Scientiarum* 28 (2018): 20, https://doi.org/10.34336/historiascientiarum.28.1_19.

[23]For an analysis of monism and its many manifestations in nineteenth-century Germany, see Todd H. Weir, *Secularism and Religion in Nineteenth-Century Germany: The Rise of the Fourth Confession* (New York: Cambridge University Press, 2014), 96–102, and the last chapter "Secularism in Wilhelmine Germany," 253–68. An earlier work edited by Todd H. Weir, *Monism: Science, Philosophy, Religion, and the History of a Worldview* (New York: Palgrave-Macmillan, 2012) is also valuable.

[24]See Wilhelm Ostwald, *Vorlesungen über Naturphilosophie* (Leipzig, Germany: Veit Verlag, 1902) and *Monistische Sonntagspredigten* (Leipzig, Germany: Akademische Verlagsgesellschaft, 1912). For an analysis of Ostwald's later influence, see C. Hakfoort, "Science Deified: Wilhelm Ostwald's Energeticist World-View and the History of Scientism," *Annals of Science* 49 (1992): 525–44, https://doi.org/10.1080/00033799200200441; and Jason Ānanda Josephson Storm, "Monism and the Religion of Science: How a German New Religious Movement Birthed American Academic Philosophy," *Nova Religio* 25, no. 2 (2021): 12–39, https://doi.org/10.1525/nr.2021.25.2.12.

[25]Jack and Scholz, eds., *Wilhelm Ostwald*, 236.

[26]Robert Sweetman, *Tracing the Lines: Spiritual Exercise and the Gesture of Christian Scholarship* (Eugene, OR: Wipf & Stock, 2016), 81.

[27]Jack and Scholz, eds., *Wilhelm Ostwald*, 236.

[28]Ibid., 244.

[29]See Richard M. Gunton, Marinus D. Stafleu, and Michael J. Reiss, "A General Theory of Objectivity: Contributions from the Reformational Philosophy Tradition," *Foundations of Science* 27 (2022): 941–55, https://doi.org/10.1007/s10699-021-09809-x; and D. F. M. Strauss, "The Significance of a Non-Reductionist Ontology for the Discipline of Physics: A Historical and Systematic Analysis," *Axiomathes* 20 (2010): 53–80, https://doi.org/10.1007/s10516-009-9081-4.

[30]For example, Victor Meyer thought that organic chemistry was "inspired by feeling and fantasy" rather than the "strict logic of physical chemistry," in Jack and Scholz, eds., *Wilhelm Ostwald*, 208.

[31]Roy Clouser, *Knowing with the Heart: Religious Experience and Belief in God (*Downers Grove, IL: InterVarsity Press, 1999), 24.

[32]Roy Clouser, *The Myth of Religious Neutrality: An Essay on the Hidden Role of Religious Belief in Theories (*Notre Dame, IN: University of Notre Dame Press, 1991), 18.

[33]Wilhelm Ostwald, *Lehrbuch der allgemeinen Chemie.* Zweite ungearbeite Auflage. II. Band, I. Teil: *Chemische Energie* (Leipzig, Germany: W. Engelmann, 1893), 471.

[34]David and Eileen Hawkin, *The Word of Science: The Religious and Social Thought of C. A. Coulson* (London, UK: Epworth Press, 1989), 24.

[35]Some recent publications displaying little, or perfunctory, mention of connections between Coulson's science and religion are Stephen G. Brush, "Dynamics of Theory Change in Chemistry: Part 2. Benzene and Molecular Orbitals, 1945–1980," *Studies in History and Philosophy of Science* 30, no. 2 (1999): 263–302, https://doi.org/10.1016/S0039-3681(98)00028-4; Kostas Gavroglu and Ana Simões, "Quantum Chemistry *qua* Applied Mathematics: Approximation Methods and Crunching Numbers," in *Neither Physics nor Chemistry: A History of Quantum Chemistry* (Cambridge, MA: MIT Press, 2012), 131–85. One exception is Ana Simões, "Textbooks, Popular Lectures and Sermons: The Quantum Chemist Charles Alfred Coulson and the Crafting of Science," *British Journal of the History of Science* 37, no. 3 (2004): 299–342, http://www.jstor.org/stable/4028426. Some publications that discuss the

science-religion interaction without mentioning the specific details of Coulson's science are Erwin N. Hiebert, "Modern Physics and Christian Faith," in *God and Nature: Historical Essays on the Encounter between Christianity and Science,* ed. David C. Lindberg and Ronald L. Numbers (Berkeley, CA: University of California Press, 1986), 424–47; David and Eileen Hawkin, *The Word of Science*; Alister E. McGrath, *The Foundations of Dialogue in Science and Religion* (Oxford, UK: Blackwell, 1998); and Peter J. Bowler, *Reconciling Science and Religion* (Chicago, IL: University of Chicago Press, 2001).

[36]J. W. Linnett, "Charles Coulson 1910–1974," *Chemistry in Britain* 11 (1975): 109.

[37]Coulson Address Box, Wesley House Archives, Cambridge, UK: "Giving and Receiving," A-94. 3.

[38]W. Harold Beales Papers, Wesley House Archives, Cambridge, UK: *A Group Speaks 1931*, 7–16.

[39]Coulson Address Box, "Giving and Receiving," A-94. 3.

[40]Coulson Papers [CP], Bodleian Library, Oxford, MS 19, A.19.1, "My Reactions at Home, June 1930," 1.

[41]Charles Coulson, "Contributions of Science to Peace," Alex Wood Memorial Lecture (London, UK: Fellowship of Reconciliation, 1953), 7.

[42]Charles Coulson, *The Spirit of Applied Mathematics* (Oxford, UK: Clarendon Press, 1953), 12.

[43]Mary Jo Nye, *From Chemical Philosophy to Theoretical Chemistry: Dynamics of Matter and Dynamics of Disciplines, 1800–1950* (Berkeley, CA: University of California Press, 1993).

[44]Kostas Gavroglu and Ana Simŏes, "The Americans, the Germans, and the Beginning of Quantum Chemistry: The Confluence of Diverging Traditions," *Historical Studies in the Physical and Biological Sciences* 25, no. 1 (1994): 47–110, https://doi.org/10.2307/27757735.

[45]Gavroglu and Simŏes, *Neither Physics nor Chemistry*, 191.

[46]Coulson, *The Spirit of Applied Mathematics*, 12.

[47]Charles A. Coulson, *Valence* (Oxford, UK: Clarendon Press, 1952), v.

[48]For a depiction of π atomic orbitals and π molecular orbitals, see Charles A. Coulson, "Quantum Theory of the Chemical Bond," *Proceedings of the Royal Society of Edinburgh Section A: Mathematics* 61, no. 2 (1942): 128, https://doi.org/10.1017/S0080454100006142; and Coulson, *Valence*, 224 and 226. Also see Gavroglu and Simŏes, "Quantum Chemistry *qua* Applied Mathematics," in *Neither Physics nor Chemistry,* 179. In the valence bond approach, molecules are viewed as aggregates of individual atoms, each linked to its nearest neighbor by bonds formed by electrons localized between two atomic nuclei. The number of bonds is equal to the element's valence or bonding capacity. The valence bond (VB) approach was vigorously promoted by Linus Pauling in the Department of Chemistry at the California Institute of Technology for two decades (1931–1951). Robert Mulliken in the Department of Physics at the University of Chicago published a number of papers during the same period but was not able to capture the attention of very many chemists. His approach was predicated on the belief that molecules were not what valence bond advocates thought they were. Molecules to Mulliken were not aggregates of distinct atoms, but things unto themselves, with their own behavior explicable only in molecular terms. Molecules can more profitably be considered as nuclei with binding electrons, these electrons being delocalized and spread throughout the whole molecule.

[49]Charles A. Coulson, "Quantum Theory of the Chemical Bond," *Proceedings of the Royal Society of Edinburgh Section A: Mathematics* 61, no. 2 (1942): 115.

[50]Gavroglu and Simŏes, *Neither Physics nor Chemistry*, 164.

[51]Ibid., 178–81.

[52]Coulson Address Box, "Giving and Receiving," A-94. 3.

[53]Ibid.

[542]S. L. Altmann and Edmund John Bowen, "Charles Alfred Coulson, 1910–1974," *Biographical Memoirs of Fellows of the Royal Society* 20 (1974): 84, https://doi.org/10.1098/rsbm.1974.0004.

[55]Coulson sensed a real mission to the "underdeveloped" world. He thought that the "overdeveloped" West bore special responsibilities, because it had the scientific know-how to help eradicate the immense problems of shortages of food, health care, and energy in the world. The West had to put its own house in order. His work as Chairman of OXFAM (1965–1971) and his work on the Central Committee of the World Council of Churches (1962–1968) give ample evidence of that conviction. During 1959–1960, he was Vice-President of the British Methodist Conference, the highest position a layperson can achieve in Methodist circles.

[56]Charles Coulson, "The Contributions of Wave Mechanics to Chemistry," The 1951 Tilden Lecture, *Journal of the Chemical Society, Part II* (1955): 2084, https://doi.org/10.1039/JR9550002069.

[57]Arie Leegwater, "Charles Alfred Coulson: Mixing Methodism and Quantum Chemistry," in *Eminent Lives in Twentieth-Century Science and Religion,* 2nd edition, ed. Nicolaas A. Rupke (Frankfurt am Main, Germany: Peter Lang GmbH, 2009), 73–103.

[58]Charles Coulson, *Christianity in an Age of Science,* Riddell Memorial Lecture (London, UK: Oxford University Press, 1953), 25.

[59]Christopher M. Rios, *After the Monkey Trial: Evangelical Scientists and a New Creationism* (New York: Fordham University Press, 2014) describes only Coulson's complementary view of science and religion on pages 87–89. Also see the exchange between Oliver R. Barclay and Coulson concerning the religious character of scientific practice discussed in Arie Leegwater's editorial, "On Boundaries: Let Science Be Science? Let Religion Be Religion?," *Perspectives on Science and Christian Faith* 61, no. 4 (2009): 209–10, https://www.asa3.org/ASA/PSCF/2009/PSCF12-09Leegwater.pdf.

[60]Coulson, *Christianity in an Age of Science,* 30.

[61]Ibid., 33.

[62]Charles Coulson, *Science and Christian Belief,* McNair Lecture (London, UK: Oxford University Press, 1955), 83.

[63]J. W. Linnett, "Charles Coulson 1910–1974," 109.

[64]Charles Coulson, "Science and Religion," *The Advancement of Science* 11 (1954): 332.

Walter Makous

Article

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Exponential Decay of Biblical Longevities

Walter Makous

The Hebrew Bible is often read that men once lived nearly a thousand years. Then, after a cataclysm in the form of a flood, their life spans followed an exponential decline to contemporary values, but no explanation for this decline was offered. Recently, it has been suggested that the decline can be attributed to marriage of the descendants of Noah to a population of short-lived survivors of the flood. This journal has previously published a paper that argued that the numbers expressing these longevities have the properties of real numbers and none of the properties of artificial or made-up numbers, and that the reasons for doubting the biblical numbers do not survive close examination. Moreover, recent work argues that humans may ultimately have biblical longevities. The present article shows that the intermarriage explanation for the decay of longevities is plausible.

Keywords: evolution, longevity, life span, Bible, negligible senescence

The Hebrew Bible, accessible as the Old Testament of the Christian Bible, reports that, early in history, men consistently lived an average of 912 years. Then the Bible reports that a cataclysm in the form of a flood killed everyone except for a single family consisting of a man (Noah), his wife, their three sons, and the sons' wives. After that, the life spans of those reported by the Bible decayed exponentially down to an asymptote of 71.7 years,[1] close to contemporary values. These longevities might be hard to accept, but a paper published in this journal argued that the numbers representing them have the properties of real data and none of the properties of made-up or artificial numbers.[2] The same paper continued that the reasons for doubting the truth of these longevities do not hold up to close examination.

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Mathematical Properties

The paper cited above starts by pointing out that natural data and manufactured numbers have different properties. The most important property of natural data is that they follow Benford's law,[3] a property that has been accepted in court to distinguish between real and falsified data.[4] Benford's law states:

> $Pd = \log_{10}(1 + 1/d)$, where Pd is the probability that the first digit of any number in a set of naturally occurring numbers is d.

For example, if we take the longevities cited in the Bible as a set of naturally occurring numbers, the probability that the first digit in any one of those numbers is 4 is $\log_{10}(1 + 1/4) = \log_{10}(1.25) \sim 0.0969$.[5]

The paper cited above shows that the biblical longevities follow Benford's law, but that they deviate from a uniform distribution,[6] and that they also deviate from the distribution of numbers offered by humans asked to produce random numbers.[7]

Natural data also represent systematic processes perturbed by random error, these perturbations tend to be mutually independent, and the distribution of the perturbations tends to be Gaussian. As reported by Makous, the biblical longevities have these properties of natural data.[8] One cannot say that these properties are inconsistent with all forms of fictional data, but they do strengthen the idea that the biblical longevities represent real instead of fabricated numbers.

Reasons to Doubt the Biblical Longevities

A principal reason for doubting such longevities is that they transcend our own experience: the longest documented human life span is 122 years and 164 days.[9] However, what limits life spans today need not always have done so. To take an example that illustrates the fact that a change of environmental conditions can dramatically affect the rate of aging, 60% of the cosmic rays that bathe the earth and damage our DNA arise from the afterglow of the monogem supernova, the effects of which reached Earth 86,000 years ago.[10] This particular event of course explains neither the magnitude nor the time course of the change in human longevities, but it is presented here to show that conditions that affect longevity can change.

Another reason for questioning the biblical longevities is that there is no archeological evidence for them. However, archeologists estimate biological age, not chronological age. The biblical life spans could have occurred only if they were associated with a retarded rate of aging.

Finally, there seems to be a dearth of reliable records of such longevities outside the Bible. However, the records that go back far enough in time actually do agree with the biblical longevities: the Roman historian, Josephus cited eleven specific authors to support the statement that, "All who have written antiquities … relate that the ancients lived a thousand years."[11] These sources are widely regarded as unreliable, but the principal reason that they are regarded as unreliable is that they seem implausible, which of course begs the question.

It is also relevant here that recent work supports the idea that humans might live to the advanced ages described in the Bible, though the emphasis of that work is on the future instead of the past.[12]

Explanations That Do Not Work

Explaining both the magnitude and the time course of the decay of longevities has been a challenge. Carol Hill attempted to resolve the problems posed by the long patriarchal longevities by denying their quantitative meaning. According to Hill,

> The key to understanding the numbers in Genesis is that, in the Mesopotamian world view, numbers could have both real (numerical) and sacred (numerical or symbolic) meaning. The Mesopotamians used a sexagesimal (base 60) system of numbers, and the patriarchal ages in Genesis revolved around the sacred numbers 60 and 7.[13]

Makous explains some of the problems posed by this approach.[14]

John Walton went more deeply into the differences between the Mesopotamian number systems and that in Genesis.[15] To reconcile the two lists of patriarchs, Walton made three changes: (1) he omitted some members from the biblical list to bring the number of patriarchs in the Genesis list into coincidence with that of the Mesopotamian list; (2) he ignored the clear statement in Genesis that the biblical longevities overlapped and instead treated them as though they were sequential, as the Mesopotamian list is; and (3) he translated the Mesopotamian longevities from a putative base 6 notation into the decimal system used in Genesis. Instead of comparing the resulting individual longevities in the two lists, he simply compared the total longevities of the two lists. When he did this, he found that the sums of the two lists of longevities were close (6695 versus 6700). Though they were not equal, he nevertheless treated them as though they were.

So, truncating one list to bring the length of the two lists into agreement, treating the list of overlapping longevities as though they were successive, and accounting for the putative differences in the base number led to two lists with nearly the same but slightly different sums. This led Walton to conjecture that the two lists have a common tradition. Readers may agree with me that such is not warranted by the evidence.

Taking a different approach, Fazale Rana and Hugh Ross have examined six variables that are known to extend life.[16] However, if all six variables work in humans as well as they work in the animal experiments, and if the effects are linearly additive, they collectively account for only 40% of the observed extension in longevities.

The Intermarriage Hypothesis

No acceptable explanation of the decline in life spans had been offered until Richard Fischer suggested that those who survived the flood can be separated into two populations:[17] (1) the descendants of Noah, who had slow aging and long life spans, like animals that exhibit *negligible senescence*;[18] and (2) a different population that were separate from Adam's descendants, who had more rapid aging and much shorter life spans. The purpose of the present note is to test the plausibility of this intermarriage explanation.

In the inheritance of polygenetic traits, such as longevity, it is equally likely that the traits of the mother and of the father will be inherited, so that the child of a long-lived parent and a short-lived parent will, on average, have equal numbers of genes for long life and for short life, and the expected longevity of the child is the mean of those of the two parents. This can be seen in any of the many recommendations for computing the expected height of a child from the heights of its parents.

Let us first consider the possibility that all Noah's descendants (the Bible treats only the longevities of males) married women who were not Noah's descendants. The Bible lists the life spans of 18 males distributed over 16 successive generations after the flood (see table 1). These are represented by the black symbols in figure 1 while the predictions based on wives not being descendants of Noah are represented by the white symbols. It is obvious that this theory does not fit the data. To fit, what is needed are generations with long life spans, to retard the decrease in life expectancies.

Perhaps some of Noah's descendants had mothers who were the progeny of Noah's other sons. For example, Noah's wife, the mother of his children, could have decreased the children's life expectancies if her own mother were not a descendant of Adam. That is, she was at least half a descendant of Adam, for Noah married the daughter of his cousin, who would have been Adam's descendant; but she might

Names	Generation	Theory	Data
Shem	1	720.9250000	600.0
Arphaxad	2	396.3125000	438.0
Sahal	3	396.3125000	433.0
Eber	4	396.3125000	464.0
Peleg	5	234.0062500	239.0
Reu	6	234.0062500	239.0
Serug	7	234.0062500	230.0
Nahor	8	152.8531250	148.0
Terah	9	152.8531250	205.0
Abram	10	152.8531250	175.0
Isaac	11	152.8531250	180.0
Jacob	12	152.8531250	147.0
Levi & Joseph	13	112.2765625	123.5
Kohath	14	112.2765625	133.0
Amram	15	112.2765625	137.0
Aaron & Moses	16	112.2765625	121.5

Table 1. Longevities of the Descendants of Noah

"Theory" is the longevity arrived at within the text; "Data" is the longevity reported in the Bible. The longevities listed for Levi and Joseph and for Aaron and Moses are the means of each of the two.

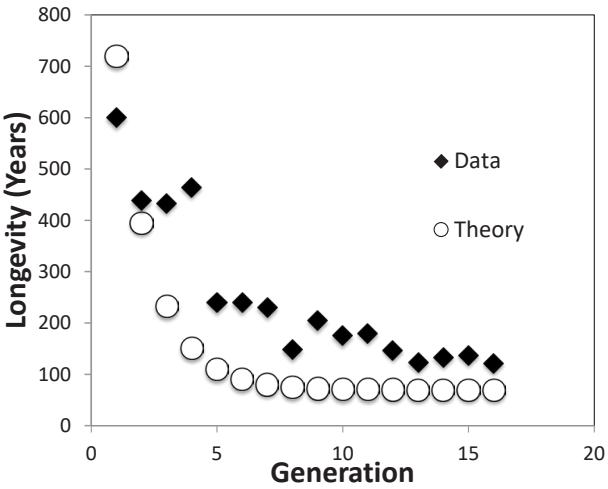

Figure 1. Longevities of Successive Generations after Noah's Generation: Mothers All Short-Lived. The black symbols represent the live spans reported in the Bible, and the white symbols represent the life expectancies based on the assumption that all males married short-lived women spared by the flood. The abscissae are the generation number minus the number of Noah's generation. Levi and Joseph were brothers, and so the life span of generation 13 is the mean of their lifetimes, 137 and 110 years, or 123.5 years; and Aaron and Moses also were brothers, and so the life span of generation 16 is the mean of their lifetimes, 120 and 123 years, or 121.5 years.

have had a mother who was not a descendant of Adam, which would make her own life expectancy equal to the mean of her father's long-expected longevity and her mother's short-expected longevity: (912 + 71.7)/2 = 491.85 years. Then the expected longevity of Noah's son, Shem, would have been the mean of Noah's life span[19] and that of his mother: (950 + 491.85)/2 = 720.925 years.

Let us assume that Shem also married a woman from the short-lived population. This corresponds to the statement in Jubilees that she had a name that was not of Adam's tribe (Sêdêqêtêlĕbâb).[20] So the expected longevity of Shem's son, Arphaxad,[21] would have been the mean of Shem's expected longevity and the expected longevity of this short-lived wife: (720.925 + 71.7)/2 = 396.3125 years. It would take about three more non-Adamic mothers to bring the expected longevity down to near 121.5 years, the life span at the end of this series of consecutive life spans.

The question, then, is where, in this sequence, those three short-lived mothers are most likely to have occurred. They would most likely be in the generations immediately preceding those in which the decreases in life spans are greatest. That would be generations 4, 7, and 12. The other generations would have mothers who are descendants of Noah's other sons, whose expected longevities are equal to those of Noah's descendants of the same generation. These theoretical longevities are plotted as white circles in figure 2, and the reported life spans are represented by the black symbols.

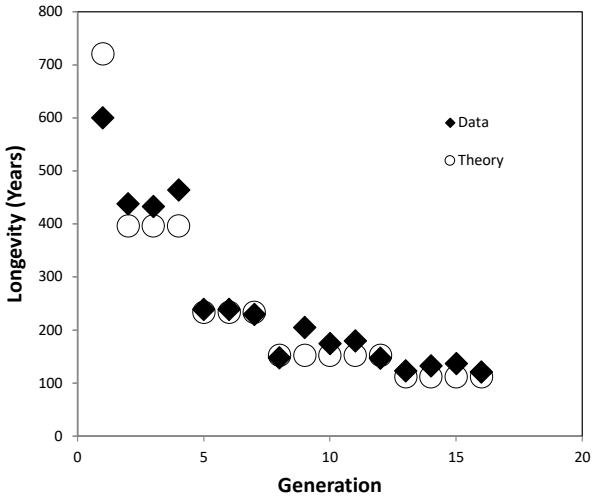

Figure 2. Longevities of Successive Generations after Noah's Generation: Mothers of Mixed Ancestry. The black symbals represent the life spans of successive generations after Noah, and the circles represent the theoretic values obtained by the assumptions in the text. "Generation" is as in figure 1.

These assumptions of course may err in several ways. For example, I assume that all descendants that are part of a given generation have the same expected longevities, and I assume that all the males—other than those of generations 4, 7, and 12—marry females of their own generation.

Nevertheless, these assumptions do account for 92% of the variance in this set of life spans. This does not prove the assumptions on which this finding is based, but this finding does show that these assumptions are among those that are possible. The importance of this statement is enhanced by the fact that they are the only assumptions that have been offered, to date, that do account for the data. Then this suggests that the decline in longevities of Adam's descendants following the flood could well be due to their occasional marriage with short-lived women left by the flood, as suggested by Fischer. It also somewhat strengthens one's confidence in the truth of the biblical longevities.

Notes

[1]Walter Makous, "Biblical Longevities: Empirical Data or Fabricated Numbers?," *Perspectives on Science and Christian Faith* 63, no. 2 (2011): 117–30, https://www.asa3.org/ASA/PSCF/2011/PSCF6-11Makous.pdf.

[2]Ibid.

[3]Alex Ely Kossovsky, *Benford's Law: Theory, the General Law of Relative Quantities, and Forensic Detection Applications* (Hackensack, NJ: World Scientific, 2015), 21; Mark Nigrini, "Digital Analysis Using Benford's Law: Tests and Statistics for Auditors," *EDPACS* 28, no. 9 (2001): 1–2, https://doi.org/10.1201/1079/43266.28.9.20010301/30389; and Frank Benford, "The Law of Anomalous Numbers," *Proceedings of the American Philosophical Society* 78, no. 4 (Philadelphia, PA: American Philosophical Society, 1938): 551–72, http://www.jstor.org/stable/984802.

[4]Kossovsky, *Benford's Law*; and Nigrini, "Digital Analysis Using Benford's Law."

[5]Benford, "The Law of Anomalous Numbers."

[6]Makous, "Biblical Longevities."

[7]Theodore P. Hill, "Random-Number Guessing and the First Digit Phenomenon," *Psychological Reports* 62, no. 3 (1988): 967–71, https://doi.org/10.2466/pr0.1988.62.3.967.

[8]Makous, "Biblical Longevities."

[9]Jean-Marie Robine and Michel Allard, "The Oldest Human," *Science* 279, no. 5358 (1998): 1834–5, https://doi.org/10.1126/science.279.5358.1831h.

[10]S. E. Thorsett et al., "Pulsar PSR B0656+14, the Monogem Ring, and the Origin of the 'Knee' in the Primary Cosmic-Ray Spectrum," *The Astrophysical Journal* 592, no. 2 (2003): L71–L73, https://doi.org/10.1086/377682.

[11]Flavius Josephus, *The New Complete Works of Josephus*, trans. William Whiston (Grand Rapids, MI: Kregel, 1999), 55.
[12]David A. Sinclair and Matthew D. LaPlante, *Lifespan: Why We Age – and Why We Don't Have To* (New York: Simon & Schuster, 2019).
[13]Carol A. Hill, "Making Sense of the Numbers of Genesis," *Perspectives on Science and Christian Faith* 55, no. 4 (2003): 239, https://www.asa3.org/ASA/PSCF/2003/PSCF12-03Hill.pdf.
[14]Makous, "Biblical Longevities."
[15]John K. Walton, "The Antediluvian Section of the Sumerian King List and Genesis 5," *Biblical Archaeologist* 44 (1981): 207–8, https://api.semanticscholar.org/CorpusID:164300791.
[16]Fazale Rana and Hugh Ross, *Who Was Adam? A Creation Model Approach to the Origin of Man* (Colorado Springs, CO: NavPress, 2005).
[17]Richard James Fischer, *Historical Genesis from Adam to Abraham* (Lanham, MD: University Press of America, 2008), 62.
[18]Caleb E. Finch, *The Biology of Human Longevity: Inflammation, Nutrition, and Aging in the Evolution of Lifespans* (Burlington, ME: Academic Press, 2007), 373.
[19]Genesis 9:29.
[20]*The Apocrypha and Pseudepigrapha of the Old Testament*, trans. R. H. Charles (Oxford, UK: Clarendon Press, 1913), scanned and ed. Joshua Williams, Northwest Nazarene College, Jubilees 7:16, http://www.pseudepigrapha.com/jubilees/7.htm.
[21]Ibid., Jubilees 7:18.

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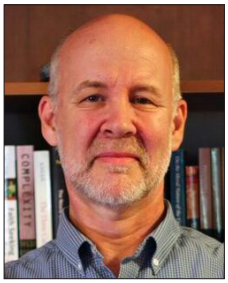

Chris Barrigar

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Evolutionary Accounts of Religion within a Christian Account of Big History

Chris Barrigar

HOW RELIGION EVOLVED and Why It Endures by Robin Dunbar. New York: Oxford University Press, 2022. xxii + 330 pages. Hardcover; $32.99. ISBN: 9780197631829.

EVOLVING BRAINS, EMERGING GODS: Early Humans and the Origins of Religion by E. Fuller Torrey. New York: Columbia University Press, 2017. 312 pages. Hardcover; $37.00. ISBN: 9780231183369. New York: Columbia University Press, 2019. Paperback; $24.00. ISBN: 9780231183376.

"Big History" is a mode of thought that seeks to integrate findings of the natural sciences, social sciences, and history into a coherent overarching story of the universe and of humanity. The humanity-related elements in Big History will necessarily include the emergence of "religion," including Evolutionary Accounts of Religion (EAR). Here we review two programmatic contributions to EAR, by Dunbar and Torrey, and then propose a theistic account of Big History through which to respond to their proposals. We accept their general argument that humanity's religious capacities have emerged through the evolutionary history of the Homo *genus, yet we offer a theistic alternative to their accounts of the evolutionary function of religion. We then argue for how one aspect of humanity's evolved religious capacities, namely the proclivity of the* Homo sapiens *brain to produce transcendent ambiguity (many gods, etc.), reflects not a flaw in God's design but an evolutionary outcome intended by God—to facilitate humanity's search for God.*

Keywords: cognitive psychology of religion, evolutionary psychology of religion, evolution of religion, origins of religion, evidential ambiguity, Big History, Dunbar on religion, design argument for God, signs for God, *sensus divinitatis*

Evolution is fundamentally a matter of biology, yet the concept of evolution is often applied analogously to other fields, including to the study of social phenomena such as religion. The notion that religious beliefs and practices (including those of Christianity) are outcomes of natural neural processes has been with us for some time through the discipline known as the cognitive science of religion (CSR). A rich and diverse literature has emerged in this field over the past quarter century—indeed, the field has become sufficiently mature that some even speak today of a "standard model" of CSR.[1] In more recent times, greater attention has been paid to the evolutionary processes behind CSR through a discipline known as the evolutionary psychology of religion (EPsR). Yet, the study of the human phenomena that are often collected within the label "religion"

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includes much more than just the relevant neural processes; it also includes practices of worship and ritual, of community formation, of leadership, and so forth. Whenever any of these phenomena, neural or behavioral, are studied from an evolutionary perspective—and such study has been increasing in recent years—these contribute to a wider category still: evolutionary accounts of religion (EAR).

Into this discussion come these two contributions: one by Robin Dunbar, emeritus professor of evolutionary psychology at the University of Oxford, and another by E. Fuller Torrey, associate director of research at the Stanley Medical Research Institute, Maryland. Both works are concerned to better understand the neural evolution of religious beliefs and behaviors. Dunbar's work is more thematic, addressing the evolutionary origins of such elements of religion as transcendence, trance states, ritual, shamanic religion, doctrinal religion, group sizes, and group division. In contrast, Torrey provides a more historically layered account of how such features neurologically evolved over the past couple of million years.

Dunbar is known as a key figure in the development of the "social brain" hypothesis—the idea that the *Homo sapiens* neocortex has grown to its current size, disproportionately large compared to other mammals, in order to handle the complexities of group relationships. His volume arises both from his many years of scholarship and from a three-year Templeton-funded project which he led. Torrey's work is older, published in 2017, yet it remains the most substantial work to date, describing how religious belief emerged through specific evolutionary stages over the past several million years.[2] Neither author is interested in simply surveying the state of the field in the evolutionary origins of religion—although both do provide a chapter overviewing different approaches in the field today. Rather, both authors seek to make an original contribution from their decades of scholarly expertise. Dunbar's volume is very accessible to nonspecialist audiences. Much of Torrey's book is also accessible, but his periodic detailed discussions of neural evolution require effort for nonspecialists. Both volumes are research laden, engagingly written, and well argued (even if one ends up disagreeing with a particular argument). Both present a constant flow of interesting material from the human sciences, most of which this review will be unable to mention, simply for lack of space. In short, although both have their respective deficiencies, and neither work should be taken as a general introduction to CSR,[3] I happily recommend both books to readers interested in the field.

For my purposes here, the value in reviewing these two works together is the helpful ways in which they potentially advance theological discussion in relation to CSR and EPsR. Regardless of their particular differences, Dunbar and Torrey together provide excellent representations of the evolutionary process, thereby prompting the sorts of theological issues I wish to address here. By placing this discussion within a Big History framework (as I will below), we gain additional conceptual resources in support of the coherence and explanatory power of Christian faith in our intellectual climate today.

Dunbar's Argument

I begin with Dunbar. His first three chapters describe what constitutes "religion," how to study religion, and why religion is beneficial to humanity. In chapter 1, he discusses current debates around the difficulty, even fallacy, of defining "religion," yet nonetheless he proposes his own "minimalist" definition of religion:

> … belief in some kind of transcendent world (that might or might not coincide with our physically observable world) inhabited by spirit beings or forces (that may or may not take an interest in and influence the physical world in which we live). (p. xvii)

Dunbar surveys various approaches to studying the origin of religion, including CSR and its interest in such neural features as theory of mind (ToM) and HADD ("hypersensitive agency detection device"). Nonetheless, while CSR "provides convincing explanations as to how human cognition underpins many aspects of religiosity … it overlooks … the core fabric of religion—in particular, ritual and the role of religion in creating communities" (p. 15). In effect, Dunbar's argument is that religion exists principally to facilitate community-cohesion because of the evolutionary and survival benefits that come with group living.

Chapter 2 identifies the origin of religion in what Dunbar calls "a feeling of divine transcendence from time to time"—or, as he prefers to call this feeling, "the mystical stance." The mystical stance is "the

motor of religiosity" (p. 48) and manifests itself in two stages: initially, as shamanic/immersive religion ("immersive" meaning ecstatic states, trances, and the like) among nomadic and pastoralist peoples; then, evolving from these, as doctrinal/institutional religions which eventually emerge within larger sedentary societies—although shamanic/immersive religion remains operative within doctrinal/institutional religion. Later chapters will have more to say about both of these.

Chapter 3 surveys "why believing might be good for you." Dunbar disagrees with those who argue that religion is an evolutionary spandrel or is evolutionarily maladaptive. "It seems to me that nothing which is so costly in time, emotion, and money as religion can possibly be entirely maladaptive or functionless" (p. 49). He identifies two *individual*-level benefits: "religion provides a *unifying framework for the world* … it allows us to make sense of our world in a way that enables us to function effectively because [religion provides resources by which] we can control [the world's] more erratic behavior"—such as by charms (protection from evil forces) and divination (future-telling) (p. 50; italics added); and religion also provides *health benefits*, providing cures for illness, including psychological illness (here Dunbar points to modern research showing the psychological benefits of religious belonging and practice). Dunbar says these individual benefits "are likely to have a direct effect on individual evolutionary fitness" (p. 55).

Religion also provides several *societal*-level benefits, which share the costs of survival and reproduction: "to benefit from the whole-is-greater-than-the-sum-of-its-parts effect that group living provides" (p. 55). Dunbar contends that this is the level at which we find the primary function or benefit of religion—*community bonding* or *cohesion* (he uses both terms). "[T]he benefits of cooperation … [are] the reason why religion became necessary: enforcing social rectitude may help to preserve the fabric of society for the other benefits that society confers" (p. 61). Consequently, the other (individual-level) benefits of religion "are secondary benefits once religion is in place" (p. 73).

Why the need for such cohesion or bonding? Because group living does not come easily to humans—"we are not naturally pro-social." Consequently, we need behavioral patterns that reinforce cooperation and protect us from cheaters and free-riders "lest crime and delinquency burst the fragile bonds that hold communities together" (p. 57). In effect, "The key to group living is cohesion" (p. 70), and religious practices, such as joining together in worship and the accompanying rituals, enhance social bonding and pro-sociality, even toward strangers. Research shows that "being actively religious increases people's willingness to behave altruistically … [and that] religiousness [does] seem to act as a guarantee of trustworthiness" (p. 59); these qualities are important for group cohesion.

The remaining chapters develop this thesis, that religion emerged for communal cohesion. Chapters 4–6 examine the evolutionary emergence of religion from psycho-neurological perspectives, while chapters 7–10 discuss the evolution of religion from social-historical perspectives. The latter four chapters provide different angles on the previous three chapters, as opposed to completely new topics; thus the chapters are thematically interwoven.

Chapter 4 considers the communities in which religious practices occur—churches, synagogues, and the like. Two questions arise here: the size of religious communities, and why they so-frequently fragment. Dunbar invokes research that indicates mammalian group size is limited by species' brain size. Correlations across species are considered, and the *Homo sapiens* brain size, which has evolved over millions of years for hunter-gatherer societies, predicts optimal human social network size to be about 150 to 175. This is why 150 to 175 also turns out to be the optimal size for religious communities.

Chapter 5 continues to discuss the brain, specifically to link three of his topics from previous chapters—brain size, group size, and the role of ritual. Monkeys, our primate cousins, can have groups of only about 50 before dividing, so how is it that humans can build groups in the 150 range before group size becomes too great to maintain cohesion? The answer lies in the evolution of neural bonding processes. For monkeys, their primary bonding method is grooming. The touch of their fingers as they groom each other triggers endorphins, which have two neurochemical roles: reinforcing the immune system, and creating bonded relationships. But the tactile closeness of monkey grooming is too intimate as a bonding mechanism for 150 or more humans in a group; so, in the process of evolving larger brains for managing the complexities of group relationships (the "social

brain"), part of this evolutionary process has been to develop endorphin-releasing mechanisms without the tactile intimacy of grooming.

Humans have developed a range of such behaviors ("grooming-at-a-distance"), including laughter, singing, dancing, emotional storytelling, feasting, and, most recently of all these, religion (religious rituals and religious story telling). However, Dunbar later notes that of these various grooming-at-a-distance behaviors, religious behaviors "seem to scale up [the bonded-group size] in a way that few of our other bonding behaviors seem capable of doing" (p. 261). Ritual has a particularly intense endorphin-releasing, and thus bonding, effect: an effect beyond even what these other behaviors provide, an effect equivalent to an intense romantic relationship. Thus, religions often use language of romantic or even erotic love to describe their encounters with the transcendent/spiritual realm.

Then Dunbar asks why it is that only humans have developed religion. His answer is that only humans have developed the capacity for "mentalizing" or "theory of mind" (ToM)—the ability to attribute intentionality (beliefs), distinct from one's own intentionality or beliefs, to the minds of others. Theorists describe modern *Homo sapiens* as capable of at least five orders (or "intentionality levels") of ToM. In first order ToM, the mind is capable of thinking "*I* believe such-and-such." In second order, "*I* believe *you* believe such-and-such." In third order, "*I* believe that *you* believe that *So-and-so* (a third person) believes such-and-such." And so forth, through levels four and five. Mentalizing serves the emergence of religion because religion is contingent on the ability to attribute intentionality to an unseen being (God, gods, angels, etc.) as well as to the beliefs of others (thus sharing beliefs, including religious beliefs, to form religious community).

Dunbar cites two situations in which diminished mentalizing (ToM) capacity produces people who are "less religious." One situation is that of autistic adults, who are "barely 10 per cent as likely to believe in God as neurotypical adults" (p. 121). The other is men vis-à-vis women on religious inclinations: "Men's lower mentalizing skills compared to women significantly predicted [men's] lower likelihood of believing in God … males were half as likely as women to believe in a personal God" (pp. 122, 123).

Chapter 6 explores ritual in more depth, with more attention to how participating in religious practices activates the endorphin system and thus enhances bonding with other participants. This discussion includes the neuroscience of "synchrony," in which participating in religious activities that involve group synchronous behavior (such as ritual, dancing, recitation in unison, chant, and the like) increases endorphin output, and thereby increases collective cooperation and cohesion. Other religious effects, such as out-of-body experiences and moments of intense meaningfulness, are also neurochemical effects, though related to serotonin rather than to endorphins.

Also essential to the emergence of religion has been the evolution of human-like speech mechanisms about 500,000 BP (years before the present), along with fourth-order intentionality in ToM (mentalizing) to enable beliefs about a spiritual realm; however, fifth-order intentionality is required for shared communal beliefs and would only have appeared with the appearance of modern humans about 200,000 years ago. "In other words, only modern humans could be meaningfully religious" (p. 170), because only modern humans have sufficient capability for language and fifth-order mentalizing.

Dunbar's remaining four chapters describe the social-historical evolution of religious neural states and social/ritual practices. He identifies four phases in this evolution, each of which "represents successive solutions to the stresses that arise as population sizes increase … solutions to the problem of social cohesion as community sizes became progressively larger over historical time" (pp. 260–61).

The first two phases he discusses in chapter 7 under the rubric of religion "Prehistory," the age of hunter-gatherers. Indirect evidence in the archeological record, such as trance-like cave art and psychoactive drugs (causing mystical trance-like experiences), indicates potential animist and shamanic religious practices before recorded history. On Dunbar's account, this first phase of religion conceived of a spirit world (though not of gods) and experienced trances and synchrony. In the second phase, still with hunter-gatherers, spirit beings become associated with illness, and thus arose the emergence of special healers, diviners, and shamans. Religion at this stage had little or nothing to do with morality.

Chapter 8 moves us from the Paleolithic hunter-gatherer age to the Neolithic period when farming and settlements appeared, about 12,000 BP. Living in groups and settlements larger than hunter-gatherer clans brought new challenges to group cohesion, including higher rates of intra-group homicide. Dunbar calls this the "Neolithic crisis"—how to inhibit internal stress, conflict, and violence within communities that shifted from nomadic life to sedentary habitation with hundreds, or eventually thousands, of residents.

Communities developed various strategies to solve this growth crisis, ensuring social cohesion within increasing populations, such as becoming socially stratified, shifting from democratic to hierarchical leadership, and transitioning to the third phase of religion, "characterized by local gods, more formalized rituals, ritual specialists (priests), and ritual spaces (temples)" (p. 257). In this phase, gods are typically many in number, although largely capricious or punitive rather than benevolent, and often require propitiation through ritual animal sacrifice. In this phase, rituals, including animal sacrifice, are particularly related to stratification, and the research is "very clear: animal sacrifice emerged *before* stratification. In effect, [the social cohesion provided by] sacrifice and its rituals … provides the gateway for increasing social complexity (and hence population size)" (p. 195; italics in original). Along the way, human sacrifice also emerged, although *after* stratification developed. Leaders justified human sacrifice as propitiating the angry gods, but its real purpose within the emergent social stratifications was to use fear to keep elites in power.

About 4,000 years ago, with the emergence of very large settlements and early cities, the fourth phase of religion began to emerge, with greater ritual complexity, priestly hierarchies, formal religious spaces or buildings, a theologically justified moral system, and a centralized bureaucracy to oversee both right doctrine and right behavior—all of which are absent from hunter-gatherer societies but all of which very rapidly appeared in urban settings during the course of the Neolithic Age (p. 188).

The emergence of moralizing high gods (MHGs) comes at a later stage within this fourth phase, during the so-called Axial Age, a period of about 600 years (800 BC–200 BC) when major religions emerge for the first time: Confucianism, Hinduism, Buddhism, Zoroastrianism, and Judaism (with Christianity and Islam emerging later from Judaism). Unlike capricious ordinary gods or high gods (who are mostly uninterested in human affairs), MHGs take an active interest in human behavior in order to "act as an all-seeing policeman in the sky … who punishes those who step out of line" (p. 58). That is, MHGs are "moralizing" in the sense that they "monitor what humans are up to and [monitor] religiously justified injunctions (such as the Ten Commandments)" (p. 193). In short, "organized religion seems to have been part of the machinery used to keep the lid on fractiousness so as to allow larger communities to exist … It is to ensure community cohesion for mutual protection that [moralizing] High Gods are necessary" (p. 194).

Nonetheless, Dunbar contends that cohesion is more effectively served by bottom-up means (such as ritual) than by top-down enforcement by MHGs; thus, MHGs should be seen as supplementing the role of bottom-up ritual in the job of collective bonding (p. 69). Regardless, overall "there is a natural progression from informal religions in small-scale societies to formal religions in large-scale societies as a way of managing the stresses involved [in maintaining cohesion within large-scale societies]" (pp. 190–91).

Chapters 9 and 10 continue to discuss dogmatic religion. Chapter 9 is concerned with charismatic leadership, the psychology of why people follow cult leaders, and why "most established religions" spawn cults "with puzzling ease" (p. 215). Chapter 10 addresses the observation that, despite the cohesion-strengthening capacity of doctrinal religion, doctrinal religion has, ironically, also produced much division and violence in history. "Deep down, religion is largely an emotional, not intellectual, phenomenon" (p. 244), and so large-scale religion taps into "the crowd effects of mass psychology [which] very easily escalate into religious conflict … However beneficial religion has been at the personal level, its ability to arouse crowd violence against members of other religions has been far beyond any secular philosophy's capacity to do so" (p. 265).

In conclusion, religion, underpinned by the mystical stance, has been important for human bonding in two ways: (1) "it triggers the neurobiological basis of social bonding, thereby creating a sense of commitment that no abstract ideological belief seems able to do"; and (2) "the religious dimension seems to scale

up in a way that few of our other bonding behaviors seem capable of doing" (p. 261). Along the way, religion provides other secondary benefits, such as improved psychological and physical health outcomes, yet can also cause division at large scales. "In short, it is difficult to see any convincing evidence for anything that will replace religion in human affairs. Religion is a deeply human trait … for better or for worse, it is likely to remain with us" (p. 268).

Torrey's Proposal

Now we turn to Torrey. As we will see, the two both complement and disagree with each other in important ways.

Torrey's volume is divided into two Parts. Part 1 ("The Making of the Gods") describes five preliminary cognitive stages hominins went through to reach the point of believing in gods. Torrey goes into detail describing the possible evolutionary neurological developments that made each of the five stages possible; however, for reasons of space, I will not describe these neurological developments here; I will only describe Torrey's account of the cognitive capacities and behavioral practices made possible by these underlying neurological developments. Torrey does argue that there is no single god part of the brain, "but there is a network that controls thoughts about gods and religious beliefs" (p. 9). This, Torrey calls "the network of the numinous," which is, in effect, his equivalent to Dunbar's "mystical stance."

The first stage on the way to human belief in gods Torrey calls "A Smarter Self." This refers to a period about two million years ago when *Homo habilis* emerged, with a significant increase in brain size and intelligence over predecessor hominins, in effect serving as "the starting gun for the human race" (p. 37).

The second stage Torrey calls "An Aware Self." This came about 1.8 mya with the emergence of *Homo erectus*, whose brain was considerably larger than previous hominins, including *habilis*. *Erectus* was the first to control and use fire, and the first to migrate and adapt to new climates and conditions, indicating increased levels of intelligence and cooperation over predecessors. Notably, *erectus* also developed a sense of self—the ability to "know that I exist" and to be the object of one's own attention, thus "An Aware Self."

Torrey's third stage, "An Empathic Self," comes about 200,000 years ago with archaic *Homo sapiens* (Neandertals and others), who developed the capacity for early forms of speech, and, as seen through paleo-archeological remains, exhibited empathic caring behavior toward others. Crucially, "Based on their caring behavior, it seems probable that … archaic *Homo sapiens* had developed a theory of mind" (p. 60). With archaic *Homo sapiens* emerges at least first-level ToM intentionality, in which "*I* think *you* are thinking such-and-such." Caring indicates first-level intentionality because it indicates the ability of one person to put themselves into the emotional (suffering) mind of another.

Beyond empathy, though, Torrey contends (as does Dunbar) that ToM is also a necessary precondition for belief in gods. "Creating gods and attributing to them theory of mind leads to several possible benefits" (p. 65), such as explaining the unknown features of life. Examples he gives include lightning (as the gods showing anger) and disease (indicating retribution from the gods). ToM is also necessary for later developments, such as attributing intentions about human punishment to the gods. Nonetheless, although first-level ToM emerged during this archaic *Homo sapiens* phase, it is unlikely that gods were conceived of at this stage, for religious belief still requires the remaining developmental stages to emerge.

Which brings us to the fourth stage, the emergence of early *Homo sapiens* about 100,000 years ago. This stage Torrey calls "An Introspective Self," reflecting the ability of a person at this stage "to objectify himself, to stand apart from himself, as it were, to consider the kind of being he is … and to reflect on their own thoughts" (p. 76). This was made possible through the emergence of second-order intentionality—the ToM ability to think about what the other is thinking *about me*. This new neural capacity for introspection led to a cascade of developments, including significant development in language, the ability to talk about oneself and one's own thoughts, and the emergence of self-adornment (which reflects thinking about what others think about me). This stage also produced more-advanced technology, the dead began to be buried, and clothing began to emerge in the form of fitted animal skins. "A new kind of hominin had clearly emerged" (p. 74).

Down the road, second-order ToM would have important implications for religion by providing an

ability "to think about the fact that the gods may be thinking about us, and [about] what the gods may be thinking [about us], and [about] what we think about what the gods are thinking about us" (p. 82). Nonetheless, even with second-order intentionality early *Homo sapiens* did not yet hold god beliefs—additional necessary developments were still needed.

These first four stages all took place in Africa. Then about 60,000 BP modern *Homo sapiens* left Africa, spreading relatively rapidly around the globe. Not long after, about 40,000 BP, Torrey's fifth stage emerged: "A Temporal Self." In this stage, cave art and material representation appears, technological innovation begins to gather speed, and autobiographical memory emerged—"an ability to project ourselves backward and forward in time" (p. 3), enabling both life-story composition from the past, and prediction and planning for the future.

Crucially for our purposes, with autobiographical memory, modern *Homo sapiens* became the first hominins to become aware of their own future death, and thus two particular experiences were now reflected on by the temporal self: dreams and death. Torrey notes various examples of this new concern with death: the "Epic of Gilgamesh," humanity's earliest recorded story, which was about seeking the meaning of death; the paintings at Çatalhöyük, Turkey, from around 9000 BP, that indicated death as a major theme with such images as "vultures with vast wings, their hooked and feathered beaks pecking at headless human bodies" (p. 152); and evidence at the British Paleolithic site at Avesbury, indicating that in the Avesbury community "death and the dead obsessed the living" (p. 189).

This fear of death became closely tied to dreams. People would at times experience dreams in which human souls would come to visit the dreamer, or the dreamer's soul would leave their body to go elsewhere. Such dreams fostered hope in the face of the fear of death so that from dreams "an idea slowly took hold that human spirits continue to live after the human body dies" (p. 119).[4] As this idea took hold in modern *Homo sapiens*, they also developed death practices such as interring grave items with bodies "so that those items will be available for use by the deceased in an afterlife" (p. 125). Notably, though, at this point the afterlife is not a place of judgment (everyone automatically goes there), and there are not yet any gods.

The emergence of autobiographical mind[5] 40,000 years ago had another crucial effect. For the first time, it prompted humans to start asking "meaning" questions, such as "Where did I come from?," "Why am I here?," and "What will happen to me after I die?" In effect, with autobiographical mind come "entirely new ideas … infinity, eternity, the meaning of life" (p. 112). With autobiographical mind also emerges another critical human feature—storytelling. This is the source of humanity's deep propensity to make sense of anything and everything through stories, such as stories about creation, about transcendent or supernatural beings (gods, goddesses, ancestor-spirits, angels, etc.), individual life stories, and eternal life stories.

We arrive then at Part 2, roughly 12,000 years ago during the late Paleolithic and early Neolithic periods, in which the gods finally emerge—in two stages. The first stage here (or the sixth stage from the time of *Homo habilis*) is the emergence of "a Spiritual Self," in which people began to worship (not just venerate) ancestors, believing that such worship could invoke beneficial responses from the ancestors being worshipped.

Ancestor worship may well have begun with hunter-gatherers, but it was facilitated further by the move to the Neolithic age of farming and the rise of settlements. When on the move, hunter-gatherers left their deceased where they died (whether buried or not), but as people settled, they began to consistently bury their dead, often inside their homes. As a result, in the Neolithic period "a concern for the deceased and one's ancestors was becoming more prominent" (p. 148). Consequently, between 10,000 and 7000 BP, we finally see the arrival of the gods, for some ancestors came to be seen as particularly powerful in their ability to assist the living, and these particularly important ancestors "crossed an invisible line and conceptually began to be regarded as gods" (p. 3). Torrey notes this idea is hardly new with him; he cites the Greek philosopher Euhemeros, who, 2,300 years ago, said that "gods were originally human rulers who were gradually deified by their subjects" (p. 156).

There is, as with each of Torrey's proposed stages, a neurological substrate to these developments. He comments that 20,000 or 30,000 years ago, "there was not yet a sufficient number of connections between the prefrontal cortex and other brain areas [for such

beliefs to form]. But by 11,000 years ago, these connections had developed, allowing for not only the cultivation of plants but the cultivation of the spiritual self as well" (p. 163).[6]

Some deified ancestors would become family or household gods. Others, though, would gain wider influence, becoming a local god. A particularly good farmer, or warrior, or leader, when they were alive, would come to be particularly associated with these capacities for their after-life contribution to their living descendants, and over time they were elevated to the status of a local or community god. Torrey observes that as groups of hunter-gatherers came together and settled in growing communities, "it would have been necessary to establish a hierarchy among the competing spirits" (p. 158). In effect, he says, as one moves up the continuum, one acquires more supernatural powers.

Ancestor worship was, however, not the only route to the emergence of gods, for Torrey also identifies a second route: "the worship of powers of fertility and yield, of the powers in nature ensuring human survival" (p. 167). Thus, nature gods arose, controlling the powers of nature, such as gods of the sun, the moon, water, wind, fertility, and the like. These gods not only explained observations in nature (such as the cycles of the seasons), but were also appealed to for positive influence in the lives of people, particularly to mitigate the harmful effects of nature. Yet the gods included a further function:

> More effectively than animal spirits or ancestor spirits, the gods provided answers for … philosophical questions … Why does the moon change shape? Why do the stars move? ... Why am I here? And especially, what will happen to me after I die? The presence of the gods has been enormously comforting as we have continued to dutifully cross the stage of life. (p. 195)

This brings us to Torrey's seventh and final stage in this journey of humanity's religious evolution. (To be clear, this is also the second stage of his Part 2.) This is the stage in which the High Gods appear, the gods of today's major religions. He calls this stage "A Theistic Self," which arises in the period between 6500 and 5000 BP. By 6500 BP, when the first written records appear, gods had already become numerous and high gods had also come along. As populations grew, cities, states, empires, and civilizations emerged, each with increasing complexity. Higher gods, with power over subordinate gods, emerged independently in regions as diverse as southwest Asia, China, and Peru. Torrey notes the correlation between "the size of a population and the type of gods that exist in that population": for instance, "between the size of societies (number of levels of political authority beyond the local community) and the existence of 'moralizing gods' (gods who tell the people what they should and should not do)" (p. 158). Thus, "from the very beginning [of emerging cities and states], the higher gods were associated with large populations" (p. 166).

Along the way, "the gods acquired political, judicial, and social responsibilities such as enforcing laws and providing shelter for orphan children" (p. 175). Conversely, at the same time, the emergence of local rulers, kings, and emperors led to some of these usurping some of the powers of the gods. In effect, just as some deceased ancestors had become divinized as gods, now some living human rulers became divinized likewise, taking on for themselves or conferred by the people, degrees of divine status and authority.

Then comes the final emergent piece of the theistic self stage: the Axial Age (so named by philosopher Karl Jaspers in that this period represented an "axis in history"). This 600-year period, beginning about 2,800 years ago, saw the remarkable flourishing of new and diverse religious ideas. At the beginning of the agricultural revolution there were an estimated five million *Homo sapiens.* By the Axial Age, this number had grown to between 200 and 300 million. Torrey comments,

> The original gods of natural forces, life, and death, that had been adequate 3000 years before, were no longer adequate for empires spanning millions of people in multiple ethnic groups. Just as governance had to be systematized to cover the new world order, so too did the gods and religions, since they are an integral part of such governance … Thus was born the "Axial Age." (pp. 197–98)

The Axial Age "was thus the culmination of a remarkable period in the evolution of *Homo sapiens*. In a mere 4000 years, the first [high] gods and civilizations emerged, spread rapidly, and were followed by the formation of all the world's major religions" (p. 201).[7]

One of the innovations of this period was monotheism—allegiance to a single high god, with no other co-reigning high gods and no secondary gods. This idea first emerges pre-Axial, around 1350 BCE (or 3350 BP) with the Egyptian Pharaoh Akhenaten who officially replaced the Egyptian pantheon of gods with one god—the sun god Ra, renamed Aten. This proved, however, very unpopular, and subsequent pharaohs re-established the old gods. The next recorded monotheism arises in the Axial Age, with Zoroaster (aka Zarathustra), who lived sometime in the early Axial Age. Zoroaster, living in Babylon (roughly today's Iran), took a local god, Mazda, from among the Babylonian gods, renamed him Ahura Mazda, and elevated him to the status of the only god (the other gods being reduced to spiritual beings).[8] Monotheism subsequently also emerged in the Axial period through the Hebrews and their Jewish descendants, though most other religions remained polytheistic. Torrey believes the emergence of high gods is an inevitable outcome of "Spiritual Self," but he does not comment in this regard on monotheism. It appears that for Torrey monotheism emerges simply as a variation of the "high god" concept.

Torrey concludes the book by asking whether gods are adaptively advantageous products of evolution, or just vestigial by-products of a primate mind. He argues for the latter: that gods are a by-product of our acquisition of autobiographical memory, and that religions followed the emergence of gods as populations increased and societies became organized. Moreover, "The history of *Homo sapiens* is littered with god contests … Such contests become especially dangerous when combined with apocalyptic beliefs about the end of the world as being glorious" (p. 221). Nonetheless, Torrey also contends,

> [H]umans need gods … [T]he human need for gods is an integral part of the brain networks that make us uniquely human … neither gods nor religions are likely to simply disappear anytime soon, even if they are no longer needed … Thus gods and their religions will probably continue to be born and die. (p. 221)

Comparison

It will be helpful now to draw some key comparisons between our two authors before moving to the theological issues they raise.

Dunbar and Torrey share two fundamental assumptions: an evolutionary account of the origins of religious beliefs and practices; and a materialist worldview—that, whether gods or God exist or not, neither gods nor God had anything to do with this evolutionary process. We will return to both these issues below.

Dunbar is thematically broader. Torrey focuses specifically on belief in gods, whereas Dunbar also discusses the evolution of religious practices, from ritual to prayer to leadership. Torrey provides a deeper dive on the neural evolution of god beliefs through each emergent Self stage over the past two million years, whereas Dunbar's descriptions of neural evolution feels a bit more *ad hoc*, but therefore thematically broader, as relevant to whatever religious topic he may be discussing—whether of belief or behavior. Both approaches bring a great deal of engaging research to their discussions.

As part of their shared evolutionary perspective, both authors agree that theory of mind and multiple levels of mentalizing had a central role in the emergence of religious belief. They don't necessarily agree on the number of levels of ToM, nor on the historical periods at which each level of mentalizing occurred, but this is no strike against either of them as our evidence for this will likely always be indirect: the thought processes of those who died in pre-history are not retained in their cranial fossils, and only circumstantial evidence of humanity's neurological development will ever be available to us.

Crucially, though, they disagree on the ultimate origins of religion. Dunbar offers a "social cohesion" account, undergirded neurologically by "the mystical stance," which arises from three potential sources: agency detection (e.g., HADD); mentalizing (ToM); and schizotypal thinking (arising from mental health issues, such as hearing voices with strange messages attributed to God). The first two of these three are well known in the CSR literature, the third (schizotypal thinking) is infrequently mentioned. Regardless, their ultimate evolutionary function is to produce social cohesion.

In contrast, Torrey offers his "response to dreams and death" account, undergirded neurologically by "the autobiographical mind." Dunbar's neurological description of "the mystical stance," including its attention to shamanism, trances, ritual, and medita-

tion, is significantly more developed than Torrey's few comments on "the network of the numinous," yet Torrey's neurological focus on the autobiographical mind and its concern with "dreams and death" is to my mind persuasive, and not addressed by Dunbar.

Unsurprisingly, then, our two authors also disagree on the evolutionary value of religion. Dunbar belongs, with others such as David Sloan Wilson and Ara Norenzayan, to the "adaptive" school. Specifically, for Dunbar religion is adaptive to environmental threats because religion triggers neurobiological processes for social bonding, and for scaling up cohesion more effectively than other human bonding behaviors. By contrast, Torrey belongs, along with others such as Pascal Boyer, to the "spandrel" school—that religion is accidental, originating as a non-adaptive by-product of evolution (namely of the evolutionary emergence of autobiographical memory). Torrey gives the impression that nonreligious people will just have to grudgingly put up with the continuing reality of religions.

Theological Issues

Readers will likely have a range of theological questions in response to the evolutionary proposals of Dunbar and Torrey. Christians familiar with CSR literature over the past 25 years are already familiar with ToM and agency-detection themes, and theological questions arising from these features of the brain have been addressed by Christian thinkers for some time.[9] Indeed, Christians have found CSR theologically helpful, supporting ancient Christian beliefs about innate human belief in God, such as Romans 1:19, Augustine's restless heart, Calvin's *sensus divinitatis*, Pascal's "infinite abyss that can only be filled by God," or, more recently, Plantinga's "properly basic belief."[10]

Nonetheless, Christian CSR discussions have paid less attention to the implications of *how* our "religious capacities" have evolutionarily emerged, and this diachronic perspective, as described by Dunbar, Torrey, and others[11] prompts additional sorts of theological questions.[12] Conversely, theology also raises challenges for EAR (and thus for EPsR and CSR). The questions that both sources of thought, EAR and theology, raise for each other are far too numerous to address in a single article. Therefore I will focus the remainder of this review on a particular question, namely, Why would God produce a neural system that produces such a plurality of transcendent-being concepts? This seems intuitively counterproductive to enabling humanity to identify and relate to the true God. In other words, why is "natural theology" (natural knowledge of God) so imprecise? I will seek to address this question through an intellectual project I will call "trinitarian Big History," along the way integrating human evolutionary history with some philosophical categories proposed by the Christian philosopher C. Stephen Evans.

My Presuppositions

I am bringing assumptions to this discussion. One is that all truth is God's truth, and so wherever the methodologies of science reveal truth, then in God's mind, and thus in our theology, these truths must somehow integrate with Christian belief. (This provides the epistemological basis for my theistic account of Big History below.) In addition, I also hold to the ancient notion that God has provided two books of revelation—scripture and creation—and these are to mutually interpret each other. Thus, if at times it feels difficult to fit Christian faith with findings of the sciences (natural or social), I see this as no different from the sorts of challenges that arise within science itself, such as the difficulty of reconciling general relativity and quantum physics: these appear to contradict each other at points and yet both are considered valid by physicists today, even though physicists are still trying to figure out how they fit together (the term "quantum gravity" is still a label without any consensus content).

When it comes to Christian faith and evolution, I have reached two positions: that the beliefs of orthodox trinitarian Christian faith are true; and that a macro-evolutionary account of biological evolution, including the so-called extended synthesis, is the most true account of biology currently available to us. To my thinking, these combine into the claim that God has created evolution as the process by which to bring about beings who bear the image of God and who are capable of *agape*-love relations with God and with others. I am further convinced that humanity is both the good creation of God and yet also corrupted (Gen. 6:12), and, as a result, humanity stands in need of God's redemption and transformation by the work of Christ (Phil. 2:9–11). Holding all these affirmations together means, in part, that it is consistent with orthodox Christian faith to suggest that God could

have designed an evolutionary process by which to bring about the emergence of cognitive capacities for "religion," in which the human/God relationship is located and practiced.

Consequently, I find persuasive the general picture Dunbar and Torrey provide of emergent religious capacities through evolutionary stages. This certainly does not mean either of them gets everything right,[13] but it does mean I would concur with their general principle that our "religious capacities" are complex (involving, for example, desires for transcendence, agency-detection, ToM, moral principles, attitudes of worship, ritual behaviors, and the like), and that these various capacities did not all appear at the same *de novo* moment in history but rather they accumulated in evolutionary stages (such as described particularly by Torrey) over millions of years, or even tens of thousands of years, depending on the particular neural feature. With these comments in place, we can turn now to Big History as the context for our evaluation of Torrey, Dunbar, and EAR/EPsR.

Trinitarian Big History

"Big History" is the term used to describe "a new disciplinary field of scholarship that studies the past at all possible scales. Its approach is historical, but it links disciplines from cosmology to geology to evolutionary biology and human history."[14] While the Big History project has produced a number of popular best sellers,[15] it also has its critics, who argue, for instance, that some Big History authors fail to meet scholarly standards of historical methodology, such as by making claims that are overly confident in their speculative historical reconstructions, or excessive in their sweep. There is also the long-standing post-modernist criticism of "grand narratives," that they are written by elites and thus risk marginalizing those without a voice to tell their part of the story.

I would contend that these are good reasons to be alert to risks in the project, but not reasons to avoid the project. Indeed, the Bible itself may be understood as an ancient version of Big History! In contrast to the Bible, though, the standard Big History literature today is written from a materialist (atheistic) interpretation. For Christians, though, who consider the supposed "objectivity" or "neutrality" of materialism to be fallacious, to engage in a trinitarian account of Big History—one that accounts for both scripture and our fields of knowledge today—could be an important intellectual project for our times. But what would trinitarian Big History look like?

I have provided just such an account, at least by implication, in my "*agape*/many-routes" (AMR) account of God's design of the universe. (An earlier version has been previously published in this journal as the "*agape*/probability account" of God's design.)[16] Here it will be helpful if I give the core proposal of the AMR account, providing a trinitarian *telos* for creation, and thereby a framework for theistic Big History:

> The trinitarian God of *agape*-love created the universe(s) to provide the space and conditions for the emergence of habitable bio-niches (planets, moons) on which *imago*-bearing *agape*-capable beings could emerge with high probability over sufficient time (billions of years), through many potential evolutionary routes—all this in order for such beings to live in *agape*-love relations with God and with each other, and to live out their *imago*-bearing vocation. Earth is one such emergent bio-niche, and *Homo sapiens* are an instance of such emergent *imago*-bearing, *agape*-capable beings.[17]

The full account in the original article includes addressing how such features of the universe as massively large numbers, self-organizing emergent complexity, stochasticity (randomness and probability), evolutionary convergence, and the statistical possibility of life elsewhere in the universe are not merely interesting features of the universe. Rather, such features are essential elements of God's design contained within the initial conditions of the universe, the unfolding of which, over billions of years, would bring about, through many potential evolutionary pathways, the eventual emergence of *imago*-bearing *agape*-capable beings.[18]

Thus, the AMR proposal provides an account of the divine *telos* behind creation, as well as an account of how the statistical features and physics of the universe serve to achieve that *telos*. It also removes any God-of-the-gaps charges because all the physics and information needed for this system to successfully unfold is front-loaded in the Big Bang (or earlier)—there are no gaps in the process that God needs to conveniently fill in along the way (though there are certainly gaps in our knowledge of the whole process). Yet the AMR account provides more than this. In effect, it also provides a framework within which

the findings of Big History through methodological naturalism can be integrated into a theistic, rather than naturalistic, account of Big History. In other words, the AMR account enables the integration of any truth from any scholarly discipline—including the formal sciences (mathematics and statistics), natural sciences (physics, cosmology, chemistry, geology, biology, zoology), social sciences (sociology, psychology, and anthropology, including paleo and evolutionary subdisciplines), and human history—into the divine story of creation, from God's launch of the universe (the Big Bang) until the emergence of *imago*-bearing, *agape*-capable beings anywhere in the universe, including *Homo sapiens* on planet Earth.

Trinitarian Big History will include, however, one more critical feature—God's action of choosing to break into time and space by becoming *incarnate*. Whether God does this on all planets where *agape*-capable beings emerge (if such beings do emerge elsewhere in the universe) we can only speculate.[19] However, we do know that God has done this, at the very least, on our planet Earth, through Emmanuel, God with us in *Homo sapiens* form at a particular place and time in Jesus of Nazareth, in order to demonstrate to *agape*-capable-but-sinful beings on Earth what constitutes God's *agape*-love, to teach humanity the two great love imperatives ("Love the Lord your God with all your heart, mind, soul, and strength," and "Love each other as I have loved you"), to achieve atonement, and to change the world through resurrection.

An important effect of theistic Big History is to change how we interpret evolution—not in terms of how evolution works but in its purpose. Materialism argues that evolution serves only two purposes, or "functions": survival and reproduction. In contrast, the AMR account argues that since there is divine purpose in creation, and thus in evolution, survival and reproduction are *subsidiary* purposes (or *supportive* purposes) to God's ultimate purpose for evolution—that *agape*-capable beings would flourish in their *agape*-relationality and in their *imago*-bearing vocation.[20] A *telos* of flourishing in all *agape* and *imago* dimensions is a vastly richer account of the purpose of evolutionary processes than the ultimately nihilist survive-and-reproduce reductionism of materialist accounts, including those of Dunbar and Torrey.

Moreover, our *agape* and *imago* capabilities are not the whole of our relationship with God, for this relationship also includes *practices*—practices of private and public worship and ritual, of community life, of moral behavior, and so forth. Yet here an important observation arises: that capacities for such practices do not arise just with Christian faith, but that they are found throughout all humanity. To understand the emergence of humanity's *agape* and *imago* capacities and practices, it is helpful to attend to the emergence of humanity's disposition to "religion" more broadly. The human sciences, particularly anthropology, psychology, and sociology, demonstrate in their respective ways how deeply inherent to human nature are our religious dispositions. So, theistic Big History will need to include an account of the emergence of "religion" at large in human history. Here then I will address two questions within theistic Big History: the evolutionary function of religion (including EAR/CSR); and the question of why God would create a system that produces such wide religious plurality as we see within humanity, including plurality of transcendence beliefs—that is, why God would create a system which so ambiguously points us to God.

The Evolutionary Origins of Religion

There is heated academic debate about the evolutionary function of religion; that is, whether religion is fundamentally an adaptation (benefiting our ability to survive and reproduce), a spandrel (a neutral side-effect of other evolutionary adaptations, as dancing is a neutral side-effect of having legs), an exaptation (a spandrel that becomes adaptively useful, as dancing well can attract a mate), or a maladaptive liability. As we have seen, Dunbar takes an adaptive position, while Torrey takes a spandrel position.

The problem with such discussions, however, is that they assume that "religion" has an essence, and so they discuss the evolutionary function of religion in relation to that essence. Yet many religion scholars today argue that "religion" has no essence.[21] Rather, "religion" is merely a catch-all term, simply a convenient way to refer to a wide range of related phenomena, whether these be beliefs, intuitions, dispositions, and/or practices. But drill down not too far below the surface and disagreement arises very quickly on what human phenomena actually belong to "religion." It is no wonder that no two definitions are the same, and yet essentialism easily becomes a default assumption. Indeed, we see the difficulty of

avoiding essentialist thinking in Dunbar, who begins his book by identifying current debates around the fallacy of defining "religion" with some sort of universal definition, yet nonetheless goes on to propose his own "minimalist" definition: this then functions as an essentialist definition for the remainder of his work.

I concur with the non-essentialists, that "religion" is too diverse and amorphous a concept to possess any essence—it is a term of convenience, not precision. This subtle distinction becomes important when it comes to the question of the evolutionary function of "religion." Scholars who argue that "religion" is either an adaptation, maladaptation, spandrel, or exaptation are making the essentialist error. Torrey prompts us to attend to humanity's evolutionary stages, helping us recognize that the sorts of human features (beliefs and practices) that scholars include under the rubric "religion" have arisen at varying periods over very long periods of time. This implies that each of the emergent features associated with "religion" need not have emerged for the same evolutionary function. That is, a feature that emerged a million years ago, and a feature that emerged 100,000 years ago, and a feature that emerged 10,000 years ago need not all have arisen for the same evolutionary function. Consequently, the many sorts of beliefs, intuitions, dispositions, and practices that get collected together under the term "religion" may have differing origins. Some may have been adaptive at their origin, others may have been maladaptive, still others may have emerged as spandrels, and still others as exaptations. Therefore, to make such generalized claims as "religion is adaptive by encouraging group cohesion" (Dunbar) or "religion is a spandrel side effect of fear and dreams" (Torrey, failing to recognize the non-essentialist implications of his evolutionary account) is to fallaciously homogenize the many features of humanity that get clumped together within the label "religion." I would contend that this explains why there is so much disagreement on the evolutionary origins or function of "religion": it is a failure first to recognize that "religion" is a non-essentialist term, and a failure secondly to discuss it as if it were a non-essentialist term.

Consequently, a Big History account of the evolutionary emergence of "religion" should first recognize that "religion" is a non-essentialist term; then identify the many human features and phenomena that get included within the term "religion;" then identify when each emerged in human evolutionary history (at least to the best of our inductive abilities, from the paleo sciences); and, finally, identify their respective evolutionary functions, whether as adaptive, maladaptive, spandrel, or exaptation. Here, however, I do not have the space for such an undertaking, and such an undertaking will always produce hypothetical reconstructions at best—though any Big History will always need to include hypothetical reconstructions to a significant extent. But for theistic Big History, following any such reconstruction, we then need to ask, *Why* would God produce a system with such incredibly diverse features as we find in the world's religions? I have not the space here to give a full answer, but nonetheless, in the remainder of this review, I will provide some direction to an answer by focusing on just a single feature of "religion," namely, "transcendent-being" beliefs.[22]

Why Such Diversity of Transcendence Beliefs?

Theistic Big History will need to include an answer to this question: Why has God designed an evolutionary system by which the human brain has evolved to produce a plenitude of "transcendent-being" beliefs—gods, goddesses, demi-gods, ancestor-spirits, nature-spirits, and so on? I will call this the question of *metaphysical ambiguity* (or, equally, *metaphysical plurality*). Ancient history and paleoanthropology reveal at least five very different clusters of transcendence-beliefs that have emerged over the last several thousand years: *Animism* (divine spirits in all of nature), *Polytheism* (gods and goddesses), *Impersonalism* (nonpersonal forces such as the Dao or karma), *Monotheism* (a single god or Creator Mind), and *Pantheism/Panentheism* (a single god and the universe together form some sort of unity). Yet, even within each of these clusters, there are multiple versions of what is believed, including different accounts of an ultimate single transcendent being, ranging from Brahman of Hinduism to Ahura Mazda of Zoroastrianism, to Allah as conceived by Islam, to the trinitarian God of Christianity.

Intuitively it can seem odd that God would intentionally create a system with such metaphysical ambiguity. As Thomas Aquinas put it in the thirteenth century, "To know in a general and confused way that God exists is implanted in us by nature." As mentioned earlier, Christians engaged with CSR over the past 25 years have frequently suggested that CSR

provides a satisfying explanation of Romans 1:19 (the natural knowledge of God within us) and of Calvin's *sensus divinitatis*. While I fully concur with this, the critic may still respond, "Surely God would want to ensure that humans have a more precise neural capacity for identifying God than one with all these 'confusions,' metaphysical ambiguities, and mis-readings of the divine. So, either God is a failed designer, thus not worthy of our devotion, or there is no God."[23] In other words, why would God create a system in which our neural processes are only roughly tuned, prompting beliefs in a wide range of transcendent-being possibilities, rather than being much more finely tuned in order to pick out the actual metaphysical/divine reality?

An immediate answer for some theists involves a combination of "free will" and "sin"—that God created a system that would give people free will to believe what they want, but that, in their sinfulness, they create false gods. In effect, God created a system that permits both free will and rebellion against God, including space to create false gods or misconstrued metaphysics. But this response does not actually answer the question, for even with free will, could God not have given humans a more precise neural capacity than we actually have by which to identify God?

I want to suggest that the answer involves how God desires to be sought—that is, the sort of evidence for God that God intends creation to possess, and the sort of neural capacities we need in order to recognize that evidence. To address this, I want to invoke the Christian philosopher C. Stephen Evans, who makes an argument which proves very helpful when integrated with our evolutionary story. Evans is concerned to understand the divine principles underlying our natural knowledge of God ("natural theology"). A brief and simplified description of his formal argument goes as follows.[24]

Evans holds that God has built the world with signs pointing humanity to God. There are many such signs, though Evans identifies five signs as particularly significant: the experience of cosmic wonder, the experience of purposive order, the sense of being morally accountable, the sense of human dignity and worth, and the longing for transcendent joy. Crucially, such signs "are not intended to give us an adequate knowledge of God. They are intended only to give us a sense that there is more to reality than the physical world. They are signs that prepare us to encounter God's self-revelation" (p. 36). That is, they point us *away* from naturalism, *preparing* us for encounters with God.

Evans then argues that signs achieve this by fulfilling two underlying principles. First, because God desires a relationship with every person, Evans argues that God would provide evidence, or signs, for himself that would be widely available to humanity at large. Evans calls this the "wide availability principle" (WAP). That is, God desires to be in mutual relationship with all humanity, and so God would make evidence or signs of himself widely available to humanity—and these five signs (along with others) are indeed widely available because they are widely found among humanity at large.

At the same time, God desires a certain *type* of relationship with people—one in which people are motivated to believe and to enter a relationship with God by love of God's goodness, rather than by coercion or fear. If God's omnipotence and omniscience were too obvious, it would undermine this goal by, in effect, coercing belief by God's sheer overpowering presence. "God would not force his knowledge on those who do not wish to know God … Such signs … point to God in a way that allows those who do not wish to believe in God to reinterpret or dismiss the sign."[25]

So, to ensure that people are attracted and persuaded through their own free will, and not epistemologically overwhelmed and thus coerced, the evidence for God needs to fulfill a second criterion, namely, to be

> the kind of evidence that a person who wished to do so could dismiss or reject. [Consequently, Evans continues,] We might expect the evidence to have a degree of ambiguity, to be such that it could be reinterpreted or explained away by those who do not wish to believe in God … The evidence would then be *easily resistible*, even though widely available.[26]

Evans calls this the "easy resistibility principle" (ERP). Indeed, his five signs meet this "easily resisted" criterion, for we see that people do indeed easily resist them by choosing materialism or agnosticism over the theism to which they point.

In sum, WAP and ERP together argue that signs pointing to God must be sufficiently *widely available*

that the vast majority of people have access to them, sufficiently *strong* that they point humanity away from naturalism by prompting humans to consider the possibility of God and thus to seek this God, yet sufficiently *weak* that they do not "prove" God (since "proof" would be epistemically coercive), and thus *resistible*.

Here we need to note a dual aspect to Evans's account of signs, to which I think he pays insufficient attention. Intuitively, one thinks of signs as external to the mind, such as a highway sign, or, say, evidence of a crime (which counts as a sign, pointing to a criminal who caused that evidence). So, unsurprisingly, Evans points to signs of God which are external to the mind: "God has made certain features of the natural world, such as beautiful sunsets or magnificent ocean or mountain vistas, with the intention that those features be signs that point to him" (p. 33).

Yet the five signs that Evans considers most significant are, to my perception, all internal to the mind. His first two, cosmic wonder and purposive order, are indeed triggered by external signs (the universe itself and order in creation), yet wonder and perception of order are, in fact, neural operations, as are the other three as well—sense of moral obligation, sense of dignity, and longing for transcendent joy. In other words, we need to note more strongly than Evans himself notes, that the notion of signs pointing us to God includes neural operations; indeed, it is the interior/neural signs Evans considers most significant.

For those five major signs (which I have called "internal/neural" signs), Evans asserts that God could have produced them by an evolutionary process, yet he provides no discussion of *how* evolution could produce them. And so here we arrive at a very helpful confluence of Christian philosophy with CSR, namely a confluence of divine design (as understood through Evans's WAP and ERP principles) with evolutionary psychology of religion (such as described by Dunbar and Torrey).

So let us unpack this confluence. From the CSR literature in recent years, we can identify at least four neural sources that prompt belief in transcendent beings: *Agency-detection* (e.g., HADD—particularly in children but also in adults);[27] *Mentalizing* (ToM); *Causality-seeking* (not only the cause of objects in the world but also the ultimate origins of everything); and *Telos-attributing* ("promiscuous teleology," the inclination to see purposeful explanations behind non-understood phenomena).[28] Employing stages of evolutionary emergence, agency detection emerged first (as HADD to detect predators); ToM emerged next (over several evolutionary stages); then causality-seeking and *telos*-attributing both arose with the emergence of autobiographical mind. Yet also with the emergence of autobiographical mind, the earlier two features (agency-detection and mentalizing) were "recruited" (or exapted) for an additional function (beyond their original evolved functions), namely prompting human minds to posit transcendent agency and transcendent mind. Collectively I will call these four features "neural transcendence-positing dispositions" (NTDs).[29]

Importantly, while these four NTDs qualify as Evans-type neural signs, none of them emerged specifically to point to God; rather, positing transcendent states and transcendent beings are among the range of applications to which each of these evolved neural functions can be put. It appears then that God's design strategy by which to create the conditions for "natural knowledge" of God (neural pointers/signs) was not that a God-specific part of the brain would emerge through evolution (indeed, neuroscientists now confirm that there is no God-specific part of the brain), but rather, that a range of neural features would evolve that include pointing to transcendence within their range of application. In effect, God has chosen a system by which our brains point us to God, not by a God-specific neural feature resulting from direct evolutionary selection, but rather, by multiple evolved neural features having the capacity to prompt transcendence-pointing ideas. For convenience, let us call this "NTDs by evolutionary side-effect" rather than "NTDs by evolutionary selection."[30] NTDs by side-effect may seem an unexpected strategy, but we will see there is good reason for this strategy.

So now let's connect the NTDs with Evans's two divine principles. In terms of wide accessibility, the NTDs are found universally in humanity (neural damage excluded); thereby meeting the wide accessibility criterion. They may, however, be suppressed by environmental factors. As one reviewer of this article has pointed out, NTDs are not only easily resisted but also easily "blanked out before we are even aware of them."[31] In "predictive brain" theory, this "blanking out" can occur through the

operation of "top-down" contextual factors such as culture or nurture. (A "nurture" example here would be Sy Garte's story, that his parents "indoctrinated him against a faith they had no actual knowledge of.")[32] Regardless of whether they are suppressed, or blanked out, by culture or nurture, NTDs remain widely found throughout humanity. Moreover, wide accessibility could also account for why God would employ a multiple NTD-producing system (in which at least four NTDs have emerged)—multiple NTDs provide built-in redundancy so that at least some NTDs might remain operative in face of neural damage or contextual suppression. And as we are about to see, each NTD points to a different facet of divine transcendence.

In terms of NTDs being strong enough to dispose humans to consider the possibility of God, that is precisely what the NTDs do, by pointing us to different facets or aspects of transcendence. *Causality-seeking* intuits or posits the possibility of an ultimate *Creative Source* of everything (whether creator gods or a single creator god), leading more formally to cosmological arguments for God. *Telos-attributing* intuits or posits that the Creative Source possesses rational purpose for creating the objects we observe, objects ranging from geological forms, to life-forms, to the whole universe—leading more formally to teleological arguments for God. *Agency detection* attributes agency to this Creative Source *in the present* (in contrast to, say, Deism, which posits a Creative Source without agency in the present)—leading not to particular arguments for God but to a particular characteristic of God, namely, as "involved in the world" (unlike, say, Deism or Brahman). *Mentalizing* (ToM) attributes *relational intentions*, such as beneficence, responsiveness to prayer, or punishment, to this Creative Source. Collectively, these four dispositions or pointers nicely fulfill both the "wide availability" principle (being widely found among humanity) and the "strength" principle (strong enough to point a large portion of humanity to posit the existence of transcendent being).[33]

Yet, at the same time, in terms of the ERP requirement, we see that these four dispositions are also *easily resistible*, in the sense that it is easy for a person to resist interpreting them as pointing to a Creator God. Here we see why God may have chosen to produce NTDs by evolutionary side effect, rather than by a more direct means (such as a God-specific part of the brain being evolutionarily selected)—namely, that "side effects" are probably easier to resist than a hard-wired evolutionarily selected circuit.

That the NTDs are easily resisted is seen in that they so readily prompt people to posit other types of metaphysical states and transcendent beings (polytheistic gods, different types of monotheistic gods, pantheism/panentheism, and so forth). They are also easily resisted by those who deny transcendence altogether, arguing, for instance, that gods or God are projections of human qualities or otherwise figments of the imagination.[34] In other words, the NTDs remain sufficiently vague in identifying the transcendence to which they point that, on their own, they produce significant *metaphysical ambiguity*, including polytheisms, monotheisms, and even atheism (though atheism is a more recent human invention, and a small-minority position within humanity, so that atheism appears to take extra effort). So, the content of these dispositions is vague and rudimentary, thereby providing easy resistibility. Yet this content is still sufficient to achieve God's desired objective—to point away from materialism and toward transcendence, thereby prompting individuals to further seek this transcendent source.

It turns out then that both divine principles—easy resistibility and wide accessibility—are successfully fulfilled by our neural evolution as identified by EPsR and CSR. In turn, this answers the critic's challenge, that God's divine design has worked poorly because our brains and their cultural contexts produce so many different metaphysical beliefs.[35] For, in terms of *how* God desires to be sought, the design has worked perfectly to fulfill God's intended WAP and ERP principles. To recall our earlier quote from Evans, "The natural signs, then, are not intended [by God] to give us an adequate knowledge of God. They are intended only to give us a sense that there is more to reality than the physical world … They are signs that prepare us to encounter God's self-revelation" (p. 36).

The next step, then, in the story painted by trinitarian Big History is not another neural evolutionary stage. For within God's design, the process of evolutionary biology has done its job. Rather, the next step has been God's own response to humanity's NTD-motivated searchings. That is, the next step is God's self-revelation in history, whereby God, the One who created this evolutionary meaning-seeking, transcendence-pointing system, came to humanity

as Emmanuel, God-with-us in Jesus of Nazareth. It is by incarnation and resurrection, not by cognitive evolution, that we are able to identify and be in relationship with the God to which our evolved NTDs point us. A further question then arises: How should we view the other religions of the world, given that these other beliefs have arisen out of neural capacities created by God, but which, by God's design, only vaguely point to God? Evans approvingly cites converts to Christian faith who "see their former faith as preparation for the good news they have come to believe" (p. 36).

Conclusion

Dunbar and Torrey have contributed to EAR and CSR by paying particular attention to the evolutionary process and stages by which humanity's neural capacities for religious beliefs and practices have emerged. This overall account can fit well with versions of Christian faith that accept macro-evolution by situating this evolutionary history within a larger framework of so-called "Big History"—in particular, by seeking to form a theistic, especially trinitarian, account of Big History (such as provided by the AMR account), in contrast to materialist Big History.

There are many further theological questions that arise with EAR, and no doubt readers will have thought of some such questions in the course of this review; however, space precludes consideration of further questions here. My hope is that readers will consider this review an invitation to continue exploring such questions.

Notes

[1]E. Thomas Lawson, "The Historical Genesis of Cognitive Science of Religion," in *The Oxford Handbook of the Cognitive Science of Religion*, ed. Justin L. Barrett (New York: Oxford University Press, 2022), 21.

[2]Readers familiar with these discussions may object that two other more recent works would be more appropriate for comparative purposes with Dunbar: Jonathan H. Turner et al., *The Emergence and Evolution of Religion by Means of Natural Selection* (New York: Routledge, 2018); and Margaret Rappaport and Christopher Corbally, *The Emergence of Religion in Human Evolution* (New York: Routledge, 2020). The work by Turner et al. is a bit too tangential in my view, in that they are using the evolution of religion not as the principal subject in itself but rather as a test case to demonstrate their principal objective, namely, to argue for "four types of sociocultural selection beyond strictly biologically based natural selection" (p. 3). I find this too methodologically tendentious to accept their findings regarding the evolution of religion without prior assessment in the literature of their proposed underlying account of sociocultural selection. Their sociocultural focus also means they are uninterested in the neural evolution of religion, which is a concern for my later theological discussion. Rappaport and Corbally offer a methodologically similar "Big History" account (over millions of years) to that of Torrey, by identifying how different cognitive aspects of religion emerged at different stages of humanity's neural evolution. There is much of interest in their proposal, and a comparative study of their proposal with Torrey would be very fruitful. Nonetheless, Torrey provides a more clearly delineated account of the historical stages of the neural evolution of religion, which is more helpful both for my purposes of exploring theological implications and for readers new to this topic to grasp how religious cognition and behaviors can be understood to emerge through evolutionary processes.

[3]For general introductions, see Claire White, *An Introduction to the Cognitive Science of Religion: Connecting Evolution, Brain, Cognition and Culture* (New York: Routledge, 2021); or, more exhaustively, Barrett, ed., *The Oxford Handbook of the Cognitive Science of Religion*.

[4]It is worth noting here that Torrey is not the first to attribute the origins of religion in part to dreams. E. B. Tylor (1832–1917), the founder of anthropology, "developed his theory of religion in close connection with dreams and visions." See Robert E. Sears, "Conceiving Religious Dreams and Mystical Experiences: A Predictive Processing Investigation," in *The Oxford Handbook of the Cognitive Science of Religion*, Barrett, ed., 215–36.

[5]Torrey uses only the standard term "autobiographical memory." However, for our purposes, I find the term "autobiographical mind" more appropriate because this implicitly acknowledges the ability to project possibilities into the future, including the possibility of an afterlife, whereas "autobiographical memory" implies only a capacity to look back at the past.

[6]Here the world's megalithic structures become relevant. Along with celestial calendar-tracking purposes, ancestor worship may be the origin of many of these structures around the world, such as at Göbekli Tepe, Turkey. Research now indicates that many of these structures were built by hunter-gatherers who would come together in large numbers for a season of construction, then return to their home locales for hunting and gathering. Thus, agriculture arose to feed these seasonal large gatherings in which hunter-gatherers would turn into engineers and builders. In effect, agriculture was "an epiphenomenon of these huge gatherings of hunters and foragers." (David Graeber and David Wengrow, *The Dawn of Everything: A New History of Humanity* [London, UK: Penguin Random House, 2021], 137.) This view is in contrast to Dunbar's self-protection thesis, that agriculture arose to feed hunter-gatherers who began to move into larger sedentary groups for self-protection.

[7]I have inserted "high" here because Torrey seems a bit loose in his language. In an earlier chapter, he explicitly describes the emergence of gods out of ancestor worship prior to the Axial Age, and it is the emergence of high gods that he otherwise describes in the Axial Age.

[8]There is debate among academics as to whether Zoroastrianism is truly monotheistic. For our purposes here, of understanding the emergence of monotheism, Zoroastrian metaphysics is sufficiently monotheistic leaning to serve our purposes of helping us trace the emergence of monotheism. Darius the Great (d. 486 BC) provides the

first written attestation to Ahura Mazda, attributing his military success to Ahura Mazda. Zoroastrian monotheism remained the dominant religion of that part of the world until the Islamic conquest of Persia (roughly present-day Iran) in the seventh century AD.

[9]Justin Barrett has been particularly prolific. See, for instance: Justin L. Barrett, *Born Believers: The Science of Children's Religious Belief* (New York: Atria Press, 2012); Justin L. Barrett, "Cognitive Science of Religion and Christian Faith: How May They Be Brought Together?," *Perspectives on Science and Christian Faith* 69, no. 1 (2017): 3–12, https://www.asa3.org/ASA/PSCF/2017/PSCF3-17Barrett.pdf; Justin L. Barrett, *Cognitive Science, Religion, and Theology: From Human Minds to Divine Minds* (West Conshohocken, PA: Templeton Press, 2011); and Kelly James Clark and Justin L. Barrett, "Reformed Epistemology and the Cognitive Science of Religion," *Faith and Philosophy* 27, no. 2 (2010): article 4, https://doi.org/10.5840/faithphil201027216.

[10]For such discussions in addition to Barrett, see also Kelly James Clark, *God and the Brain: The Rationality of Belief* (Grand Rapids, MI: Eerdmans, 2019), chap. 2, "Brain and Gods"; Greg Cootsona, "Science and the *Sensus Divinitatis*," in *Connecting Faith and Science,* ed. Matthew Hill and Wm. Curtis Holtzen (Claremont, CA: Claremont Press, 2017), 87–116; and Adam Green, "Cognitive Science and the Natural Knowledge of God," *The Monist* 96, no. 3 (July 2013): 399–419, https://api.semanticscholar.org/CorpusID:145473784.

[11]For some of these others, see endnote 2 above.

[12]For instance, given that the last 40,000 years (since the emergence of autobiographical mind) is but a blink in the two-million-year history of the *Homo* genus, why would God produce a system in which it would take so long for beings to emerge with neural capacity for god beliefs and accompanying religious practices (such as ritual, prayer, etc.)? Why, moreover, would God create a system in which belief in gods and goddesses emerged well before belief in a single God emerged—in other words, why a system in which polytheism seems more intuitive to *Homo sapiens* than monotheism? And what is the relationship between the emergence of the *sensus divinitatis* as a cognitive disposition and monotheism as an idea? These are just a few of the sorts of theological questions that arise from EPsR.

[13]For instance, while I find that Torrey provides a clearer theoretical account than Rappaport and Corbally of the evolutionary stages of humanity's religious neural capacities, Rappaport and Corbally identify two evolutionary stages that Torrey omits, stages which appear to me necessary to include in an EPsR account of "religion"—the emergence of moral capacity "around 1.5–1 million years ago," and the evolutionary "down-regulation of aggression [and] greater social tolerance among adult humans, especially while feeding" (Rappaport and Corbally, *The Emergence and Evolution of Religion*, 146).

[14]David Christian, "What Is Big History?," in *Journal of Big History* 1, no. 1 (2017): 4, https://doi.org/10.22339/jbh.v1i1.2241.

[15]Examples of Big History familiar to the reading public include Stephen Hawking, *A Brief History of Time* (New York: Bantam, 1990); Jared Diamond, *Guns, Germs, and Steel: The Fates of Human Societies* (New York: W. W. Norton, 1997); Yuval Noah Harari, *Sapiens: A Brief History of Humankind* (New York: Signal Press, 2016); Sean Carroll, *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself* (New York: Dutton, 2017); and David Graeber and David Wengrow, *The Dawn of Everything: A New History of Humanity* (New York: Penguin Random House, 2021).

[16]Chris Barrigar, "God's *Agape*/Probability Design for the Universe," *PSCF* 70, no. 3 (2018): 161–75, https://www.asa3.org/ASA/PSCF/2018/PSCF9-18Barrigar.pdf. Note that since publishing this article I have changed the name for my proposal to the "*Agape*/Many-Routes" account of God's design, as I feel this more precisely captures the core idea of the proposal. The term "Big History" had not been popularized by the time my article appeared, so I do not mention the phrase "Big History" in the article, but the article's proposal for God's *telos* for the universe and the place of evolution and the incarnation in that *telos*, amounts to an account of God's relation to Big History. I have produced a popularized video version of the AMR account, available at https://www.youtube.com/watch?v=wgnphHLUASo.

[17]This is an updated version of that which I presented in my *PSCF* article. Two years after my initial publication of the *agape*/probability account (in *Freedom All the Way Up: God and the Meaning of Life in a Scientific Age* [Friesen, 2017]), Michael Murray made a similar proposal:

> [O]ur evolutionary history seems to have been set up in a way that pushed us down an evolutionary path that allowed for the emergence of creatures with the critical mental abilities needs to be able to engage in relationships of love and friendship. We might thus see this evolutionary history as one that was crafted for the purpose of yielding creatures that are made for the very purposes God intended for us, and perhaps for manifesting the divine image. (p. 18)

Michael Murray, "Reverse Engineering the *Imago Dei*," unpublished paper presented at the Toronto Christian Scholar Symposium, Wycliffe College, January 25, 2019, p. 18, cited by Justin L. Barrett with Pamela Ebstyne King, *Thriving with Stone Age Minds: Evolutionary Psychology, Christian Faith, and the Quest for Human Flourishing* (Downers Grove, IL: InterVarsity Press, 2021).

[18]Central to the AMR account is the principle of "multiple realizability." Michael Gazzaniga provides the following illustration:

> Eva Marder has been studying the simple nervous system and resulting motility [cellular behavior] patterns of spiny lobster guts. She has isolated the entire pattern of the [lobster's neural] network with every single neuron and synapse worked out, and she models the synapse dynamics to the level of neurotransmitter effects. Deterministically speaking, from knowing and mapping all this information she should be able to piece it together and describe the resulting function of the lobster gut. Her laboratory simulated more than 20 million possible network combinations of synapse strengths and neuron properties for this simple little nervous system. By modelling all these combinations, it turned out that about 1–2 percent could lead to the appropriate dynamics that would create the motility pattern observed in nature. Even though it is a small percent, it still turns out to be 100,000 to 200,000 different tunings that will result in the exact same behavior [of the lobster gut] at any given moment … The philosophical concept of multiple realizability—the idea that there are many ways to implement a system to produce one behavior—is alive and well in the nervous system. (pp. 130–31)

Michael Gazzaniga, *Who's in Charge? Free Will and the Science of the Brain* (New York: HarperCollins, 2011), 130–31. The spiny lobster example applies analogously to *agape*-capability, that multiple different evolved "neural tunings," through multiple potential neural pathways, could also produce *agape*-capability. The importance of multiple realizability (multiple different potential pathways to *agape*-capability) is to enable new evolutionary routes to emerge in order to get around evolutionary bottlenecks and dead-ends on the way to *agape*-capability finally emerging.

[19]For a survey of various discussions of this topic, see Paul Brazier, "C. S. Lewis: The Question of Multiple Incarnations," *The Heythrop Journal* 55, no. 3 (May 2014): 391–408, https://doi.org/10.1111/heyj.12049.

[20]For discussions of flourishing from Christian perspectives, see Barrett with King, *Thriving with Stone Age Minds*; and Jonathan T. Pennington, *The Sermon on the Mount and Human Flourishing* (Grand Rapids, MI: Baker, 2017).

[21]This discussion has been around for some time. For a review of this discussion, see Nigel Ajay Kumar, *What Is Religion? A Theological Answer* (Eugene, OR: Wipf & Stock, 2013), 3–8.

[22]There are various terms that are used in the CSR literature, ranging from "theism" to "supernatural beings" (which is much wider in scope than "theism"). I prefer the term transcendence, because it allows us to distinguish what Martha Nussbaum has called "internal transcendence" (transcendent qualities in the physical world, ranging from visible-light wavelengths to widely held public opinions) from "external transcendence" (transcendent entities beyond the physical world, such as personal gods or impersonal forces such as karma or the Dao). Through the remainder of this paper, I will use the term "transcendence" to mean "external transcendence." I would consider "supernatural beings" equivalent to my term "transcendent beings."

[23]Various figures have charged that religious belief is "unreliably formed and hence epistemically tainted." For a response, see Hans Van Eyghen, "Is Supernatural Belief Unreliably Formed?," *International Journal for the Philosophy of Religion* 85 (2019): 125–48, https://doi.org/10.1007/s11153-018-9671-4. My proposal here reinforces Van Eyghen's argument.

[24]Evans has published both an academic and a more popular account. See, respectively, C. Stephen Evans, *Natural Signs and Knowledge of God: A New Look at Theistic Arguments* (New York: Oxford University Press, 2012); and C. Stephen Evans, *Why Christian Faith Still Makes Sense* (Grand Rapids, MI: Baker, 2015).

[25]Evans, *Natural Signs and Knowledge of God*, 17.

[26]Evans, *Why Christian Faith Still Makes Sense*, 25.

[27]HADD is particularly a feature of the minds of children, and diminishes into adulthood, yet nonetheless remains in adulthood. See Barrett, *Cognitive Science, Religion, and Theology,* 70–71.

[28]For a discussion of intuitive or promiscuous teleology, see Johan De Smedt and Helen De Cruz, *The Challenge of Evolution to Religion,* Cambridge Series: Elements in the Philosophy of Biology (Cambridge, UK: Cambridge University Press, 2020), 9–12. The term "promiscuous teleology" was coined by Deborah Kelemen to describe the minds of children. Research indicates, however, that as children develop into adults, promiscuous teleology diminishes due to greater understanding of how things work; nonetheless, in adulthood teleological interpretations of non-understood phenomena do not disappear. See Barrett, *Born Believers*. I would point out that while HADD and *telos*-attribution can appear very similar, they are not the same thing: agency can be creative without teleological intent. This is seen, for instance, in the Brahman of Hinduism, and in the God of Deism, both of whom create but then leave the creation alone, to run its own course.

[29]I am not claiming that there are only four NTDs; there may be others. The CSR literature is not consistent with terminology, so other authors may use different terminology than I have used here. For instance, while the terms "mentalizing," "theory of mind," "agency detection" and "HADD" are well established in the literature, I have coined the terms "causality-seeking" and "*telos*-attributing." However, my ideas behind this terminology are common in the CSR literature.

[30]I had considered calling the NTDs "neural spandrels," which seems less awkward than "NTDs by evolutionary side-effect." However, since spandrels are normally phenotypical, using the term "neural spandrel" raises a number of difficulties. Nonetheless, this term does convey the sense that the NTDs are not evolutionarily selected for.

[31]This anonymous reviewer points to "the predictive brain," or "predictive error theory" (PE). Over the past twenty years, PE analysis has been applied across numerous neural operations and is now understood as a central function of the neocortex. Here the reviewer states that, "How we perceive the signals of [NTDs] might be blanked out by error-checking before we are even aware [of them]—and those [blanking-out error checks] are put in place at the top neural level by 'culture' or rearing, if you will." From a theistic perspective, such occasions would amount, ironically, to erroneous "error-checking." How PE applies to religion has been considered by a number of figures. See Uffe Schjoedt and Michiel van Elk, "Neuroscience of Religion," in *The Oxford Handbook of the Cognitive Science of Religion*, Barrett, ed., 327–48.

[32]Sy Garte, "I Was Indoctrinated to Despise Christians. Then I Became One," in *Premier Christianity*, April 20, 2023; accessed online at https://www.premierchristianity.com/real-life/i-was-indoctrinated-to-despise-christians-then-i-became-one/15353.article?fbclid=IwAR1QOxLHQsD4DTecyvu0mr5izrdYDew_PqHYXWS-Twwxtp6deSo7XkEfu1A.

[33]To be clear, I am not saying that each of these neural features serves solely a transcendence-related purpose, as if, for instance, humanity's promiscuous teleology disposition functions only to seek god/gods. Rather, I am saying that as each of these neural features has evolved, with infinite scope of conscious application (e.g., Is there purpose to the sun shining?, Is there purpose to me stubbing my toe?), the scope of how humans apply these features is so wide that it includes applying them to the concepts of transcendence produced by autobiographical mind, thus raising the possibility of gods/god.

[34]As "projectionism" is a particularly common psychological argument against theism, I will add some comment here. There is no need to deny that we humans do have this propensity to project our own wishes and self-images onto God, and that we appropriate God all-too-easily for our own personal ends. Indeed, theists can readily affirm that humans project their own images onto transcendence. For instance, pastoral theologians are well

aware that adult children of alcoholics often understand God as they understand their own alcoholic parent: as untrustworthy and as needing to be appeased and danced around. The problem with projection theses, however, is that they draw a false conclusion from their valid observations. The Bible itself is well aware of this phenomenon and has a specific term for it—idolatry. The phenomenon of projection, however, simply does not demonstrate the non-existence of God. Indeed, parents do the same with their children, projecting their own qualities, hopes, and desires onto their children—but it does not therefore follow that their children do not exist! Furthermore, the atheism of the projectionists can itself be subjected to the same interpretation, that their atheism is itself self-deceptive, merely a projection of their own wish-fulfillments and will-to-power. Projectionism simply observes that humans do project their own desires and qualities onto God, and even onto humanity itself; however, the phenomenon of projectionism provides no grounds by which to draw either theistic or materialistic implications.

[35]See Jeffrey P. Schloss, Justin L. Barrett, and Michael J. Murray, "Looking Past vs. Overlooking Cognitive-Evolutionary Accounts of Religion: A Response to Nathaniel Barrett," *Journal of the American Academy of Religion* 78, no. 3 (2010): 622–28, https://doi.org/10.1093/jaarel/lfq049.

> Thus any natural predisposition to form beliefs in invisible and/or counterintuitive agents is context-dependent … And whether those spirits are conceived of as ancestors or gods, or spirits, or bodhisattvas, will depend on local factors. Even more importantly, the meaning given to and believed to be given these entities will covary with myriad individual, cultural, and historical factors. (p. 625)

GOD AND NATURE

Winter 2024

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Origen: A Black Scientist and Early Church Father *by* Omololu Fagunwa (Winter 2022)

The Boundaries of Being Human, A Reflection from Science and Ecclesiastes *by* Oscar Gonzalez (Winter 2022)

A Pastor's Journey in Search of Consensus *by* Terry Defoe (Winter 2020)

Birds of New Zealand: A Gordon College/ASA Expedition *by* Janel Curry, Greg Smith, and Vicki Best (Fall 2019)

Environmental Problems as a Place for Compromise and Dialogue *by* Johnny Wei-Bing Lin (Spring 2019)

The Genetics and Theology of Race *by* Sy Garte (Winter 2018)

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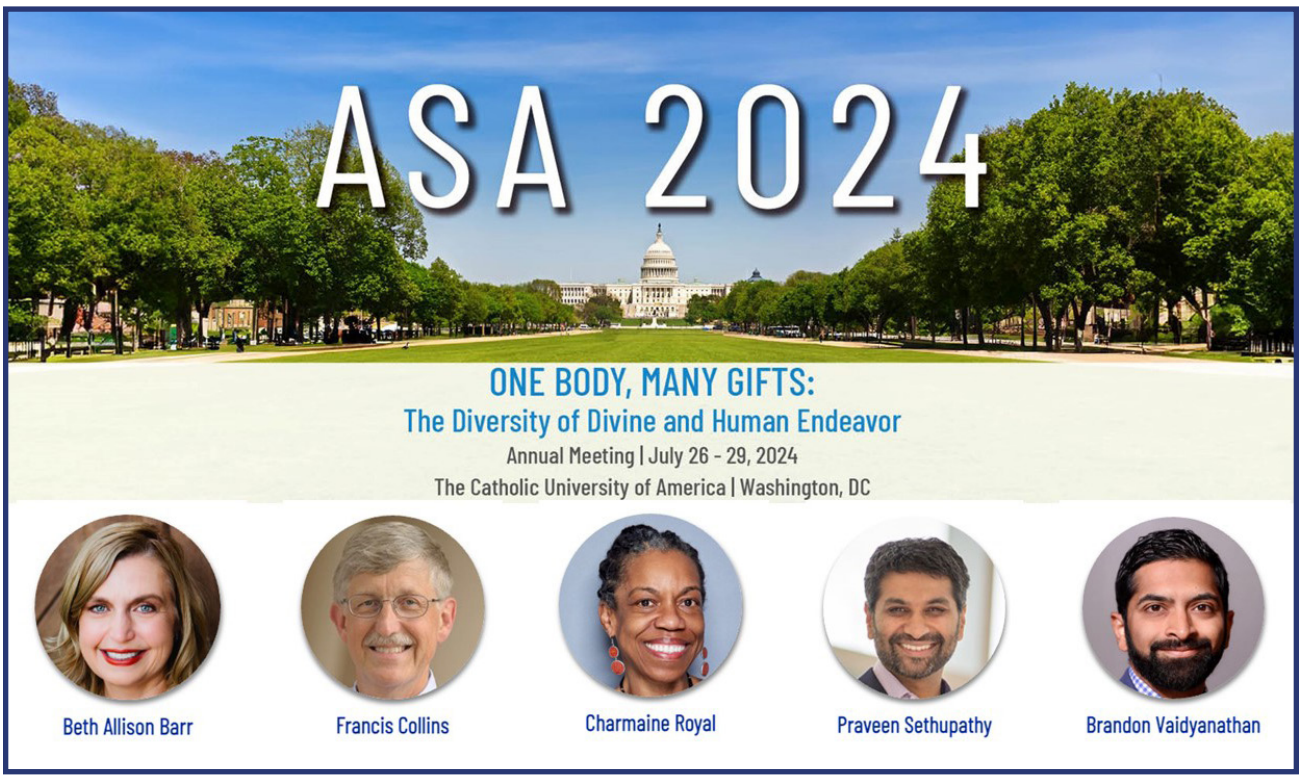

Behavioral Sciences

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TRAUMA-INFORMED EVANGELISM: Cultivating Communities of Wounded Healers by Charles Kiser and Elaine A. Heath. Grand Rapids, MI: Eerdmans, 2023. 213 pages, index. Paperback; $19.99. ISBN: 9780802882356.

Trauma-Informed Evangelism is a well-written, thought-provoking, and necessary contribution to the field of evangelism, introducing the recovery principles of trauma-informed care. Trauma-informed care, as practiced in the fields of mental health and substance abuse treatment, recognizes that all people have experienced trauma, that many problematic effects and symptoms are a result of these traumatic experiences, and that the key to helping others heal is found in treating them with kindness and respect to assist them in developing personal empowerment. The main goal in the work is to avoid re-traumatizing people. The key shift in conceptualization moves from one of pathology, to the normal, protective response of the body to threat—from "What is wrong with you?" to "What happened to you?"

Authors Kiser and Heath encourage trauma-informed spiritual care that can be adapted by lay persons, clergy, and clinicians alike. *Trauma-Informed Evangelism* urges readers to recognize the experiences of spiritual harm, understand that this harm has had a significant impact on the survivor's thoughts, feelings, and behaviors regarding spiritual matters (which arguably leads to holistic complications), and to witness these stories in a manner that creates a place of healing rather than of re-traumatization.

The authors break this work into three categories: (1) Disordered Imagination, (2) Healing Imagination, and (3) Embodied Imagination. Disordered imagination begins with the premise that trauma-informed evangelism requires that we understand our neighbors' experiences of harm in a spiritual context so that we can minister to them effectively. As in any type of trauma-informed care, the invitation to share stories without expectation or judgment is an imperative first step. This section begins by introducing a handful of oft-relayed themes, including rejection trauma in terminating relationships, injustice toward marginalized individuals and by those who abused their pastoral authority, and secondary wounding, having witnessed harm toward others.

Kiser and Heath acknowledge complex theological and social questions which arise when we are faced with spiritual harm. They briefly examine questions of the nature of God, and of humankind acting in harmful ways or failing to prevent harm. The authors do a nice job throughout the work of covering the natural and obvious questions that will arise for the reader. This involves discussions of the nature of spiritual abuse and trauma, problematic narratives of supremacy and hierarchy, and healing the historical wounds of exploitation and perpetration within Christendom. They challenge the ever-present presuppositions of those who comprise the in-group and of those who comprise the out-group in the church, who gets to decide, and how these practices have been kept in place.

The authors challenge traditional church norms and beliefs which keep some of these harmful practices in effect. They also introduce alternative, nontraditional theological perspectives that could combat some of these views. However, it is important to note that theological beliefs are simply one piece of the equation. And that, people being people, we are prone to wounding others regardless of the rightness or wrongness of our theological perspectives. Even with the best of intentions, two people can have vastly different perspectives on the best way to problem-solve. And when our deeply held religious convictions are part of the decision-making, we can often be seen doubling down on our positions, inadvertently doing spiritual harm.

Healing imagination tasks the reader to entertain new narratives of the inherent meaning of Jesus as a trauma survivor, to discover and reimagine God in the midst of trauma, and to consider the challenge of producing compassionate, trauma-informed leaders. The authors introduce thought-provoking, alternative interpretations to challenge the traditional meaning we have given the crucifixion story, to God's purpose and reactions to harm, and to how we as evangelists should understand and respond to trauma.

Embodied imagination proposes several alternative approaches to evangelism. This includes the suggestion that our traditional attempts to minister to and to convert those with problems of spiritual trauma are counterproductive, largely due to the instinctual trauma response. That evangelism is "witness-oriented rather than results-oriented" (p. 118) requires that we embody the Good News and release the outcomes to God. It asks evangelists to consider "radically inclusive hospitality" which further expands the boundaries of who is included in the church, and it tightens the boundaries of acceptable behavior to avoid harm and exclusion (p. 140). Evangelists must finally learn to keep a healthy and well-differentiated self from their neighbors, allowing others their autonomy and not becoming discouraged when their best efforts don't deliver the expected results.

Trauma-Informed Evangelism will probably be best enjoyed by those with non-traditional views of Christianity as it considers alternative perspectives such as womanist and queer theology. However, those of a more conservative nature, who are open to the simple and practical message of trauma-informed care, may find a great deal of applicable materials within

the scope of their personal Christian beliefs. *Trauma-Informed Evangelism* is well conceptualized and worthy of a careful read. The discussion questions at the end of each chapter help facilitate reflection and planning for individuals or groups interested in developing this mode of evangelism.

As a clinical trauma specialist and Christian, I found this work especially relevant to my current task, building the mental health department in a residential drug and alcohol treatment center for adult males. The vast majority of these men report trauma, including childhood sexual abuse, violent experiences during incarceration, family of origin abuse, and medical trauma inherent in abusing substances. They have been the victims of trauma, and they have been the perpetrators of trauma. They identify the church as the key component of their healing, but also a key factor of their wounding. The explanations of spiritual wounding and trauma-informed care in this book are sound; they are as applicable to the neighbor who has found moderate offense as to deeply wounded brothers and sisters with complex consequences. I plan to use this material to deepen the focus on the concepts of spiritual wounding and trauma-informed care into my practice.

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DISCIPLES AND FRIENDS: Investigations in Disability, Dementia, and Mental Health by Armand Léon van Ommen and Brian R. Brock, eds. Waco, TX: Baylor University Press, 2022. 330 pages. Hardcover; $59.99. ISBN: 9781481317009.

It has been almost fifty years since I started supporting individuals affected by intellectual and developmental disabilities, and I wish this edited book had been available at that time. While the focus of the different chapters in this book touches on subjects having to do with disability, dementia, and mental health, the real emphasis is on the practical theology of John Swinton, and the ways friendship in and through Jesus informs the "tension between reflection and action, and research and practice" (p. 56).

The book has an introduction and an afterword, and it is divided into four sections: (1) Practical Theology in a Swintonian Key, (2) Vulnerability Subverted, (3) Quests for Faithful Embodiment, and (4) Gently Living in a Violent World. According to the publisher's description of the book, it is directed toward "students and scholars of practical theology, disability theology, mental health, dementia and cognate fields" (https://www.baylorpress.com/9781481317009/disciples-and-friends/). While some of the language is almost inaccessible without a theological background, much of the writing is practical and applicable to those of us who see working for and with people affected by disability, dementia, and mental health as a vocation rather than as a career.

Readers will each have their favorite authors based on their own interests and passions. As a behavior support practitioner as well as a social work professor, I was most affected by the chapter written by Grant Macaskill, a theologian from the University of Aberdeen who identifies as autistic. He writes movingly about the autistic gain for the church when we radically empower the neurodiversity model to discontinue talking about normalcy as a goal and embrace the differences diversity brings within the rich tapestry of the body of Christ. In a similar way, Bill Gaventa's chapter, entitled "All God's Children Got a Place in the Choir" provides another view of the many members of the body whose differences make the body stronger by embracing Paul's vision of God's choice to use the "weak" to bring strength and the "foolish" to bring wisdom to the world the church ministers to (e.g., 1 Corinthians 1 & 2). In his chapter, he asks three questions that I wish I had been asking years ago:

1. Who am I?
2. Why am I?
3. Whose am I?

I have spent some hours reflecting on these three questions, trying to move past the role definitions we so easily gravitate to. Finding the "why" of my existence, the purpose I have in life, is an equally deep question, and asking who I belong to within our kingdom relationships will hopefully help me find my place in God's choir. Reading this book will, I believe, prompt readers to ask the same questions I asked myself. Finding the "why" of our existence and the purpose of our lives are deep questions for all of us. In our Christian lives, finding out who we belong to will help us to find our place in God's choir with all the other critters. For some of us, the call is to be "disciples and friends" to persons with disabilities, dementia, and neurodiversity, and this book may bring that into focus for some readers.

The body of Christ is far more than the worship center of the Christian faith; it is the place where Jesus interacts with all the people Jesus came to minister to as recorded in Luke 14:13–23—"the sick, the lame, the blind, the deaf, the prisoners, the poor, the weak." According to the United Nations, the largest minority group in the world is people affected by various disabilities, accounting for approximately 650 million people out of a population of 7.88 billion people (https://www.un.org/disabilities/documents/toolaction/pwdfs.pdf). It is with and for these people that John Swinton's work seeks to create opportunities for friendships to develop amongst people who come together to experience the friendship of Jesus. Within these relationships we come to know the peace of Jesus, and as Medi Ann Volpe writes in one of the chapters, Jesus *is* our peace, Jesus *makes* our peace,

and Jesus *preaches* our peace. The people I have known over the years whose differences were labeled and diagnosed have ministered the peace of Jesus to me in ways that are too deep for words. They have taught me what friendship is, and reading this book I have come to understand that John Swinton's life and teaching is devoted to cultivating friendship and creating communities in which there are no dividing walls—where all people in need of grace and redemption, love and forgiveness, healing and hope come together as one body with many members.

There are precious few things I would change about this book. I would make the last chapters in the section "Gently Living in a Violent World" the first chapters: I think they are much more inviting to readers, and from my perspective, they contain more information on how to live out this theology of friendship.

Overall, I would encourage all Christians whose lives intertwine with people on the margins of ability and disability to read this book and let it speak to their hearts and their minds. I am looking forward to being able to use this book both as a practitioner and a professor, and in these roles, I am thankful to have read about all the ways I can learn to be a deeper and better friend and human being.

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History of Science

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HELMHOLTZ AND THE CONSERVATION OF ENERGY: Contexts of Creation and Reception by Kenneth L. Caneva. Cambridge, MA: MIT Press, 2021. 735 pages, including notes (138 pages), bibliographies of primary and secondary sources (80 pages), and an index (17 pages). Hardcover; $125.00. ISBN: 9780262045755.

By examining the pagination details mentioned above, one could easily surmise that one will be reading and examining a book grounded in textual detail. And one would be spot on. The weight of the author's research is, quite honestly, breathtaking. Kenneth L. Caneva has devoted his academic life to an examination of energy concepts. He is a professor in the Department of History at the University of North Carolina-Greensboro. A former student of Thomas S. Kuhn, he has also authored two other books: *The Form and Function of Scientific Discoveries* (Dibner Library Lecture, 2000) and an authoritative biography, *Robert Mayer and the Conservation of Energy* (Princeton University Press, 1993). *Helmholtz and the Conservation of Energy* is his latest contribution.

Before we examine the book proper, the obvious question arises: Who was Hermann von Helmholtz? To answer that question one can best turn to the 937-page scientific biography of Helmholtz by David Cahan (*Helmholtz: A Life in Science*, The University of Chicago Press, 2018). Helmholtz (1821–1894), a German physiologist and physicist, is described by Steven Shapin in his review of Cahan's book as "a theorist of (not quite) everything." Helmholtz had an immense range of scientific and cultural interests: physics, physiology, psychology, aesthetics, philosophy. He invented the ophthalmoscope, measured the nervous impulse, contributed to meteorology and atmospheric physics, and helped build some of Germany's scientific and technological institutions.

Caneva wants to explore the context and reception of one of Helmholtz's early (1847) seminal essays, "*Über die Erhaltung der Kraft*" ["On the Conservation of Force"] by examining how this essay shaped the discussion and acceptance of a physical principle: the conservation of energy. How was "conservation of force" eventually transformed into a principle of energy conservation? Caneva offers us a contextualist historiography of this long and complex transition by providing an in-depth analysis of Helmholtz's contribution and influence in the discovery process.

The discovery of the principle of energy conservation is a classic case in the history of nineteenth-century science. Although overshadowed in the public mind by Charles Darwin's principle of natural selection, its historical development raises similar issues. Who discovered the principle of energy conservation? An easy question to pose, but a very complicated one to answer. And more to Caneva's point of interest: Is conservation of energy what Helmholtz initially meant by the conservation of force?

Caneva offers this book as an example "of how what is generally accepted as scientific knowledge is reshaped as it passes through the hands of people with different agendas using different language." It is not an individualistic process, but rather reflects a "collective construction of scientific knowledge." Caneva concludes the book with this assertion: "The cumulative force of this study has implicitly rendered otiose the question of who discovered the conservation of energy" (p. 466). In a real sense, no one individual has discovered the conservation of energy: one could reference Robert Meyer (1842), Helmholtz (1847), William Thomson (1851) [force to energy], and Helmholtz (1853) again. With meticulous detail Caneva highlights the terminological shifts that have taken place as well as the rhetorical skills exercised when the "law" or "principle" was presented to various publics, even in popular scientific settings.

The book has eleven chapters, followed by a "Historiographical Excursus: How Others Have Interpreted Helmholtz's Achievement" (pp. 471–99). In chapter 1, "Helmholtz's Self-Described Principal Concerns,"

Caneva traces out four factors that were central to Helmholtz's thinking: (1) a conviction that the construction of a perpetuum mobile is impossible, (2) a concern with the nature of heat and the source of animal heat, (3) a belief in the illegitimacy of a vital force, and (4) the application of rational mechanics' principles of vis viva [mv^2] and its conservation. According to Caneva, Kantian philosophical concerns do not dominate, nor does Helmholtz's reliance on industrial mechanical steam-engine considerations or metaphors. Succeeding chapters (2–6) trace out the broader and more immediate contexts, the question of Kantian influence, and what Helmholtz believed he had accomplished.

Chapters 7–9 consider the reception of "The Conservation of Force." In chapter 9, "Helmholtz's Place in the Acceptance of the Conservation of Energy—by far the longest (pp. 235–428) and most important chapter—Caneva traces how Helmholtz's formulation in his 1847 essay, "The sum of the existing living and tensional forces is thus always constant" (p. 239), has been transformed into a principle of the conservation of energy. How does a paper first rejected by the physics community, yet hoping to find unifying elements in nature, lead finally to the conservation of energy (the first law of thermodynamics)? Even if one looks closely at the phrase, "tensional" forces, one notices that Helmholtz integrates force over distance, that is, force is thought of in terms of the velocity of a body rather than its acceleration. Force, for Helmholtz, is a measure of the quantity of motion rather than a cause of motion. Caneva's goal is to render intelligible Helmholtz's role and significance in the complicated transition to the final expression of the conservation law.

Near the end of the book, in the "Historiographical Excursus," Caneva critically assesses the work of earlier commentators who have written about Helmholtz and the conservation of energy. Thomas Kuhn (Caneva's advisor), Yehuda Elkana, Peter Harman, Norton Wise, all are subject to criticism. Caneva detects anachronistic tendencies, lack of sound textual evidence, and a desire to confirm a preconceived idea that lie at the root of most failed interpretations (p. 499).

The book is not an easy read. Amidst all the intricate detailed analysis and convoluted arguments what can an ASA member profitably learn? First, clarification of concepts can be a long and complicated process. Think just of the historical development of the concept of biological evolution. Secondly, ideas and concepts are shaped by a myriad of causes and influences. The art or skill lies in learning how to weigh the stunning array of causes. In the case of Helmholtz, historians have identified several causes: philosophical, physical, technological, physiological, and even cultural. How to accurately weigh each factor without becoming ahistorical, that is, misreading an author's intent by reading modern concepts into it and becoming anachronistic, has been Caneva's goal.

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TECHNOLOGY

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ROBOT ETHICS by Mark Coeckelbergh. Cambridge, MA: MIT Press, 2022. 272 pages. Paperback; $16.95. ISBN: 9780262544092.

Mark Coeckelbergh is Professor of Philosophy of Media and Technology at the University of Vienna. This compact and easy-to-read book is his second on technology-related ethics, following his earlier *AI Ethics* (2020). In *Robot Ethics*, Coeckelbergh surveys situations where robots might be incorporated into daily life, and then explores ethical implications in each.

The book begins by introducing the reader to the field of robot ethics. As a first principle, "a robot cannot and should not be reduced to the material artifact 'robot' but instead must be connected to its use, and its social and cultural contexts" (p. 8). The author then identifies a major stumbling block, namely, that there is no clear definition of the term "robot." To make matters even more problematic this same definition limitation exists for the closely related concept of artificial intelligence (AI). In light of this lack of specificity, Coeckelbergh casts a large net around multiple technologies and machines that he considers related to robots or artificial intelligence.

Coeckelbergh first explores the effect of robots in the workplace and the resulting consequences for employee safety and job security. He then discusses robot companions and how these can be connected to a form of deception. Coeckelbergh provides the following example. Your elderly parent requires more care. You do not have the time to provide said care. You hire or purchase a robot that looks and behaves human-like to help. Do you tell your elderly parent that the companion is a robot? What if you do tell your parent that it is a robot, but your parent insists that it is alive—are there ethical issues with a robot providing care to someone who believes it is alive?

The author then explores the negative side of robot companionship, the ethics of robot abuse. Since robots are objects and the property of its owner, is it ethically permissible for people to be violent or abusive to their robots? Robot companionship leads to special forms of robotic companions, such as healthcare robots and personal assistant robots. When robots begin to replace healthcare workers or other experts, then additional problems arise, such as in quality of service, expertise,

moral agency, and responsibility when things go wrong. If your elderly parent is injured by the robot, who handles your complaint? How much freedom should a robot have to interact with the world on its own?

Continuing this theme, the author then explores additional robotic applications, such as self-driving cars, military drones, and other examples to help the reader grasp the breadth of the underlying ethical concerns when autonomous machines intersect with humans. "Robots function as mirrors that show and reflect us—that is, the human being in all its facets, and with all its problems and challenges, including ethical ones" (p. 195).

At this point, the text turns to more futuristic concerns. The book's final chapters consist of three essays. First, what ethical concerns should we consider when robots become androids/cyborgs and start to look and behave like us? People begin to use terminology like "eerie" and "creepy." Second, what happens when we replace soldiers with robots? This takes us into the ethics of automated war. Third, when should we start to be concerned about our own existence? This gives rise to the post-humanist view that idealizes a time when people and technology merge into something new, like cyborgs (merged biology and technology) or uploading our consciousness into a computer (no longer needing our body). Coeckelbergh contrasts the posthuman view with what he thinks is a more useful ethic—environmental ethics. "Instead of being mesmerized by transhumanist science fiction and posthumanist fantasies about cyborgs, we should focus on real and urgent problems with the natural environment and our planet, like climate change" (p. 204). He ends on a positive note with society using robots and artificial intelligence to work for the common good to solve global problems.

I found *Robot Ethics* to be enlightening, providing a clear presentation of many ethical concerns that arise with robots. Coeckelbergh not only introduces us to the implications but also to the leading thinkers. As practitioners and as a society, we do not put enough thought into the effects our creations have on ourselves. Consider, for example, the repercussions that ChatGPT has on school assessment strategies as well as on the writing, acting, and artistic guilds, as seen in recent strikes in these professions. I have already recommended the text to my coworkers working in artificial intelligence and robotics. The text is not a warning to stop advancement in robotics but instead a call to be more reflective. I think the text would also work well in a reading or study group. There are many ideas that could be fruitfully explored in a group.

I found that the text has two minor weaknesses. An inherent problem when casting a wide net is that different subjects can be treated as the same thing. In this case, the author risks mixing standard weaknesses in engineering or business practice, with robotics, resulting in a less clear understanding of robot ethics. For instance, is ChatGPT inherently harmful, or are the harms associated with ChatGPT a function of the way business introduced it to society? More specifically to robotics, when does smart software evolve into robots? For example, should your dishwasher be considered a robot? If it can be controlled remotely from your cell phone, does it qualify? What if we connect the dishwasher to the internet of things managed by a machine learning program that has figured out when you like to wash? At this point, some would still say that the dishwasher is not a robot, while others might say that it has become that. The internet of things has its own ethical and security problems not related to robotics; however, merging the two in a conversation by calling it all robotics lessens our understanding of robots.

I heard it once said that ethicists are great in analyzing and defining ethical concerns, but not as good in providing answers. This book raises many worthwhile questions, but if you are expecting to find solutions, then you will need to look elsewhere. The author wants us to think about these things so that we do not simply walk into the future without care. Coeckelbergh wants to identify the canaries in the coalmine, as it were. This text is an exploration and introduction to the key questions and people, not a compendium of ethical principles or solutions. I found this approach very useful but felt like I wanted a little more. A small dose of positivity would have been nice, with fewer post-apocalyptic scenarios. Although the text's purpose is more modest, it would have also benefited from some successful integration stories or theoretical integration strategies.

Even though I did not like how the book began its definition of robots (the author acknowledged the limitations of his position), I highly recommend this book as an introduction to the ethical questions and problematic situations associated with robots. Robots are in our future, whether we want them or not, so it is best to be thinking about these sorts of important concepts.

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THE REVOLT AGAINST HUMANITY: Imagining a Future without Us by Adam Kirsch. New York: Columbia Global Reports, 2023. 104 pages. Paperback; $16.00. ISBN: 9781735913766.

In Eden, the serpent lied to Eve about the forbidden fruit. She was told that disobedience would allow her to "be like God." Already bearing God's image and likeness, Adam and Eve swallowed the serpent's lie, together with the forbidden fruit. Wanting to be more than mere creatures, wanting life on their terms, they sinned against their creator. Likewise, their son Cain

wants his way. God rejects Cain's sacrifice but does not reject Cain. Instead, God points to the root cause of Cain's sin and lays out the path to restoration. Cain's response? He kills his brother.

Throughout humanity's long rebellion against God, these two aspirations have persisted, together with their common result. The first, the desire to "be like God, knowing good and evil," goes beyond intellectual assent to intimacy with evil. And just as "Adam knew Eve his wife, and she conceived and bore Cain," intimacy with what God forbids gives birth to death. Then, unable to sin without consequences, the second aspiration is to destroy, to deface the created order and kill, to embrace death as an escape from God.

The Revolt against Humanity presents and analyzes the latest versions of these longstanding evil choices: transhumanism and Anthropocene antihumanism. Adam Kirsch well describes the heart of the transhumanist vision: the aspiration to transcend our creaturely status. Ray Kurzweil, Max More, and others seek release from all human suffering through science and technology. By human reason alone, they would obtain godlike powers, but not to please God, not to love God and neighbor. Instead, they would overturn God's decree, summarized in Ezekiel 18, that "the soul who sins shall die."

What do transhumanists think of God? Well, most have no use for the holy God of the Bible. Instead, they would create "spiritual machines," to use Kurzweil's term, or they would "create God" as members of the "Terasem transreligion," founded by Martine (formerly Martin) Rothblatt, whose disdain for traditional accounts of humanity and human limitations is expressed in her book, *From Transgender to Transhuman: A Manifesto on the Freedom of Form*. With such a god, transhumanists believe that even the heat death of the universe is not an obstacle. Science will surely reveal ways to alter the very laws of the universe, won't it?

Ready to join the transhumanist movement? Few believers would. Instead, they would agree with Christina Bieber Lake's analysis of transhumanism, including the claims of so-called Christian Transhumanism. Her plenary address at ASA's 2021 virtual annual meeting—with responses from John Wood, William Hurlbut, and Brent Waters—shows how its eschatology fails. Technoscientific hyper-postmillennialism presumes that salvation is achievable by human effort. It has no use for Christ's sacrifice for our sins, destroying fundamental Christian doctrines, such as hope in God and divine grace.

Kirsch is no transhumanist. Instead, he sees transhumanism as an optimist's escape from the problems of this world. Yes, those problems may, at least in part, be traced back to science and technology run amok: the depletion of natural resources, pollution and climate change, species extinction, and the broader degradation of nature. These ills threaten what matters most to transhumanists: the mind, with its ever-expanding knowledge, driven by science.

What is the transhumanist solution? Acknowledging that science and technology can be problematic, they still believe more will do the trick, especially as they produce advances in computers and information technology. After all, though minds have emerged from our brains, they see no reason why they must be biological; artificial intelligence will serve just as well, nay, even better. After the singularity, when computer intelligence exceeds that of human beings, biological life will be obsolete. In its place, life will continue in computational systems, human minds being uploaded, either from the living or the dead, their brains preserved through cryonics.

Is transhumanism too optimistic? Perhaps, but Kirsch is concerned about a darker alternative: Anthropocene antihumanism. It sees humanity as an unfortunate and unnatural infestation of Earth. Rather than enhancements to human life, it believes eliminating humanity is the answer. Nature, interpreted as inherently good and robust, would recover. Its wonders would thrive, even if no humans were around to observe it. Indeed, antihumanists seek to eliminate human perspectives of what it means to thrive; anthropocentric definitions got us into this mess, so it is critical to move past them.

Kirsch concludes with a quick survey of the spiritual dimensions, broadly defined, of the rebellion by anti- and transhumanists. He mentions the apocalyptic elements of Christianity and other religious traditions, the hopelessness of H.G. Wells as he anticipated the extinction of human life, Nietzsche's nihilism, Foucault's concerns about "biopolitics," and the general loss of meaning that has accompanied the rise of godless modern experimental science. With this background, Kirsch looks to the future, but not with confidence. "We can only hope that we don't have the bad luck to be born into the last generation, the one that sees humanity as we have known it disappear."

Kirsch does not offer a Christian response to the revolt he describes; his spiritual commitments are not clear. Still, *The Revolt against Humanity* offers a provocative look at where progress has taken us, one Christians should consider. Advances in science and technology offer new ways to fulfill the first and second great commandments, respectively. However, apart from faith in God as their source, they cannot address the despair of a frustrated world.

I recommend Kirsch's book to Christians that view science and technology as inherently good and beneficial. Its few pages are thought-provoking, giving believers many opportunities to reflect and check their Bibles

for God's answer to human sin: the gospel of Jesus Christ. I also recommend a "Thinking in Public" interview by Albert Mohler: "The New Religion of Artificial Intelligence and Its Threat to Human Dignity—A Conversation with Adam Kirsch," recorded April 12, 2023. It is available online at https://albertmohler.com/2023/04/12/adam-kirsch.

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HOW TO SELL A POISON: The Rise, Fall, and Toxic Return of DDT by Elena Conis. New York: Bold Type Books, 2022. 388 pages. Hardcover; $30.00. ISBN: 9781645036746.

Suppose you were creating a new college course on the interaction between chemistry and public policy (this happens to be true for this reviewer). Elena Conis's *How to Sell a Poison* would be a nearly perfect book to read as you set your syllabus. The author presents a thorough historical context with sufficient, but still accessible, chemical detail. The book does not gloss over complexities in the interactions between politicians, industry, and environmental advocates, but it also manages to compel the reader with winsome writing and a peppering of human-interest narratives. And while the book inexplicably does not have a complete set of references, it is an excellent resource for a reader who wants to develop an understanding of the history of DDT and why there are some who are calling for its continued and increased usage to combat malaria.

The structure of *How to Sell a Poison* is mostly chronological, including some information of the early uses of DDT by Swiss potato farmers, the promotion of its use by the United States military in World War II, an explosion of usage in the 1950s and 1960s as both an agricultural and a consumer product, the mounting evidence of DDT's negative environmental impact, advocacy and legislative action in the 1960s and 1970s, and the ongoing debate regarding continued or increased use of DDT to keep malaria in check. This historical structure is written in a compelling way, with most chapters headed by an account of one of the primary actors in an ongoing drama created by benefits and dangers of the pesticide's use. Going far beyond the well-known story of Rachel Carson and her seminal *Silent Spring* (1962), we meet chemists, soldiers, physicians, patients, agricultural workers, government scientists, politicians, supreme court justices, concerned citizens turned plaintiffs, journalists, environmentalists, industry executives, and lobbyists. By the end of the book, the reader will feel that they have been inside the mind of all of the important actors in the multiact drama that was and is DDT.

Conis includes sufficient chemical detail even while she keeps the book accessible to a general audience. The reader comes to understand the molecular structure of DDT, how it is synthesized, why it is persistent in the environment, how it kills insects, and why it increasingly bioaccumulates going up the food chain. These details are not presented in a tacked-on chapter, but in the historical context as needed to understand the DDT narrative.

One of the greatest strengths of the book is that it does not gloss over the complexities or nuances in the DDT story. This is important to gain an authentic understanding of how DDT became ubiquitous and how it fell out of favor. Yes, the story of Rachel Carson's *Silent Spring* is included, but so is the congressional testimony that followed and the ultimate lobbying of tobacco interests encouraging a DDT ban as part of a scapegoat campaign to cover up their own cancer problems. The reader also comes to understand the crucial role that the DDT controversy played in the establishment of the U.S. Environmental Protection Agency and the Environmental Defense Fund. A true historian, Conis gives you a compelling behind-the-scenes understanding of who held influence regarding DDT and how their influence was wielded.

Nearly every chapter begins with a narrative regarding one of the main actors in the DDT story. This feature makes the book easy to read and compelling. You see the promise and the problems of DDT from the point of view of a land developer, a chemist, a government scientist, a physician, a health department officer, a member of congress, an organic gardener caught in the overspray, an attorney, an immigrant agricultural worker, a bird enthusiast, the surgeon general, a university professor, a journalist, the EPA director, the mayor of a small town, and several others. As their stories are told, the reader is led to an understanding of the many facets of DDT in an organic and interesting way. Each story is backed up by references, as appropriate, to letters, articles, books, or government documents. But even as the stories are historically documented, they read more like a story than a history textbook.

The one frustrating aspect of the book for this reviewer is the lack of a comprehensive bibliography. The author refers to many documents in the chapters, but then does not include a complete reference to all of them so that the reader can find those documents. This will not bother most readers, but as an instructor designing a class, this reader is seeking primary documents (public laws, scientific journal articles) to give to my students to directly illustrate the connections between chemistry and public policy.

Overall, this is an excellent book for anyone who is seeking a thorough and nuanced understanding of DDT.

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Theology

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GOD'S GIFT OF SCIENCE: Theological Presuppositions Underlying Exploration of the Natural World by Graeme Finlay. Eugene, OR: Wipf & Stock, 2022. 156 pages. Paperback; $22.00. ISBN: 9781666748062.

Graeme Finlay has had a long career as a cancer researcher and teacher of scientific pathology at the University of Auckland, New Zealand.

Many different books have approached the very critical topic of science and faith over the last twenty years. Polling research has shown that one of the principal reasons that young people leave churches, and their faith, is due to a perceived conflict between these two. It is a topic that should concern us all, and it is very important that it be approached from a variety of perspectives.

The particular approach of Finlay is not predominantly as an academic expert in the history of science, nor as one who is principally interested in winning critical debate points in the science and faith dialogue, but as a scientist who has lived this out and deeply studied it at a personal level. Finlay links his understanding of science, including its history and philosophy, to the very nature and personality of God. One can sense the spiritual depths of his personal faith in his writings. The beauty of this book is that it brings a deep understanding of science and connects its deep mysteries with the nature and character of God. I have read and studied many books on the topic of science and faith, but have yet to see one presented in such an evidently personal way.

One could look at the book with a strictly academic eye and focus on missing arguments or insufficient detail in some of the reflections, but that would be to miss the point. At some level, we need to step back from the mountains of information and make the science/faith discussion real at the personal level, not just in our minds, but also in our hearts and in our own faith walk. That is the real value of this book.

Finlay's book is divided into six chapters. The first chapter, "Science is Not Self-Sufficient," examines the nature and limits of science. He quotes Nietzsche,

> Strictly speaking, there is no such thing as science "without any presuppositions" … a philosophy, a "faith" must always be there first, so that science can acquire from it a direction, a meaning, a limit, a method, a right to exist … It is still a metaphysical faith that underlies our faith in science. (p. 11)

Finlay then himself states, "If we are to live truthfully, we should seek to discover the worldview that sustains and informs the scientific enterprise" (p. 11). This turns out to be the core truth that drives the entire book.

The second chapter, "One Source of Creation," relates science to the nature of God. God is almighty, wise, ordered, faithful, free, creative, holy, and redeeming. He speaks to us and is to be worshipped. Although each of these is treated as a small vignette, the sum total of the chapter makes the very significant point that science has emanated from, and is an integral part of, the very quality and character of God. The science that we observe and study is meant to bring us into relationship with him. This is the principal and most powerful contribution of this book.

Chapter three, "Science and the Nature of Humanity," outlines some of the social progress that has been brought about by people of faith. He relates this to humanity being made in the image of God (*imago Dei*) and the biblical nature of work for the person of faith. He examines the elimination of slavery, as well as contributions to medicine and education/literacy. This part mostly reads as a historical examination of the influence of the Christian faith on social progress. I would have been very interested to see how he views the role of faith in more-contemporary topics of social discourse.

Chapter four, "The Death of Science," outlines how the author views the future of scientific endeavor in the absence of a strong spiritual faith foundation. He quotes Thorson, "If the age of science comes to an end, it will really be because people collectively have not cherished and sustained that practicing faith in the reality and authority of truth" (p. 64). Finlay is convinced of this and understands the "growing threats to science in deeply theological terms" (p. 64). He discusses the influence of powerful special interest groups, such as the tobacco industry's connection to cancer and the fossil fuel industry to climate change, as examples where strong commercial interests can undermine science. He is concerned that the moral underpinnings of science are weakening and that we need "to return to God on whose truth science is most securely founded" (p. 68).

Chapter five, "Discovery in Theology and Science: Surprise," is an attempt to relate scientific discovery to elements of surprise as seen in some passages in scripture. Although one can readily agree with the premise that the surprise of scientific discovery is related to the mystery of God, this part felt labored and did not really work in my opinion. The most interesting part of the chapter was the surprise/discovery he experienced in his own research on cancer drug research and how that relates to God.

Chapter six, "Science and Theology in Sustainability and Justice," is almost entirely an examination of the severe consequences and implications of climate change. This final chapter has the objective of bringing everything up to the modern day and underlines our responsibility to the planet as people of faith. Although this is well referenced and is interesting, it is surprising

that the author did not spend more time on his own scientific discipline—it would have been very interesting to have heard his insights about the future of cancer research, its impact on humanity, and the role of faith.

Finlay's book principally treats the question of why science needs faith, and that is done quite well. One part that was missing is the misunderstanding of science within the church itself, and the dangers that arise in faith communities when faith is dissociated from science. I would have loved to have heard some of his personal thoughts on this.

The book is highly footnoted, and the sources are quoted heavily. This significantly adds to the book, especially in the areas where Finlay is not an academic expert. Many of the references are not particularly recent, but I have come away with a list of books I want to read. Overall, this is an excellent book that will stimulate thinking in the area of science and faith and touch the reader's heart at the same time. I haven't marked up a book to this extent for a long time.

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PROVIDENCE AND SCIENCE IN A WORLD OF CONTINGENCY: Thomas Aquinas' Metaphysics of Divine Action by Ignacio Silva. Abingdon, UK: Routledge, 2022. 170 pages. Paperback; $52.95. ISBN: 9781032002781.

Ignacio Silva (DPhil, Oxford) is an Argentinian theologian who specializes in the dialogue between science and theology. This book is a proposal for fellow scholars and others to reconsider the contribution of Thomas Aquinas's metaphysics as a means of resolving the question of divine action in the light of science. Although Aquinas is the thirteenth century's most famous friar and Catholicism's most renowned theological authority alongside Augustine, he is often viewed today as contributing few insights as regards an allegedly "modern" argument.

Silva argues that Aquinas supplies a way of getting beyond two mistaken views held by people today: (1) on the one hand, that God needs the natural world to be fundamentally open to outside influence; and (2) on the other hand, that God causes things to exist in a way that is similar to the way other natural causes cause things to occur.

Silva's goal is to get beyond the current situation in which "many today find it necessary to search for a lack of natural causation so as to find a space for God to act" (p. 139). According to this way of thinking, God's actions are only localized occasions, hence the school of thought known as occasionalism. Conversely, another tendency is for believers to argue that God's powers are self-restricted in order to account for natural powers. The latter point of view is sometimes stipulated in terms of the biblical concept of *kenosis* ("Christ … emptied himself," Phil. 2:7).

Silva's main point concerns a correct notion of causation such that we not restrict divine providence to an inadequate understanding of causation: "the idea of requiring insufficient causation for God to act depends on a deterministic notion of causation that, ultimately, renders God to act as a cause among causes" (p. 49). Silva holds that much causation is subject to chance contingencies. Thus, Silva's strategy is to think of causation in the context of potency and act. This allows a fresh and fuller way of dealing with the four parameters of divine providence: God's omnipotence, God's involvement with nature, nature's autonomy, and the success of science. The scope of the inquiry is enormous and Silva's handling of the thought of Thomas Aquinas is, unsurprisingly, difficult, yet hugely beneficial.

On the one hand, readers must be prepared for a dense tutorial in accounts of causality, powers, natures, and other metaphysical categories in order to appreciate the argument of this book. On the other hand, the argument over the relationship between God as the creating cause of the world and the secondary causes that act to create other effects in the world, is startlingly simple. It is best understood as a form of instrumental causality according to Silva. It is analogized (as so much of Aquinas's theology is) as follows:

> The knife is moved by the man to cut, and to do it in such a manner. Without the man's power, the knife could not cut, but without the edge of the knife, the man could not cut in this manner … the effect is both produced completely by God and by the natural agent … (p. 129)

Thus, without God, nature would not have the necessary powers to cause the effects it possesses. Without those natural efficient causes, God's power could not be effective. There is no split between divine and natural causation in any given effect; both are completely causal of any given effect. It is analogically helpful, although Silva does not discuss this idea, to invoke here the Incarnation of Jesus Christ: he is both fully divine and fully human, not half of each.

God acts in three ways: through creation itself, through natural (secondary) causes, and through three types of miracles—although, sadly, the latter do not receive much attention in this book. But the threefold action of God is intended to counter, on the one hand, the view that causality is always deterministic and, on the other hand, that God's action in the universe endangers nature's autonomy.

For some readers, the most difficult aspect of the argument will be the presentation of natural entities' powers of operation in terms of the four Aristotelian causes. The key is to think of causation in context. From Aristotle, change is a key feature of contingency. Change is organized into potency and act, essence and accident. These categories explain how causation results in real life. Moreover, theologically speaking, for Aquinas, "affirming that natural things do not operate, and that it is only God who does, diminishes the divine power" (p. 98, quoting the *Summa contra Gentiles III*, c 69). This is the counterintuitive power of the Thomist position. It opposes the view that attributes all natural causes to God's intervention. Holding that view would mean, in the end, that God actually does not create anything apart from God. But for God to create a world means to distinguish something apart from God and to allow contingency to exist in the spatio-temporal realm. The key point about the distinction between the eternal and the temporal realms is to ask why God creates in this way. Silva casually mentions that "God acts through natural causes because of the immensity of his goodness …" (p. 101). So, it is not a matter of metaphysical necessity that lies behind the Thomist view, it is God's goodness that is the key.

The position that created natural things are themselves creative needs to be exactingly well laid out; otherwise this position will be perceived as a way of extracting God from the world altogether. Here, Silva stipulates that "God's causality penetrates most intimately the causality of created natural things," while God upholds the creation "in its being" (p. 99). This is uncontroversial, but the provision for miracles is bound to raise questions about why God would act in this way. What Silva could have used are some examples of why some philosophers dissent from Aquinas on miracles, with responses to those dissents.

Silva covers an enormous amount of reflection on the notion of causality, including some original and highly potent insights. He claims that final causality is the "cause of the efficient cause in terms of its causality" (p. 71). This relationship, as well as the relationship between the material and formal cause, as first demarcated by Aristotle, is laid out in dense, logical prose. The book ends with some subtle yet significant comments on the differences between Aquinas's views and those of twentieth-century thinkers such as Austin Farrer, who referred to Aquinas in proposing a double agency account of creation while resorting to fideism. Farrer refused to suggest any explanation for the causal joint between God's creation and the world's operation. This analysis is original and should have been given more prominence. There is, indeed, a great deal of difference between fulsome and evasive double agency accounts of created causality; however, Silva ignores almost completely the medieval development of the theorem of the "supernatural," which came about because of the theoretical stance taken by Philip the Chancellor (d. 1236). This lapse is not critical, but it does exemplify the lack of a historical dimension to the book's argument.

Another quandary concerns the book's form of exposition. It is largely descriptive. While its argument details Aquinas's metaphysics of causal relations and the universe's created dependency on God, it lacks a dialectical edge. Although the argument is sufficiently sound, it is in need of an engagement with the open theists and others who would contest the account of divine power that Thomas Aquinas developed. There are quite a few references to other contemporary positions on providence and causality, especially in the final chapter. The names of William Carroll, Robert Russell, and Michael Dodds appear, but there could have been a more probing engagement of these contemporary voices. The Copenhagen interpretation of quantum physics is treated in the light of the proposed view of moderate determinism in contrast to the non-interventionist, objective (NIODA) view of divine action in Robert Russell. Here, I'm unsure whether NIODA has been properly interpreted. Although I think Silva's position is correct, is Russell's understanding of God's causality really reducible to natural causality as Silva contends? The textual citations for this allegation are not convincing.

Finally, despite what I take to be a largely satisfying account of God's creative action, the issue of evil and theodicy are not dealt with in this book. Aquinas makes contingency (and accidents in general) central for the notion of creation. Silva sees contingency as a sign of the perfection of divine providence, but this contradiction (between created contingency and the fact of natural "evil") is a real difficulty for God's involvement with evil or deficient effects in creation. Regardless, altogether this is a provocative, dense volume that could easily have been double the length if key problems had received more comprehensive treatment.

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