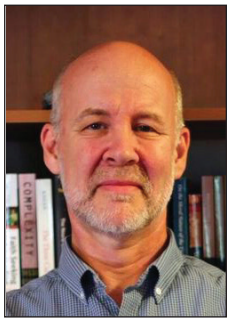

Chris Barrigar

God's *Agape*/Probability Design for the Universe

Chris Barrigar

Current Christian theologies of creation and apologetics often fail to take sufficient account of a range of elements within mainstream scientific knowledge today. In particular, it remains unclear how such phenomena as randomness and contingency, probabilistic physics, thermodynamics, massively large numbers, astrobiology, evolution, and multiple-realizability all fit with a teleological universe. Moreover, the supposed inability of such features to fit with a purposeful universe is frequently used by materialists (atheists) to critique theism. The author proposes a new account of God's design of the universe, called "the Agape/Probability *account," which contends that these phenomena are strategically built into the universe by God in order to achieve God's* agape-*love* telos *for the universe. This enables Christians to gain a more comprehensive picture of how contemporary science fits with faith, provides an alternative pro-evolution account to young earth creationism and intelligent design, and provides new resources in responding to materialist arguments against theism.*

Christian theology holds that God designed and created creation, and that God did so with purpose (a *telos*). Nonetheless, for two millennia the nature of that design has been subject to much debate. One debate concerns the particular *telos* of God's action, for scripture and Christian tradition use a range of concepts to identify that telos, such as "the kingdom of God," "love," "salvation," "oneness with Christ," and "deification." So, how should all these be related? Let us call this "the divine-purpose problem" (the problem being with our language for God's purpose, not with God's purpose itself).

Another debate concerns God's method in creating this purposeful universe—how should we best conceive of God's creative strategy? Let us call this "the divine-strategy problem." Here we may identify two types of strategies that theists have proposed: "front-loaded," by which God launched the universe with the initial conditions necessary for the emergence of creation as God desired it, to fulfill the divine *telos*; and "punctuated," by which God not only launched the universe but has also acted from time to time within creation to bring about particular effects to fulfill that *telos*. (Both types agree that God also sustains the ongoing existence of the universe.)

Front-loaded accounts have been proposed by numerous figures, including John Polkinghorne, Arthur Peacocke, Howard Van Till, Ian Barbour, and Keith Ward. Historically, however, orthodox Christian thought has been much more sympathetic to punctuated accounts, for several reasons: it seems very difficult to connect front-loaded accounts with teleology (divine purposefulness), particularly to fine-detailed elements of human physiology such as eyes or opposable thumbs (as frequent exemplars of God's purposeful design); it is difficult to reconcile front-loaded accounts with God's creation of Adam and Eve; and front-loaded accounts are historically

Chris Barrigar *is pastor of St. Peter's Anglican Church, Montreal, Canada. He holds a PhD in philosophy from McGill University, Montreal, and has taught at the graduate level for a number of Canadian, Indian, and British institutions. He is author of* Freedom All the Way Up: God and the Meaning of Life in a Scientific Age *(Friesen, 2017).*

associated with deism rather than theism—that is, with belief in a nonrelational Creator who, since launching creation, has simply left creation to its own devices.

Punctuated accounts may be subdivided into two types: "interventionist," such as young earth creationism (YEC) and intelligent design (ID), which hold that God intervenes on occasion by suspending, bypassing, or modifying the laws or structures of nature to achieve a particular outcome; and "non-interventionist" (commonly called "Non-Interventionist Objective Divine Action," or NIODA) whereby, rather than directly intervening in nature, God acts as one more force among the range of forces (often proposed at the quantum level) within a particular physical context to facilitate a particular outcome.

The problems with YEC and ID are well documented in this journal. It is not, however, just YEC and ID accounts that are deficient, for it is a common problem in creation discussions across the board that inadequate attention is given to such scientifically recognized features in nature as genuine randomness, probabilistic physics, massively large numbers, thermodynamics, human evolution, evolutionary convergence, and the probability of life occurring elsewhere in the universe. Christian scientists and theologians today do discuss some of these features, particularly human evolution; and as I write this, a cohort of scholars is working on "theology and astrobiology" at Princeton's Center of Theological Inquiry. Certainly some thinkers are more broadly integrative than others (such as John Polkinghorne, with his comprehensive integration of the sciences and faith). Nonetheless, much work remains in the task of understanding how these features of nature serve as intentionally strategic elements in God's design.

To this end, this article describes, within Trinitarian Christian orthodoxy, a new account of God's design which I call "the *Agape*/Probability (A/P) account."[1] The A/P account addresses both the purpose problem and the strategy problem: first, by identifying a particular divine *telos* for the universe(s); then, by providing a new front-loaded account of how God designed creation to bring this *telos* about—an account that bypasses the three traditional problems identified above with front-loaded models.[2]

The *Agape*/Probability Account

The purpose problem exists because both Scripture and Christian tradition have produced numerous ways to speak of God's purpose. The A/P account suggests that God's purpose derives from God's own eternal nature, which is fundamentally *agape*-love, as seen in God's incarnation as Emmanuel, Jesus of Nazareth (John 3:16). In this context, the Greek word *agape* does not mean simply love as "emotional attachment" or as "desire," but rather love as "sacrificial self-giving." The self-giving love modeled by Jesus was at times directed toward God, yet most of the New Testament record is of his self-giving actions directed to the well-being of others whom he had never previously met—the Samaritan woman at the well, the Centurion's servant, the ten lepers, among many others. It is precisely in the servanthood, suffering, and death of Jesus that we see God's definitive account of what constitutes *agape*-love, namely, *self-giving*—specifically *self-giving to God and self-giving for the blessing of others, particularly those who are vulnerable as well as strangers and enemies.* The A/P account holds that it is through the concept of *agape*-love that all other *telos*-like terms and concepts ("kingdom of God," "union with Christ," "salvation," and so forth) must be interpreted and placed within a Christian worldview. From this the A/P account proposes that the divine purpose in creation was to bring about beings in relationships of *agape*-love with God and with others.

Nonetheless, a more comprehensive understanding of this purpose can be seen through what we observe in the book of nature. For instance, such features of nature as randomness, order, emergent-complexity, thermodynamics, massively large numbers, evolution, and astrobiology (organic compounds detected in space) must be seen not as interesting-but-incidental side effects of God's creative activity, but rather as essential elements to achieving the divine purpose. Here then the purpose question merges with the strategy question: how do such scientifically observed features of nature strategically serve the divine *telos*? The A/P account makes a two-part proposal. This is the first part:

> God created the universe(s) to provide the space and conditions for the emergence of habitable bio-niches in which *agape*-capable beings would eventually emerge to live in *agape*-love relations with God and with others. Earth is one such emergent bio-niche, and *Homo sapiens* are an instance of such emergent *agape*-loving beings.

Carl Sagan once commented, "If you wish to make an apple pie from scratch, you must first invent the universe."[3] Sagan was right, except that the Universe-Maker's intention was more profound than baking apple pies—the Maker's purpose was to create *agape*-capable beings in self-giving relationships with God and with others. So we can slightly revise Sagan's words in this way: *If you want to make* agape-*relationships from scratch, you must first invent the universe*—which is precisely what the Creator has done. Now let us examine some features of God's strategy in creating such a universe.

Freedom, Randomness, and Order in Creation

An essential element of *agape*-love is the neural capacity conventionally called "free will"—the neural capacity to choose between options or possibilities. The actual existence of free will, let alone its nature, is a highly controversial subject in both neuroscience and philosophy. The A/P account defends the existence within humans of sufficient free will for purposes of choosing to engage, or not engage, in *agapic* actions and relationships.[4] Regardless, though, of our particular case as *Homo sapiens*, "the issue facing God" (to speak anthropomorphically) was how to bring about the existence in the universe of beings with sufficient free will to choose *agapic* behaviors.

No doubt God could conceive of a variety of routes to this end. For instance, God could choose a *de novo* method by which to create *agape*-capable beings, such as described in Genesis 1 with Adam from the dust and Eve from his side. Maybe somewhere in our universe, or in another universe, God has indeed created by a *de novo* method; however, the book of nature, as understood through mainstream contemporary science, does not show *de novo* as having been God's actual method of creation on Earth. In contrast to a *de novo* method, what the book of nature does show is a system of *creatio emergens*—continuing, emergent creation. That is, *agape*-capable beings on Earth have emerged through the standard processes of nature which themselves emerged from the big bang—a multibillion-year process of "entropy-defying self-organization,"[5] with emergent levels of complexification, including the emergence of biology and evolution.

This is a system, then, in which "free will" is not a product of soul (as in traditional theology) but is rather an emergent property of some forms of evolved beings within this system. (Note, though, that this does not eliminate the place of soul in Christian anthropology.)[6] On this basis, the A/P account proposes that the universe is a system designed by God to naturally bring about, over sufficient time, the existence of *agape*-capable beings. In other words, on the A/P account God's intention was not specifically to bring about *Homo sapiens* on Earth, but rather to bring about *agape*-capable beings—and the universe was created by God with the right initial conditions to ensure the eventual emergence of such beings.

Such an outcome requires predictability (for God to successfully predict that *agape*-capable beings would eventually emerge in the universe) without predetermination (in order to preserve free will)—a tricky combination, at first blush. Nonetheless, predictability can exist without predetermination if the basis of predictability is probability rather than certainty. In effect, God could create a physical system that is probabilistic. This is precisely how today we understand the nature of physics—as probabilistic. More specifically, God could devise a system with *very high probability*.[7] That is, God's creative strategy could be to devise a physical system by which to achieve the desired outcome, namely, the nondeterministic yet highly probable emergence of *agape*-capable beings in the universe, over sufficient time.

In order to ensure this nondeterministic-yet-highly-probable outcome, what qualities has God built into the universe? For nondeterminism, we see *indeterminism* at the quantum level, along with *randomness* and *entropy* at the classical level; for probability, we see *order*; and for *high* probability, we see *massively large numbers*. Let's look at each of these in turn, beginning with randomness.

The existence of quantum indeterminism and of genuine randomness are uncontroversial postulates in mainstream science, yet the existence of randomness has been denied in some theological circles. Some theists object to the suggestion that God would permit, let alone intentionally bring about, genuine randomness in creation, as this would supposedly compromise God's sovereignty. In recent years, however, a number of Christian scholars have argued for the theological compatibility of genuine randomness with God's nature and purposes.[8]

The A/P account argues not simply that randomness fits with God's sovereignty, but that randomness is *essential* to God's teleological strategy, built into the universe right from the big bang. We see this analogously in our high-tech world today. A widely found example is random number generators, which are used for lotteries, for encryption, for the shuffle option on a CD player, for noncharacter players in video games, and for numerous other applications. Or, to take a very different example, the random motion and multiplication of bacteria cultivated in a petri dish are likewise initiated purposefully by the scientist or technician engaged in a particular research project or medical test. Such applications are teleological, for they intentionally employ randomness as part of a process to achieve intended, purposeful outcomes; moreover, this randomness is critical to the process and its purpose.

So too with God's creative process. For one, complexity theory has established that randomness is inherent to the emergence of order in general.[9] For another, randomness is integral to sustaining life. As Peter Hoffmann dramatically puts it, "Without the chaos of the molecular storm, the molecular motors in our cells would not move and we would be dead."[10] For yet another, randomness is an essential element of free will. As neuroscientist Peter Tse has argued, the molecular randomness of thermal noise is actually a crucial element in the neural processes that enable free will.[11] These are just three examples of how randomness is an essential feature of our universe. In effect, the claim that God could not use randomness is itself a claim that both limits God's sovereignty and contradicts God's book of nature.

While quantum indeterminacy, thermal noise, and the molecular storm give us randomness, as required for a nondeterminist physical reality, God's purpose also requires a significant degree of *predictability*, which itself requires *order*—so there needs to be a capacity built into physical reality by which order and increasing complexity can emerge from randomness. Galaxies emerged from the big bang, simple life emerged from inorganic elements, complex life emerged from simple cellular structures. The emergence of self-organizing order and complexification is the point at which the various "laws" and regularities of nature enter the picture, as well as patterns of bottom-up and top-down causation. This is also the point at which misunderstanding of thermodynamics, particularly the second law, can enter in. As Miguel Rubi puts it,

> The development of order from [randomness], far from contradicting the second law, fits nicely into a broader framework of thermodynamics … [T]he second law does not mandate a steady degeneration. Rather, the second law of thermodynamics quite happily co-exists with the spontaneous development of order and complexity.[12]

Randomness, Probability, and *Agape*-Capability

This coexistence of order with randomness is essential to free will and to *agape*-capability, and thus is essential to God's *agape*-love *telos*. Nonetheless, this teleologically essential blend of randomness and order is itself insufficient for bringing about *agape*-capable beings. So God has also built into the cosmic system a means to ensure with *high probability* that *agape*-capability will indeed emerge, namely, *massively large numbers*—ranging from stars in the universe to cells in a body, from base-pairs in DNA to neurons in a brain, perhaps even universes in a multiverse!

An illustration may be helpful here. One example of a high-probability method of creation is *spawning*: many fish and mollusc species spawn massive numbers of eggs at a time in order to ensure that a sufficient proportion survives. In many species, only one-in-several-million eggs spawned survives to reproduce. In the particular case of oysters, one female will produce about 114 million eggs per spawn, with an average of two surviving to reproduce;[13] this means that the odds of surviving for oyster eggs—1 in about every 57 million—are worse than the odds of winning a typical lottery! Nonetheless, this massively large numbers approach to reproduction enables oysters to flourish. Or, to provide another example, Francisco Ayala reports that the probability of an *E. coli* bacterial cell developing both the mutation that enables resistance to streptomycin (an antibiotic which normally kills *E. coli*) and the mutation that enables *E. coli* to grow without histidine (an amino acid normally required by *E. coli* for growth) is about 4 in 10 *million billion* cells. Ayala then comments that "an event of such low probability is unlikely to occur in a large laboratory culture of bacterial cells, yet natural selection commonly results in cells possessing both properties."[14]

For God's purposes, the advantage of massively large numbers is that they avoid a deterministic process while providing high-probability outcomes. This is achieved by providing infinite opportunities for random "trial-and-error" to produce the sorts of successive steps needed to produce the ever-increasing complexity required for *agape*-capability to eventually emerge in the universe. Such steps, achieved through endless opportunities for trial-and-error, include producing that rare planet or moon with water and an atmosphere in a habitable zone, that one-in-a-gazillion occurrence of a cell-within-a-cell to create the first mitochondria, or that one-in-a-bazillion mutation needed for the emergence of metabolism.

In effect, through the phenomenon of massively large numbers, there can be a high probability (on a universal scale) that low-probability biological events (on a local scale) will be repeatedly achieved across the universe with sufficient time. Of course, once life forms have emerged, extinctions (including mass extinctions), genetic bottlenecks, and evolutionary one-offs and dead ends are inevitable along the evolutionary trail. This massively large numbers approach enables *agape*-producing processes to get going again on other evolutionary tracks following such extinctions, bottlenecks, or dead ends.

Despite what appear to be long odds for the emergence of life, the field of astrobiology exists because there are countless billions of celestial bodies, offering the statistical possibility that life-producing biochemical processes will recur across the universe, given sufficient time. For materialists, the holy grail of such cosmic searching is not merely the discovery of cellular life elsewhere in the universe, but the discovery of other conscious, intelligent beings in the universe. In contrast, the A/P account is principally interested in whether there exist other *agape*-capable beings in the universe; in effect, for the A/P account, consciousness is simply a condition of possibility for intelligence and, in particular, for *agape*-capability. We may be surprised when we find other *agape*-capable, or proto-*agape*-capable, beings in our universe, but such a situation will essentially be no different than those many occasions over the past 5,000 years of human history when explorers, traders, or warriors have been surprised to discover previously unknown people-groups living on the other side of a distant mountain range, body of water, or desert. "Oh! We're not the only ones here after all!"

To summarize thus far, the A/P account proposes that God has brought about, and sustains, a physical-chemical system (the universe) that combines randomness, order, and massively large numbers to create a probabilistic rather than deterministic system, by which to bring about the highly probable emergence of beings with sufficient free will for purposes of choosing lives of *agape*-love. In effect, God allows the created order to evolve on its own, to "make itself" (to use Polkinghorne's phrase) from initial conditions which lead to the probabilistic emergence of *agape*-capable beings. God is able to act as a causal force in this creation, but he chooses to reserve moments of such action for *agapic* acts in *agapic* relationships (more about which, below). Earth may be the only eco-niche yet to emerge with *agape*-capable beings, or there may already be other such inhabited eco-niches, with some statistically discernible pattern to their emergence across the universe. We do not yet know.

Predictability

We need to say more about *predictability*, in particular about the A/P claim that the emergence of *agape*-loving beings could be predicted by God without being predetermined. Predictability faces two hurdles: randomness and complexity.

We have already discussed how randomness serves the emergence of *agape*-capability, yet randomness is often understood to be an inhibition to prediction. That randomness serves the emergence of *agape*-capability does not necessarily mean that God could predict the emergence of *agape*-capability from the initial conditions of the universe(s). Furthermore, as order emerges, new levels of self-organising patterns known as *complex systems* likewise emerge, and these too provide a prediction problem, especially when they become *dynamic* complex systems, that is, when they involve internal change. Countless examples exist of dynamic complex systems, including galaxies, Earth's climate, the stock market, and the brain. In fact, emergent levels of complexity occur at every level of physical, cosmological, chemical, and biological existence—including the neurological structures and processes which make *agape*-love possible.

The problem for predictability arises because it appears that emerging levels of complex order simply cannot be predicted. Each level of complexity has its own properties, laws, regularities, and behaviors: that is, each level needs methodological tools distinct to each level of complexity. For instance, the methods and tools for understanding atomic structure are not the same methods or tools needed for understanding crystalline structures, which are not those needed for understanding complex solids or fluids, which are not those needed for gene analysis—all the way up the chain of complexity in nature. Consequently, scientists say that one "lower," or less-complex, level does not enable us to predict the next level of emergence. As Nobel-winning physicist Philip W. Anderson comments, "The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe."[15] In short, we can never exhaustively anticipate what possibilities exist for the next level of organization, and thus they cannot be predicted.

Into this picture comes the further complication that many dynamic complex systems are *chaotic*. In complex systems theory, chaos refers to the unpredictable outcome of a process in a dynamic (changing) system. In dynamic complex systems, there is a set of initial conditions which makes outcomes predictable to a certain point (just as weather forecasts are reasonably accurate for a few days), yet there comes a point at which predictions become increasingly unreliable because the tiniest error in estimating the initial conditions results in increasingly magnified errors over the longer term. The actual initial conditions make such systems locally determinist, yet only their short-term outcomes are predictable—their medium-term or long-term outcomes are not predictable because of our limited knowledge of the initial conditions.

In effect, the existence of both randomness and complexity seems to combine into a powerful two-punch argument that it simply would not be possible for God to have predicted that loving-beings would come to exist from the initial conditions of the universe. Yet it turns out that significant patterns of predictability *are* possible, despite both randomness and complexity within the structures of nature. At the quantum level, Schrödinger's wave functions are predictable probability distributions. At the classical level, boundary constraints on randomness in a particular system can be knowable, thereby allowing predictability for conditions within that system.[16] Once order has arisen within a system, you can start to measure it, even if only by way of estimated round numbers (as is necessary with massively large numbers). Then, once you can measure something, probabilities become part of the picture—at which point some degree of prediction becomes possible.

For instance, to return to our earlier example of spawning, despite the randomness of the spawning process, hatchling survival rates are so consistent that scientists are able to accurately predict stock sizes for purposes of fisheries conservation and management policies. Or, to use a very different example, we can look at American driving patterns. According to the Federal Highway Administration, there are over 210 million drivers in the USA. Their driving habits relative to each other are completely random, yet each year the average miles driven per driver varies by only a very small amount. This phenomenon is so reliable that trend predictions become possible for public policy purposes, such as where to spend money for new highway projects. Underneath such examples lies a remarkable feature about randomness. As Leonard Mlodinow observes with regard to the randomness of human behavior,

> A statistical ensemble of people acting randomly often displays behavior as consistent and predictable as a group of people pursuing conscious goals … [I]n aggregate their [individually random] behavior [i.e., the actions of American drivers] could hardly have proved more orderly.[17]

Of course, this observation is not limited to just patterns of human behavior, for aggregates of all sorts of random-acting objects end up displaying consistent, measurable—and thus probabilistically predictable—patterns. As Melanie Mitchell puts it, "even though 'prediction becomes impossible' at the detailed level, there are higher-level aspects of complex systems that are indeed predictable."[18]

We see such patterns of probabilistic predictability operating in at least two different fields of mathematics: *cellular automata simulation* and *statistical mechanics*. The former uses mathematical models to demonstrate that computationally irreducible physical processes can be predictable at a coarse-grained level of description, emulating large-scale behavior without accounting for small-scale details.[19] The latter, statistical mechanics, also provides predictability

from randomness. In the 1800s, James Maxwell and Ludwig Boltzmann both found that the random movement of molecules can be quantified by averaging large numbers of molecules in a volume. The value of statistical mechanics to science lies in its ability to measure probability distributions of macrostates—that is, to predict the average behavior of randomly distributed molecules in a system on the basis of the most probable distributions (such as in the ideal gas law). In effect, statistical mechanics provides a powerful set of mathematical tools by which to make probabilistic macroscopic (classical, Newtonian-level) predictions from randomised microscopic (atomic or molecular) properties.

Importantly for our purposes, statistical mechanics can be applied to complex systems. Traditionally, complex systems (such as neural networks or the internet) were modeled as purely random graphs, yet scientists and mathematicians now understand the evolution of complex networks to be governed by deeply inherent organizing principles. The journal *Physica A* is dedicated to studying the application of statistical mechanics to as broad a range of subjects as possible. To take just a single representative example, the most frequently downloaded article from this journal reports on "link algorithms." Links between nodes are a fundamental element of any complex system, be it a biological system of cells, an internet system of web users, or a distribution system for retail outlets. Statistical mechanics can be used to formulate link-prediction algorithms to predict the links that may appear in the future of evolving networks, and thus predict future evolution of networks.[20]

Statistical mechanics, together with ever-increasing computing power, has provided us with degrees of probabilistic-prediction capability, within conditions of both randomness and complex systems, that earlier generations of mathematicians and scientists would not have imagined possible.

Furthermore, even without statistical mechanics, science sometimes discovers predictability where it is not expected. For instance, researchers at Cambridge University, working in a field called granular physics, tried to figure out the possible number of configurations that 128 soft spheres, like tennis balls, could take. (Granular physics deals with the behavior of granular entities, such as snow, soil, and sand). This configuration problem, which amounts to figuring out the configurational entropy of granular systems, was considered unsolvable because the calculations involved are so complicated that "they have been dismissed as hopeless"—except that these researchers came up with a way to solve the problem anyway. (For the record, the answer is about 10^{250} configurations; this number vastly exceeds the total number of particles in the universe.) As it turns out, the method they came up with has incredible predictive powers. For instance, it could help predict how avalanches move or deserts change—predictions that previously were thought impossible, until this technique was discovered.[21]

God and Predictability, Part 1

It seems likely that science will continue to have such moments of discovery, finding elements of predictability within conditions that were previously thought unpredictable. The point here is simple: it may well be that the physical conditions of the universe include features that make probabilistic prediction significantly more possible than we can conceive, particularly for God. In effect, God possesses probabilistic-prediction capabilities greater than we can imagine, because God built into the initial physical conditions of the universe(s) statistical features that would enable God to predict the highly probable emergence of *agape*-capable beings over sufficient time. Such features would include statistical mechanics, the law of large numbers, the central limit theorem (bell curve), regression to the mean, power laws, and all the other various features of mathematical order known and not-yet-known to the statistical sciences. That is, while preserving a level of randomness sufficient for the emergence of free will (at least sufficient for *agape*-capability), God could have a much fuller grasp than we can imagine of the initial conditions of any particular process or system, enabling greater predictability by God within complex systems ranging from the universe to neural networks.

All these various factors make the job of prediction-with-high-probability more conceivable for God than we might initially imagine. At the same time, they raise the question of the "degree of resolution": how fine-grained or coarse-grained need God's predictions be of specific emergent systems or evolutionary pathways for purposes of bringing about *agape*-capable beings? They do not need to be so fine-grained that God needs to predict every possible

evolutionary pathway that can evolve anywhere in the universe—even for God such predictive precision would be possible only under determinist initial conditions, thus eliminating the possibility of free will. Rather, God's predictions can be sufficiently located on a fine-grain/coarse-grain spectrum to allow for multiple routes to multiple forms of *agape*-love capability. We will now see precisely this evolutionary reality of multiple routes to equivalent evolutionary traits.

Multiple-Realizability, Convergence, and Predictability in Biology

We are all aware of evolutionary *di*vergence—that there are millions of species that have come to exist across our planet. The tree of life is, in effect, a tree of divergences. Yet within evolution there is not just divergence but also *con*vergence—the phenomenon whereby two or more different life-forms produce, or "converge on," very similar evolutionary outcomes. So the tree of life is also a tree of *con*vergences: facing similar environmental challenges to survival and reproduction, biological forms of very different evolutionary origins will often evolve similar or identical solutions to those challenges. George McGhee, professor of paleobiology at Rutgers University, comments,

> We live in a universe where convergence in evolution is rampant at every level, from the external forms of living organisms down to the very molecules from which they are constructed, from the ecological roles in nature to the way in which minds function.[22]

Paleobiologist Simon Conway Morris, well known to readers of this journal, speaks of "the sheer ubiquity of evolutionary convergence … the propensity for biological forms (and examples of this extend from molecular systems to social systems) to navigate repeatedly to the same solution."[23]

There are literally countless examples of convergence in nature, at all levels of biology. Importantly, convergence is found not only at the phenotype level but also at all biomolecular levels, including DNA, RNA, genes, proteins, and enzymes. Of particular interest to our discussion here are convergences associated with the nervous system, such as consciousness, emotions, and intelligence. The intelligence of some species of animals is well documented. Among mammals there is a diverse range of intelligent species, from chimpanzees to elephants to dolphins. Since mammals, with their six cortical layers, share a common neural evolutionary history, it is not surprising to see intelligence, even if of varying levels, arising repeatedly among various mammalian species. Yet intelligence is not just limited to mammals, for it is also convergently found in two other very different families in the animal kingdom—cephalopods (squid, octopi) and corvids (crows, ravens, jays). Conway Morris concludes, contrary to Stephen Jay Gould, that "however many times we re-run the tape [of the evolution of life on Earth], we *will* end up with much the same result. This must include intelligence."[24]

Underneath the surface phenomena of convergence is the concept of *multiple-realizability,* the idea that multiple routes are capable of producing the same outcome or trait. Continuing at the level of intelligence, we see this in the many recent studies on corvid intelligence. Indeed, Clayton and Emery contend that some members of the crow family are on an intellectual par with the great apes.[25] Corvid intelligence is surprising not only because their brains are so much smaller than those of apes, elephants, or dolphins, but also because their neural architecture is so completely different from that of either mammals or cephalopods.

The neural basis of corvid intelligence is an area of their brains called the nidopallium caudolaterale (NCL). Just as the prefrontal cortex (PFC) is a component of the mammalian forebrain, so too is the NCL a component of the avian forebrain. Corvid NCLs have developed a variety of functions analogous to those found in the PFC of intelligent mammals, even though structurally the NCL looks nothing like the PFC and even uses a different type of neuron. The advanced intelligence demonstrated by some corvid NCLs "emphasizes that intelligence in vertebrates does not necessarily rely on a neocortex but can be realized in endbrain circuitries that developed independently via convergent evolution."[26] In other words, primates and corvids have both developed the ability to form executive functions, situation analyses, abstract behavioral rule formation, and flexible (nonstimulus-determined) rule implementation—yet have done so with a "strikingly different neuroarchitecture," as Veit and Nieder put it. In short, very different brain structures and neural architectures are capable of producing intelligence.

Similarly with human intelligence, as Jung and Haier have found with regard to humans, "different types of brain designs can produce equivalent intellectual performance."[27]

Recent research with lobsters provides a further helpful illustration of multiple-realizability at the neural level. Michael Gazzaniga describes some of this research as follows:

> Eve 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 modeling 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 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.[28]

As Marder and her coauthors state, "We found that virtually indistinguishable [neural] network activity can arise from widely disparate sets of underlying neural mechanisms."[29]

Our reason for discussing multiple-realizability and convergence is to propose that neural structures for free will and *agape*-capability are multiple-realizable and convergent—not only on Earth but, as astrobiology would suggest, cosmically as well. Consequently, multiple-realizability and convergence give grounds for some level of predictability, for which a range of tools makes such predictability potentially possible. For instance, McGhee proposes a discipline he calls "theoretical morphology," which provides an analytical framework to predict evolutionary convergences. More widely found is the application of statistical mechanics to evolutionary biology (a field called biophysics), making quantitative biology, including evolutionary development, a predictive science.[30] The field of cooperation-modeling likewise provides levels of evolutionary prediction.

But then the question arises as to the *degree* of predictability by such methods. Harvard herpetologist Jonathan Losos suggests a modest degree. Here he comments on the emergence of *Homo sapiens:*

> Can we predict evolution? In the short-term, yes, to some extent. But the longer the passage of time and the more different the ancestors or conditions, the less likely we are to prognosticate successfully … Were we [*Homo sapiens*] destined to be here? Hardly. If any of a countless number of events had occurred differently in the past, *Homo sapiens* would not have evolved. We were far from inevitable … On the other hand, perhaps with a different historical sequence humanoid dopplegängers could have evolved prolifically. Perhaps the world would have been populated by marsupial humans, as well as lemur humans, bear humans, crow humans, even lizard humans … It could have been.[31]

The A/P account proposes that neural *agape*-capability is multiple-realizable through many possible evolutionary routes, including within diverse morphologies and phenotypes. Consequently, the A/P account contends that God was not concerned to bring about *Homo sapiens* in particular; consequently, the A/P account is readily able to accommodate the possibility that it could have been marsupial humans or lizard humans, rather than mammalian humans, which emerged on Earth bearing *agape*-capability. But then this simply reinforces our question: what degree of predictability does God require in order to bring about *agape*-capable beings?

God and Predictability, Part 2

We have seen throughout this article a number of contexts in which probabilistic predictability is possible today in ways which scientists once would not have imagined possible. Analogously, the A/P account contends that God has sufficient predictive resources, both known and unknown to us, that God could predict with very high probability that beings with consciousness and sufficient free will for purposes of *agape*-love would eventually emerge from the physical-chemical processes launched by God at the creation of the universe(s). And God has created a range of tools to facilitate this predictability—the

laws (or regularities) of physics, along with mathematics and statistics.

All the same, these tools do not enable total predictability for God, such as predicting that mammalian humans would come about instead of, say, marsupial humans. Neither does it enable prediction of every specific neural pathway for every type of *agape*-capable being that will ever emerge on every possible eco-niche in the universe. Only a system without randomness could provide such deterministic predictability, but such predictability and control is not God's objective. Rather, God has created the physical-chemical system we experience in our universe with its particular balance of randomness, order, emergent complexity, laws, regularities, and probabilities,[32] because it provides just what God desires, namely, a process by which beings with neurophysiological *agape*-love capabilities would emerge through convergence and multiple-realizability.

This provides us, then, with the second part of the A/P account:

> God's design of the initial conditions of the universe(s) provided God with a degree of predictive resolution such that God foreknew *that many possible routes could come about in the universe(s) to provide agapic neural capabilities, and that one or more of these would come about (*by way of high probability through massively large numbers over sufficient time)*, without needing to predict (foreknow) which actual neural routes would come about.*

This is the heart of the probability component of the A/P account.

This creative process may seem incredibly slow to us. For instance, it has taken about 14 billion years for the *agape*-capable beings of which we are aware (*Homo sapiens* and other *hominins* on Earth) to emerge in our universe. Why would God have chosen such a slow process? From God's perspective this may not be such a slow process, for God's sense of time is likely very different from ours. From our perspective, though, this apparent slowness is simply the result of creating a system that relies on probability rather than determinism. This then provides the story of order, regularities, determinism, randomness, and probabilities that exist "all the way up" the system of creation, running through everything in our universe, told to us through the tools of math and science. In turn, this provides us with the physical-chemical-biological-statistical means by which God's *agape*-purpose for the universe is accomplished. In other words, this is the story of the emergent creation within which Emmanuel has brought to *agape*-capable beings on Earth 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." That is, love God and love others with *agape*-love.

Theological Implications

Understanding Adam and Eve

The A/P account immediately gives rise to a number of theological questions. One question concerns Adam and Eve. There currently exist a number of proposals for how to understand Adam and Eve within evolutionary theism.[33] The A/P account is amenable to such proposals, while not requiring any particular proposal.

Bearing the Imago Dei

Another question concerns the *imago Dei*: within the A/P account, how do *agape*-capable beings bear the image of God? With regard to humanity, this question is being increasingly addressed by evolutionary theists, because of how the *imago Dei* may relate to evolutionary development. The A/P account can accommodate a range of possibilities; however, my own preference begins with observing that the *imago Dei* concept is a derivation of the Ancient Near Eastern concept of *şelem*—whereby a king (or sometimes priest) is considered an image or icon of a god, mediating that god's presence and interests to the people. Genesis 1:26 uses *şelem* (translated as "image of God"), but reshapes its meaning so that not just kings but all people, regardless of race, gender, or class, are *şelem*, imaging (thus representing and mediating) YHWH's presence and interests.[34] That is, humanity is commissioned (or elected) by God to represent God's interests on Earth, and the primary job given humanity in this representative role is to "rule" the Earth for God—to serve as God's stewards (overseers and caretakers) of the whole planet.

From an A/P perspective, this means that God delegates to *agape*-capable beings, at some point in their evolutionary development (possibly with the emergence of gene-culture coevolution), the oversight and stewardship of their home bio-niche. Why should God give them such responsibility? Precisely because evolution produces in *agape*-capable beings

not just *agape*-capability but also capabilities for great destruction. So *agape*-capable beings anywhere in the universe reach a point in their evolutionary development whereby God elects them to this status ("being in the image of God"), as a commission to the vocation of being God's "*agapic* stewards" of their home bio-niche.[35]

The Location of Divine Action

A third issue concerns divine action. The A/P account is rooted in Trinitarian orthodoxy, and so is a theist, not deist, model, employing a classical account of creation as an act of the Triune God. As such, it affirms not only that God created the universe(s), and created creation with a *telos* reflecting God's own nature (as *agapic*), but also that God is at all times actively engaged with creation by sustaining the continuing existence of creation (presumably by sustaining the physical fields and forces undergirding the universe); moreover, God is able to act as a causal force in creation. Nonetheless, on the A/P account's front-loaded approach, God has chosen to create a system whereby God would not need to be involved in the emergent-creative process after its initial launch; that is, God has chosen to reserve God's post-big-bang involvement in the universe for actions and relationships of *agape*-love.

Some may suggest this is an excessively front-loaded approach; for, while preserving much of the front-loaded emergence process of creation, God could also have "steered" (or perhaps "nudged") the emerging-complexity and evolutionary processes at particular moments along the way. (This would be the "punctuated" divine action model.) I see, however, three problems with this steering or nudging approach. *First*, it is theologically unnecessary, and certainly not required or even implied by Christian orthodoxy.

Second, it is unclear why God would need to steer or nudge the process at all, as the initial conditions have proved capable of providing the intended outcome. For instance, it is well known that mammal species will protect other mammal species, sometimes at risk to themselves: dogs will protect their owners when the owner is threatened; whales are known to protect seals from sharks; dolphins have been known to protect injured swimmers from sharks; and a marine biologist recently reported being protected by a humpback whale from an attacking tiger shark. These are signs of altruism as an evolved trait among mammals, and, as such, signs of proto-*agape* capability. Evolutionarily, the genetic disposition to such altruistic behaviors would have emerged as far back as the last common ancestor to these various mammals, roughly 65 mya.[36] So, at what point would divine nudges to proto-*agape*-capability, then to *agape*-capability, have been needed? On cosmic and evolutionary timeframes, there seems no need to posit divine steering or nudging—the God-created process and time-frame is sufficient for the probabilistic emergence of *agape*-capability in the universe.

Third, the steering/nudge approach is apologetically unhelpful. One of materialism's objections to theism is that divine action gets invoked *ad hoc* into natural processes; on the A/P account, however, the universe is itself capable of producing the outcome God desires (i.e., *agape*-capable beings), thereby removing this materialist objection. In short, by avoiding the need for divine steering or nudging over the 13.8 billion years of the universe's existence, the A/P account bypasses all three of these problems while remaining theologically orthodox.

Divine action in *agapic* relationships is a separate matter. Divine *agapic* action can take diverse forms, including giving gifts and fruit of the Holy Spirit; providing inspiration, wisdom, guidance; providing healing (emotional, relational, and physical); and acting in physical surroundings (nature) to bring about *agapic* consequences for people and/or animals. Here the A/P account requires no particular account of divine action. That is, the A/P account does not inherently choose between interventionist accounts or noninterventionist accounts. I would, however, note that I personally lean to the latter.

The term "miracle" derives from the Latin Vulgate, and has, in my view, misled discussions of divine action for many centuries by implying divine intervention by suspending or bypassing natural laws. Rather, the Greek New Testament word underlying "miracle" is simply *dynamis*—God's "power." This is a much more general word, leaving wide open the possibilities for *how* God acts. Over the past few decades, a common suggestion has been that God acts on neurons or other cellular structures through the quantum level—although detractors have made various arguments against the physical possibility of God acting through the quantum level for specific macro/classical-level effects. Regardless,

there is much work being done these days in the area of divine action, and the A/P account is fully open to these. In *Freedom All the Way Up,* I address this theme further, including commending Basil Favis's proposal for God operating through multiple dimensions.[37]

The Nature of Agape-*Love*

A fourth issue concerns the nature of *agape*-love. The A/P account's definition of *agape*-love ("self-giving for the blessing of God and of others") can incorporate many of Thomas Oord's valuable insights into the theology and science of *agape*-love.[38] The A/P account is, however, more comprehensive than Oord's in terms of connecting *agape*-capability with both God's *telos* for the universe and the physical-chemical-mathematical structure of the universe. It does so within an orthodox Trinitarian faith, without invoking Oord's problematic process theism. At the same time, the A/P definition of *agape*-love falls squarely within the ancient tradition of *kenotic* theology (*kenosis* as divine self-emptying, and thus self-limitation, based on Phil. 2:6–7). This is a tradition which has received renewed attention in the past couple of decades by such figures as Colin Gunton, C. Stephen Evans, Oliver Crisp, and John Polkinghorne. Polkinghorne speaks of God's "kenosis of omnipotence" and "kenosis of omniscience,"[39] both of which fit the A/P account of God's *agape*-love.

In light of the kenotic implications of *agape*-love, some have suggested that the A/P account is trying to support an open theism model of God. In fact, open theism was not on my radar at the beginning of this project—my intention was solely to figure out how to bring together orthodox Christian doctrines of creation, Incarnation, and Christology with various features of creation as presently understood by science. If the final product (the A/P account) looks like open theism, then this is simply the result to which the logic has led; however, the A/P account is not intended to provide an argument for or against open theism, even if it has potential implications for this debate—and I would welcome scholars investigating these potential implications.[40]

On the A/P account, traditional Christian doctrines about human sinfulness, humanity's need for atonement, and God's redeeming grace are applicable to all *agape*-capable beings, not only to humans. This raises the question, would the Second Person of the Trinity, the *Logos*, self-incarnate on only one bio-niche in the universe, or on every bio-niche where *agape*-capable beings emerge? My inclination is to suggest on every bio-niche, but further theological discussion would be valuable here too.

Eschatology

This brings us to eschatology. As earlier noted, there are many different ways to describe God's eschatological outcome for creation—such as "uniting everything in heaven and earth in Christ" (Eph. 1:10; Col. 1:20), "the new creation" (Gal. 6:15), and "the new Jerusalem" (Revelation 21). The A/P account inherently requires no particular eschatological account (that is, it can fit with any orthodox eschatology); however, in *Freedom All the Way Up,* my discussion of eschatology, and therefore of the A/P account within eschatology, focuses on "the resurrection of the body," "eternal life," and "the new creation."[41] With regard to scientific proposals for the ultimate future of Earth and the universe, I affirm Polkinghorne's helpful comment that

> what is ultimate is not physical process but the will and purpose of God the Creator. God's final intentions will be no more frustrated by cosmic death on a timescale of tens of billions of years than they are by human death on a timescale of tens of years. The ultimate future does not belong to scientific extrapolation but to divine faithfulness.[42]

Conclusion

Finally, we should review what the A/P account gains for us. *First*, it provides a new interpretation of the universe: as God's great "freedom system," with freedom built into this whole complex, emergent system, all the way up from the big bang to the emergence of beings with sufficient free will to choose lives of *agape*-love and *agapic* freedom (in contrast to autonomous freedom). That is, the universe is a birthing-space, nursery, and home for *agape*-capable beings in freely chosen *agape*-love relationships with God and with others.

Second, the A/P account provides a fuller understanding of God's design of creation, particularly of how such features as randomness, contingency, multiple-realizability, massively large numbers, and statistics (particularly probability) are not accidental or incidental but rather strategically critical to God's *agapic telos* for the universe.

Third, for those who accept both an old universe and human evolution, the A/P account provides a powerful alternative to ID: unlike ID, the A/P account employs a mainstream account of the emergence of complexity; provides a more specifically theological *telos* to God's design of the universe (the emergence of *agape*-capable beings); and demonstrates how this *telos* is served by the various features of nature to which we have referred throughout this article, from neuroscience to astrobiology.[43]

Fourth, the A/P account enables important new contributions to a range of other widely discussed issues, such as humanity's significance within the cosmos, the problem of suffering, and the meaning of life. But these issues are discussed in *Freedom All the Way Up*, so I have not explored them here.

In sum, by offering a significant new model for God's design of creation, the A/P account advances the coherence and explanatory power of Trinitarian Christian faith for our scientific age today—a significant gain in the task of *fides quaerens intellectum*, of our faith seeking deeper understanding. ✧

Notes

[1]The A/P model is first described in Christian J. Barrigar, *Freedom All the Way Up: God and the Meaning of Life in a Scientific Age* (Victoria, BC: Friesen, 2017). This article is a significantly revised version of the account described in the book. The author wishes to thank Randy Isaac for his assistance with this article, as well as the anonymous reviewers.

[2]The A/P account fits well with Polkinghorne's account of God's *agapic* nature and relationship to creation (see his many writings, including *The Faith of a Physicist: Reflections of a Bottom-Up Thinker* [Princeton, NJ: Princeton University Press, 1994] and *The Polkinghorne Reader: Science, Faith and the Search for Meaning*, ed. T. J. Oord [West Conshohocken, PA: Templeton Press, 2010]), but advances Polkinghorne's account in ways that will be developed throughout the course of this article. The A/P account can also be understood as advancing Van Till's Robust Formational Economy Principle. Van Till proposed that the universe has

> the requisite resources, capabilities and potentialities (the "right stuff") to actualize—without need for supplementary acts of form-conferring divine intervention—every kind of physical structure and biological organism that has ever appeared in the universe's formational history. (Howard Van Till, "Is the Creation a 'Right Stuff' Universe?," *Perspectives on Science and Christian Faith* 54, no. 4 [2002]: 232)

The A/P account agrees with this. Van Till's proposal, however, was unable to integrate teleology with the inherent indeterminacy and contingency in the universe, thus unable to assure a specific desired outcome; on the other hand, the A/P account seeks to get past this difficulty through its use of statistical mechanics, probability theory, evolutionary convergence, and multiple-realizability, while also directly connecting all this with God's *agape*-love *telos*.

[3]Sagan cited by John Matson, "Ring Theory," *Scientific American* 308, no. 2 (2013): 15. Matson does not provide the original source for this quote from Sagan.

[4]For this defense of the existence of free will as sufficient for *agapic* purposes, see Barrigar, *Freedom All the Way Up*, 227 n8, 228 n16. To give a very brief outline of this defense, particularly against the claims of Libet and Wegner, I employ Peter Tse's neuroscience-based account of "strong free will" (*The Neural Basis of Free Will: Criterial Causation* [Cambridge, MA: The MIT Press, 2013]), Patricia Churchland's neurophilosophy defense of human ability to make genuine choices (*Touching a Nerve: Our Brains, Ourselves* [New York: Norton, 2014], 179), and the standard neuroscientific account of the executive control functions of the prefrontal cortex.

[5]Melanie Mitchell, *Complexity: A Guided Tour* (New York: Oxford University Press, 2009), 38.

[6]Two traditional roles for soul are to animate consciousness and to animate free will. Although I see consciousness and free will as properties of emergent neurobiology, not of soul, soul remains necessary for the doctrines of eternal life and of the resurrection of the dead at the new creation (see chapter 8 of *Freedom All the Way Up*). In this regard, I find Polkinghorne's notion of the soul as "information" potentially helpful.

[7]One reader has asked why God would require a system of high probability; that is, could not God have chosen to build a system with moderate or even low probability of *agape*-beings emerging? These latter possibilities would align with two related Christian doctrines: the aseity, or self-sufficiency, of God; and the freedom of God—that God was not compelled, but rather freely chose to create loving beings. This latter point reconceives the traditional notion of how God is free with regard to creation. The traditional notion is that God is free at the level of *choice*—of whether to create or not create. The probabilistic nature of creation provides, however, a further level of protection to God's freedom: a creation in which exists the statistical possibility that *agape*-creatures might not emerge also protects God's freedom by the *method* of how God has created. In other words, God desired to bring about loving beings, yet a mid- or low-probability method of their creation would maintain God's aseity and freedom (as would, of course, a high-probability version). We can speak then of different versions of the A/P account—high-probability, mid-probability, and low-probability versions, all of which could be consistent with both God's purpose and God's aseity. Nonetheless, I lean toward the high-probability version because of what we observe about the actual universe as God has created it, namely, that the feature of massively large numbers at all emergent levels implicitly points to a method of creation that aims for the highest possible likelihood of *agape*-capable beings eventually emerging from the system.

[8]See Stephen Barr, *The Believing Scientist: Essays on Science and Religion* (Grand Rapids, MI: Eerdmans, 2016); Vern Poythress, *Chance and the Sovereignty of God: A God-Centered Approach to Probability and Random Events* (Wheaton, IL: Crossway, 2014); James Bradley, "Randomness and God's Nature," in *Perspectives on Science and Christian Faith* 64,

no. 2 (2012): 75–89; Paul Ewart, "The Necessity of Chance: Randomness, Purpose, and the Sovereignty of God," *Science and Christian Belief* 21, no. 2 (2009): 111–31; David Bartholomew, *God, Chance, and Purpose: Can God Have It Both Ways?* (Cambridge, UK: Cambridge University Press, 2008); Richard G. Colling, *Random Designer: Created from Chaos to Connect with the Creator* (Bourbonnais, IL: Browning, 2004); and various writings of Polkinghorne.

[9]For an interesting illustration of this, see Giuseppe Longo and Maël Montévil, "Randomness Increases Order in Biological Evolution," *Computation, Physics, and Beyond: Lecture Notes in Computer Science* 7160 (2012): 289–308. We can point to the emergence of order from disorder elsewhere as well, such as in nonlinear systems "in which intrinsically disordered processes, such as thermal fluctuations or mechanically randomized scattering, lead to surprisingly ordered patterns," including in nonlinear oscillators: see Sebastian F. Brandt, Babette Dellen, and Ralf Wessel, "Synchronization from Disordered Driving Forces in Arrays of Coupled Oscillators," *Physical Review Letters* 96, no. 3 (2006): 034104.

[10]Peter Hoffmann, *Life's Ratchet: How Molecular Machines Extract Order from Chaos* (New York: Basic Books, 2012), 72. Colling makes a similar comment: "Without the Second Law and its inherent quality to make physical matter and energy randomize, nothing in the world would happen. Everything would stop. There would be no chemical reactions, no physics, no connections, no movement, no life—nothing!" (*Random Designer*, 25).

[11]Tse, *The Neural Basis of Free Will: Criterial Causation*. Tse's "Burst Packet Theory" for how free will exists and functions includes randomness at the synaptic and neurotransmitter level, particularly in the frontal parietal circuits of the PFC.

[12]J. Miguel Rubi, "The Long Arm of the Second Law," *Scientific American* 299, no. 5 (2008): 67.

[13]T. Ryan Gregory, "Understanding Natural Selection: Essential Concepts and Common Misconceptions," *Evolution: Education and Outreach* 2, no. 2 (2009): 157, DOI 10.1007/s12052-009-0128-1.

[14]Francisco J. Ayala, *The Big Questions: Evolution* (London: Quercus, 2012), 34.

[15]Anderson cited by Michael S. Gazzaniga, *Who's in Charge? Free Will and the Science of the Brain* (New York: HarperCollins, 2011), 134.

[16]Randy Isaac commented on an earlier draft of this paper:

> In any system with randomness, the randomness is a feature of only one or a few degrees of freedom. Other degrees of freedom constrain the system. Furthermore, the degrees of freedom with random values generally work together to generate other parameters that are predictable. For example, random momentum of gas molecules leads to predictable pressure, temperature, and volume though the momentum of any particular molecule has a random value. So randomness may inhibit prediction of one degree of freedom but enable another.

[17]Leonard Mlodinow, *The Drunkard's Walk: How Randomness Rules Our Lives* (New York: Vintage, 2008), 147.

[18]Mitchell, *Complexity: A Guided Tour*, 38.

[19]Navot Israel and Nigel Goldenfeld, "Coarse-Graining of Cellular Automata, Emergence, and the Predictability of Complex Systems," *Physical Review E* 73, no. 2, 026203 (2006): 1–17.

[20]L. Lü and T. Zhou, "Link Prediction in Complex Networks: A Survey," *Physica A* 390, no. 6 (2011): 1150–70.

[21]"How Many Ways Can You Arrange 128 Tennis Balls? Researchers Solve an Apparently Impossible Problem," University of Cambridge website, Research/News, January 27, 2016, www.cam.ac.uk/research/news/how-many-ways-can-you-arrange-128-tennis-balls-researchers-solve-an-apparently-impossible-problem. See Stefano Martiniani et al., "Turning Intractable Counting into Sampling: Computing the Configurational Entropy of Three-Dimensional Jammed Packings," *Physical Review E* 93 (2016): 012906. On granularity of prediction in complex systems, see Renate Sitte, "About the Predictability and Complexity of Complex Systems," in *From System Complexity to Emergent Properties*, ed. M. A. Aziz-Alaoui and C. Bertelle (Berlin/Heidelberg: Springer-Verlag, 2009), 23–48.

[22]George McGhee, *Convergent Evolution: Limited Forms Most Beautiful* (Cambridge, MA: The MIT Press, 2011), 245–46.

[23]Simon Conway Morris, "Evolution and the Inevitability of Intelligent Life," in *The Cambridge Companion to Science and Religion*, ed. Peter Harrison (Cambridge, UK: Cambridge University Press, 2010), 149.

[24]Morris, "Evolution and the Inevitability of Intelligent Life," 150–51.

[25]Nicola S. Clayton and Nathan J. Emery, "Canny Corvids and Political Primates," in *The Deep Structure of Biology: Is Convergence Sufficiently Ubiquitous to Give a Directional Signal?*, ed. Simon Conway Morris (West Conshohocken, PA: Templeton Foundation Press, 2008), 128.

[26]Lena Veit and Andreas Nieder, "Abstract Rule Neurons in the Endbrain Support Intelligent Behavior in Corvid Songbirds," *Nature Communications* 4 (2013): 7.

[27]University of California-Irvine, "Brain Network Related to Intelligence Identified," *ScienceDaily* (September 19, 2007), www.sciencedaily.com/releases/2007/09/070911092117.htm.

[28]Gazzaniga, *Who's in Charge?*, 130–31.

[29]Astrid A. Prinz, Dirk Bucher, and Eve Marder, "Similar Network Activity from Disparate Circuit Parameters," *Nature Neuroscience* 7 (2004): 1345.

[30]The application of statistical mechanics to biology can be done in two ways:

> First, biophysics identifies quantitative phenotypes in a cell: molecular binding affinities, gene expression levels, protein folding stabilities, etc. With modern experimental techniques, these phenotypes can be measured in vivo. Second, statistical mechanics provides key concepts to link "microscopic" sequence information and "mesoscopic" phenotypes to "macroscopic" fitness and evolution. (From the website of Michael Lässig's lab, www.thp.uni-koeln.de/~lassig/research.html)

[31]Jonathan B. Losos, *Improbable Destinies: Fate, Chance, and the Future of Evolution* (New York: Riverhead, 2017), 334.

[32]This is what philosopher of science Nancy Cartwright calls our "dappled world." See Cartwright's many writings since *The Dappled World: A Study in the Boundaries of Science* (Cambridge, UK: Cambridge University Press, 1999). There is much debate in the philosophy of science about whether the laws of nature are inherent within nature or are humanly constructed patterns that simply help us make sense of the regularities in nature. The A/P account requires no particular view in this debate; that is, on the A/P account God has built sufficient regularities into the universe(s) to ensure that *agape*-capable beings come about, regardless of whether these regularities are understood as "laws" or otherwise.

[33]See http://biologos.org for examples of such proposals. See also, Christopher Lilley and Daniel J. Pedersen, eds., *Human Origins and the Image of God: Essays in Honor of J. Wentzel van Huyssteen* (Grand Rapids, MI: Eerdmans, 2017).

[34]See J. Richard Middleton, *The Liberating Image: The* Imago Dei *in Genesis 1* (Grand Rapids, MI: Brazos Press, 2005).

[35]For a fuller discussion of the *imago Dei* and stewardship of the earth within the A/P account, see Barrigar, *Freedom All the Way Up*, 135–44.

[36]M. A. O'Leary et al., "The Placental Mammal Ancestor and the Post-K-Pg Radiation of Placentals," *Science* 339, no. 6020 (2013): 662–67.

[37]See Barrigar, *Freedom All the Way Up*, 49–52.

[38]Thomas Oord's many works on love include *The Uncontrolling Love of God: An Open and Relational Account of Providence* (Downers Grove, IL: InterVarsity Press, 2015) and *Defining Love: A Philosophical, Scientific, and Theological Engagement* (Grand Rapids, MI: Brazos Press, 2010).

[39]Polkinghorne, *The Faith of a Physicist*, 81.

[40]Of course, some figures have already investigated the relationship between current scientific knowledge and kenotic theology. See, for instance, William Hasker, Thomas Oord, and Dean Zimmerman, eds., *God in an Open Universe: Science, Metaphysics, and Open Theism* (Eugene, OR: Wipf & Stock, 2011); and Thomas Oord, ed., *Creation Made Free: Open Theology Engaging Science* (Eugene, OR: Wipf & Stock 2010).

[41]For a fuller discussion of eschatology, see Barrigar, *Freedom All the Way Up*, 210–15.

[42]John Polkinghorne, *The God of Hope and the End of the World* (New Haven, CT: Yale University Press, 2002), 12.

[43]There are a couple arguments made by ID that could be deployed against the A/P account. One is that new information requires an intelligent agent. Randy Isaac has refuted this in his blog-article, "Theistic Evolution: The Source of New Information," at https://network.asa3.org/blogpost/1355195/Musings-of-the-ASA-Director-Emeritus (February 12, 2018). A second is made by figures such as Hubert Yockey and Harold Morowitz, who calculate that it is massively improbable that even simple life would emerge in the universe. Isaac has also shown the fundamental flaw in these sorts of calculations. Go to Isaac's blog, then search the tag "Probabilities."

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