PERSPECTIVES on Science and Christian Faith

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In This Issue …

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

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The Power to Give Power

James C. Peterson

At the ASA annual meeting this last July, two of the first three plenary speakers featured the same quote from C.S. Lewis in his essay *The Abolition of Man*.

> What we call Man's power over Nature turns out to be a power exercised by some men over other men with Nature as its instrument.[1]

Here are further quotes in the case Lewis builds.

> In reality, of course, if any one age really attains, by eugenics and scientific education, the power to make its descendants what it pleases, all men who live after it are the patients of that power. They are weaker, not stronger: for while we may have put wonderful machines in their hands we have predordained how they are to use them …
>
> There neither is nor can be any simple increase of power on Man's side. Each new power won by man is a power over man as well. Each advance leaves him weaker as well as stronger. In every victory, besides being the general who triumphs, he is also the prisoner who follows the triumphal car …
>
> At the moment, then, of Man's victory over Nature, we find the whole human race subjected to some individual men …[2]

Lewis is eloquently stating here an important caution. At the risk of tampering with Saint Clive, to whom I am forever grateful, I want to note that this caution is not necessarily a prohibition. Lewis is concerned that human beings will use shaping powers such as "eugenics and scientific education" to manipulate and predestine, to decide and settle who future people will be and how they will desire to live. While this warning is an important one, to a significant degree we cannot avoid deeply shaping our children. My wife and I chose for our children what language is their native tongue and what place their native land. Such choices are formative, but we can wield such power in a way that gives future generations more choice, not less. There are advances that can make people in the future more able to pursue whatever they choose. Welcoming the next generation does not have to be a zero-sum game in which our use of power requires their proportional loss.

Ms. Taubert used her considerable power over her first-grade students, to teach me to read. That opened up new worlds for me, giving me freedom to explore wherever I wished. She used her shaping power to give me power. Dr. Olson gave me, I am told, a DTP vaccination that altered my body to increase my health, and hence my choices. These are both expressions of power of one person over another, to serve, not to control. The purpose and accomplishment of their decisions was to increase mine. It was not predestination, but rather empowerment.

We make decisions that deeply affect others. The question is whether we will be conscious and conscientious in doing so. We can disperse such formative decisions for children to their parents lest any one group use such power against another, and we can agree, even require, that choices on behalf of others should increase their choices, not decrease them. That would not mean a few individual men dictating life to anyone, let alone all who follow. Power to shape others can be used to give power.

In the first article of this reader-empowering issue, Walter Bradley increases our knowledge and wonder at how astoundingly fine tuned our physical world is. That is evidence that we are not the only conscious power in this world. The second article by Chris Barrigar describes God, the involved Creator, sovereignly sharing power by creating a world of chance and choice. Alan Dickin then makes a case for when and where our choices early led to disaster, yet also led to God's redemptive intervention. As Hal Poe then describes, God is pervasively active in the world he has entrusted to us. Insightful book reviews and spirited letters round out the issue. ✧

Notes

[1]C.S. Lewis, *The Abolition of Man* (New York: HarperCollins, 1944), 56.
[2]Ibid., 58, 59, 68.

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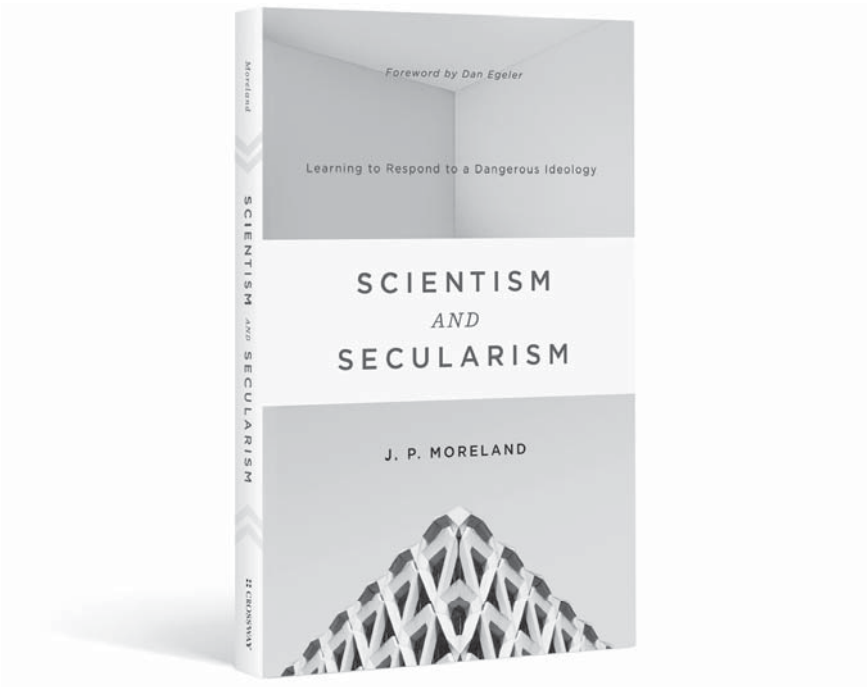

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The Fine Tuning of the Universe: Evidence for the Existence of God?

Walter L. Bradley

Walter L. Bradley

Investigations by cosmologists during the past sixty years have uncovered a remarkable new picture of our amazing universe and its incredible journey from the big bang to our "finely tuned" habitat. It appears that the initial conditions, the mathematical forms that nature takes, and the universal constants must each be precisely tuned to have a suitable habitat for complex, conscious life. Whether this fine tuning is evidence for a creator God is explored, while trying to avoid making fallacious "God of the gaps" claims and instead pointing appropriately to patterns in nature that provide legitimate evidence for a creator God.

Why is "Fine Tuning" such a popular subject today, as evidenced by the many books that have been written on this topic? Here are some examples: *The Anthropic Cosmological Principle*,[1] *Universes*,[2] *The Accidental Universe*,[3] *The Cosmic Blueprint*,[4] *Cosmic Coincidences*,[5] *The Anthropic Principle: Man as the Focal Point of Nature*,[6] *Universal Constants in Physics*,[7] *The Goldilocks Enigma: Why Is the University Just Right for Life?*,[8] *Cosmic Jackpot: Why Our Universe Is Just Right for Life*,[9] *The Constants of Nature: The Numbers That Encode the Deepest Secrets of the Universe*,[10] *Why the Universe Is the Way It Is*,[11] *Just Six Numbers: The Deep Forces That Shape the Universe*,[12] and *A Fine Tuned Universe: The Quest for God in Science and Theology*.[13]

There is good reason for these discussions. Fine tuning describes one of the great mysteries of the universe, and one that may have significant metaphysical implications. Even atheists such as Stephen Hawking note,

> To understand the universe at the deepest level, we need know not only how the universe behaves but why. Why is there something rather than nothing? Why do we exist? Why this particular set of laws and not some other?[14]

The universe is such a remarkable place of habitation for complex, conscious life that it is extremely difficult to believe that it is the result of a long series of cosmic accidents. The elegant mathematical forms that are encoded in nature, the twenty-two universal constants with values within very narrow ranges of exactly what they need to be,[15] and the multitude of initial conditions that must be within a very narrow bandwidth, which they are, would seem to suggest a universe that has been carefully crafted for our benefit.

This article will specifically explore the fine tuning of our universe, the mathematical forms that nature takes, the universal constants, and the precise initial conditions when the universe exploded into existence in the "big bang." Then this article will explore whether fine tuning provides significant warrant for belief in a creator God.

Walter L. Bradley, *PhD, is Professor Emeritus of Mechanical Engineering for both Texas A&M University (2000) and Baylor University (2012). An ASA Fellow, he has spoken about "Fine Tuning" on 74 university campuses to more than 50,000 students and professors over the past thirty years. Each lecture was followed by an open Q&A for an hour or more. He has deeply appreciated both that feedback and that of anonymous* PSCF *reviewers.*

Universal Constants, Initial Conditions, and the Laws of Nature "Work" Together

Important provisions for complex, conscious life in our universe are executed through the combination of natural laws, universal constants, and initial conditions. But how does this work? A simple example will be used to illustrate.

Suppose you are in Pisa, Italy, at the top of the Leaning Tower of Pisa and want to throw a water balloon timed to hit your friends as they walk on the plaza directly below you. The relevant natural law is expressed mathematically by Newton's differential equation for motion in a gravitational field. This law of nature (expressed in mathematical form) can be solved to give an algebraic equation, as seen in equation 1. The solution requires specification of a universal constant, G, for gravitational force; the mass of the earth, M; the height of the tower, h_0; and the initial velocity with which the water balloon is thrown, v_0, to determine how long, t, it will take for the balloon to reach the plaza:

$$h(t) = h_0 - (GMt^2)/2r^2 - v_0t \qquad (1)$$

This equation describes the fundamental law of nature that mass attracts mass with a force that we call the gravitational force of attraction between two masses (the water balloon and the earth in this case) scaled by the universal constant, G. In addressing various phenomena in nature, one must always know the appropriate law(s) of nature, expressed in mathematical form, with the initial conditions and the appropriate universal constants. If one sets h(t) = 0, then one can solve the equation to specify the time, t, that it will take for the balloon to reach the plaza below. Note that the drag force on the water balloon was not included in this calculation, in order to keep the equations in the illustration simple. There are many more-complicated phenomena in nature, but one can always predict the behavior of each phenomenon if one knows the appropriate law(s) of nature, the values of the associated universal constants, and the specification of initial conditions. It is worth noting the connectedness between the universal constants, the initial conditions, and the laws of nature. There are many different possible solutions (times) for h(t) = 0, depending on the values of the universal constants and initial conditions in combination with the mathematical form that the law of nature takes to prescribe h(t).

Requirements for a Universe to Support Complex, Conscious Life

Living systems may be distinguished from nonliving systems by their unique capacity to process energy from their surroundings (chemical or electromagnetic from the sun), store information, and replicate. In living systems, these remarkable capacities are executed by biopolymers such as DNA, RNA, and proteins. Living systems levitate above thermodynamic equilibrium, whereas nonliving matter will exist at, or very near, thermodynamic equilibrium.

Designing *a universe* is much more complicated than designing *in a universe*, as engineers and scientists do in our universe. When human beings design and create something, they are operating in a universe where the laws of nature have already been put into place and the universal constants have already been specified. Designing a universe requires that one specify the mathematical forms that the laws of nature take, defining the fundamental characteristics of the universe. Then, the universal constants which scale the characteristics of these laws of nature must be specified; for example, G as in $F = G[m_1m_2]/d^2$ where F is the force of attraction, the two m's are the two masses that have a gravitational attractive force between them, and d is the distance between the two masses. Our present universe is also the consequence of the initial conditions at the moment of the big bang such as the rate of expansion, which has a profound impact on the universe that unfolds. For example, if the post-big-bang rate of expansion is too rapid, then gravitational forces are insufficient to create stars and planets. If the initial rate of expansion is too slow, then the universe might simply expand briefly and then collapse so that all of the mass of the universe is in one place with an overwhelming gravitational force, precluding satisfying the list of design requirements given below.

A partial list of necessary requirements for a habitable universe for complex, conscious life similar to life forms that have been found in this universe must meet at least the following requirements suggested by Ward and Brownlee.[16]

1. The first requirement is a star that is located in a relatively "quiet" region of the universe where not too many neighbors are producing high-intensity, sterilizing radiation. This star needs to have its highest intensity of radiation in the range that is suitable to drive the chemical reactions

essential to life without destroying the products of these reactions. There must also be a means of transporting the energy from this star at the center of the solar system to planets where chemical reactions between the chemical building blocks in solution require energy to enable the chemical assembly of the building blocks into biopolymers.

2. There must be a planet or moon in the solar system of the star in requirement "1" that is terrestrial; in other words, solid rather than gaseous.
3. This universe must have sufficient chemical stability and elemental diversity to build the complex molecules necessary for essential life functions: namely, processing energy, storing information, and replicating.
4. There must be chemical reactions that allow predictable polymeric compounds like DNA, RNA, and proteins to form from various elements in simpler compounds.
5. There must be a "universal connector," an element that is essential to building the molecules of life. It must readily bond chemically with almost all other elements, including itself, forming bonds that are stable but not too stable so that disassembly is also possible. Only carbon in our naturally occurring 92 elements satisfies this chemical characteristic. This is the reason why, when we look for life on other planets, we begin by looking for carbon-based compounds. It is difficult to imagine living systems without a carbon-like element.
6. A "universal solvent" in which the chemical reactions can take place is essential, since chemical reactions in solids are much too slow and complex life could not be sustained as a gas. This solvent must readily dissolve both the reactants and the reaction products essential to living systems: that is, a liquid with the properties of water, which is very nearly a universal solvent.
7. The temperature range on the terrestrial planet or moon (see requirement 2) must maintain the universal solvent as a liquid rather than as a solid or as a gas for some portion of the year.
8. The right concentration of heavy (radioactive) elements must be present in the planet (see requirement 2) to heat the core of the planet and provide the necessary energy to drive plate tectonics to build up land mass in what would otherwise be a smooth round planet completely covered with the solvent.
9. The amount of solvent must be carefully coupled to plate tectonics activity to provide the planet with similar proportions of its surfaces as oceans and land mass.
10. The planet must have the right protection from the destructive forces in nature such as radiation and asteroids over a reasonable period of time.
11. The planet must have just the right stabilized axis tilt and angular velocity to give moderate, regular, and predictable seasons and moderate temperature fluctuations from day to night.

While one is tempted to think that these requirements are easily met, given the large number of stars, it should be noted that there are few places in the universe that are sufficiently free of sterilizing radiation to provide a suitable solar system. The number of candidate "neighborhoods" is further reduced by the requirement of a sun with the right amount of mass to give the right electromagnetic radiation spectrum. Furthermore, the occurrence of a suitable satellite in conjunction with such a star is even more problematic. Only Earth in our solar system of sixty-two satellites meets the above requirement for a "home" (Earth) in a safe neighborhood such as that of our sun and solar system, which are well placed in a quiet place in a suitable universe as described above.

In the following sections, how these universal and local needs (or design requirements) are met by the specific mathematical forms encoded in nature, the exact values of the universal constants in the universe, and the remarkable "coincidence" that initial (or boundary) conditions are exactly what they must be, will be presented. The developmental path that our universe navigated is consistently remarkable, making the origin of this place for life all the more wondrous and enigmatic. Unless *all* of these conditions, and many more not included in this list, are met, the universe would not allow for the development of complex, conscious life forms. Therefore, the above requirements for our universe are necessary conditions, but they are not by themselves sufficient for a habitat suitable for complex human life.

Ward and Brownlee express their wonder in their book, *Rare Earth*.

> If some god-like being could be given the opportunity to plan a sequence of events with the expressed goal of duplicating our "Garden of

> Eden," that power would face a formidable task. With the best of intentions, but limited by natural laws and materials, it is unlikely that Earth could ever be truly replicated. Too many processes in its formation involved sheer luck. Earth-like planets could certainly be made, but each outcome would differ in critical ways. This is well illustrated by the fantastic variety of planets and satellites that formed in our solar system. They all started with similar building materials, but the final products are vastly different from each other. Just as the more familiar evolution of animal life involved many evolutionary pathways with complex and seemingly random branch points, the physical events that led to the formation and evolution of the physical Earth also required an intricate set of nearly irreproducible circumstances.[17]

Mathematics and the Deep Structure of the Universe

Mathematics, in contrast to arithmetic, is an abstract intellectual activity that was developed by the Sumerians (in the region of Babylon) between the twentieth and the sixteenth century BC.[18] In Greece, Pythagoras was a key mathematician, as were his successors, Euclid and Archimedes between 400 BC and 200 BC.[19] Their studies focused especially on geometric objects, such as straight lines, circles, ellipses, and conic sections. In the third century BC, Apollonius of Perga wrote eight monumental volumes devoted to these curves, describing their properties as "miraculous."[20]

Because mathematics was considered to be an abstract idea, it came as a great surprise that the natural world was full of mathematical forms. Imagine the delight of Johannes Kepler (1571–1630) some eighteen centuries later, when he discovered that the orbits of planets around the sun conformed to these same beautiful but abstract mathematical forms. Kepler declared that the chief aim of all investigations of the external world should be to "discover the rational order and harmony which has been imposed on it by God and which he revealed to us in the language of mathematics."[21] Galileo Galilei (1564–1642) asserted that "the laws of nature are written by the hand of God in the language of mathematics."[22]

In his *Mathematics: The Loss of Certainty*, historian Morris Kline demonstrates that the religious mathematicians of the sixteenth and seventeenth centuries, including Newton, Galileo, Kepler, and Copernicus, all viewed the universe as orderly and capable of mathematical description precisely because a rational God had fashioned it that way.[23] These scientist-mathematicians believed that since God had designed the universe, then "all phenomena of nature would follow one master plan. One mind designing a universe would almost surely have employed one set of basic principles to govern all related phenomena."[24]

Only in the twentieth century have we come to fully understand that the incredibly diverse phenomena that we observe in nature are the outworking of a very small number of physical laws, each of which may be described by a simple mathematical relationship. Indeed, so simple in mathematical form and so small in number are these fundamental physical laws that they can all be written on one side of one sheet of paper, as seen in figure 1. It is truly remarkable that the wide diversity of phenomena in nature can be described by a few simple mathematical relationships.

Nobel laureate physicist Eugene Wigner in his widely quoted paper, "The Unreasonable Effectiveness of Mathematics in the Physical Sciences," notes that scientists often take for granted the remarkable—

The Fundamental Laws of Nature

- Mechanics (Hamilton's Equations)

$$\dot{p} = -\frac{\partial H}{\partial q} \qquad \dot{q} = -\frac{\partial H}{\partial p}$$

- Electrodynamics (Maxwell's Equations)

$$F^{\mu\nu} = \partial^{\mu} A^{\nu} - \partial^{\nu} A^{\mu} \qquad \partial_{\mu} F^{\mu\nu} = j^{\nu}$$

- Statistical Mechanics (Boltzmann's Equations)

$$S = -k \int f \log f \, dv \qquad \frac{dS}{dt} \geq 0$$

- Quantum Mechanics (Schrödinger's Equations)

$$I\hbar \left| \psi \right\rangle = H \left| \dot{\psi} \right\rangle \qquad \Delta X \Delta P \geq \frac{\hbar}{2}$$

- General Relativity (Einstein's Equation)

$$G_{\mu\nu} = -8\pi G T_{\mu\nu}$$

Figure 1. The Five Essential Fundamental Laws of Nature for Life

even miraculous—effectiveness of mathematics in describing the real world. Wigner muses:

> The enormous usefulness of mathematics is something bordering on the mysterious … There is no rational explanation for it … The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve.[25]

Albert Einstein was also struck by the wondrous orderliness of the world as he explained it:

> You find it strange that I consider the comprehensibility of the world (to the extent that we are authorized to speak of such comprehensibility) as a miracle or as an eternal mystery. Well a priori, one should expect a chaotic world, which cannot be grasped by the mind in any way … The kind of order created by Newton's theory of gravity, for example, is wholly different. Even if man proposes the axioms of the theory, the success of such a project presupposes a high degree of ordering of the objective world and this could not be expected a priori. That is the "miracle" which is being constantly reinforced as our knowledge expands.[26]

The splendid orderliness of the cosmos, expressed in the mathematical forms seen in figure 1, is remarkable in many additional ways to enable a universe with a suitable place for habitation by complex, conscious life. The particulars of the mathematical forms themselves are also critical.

Consider the problem of stability at the atomic and cosmic levels. Both Hamilton's equations for nonrelativistic Newtonian mechanics and Einstein's theory of general relativity (fig. 1) are unstable for a sun with planets unless the gravitational potential energy is proportional to the radius "r^{-1}," a requirement that is met only for a universe made with three spatial dimensions. Newtonian mechanics describe a crucial feature of the physical world, Newtonian gravitational attraction, that makes possible the peculiar behavior of planets having very stable orbits around their respective star, their sun.

For Schrödinger's equations for quantum mechanics to give stable, bound energy levels for atomic hydrogen (and by implication for all of the various types of atoms), the universe must have no more than three spatial dimensions. Furthermore, the physical reality captured in Schrödinger's equations makes possible a universe with 92 different elements. If nature did not have the characteristics implicit in Schrödinger's equations, all atomic orbitals would collapse, with the electrons being attached to the atomic nuclei, meaning no chemistry, no periodic chart, and no life. Maxwell's equations for electromagnetic energy transmission also require that the universe be no more than three-dimensional. Maxwell's equations describe a facet of nature without which life could not exist, since getting the energy from the sun to planets where life can exist is essential.

Furthermore, Richard Courant illustrates this felicitous meeting of natural laws with the example of sound and light:

> The actual physical world in which acoustic or electromagnetic signals are the basis of communication seems to be singled out among the mathematically conceivable models by its intrinsic simplicity and harmony.[27]

Boltzmann's equation for the second law of thermodynamics provides an essential predictability to the behavior (directionality) of chemical reactions.

To summarize, for life to exist, an orderly (and by implication, intelligible) universe is needed. Order at many different levels is required. For instance, to have planets that circle their stars, Newtonian mechanics operating in a three-dimensional universe is essential. For there to be multiple stable elements of the periodic table to provide a sufficient variety of atomic "building blocks" for life, an atomic structure to be constrained by the laws of quantum mechanics is necessary. The orderliness in chemical reactions that is the consequence of Boltzmann's equation for the second law of thermodynamics is essential for chemical reactions to "go" in predictable ways. For an energy source like the sun to transfer its life-giving energy to a habitat like Earth, the laws of electromagnetic radiation, which Maxwell's equations describe, must describe and compel this essential feature of our universe.

The universe is indeed orderly, and in precisely the ways necessary for it to serve as a suitable habitat for complex, conscious life. The wonderful internal ordering of the cosmos is matched only by its extraordinary economy. Each one of the fundamental laws of nature is essential to life itself. A universe lacking any one of the laws shown in figure 1 would almost certainly be a universe without life. Many modern scientists, like the mathematicians centuries before them, have been awestruck by the evidence

for intelligent design implicit in nature's mathematical harmony and the internal consistency of the laws of nature. Arizona State astrophysicist Paul Davies declares:

> All the evidence so far indicates that many complex structures depend most delicately on the existing form of these laws. It is tempting to believe, therefore, that a complex universe will emerge only if the laws of physics are very close to what they are … 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.[28]

British astronomer Sir Fred Hoyle likewise comments:

> I do not believe that any scientist who examines the evidence would fail to draw the inference that the laws of nuclear physics have been deliberately designed with regard to the consequences they produce inside the stars. If this is so, then my apparently random quirks have become part of a deep-laid scheme. If not, then we are back again to a monstrous sequence of accidents.[29]

Nobel laureates Eugene Wigner and Albert Einstein have respectfully evoked "mystery" or "eternal mystery" in their meditations upon the brilliant mathematical encoding of nature's deep structures. But as Kepler, Newton, Galileo, Copernicus, Davies, Hoyle, and many others have noted, the mysterious coherency of the mathematical forms underlying the cosmos is solved if one recognizes these forms to be the creative intentionality of an intelligent creator who has purposefully designed our cosmos to be a habitat for *Homo sapiens*.

Universal Constants

When scientists use the term "fine tuning" today, they generally are talking about the fine tuning of the universal constants, though the term has been used more broadly so far in this article. The deepest level of cosmic harmony and coherence is that of the elemental forces and universal constants that govern all of nature. The universe is embodied in the scaling of the various physical phenomena such as the gravitational force, the rest mass of the electron, and the speed of light.

The crucial role of universal constants can be illustrated by an example. If I were designing the first automobile, I would need to select an engine size for this car. Having no idea of how much horsepower the car will need, I might choose an engine with one horsepower. I install this engine into my first prototype and discover much to my dismay that the car will barely move. To rectify this problem, I replace this engine with one with 10,000 "horse power." Now I barely touch the accelerator and the car takes off like a rocket, causing a nonfatal crash that totally destroys my prototype. After building a new prototype, I equip it with a 100 horsepower engine which works just fine. Scaling the optimal engine size for a vehicle and many other components, is an example of what engineers do in their design work. It is quite analogous to the relative scaling of the universal constants in nature.

One of the remarkable discoveries of the past twenty years is that a functional universe suitable for complex, conscious life requires that the many universal constants in nature must be very nearly what we now know them to be. Many journal articles and books have documented this remarkable and surprising new insight, which has come to be known as the "fine tuning" of the universe. Table 1 provides an illustrative set of examples of important "universal constants" that must have values that are essentially what they are to provide a universe that is suitable for complex, conscious life: for example, the speed of light; the gravitational-force constant; the rest masses of the protons, electrons, and neutrons; the unit charge for the electron or proton; the weak nuclear force; the strong nuclear force; the electromagnetic coupling constants; Plank's constant; and the Boltzmann constant. These are all universal constants that are indispensable in the mathematical description of the universe.

When cosmological models were first developed in the mid-twentieth century, cosmologists naively assumed that the selection of a given set of constants was not critical to the formation of a suitable habitat for life. Through subsequent parametric studies using mathematical models that varied these constants, scientists now know that relatively small changes in any of the universal constants produce a dramatically different universe that is not hospitable to life of any imaginable type.

Let us examine several examples that constrain the selection of the universal constants to a remarkable degree. Twentieth-century physicists have identified four fundamental forces in nature. These may each be expressed as dimensionless numbers to allow a comparison of their relative strength. These values vary by a factor of 10^{41} or 41 orders of magnitude. Yet modest changes in the relative strengths of any of these forces and their associated constants would produce dramatic changes in the universe, rendering it unsuitable for life. Several examples to illustrate this fine-tuning of our universe are presented next.

Balancing Electromagnetism and Gravitational Forces

The electromagnetic force is 10^{38} times stronger than the gravitational force. Gravity draws hydrogen into stars, creating a high-temperature plasma. The protons in the plasma must overcome their electromagnetic repulsion to fuse. Thus, the relative strength of the electromagnetic force to the gravitational force determines the rate at which stars "burn" by fusion. If this ratio of strengths were altered to 10^{32} instead of 10^{38} (i.e., if gravity were much stronger than it actually is), stars would be a billion times less massive and would burn a million times faster.[30]

Electromagnetic radiation and the light spectrum also depend on the relative strengths of the gravity and electromagnetic forces and their associated constants. Furthermore, the frequency distribution of the electromagnetic radiation produced by the sun must be precisely tuned to the energies of the various chemical bonds on Earth. Excessively energetic photons of radiation such as the ultraviolet radiation emitted from a blue giant star, destroy chemical bonds and destabilize organic molecules. Insufficiently energetic photons, such as infrared and longer wavelength radiation from a red dwarf star, would result in chemical reactions that are either too sluggish or would not occur at all. Most life on Earth depends upon fine-tuned solar radiation, which requires, in turn, a very precise balancing of the electromagnetic and gravitational forces.

As previously noted, chemical bonding energy relies upon quantum mechanical calculations that include the electromagnetic force, the mass of the electron, the speed of light (c) and Planck's constant (h). Matching the radiation from the sun to the chemical bonding energy in plants on earth requires that the magnitude of six constants be selected to satisfy the following inequality, with the caveat that the two sides of the inequality are of the same order of magnitude, guaranteeing that the photons are sufficiently energetic, but not too energetic.[31]

$$(m_p^2\, G)/(hc) \geq [e^2/\{hc\}]^{12}[m_e/m_p]^4 \qquad (2)$$

Table 1. An abbreviated list of fundamental constants of physics and chemistry based on the values provided by CODATA.

Quantity	Symbol	Numerical Values	Unit
speed of light in vacuum	c	299 792 458	$m\ s^{-1}$
magnetic constant	μ_0	12.5664×10^{-7}	NA^{-2}
electric constant	ε_0	$8.854\ 187\ 817 \times 10^{-12}$	$F\ m^{-1}$
gravitational constant	G	6.6738×10^{-11}	$m^3kg^{-1}s^{-2}$
Planck's constant	h	$6.626070040 \times 10^{-34}$	Js
elementary charge	e	$1.6021766208 \times 10^{-19}$	C
magnetic flux quantum	φ_0	$2.067833831 \times 10^{-15}$	Wb
conductance quantum	G_0	$7.7480917310 \times 10^{-5}$	S
electron mass	m_e	$9.10938356 \times 10^{-31}$	kg
proton mass	m_p	$1.672621898 \times 10^{-27}$	kg
fine-structure constant ($e^2/4\pi\varepsilon_0 hc$)	α	$7.2973525664 \times 10^{-3}$	
inverse fine-structure constant	1/α	137.035999139	
Avagadro constant	N_A	$6.022140857 \times 10^{23}$	mol^{-1}
Faraday constant $N_A e$	F	96485.33289	C/mol
molar gas constant	R	8.3144598	$J/mol^{-1}\ K^{-1}$
Boltzmann constant, R/N_A	k	$1.38064852 \times 10^{-23}$	JK^{-1}

Substituting the values in equation 2 for h, c, G, m_e, m_p and e (with units adjusted as required) allows equation 2 to be evaluated to give

$$5.9 \times 10^{-39} > 2.0 \times 10^{-39} \quad (3)$$

In what is either an amazing coincidence or careful design by an intelligent Creator, these constants have the very precise values relative to each other that are necessary to give a universe in which radiation from the sun is tuned to drive the necessary chemical reactions that are essential for life. This result is illustrated in figure 2, where the intensity of radiation from the sun and the biological utility of the radiation are shown as a function of the wavelength of radiation.[32] While thermal energy from the sun is the primary source of energy for living systems on planet Earth, it is worth noting that there are several less common sources as well. Hot thermal vents in the oceans, for example, have provided the energy needed to supply simple life forms that are beyond the reach of sunlight. Other less common sources of energy for living systems include chemical gradients in oceans, gravitational interactions between two bodies like those found around "black smokers" on the ocean floor, or thermal gradients due to radioactive decay. However, the greatest intensity of radiation from the sun occurs at the place of greatest biological utility. Is this another remarkable coincidence, or another example of carefully crafted design in the functionality of the universe?

Happily, our star (the sun) emits radiation (light) that is finely tuned to drive the chemical reactions necessary for life. But there is still a critical potential problem: getting that radiation from the sun to the place where the chemical reactions occur. Passing through the near vacuum of space is no problem. However, absorption of light by either the earth's atmosphere or by water where the necessary chemical reactions occur, could render life on Earth impossible. It is remarkable that both the earth's atmosphere and water have "optical windows" that allow visible light (just the radiation necessary for life on Earth) to pass through with very little absorption, whereas shorter wavelength (destructive ultraviolet radiation) and longer wavelength

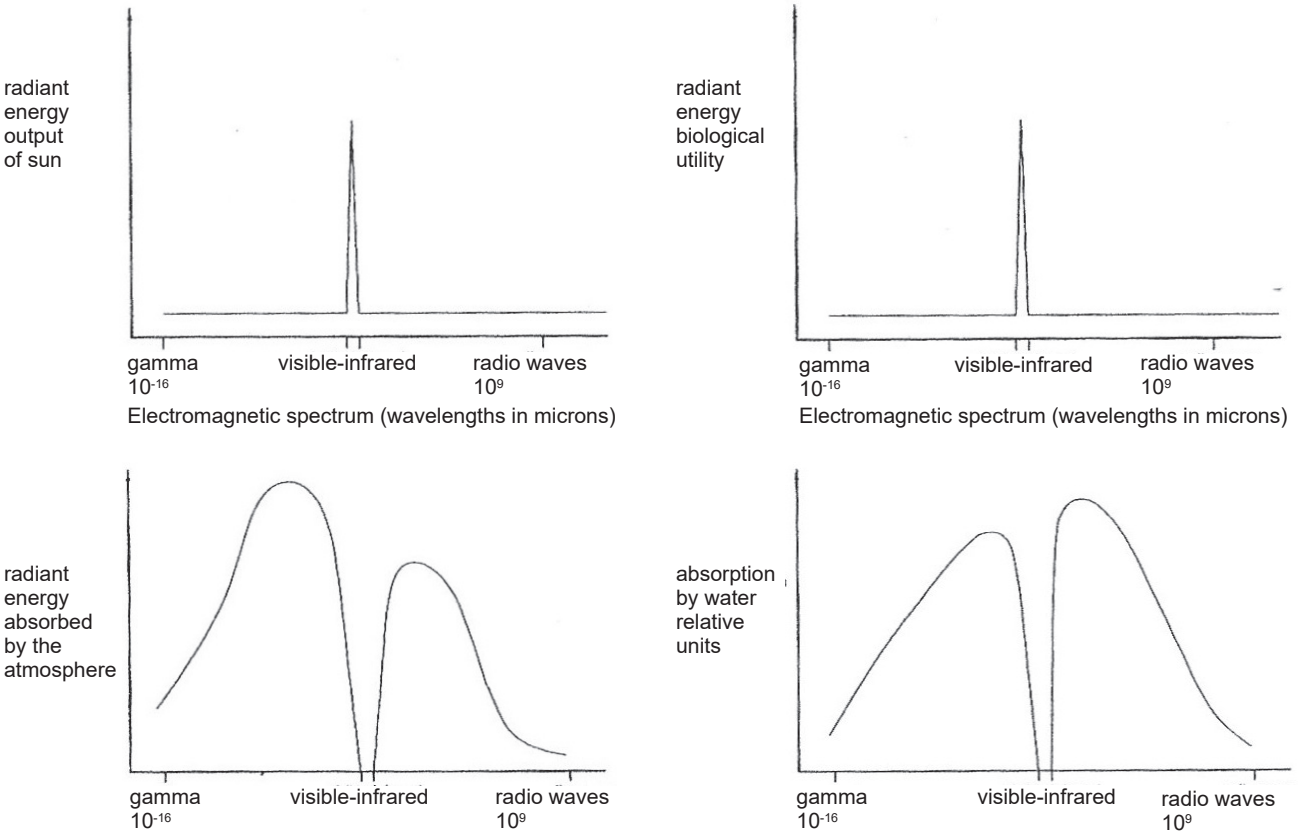

Figure 2. The visible portion of the electromagnetic spectrum (~ 1 micron) is the most intense radiation from the sun (upper, left): has the greatest biological utility (upper, right); and passes through the atmosphere of Earth (lower, left) and water (lower, right) with almost no absorption. It is uniquely this same wavelength of radiation that is ideal to foster the chemistry of life. This is either a truly amazing series of coincidences or else the result of careful design.

(infrared) radiation are both highly absorbed, as seen in figure 2. This allows solar energy in the form of light to reach the reacting chemicals in the universal solvent, which is water. The *Encyclopaedia Britannica* observes in this regard, "Considering the importance of visible sunlight for all aspects of terrestrial life, one cannot help being awed by the dramatically narrow window in the atmospheric absorption … and in the absorption spectrum of water."[33]

It is remarkable that the optical properties of water and of our atmosphere, the chemical bonding energies of the chemicals of life, and the radiation from our sun are all precisely harmonized to allow living systems to utilize energy from the sun, without which life could not exist. It is analogous to your car, which can run using only gasoline as a fuel. Happily, but not accidentally, the service station has an ample supply of exactly the right fuel for your automobile. But someone had to drill for and produce the oil, someone had to refine it into liquid fuel (gasoline) that has been carefully optimized for your internal combustion engine, and others had to truck it to your service station. The production and transportation of the right energy from the sun for metabolic motors of plants and animals is much more remarkable.

Finally, without this unique window of light transmission through the atmosphere of Earth and through water, made possible by the intricate framework of "just right" universal constants, vision would be impossible and sight-communication would cease, since living tissue and eyes are composed mainly of water.

Nuclear Strong Force and Electromagnetic Force

The nuclear strong force is the strongest force within nature, occurring at the subatomic level to bind protons and neutrons within atomic nuclei.[34] Were we to increase the ratio of the strong force to electromagnetic force by only 3.4%, the result would be a universe with no hydrogen, no long-lived stars that burn hydrogen, and no water (a molecule composed of two hydrogen atoms and one oxygen atom), our "universal solvent" for life. Likewise, a decrease of only nine percent in the strong force relative to the electromagnetic force would decimate the periodic table of elements. Such a change would prevent deuterons from forming from the combination of protons and neutrons. Deuterons, in turn, combine to form helium, then helium fuses to produce beryllium, and so forth.[35]

Within the nucleus, an even more precise balancing of the strong force and the electromagnetic force allows for a universe with an abundance of organic building blocks, including both carbon and oxygen.[36] Carbon serves as the universal connector for organic life and is an optimal reactant with almost every other element, forming bonds that are stable but not too stable, allowing compounds to readily be formed and also to be disassembled. Oxygen is a component of water, the necessary universal solvent in which life chemistry can occur. This explains why people first look for signs of organic molecules (ones containing carbon atoms) and signs that Mars once had water when they speculate about life on Mars.

Quantum physics examines the most minute energy exchanges at the deepest levels of the cosmic order. Only certain energy levels are permitted within nuclei-like steps on a ladder. If the mass-energy for two colliding particles results in a combined mass-energy that is equal to or slightly less than a permissible energy level on the quantum "energy ladder," then the two nuclei will readily stick together or fuse on collision, with the energy difference needed to reach the step being supplied by the combined kinetic energy of the colliding particles. If this mass-energy level for combined particles is exactly right, then the collisions are said to have resonance, which is to say that there is a high efficiency within the collisions. On the other hand, if the combined mass-kinetic energy results are a value that is slightly higher than one of the permissible energy levels on the energy ladder, then the particles will simply bounce off each other rather than fusing (i.e., sticking together).

It is clear that the step sizes between quantum nuclear energy levels depends on the balance between the strong force and the electromagnetic force, and these steps must be tuned to the mass-energy levels of various nuclei for resonance to occur and give an efficient conversion by fusion of lighter elements into carbon, oxygen, and heavier elements.

Distinguished cosmologist George Ellis concluded his article in *Scientific American* as follows: "The laws of nature exhibit an incredibly unlikely degree of fine tuning that is required to produce a life-friendly universe."[37]

In 1953, Sir Fred Hoyle et al. predicted the existence of the unknown resonance energy level for carbon, and it was subsequently confirmed through experimentation.[38] In 1982, Hoyle offered a very insightful summary of the significance he attached to his remarkable predictions.

> From 1953 onward, Willy Fowler and I have been intrigued by the remarkable relation of the 7.65 MeV energy level in the nucleus of 12 C to the 7.12 MeV level in 16 O. If you wanted to produce carbon and oxygen in roughly equal quantities by stellar nucleo-synthesis, these are the two levels you would have to fix, and your fixing would have to be just where these levels are actually found to be. Another put-up job? Following the above argument, I am inclined to think so. A common sense interpretation of the facts suggests that a super intellect has "monkeyed" with the physics as well as the chemistry and biology, and there are no blind forces worth speaking about in nature.[39]

Rest Masses of Elemental Particles

Scientists have been surprised to discover the extraordinary tuning of the masses of elementary particles to each other and to the forces of nature. Stephen Hawking has noted that the difference in the rest mass of the neutron and the rest mass of the proton must be approximately equal to twice the mass of the electron. The mass-energy of the proton is 938.28 MeV and the mass-energy of the neutron is 939.57 MeV. The mass-energy of the electron is 0.51 MeV, or approximately half of the difference in neutron and proton mass-energies, just as Hawking indicated it must be.[40] If the mass-energy of the proton plus the mass-energy of the electron were not slightly smaller than the mass-energy of the neutron, then electrons would combine with protons to form neutrons, with all atomic structures collapsing, leaving an inhospitable world composed only of neutrons.

On the other hand, if this difference were larger, then neutrons would all decay into protons and electrons, leaving a world of pure hydrogen, since neutrons are necessary for protons to combine to build heavier nuclei and the associate elements. As things stand, the neutron is just heavy enough to ensure that the big bang would yield one neutron to every seven protons, allowing for an abundant supply of hydrogen for star fuel and enough neutrons to build up the heavier elements in the universe.[41] Again, a meticulous inner "design" assures a universe with long-term sources of energy and elemental diversity.

Balancing the Nuclear Weak Coupling Force

The weak force governs certain interactions at the subatomic or nuclear level. If the weak force coupling constant were slightly larger, neutrons would decay more rapidly, reducing the production of deuterons, and thus of helium and elements with heavier nuclei. On the other hand, if the weak force coupling constant were slightly weaker, the big bang would have burned almost all of the hydrogen into helium, with the ultimate outcome being a universe with little or no hydrogen and many heavier elements instead. This would leave no long-lived stars and no hydrogen-containing compounds, especially water. In 1991, Reinhard Breuer noted that the appropriate mix of hydrogen and helium to provide hydrogen-containing compounds, long-term stars, and heavier elements is approximately 75% hydrogen and 25% helium, which is just what we find in our universe.[42]

This is obviously an illustrative—but not exhaustive—list of cosmic "coincidences." Clearly, the four forces in nature and the universal constants must be very carefully calibrated or scaled to provide a universe that satisfies the key requirements for life that have been enumerated on the original initial "needs statement": for example, elemental diversity, an abundance of oxygen and carbon, and a long-term energy source (our sun) that is precisely matched to the bonding strength of organic molecules with a minimal absorption by water in Earth's terrestrial atmosphere. John Wheeler, Professor of Physics at Princeton, in discussing these observations claimed: "The necessity to produce life lies at the center of the universe's whole machinery and design … Slight variations in physical laws such as gravity or electromagnetism would make life impossible."[43]

Initial Conditions

The "big bang" follows the physics of any explosion, though on an inconceivably large scale. The critical boundary condition for the big bang is its initial velocity. If the velocity is too fast, the matter in the universe expands too quickly, and never condenses into planets, stars, and galaxies. If the initial velocity is too slow, the universe expands only for a short time and then quickly collapses under the influence of gravity. Well-accepted cosmological models tell us that the initial velocity must be specified to a precision of $1/10^{60}$. Newer models tell us that the initial velocity needs to be specified to $1/10^{123}$.[44] Furthermore, the ratio of the gravitational energy to

the kinetic energy must be equal with a variation of no more than one part in 100,000. While these numbers may change over time, all possible models of the big bang will contain boundary conditions of a remarkably specific nature that cannot simply be described as "fortuitous." It is clear that the initial conditions for a "big bang beginning" for the universe are very demanding in their required precision.

By Many Measures, Nature Appears to Be Finely Tuned

There are literally hundreds of examples of fine tuning that seem to be essential to enable the universe to have the many features that are essential for complex, conscious life. What remains to be explained is how the universe just happens to have this remarkable combination of particular laws of nature with (1) just the right mathematical form, (2) universal constants that must be and are remarkably precise, and (3) mind-boggling initial conditions that our universe satisfies with amazing specificity.

Metaphysical Implications of Fine Tuning

"Finely tuned" is a description of how our universe appears that is widely accepted in the scientific community. This observation raises the very interesting question of why the universe is finely tuned. Is there a fine tuner? The remainder of this article will explore this metaphysical question: namely, does fine tuning point to an intelligent agency, a supernatural fine tuner?

Richard Dawkins, a British zoologist and one of the world's foremost apologists for classical Darwinism and atheism, addressed the question of design in his 1996 book *Climbing Mount Improbable*, by comparing particular, designed artifacts with similar accidents in nature.[45] Dawkins illustrates the concept of design by comparing the example of Mount Rushmore upon which are carved the clearly recognizable images of Presidents George Washington, Thomas Jefferson, Abraham Lincoln, and Theodore Roosevelt (fig. 3) to a naturally occurring rock in Hawaii that casts a shadow that resembles President John F. Kennedy (fig. 4), illustrating the difference between an accidental occurrence and an artifact that was the result of design and execution. Obviously, one could confirm this interpretation by carefully examining the surfaces of both images. One would have marks from chisels and dynamite utilized by the sculptor Gutzon Borglum, while the other would have a surface that was the result of natural weathering since there was no designer. The sheer number of details in which the Mount Rushmore sculptured faces resemble the four presidents testifies to the presence of an intelligent agent, a human sculptor. No one could seriously attribute these magnificent faces to the "creative" forces of wind, rain, sleet, and hail.

Generally, design is associated with complexity, which can sometimes be quantified with information content. To specify the three-dimensional topography of Mount Rushmore requires orders of magnitude more pieces of information than that required to create a two-dimensional silhouette with minimum features that looks like John Kennedy, but only when viewed from a certain direction. What does the nature of nature previously presented in this article suggest about the origin of our magnificent universe?

This second level of examination to be used to interpret the fine-tuning data is called "abduction,"[46] or

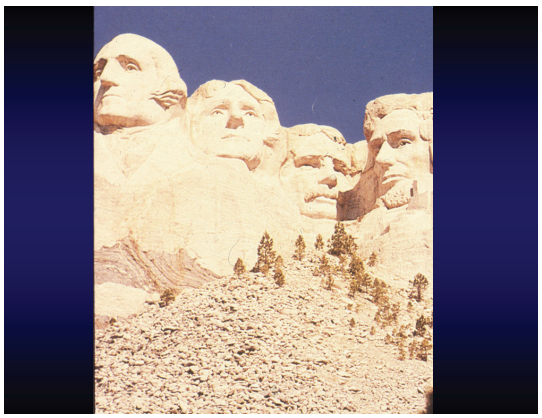

Figure 3. Mount Rushmore

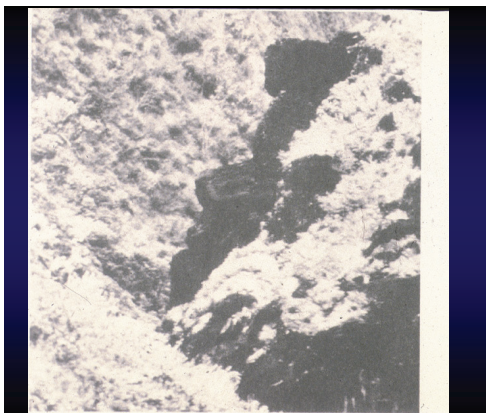

Figure 4. Rock in Hawaii

"inference to the best explanation," which is a means of justifying a hypothesis when there is insufficient data for the claim to have the warrant of an established theory. This approach allows one to posit a (maybe very) tentative hypothesis, while avoiding the erroneous claim that you cannot know anything about a question unless you have a much greater amount of data.

Proclivities of Theists and Atheists in Interpreting the Fine-Tuning Data

Theists believe that God can choose to act by performing miracles (God acting in some extraordinary, unpatterned ways that are not described by the laws of nature). They also believe that God can choose to act in his customary (patterned) ways, as described by the so-called laws of nature. Alternatively, God can choose to act in some combination of patterned and extraordinary ways to create a suitable habitat for human beings. Some theists believe that God chose to work only in his customary way (as described by the laws of nature) in the creation of our universe, while others believe that he chose to use some combination of miracles and processes.

Atheists believe that there is no God, and that all explanations of phenomena in nature will in due course be found to have "natural" explanations that describe the autonomous functioning of nature. Some, like Victor Stenger in his book *The Fallacy of Fine Tuning: Why the Universe Is Not Designed for Us,* seek to dispute the claims that the universe is fine tuned.[47] Michael Strauss has provided an excellent critique of Stenger's book, showing in detail why Stenger's claim that there is no fine tuning is clearly wrong.[48]

Many scientists (including atheists) seem to implicitly accept the evidence for fine tuning in the universe, responding to the overwhelming evidence for fine tuning by embracing the idea of a multiverse. If there actually are 10^{500} universes produced by inflation and if each universe has a different set of "natural laws," universal constants, and initial conditions, then fine tuning by accident becomes more plausible. However, there are serious questions about the existence of a multiverse, since it is impossible to "see" outside our own universe. In an editorial entitled "A Crisis at the Edge of Physics," in *The New York Times* (June 5, 2015), Adam Frank and Marcelo Gleiser (based on a recent article in *Nature)*, highlight the growing criticism of positing a multiverse, asserting that it is an audacious claim that can be neither confirmed nor refuted by experimental observations.[49] Alan Lightman, a professor of physics at MIT, confesses in his excellent book, *The Accidental Universe,* that he is an atheist who accepts the existence of a multiverse because he finds the arguments for fine tuning very persuasive and the multiverse seems to be the only alternative, acknowledging that this must be taken by faith as we cannot see outside our own universe.[50] This is an example of how the remarkable fine tuning in our universe is taken seriously by a thoughtful atheist.

One of the most compelling arguments for fine tuning comes from a leading string theorist, Leonard Susskind, in the foreword to his 2005 book *The Cosmic Landscape.*

> The real mystery raised by modern cosmology concerns a silent "elephant in the room," an elephant in the room I might add, that has been a huge embarrassment to physicists: why is it that the universe has all of the appearances of having been specially designed just so that life forms like us can exist. This puzzled scientists and at the same time encouraged those who prefer the false comfort of a creationist myth … In the past most physicists (including me) have chosen to ignore the elephant—even to deny its existence. They preferred to believe that nature's laws follow from some elegant mathematical principle and that the apparent design of the universe is merely a lucky accident. But recent discoveries in astronomy, cosmology, and above all, String Theory have left theoretical physicists little choice but to think about these things.[51]

Paul Steinhardt, Albert Einstein Professor in Science (Princeton) and Director of the Princeton Center for Theoretical Science, made some extraordinary claims in an interview with science writer John Horgan that was published in *Scientific American*, December 1, 2014.[52] Steinhardt complained that inflation theory, which he helped to create in 1982, was "developed" in part to "create" a multiverse that was in turn motivated by the desire to account for "fine tuning" in our universe by predicting an almost infinite number of alternative universes besides our own, with one or more having universal constants with the necessary values to permit life. Steinhardt said, "The fact that we had to introduce fine tuning (into the inflation model) to remove the "fine tuning" (that

we see in our universe) was worrisome. This problem has never been resolved." Since inflation theory requires new physical laws and new finely tuned constants, it did not resolve the challenge of accounting for fine tuning. It only pushes fine tuning down one level.

What about the "God-of-the-Gaps" Problem?

It is difficult to do justice to this extremely important question in the limited remaining space for this essay. Fortunately, this topic has been thoughtfully addressed in articles in this journal, *Perspectives on Science and Christian Faith*. Randy Isaac highlights his reasons for avoiding fine-tuning arguments as his primary support of biblical theism, but sees fine tuning as consistent with and reinforcing his faith commitment to biblical theism.[53] Ron Larson, Jack Collins, and David Snoke argue in different ways that we should be mindful of the God-of-the-gaps mistakes that can and have been made in the past so as not to repeat them. They offer clear directions on ways that this can be done.[54] I would add one additional approach that I have used in this article. If one frames the discussion of God's work in nature more carefully, the God-of-the-gaps concern can be minimized. God's work in nature in his customary patterned way (what we call the laws of nature), should be distinguished from God working in some extraordinary way, which may be viewed as a miracle.

Features in nature such as fine tuning can tentatively be assumed to be the consequence of God working in an extraordinary way. However, the discovery of the Grand Theory of Everything would not change my belief in God, but only my view of how God created and operates creation. It changes the question, "Did God do it or did nature do it autonomously?" to an a priori assumption that God did it, with the remaining question, "How did God do it—in his customary way (sometimes called the laws of nature), or in some extraordinary way (sometimes called a miracle)?"

Conclusion

Does our universe look more like Mt. Rushmore (fig. 3) or the rock in Hawaii (fig. 4)? The "nature of nature," especially fine tuning, provides clear and compelling evidence for our all-powerful, loving Creator God, who can be seen through "the things that have been made, so that those who do not believe are without excuse" (Rom. 1:20). ✧

Notes

[1]John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (New York: Oxford University Press, 1988).
[2]John Leslie, *Universes* (New York: Routledge, 1989).
[3]Paul Davies, *The Accidental Universe* (Cambridge, UK: Cambridge University Press, 1982).
[4]Paul Davies, *The Cosmic Blueprint* (Portsmouth, NH: Heinemann, 1988).
[5]John Gribbin and Martin Rees, *Cosmic Coincidences* (New York: Bantam Books, 1989).
[6]Reinhard Breuer, *The Anthropic Principle: Man as the Focal Point of Nature*, trans. Harry Newman and Mark Lowery (Cambridge, MA: Birkhäuser Boston, 1991).
[7]Gilles Cohen-Tannoudji, *Universal Constants in Physics,* trans. Patricia Thickstun (New York: McGraw-Hill, 1993).
[8]Paul Davies, *The Goldilocks Enigma: Why Is the Universe Just Right for Life?* (New York: Penguin Books, 2006).
[9]Paul Davies, *Cosmic Jackpot: Why Our Universe Is Just Right for Life* (Boston, MA: Houghton Mifflin, 2007).
[10]John D. Barrow, *The Constants of Nature: The Numbers That Encode the Deepest Secrets of the Universe* (New York: Vintage Books, 2002).
[11]Hugh Ross, *Why the Universe Is the Way It Is* (Grand Rapids, MI: Baker Books, 2008).
[12]Martin Rees, *Just Six Numbers: The Deep Forces That Shape the Universe* (New York: Basic Books, 2000).
[13]Alister E. McGrath, *A Fine Tuned Universe: The Quest for God in Science and Theology* (Louisville, KY: John Knox Press, 2009).
[14]Stephen Hawking and Leonard Mlodinow, *The Grand Design* (New York: Bantam Books, 2010), 9–10.
[15]Peter J. Mohr, David B. Newell, Barry N. Taylor, "CODATA Recommended Values of the Fundamental Physical Constants: 2014," *Reviews of Modern Physics* 88, no. 3 (26 September 2016): 035009, https://link.aps.org/doi/10.1103/RevModPhys.88.035009.
[16]Peter D. Ward and Donald Brownlee, *Rare Earth: Why Complex Life Is Uncommon in the Universe* (New York: Copernicus Books, 2000).
[17]Ibid., 37.
[18]George F. R. Ellis, "Does the Multiverse Really Exist?," *Scientific American* 305, no. 2 (August 2011): 38–43.
[19]Richard Dawkins, *Climbing Mount Improbable* (New York: Norton, 1996), 2–4.
[20]Ibid.
[21]Johannes Kepler, *De Fundamentis Astrologiae Certioribus,* Thesis XX (1601).
[22]Galileo Galilei; this comment is widely attributed to Galileo, but without reference.
[23]Morris Kline, *Mathematics: The Loss of Certainty* (New York: Oxford University Press, 1980).
[24]Ibid., 52.
[25]Eugene Wigner, "The Unreasonable Effectiveness of Mathematics in the Physical Sciences," *Communications on Pure and Applied Mathematics* 13, no. 1 (1960): 1–14.
[26]Albert Einstein, *Letters to Solovine* (New York: Philosophical Library, 1987), 131.

[27]R. Courant and D. Hilbert, *Methods of Mathematical Physics*, vol. 2, *Partial Differential Equations* (New York: John Wiley & Sons, 1966), 765–66.
[28]Paul Davies, *Superforce: The Search for a Grand Unified Theory of Nature* (New York: Simon and Schuster, 1984), 243.
[29]Fred Hoyle, *Religion and the Scientists,* quoted in Barrow and Tipler, *The Anthropic Cosmological Principle*, 22.
[30]Leslie, *Universes*, 36–39.
[31]Barrow and Tipler, *The Anthropic Cosmological Principle,* 336.
[32]Michael Denton, *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe* (New York: The Free Press, 1998), 54–57.
[33]*Encyclopaedia Britannica*, vol. 18, 15th edition (1994): 200.
[34]Barrow and Tipler, *The Anthropic Cosmological Principle,* 322.
[35]S. W. Hawking, "Is the End in Sight for Theoretical Physics?," *Physics Bulletin* 32, no. 32 (1981): 15–17.
[36]Leslie, *Universes,* 35–40.
[37]Ellis, "Does the Multiverse Really Exist?," 43.
[38]F. Hoyle et al., "The 7.68-MeV State in C^{12}," *Physics Review* 92 (1953): 649.
[39]F. Hoyle, "The Universe: Past and Present Reflections," *Annual Review of Astronomy and Astrophysics* 20 (1982): 16.
[40]Hawking, "Is the End in Sight for Theoretical Physics?," 15.
[41]Barrow and Tipler, *The Anthropic Cosmological Principle*, 371.
[42]Breuer, *The Anthropic Principle*, 102.
[43]John Wheeler, quoted in John Boslough, "Inside the Mind of John Wheeler," *Reader's Digest* (September 1986): 107.
[44]William Lane Craig, "Design and the Anthropic Fine-Tuning of the Universe," in *God and Design,* ed. Neil A. Manson (New York: Routledge, 2003), 157.
[45]Dawkins, *Climbing Mount Improbable*, 5.
[46]*Stanford Encyclopedia of Philosophy*, substantive revision, April 28, 2017, s.v. "Abduction."
[47]Victor J. Stenger, *The Fallacy of Fine Tuning: Why the Universe Is Not Designed for Us* (Amherst, NY: Prometheus), 2011.
[48]Michael Strauss, blog, http://www.michaelgstrauss.com/2017/07/is-fine-tuning-fallacy.html.
[49]Adam Frank and Marcelo Gleiser, "A Crisis at the Edge of Physics," *New York Times*, June 5, 2015, New York edition, SR5, https://www.nytimes.com/2015/06/07/opinion/a-crisis-at-the-edge-of-physics.html.
[50]Alan Lightman, *The Accidental Universe: The World You Thought You Knew* (New York: Vintage Books, 2014), 1–22.
[51]Leonard Susskind, *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design* (New York: Little, Brown & Company, 2005), x, xi.
[52]John Horgan, "Physicist Slams Cosmic Theory He Helped Conceive," *Scientific American* (December 1, 2014), https://blogs.scientificamerican.com/cross-check/physicist-slams-cosmic-theory-he-helped-conceive/.
[53]Randy Isaac, "From Gaps to God," *Perspectives on Science and Christian Faith* 57, no. 3 (2005): 230–33.
[54]Ronald Larson, "Revisiting the God of the Gaps," *Perspectives on Science and Christian Faith* 61, no. 1 (2009): 13–22; ___, "Design or the Multiverse?," *Perspectives on Science and Christian Faith* 63, no. 1 (2011): 42–47; Jack Collins, "Miracles, Intelligent Design, and God-of-the-Gaps," *Perspectives on Science and Christian Faith* 55, no. 1 (2003): 22–29; David Snoke, "In Favor of God-of-the-Gaps Reasoning," *Perspectives on Science and Christian Faith* 53, no. 3 (2001): 152–58.

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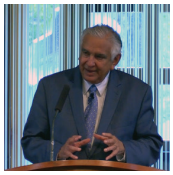
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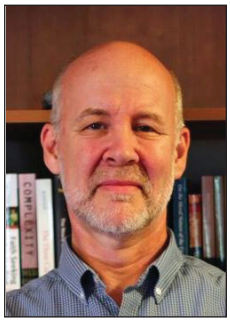

Chris Barrigar

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

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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."

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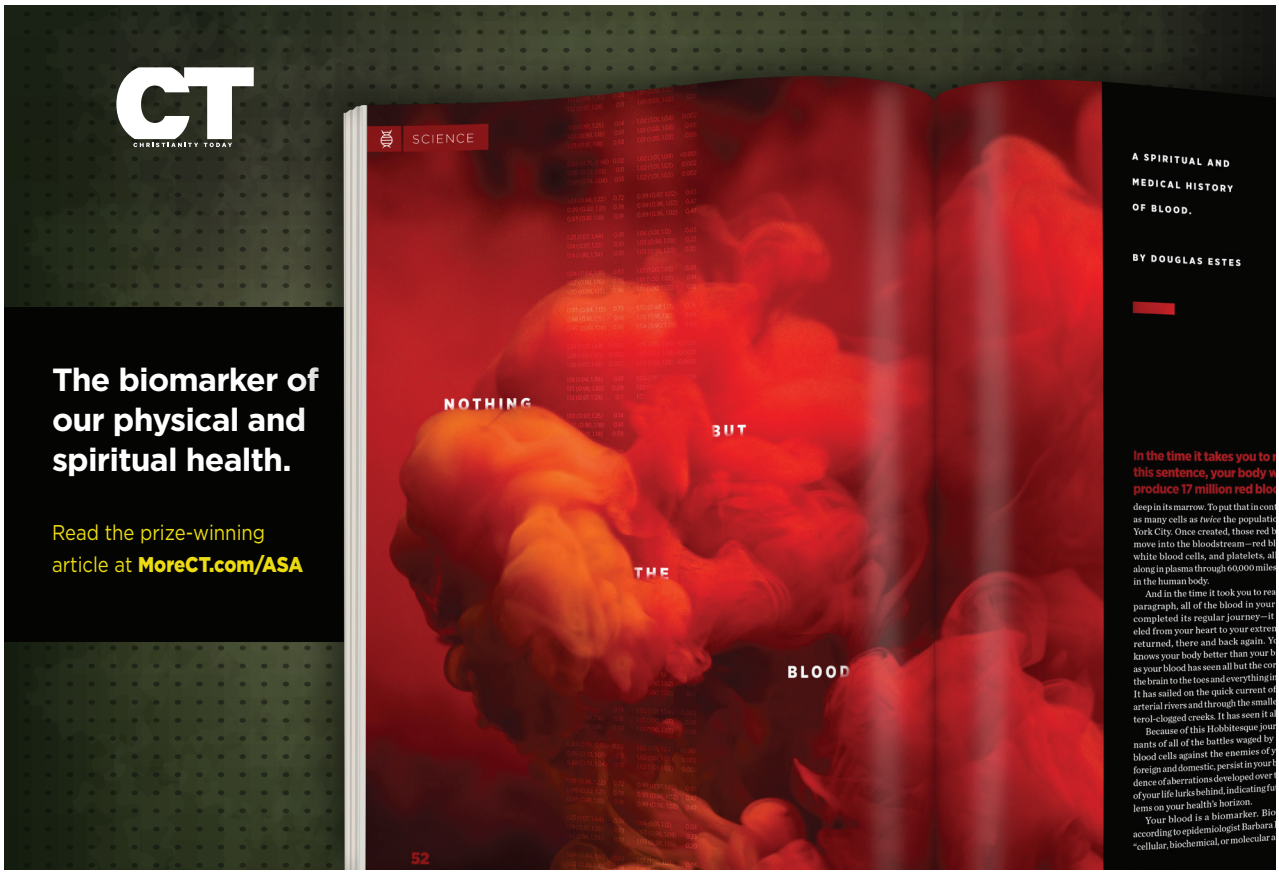

Alan Dickin

Article

New Historical and Geological Constraints on the Date of Noah's Flood

Alan Dickin

This article proposes a revision of the most likely date of Noah's Flood from ca. 2900 to 5700 BC. A date around 2900 BC cannot be reconciled with the Genesis text as an eyewitness account of a real flood that devastated the Mesopotamian plain, killing all of its known inhabitants except those on the Ark. On the other hand, a devastating flood at 5700 BC could have had this effect, and is much more consistent with geological evidence for the date of severe flooding episodes in the ancient Middle East. In this article, a Neolithic date for the Flood is examined in the light of ancient literary accounts and geological evidence, and the implications for the construction of the Ark and for the origins of Sumerian religion are briefly examined.

Noah's Flood is one of the most important cosmic events in biblical history,[1] but current views remain highly polarized between "literal" interpretations of a global flood[2] and interpretations that see the account as largely nonhistorical, perhaps in the form of a parable.[3] The concept of a global Flood is unscriptural, because ancient peoples had no knowledge of the earth as a globe (Ps. 93:1). On the other hand, viewing the Flood as a parable implies that God did not actually save Noah (Heb. 11:7).

There have been many searches for a "middle way" between these extremes, generally attributing the Genesis account to the flooding of the plain of Mesopotamia. Based on Calvin's doctrine of "divine accommodation,"[4] such an interpretation would represent the flooding of the entire earth *as it was then known*.[5] In a series of papers on this question, Carol Hill and Alan Hill showed that the biblical account of the Flood is consistent with climatic, geological, and hydrological factors that have repeatedly led to catastrophic flooding of the Mesopotamian plain.[6] Specifically, Carol Hill argued that a real flooding event around 2900 BC could have led to the Genesis account, when told from the "worldview perspective" of Noah.[7] However, Paul Seely cited archaeological evidence that the relatively minor flood of 2900 BC was not adequate to annihilate the inhabitants of Mesopotamia, and was therefore not consistent with an eyewitness account of a cataclysmic flood.[8]

The claim that the Flood killed all of the known inhabitants of the world except those on the Ark (Gen. 6:13,17; 7:23) is significant, because it leads to the biblical belief that the ancient world's known people groups were all descended from Noah (Gen. 10:32; 11:1). For this claim to be credible, it is necessary that the descendants of Noah were isolated for some period of time after the Flood, and some indication of the duration of this isolation can be obtained from the genealogies in Genesis 10–11 (table 1).

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Table 1. Lineages of the Descendants of Noah through Different Family Branches*

Shem	Shem	Shem	Ham	Ham	Japheth
Arphaxad	Arphaxad	Aram	Cush	Canaan	Gomer
Shelah	Shelah	Uz	Raamah	Sidon	Ashkenaz
Eber	Eber		Sheba		
Peleg	Joktan				
Reu	Almodad				
Serug					
Nahor					
Terah					
Abraham					

*Only the first-born of the final generation is listed

Table 2. Summary of Major Mesopotamian Periods

C-14 Age BC	Name of Period in Mesopotamia		General Name of Period
1600 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			
	Old	Babylon	
	Babylonian	Larsa	Middle Bronze
	Period	Isin	
2020 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			
	3rd Dynasty of Ur		~~~~~~~~~~~~~~~
2200	Gutian Period		
	Akkadian Dynasty		
2350 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			
		III	
2600	Early		
	Dynastic	II	Early Bronze
2750	Period		
		I	
2900 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			
	Protoliterate (Jemdet Nasr)		
3200 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			
		Late	
3600	Uruk		
		Early	
4000 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			Chalcolithic
		Late	
4500	Ubaid		
		Early	
5500 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			
		Late	
5800	Halaf		Neolithic
		Early	
6200 ~~~~~~~~~~~~~~~~~~~~~~~~~~~			

Compared with the line of the elect in column 1 of table 1, the limited depths of the nonelect lineages (columns 2–6) give an idea of the perceived length of family memories among the descendants of Noah. These lineages attempt to explain the origins of world people groups within the limits of anthropological understanding at the time when the Table of Nations (Genesis 10) was compiled. Assuming a typical generational cycle of 30 years (Genesis 11), the data suggest that decades of isolation occurred. After that time, alien peoples would not have been distinguishable from distant family members.

The proposed flooding event at 2900 BC directly preceded the Early Dynastic period in Mesopotamian history (table 2). This was a time when great cities with walls were being built for defense against attack by other city states.[9] Hence, this is definitely not a period when the Mesopotamian descendants of Noah's family could have believed themselves to be the only survivors of a great flood. However, this conundrum can be solved by postulating an earlier date for the Flood. At such an earlier time in human history, humankind's horizons would have been smaller, and hence it is more credible that Noah's family could have believed themselves to be the only survivors of the Flood. Geological evidence can place paleo-environmental constraints on the possible timing and extent of catastrophic ancient flooding events in Mesopotamia, and thus identify the most likely date of Noah's Flood. A reexamination of the problem is therefore warranted.

Ancient Flood Stories

It has long been known that the biblical Flood story has very close parallels to the three Mesopotamian accounts of the deluge contained in works often referred to by modern scholars as the Atrahasis Epic, Gilgamesh Epic, and Sumerian Flood Story. The closest biblical parallel is found with tablet 11 of the Gilgamesh Epic, on which the Flood Hero (Utanapishtim) is referred to as "man of Shuruppak." This ancient city is mentioned in both the Sumerian Flood Story and the Sumerian King List as the location of the last dynasty before the Flood. A summary of the relevant parts of the King List is shown in table 3.

This summary shows that according to the King List, there were five dynasties that ruled over Mesopotamia before the Flood, comprising a total of eight kings. However, this part of the King List is not historically reliable, because it omits the city of Uruk, which is known from archaeological evidence to be the principal city of Mesopotamia at that time.[10] In contrast, the postdiluvian section is in relatively good accord with archaeological evidence, and records the

Table 3. Summary of the Sumerian King List (WB444)

Name of Dynasty	Number of Kings	Total length of reigns, yr
Eridu	2	64,800
Badtibira	3	108,000
Larak	1	28,800
Sippar	1	21,000
Shuruppak	1	18,600
~~The Flood~~~~~~~~~~~~~~~~~~~~		
Kish 1	23	24,510
Uruk 1	12	2,310
12 more dynasties	45	5,332

dominance, first of the city Kish, and then of Uruk, followed by twelve more dynasties in total (locations of important ancient sites are shown in fig. 1). The penultimate king of the dynasty of Kish was En-Mebaragesi, who is attested in two of the earliest contemporary royal inscriptions,[11] one of which was excavated from a level dated to around 2500 BC at Khafajah (ancient Tutub). These records allow the beginning of the Kish dynasty to be placed around 2900 BC.

In a detailed analysis of the date of the Flood, Max Mallowan compared the literary accounts with archaeological evidence of possible flood deposits in excavation sections at several ancient cities.[12] Three deposits had been found at Kish, of which the thickest (0.4 m) was however too young, since it occurred near the end of the Early Dynastic period (ca. 2400 BC), and after the reign of Gilgamesh. However, the earliest deposit, around the beginning of the Early Dynastic period (2900 BC) appears consistent with the literary evidence.

Although this flood left visible deposits within some city streets, it evidently did not wash away the (mud-brick) walls of adjacent houses. A similar deposit, around 0.6 m thick and consisting of a mixture of sand and clay, was found at the base of the Early Dynastic stratigraphy in Shuruppak (Tel Fara).[13] This was unequivocally identified by the excavators as a flood deposit, and was possibly of the same age as the oldest Kish flood stratum, but was not subjected to any further archaeological investigation.

Taken together, the Mesopotamian literary and archaeological evidence was seen to imply an association of the Mesopotamian Flood stories with a significant inundation that occurred around 2900 BC. However, both the Mesopotamian and biblical Flood accounts speak of cataclysmic devastation and

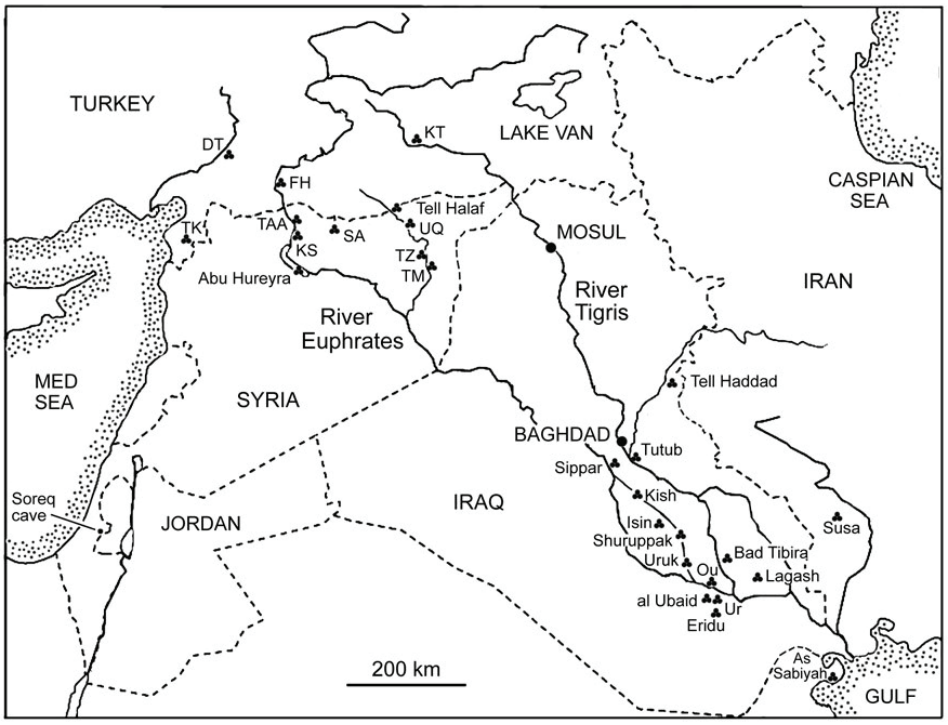

Figure 1. Map of the Middle East showing the location of ancient sites and other features mentioned in the text. Acronyms = ancient sites mentioned in figure 7. Ou = Oueili.

human annihilation that is quite at odds with the archaeological evidence. For example, Genesis 7:21–23, NIV claims that

> *Every living thing that moved on the earth perished – birds, livestock, wild animals, all the creatures that swarm over the earth, and all mankind. Everything on dry land that had the breath of life in its nostrils died. Every living thing on the face of the earth was wiped out; men and animals and the creatures that move along the ground and the birds of the air were wiped from the earth. Only Noah was left, and those with him in the ark.*

According to the Documentary Hypothesis, these verses actually come from two different source traditions, P (v. 21) and J (vv. 22–23).[14] Therefore, these can be considered as two semi-independent attestations of the same event. Furthermore, the three separate Mesopotamian sources tell the same story. For example, after the waters have receded, the Flood Hero of the Gilgamesh Epic describes the scene as follows:

> *I looked at the weather; silence reigned;*
> *For all mankind had returned to clay*
> *The flood-plain was flat as a roof.*[15]

Mallowan suggested that the flood deposit separating the Protoliterate (Jemdet Nasr) and Early Dynastic levels at Fara may have caused social upheaval and led to changes in building and pottery styles, but he also argued that "no flood was ever of sufficient magnitude to interrupt the continuity of Mesopotamian civilization."[16] Therefore, Mallowan concluded that the biblical Flood story was based on a real event that probably occurred around 2900 BC, but was "written down for a didactic purpose and given the appearance of a world-wide catastrophe."[17] However, since the work of Mallowan, historians have completely reevaluated the evidence from the Sumerian King List, based on the publication of new Sumerian texts. This, therefore, requires a complete reassessment of the evidence.

Reassessment of the Sumerian King List

As noted above, the Sumerian King List is pivotal for dating the Flood, by placing it before the first dynasty of Kish around 2900 BC. There are several versions of the King List, of which the most complete is the Weld-Blundell prism (WB444), hence often taken to be the definitive version. More than half of the extant fragments of the King List derive from the Old Babylonian period in the city of Nippur (ca. 1700 BC). Most of these copies are broken, but some of them have a summary at the end which can be used to assess the overall structure. Significantly, this summary does not mention the antediluvian section. This observation led Thorkild Jacobsen to suggest that the antediluvian section was a "prequel" added to the beginning of the King List after its original composition.[18] Additional evidence for this theory was given by Jacob Finkelstein and William Hallo.[19] For example, the wording used to indicate a transition between dynasties is different in the antediluvian and postdiluvian sections, and the antediluvian section also has more variability in the order of cities in different versions.

Evidence supporting this view came from a new version of the King List discovered in Ur, published in 2003.[20] This tablet is dated to the third dynasty of Ur (ca. 2100 BC) and is therefore the earliest known form of the King List. Not only does this version lack the antediluvian section, but it does not mention the Flood at all. This discovery confirmed a theory that was previously held by many historians of ancient Mesopotamia, that the original composition of the King List began with the cuneiform signs "nam lugal" (kingship), hence translated, "When kingship descended from heaven, the kingship was in Kish."

This claim is supported by archaeology, since the dynasty of Kish saw the first architectural development of the royal palace. The palace was characterized by three new defensive features that are not seen in earlier temple-related architecture: a double-walled enclosure, entrance through a labyrinth, and a royal audience hall.[21] This development shows that the original version of the King List was correct in presenting the Early Dynastic period as an era when secular kingship was first instituted, involving hegemony over the Mesopotamian plain that moved from one city state to another. However, it said nothing about the Flood.

From this position, it was a fairly small step for secular historians to conclude that the deluge, like the antediluvian kingship, was largely fictitious. Their conclusion was based on examination of the cuneiform signs used to write the Flood, pronounced a-ma-ru. This word sounds very similar to the Sumerian and Akkadian names for the Amorite peoples (mar-ru and amurru respectively).[22] The

similarity was observed by several scholars, and led William Hallo to suggest that the cosmic Flood was merely a cultural motif, inspired by devastating Amorite invasions of Mesopotamia.[23] These invasions began at the end of the third millennium and led to the fall of the Ur III dynasty around 2000 BC.

This argument was more recently championed by Y. S. Chen, who suggested, from the absence of earlier Flood texts, that these stories could not have existed in the third millennium:

> With the Flood being such a pivotal mythological and historiographical motif, it would be unthinkable for it not to be reflected in textual traditions soon after it came into circulation orally.[24]

However, if the writing of literature did not *exist* near the time of the Flood, the story could not have been written down at that time. And in fact, there are very few extant literary works from the third millennium. So, the writing of flood myths in the Old Babylonian period says more about the changing interests of kings and scribes than the actual prehistory of Mesopotamia.

Recent studies on the development of Sumerian literature suggest that the original motivations for the development of Sumerian textual traditions were quite different from the motivations of later times. Although most Sumerian literary texts come from the Old Babylonian period, an examination of tablet find-sites shows that they are not in libraries (as in later times) but in scribal schools.[25] Thus, Piotr Michalowski suggested that the motive for writing Sumerian literary texts was the opposite of that behind a modern musical score.[26] A score is the permanent record, from which ephemeral musical performances are created. In contrast, it appears from the variation of individual tablets that literary texts were written as "ephemeral" practice pieces, from an oral tradition that was handed down as the "permanent" record. The very sparse literary record surviving from Early Dynastic times supports this view.[27]

Given this background, it is important to review the evidence for the earliest attestation of the Flood tradition, which is also linked to the Gilgamesh epic tradition.

Relationship between the Gilgamesh and Flood Traditions

The late-third-millennium Ur III dynasty shows the first development of a significant literary tradition, with short stories emerging about three Early Dynastic kings of Uruk: Enmerkar, Lugalbanda, and Gilgamesh. In fact, Gilgamesh was already attested by the end of the Early Dynastic period as a deified figure. He is named with the divine designator (dingir) in an archaic inscription on a mace head,[28] and also in god lists from this period.[29] Therefore, Gilgamesh, the archetypal hero, was evidently already a powerful symbolic figure by the end of the Early Dynastic period. This may have encouraged Shulgi, second king of the Ur III dynasty, to co-opt Gilgamesh as a pattern for his own deification.[30] This is a reasonable theory, since Shulgi's dynasty traced its own ancestry to the city of Uruk. And by establishing the Gilgamesh stories as canonical pieces, Shulgi could mandate this material for training the next generation of scribes. However, only fragments of these epic stories are preserved from the third millennium. To study their detailed content, it is necessary to examine second-millennium copies.

Five Gilgamesh stories are known from the Old Babylonian period, but some of them were quite incomplete before a new trove of literary texts was discovered at Tell Haddad, northeast of Baghdad.[31] One of these stories is the Death of Gilgamesh, whose text had been very incomplete before the Tell Haddad discovery. This story contains a speech by Enki, god of wisdom, which begins with an "introduction formula" first seen in the Early Dynastic period:[32]

> [In those days,] *in those far-off days,*
> [in those nights,] *in those far-off nights,*
> [in those years,] *in those far-off years,*
> *after* [the assembly] *had made the Deluge sweep over,*
> *so we could destroy the seed of mankind,*
> *in our midst a single man still lived,*
> *Ziusudra, one of mankind still lived!*
> *From that time we swore by the life of heaven and the life of earth,*
> *from that time we swore that mankind should not have life eternal.*
> *And now we look on Gilgamesh:*
> *Despite his mother* (a goddess) *we cannot show him mercy!*[33]

The tradition of a devastating Flood is an integral part of this story, since it explains why Gilgamesh

must die. And since the Death of Gilgamesh is an important part of the Gilgamesh cycle, it seems almost certain that the account originated in the third millennium, even though the tablet translated above is of Old Babylonian age. Hence, this contradicts the idea of Hallo and Chen cited above, that the cosmic Flood was an invention of the Old Babylonian period. Instead, it suggests that the Flood was a much older tradition, but only added to the beginning of the King List in the Old Babylonian period. Therefore, although the King List provides evidence that the cosmic Flood preceded the first dynasty of Kish, it provides no information on how *much* earlier it occurred.

Gilgamesh the king is placed in the first (postdiluvial) dynasty of Uruk by the King List and the Tummal Chronicle.[34] This evidence dates Gilgamesh to around 2700 BC. On the other hand, the Flood hero is regarded as an almost-mythical figure in the Death of Gilgamesh and the Gilgamesh Epic, since he was unique in having attained immortality. This therefore implies that the Flood occurred long before the time of Gilgamesh, rather than just 200 years earlier. And the earlier setting is consistent with the belief that the Flood annihilated the whole (known) human race outside the Ark.

This "primitive" setting is not consistent with any date for the Flood after the ascendancy of Uruk in the mid- to late-fourth millennium, when Sumer had a huge influence on world culture, well outside the Mesopotamian plain. The cultural influence of Uruk on Egypt is demonstrated by the presence of Sumerian cylinder seals in predynastic Egyptian graves.[35] On the other hand, the influence on Susa in Iran was even greater, with almost-identical copies of Mesopotamian pottery, cylinder seal iconography, administrative tablets, and architecture being discovered there.[36] And sites in Syria and southern Turkey (Anatolia) also show a pervasive cultural influence, as summarized by Hans Nissen: "Syria in its entirety appears to have adopted the southern Mesopotamian Uruk-Warka set of artifacts and ideas."[37] Hence it has become commonplace among secular archaeologists to use Guillermo Algaze's term "the Uruk World System" to refer to the Middle East of the late fourth millennium, without any sense of exaggeration.[38] Therefore, it is simply not credible that a moderate-sized flood in Mesopotamia around 2900 BC could have been seen as annihilating the whole human race.

Excavation records from the ancient city of Eridu, attested by both literary and archaeological sources as the oldest city in southern Mesopotamia, place the earliest mud-brick buildings at Eridu in the late sixth millennium.[39] However, a devastating flood that wiped out all of the known inhabitants of Mesopotamia would have severely damaged the early mud-brick architecture of Mesopotamia. Therefore, it seems most likely that the cosmic Flood predated the founding of Eridu. Such an early date is also more consistent with the biblical impression that the Flood was so far back in prehistory that it was believed that all humanity was descended from a single family of survivors. On the other hand, the Flood must have postdated the agricultural revolution (during the ninth millennium BC[40]) since the story of Cain and Abel is set in a Neolithic agricultural context (Gen. 4:2).

Geological Evidence for the Date of the Flood

Lower Mesopotamia is a delta plain built up by sediment deposition from the Tigris and Euphrates Rivers. It is one of the flattest places on Earth, covering an area of more than 100,000 square km with less than 50 m of vertical relief (fig. 2). In particular, the very low gradient of these rivers (around 6×10^{-5} between Baghdad and the sea) causes the flow to back up very readily and breach the levees. Hence, this is one of the few areas in the world where a catastrophic river flood in prehistory could have appeared to destroy all of the known earth. In that case, evidence for such a flooding event may be preserved in geological records.

Before the completion of major dams over the past 50 years, the Tigris and Euphrates often flooded due to spring snow-melt in their headwaters in southeast Turkey (fig. 1). Furthermore, the peak springtime discharges of these rivers were often ten times the autumn discharge.[41] The peak flow of the Tigris normally occurred in April, whereas the Euphrates peaked in May. This seasonality accords well with the biblical description of the Flood beginning on the seventeenth day of the second month (ancient Middle Eastern calendars dated the new year from the first new moon after the spring equinox).[42]

To date wet climatic periods that may have caused catastrophic flooding in Mesopotamia, we can study ancient sediment records from Lake Van, which lies

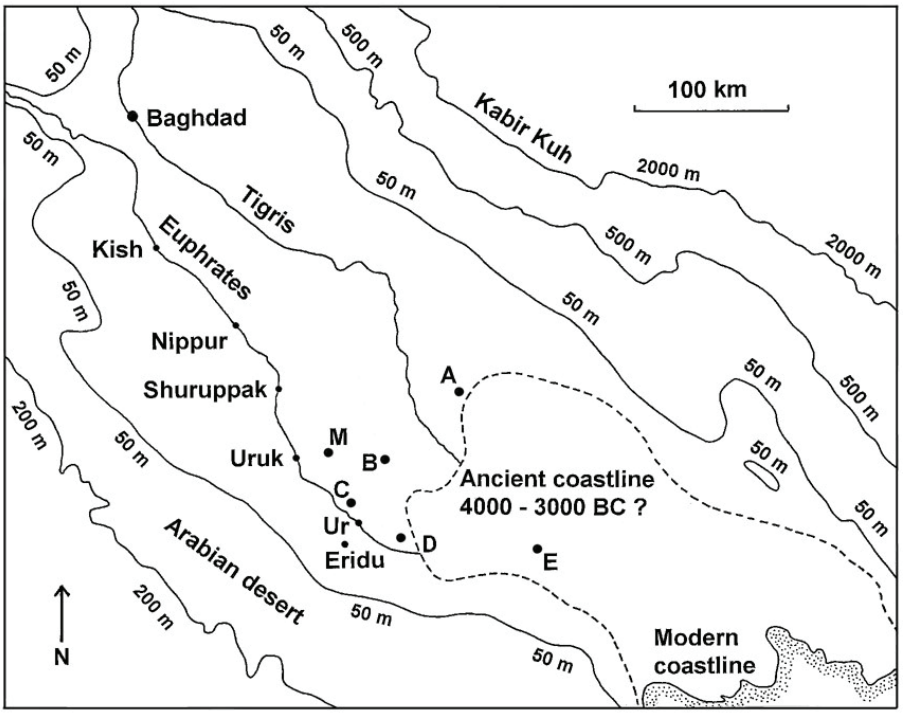

Figure 2. Topographic map of the Mesopotamian Plain showing contour lines, borehole locations, and ancient city sites relative to ancient courses of the Tigris and Euphrates Rivers.

between the headwaters of the Tigris and Euphrates in southeast Turkey (fig. 1). Because Lake Van lies in a closed watershed, it forms a "terminal lake" which is fed by rivers but has no outflow. The levels of such lakes are determined by a balance between river influx and water loss by evaporation, and they are therefore very useful as monitors of past climate. During wet periods the lake level rises, whereas in dry periods the lake level falls and salinity increases to the point at which salt deposits may form. Such processes are seen at another well-known terminal lake, the Dead Sea.

Water-level variations of about 0.5 m occur on a seasonal basis in Lake Van, with a marked rise in May from a combination of snow melt and spring rains, followed by a drop over the summer due to evaporation. Lake-level variations of over 1m also occur between wet and dry years. However, sediment records from the floor of the lake record changes in lake level of over *400 meters* over the past 15,000 years. These records can be precisely dated, because the bottom sediments in Lake Van often preserve annual deposition layers (varves) whose ages have been verified by radiocarbon dating.[43]

By combining the record of past lake levels with the underwater shape of the lake, the varve data can be translated into a model of relative precipitation in the headwaters of the Tigris and Euphrates from 13,000 to 2000 BC (fig. 3). This model shows evidence of three periods of very high precipitation around 11500, 8500, and 6000 BC, but the most recent of these was the wettest. Within this wet period, the most intense episode of precipitation is constrained by the time when one of the core locations was first flooded by rising lake level (point x in fig. 3) around 6100 BC.[44] However, due to a lack of cores at slightly shallower depths in the lake, the data do not yet allow the wettest individual years after 6100 BC to be pinpointed. This therefore requires us to look

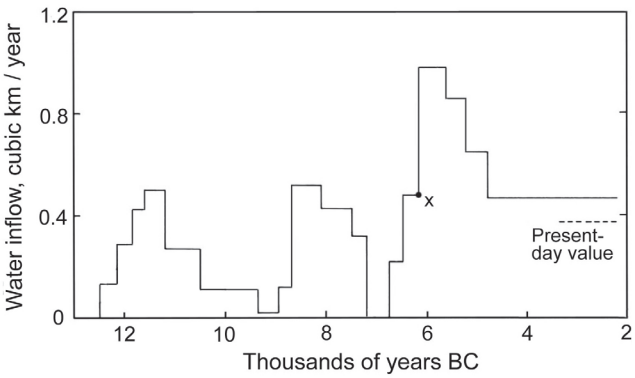

Figure 3. A reconstruction of past water inflow to Lake Van from precipitation. For discussion of point "x" see text.

for other records of ancient rainfall in the Middle Eastern region.

Climatic evidence suggests that Mesopotamia is part of a regional weather system that affects the whole Fertile Crescent.[45] Therefore relevant evidence of the ancient rainfall history of Mesopotamia can also be derived from stalactites and stalagmites in Soreq Cave near Jerusalem. Calcite growth layers were sampled at intervals of 1 mm, and were dated by the uranium-series method.[46] Stable oxygen and carbon isotope measurements were then used to obtain paleoclimate information. For example, low delta O-18 ratios are indicative of a wet climatic period between 6500 and 5000 BC, with a maximum intensity at 5700 BC. Similar delta O-18 signatures for Lake Van and for Lake Mirabad in the Zagros Mountains suggest that high rainfall affected much of the Fertile Crescent at that time.[47]

More specifically, carbon isotope measurements on Soreq Cave deposits provide a record of ancient flooding events during the same period (fig. 4). During this time interval, high delta C-13 signatures were observed that are unique in the past 100,000 years.[48] These signatures were attributed to enhanced weathering of bedrock and a lack of equilibration between groundwater and soil organic matter, due to extreme summer rainfall events. Furthermore, these signals were accompanied by unusual iron-rich coloration and large detrital fractions in the deposited calcite, indicative of floodwaters entering the cave.[49] Although these records do not allow individual flooding events to be isolated, they show that the intensity of flooding during the interval 6500–5000 BC was never subsequently repeated (fig. 4).

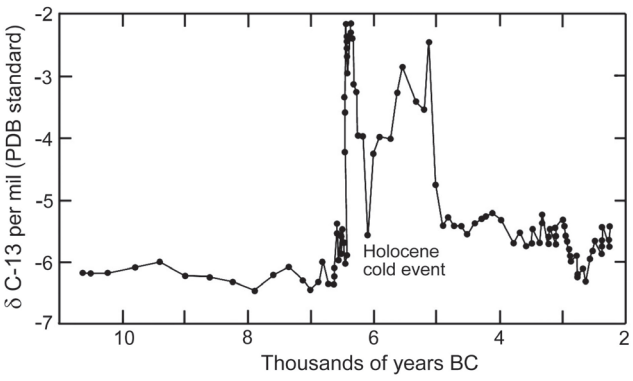

Figure 4. Record of carbon isotope ratios relative to the PDB standard for a stalactite from Soreq cave near Jerusalem. Data from Bar-Matthews et al.[50]

The wet period was itself interrupted by a briefer period with low delta C-13 signatures at 6200 BC. This is attributed to a brief period of cold, dry weather that is recognized throughout the northern hemisphere[51] and has been precisely dated in Greenland ice cores.[52] This event provides a precise reference point for the stalactite cave record in figure 4, demonstrating the accuracy of the age calibration.

The very wet climatic interval in Soreq Cave is also marked in Mediterranean sediment cores of this age as a widely observed "anoxic sapropel" layer enriched in organic matter.[53] This layer is called "Sapropel 1" because it is the youngest of a series of such deposits spanning the last glacial cycle. It is attributed to a massive injection of fresh water into the Mediterranean due to extreme flooding of rivers such as the Nile.[54] This freshwater incursion led to the development of anoxic conditions, which caused enhanced preservation of organic matter. The phenomenon probably does not date a single great flood, but it does indicate a period of unusually severe summer rainfall events. Taken together, the evidence suggests that the early sixth millennium BC was a period of intense flooding in the Middle East that was never again repeated. Therefore it represents the most likely period for extreme flooding events in the sedimentary record of Mesopotamia.

The Flood in the Sedimentary Record

As discussed above, there have been many attempts to locate the sedimentary deposit left by Noah's Flood. One issue inhibiting this search has been a misunderstanding of the type of deposit to be expected from flooding of a delta plain such as Mesopotamia. However, a detailed study based on over 200 auger sections drilled in the 1970s has clarified the distinct types of sediment to be expected on the Mesopotamian delta plain.[55] The study area was in the vicinity of the ancient city of Sippar, about 40 km south of Baghdad. The results are summarized in figure 5 on a cross-section through 16 auger holes.

The most common deposits were homogeneous (poorly banded) grey-brown silty clays with few remains of vegetation or shells. These are identified as flood-plain deposits, consisting of repeated fine-sediment deposition from standing water, due to minor flooding events. The brownish coloration is evidence of exposure to air, implying small sediment

accumulations that dried out before subsequent flooding events. In contrast, coarser greenish-grey silty to sandy deposits are interpreted as channel-belt and crevasse-splay deposits. The greener color indicates more rapid sedimentation, preventing oxidation. Crevasse-splay deposits are coarse-grained flood deposits that form near the river channel when it overflows its banks. Over time, these deposits can build up natural levees on either side of the channel. A third type of material, comprising the upper 1–2 m of each auger section, consisted of grey-brown fine sand and silt, attributed to wind-blown sand and dust.

An important feature of the river systems of Mesopotamia is avulsion, meaning a change in the course of the river that results from a major flooding event. The process of avulsion has occurred many times over the history of the plain, and causes the lateral movement of channel-belt deposits with depth through a section (fig. 5). Avulsion can cause the development of a new channel where none existed before, and is most likely what led to the 3 m thick "Flood stratum" identified by Leonard Woolley on one side of the city of Ur.[56] Most major cities were built on the banks of one of the major channels of the Euphrates River, and were therefore highly susceptible to avulsion events.

The conclusion that we reach from this evidence is that flooding events do not necessarily lead to the expected types of sedimentary deposit in the geological record. This was already noted by Carol Hill, who pointed out that major flooding events can cause erosion just as much as sediment deposition.[57] When the river bursts its banks, it may cause (local) proximal development of crevasse-splay deposits. However, the distal effects of prolonged submergence lead to organic-rich deposits over a much wider area. Therefore, the best indicator of a major flooding event is likely to be an organic-rich sapropel layer similar to the one developed in the Mediterranean by catastrophic flooding of the Nile River.

Borehole Sections from Southern Mesopotamia

Most borehole sections in Mesopotamia do not reach the depths of around 10 m needed to search for flood deposits around 6000 BC. However, around 1980, eight boreholes were drilled through the postglacial alluvium in the southeast part of the plain, and their stratigraphy was analysed by Adnan Aqrawi.[58] Of particular interest for the present investigation is borehole C, near the ancient city of Ur on the southwest side of the plain, and borehole B, located 40 km to the northeast, near the central axis of the plain (fig. 2). At certain horizons, organic-rich sediments were found that allowed these sections to be calibrated by radiocarbon dating.[59]

The postglacial sedimentary record of Mesopotamia must be seen within the context of sea-level rise since the last glacial maximum (around 20,000 years BC). At that time, sea level was about 125 m below its present-day level, and it rose over the following 15,000 years at just under 1 cm per year as the ice sheets melted.[60]

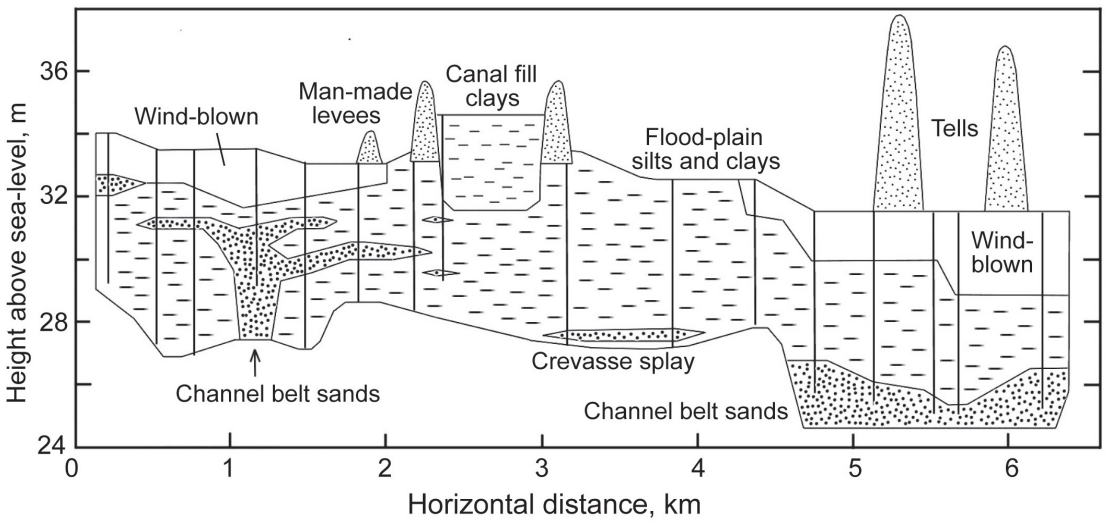

Figure 5. Cross-section of flood-plain deposits in the region of Sippar based on 16 auger sections. Note the 200 times vertical exaggeration. Redrawn from Heyvaert and Baeteman.[61]

As global sea level rose, it would have overtopped any natural rock ridges in the dried-up seafloor, causing local flooding of some low-lying areas. This observation led William Ryan and Walter Pitman to propose that the Genesis Flood occurred when sea level overtopped the Bosphorus Straight between the Mediterranean and the Black Sea at the end of the last ice age.[62] Based on the premise that the Black Sea had partially evaporated due to low rainfall in the previous millennium, they argued that sea-level rise created a massive waterfall, rapidly refilling the Black Sea and giving rise to the biblical and Mesopotamian flood stories. However, this theory has a fatal flaw. The water level in the Black Sea never fell again after the influx stopped, whereas both biblical and Mesopotamian sources give detailed accounts of the ebb of the Flood, including the release of birds to test the reappearance of land. This shows that the "Black Sea Flood" can have no connection with the biblical Flood story. Instead, Genesis is clearly describing a catastrophic river flood, of the type that frequently devastated Mesopotamia before the construction of major dams on the headwaters of the Tigris and Euphrates Rivers.[63]

Nevertheless, postglacial sea-level rise would still have had a critical effect on flooding conditions in Mesopotamia. For example, the huge drop in sea level during the last glacial period allowed rivers to cut small gorges in their earlier flood-plain deposits, thus confining the river to these gorges and severely limiting flooding events.[64] However, when rising sea level impinged on the preglacial delta plain around 6000 BC, it quickly flooded these gorges, backing up the river flow and preventing subsequent river floods from easily draining away. The effect of this sea-level rise is most clearly seen in boreholes B and C, comprising 15 m sections spanning most of the Holocene period (the last 10,000 years).

The stratigraphic logs are shown in the form of a "fence diagram" in figure 6, describing the lateral distribution of sediments according to grain size and type.[65] This sedimentological evidence was combined with an analysis of microfossils and the carbonate content of the core to determine salinity conditions at the time of sediment deposition.

Holocene sedimentation began with mixed deposition of sand and silt containing significant amounts of gypsum and dolomite. These are indicative of evaporitic conditions in short-lived lakes (playa), formed on flat-lying land above sea level. Rising sea level caused a flooding event (marine transgression) at 11 m depth in drill-core C, marked by a sharp increase in the carbonate content of the core and a

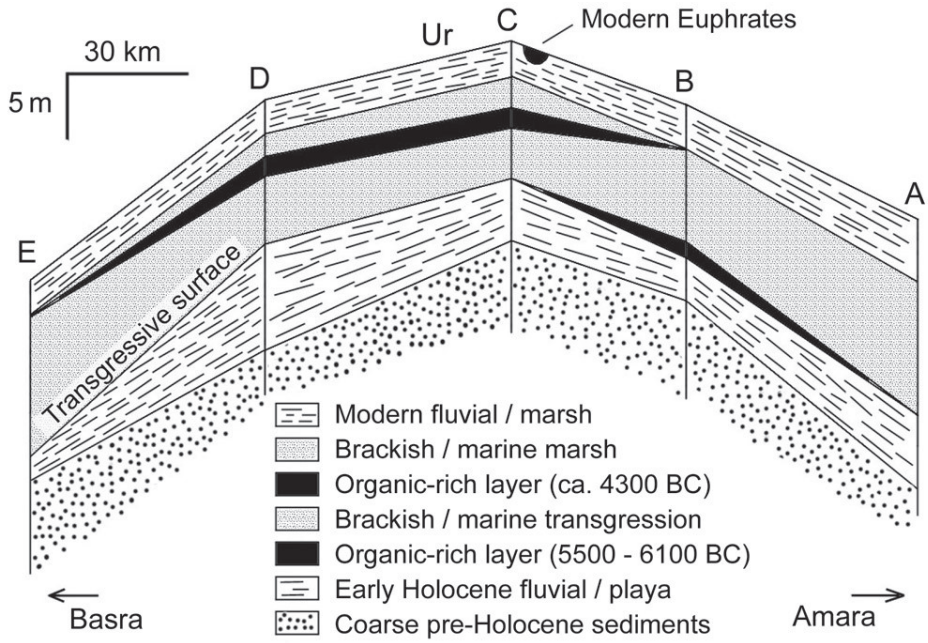

Figure 6. "Fence diagram" showing sedimentary borehole sections in southern Iraq, looking along the course of the Euphrates from the east. Localities are shown in figure 2. Data from Aqwari.[66]

change in the isotopic composition of carbonates.[67] The date of this event is given by radiocarbon dating of organic-rich sediment from immediately below the transgressive horizon in borehole B (fig. 6). Two samples gave calibrated radiocarbon ages of 6150 and 5550 BC, sampled from the lower and upper halves respectively of a 1 m thick layer (from 11 to 12 meters depth).[68] The age of this organic-rich layer therefore suggests it to be a lateral equivalent to Sapropel 1 in the eastern Mediterranean.

The organic-rich layer may once have been more widely extensive, but was probably eroded by the subsequent marine transgression. After this event, brackish conditions persisted for about 1500 years, followed by another organic-rich layer. This horizon was dated to around 4300 BC in borehole C, near Ur (fig. 6). This material occurs within a 1 m thick clay-rich layer that is the correct age to be correlative with the probable avulsion flood deposit excavated by Leonard Woolley at Ur.

More recently, a new borehole penetrating to similar depths was drilled about 20 km east of Uruk (borehole M, fig. 2), and about 20 km upstream of borehole B.[69] This borehole log also contains organic-rich horizons, but unlike the downstream boreholes studies by Aqwari, there was no evidence for marine incursion. Instead, the section contained freshwater diatom species throughout. This evidence suggests that the marine transgression on the seaward end of the Mesopotamian plain was not directly responsible for Noah's Flood. Nor is there any evidence of other types of marine incursion such as tsunami. However, the marine transgression played a critical role in the flooding history of Mesopotamia by backing up the river flow and preventing river-floods from rapidly draining away.

The timing of the marine transgression is more precisely constrained by sediment sections in the nearby Karun River of southeast Iran.[70] Organic-rich sediments immediately below the marine incursion date this event to 5600–5900 BC, coinciding with the minimum in the delta O-18 records that marks the peak in rainfall intensity. This therefore created the conditions for a "perfect storm" with the greatest flood risk. However, after this period, the rate of sea-level rise dropped by a factor of ten (around 5000 BC)[71] so that after that time, the risk of catastrophic flooding was reduced.

The effect of marine transgressions backing up river floods in the mid-Holocene wet period can explain why deluge accounts seem common around the globe. The flooding of the Black Sea provides an example of such a scenario, since it apparently occurred around the same time as the Mesopotamian flood. Although it cannot explain the biblical Flood story, it provides an example of how sea-level rise may have given rise to similar stories in other cultures.[72]

Evidence for a Cultural Gap

If river flooding caused by heavy rainfall events between 6000 and 5500 BC was exacerbated by sea-level rise, this prompts us to ask whether there is any archaeological evidence for cultural disruption in Mesopotamia in this time period. Although the evidence remains incomplete, there is a significant cultural break within this interval, between Late Neolithic (Halaf) and Early Chalcolithic (Ubaid) settlements.[73] For example, in northern Mesopotamia and environs, there is a gap of over 500 years between the end of Halaf occupation at several well-dated sites and the beginning of Ubaid occupation at others (open boxes in fig. 7). On the other hand, the site of Domuz Tepe, whose occupation continued until 5500 BC, is located to the west, outside the Euphrates watershed (DT on map, fig. 1).

It is notable that the majority of the Neolithic sites in northern Mesopotamia were active either before or after the Halaf-Ubaid transition, but very few early sites were resettled after the transition. The disappearance of these settlements followed an episode of mass human emigration from Eastern Anatolia into Europe (deduced from genetic evidence).[74] Therefore, although the Flood evidently did not annihilate these peoples on the upper reaches of the Euphrates, extreme variations in the amount of precipitation during the early sixth millennium BC may have disrupted agricultural production, encouraging migration toward areas of greater climatic stability to the northwest.

Around the same time as this major human migration to the northwest, other migrations also occurred: southward along the Mediterranean coast into Egypt, northward from the Caucasus into the Eurasian steppe, and eastward from the Zagros Mountains into Asia.[75] This massive outward migration from northern Mesopotamia would have increased the

isolation experienced by Noah's descendants after the Flood, leading them to believe that they were the only survivors of the catastrophe. It also explains their belief that they were the ancestors of all the nations, which evidently spread out after the Flood much as described in Genesis 10.

Unlike northern Mesopotamia, it is particularly notable that no settlement sites are known in southern Mesopotamia before 5500 BC. Although this area currently requires irrigation for large-scale farming, the immediate banks of the Euphrates have always been habitable, even in dry periods. Hence, there is no reason to believe that the river banks of the Mesopotamian plain were unoccupied during the Halaf period. The most logical explanation is that there *were* Halaf-age settlements along the rivers of southern Mesopotamia, but they were wiped out by the Flood.

The earliest known settlement in southern Mesopotamia is Oueili, an Early Ubaid site that was apparently abandoned at the end of the Ubaid period and therefore never developed into a major city.[76] Two charcoal samples from Phase I of the occupation give calibrated radiocarbon ages of ca. 5360 and 5600 BC (based on analyses by Valladas et al.,[77] recalibrated by Hritz et al.). Unfortunately, the error bars are relatively large, partly because this is a nonideal part of the radiocarbon calibration curve that causes some magnification of analytical errors.[78] Another very early Ubaid site, As-Sabiyah in Kuwait, has yielded charcoal dating to 5430 BC.[79] In comparison, the oldest dated organic material at Uruk, from a deep sounding of the Eanna temple complex, gave a calibrated age of ca. 5000 BC (fig. 7).

Shell material has been radiocarbon dated from both Oueili and Eridu, the latter from samples of clay bricks near the base of the mound. This material gives ages as old as 6300 BC from Oueili and 5700 BC from Eridu.[80] However, these ages cannot be used to date the occupation. They almost certainly represent shells that were incorporated into clay deposits used by later settlers to make clay bricks. The younger of these clay deposits may even have been laid down by Noah's Flood itself.

It is concluded that the Flood most likely occurred around 5700 BC, before the settlement of Oueili, corresponding to the radiocarbon age of the upper part of the sapropel layer dated by Aqwari. This early date makes the extreme effects described in the Flood narratives much more credible. At this time, lower Mesopotamia had only recently been colonized by people migrating southward from the villages of

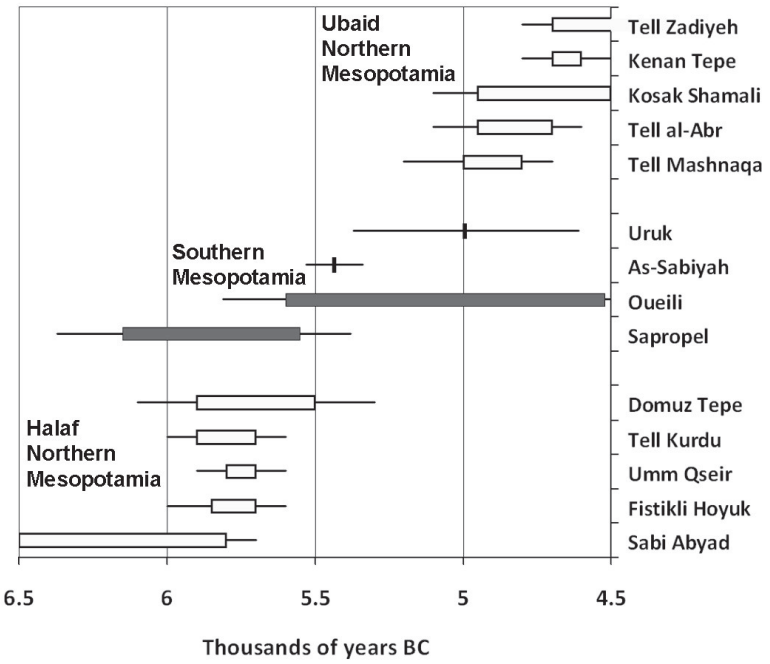

Figure 7. Calibrated C-14 dates on well-constrained dating material from different sites. Wide bar = range between oldest and youngest reliable ages, thin bars = 95% confidence limits on ages.

northern Mesopotamia where the agricultural revolution began. These people would have been living in small settlements on the immediate banks of the Euphrates, and their nascent civilization would have been completely overwhelmed by the greatest flooding event that Mesopotamia has ever seen. In such circumstances, it is not hard to see how the devastation of the Flood would have seemed like a return to cosmic chaos.

Construction of the Ark

A question that arises from a Late Neolithic date for the Flood (nearly 3,000 years earlier than the widely accepted date) is whether the pre-Chalcolithic peoples of Mesopotamia would have been capable of constructing the Ark described in Genesis. The quoted dimensions of 300 cubits long, 50 cubits wide, and 30 cubits high, when translated into the form of a ship, would make the Ark the largest wooden vessel ever to float, with a size equivalent to a small container ship.

The largest commercial wooden ship ever built was the schooner Wyoming, launched in Maine in 1909 and weighing 3,400 tons.[81] The hull was 330 feet long, making her 120 feet shorter than Noah's Ark, and she was also strengthened with iron cross-bracing. Nevertheless, the size of her hull caused excessive flexing of the planking in heavy weather, causing her to habitually leak and eventually to sink in a storm. This experience suggests that a wooden ship of the size and type commonly illustrated in children's Bibles is unlikely to have survived the Flood, even if it could have been built. But, in fact, the popular conception of the Ark as a wooden "cargo ship" is not biblically based. A literal translation of the relevant verses in Genesis 6:14 and 6:16 reads as follows:

> *Make for yourself a basket-vessel of building-wood; nests you shall make together with the basket-vessel; and you cover inside the house with pitch and outside with pitch.*
>
> *Noon-day you shall make for the basket-vessel, and to a cubit you shall end it above, and a door of the basket-vessel in the side you shall put; lower, second and third you shall make.*

This translation is somewhat opaque, but it is based on Hebrew word usages elsewhere in the Old Testament. For example, the Hebrew word for the Ark is unique to the Flood story and the story of Moses's birth, when his mother places him in a basket of papyrus covered in pitch. In contrast, the Hebrew word used for the Ark of the Covenant is the same as for a money chest. Therefore, Noah's Ark was not a wooden box. On the other hand, a better understanding of the nature of the Ark can be gained by comparing the biblical account with Mesopotamian descriptions of its building.

In the Atrahasis and Gilgamesh epics, the Flood Hero is given a dream or vision in a reed hut, where he receives the instruction, "Dismantle your house, build a boat." This type of reed hut can still be seen in modern Iraq,[82] where the Marsh Arabs construct communal buildings up to 100 feet long and 30 feet high called mudhifs. These structures are based on a framework of giant reed bundles, covered with reed matting and waterproofed with pitch.

The dimensions of the Ark in the Gilgamesh Epic seem to approximate a giant cube. However, Stephanie Dalley suggested that what was actually intended was a scaled-up version of a tub-shaped craft called a quffah, usually made by covering a wooden frame with bitumen-coated reed matting.[83] Unfortunately, this description is missing from the Atrahasis Epic, due to damaged areas of the tablet. However, a small tablet that appears to fill this gap was recently described by Irving Finkel.[84] This so-called "Ark Tablet" is dated to around the same time as the Atrahasis Epic (ca. 1700 BC), and uses the same name for the Flood Hero (Atrahasis, meaning extra wise). The tablet gives detailed instructions for building the Ark, describing it as circular, with a diameter of about 230 feet (70 m). It was apparently to be constructed like a giant basket, by winding a thick "rope" made of palm fiber into an enormous spiral mat, and attaching this to a wooden frame before covering it with pitch. Hence the craft is clearly a giant quffah, of the type previously proposed by Dalley.

A scaled-down version of the "Atrahasis Ark" with a diameter around 50 feet was constructed in 2014 as part of a TV documentary about the Ark Tablet.[85] Although scaled down from the dimensions in the tablet, the "TV Ark" was about three times the diameter of the largest known quffahs from Iraq (which have a diameter of 15 to 20 feet). The experiment showed that scaling up a design in this way is impractical, because when launched, the vessel leaked badly and was only made to float with the assistance of a high-powered pump. This

suggests that the design of the Ark described in the Mesopotamian accounts was a *conceptual* scaling-up of later commercial vessels, rather than an eyewitness description of the actual Neolithic Ark.

The type of vessel described in the Ark Tablet is quite similar to the idea of a giant basket, as implied by the Hebrew word for the Ark. A waterproof basket can be made of reeds or papyrus covered in pitch, but like the TV Ark, this cannot be scaled up to the reported size of Noah's Ark and still be seaworthy. In addition, the biblical instructions for building the Ark imply that it was made primarily of the type of wood normally used for building houses. This type of material does not lend itself to basket making. However, it is inherently buoyant, and can therefore be used to make a giant raft.

Most wooden rafts are made by tethering together a bottom layer of large spars or tree trunks, and then lashing a second layer of spars across them at right angles to make a floating platform on which a shelter can be erected. This type of design is used at the present day to ship rafts of teak or bamboo down the Irrawaddy River.[86] The raft would also have needed a fence round it to keep the animals from falling off, forming a kind of stockade. Hence, such a vessel could have had the appearance of a giant basket.

Another basis for comparing the Ark with a giant basket arises from the Hebrew word used for the habitations on the Ark (*qnen*), the singular of which is translated *nest* in other biblical occurrences. Jason McCann has argued that the Hebrew root of this word relates to construction from material like reeds,[87] and his theory is supported by the New Jerusalem Bible, which translates Genesis 6:14 as follows:

> *Make yourself an ark out of resinous wood.*
> *Make it of reeds and caulk it with pitch inside and out.*

As pointed out by McCann, this translation of Genesis 6:14 is consistent with the Atrahasis and Gilgamesh accounts, both of which describe three components used to build the Ark: wood, reeds, and pitch. Therefore, this also implies the building of a typical Marsh Arab mudhif on a raft.

Mudhifs are constructed with a framework of large reed-bundle arches, the ends of which are usually buried in the ground. However, the same framework could easily be built into the structure of a raft (fig. 8). To complete the mudhif, the framework is covered in reed matting, which must be waterproofed with pitch to repel rain. Therefore the use of pitch in Genesis 6:14 may refer to covering one or more mudhifs with pitch rather than the raft itself. Similarly, the reference to making "noon-day" for the Ark, usually taken to mean a window, probably refers to the lattice-work that forms the end of a typical mudhif to admit light to the interior. Genesis 8:6 reports that Noah opened this window to release the raven after the Flood.

One of the reasons why the Ark has traditionally been identified as a wooden ship is the reference in Genesis 6:16 to it having three decks. However, the Hebrew text does not contain any mention of decks, but simply gives instructions for building the Ark, with "lower, second and third." These instructions more likely refer to the horizontal reed bundles that complete the framework of the mudhif, and are anchored to the vertical bundles by large hoops or rings also made of bundles of reeds (fig. 8). These hoops form an essential part of the structure, and became an important symbol in later Sumerian iconography. The horizontal bundles have the *appearance* of deck-beams, although mudhifs do not normally have internal floors. The lowermost of these horizontal bundles would have been critical in anchoring the reed framework to a raft (fig. 8), since the vertical reed bundles could not be buried in the ground like a normal mudhif.

A critical feature which the Genesis text shares with the Mesopotamian accounts is the reported deck area of the vessel (Gen. 6:15). In the Gilgamesh Epic, the

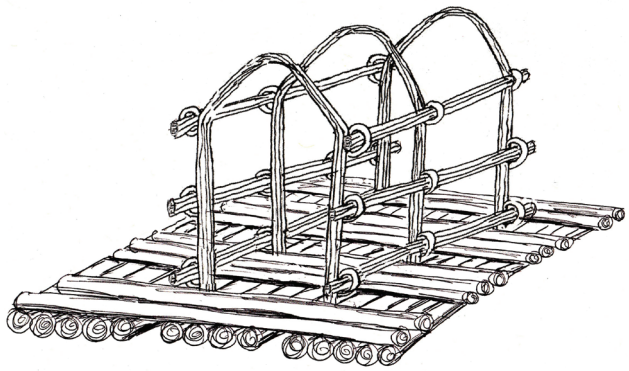

Figure 8. Schematic drawing of the framework for a reed-built mudhif installed on a wooden raft. Note that the overall size of the raft was larger than this. Modified after Jacobsen.[88]

Flood Hero specifically describes the construction as follows:

> *By the fifth day I had set her hull in position, one acre was her area.*[89]

In the Ark Tablet, Enki gives instructions that are identical in size:

> *Draw out the boat that you will make on a circular plan,*
> *Let her length and breadth be equal, Let her floor area be one field.*[90]

The words "acre" and "field" are alternative translations of the Akkadian ideogram IKU,[91] a standard unit of area that seems to be derived from the Sumerian word for a dyked (one acre) field.[92] A Sumerian acre was defined as a field measuring 60 feet by 600 feet (smaller than an English acre). And although the biblical instructions for building the ark have different proportions, it is significant that the surface area (ca. 34,000 square feet) is almost exactly the same.[93] So, rather than seeing these as the dimensions of an impossibly large ship, we should view the Ark as a "floating field." In fact, the Marsh Arabs still build artificial islands in the marshes of southern Iraq by laying down a reed-mesh framework and filling it with mud, to build a platform for their reed huts and a dry resting place for their water buffalo. In comparison, we can conceive that the original Ark was a giant floating raft made of logs on which the animals lived, with one or more mudhifs for human habitation.

The timber required for a raft of this size might amount to a few thousand tree trunks. Although timber was scarce in later historical times, this number of trees would have been available from the riverbanks of ancient Mesopotamia, the principal site where mature wilderness would have existed. Similarly, the pitch necessary for waterproofing probably came from near the Euphrates River at Hit, 150 km west of Baghdad.[94] Hence, both these materials could have been transported by water to the construction site of the Ark on rafts.

In the absence of metal tools for felling trees, the Late Neolithic peoples of Mesopotamia would have used implements made from flint, obsidian, or highly fired clay. The latter type of implement has been found in the Ubaid-period ruins at Oueili.[95] Therefore, when we shed some of our modern preconceptions, the ancient description of the Ark may not be as far-fetched as it initially seems. Such a craft could indeed have been built in the Late Neolithic period.

Implications for Primeval History

The proposed Neolithic date for the Flood has major implications for how Genesis is read as a record of the real experiences of ancient Middle Eastern peoples. Based on Old Babylonian versions of the Sumerian King List, a 2900 BC Flood would have been a comparatively late event in the Mesopotamian prehistory of Genesis, nearer to its end than its beginning. However, given the biblical setting of Cain and Abel in the Neolithic period (after the agricultural revolution around 8500 BC), the proposed new date for the Flood places it much nearer to the time of Adam than of Abraham.

A well-known feature of the Priestly Flood story in Genesis is the idea that the Flood was a return to cosmic chaos.[96] This idea seems far-fetched from a modern perspective, especially given the view discussed above that the Flood story was more of a parable than a real event. However, if the Flood occurred only a few hundred years after God's first revelation to humankind in southern Mesopotamia, the catastrophic flooding of the whole Mesopotamian plain for a whole year could indeed have seemed like a return to the beginning of creation. Hence, the view of Noah as a new Adam (Gen. 9:1) seems quite reasonable.

Since Noah offered sacrifices after he emerged from the Ark, it seems inevitable that the Ark would have been preserved for many years as a shrine. It would have had huge religious and cultural significance as the preserver of human life during the cosmic disaster. Most likely it would have been repaired for many decades *in situ*, and the enclosing fence may have made it look more like a holy enclosure than a raft, prompting later observers to think that it floated like a giant basket. On the other hand, the mudhif on the Ark probably become the archetypal Holy of Holies, representing the place where God spoke with Noah.

It has been pointed out before that Mesopotamian temple architecture often refers back to a primeval reed hut as the archetype of the sacred shrine.[97] This motif was used in an Early Dynastic dedicatory inscription, in which King Ur-Nanshe of Lagash invoked the "pure reed" of the primeval shrine as a blessing on a new brick-built temple.[98] This inscription (ca. 2500 BC) gives one of the earliest written descriptions of the reed-built shrine, and it specifically describes the pillars of the shrine built from reed bundles, including the hoops that held the

structure together (fig. 8). By the end of the Late Uruk period (ca. 3300 BC), these reed pillars with hoops attached, forming the "ring-pole standard," had become emblematic of Sumerian sacred architecture, as shown on an early cylinder seal (fig. 9a).

The ring-pole standard also gave rise to the cuneiform sign for temple cities such as Ur (fig. 9b).[99] On this fragment of a clay tablet, the city of Ur is indicated by the first panel on the right-hand side. Here, the ring is simplified into a triangle to facilitate drawing with a stylus, and the standard is combined with a simplified picture of a ziggurat temple. Finally, on another cylinder seal, ring-pole standards with three pairs of rings are shown on either side of a brick-built temple (fig. 9c). In this detailed image, the origin of the ring-pole as a bundle of reeds is indicated by the horizontal bindings at intervals along its length.

The ring-pole emblem runs through the whole history of Mesopotamian religion, linking the monumental temple architecture of the fourth, third, and second millennia with their earliest forerunners after the Flood, consistent with Noah's Ark being the primeval shrine of Sumerian religion. However, the long duration of Mesopotamian civilization gives more than enough time for the early true religion of Noah to be corrupted into the polytheistic pagan culture that Abraham was called to leave. ✧

Notes

[1]Davis A. Young, *The Biblical Flood: A Case Study of the Church's Response to Extrabiblical Evidence* (Grand Rapids, MI: Eerdmans, 1995).

[2]John C. Whitcomb and Henry M. Morris, *The Genesis Flood: The Biblical Record and Its Scientific Implications* (Phillipsburg, NJ: Presbyterian & Reformed Publishing, 1961).

[3]John Goldingay, *Genesis for Everyone: Part 1 Chapters 1–16* (Louisville, KY: Westminster John Knox Press, 2010).

[4]John Calvin, *Commentaries on the First Book of Moses* (1554), *Calvin's Commentaries*, vol. 1, trans. John King (Calvin Translation Society, 1847), 47.

[5]Paul H. Seely, "Noah's Flood: Its Date, Extent, and Divine Accommodation," *Westminster Theological Journal* 66 (2004): 291–311.

[6]Carol A. Hill, "The Noachian Flood: Universal or Local?," *Perspectives on Science and Christian Faith* 54, no. 3 (2002): 170–83; Carol A. Hill, "Qualitative Hydrology of Noah's Flood," *Perspectives on Science and Christian Faith* 58, no. 2 (2006): 120–29; Alan E. Hill, "Quantitative Hydrology of Noah's Flood," *Perspectives on Science and Christian Faith* 58, no. 2 (2006): 130–41.

[7]Carol A. Hill, "A Third Alternative to Concordism and Divine Accommodation: The Worldview Approach," *Perspectives on Science and Christian Faith* 59, no. 2 (2007): 129–34.

[8]Paul H. Seely, "Genesis 1–11 in The Light of Its Second Millennial Worldview: A Response to Carol Hill's Worldview Alternative," *Perspectives on Science and Christian Faith* 60, no. 1 (2008): 44–47.

[9]Hans J. Nissen, *The Early History of the Ancient Near East* (Chicago, IL: University of Chicago Press, 1988), 72.

[10]Ibid., 71.

[11]J. Nicholas Postgate, *Early Mesopotamia: Society and Economy at the Dawn of History* (Oxford, UK: Routledge, 1992), 30.

[12]M. E. L. Mallowan, "Noah's Flood Reconsidered," *Iraq* 26, no. 2 (1964): 62–82.

[13]Erich F. Schmidt, "Excavations at Fara, 1931," *Museum Journal* 22 (Philadelphia, PA: University of Pennsylvania, 1931).

[14]Richard E. Friedman, *The Bible with Sources Revealed* (New York: HarperOne, 2003), 44.

[15]Stephanie Dalley, *Myths from Mesopotamia: Creation, the Flood, Gilgamesh, and Others* (Oxford, UK: Oxford University Press, 1991), 113.

[16]Mallowan, "Noah's Flood Reconsidered," 81.

[17]Ibid.

[18]Thorkild Jacobsen, *The Sumerian King List, Assyriological Studies 11* (Chicago, IL: University of Chicago Press, 1939).

[19]Jacob J. Finkelstein, "The Antediluvian Kings: A University of California Tablet," *Journal of Cuneiform Studies* 17

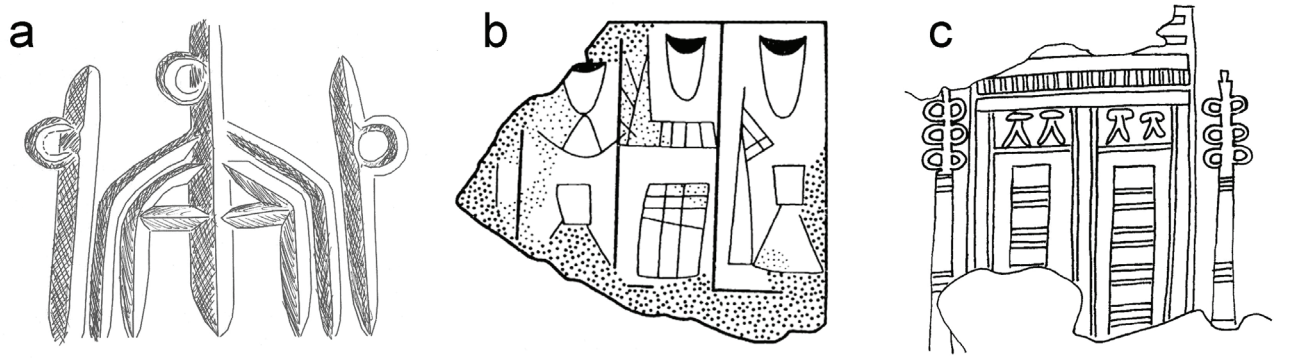

Figure 9. Drawings showing the ring-pole standard in early iconography: (a) Uruk-age cylinder seal showing a reed-built shrine,[100] (b) Protoliterate-age tablet showing cuneiform signs (right) for the city of Ur,[101] (c) Uruk-age cylinder seal showing a reed pillar next to a brick-built temple.[102]

(1963): 39–51; and William W. Hallo, "Beginning and End of the Sumerian King List in the Nippur Recension," *Journal of Cuneiform Studies* 17 (1963): 52–57.

[20]Piotr Steinkeller, "An Ur III Manuscript of the Sumerian King List," *Orientalia Biblica et Christiana,* vol. 14 (Hamburg, Germany: Harrassowitz, 2003), 267–92.

[21]Peter R. Moorey, *Kish Excavations, 1923–1933* (Oxford, UK: Oxford University Press, 1978).

[22]William W. Hallo, "The Limits of Skepticism," *Journal of the American Oriental Society* 110, no. 2 (1990): 187–99.

[23]Ibid.

[24]Y. S. Chen, "The Flood Motif as a Stylistic and Temporal Device in Sumerian Literary Traditions," *Journal of Ancient Near Eastern Religions* 12, no. 2 (2012): 158–89.

[25]Gonzalo Rubio, "The Inventions of Sumerian: Literature and the Artifacts of Identity," in *Problems of Canonicity and Identity Formation in Ancient Egypt and Mesopotamia*, ed. Kim Ryholt and Gojko Barjamovic (Copenhagen, Denmark: Museum Tusculanum Press, 2016): 246.

[26]Piotr Michalowski, "Maybe Epic: The Origins and Reception of Sumerian Heroic Poetry," in *Epic and History*, ed. David Konstan and Kurt A. Raaflaub (Malden, MA: Blackwell Publishing, 2010), 7–25.

[27]Robert D. Biggs, "The Abū Ṣalābīkh Tablets: A Preliminary Survey," *Journal of Cuneiform Studies* (1966): 73–88.

[28]Albert T. Clay, *Miscellaneous Inscriptions in the Yale Babylonian Collection,* vol. 1 (New Haven, CT: Yale University Press, 1915), 1.

[29]Michalowski, "Maybe Epic: The Origins and Reception of Sumerian Heroic Poetry," 13.

[30]Piotr Michalowski, "The Mortal Kings of Ur: A Short Century of Divine Rule in Ancient Mesopotamia," in *Religion and Power: Divine Kingship in the Ancient World and Beyond*, ed. Nicole Brisch (Chicago, IL: Oriental Institute of the University of Chicago, 2008), 33–45.

[31]Antoine Cavigneaux and Farouk Al-Rawi, "New Sumerian Literary Texts from Tell Haddad (Ancient Meturan): A First Survey," *Iraq* 55 (1993): 91–105.

[32]Biggs, "The Abū Ṣalābīkh Tablets: A Preliminary Survey," 81.

[33]Andrew George, *The Epic of Gilgamesh: A New Translation* (New York: Penguin Classics, 2000), 199.

[34]Edmond Sollberger, "The Tummal Inscription," *Journal of Cuneiform Studies* 16 (1962): 40–47.

[35]Toby A.H. Wilkinson, "Uruk into Egypt: Imports and Imitations," in *Artefacts of Complexity: Tracking the Uruk in the Near East*, *Iraq Archaeological Reports* 5, ed. J. Nicholas Postgate (London, UK: British School of Archaeology in Iraq, 2002), 237–48.

[36]Guillermo Algaze, *The Uruk World System: The Dynamics and Expansion of Early Mesopotamian Civilization* (Chicago, IL: University of Chicago Press, 1993), 15.

[37]Hans J. Nissen, "Cultural and Political Networks in the Ancient Near East during the Fourth and Third Millennium BC," in *Uruk Mesopotamia and Its Neighbors: Cross-Cultural Interactions in the Era of State Formation*, ed. Mitchell S. Rothman (Santa Fe, New Mexico: School of American Research Press, 2001), 164.

[38]Algaze, *The Uruk World System*.

[39]Carrie Hritz et al., "Mid-Holocene Dates for Organic-Rich Sediment, Palustrine Shell, and Charcoal from Southern Iraq," *Radiocarbon* 54 (2012): 65–79.

[40]A.M.T. Moore, G.C. Hillman, and A.J. Legge, *Village on the Euphrates: From Foraging to Farming at Abu Hureyra* (New York: Oxford University Press, 2000), 478.

[41]Dina K. Saleh, *Stream Gage Descriptions and Streamflow Statistics for Sites in the Tigris River and Euphrates River Basins, Iraq* (Sacramento, CA: US Geological Survey Data Series 540, 2010).

[42]Wayne Horowitz, "The 360 and 364 Day Year in Ancient Mesopotamia," *Journal of the Ancient Near Eastern Society* 24 (1996): 36.

[43]Gunter Landmann, Andreas Reimer, and Stephan Kempe, "Climatically Induced Lake Level Changes at Lake Van, Turkey, during the Pleistocene-Holocene Transition," *Global Biogeochemical Cycles* 10, no. 4 (1996): 797–808.

[44]Ibid., 806.

[45]Carol Hill, "Qualitative Hydrology of Noah's Flood."

[46]Miryam Bar-Matthews et al., "The Eastern Mediterranean Paleoclimate as a Reflection of Regional Events: Soreq Cave, Israel," *Earth and Planetary Science Letters* 166, no. 1–2 (1999): 85–95.

[47]Neil Roberts et al., "Climatic, Vegetation and Cultural Change in the Eastern Mediterranean during the Mid-Holocene Environmental Transition," *The Holocene* 21, no. 1 (2011): 147–62.

[48]Miryam Bar-Matthews, Avner Ayalon, and Aaron Kaufman, "Timing and Hydrological Conditions of Sapropel Events in the Eastern Mediterranean, as Evident from Speleothems, Soreq Cave, Israel," *Chemical Geology* 169, no. 1–2 (2000): 145–56.

[49]Miryam Bar-Matthews, Avner Ayalon, and Aaron Kaufman, "Late Quaternary Paleoclimate in the Eastern Mediterranean Region from Stable Isotope Analysis of Speleothems at Soreq Cave, Israel," *Quaternary Research* 47, no. 2 (1997): 155–68.

[50]Bar-Matthews et al., "The Eastern Mediterranean Paleoclimate as a Reflection of Regional Events," 90.

[51]Johannes van der Plicht et al., "Tell Sabi Abyad, Syria: Radiocarbon Chronology, Cultural Change, and the 8.2 Ka Event," *Radiocarbon* 53, no. 2 (2011): 229–43.

[52]Takuro Kobashi et al., "Precise Timing and Characterization of Abrupt Climate Change 8200 Years Ago from Air Trapped in Polar Ice," *Quaternary Science Reviews* 26, no. 9–10 (2007): 1212–22.

[53]Bar-Matthews et al., "Timing and Hydrological Conditions of Sapropel Events in the Eastern Mediterranean."

[54]Rick Hennekam et al., "Solar Forcing of Nile Discharge and Sapropel S1 Formation in the Early to Middle Holocene Eastern Mediterranean," *Paleoceanography* 29, no. 5 (2014): 343–56.

[55]Vanessa Heyvaert and Cecile Baeteman, "A Middle to Late Holocene Avulsion History of the Euphrates River: A Case Study from Tell ed-Dēr, Iraq, Lower Mesopotamia," *Quaternary Science Reviews* 27, no. 25–26 (2008): 2401–10.

[56]Leonard C. Woolley and Peter R. S. Moorey, *Ur 'of the Chaldees': A Revised and Updated Edition of Sir Leonard Woolley's Excavations at Ur* (Ithaca, New York: Cornell University Press, 1982).

[57]Carol Hill, "Qualitative Hydrology of Noah's Flood," 126.

[58]Adnan A.M. Aqrawi, "Correction of Holocene Sedimentation Rates for Mechanical Compaction: The Tigris-Euphrates Delta, Lower Mesopotamia," *Marine and Petroleum Geology* 12, no. 4 (1995): 409–16.

[59]Ibid.

[60]Kevin Fleming et al., "Refining the Eustatic Sea-Level Curve Since the Last Glacial Maximum Using Far- and Intermediate-Field Sites," *Earth and Planetary Science Letters* 163, no. 1–4 (1998): 327–42.

[61]Heyvaert and Baeteman, "A Middle to Late Holocene Avulsion History of the Euphrates River."
[62]William B. F. Ryan and Walter C. Pitman, *Noah's Flood: The New Scientific Discoveries about the Event That Changed History* (New York: Simon and Schuster, 1998).
[63]Mallowan, "Noah's Flood Reconsidered."
[64]Michael D. Blum and Torbjörn E. Törnqvist, "Fluvial Responses to Climate and Sea-Level Change: A Review and Look Forward," *Sedimentology* 47, supplement 1 (2000): 2–48.
[65]Adnan A.M. Aqrawi, "Stratigraphic Signatures of Climate Change during the Holocene Evolution of the Tigris-Euphrates Delta, Lower Mesopotamia," *Global and Planetary Change* 28, no. 1–4 (2001): 267–83.
[66]Adnan A.M. Aqrawi, "Brackish-Water and Evaporitic Ca-Mg Carbonates in the Holocene Lacustrine/Deltaic Deposits of Southern Mesopotamia," *Journal of the Geological Society of London* 152, no. 2 (1995): 259–68.
[67]Aqrawi, "Stratigraphic Signatures of Climate Change during the Holocene Evolution of the Tigris-Euphrates Delta, Lower Mesopotamia."
[68]Hritz et al., "Mid-Holocene Dates for Organic-Rich Sediment, Palustrine Shell, and Charcoal from Southern Iraq," 68.
[69]Jaafar Jotheri et al., "Holocene Fluvial and Anthropogenic Processes in the Region of Uruk in Southern Mesopotamia," *Quaternary International* 483, no. 30 (2018): 57–69.
[70]Frieda Bogemans et al., "New Data on the Sedimentary Processes and Timing of the Initial Inundation of Lower Khuzestan (SW Iran) by the Persian Gulf," *The Holocene* 27, no. 4 (2017): 613–20.
[71]Fleming et al., "Refining the Eustatic Sea-Level Curve Since the Last Glacial Maximum," 339.
[72]Ian Wilson, *Before the Flood: The Biblical Flood as a Real Event and How It Changed the Course of Civilization* (New York: St. Martin's Press, 2002), 156.
[73]Stuart Campbell and Alexandra Fletcher, "Questioning the Halaf-Ubaid Transition," in *Beyond the Ubaid: Transformation and Integration in the Late Prehistoric Societies of the Middle East*, ed. Robert A. Carter and Graham Philip (Chicago, IL: University of Chicago Oriental Institute, 2010), 69–83.
[74]Ayça Omrak et al., "Genomic Evidence Establishes Anatolia as the Source of the European Neolithic Gene Pool," *Current Biology* 26, no. 2 (2016): 270–75.
[75]Iosif Lazaridis et al., "Genomic Insights into the Origin of Farming in the Ancient Near East," *Nature* 536, no. 7617 (2016): 419; Farnaz Broushaki et al., "Early Neolithic Genomes from the Eastern Fertile Crescent," *Science* 353, no. 6298 (2016): 499–503.
[76]Jean-Louis Huot, "The First Farmers at Oueili," *The Biblical Archaeologist* 55, no. 4 (1992): 188–95.
[77]Hélène Valladas, J. Evin, and M. Arnold, "Datation par la méthode du charbon 14 des couches Obeid 0 et 1 de Tell el Oueili (Iraq)," in *Oueili: Travaux de 1987 et 1989,* ed. Jean-Louis Huot (Paris, France: *Editions Recherche sur les civilisations*, 1996): 381–83.
[78]Minze Stuiver and Gordon Pearson, "High-Precision Bidecadal Calibration of the Radiocarbon Time Scale, AD 1950–500 BC and 2500–6000 BC," *Radiocarbon* 35, no. 1 (1993): 1–23.
[79]Robert Carter and Harriet Crawford, "The Kuwait-British Archaeological Expedition to As-Sabiyah: Report on the Third Season's Work," *Iraq* 64 (2002): 1–13.
[80]Hritz et al., "Mid-Holocene Dates for Organic-Rich Sediment, Palustrine Shell, and Charcoal from Southern Iraq," 68.
[81]Maine Maritime Museum, "Schooner *Wyoming* Fact Sheet," http://www.mainemaritimemuseum.org/media/docs/resources/2013/01/28/Schooner_Wyoming_Fact_Sheet_1.pdf.
[82]Elizabeth W. Fernea and Robert A. Fernea, *The Arab World: Personal Encounters* (New York: Anchor Press, 1987).
[83]Dalley, *Myths from Mesopotamia*, 133.
[84]Irving Finkel, *The Ark before Noah: Decoding the Story of the Flood* (London, UK: Hodder and Stoughten, 2014).
[85]Ibid., 31.
[86]Surinder M. Bhardwaj, Lewis Owen, and Thomas R. Leinbach, "Irrawaddy River," in *Encyclopaedia Britannica* (March 9, 2017), accessed December 2017, https://www.britannica.com/place/Irrawaddy-River.
[87]Jason M. McCann, "'Woven-of-Reeds': Genesis 6:14b as Evidence for the Preservation of the Reed-Hut Urheiligtum in the Biblical Flood Narrative," in *Opening Heaven's Floodgates: The Genesis Flood Narrative, Its Context and Reception*, ed. Jason M. Silverman (Piscataway, NJ: Gorgias Press, 2013), 131–58.
[88]Thorkild Jacobsen, "Ur-Nanshe's Diorite Plaque," *Orientalia Nova Series* 54 (1985): 65–72.
[89]George, *The Epic of Gilgamesh*, 90.
[90]Finkel, *The Ark before Noah*, 108.
[91]Ibid., 377. Ideograms (signs meaning an idea) are capitalized.
[92]Postgate, *Early Mesopotamia,* 182.
[93]Finkel, *The Ark before Noah*, 314. Size given here is based on 1 cubit = 1.5 feet.
[94]Daniel T. Potts, *Mesopotamian Civilization: The Material Foundations* (Ithaca, NY: Cornell University Press, 1997).
[95]P. Anderson-Gerfaud, "L'utilisation de certains objets en céramique de Tell el'Oueili (Obeid 4): Rapport preliminaire sur les microtraces," in *Larsa et Oueili: Travaux de 1978–1981*, ed. Jean-Louis Huot (Paris, France: *Editions Recherche sur les civilisations*, 1983), 177–91.
[96]Joseph Blenkinsopp, *Creation, Un-creation, Re-creation: A Discursive Commentary on Genesis 1–11* (New York: T&T Clark International, 2011).
[97]A. Leo Oppenheim, "The Mesopotamian Temple," *The Biblical Archaeologist* 7, no. 3 (1944): 54–63; McCann, "Woven-of-Reeds."
[98]Jacobsen, "Ur-Nanshe's Diorite Plaque."
[99]Krystyna Szarzynska, "Archaic Sumerian Standards," *Journal of Cuneiform Studies* 48 (1996): 1–15.
[100]Donald J. Wiseman and Bedřich Forman, *Cylinder Seals of Western Asia,* illustrated by Bedřich Forman and Werner Forman (London, UK: Batchworth Press, 1959).
[101]Margaret W. Green, "A Note on an Archaic Period Geographical List from Warka," *Journal of Near Eastern Studies* 36, no. 4 (1977): 293–94.
[102]Henri Frankfort, *The Art and Architecture of the Ancient Orient,* 5th ed. (New Haven, CT: Yale University Press, 1996), 36.

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Harry Lee Poe

Communication

Divine Action in the Twenty-First-Century Universe

Harry Lee Poe

When the South Carolina Honors College at the University of South Carolina grew concerned that their students felt they had to choose either their faith or modern science, faculty invited Hal Poe to bring a lecture to help the students think through how God might be able to act in the universe without violating the laws of nature. Poe spoke on September 26, 2017. In his lecture, Poe developed the idea that how science interacts with the laws of nature, suggests how God can interact with a universe governed by such laws of nature.

Many people believe that God cannot be involved in the universe, because that would mean violating the laws of nature. They tend to believe that the universe operates like a great clock, impervious to any outside influence beyond the closed continuum of cause and effect. David Hume, writing in the eighteenth century, defined a miracle as "a violation of the laws of nature." Since a violation of the laws of nature is impossible, then God cannot be involved in the universe.

With his definition, Hume not only affirmed the clockwork universe, but he also defined deity without saying so. The deity that Hume argues cannot violate the laws of nature, is not the God of the Bible, but the God of the philosophers. The intelligentsia of his day had long since forsaken the God of the Bible for the deistic God who set the clock in motion and remained aloof from its operation. The completely self-sufficient clock required no interference—the first self-winding clock. The problem with this view is that the universe of Hume, Aristotle, and Isaac Newton no longer exists.

Harry Lee Poe *holds the Charles Colson Chair of Faith and Culture at Union University. The author of seventeen books on faith and culture, Poe has published four books on science and faith with his colleague Jimmy H. Davis, including* Science and Faith, Designer Universe, Chance or Dance, *and* God and the Cosmos. *A Fellow of the ASA, Poe served on the Executive Council and was president of the ASA in 2014–2015.*

Big Bang Cosmology: Things Happen

Between the work of Edgar Allan Poe, George Lemaître, and Edwin Hubble, the big bang theory has become the commonly accepted cosmology of the scientific community. When Poe first proposed the big bang theory in 1848, the scientific community still lived in the universe of Aristotle, a universe of eternal duration. Hume proposed that with infinite time, an infinite number of possibilities could occur by accident, and that life was one such accident. The big bang universe, however, has not had so much time for accidents. It had to get it right the first time. This fact may merely mean that we lucked out. In terms of our topic, however, the most fascinating thing to me about the big bang universe is that it does things. Clocks are just static machines that turn. Instead of the static clock of Aristotle and Newton, the big bang universe does things that have never happened before.

The laws of nature did not cause the big bang universe. Instead, the universe produces the laws of nature. We should recall that the laws of nature are what Captain Barbossa of *Pirates of the Caribbean* would call "more guidelines than rules." The laws do not constrain nature, but rather they describe the

behavior of nature. The laws of nature are more an effect than a cause, the result of the interaction of the fundamental forces. This dynamic interaction makes a universe quite different from that in which Aristotle and Newton lived. The old universe was a closed, hermetically sealed universe in which every event was determined and could be predicted with absolute certainty. Until the twentieth century, modern science nostalgically clung to Aristotle's universe, probably because scientific experimentation often takes place in a hermetically sealed environment that we call the laboratory. There, efforts are made to "control" everything except a specific variable. In the universe in which we actually live and the forces of nature operate, everything is variable. In a special sense, everything is out of control.

Carl Sagan once remarked, "The universe is a pretty big place. If it's just us, seems like an awful waste of space." Others have made similar comments aimed at refuting the idea of God based on the vastness of the universe. It is not really an argument, but a pondering about the place of humanity in a vast universe. It was the same pondering of King David some 3,000 years ago when he wondered,

> When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained;
>
> What is man, that thou art mindful of him? and the son of man, that thou visitest him? (Ps. 8:3–4, KJV)

It is not a scientific question, but an existential, philosophical question. It is a question that works in Aristotle's universe of infinite time and space, but not in our universe. In our universe, we look at the heavens and do not see simply vast space, but also vast time, for time and space are one.

When Edgar Allan Poe first described what we call the "theory of relativity," he did not use the word *time*, but *duration*, because our culture has so much baggage connected with the word "time." Our universe needs time as much as it needs space, and in our universe, it takes around ten billion years to establish conditions necessary for life. In the early life of the universe, its nature and laws changed several times within the first minute. From our perspective, it was only a flash in the pan of time, but from the perspective of the events themselves, each new episode involved the entire history of the universe from its very beginning up to that point—eons of time.

To have life, we first needed matter. To get matter, we had to have atoms which required nuclei which required particles. Before any of that could happen, the universe had to have enough room for things to move around so anything could happen. At first, everything existed as a great realm of opaque plasma, but as space expanded, the universe continued to cool and condense into neutral atoms, and the universe became transparent. With the advantage of time and space, gravity had room to draw atoms together into massive spheres whose fusion resulted in combustion to form the first generation of stars. These stars became the great furnaces that produced the 94 elements in nature. At the end of their lives of a few billion years, the stars exploded and their matter was flung out to re-form into second-generation stars with solar systems. The elements of the star dust that formed Earth became the stuff of life. It takes time and space for life.

The big bang has resulted in an open, indeterminate universe in which unforeseen things that never happened before can suddenly happen without prediction. Looking backward from the new event, however, every step that led to the event can be described as consistent with the fundamental forces and their laws.

Chaos Theory: Unexpected Things Happen

Meteorologists produced a number of models in 2017 for how Hurricane Harvey might behave. They could not say with any certainty what would happen except that a lot of rain would fall. Looking back on the event, however, meteorologists can explain why Harvey behaved the way it did. Then, the nation spent hours before the TV as meteorologists presented multiple models of what path Hurricane Irma might take. The weather is an example of what physicists call "chaos theory." Chaos theory is sometimes called the "butterfly effect" with the explanation that if a butterfly flaps its wings in equatorial Africa, then a category five hurricane will wipe out Barbuda. It is actually more complicated than that. If a butterfly flaps its wings in equatorial Africa, the price of gas will go up fifty cents a gallon in Texas. When Edgar Allan Poe first proposed chaos theory in 1848, he argued that every particle of the universe exerts attraction and repulsion on every other particle of the universe.

The laws of nature are all working, but that is what makes prediction difficult—too many variables. The laws of nature interact like one massive game of "rock, paper, scissors." Put another way, one law seems to "trump" another law, but it is not a case of the suspension of a law of nature. Rather, it is the result of the interaction of multiple laws of nature with sometimes surprising results.

Quantum Theory: Seemingly Contradictory Things Happen

Quantum theory deals with the behavior of the subatomic world. Imagine Earth traveling in its orbit at some 93 million miles from the sun, when suddenly it jumps to the orbital path of Mars some 142 million miles from the sun. Furthermore, imagine Earth changing orbital paths without actually traveling from one path to the other. Electrons behave this way. This movement of electrons from one orbital path around the nuclei of atoms to another orbital path is called a quantum leap. The quantum world is very peculiar if you think our world is the standard. It defies the received logic of Aristotle.

To make matters more interesting, if you try to locate the position of an electron, you cannot measure its velocity, but if you measure its velocity, you cannot locate its position. The act of measuring affects the outcome of the experiment. The electron behaves like a particle—a discreet, limited, finite entity—when you want to find its location. If, on the other hand, you want to know its velocity, it behaves like a wave—extended, infinite, unbounded. It can express both the characteristics of a particle and a wave—two apparently mutually exclusive entities. According to the Law of Noncontradiction, Aristotle teaches us that a thing cannot be X and not-X at the same time; therefore, electrons do not exist … or Aristotle is wrong again.

Genetic Theory: Matter Makes Copies of Itself

Our DNA does not determine who we are so much as it determines the possibilities for whom we may become. Every organism is encoded at conception with a complete blue print. Every cell of the body contains a complete set of directions, which might seem excessively redundant, but it comes in handy. The DNA not only contains the code, it also reads the code and directs the cell to do what the directions say in the proper sequence. When one male cell and one female cell come together at conception, the DNA strands of each cell unzip like the zipper on a jacket, and half the female strand zips itself onto half the male strand. This has been going on for about 4 billion years.

As it turns out, the DNA process is anything but deterministic. Pediatricians tell pregnant women not to drink alcohol, take drugs, or smoke during pregnancy. We are told to avoid radioactive contamination and carcinogens. DNA is subject to rock and roll. Bits of data can be damaged, destroyed, or dislocated; this results in a slight or major change in an organism from parent to child. Over time, these changes mount up and you can end up with something that looks and behaves absolutely nothing like its distant ancestors.

A Porous Universe: The Control Panel Is Always Open

At every organizational level, the physical universe is indeterminate and open. The universe is open to influence by itself, and we are part of it. Science and technology exist because we live in a universe that invites interference with its most basic forces and laws of behavior. We live in a universe in which we can manipulate, violate, contravene, and interfere with nature and its course. We can interject our will into almost every imaginable situation. The alteration of the course of nature is the history of human culture from the time when we first realized that we could control the behavior of fire to the time we realized that we could control the behavior of atoms and cause them to do what they would not naturally do.

We violate the way that nature normally behaves, as when Thomas Edison found a way to capture lightning in a jar, and caused it to go where he wanted it to go, when he wanted it to go there, and in the degree to which he decided to make it go. My cousin violated the way light behaves in nature when he amplified it with stimulation by emissions of radiation to create the laser. Yet, we have not really violated nature. Nature is as open as the control panel on any electronic device because the laws form the openness. Genetic engineering and atomic acceleration tell us that we live in a universe in which intelligence can alter or change what would

normally happen in nature. Humans learned how to violate gravity only because fast-moving air creates less pressure. Rock breaks scissors. Scissors cut paper. Paper covers rock. The laws are more guidelines than rules.

The possibility of laboratory science tells us something else about our universe. It is possible to suspend the effects of chaos theory locally. The purpose of a laboratory is to prevent contamination of an experiment by forces outside the control of the experimenter. While humans cannot control for all forces, we have had remarkable success at limiting the extent to which the variables of which we are aware might interact with the matter under investigation. Thus, we can cause something to happen locally that does not have an effect on the environment around it. We know how to manipulate a deadly infectious pathogen without killing the biologists who study it or setting off a global pandemic that wipes out all human life on earth. We can create a nuclear reaction that would not normally occur in nature; we can then use it to destroy a city, or, by controlling the reaction locally, we can provide electric energy to that same city.

We live in a porous universe that allows for intelligent intervention, interference with the processes of nature, and violation of the normal course of events. Not only does the universe allow—nay, invite—such interaction, it does so without disrupting the normal course of events in the processes of nature beyond intelligent intervention. The fact of science and technology is the smoking gun that tells us that Divine action does not contradict a universe characterized by orderly processes that we can predict and affect with a high degree of accuracy.

The God Who Is Involved with the Universe

I have not been arguing for the existence of God. I have merely been discussing an issue that confuses people about God, if God exists. Given the kind of universe that modern science believes we have, we can make a few modest observations. If God exists, then God has at least as much freedom as humans have to interact with the universe.

A second observation involves the nature of God. I have been speaking from a Christian perspective that conceives of God in three persons: God as the Ancient of Days who exists eternally outside of time and space, for whom duration is an unrelated concept; God as the Eternal *Logos* who creates the physical universe and then partakes of physical existence; God as the Holy Spirit who is present throughout all of time and space simultaneously. This kind of God cannot suddenly intervene in the universe, because this God has always been involved with it. This God has never been absent or withdrawn or uninvolved with the universe.

Other religions have alternative conceptions of deity, each with its own set of issues when it comes to modern science. The issues are different for each religion, and we do well to remember that the word God means different things to different people. In Islam, God is wholly other. In Hinduism, God is the whole and the world is the body of God. In Buddhism, the world is an illusion and God is the reality. The difficulty of the Christian notion of God as three persons is that it embraces all three of these conceptions of deity at once, as to who God is, without being polytheistic. It was a difficult trick to pull off in Aristotle's universe, but in our new universe in which we realize that an electron is both a wave and a particle, perhaps this understanding of God as trinity, now makes more sense. ✧

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Biology

I CONTAIN MULTITUDES: The Microbes within Us and a Grander View of Life by Ed Yong. New York: HarperCollins, 2016. 368 pages. Hardcover; $27.99. ISBN: 9780062368591.

In 1675, Antonie van Leeuwenhoek looked through a two-millimeter-thick sphere of glass at a puddle of rainwater. What he saw, he called "animalcules," and he became the first person ever to see them. Today, we know these "animalcules" as microbes. In his book, *I Contain Multitudes*, science writer Ed Yong chronicles the history-to-date of microbiology by telling the stories of people just like van Leeuwenhoek, "the people who thought to look."

Ironically (or perhaps not), van Leeuwenhoek is also the man who documented the first account of antisepsis by adding wine vinegar to one of his collections and noting that the animalcules fell dead. But before antibiotics came many other notable discoveries—and discoverers—in microbiology. Yong takes his readers on a time hop, paying visits to some of the key players in our understanding of the microbial world. And they are not always human.

The first one is, though, and he is the reason I picked up this book. Rob Knight, a pioneer in the field of microbiome research, is mentioned on page 2. Knight is the director of the UC San Diego Center for Microbiome Innovation (I have recently joined his team as their Communication Officer). Although I have an advanced degree in microbiology, I needed a bit of a refresher. This book provided just that. Yong uses historical anecdotes and imaginative descriptions to introduce his readers to extraordinary examples of just how ubiquitous microbes are.

In 1941, for example, we meet "the squiggly worm," as it is known to the Navy. *Hydroides elegans* is a worm that builds its tubular house on the hulls of ships, and relies on bacterial cues to tell it where to settle. In 2005, we meet a group of corals in the northern waters of the Line Islands that rely on the algae that live inside their cells for nutrients. *Wolbachia*, a microbe that was first discovered in 1924, is one player that makes multiple guest appearances.

According to Yong (and, it would seem, science), microbes make us who we are. He cites examples of microbes that influence the development of guts and bones, blood vessels, the immune system, and the brain. Could it be that God, in his creativity, uses microbes as tools—colored pencils if you will—in the making of each of his children, his masterpieces?

As we know, though, microbes are not always good. In fact, Yong notes that the predominant view of microbes is as disease-causing agents. The rabies virus infects the nervous system and makes its carriers violent and aggressive, and the brain parasite *Toxoplasma gondii* is another puppetmaster. It can sexually reproduce only in a cat; if it gets into a rat, it suppresses the rodent's natural fear of cat odors and replaces it with something like sexual attraction. The rat scurries *toward* nearby cats, with fatal results. Could these be effects of the Fall? These questions provide food-for-thought for Christians who are interested in the study of origins as well as in the history and advancement of science. In these types, this book finds an ideal audience.

Indeed, each example of cooperation Yong cites is tinged with conflict, manipulation, and deceit, even outside the microbial world. Take the relationship between acacia trees and ants. The trees rely on the ants to defend them from weeds, pests, and grazers. In return, they give their bodyguards sugary snacks to eat and hollow thorns to live in. It looks like an equitable relationship, until you realize that the tree laces its food with an enzyme that stops the ants from digesting other sources of sugar. The ants are indentured servants, Yong says.

Whether creatures know it or not, we are all constantly managing the relationships with our microbes. Yong highlights examples including the frontal part of the mammalian gut, which contains a layer of epithelial cells that spray the lining with antimicrobial peptides so that microbes cannot settle there. If any microbes successfully evade the antimicrobial bullets and cross the epithelium, there is a host of immune cells on the other side lying to swallow them. The cells are not just sitting in wait, Yong says. Some of them reach through the epithelium to check for microbes on the other side.

Have you heard of HMOs? Human milk oligosaccharides. They are the third-biggest part of a human mother's milk, but babies cannot digest them. The sugars pass through the stomach and small intestine undigested, and land in the large intestine where most of the gut bacteria live. What if HMOs are not food for the baby at all? What if the mother is feeding her child's microbes?

Yong suggests that we adopt a more holistic view of biological life, one that redefines what it means to be an individual and emphasizes the indivisibility of microbes from animal life. (While the book calls this notion into question, it leaves little room for readers to question Darwin's theory of evolution.)

Do you like sushi—the kind wrapped in seaweed? Did you know that the reason you can eat it is because your gut microbes acquired a gene (through horizontal gene transfer, or HGT) from marine microbes that were already good at digesting seaweed?

Scientists have discovered that genes also move from microbes into their host animal's genome, although Yong points out that their mere presence does not necessarily make them important: "Just because someone has a guitar in their room doesn't make them Slash."

That is not always the case though. Some animals, such as scorpions, mites, sea anemones, oysters, and water fleas, have used horizontally transferred genes to defend themselves against parasites.

Scientists are now building their own microbial minions, Yong says, citing examples of bacteria engineered to eliminate cancer cells or to go after pathogens. But, in the end, it would seem that God's design is superior:

> With all our intelligence and technology, [we] positively struggle to create new antibiotics … but simple animals like ticks and sea anemones can make their own, instantly achieving what we need many rounds of research and development to do. (p. 200)

The book starts and ends with the same dizzying shift in perspective, reminding readers of the reach of science, from the first looking glass to microbial minions. For Christians, this book reminds us of God's infinite character—infinitely large, infinitely small, and infinitely creative.

In summary, Yong uses historical anecdotes and imaginative descriptions to introduce readers to key players in our understanding of the microbial world. From the squiggly worm to corals, Yong chronicles example after fascinating example of the ubiquitous presence of microbes and the roles they play in sustaining life, or in taking it. This book finds an ideal audience in the layperson who is fascinated by science and nature, and in Christians who want to see for themselves evidence of God's design, right down to his signature in a cell.

Reviewed by Deborah Jude, UC San Diego Center for Microbiome Innovation, La Jolla, CA 92093-0403.

ENVIRONMENT

MAKING THE MOST OF THE ANTHROPOCENE: Facing the Future by Mark Denny. Baltimore, MD: Johns Hopkins University Press, 2017. 224 pages. Hardcover; $24.95. ISBN: 9781421423005.

The idea of the Anthropocene is, I have to admit, a disturbing one. Modern humans have changed the planet to such an extent that future scientists will see human influence everywhere they look, even in the remotest places: in the geologic record (due to nuclear tests), in the fossil record (due to rampant relocation of species), in ice cores (due to climate change), and in sediments (due to pollution by chemicals, nutrients, plastics, etc.). Given that human fingerprints are now all over everything, how then should we live? This, asked in the collective sense, is the driving question behind Mark Denny's *Making the Most of the Anthropocene*.

Of course, to chart a course for the future, either personal or collective, we would need some predictions about the challenges we will be facing, so that we can be prepared to meet them when they arrive. But how predictable is the future, really? Denny's book digs into this problem with, as he claims, "shtick," although if I had to pick a Yiddish term to describe his approach, I would have chosen "chutzpah." Taking a realpolitik approach to human nature, Denny argues that humanity will not be able to mount an adequate defense against, for example, climate change, due to our collective willingness to cheat when it comes to protecting the common good, and to follow narrow paths of self-interest rather than cooperate. Certainly the past 25 years of US history, with its glaring lack of action to address climate change, not to mention millennia of Jewish and Christian teachings on the fallenness of human nature, suggest that he is correct. Denny lumps these human failings under the term "collective stupidity," while you or I might use "original sin" to describe the same tendencies.

Is this another example of an elite member of the intelligentsia looking down on Joe Average? The "shtick" of this book is that Denny spins his dark tale with disarming humor and cleverness, without a shred of anger or bitterness. In this day and age, Denny's humane tone makes reading his book feel good for the soul, like a day at the spa—in spite of where he is taking you. It is a bit like enjoying an entertaining, Byzantine bus tour of a city and realizing part way through that you are being kidnapped. In reality, Denny is using all of his powers of persuasion—charm, logic, data, experience—to make his readers think differently, perhaps more realistically, about the future.

Climate activists sometimes say that only hope will motivate us to take action. Denial on the one hand, or gloom-and-doom on the other, are immobilizing. But Denny is trying to offer reality, not motivation, a little like the jaded author of the biblical book of Ecclesiastes. Each chapter is a shock to the system

and a pleasant surprise, containing unvarnished attempts at truth-telling that contrast starkly, in content and tone, with everything else you have read.

In the end, Denny argues that we need to use all the tools available—science, technology, diplomacy, and our very limited supply of wisdom—to avoid the worst effects of climate change. For example, he recommends that we nurture and develop, rather than reject, the "technological monster" of nuclear power, in spite of our disappointments with it (three accidents so far). Don't like nuclear power? He demonstrates the human brain's general inability to understand risks in a one-page chapter entitled "You Suck at Statistics."

It is stunts like this that make reading *Making the Most of the Anthropocene* so enjoyable. Many of Denny's chapter-essays are fascinating, opinionated, and subversive. Love, peace, and granola, anyone (chap. 31)? While at first they seem loosely connected to each other, eventually they form a web. Why does it matter that "Nobody Understands Economics" (chap. 35)? Economic scenarios are a larger uncertainty in next-century climate projections than the scientific uncertainty in climate models, and this has been true for many years.

Denny has written at least nine previous books about science for a general audience, and his ability to avoid jargon and hold the reader's attention while still getting the science right rarely wavers in this one. The only error I noted in the entire book had to do with details of the history of the discovery of the ozone hole by members of the British Antarctic Survey—a minor issue that does not substantially detract from the overall achievement. In this book, Denny has expanded his scope to cover a lot more than science, and readers will benefit from his ambition.

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Ethics

LOSING SUSAN: Brain Disease, the Priest's Wife, and the God Who Gives and Takes Away by Victor Lee Austin. Grand Rapids, MI: Brazos Press, 2016. 150 pages. Paperback; $17.99. ISBN: 9781587434075.

Victor Lee Austin's *Losing Susan* is a difficult book to classify. One could potentially find it shelved in bookstores under biography, medical ethics, caregiving, death and dying, spirituality, or theology. It would not be out of place in any of these sections. *Losing Susan* can also be a difficult book to read. The very title of the book gestures toward the unflinchingly honest and often painful account of a husband attempting to care for his wife in the face of terminal brain disease. The "In Memoriam" page with which the book begins signals to the reader from the outset that there will be no fairy tale ending to this story. The shadow of death hangs over everything. Even the depiction of the joyous courtship and marriage of the Austins ends on a foreboding note with the observation, "It would be fifteen years before her tumor was found" (p. 21). However, darkness is not the couple's only companion. There is another strange, often silent, character who accompanies Susan and Victor as they journey through the valley of the shadow of death: "the one everyone calls God" (p. 10). It is the God "who gives and takes away," whose presence sustains Victor and whose sheer ineffability gives rise to this priest and theologian's most raw and piercing reflections.

The book is simply divided into three chapters, entitled, "The Beginning," "The Middle," and "The End." "The Beginning" traces the initial meeting between Victor and Susan, the blossoming of their friendship while walking together to church during college, their courtship, and the early years of their marriage. Set to the soundtrack of the Song of Songs, the opening chapter is the story of a man who has been given the desire of his heart and has the opportunity to delight in the embodied presence of his bride. In the person of Susan, we encounter a woman of deep faith, with an aptitude for hospitality and for organically integrating the habits and practices of the Christian faith into the ongoing life of the home. A gifted writer, Susan stands as a true intellectual equal and spiritual partner to her husband.

Susan's first seizures led to the detection of her brain tumor and marked the beginning of her descent into illness. "The Middle" depicts this period of almost twenty years during which Victor would come increasingly to serve as caregiver to his wife. While this period is not bereft of grace or moments of joy, the burden of being a caregiver to a spouse whose health is failing takes its toll. Austin is racked by the guilt of not recognizing particular symptoms earlier. He experiences the agony of having to treat his life partner and mother of his children as a child herself. He is plagued by the anxiety that is brought on by the feeling of being out of control and not knowing how to respond to Susan's condition.

The occurrence of a grand mal seizure in July of 2011 marks the beginning of "The End," which traces the last year and a half of Susan's life. Amidst the forthright description of the travail and anguish that accompanied such things as selecting a nursing home

and signing a "do not resuscitate" order, Austin is also able to write movingly about finding joy in the midst of caring for a now-incontinent spouse. The relational journey which began as a type of Song of Songs existence now moves into the territory of the book of Job. While Austin refers to Job as "the best book in the Bible" (p. 135), it is ultimately the crucified Christ screaming out in prayer to God who is given the last word. *Losing Susan* then concludes with a hauntingly beautiful midrash on the crucifixion and resurrection of Christ written by Susan Austin entitled, "To Plumb the Depths of God's Love."

In some ways, *Losing Susan* could be seen as an indictment of a medical system that now treats conditions, rather than patients. While Austin is thankful for the medical treatment that Susan has received, his first-person account of the bewilderment that he often experienced as a medical layperson attempting to navigate the labyrinthine realities of the medical bureaucracy in his efforts to secure the best care of his wife should be required reading for all healthcare professionals. The darkness of this largely inhumane, and often inept, healthcare system was punctuated by glimmers of light in the form of particular nurses, therapists, and doctors, who took the time to genuinely care for Susan, advocate for her needs, and listen to her family.

In keeping with Austin's conviction that there are three major *dramatis personae* in this story, theological reflections are skillfully woven throughout the book. As one might expect, there are significant discussions of the gift of love, faithfulness, and the problem of evil. However, Austin's telling of the story also allows him to reflect upon other less obvious theological themes, including how we come to know God, the relation of free will and providence, the doctrine of the Trinity, and prevenient grace, to name just a few. The centrality of the embodied character of human existence is a recurring theme throughout the book. Also present are important practical reflections upon the comfort found in the liturgy, the importance of pastoral visitors for the sick and their families, and the experience of being sustained by the prayers of the community of faith.

This short but poignant book will find an obvious audience among caregivers, health professionals, ethicists, and theologians. Beyond that, it commends itself to all people of faith who are ultimately pressed with the painful question of the seeming absence of the God who has drawn so uncomfortably near to us in the flesh of the crucified Jesus.

Reviewed by Robert J. Dean, Providence Theological Seminary, Otterburne, MB R0A 1G0.

History of Science

REVOLUTIONARY SCIENCE: Transformation and Turmoil in the Age of the Guillotine by Steve Jones. New York: Pegasus, 2017. 353 pages. Hardcover; $27.95. ISBN: 9781681773094.

Have you ever wondered why so many Paris Metro stations carry the names of French scientists and intellectuals? *Revolutionary Science* is a book that may give a partial explanation. The book surveys the rich scientific landscape of the French capital and details the contributions of many late eighteenth-century scientists, aristocrats, and radicals who lived during the French Revolution. The book is written by John Stephen Jones, former Head of the Department of Genetics, Evolution and Environment at University College, London. He has also been a BBC television presenter and has won the 1996 Royal Society Michael Faraday prize "for his numerous wide-ranging contributions to the public understanding of science," or to use the French term that I am confident Jones would prefer, "*vulgarisation scientifique.*" Jones is in love with France, particularly Paris.

Paris was the world capital of science at the time of the French Revolution. Jones creates an elegant and stimulating narrative recounting the many scientific discoveries made by Enlightenment-era French scientists, radicals, and intellectuals. At the same time, Jones wants the reader to become aware that these same persons were also deeply involved in civic and business affairs. We think, naturally, of their efforts to develop a system of weights and measures, of Antoine Lavoisier's chemical and physiological investigations, of the development of modern cartography, of the many discoveries in electricity—such as the unit for electrical current by Andre-Marie Ampere, of the study of metabolism by Lavoisier and Laplace, of the investigation of venereal disease or the introduction of new food-stuffs—such as the potato by Parmentier—into the French cuisine. But, Jones reminds us, Lavoisier was also a munitions expert and tax-collector; Lagrange, founder of the decimal system of measurement, was President of the Senate later in life; and E. I. du Pont de Nemours was both a chemist (expert in explosives) and founder of the world's largest chemical company after he fled to the United States.

In many ways this is an unusual history of science book. Ostensibly a book about science in revolutionary France, it wanders in ways that cleverly illuminate later developments. During any specific wandering, we are offered fascinating historical tidbits of information. One word of warning: it would

help to have a French dictionary at hand. For example, in chapter 1, "The Wall of the Farmers-General": the wall, which was a tax-collection site for farmers bringing their produce into Paris, was derided by French citizens in the extremely clever epigram, *"Le mur murant Paris rend Paris murmurant"* [The wall surrounding Paris renders Paris murmuring or, stronger yet, growling] (p. 34).

The third chapter is representative of the format of the book and the structural flow of each chapter: Begin with an arresting title ("Let Them Eat Chips"), provide a journalist's eye for detail, and then weave the details about the person's life, cultural, civic, and scientific efforts and influence into a compelling story. Marie Antoinette may have uttered the famous phrase "Let them eat cake" to hungry and revolutionary French citizens. Jones, however, introduces us to Antoine Parmentier, trained as a medical chemist and later the chief apothecary to the Napoleonic armies. Parmentier first planted potatoes in the King's royal garden and then promoted them so avidly that the potato came to play an important role in the French diet.

This narrative strategy is faithfully followed in other chapters. For example, chapter 2, "From Ash to Ash," is devoted to the role of the element nitrogen in development of explosives from saltpetre to TNT, with attention paid to such luminaries as Lavoisier, DuPont, and Alfred Nobel. Chapter 7, "A Degree of Latitude," introduces us to the world of measurement (metrology) alive in Paris. It details the shaky foundations of the metric system as well as efforts to establish the Paris meridian. The last two chapters (8 and 9), "President Jefferson's Moose," and "Handing It On," introduce us to such biological luminaries as Buffon, Saint-Hilaire, Cuvier, and Lamarck. However, one looks in vain for a discussion of religion/science themes. These themes are rather muted, even when Lamarck or Darwin are on offer.

This is the American edition of *Revolutionary Science* and it carries a different title than the original British title: *No Need for Geniuses: Revolutionary Science in the Age of the Guillotine*. Jones's original title comes from an apocryphal comment made by one of the judges at the execution of Lavoisier (the tax-collector) by the guillotine. In fact, in the prelude (p. 32) and conclusion (p. 343), Jones claims that you are reading a book with that title. More rigorous editing was in order. The book would also benefit from more explanatory notes and a bibliography, though one should keep in mind that Jones did not aim to write an academic historical treatise. There is also another factual error on p. 68, where Jones states that the arrangement of the chemical periodic table is based on the atomic weights of the elements, rather than on their atomic number (that is, the number of protons in the nucleus).

All in all, this is a pleasurable book to read, giving an English-speaking reader a much better insight into the lives of many of these French administrative scientists (see p. 338). Many of them ended up as martyrs to the Terror. Those who survived, after pragmatically testing the winds of change, would later occupy many influential civic roles.

Reviewed by Arie Leegwater, Calvin College, Grand Rapids, MI 49546.

ESSENTIAL READINGS IN MEDICINE AND RELIGION by Gary B. Ferngren and Ekaterina N. Lomperis. Baltimore, MD: Johns Hopkins University Press, 2017. 278 pages. Paperback; $32.95. ISBN: 9781421422909.

Essential Readings in Medicine and Religion is a companion piece to Ferngren's 2014 book, *Medicine and Religion* (see my review in *PSCF* 66, no. 4 [2014]: 256–258), and "supplies a collection of texts and places them in their respective contexts in order to specifically address the historical relationships between medicine and religion." The authors are knowledgeable about this subject: Ferngren is both a professor of history at Oregon State University and a professor of the history of medicine at First Moscow State Medical University; Lomperis is a PhD candidate in theology at the University of Chicago and holds a junior fellow position at the Martin Marty Center for the Advanced Study of Religion. In a manner similar to *Medicine and Religion*, this book provides a historical overview of human history at the intersection of medicine and faith over several millennia. The book has a straightforward format over its eight chapters. The authors provide an overview of a historical period; this is then followed by a series of writings from that geographic region and time. The authors provide histories of each period that are easy to read, and I believe the chosen writings are pertinent and illuminating.

The book begins in the Ancient Near East, composed of ancient Egypt and Mesopotamia (including Israel) in which disease was attributed to actions of the gods (as retributive), to demons and sorcerers, or to a consequence of natural mechanisms (such as fractures). Early human writings in this region of the world described disease processes related to sin, which required forgiveness from a deity. It is fascinating to realize that such thoughts are still present in many aspects of human culture 3,000–4,000 years later. An introduction to Greek literature follows in which the professionalism of medicine is first codi-

fied from the writings of Hippocrates. Although Hippocrates had nonphysiologic-based beliefs that continued to hold sway for many centuries (such as the belief in "four humors"), he and his surrounding culture concentrated on the natural aspects of disease. Using a physician to cure disease was deemed essential ("Prayer indeed is good, but while calling on the gods man should himself lend a hand"), and the codification of medical professionalism began to occur via writings such as the Hippocratic Oath.

The authors then continue with a chapter on the Roman medical beliefs, in which a significant change occurred. Initially, the healing arts were colloquial, involving the male head of the household using folk remedies; however, over time Greek influences developed medical professionalism as early as the 200s BCE. The authors point out that although religious cults existed to cure disease, a naturalistic approach to therapy was emphasized. As Sophocles said: "No good physician chants incantations over a malady that needs the knife." Greek and Roman culture influenced Western thought in which individuals over the centuries have subsequently used medical professionals for healing of disease, as compared to the use of alternative spiritual/religious techniques.

Next the authors explore Christianity and medicine. They point out that Jesus performed exorcisms in the Gospels, but he also performed separate healing miracles. Thereafter, early Christians attributed disease to God, demons, or natural processes, but they also tended to minimize the association of sin with disease. Although at times persecuted, early Christians in Rome cared for the sick and buried the dead during times of plague throughout the empire. They were instrumental in the initial development of the idea of a hospital in 372 CE to care for the poor, sick, and orphaned. As a physician, I found it interesting to read the accounts of early hospitals, including those written by Jerome who wrote about Fabiola, founder of the first hospital in Rome in 390 CE, in that such institutions provide parallels to modern hospital care.

The authors follow with "The Middle Ages" and this period's emphasis on "library medicine," which included reading authoritative texts while ignoring any semblance of experimentation to improve care and outcomes. This chapter, in particular, has relevance to modern medical science, in which there is a growing concern that the understanding of translational science (the so-called "bench-to-bedside" phenomenon) has become a lost skill among physicians.[1] During this period, medical education shifted from monasteries to universities, a change with effects lasting to our current times. The chapter that follows ("Islam") is extremely beneficial, as that culture brought forth many innovations that are still used in modern medicine, including the importance of physical medicine, medical ethics, and "medical encyclopedism" that has some parallels to modern medical journals.

The chapter on "The Early Modern Period" emphasizes the influence of both the Protestant and Catholic reformations in relation to medical theory. Specifically, old ideas were reevaluated for relevance. Martin Luther believed society should use medicine but also believed that it should be recognized solely as a gift from God. Andreas Carlstadt recommended the detachment of the spiritual from bodily influences, such as food and medicine, while instead yielding to the will of God. These disparate ideas have influenced current false notions about medicine. The idea of reevaluating or reforming medical therapies based on the scientific method is extremely valid; however, movements that have entered the realm of pseudo-science, such as homeopathy and the anti-vaccination movement, have continued to be disastrous. The book ends with "The Nineteenth through the Twenty-First Centuries," the "modern" approach to the medicine and faith intersection. The authors discuss the growing influence of secularism, the use of faith-based organizations to provide medical outreach, the belief of some Pentecostals that only unbelievers use medicine, and the continuing ethical and moral issues raised by advanced medical technologies, including genomic medicine.

Overall, this book is very good, and I would recommend it to anyone who has an interest in faith-medicine issues. As a physician, I interact with families who would prefer to use prayer over medicine, and although this issue can be difficult to discuss in the clinic and hospital setting, I think understanding the historical background of such ideas can provide insight for further patient-family-physician conversations to improve care. Additionally, the book's format of providing a historical overview of a time period followed by relevant writings is extremely helpful, and this book may be most beneficial as a reference.

I found a minimal number of weaknesses in the book. I would have preferred more writings from China and India, which have had a significant influence on the field of medicine. Moreover, I think the book would have benefited from even more modern writings, especially with regard to theology and the genome, as well as theology in relation to medical ethics—extreme prematurity care, use of biologic agents, healthcare costs, and end-of-life care come

to mind. However, more writings can be included in future editions. I would highly recommend this book to anyone who is interested in the relationship between faith and medicine as it stretches across human existence.

[1]A. Schafer, ed., *The Vanishing Physician Scientist?* (Ithaca, NY: Cornell University Press, 2009).

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ORIGINS

EVOLUTION: Scripture and Nature Say Yes! by Denis O. Lamoureux. Grand Rapids, MI: Zondervan, 2016. 196 pages. Paperback; $16.99. ISBN: 9780310526445.

The title of Denis Lamoureux's newest book says more than a reader might get from a first glance. A first glance might suggest that this is simply one more book arguing that scripture, properly understood, does not preclude a belief that living things arose through the natural process of evolution. *Evolution: Scripture and Nature Say Yes!* does make that argument, but the title also reveals Lamoureux's deep commitment to learning from both scripture and nature. He argues that "[t]ogether these two divine books provide an integrated revelation of our Creator, his creation, and us" (p. 181) and that Christians who limit themselves to one or the other will find their understanding of God, creation, and themselves to be incomplete.

Lamoureux unfolds this argument by first disassembling the belief that Christians must choose between science and faith—between evolution and Christianity. He does not dismantle this common approach to science and faith without leaving the reader with another option. He opens "Two Divine Books" in chapter two, offering an alternative to biblical concordism and including excellent examples of scientific findings that support evolutionary theory. In chapter three, he provides language that more clearly defines beliefs and belief systems. He clearly explains what it means for evolution to be a scientific theory. He distinguishes between purposeless and purposeful creation. He concludes chapter three by offering a new way to think about the relationship between science and faith that is free from an "either/or" dichotomy (p. 60).

Chapter four delves into a discussion of design. Again, Lamoureux provides helpful and important distinctions and definitions. He distinguishes between Intelligent Design Theory and the general concept of intelligent design. He also lays out his understanding of special revelation and general revelation. He argues that "creation offers a divine message that is active, understandable, non-verbal, never ending, universal, revelatory, rejectable, and makes humans accountable" (p. 73). He carefully avoids overextending the limits of creation's witness when he makes it clear that "though the physical world clearly reveals that there is design, it does not tell us precisely who the Intelligent Designer is" (p. 83).

The idea that the Bible contains ancient science is the focus of chapter five. Lamoureux's theological and biblical argument for accommodation is compelling and helpful. He includes examples of ancient science from botany, human reproduction, taxonomy, astronomy, and geology. I think readers would find it difficult to finish reading this chapter and not agree with his conclusion that the Bible is not a book of science, but rather a book that "convicts us of our sinfulness and reveals that Jesus can restore our relationship with God" (p. 112).

I found the last chapters of this book quite helpful. Chapter six lays out various positions along the Young Earth Creation/Dysteleological Evolution continuum. Chapter seven considers the historical example of Galileo to illustrate how both scripture and science can be misused, and makes a compelling case for complementary roles for scripture and science.

Chapter eight discusses Darwin's personal struggle with religion. Lamoureux cites Darwin's own words to dispel the perception that Darwin was a steadfast atheist. Some readers may find comfort in learning that Darwin's questions about faith mirror their own. The book ends with a personal chapter in which Lamoureux narrates moving stories of students who have shared with him their struggles with an either/or worldview.

Lamoureux, who holds PhDs in both biology and theology in addition to a doctor of dental surgery degree, has a remarkably personal and accessible writing style. His tone is conversational, inviting the reader not only into the depths of his biblical and biological knowledge but also into his personal journey of faith. In fact, it may be this simple, personal, open voice that is the greatest strength of his book, which makes it more accessible than his earlier *Evolutionary Creation: A Christian Approach to Evolution*. Some of the arguments in the book are condensed and simplified versions of the arguments he laid out in *Evolutionary Creation*. However, the audience for this book is different from his earlier book.

This book is not for those who have comfortably settled in the Evolutionary Creation/Theistic Evolution

camp. It does not address human evolution in any depth or explore the newest genetic evidence for evolutionary theory. Rather, it is for those who are just embarking on a journey of reconciling evolutionary theory and their Christian faith. It is easy to read, understandable, clear, and accessible enough that beginners will not get lost in the details of the science or the theological arguments. Evangelical Christians will welcome his evangelical faith, expressed without hesitation, and will be drawn into his contagious enthusiasm for science. I will keep a few copies of this book on my office shelf to loan to students who come into my office with questions about how to navigate the integration of science and faith.

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Science and Religion

MAKING SENSE OF SCIENCE: Separating Substance from Spin by Cornelia Dean. Cambridge, MA: Harvard University Press, 2017. 281 pages. Hardcover; $19.95. ISBN: 9780674059696.

Science can tell us what foods and activities are healthy for us, what medicines we should take when we are ill, where and how we should build our homes, how our activities can affect the environment and human health, and the viability of local and global economic activities. However, despite its success at illuminating the workings of the cosmos, the information science provides is rarely wholly unambiguous, leaving the way open for unscrupulous or unwary hucksters to manipulate, denigrate, and exaggerate scientific claims as they craft whatever narrative best serves their particular interests. Thus the public, the politicians and policymakers charged to represent them, and journalists reporting on scientific issues often find themselves presented with assertions of dubious veracity, if not multiple mutually incompatible scientific claims. Cornelia Dean's *Making Sense of Science: Separating Substance from Spin* is designed to help nonscientists navigate this situation.

Dean has thirty years of experience as a science journalist, including seven heading the *New York Times* science department. *Making Sense of Science* grew out of her concerns about the decline of responsible science coverage in an age where misinformation promoting websites is easy to come by. Her 2009 book, *Am I Making Myself Clear?*, attempted to fill in the gap by equipping scientists to communicate with the public. *Making Sense of Science* is a follow up to that work, this time aimed at helping the public assess scientific claims.

Dean's stated aim in *Making Sense of Science* is to show "the kinds of thinking we do in the newsroom when we try to decide whether a given finding is newsworthy, trustworthy, and important." However, she also seeks to equip her readers with the ability to make such judgements themselves, even providing an appendix with guidelines for evaluating scientific claims.

Making Sense of Science is divided into five chapters, which gradually transition from preparing readers to interpret scientific findings to exploring a host of issues associated with how scientific information is used and presented in the scientific community, the courts, marketing campaigns, politics, and other venues. The first chapter addresses how popular aversion to science and uncritical thinking lead us to misinterpret both scientific information and its relevance for our lives, particularly when understanding and acting on risks. The second outlines how science works, and what distinguishes science from nonscience. Dean explores the nature of scientific knowledge and explains how population-based studies are designed, how statistical data analysis and model building affect the results of scientific studies, and how the peer review and publication process gives preference to certain types of findings. The third chapter, entitled "Things Go Wrong," explores problems that can occur both within science and as science engages the wider world. It covers a range of moderately disjointed topics including not only scientific misconduct but also problems with the use of science in the courtroom, how scientists interact with journalists, and how the media handles scientific controversies. The fourth chapter focuses on how financial interests can work against the scientific ideals of "universalism, communalism, disinterestedness, and [detached scrutiny]," by discussing numerous issues related to diet, medicine, and health. The final chapter addresses the impact of politics on science as well as the use and abuse of science in politics, a topic that also serves as a sort of common thread running throughout the book. Noteworthy for exploring how political considerations exert an influence on what scientists study and how science and technology shape public policy, it concludes with Dean's assessment of the evolution wars and the compatibility of science and religion.

So has Dean succeeded in achieving her aims? *Making Sense of Science* is easy to read at the sentence level and clearly illustrates how journalists evaluate scientific findings. However, it is less clear whether she has successfully equipped her readers with the

tools needed to evaluate scientific claims. Her work explores many concepts needed to understand how scientific knowledge is produced, disseminated, and deployed and offers useful rules of thumb that readers can use to evaluate scientific findings, including a very helpful discussion of the role of probability and statistics in scientific model building, forecasting, and evaluation. However, readers are likely to lose track of Dean's argument amidst the book's rambling discourse, a problem exacerbated by poor editing. In some places sentences unconnected to the topic at hand seemingly appear out of nowhere and in others a discussion is dropped in midthought, only to be picked up pages later with nary a reference to anything said in between. Readers are also likely to be confused by how often Dean's own judgements ignore her own guidelines for responsibly assessing scientific findings. For instance, her treatment of food and health largely eschews careful analysis in favor of extolling the virtues of organic agriculture and demonizing "Big Ag." At one point she even stoops to encouraging readers to avoid foods for which you would "need a degree in chemistry to know what you are eating."

Dean's portrayal of science is also at times misleading. She understandably focuses on science of interest to medical, environmental, and public policy concerns, much of which can be difficult to study or relies on speculative modelling. This, along with Dean's tendency to focus on problems in science rather than its ordinary operations, means that Dean effectively leaves readers with the impression that science is a more tepid, self-contradictory, and error-prone enterprise than it actually is. In short, the science she enjoins her readers to make sense of is far too easy to dismiss. This makes it hard to take her seriously when she alternately portrays science as unsure and encourages readers to accept the reality of global warming or scientific origin accounts on the authority of a supposed consensus.

Dean's reliance on the authority of luminaries rather than argumentation also limits the usefulness of the work as a resource for those who wish to understand the actual content of science and society issues or engage in the sort of thinking needed to develop their own position. This is well illustrated by her treatment of science and religion. Dean's account focuses narrowly on public debates over origins science and is at its best when exploring the debate's American educational context and the Discovery Institute's antievolutionary efforts. In contrast, the case for consensus origins science and its incompatibility with "literal" creation accounts that address "our place in the universe" are largely addressed via assertions based on the authority of mainline science and religion luminaries. Nowhere does she seriously explore the content of either evolutionary science or antievolutionist objections to it. Thus while readers of *PSCF* will likely find themselves in sympathy with her conclusion, that it is possible to believe in both science and a God "to whom one can pray," readers who do not agree with her at the outset will likely be left unpersuaded of either the reliability of evolutionary accounts or their compatibility with a coherent Christian theology.

It is also worth noting that while I enjoyed hearing Dean's insights into the role of special interests in the shaping of public perceptions and policy, her treatment of familiar topics often seemed sloppy, inaccurate, and misleading. The most notable example involved her confusion of ground level ozone with chlorofluorocarbons and smog, although it is also evident in her shallow account of scientific rationality based on an overly simplistic account of Popperian falsifiability and her sloppy use of ambiguous examples when summarizing Daniel Kahneman's *Thinking, Fast and Slow*. This left me wondering whether Dean accurately portrayed topics I knew less about.

Nevertheless *Making Sense of Science* can still be commended as one of the few popular-level books that seek to address the role of cognitive bias, modeling and statistics, and science's social and professional structure in the making of scientific claims. Dean is also at her best when discussing the public context of scientific issues; readers of *Making Sense of Science* will gain an appreciation for how science impacts American life. Dean also does well to introduce readers to the concepts and precedents that guide regulators, jurists, and others who use scientific findings in decision making, thus cautioning them about the role of politics and special interest-driven marketing campaigns in sidestepping the implications of unwelcome scientific findings. Yet in its treatment of scientific issues, *Making Sense of Science* does better at spurring further study than offering a clear and reliable guide.

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ASTROPHYSICS AND CREATION: Perceiving the Universe through Science and Participation by Arnold Benz. New York: Crossroad, 2017. 144 pages. Hardcover; $13.56. ISBN: 9780824522131.

In this short work, Benz takes the reader on a tour of the universe while also trying to make sense of religious experience. He does the first very well. But in the process of building his philosophy, he ends up

throwing out the Christian God, whom he replaces with an undefinable force that is known through "participatory perception."

The length of this book belies the breadth of its content. It is packed full of information and ideas spread over 12 chapters and divided into 3 parts. The first part is a description of the universe, focusing primarily on star and planet formation, entitled "Amazing Formation." Here Benz shows his ability to simplify complex science to a popular audience. Molecular clouds, accretion disks, planets, stars, black holes, and the big bang all are described without technical language. In fact, as part of the translation into English, he even removed SI units. For example, a density measurement is described as atoms per gallon instead of per cubic meter or centimeter. It is impressive and approachable for someone without background in astronomy.

The second part is entitled "Dissolution and Horror" and deals with topics such as stellar evolution, supernovae, and extinction causing meteors. Again, the science is accessible and engaging. Here Benz begins to build his thesis by pointing out that the formation of stars and planets required the destruction of previous generations of stars through supernovae, and biological evolution was shaped by meteors (among other destructive processes).

In this section, he also builds his philosophy of reality and science in chapters 7 and 8. He argues that reality perceived through science is on a different plane than religious "perceptions." This is not just observing reality through different lenses, but observing different levels of reality. For Benz, the overlap comes through "participatory perceptions." An example he provides is art. When observing a painting, colors can be defined scientifically with light wavelength or frequency. The chemical composition of the paint can be studied and is different depending on whether the artist used watercolors or oils. But an individual can also be moved by art at an emotional level and that emotional engagement is not quantifiable. Both the scientific observations and the emotional perceptions are real, but they reflect different kinds of reality.

However, science and other "perceptions" are interpreted; so in chapter eight Benz describes three types of interpretations. The first is "explaining and modeling." Scientists interpret this way when they use the scientific method and then publish their results. "Comprehending" is nonmathematical and might be best modeled by what Benz himself did in chapters 1–6. Finally, "construing" is what scientists do "with friends in the evening over a glass of wine at the fireplace," or, as reflected in the last four chapters, what scientists "write in popular science books." I see this chapter as the keystone that holds the rest of the book together. It is an interesting way of thinking about interpretation, though those in the social sciences and related areas of research would object to his claim that explaining and modeling require mathematical equations.

From here, Benz goes downhill rapidly in part three, "Interpreting the Universe as a Creation." Since he thinks that God cannot be seen in science, he is left with "construing" as the only remaining avenue to God. He is obviously fully engaged with existentialism. He rightly rejects the deistic "watchmaker" god and the nonoverlapping magisteria model of faith/science integration. But in the process he redefines God and Creation to be unrecognizable to traditional Christian theism.

First, he defines creation as the recycling of new out of old. As new stars form out of molecular clouds that are the remnants of previous stars' supernovae, so Jesus's resurrection was a new hope and new life out of death and despair. When Benz speaks of creation, he does not refer to God's making the universe out of nothing (*ex nihilo*). Rather, old material must be present and creation is better understood as recycling (*creatio continua*). It should be noted that Benz is agnostic about the origin of the big bang. He repeatedly says that we cannot know anything about its origin; he is happy to leave God out of it. This was surprising, as most Christian scientists argue that the big bang fits the biblical testimony of creation *ex nihilo*. Benz argues that his conception of creation as a regenerative process is how it would have been understood by ancient readers, but provides no support for this claim.

Secondly, Benz's concept of God appears to be something more akin to a transcendent force. On several occasions he opposes the idea that God is a person. He claims that conceiving or describing God as a person is simply metaphorical. Obviously, this is a significant departure from orthodox Christian belief. In what sense is Jesus God if God is not a person? Benz argues that characteristics of personality were ascribed to God by the writers of scripture as an attempt to make sense of their experiences. But traditional Christian theology argues that our personhood was given to us as part of being made in God's image, not the other way around. Again, Benz provides no support for this concept of God except to claim that the traditional view is "much criticized among physicists." Criticism by physicists is hardly proof or reason to abandon centuries of confessional Christianity. To support his claim that the traditional

view is "much criticized," Benz provides only one reference, that of Albert Einstein. Statements such as "God cannot be experienced objectively" raise questions about the incarnation. One of the unique aspects of Christianity that apologists often cite is that Christianity and the Bible make historical claims. Jesus, the God-man, coequal with the Father, told his disciples to make physical observations to confirm his resurrection (Luke 24:39; John 20:27).

In sum, there is one major assumption that Benz makes as outlined in the preface to the English edition. This is that "God cannot be evidenced by scientific methods." In defense of this claim, Benz uncritically cites Hume, including Hume's thesis that miracles are impossible, without ever acknowledging the many Christian responses. Since Benz cites the resurrection as an example of his idea of creation, I wonder if he considers it to be a literal, physical, and observable miracle. Those who disagree with Benz's assumption will remain unconvinced. But oddly enough, Benz says there is at least one condition in which he would recognize scientific evidence for God: if the laws of physics were one way on Earth, or in our region of the universe, while different elsewhere. I found this strange but keeping in line with his rejection of traditional Christian thought. Christianity has offered a framework in which science can flourish by understanding God as immutable and constant. The laws of nature are universal because they reflect God's attributes. This offers a response to the problem of induction. But Benz rightly acknowledges induction as a piece of the scientific process. The conclusion we are left with seems to be that only a God whose laws are not universal would be detectable by science, which depends on the universality of natural laws!

Perhaps Benz avoided the dialogue and debate that might make his philosophy more robust because the book is intended for a popular audience. The science content is engaging and accessible. But I wonder if the average person looking for an accessible review of astrophysics wants a popular work on existentialism. The Christian wanting a perspective on faith and science will find the faith dimension sorely lacking.

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ON FAITH AND SCIENCE by Edward J. Larson and Michael Ruse. New Haven, CT: Yale University Press, 2017. 298 pages. Hardcover; $30.00. ISBN: 9780300216172.

Two of the most distinguished, well-known historians and philosophers of science collaborate in another recounting of the historical encounter between science and faith. Much has been written on this topic and one might wonder what new insights there could possibly be. Yet, these skilled authors shed more light on the interface between these two paradigms.

Ed Larson is professor of history and Hugh and Hazel Darling Chair in Law at Pepperdine University. His most acclaimed work is the book *Summer for the Gods: The Scopes Trial and America's Continuing Debate over Science and Religion*, for which he received the Pulitzer Prize for History in 1998. He has written nine other books, several of which deal with evolution and creation, and has made frequent appearances in public forums to discuss faith and science.

Michael Ruse is Lucyle T. Werkmeister Professor and director of the History and Philosophy of Science program at Florida State University. He taught at the University of Guelph in Ontario for 35 years and has been at Florida State since 2000. Though a self-described atheist not subscribing to Christian faith, Ruse argues that Christianity and evolution are compatible and he disagrees sharply with the harsh arguments of the so-called "new atheists." He has published numerous books and articles and participated in countless public events to make his case.

Larson and Ruse alternate as lead authors of the nine chapters, blending the views from their expertise in history and philosophy, respectively. They do not claim to be breaking new ground or proposing major new insights. Rather, they want to show how the science-faith interface cannot be described in a straightforward set of models, such as the conflict model or the compatibility model. They

> favor what might be called a "coexistence" approach, which views religion and science as two big messy and sometimes internally inconsistent categories of human perception and understanding that coexist in the same place and time, sometimes in a complementary or conflicting relationship but most often in a complex one, with both categories currently growing in influence and authority in many regions. (p. 12)

The conflict model exists and thrives as well as the complementary approach, with a wide range of complex interactions in between.

The first two chapters provide a high-level overview of the trajectory of science, particularly astronomy and physics, from ancient days until now. Ancient metaphors depicted the universe as an organism largely controlled by gods or vital forces. Then Galileo, Kepler, Newton, and others helped to transform the metaphor from that of an organism to that of a machine. The mechanistic universe took hold, incorporating even biology, thanks to Charles

Darwin, until the twentieth century revolutions of quantum mechanics and relativity shook the foundations. The story as told by these authors is clear and concise. They point out that the dominant players in the Scientific Revolution were Christians and their scientific work was done in the context of what they regarded to be a divinely created universe. The rise of mechanistic and reductionist views also gave room for agnostic and atheistic ideas to flourish, leading to a complex blend of theistic and nontheistic philosophies in science.

Chapter 3 considers the brain, the mind, and the soul. Ruse pens this chapter with a deft articulation of the challenge of understanding consciousness. He shows how advances in computer technology and in modern physics influenced our ideas of the mind and the brain. But in the end, he admits that we have made relatively little progress since Plato when it comes to understanding consciousness. It is no wonder that the "new mysterianism," which claims that consciousness is beyond our comprehension, is an attractive position.

Larson continues with a historical account of geology and how it was primarily Christian geologists who blazed the path in discoveries of the age of the earth. Again, the controversies seldom pitted science against faith in a simple conflict or compatibility model.

Ruse goes on to provide an insightful account of the grand philosophical motivations that set the stage for Darwin's theory of evolution. He points out that humans, particularly in the Christian and Judaic traditions, seek to answer three big questions:

1. Where did everything come from?
2. What kind of world do people live in?
3. Where do humans fit into the scheme of things?

Darwin's ideas provided provocative, though tentative, answers to these questions. While there were similarities to the Judeo-Christian views held at that time, the differences were significant enough to generate a complex set of reactions. The problem of evil, cast in a prominent role in Darwin's ideas, and the clash between Providence and progress seemed to dominate, as they do today.

When Larson traces the scientific ideas that Darwin presented, as well as their reception, he dismisses the broad scope of the biosphere to concentrate solely on the evolution of humanity. He points out that

> the big issue has never been the theory of evolution in general, but applying it to humans. After all, many people care more about humans than they do about other animals. And who cares if plants evolved? But many people find the idea of descending from monkeys or being related to apes as really quite degrading to their self-image. (p. 159)

Ultimately, the Christian understanding of human behavior in the context of a spiritual condition before God comes into conflict with the socio-philosophical extension of Darwinian ideas.

> Today, Darwin's sketchy social theories have matured by way of E. O. Wilson's sociobiology and modern evolutionary psychology to become foundational for understanding in the social sciences. Through these, human behavior is reduced to the physical, and people become merely matter in motion with evolved self-consciousness. (pp. 183–84)

The last three chapters of the book are devoted to highly pertinent issues in today's society. They explore sex and gender, from the mystery of why sexual reproduction exists in the first place to the role that our religious beliefs play in setting our cultural practices. They move on to examine the unsettling history of eugenics with the prospect for modified versions in our hopes for genetic engineering. Finally, they conclude with a chapter on living on the earth, devoted mainly to climate change and the close relationship between Christian stewardship and scientific ecological responsibility.

Few books manage to cover such a breadth of issues with the clarity that these authors do. They provide no easy answers but encourage readers to actively engage in discussion. They provide a very helpful bibliographic essay to guide further research.

The book concludes with the following sentences:

> The inhabitants of this earth face serious physical and social issues. Standing still and doing nothing is not an option. Hard thinking about the science and technology combined with deep moral seriousness and the religious conviction of believers are absolute requirements. Together with the realization that others, no less learned and no less serious, will come from other directions. No one should feel threatened by differences, nor should anyone quake and yield because there are differences. But if humans are in this together, sympathy and understanding are essential. Then perhaps we can move forward together. (p. 276)

Larson and Ruse have provided us with a valuable resource that deserves a place in the library of anyone seeking to understand the history and philosophy of the relationship between science and faith.

Reviewed by Randy Isaac, ASA Executive Director Emeritus, Topsfield, MA 01930.

TECHNOLOGY

THE TETRIS EFFECT: The Game That Hypnotized the World by Dan Ackerman. New York: PublicAffairs, 2016. 265 pages. Hardcover; $15.00. ISBN: 9781610396110.

We may stare at computer-powered screens more and more, but in some ways, we think less and less about digital technology. It has become the water in which we swim: critical to our day-to-day life, and an assumed part of our background. Jacques Ellul warned that Christians, of all people, should be conscious of the ideological imperatives of technology; it is hard for us to bear witness to the world when we don't understand the ground we are standing on.

For me, then, the real value of books like Dan Ackerman's *The Tetris Effect: The Game That Hypnotized the World* is that they drill into the everyday work of technology creation, revealing what a messy and human process it is. As consumers, we frequently purchase shiny digital devices, software products, and entertainment titles without giving a second thought to who makes them and how. But the how matters a great deal, and that's true of something as serious as a hadron collider just as much as of a best-selling plaything.

The Tetris Effect is primarily an in-depth biographical history of the men (and it was pretty much all men) who created, marketed, and distributed one of the most profitable and significant video games of all time. Ackerman weaves a tale that traces the game from its creation by Alexy Pajitnov in the Soviet Union in the early 80s, through its diffusion around the world, to its tortuous legal commercial path into mainstream financial success.

The strength of this account is its highly readable prose and the colorful cast of characters that Ackerman assembles. His blow-by-blow account helps us understand that technology never just *appears* fully formed. We get to see how a programmer in a totalitarian dictatorship gets access to subpar computing equipment and finds space to do creative work. We get to see how cross-border business negotiations—a topic that would normally lull readers who are not in the import/export business to sleep—shape what we as consumers have access to and how the process changes the product. And more than anything else, we get to see how contracts, courts and legal maneuvers define our technology. This book is really a legal thriller in disguise.

That having been said, the book certainly has its limitations. Some of these are due to Ackerman's undoubted need to write for a general audience. Practically all video game history writing at this point is biographical, which means the writers follow individual characters, rather than talking about institutions or large-scale cultural factors. This makes for a pleasing read, but it often obscures the fact that humans are social in addition to being individual.

We like the Great Man theory of technology history (e.g., we got the light bulb from Edison, DNA from Watson and Crick, and the Teflon-coated electric grill from heavyweight inventor George Foreman), as it makes for engaging, accessible stories. But it badly oversimplifies the reality of decision making. No Great Man acts alone (the complex narrative here does illustrate this claim), and no Great Man exists without a social context (the book does not sufficiently address this assertion). All that to say that the scholar in me wishes for a few more detours into the nature of early 1980s Soviet bureaucracy or computer architecture, as we only get small tastes of those important topics and they are not quite as accurate as I would like. But on the flip-side, the reader in me often feels that story gets dragged out at points, and I'm pretty sure that's Ackerman's greater concern.

Ackerman also tries to make the book about more than history, and he includes a few interludes on the science of *Tetris*, primarily psychological but also mathematical. These bits are interesting, but they really feel a bit pasted in. He has clearly gathered mounds of data on the historical development of the game, but whether this is fair or not, the other bits feel more as if he looked at one or two sources and wrote the section. Still, if you're interested in the use of *Tetris* to treat PTSD or the number of possible game states for the program, you'll find some worthwhile nuggets here.

The other issue is that Ackerman seems to almost assume the importance of the game he's writing about. There's no question that *Tetris* is a landmark game, and it has had a unique staying power, unrivaled by any other video game from the late 1980s. But there are far more financially successful games, and I would argue that longevity does not automatically confer true cultural impact.

In the end, though, it is the granular and surprisingly interesting account of the various negotiations and investments and product development that is the real value of the book. I don't mean that this will teach readers how the industry works today. *Tetris* came about at a time when the games industry was

still establishing itself and regularizing systems of production. The people negotiating legal rights and systems of distribution and financing, as well as the people actually producing the games were, from the 1970s till the early 1990s, essentially breaking new ground, and today much of that work has become routine. No, the value of an account like this is that it shows the complicated web of interactions necessary to get *any* piece of technology created.

I don't think this is a perfect book for the reasons listed above, but it is worthwhile reading. If Christians want to be able to understand and speak to the digital world, it is important to get a sense of its fluidity and its very human character. Somewhat ironically, I think, Ellul himself, in his powerful call to interrogate the ideological baggage of technology, overlooked the actual conditions of design and production. I think Ellul is right to note the technological imperative of constant development throughout our culture, but when we look at the actual day-to-day activity of technology development, as *The Tetris Effect* does, we can see that ideology gets distinctly muddy, and a cocktail of ideas motivates the people who develop the digital artifacts we use. And it is in the trenches of technological development where grace and truth can make a difference. Understanding that has real impact—maybe even greater than the *Tetris* effect.

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Theology

FREEDOM ALL THE WAY UP: God and the Meaning of Life in a Scientific Age by Christian J. Barrigar. Victoria, BC: FriesenPress, 2017. 252 pages. Paperback; $14.49. ISBN: 9781460293836.

Freedom All the Way Up places the creation of love-capable beings at the core of its considerations: the universe exists to bring into being entities who freely love each other and everything else within it and beyond it. Christian J. Barrigar is an Anglican Pastor who holds two Masters degrees from the University of Toronto and a PhD in philosophy from McGill. He believes that God, in infinite freedom, brought into being at the big bang an initial mixture of physical magnitudes and forces destined over time to produce conscious, meaning-seeking, and significantly free beings capable of self-giving love. This view is not merely wishful thinking. Barrigar draws together a wealth of data that, when supplemented with some provocative yet disciplined theological and scientific speculations, can be forged into a fascinating narrative about how God used the past 13-plus billion years to evolve love-capable entities, what he calls *agape*-capable beings.

"So what is the meaning of life?" asks Barrigar in his first chapter, setting the stage for what his book aims to deliver. We all experience some meaningful events in our lives, but do our lives as a whole possess any ultimate meaning or purpose? Materialist, naturalist, and secular humanist worldviews surely give us motivation to construct meanings for ourselves, but, notes Barrigar, constructed meanings are all biodegradable: thus, living one's life within their terms tends to lead one toward nihilism, the view that nothing has meaning. So, are we condemned to meaninglessness?

Chapter two aims to recover rather than construct meaning, specifically to recover the religious basis for ultimate meaning in a scientifically respectable way. This chapter is the backbone of the whole book in that it lays the theoretical groundwork for the plausibility of a reenchanted universe, that is, a universe that has a grand *telos* rooted in God's intention to program its initial conditions toward the emergence of *agape* (love)-capable beings. It contains a fascinating discussion of a number of technical (largely scientific) topics that may be partially lost on readers innocent of recent scientific theories dealing with the entanglement of the deterministic elements of classical dynamics with the statistical probabilities of quantum mechanics. However, the gist of the chapter, in significantly simplified terms, might be put this way without too much distortion: through the big bang, God combined randomness with order by exploiting nonequilibrium thermodynamics and the law of massively large numbers to produce a long series of entropy-defying self-organizations that eventually and inevitably secure the emergence of beings with sufficient free will for genuinely engaging in *agape*-love relationships.

Chapter Three, "Responding to Materialism," is another large chapter filled with lots of interesting theological and scientific ideas and speculations that merit much more attention than I will be able to give them here. Barrigar first looks at a few of the materialistic accounts of the universe's origin, spending most of his time on "multiverse" proposals, at least one version of which he's willing to consider as subsumable within his theistic framework. The problems with most multiverse scenarios, however, are that they tend to rely upon "no-origin" models, models that posit an infinity of antecedent universes, and thus imply determinism (no possibilities beyond actuality) which alone cannot produce the freedom upon which *agape*-capable beings will need to rely.

Barrigar argues that his account of things shows how the problem of evil and human suffering is not so big a problem after all. Since God did not (perhaps could not?) create human freedom directly, God had to deploy indirect means to evolve human freedom and, of course, evolution depends upon random physical, biological, and evolutionary forces that always bring with them waste, suffering, and tragedy. Consequently, the good of human freedom as well as the *agape*-capable beings who depend upon it, could not be separated from nasty human suffering. Barrigar believes this blend of the free will defense and a greater-good account of natural evil in the world sits comfortably upon the foundation of his *agape*-probabilistic account of things.

Chapters four and five examine the nature of the *agape*-love that God engineered to emerge in creation. Questions such as "what do the scriptures have to say about God's *agape*-love for humanity?" and "how is God's *agape*-love manifested in his creation, in the lives of those who bear his agapic image, and in him who is the incarnated icon of God's *agape*-love?" are addressed and analyzed in detail and to rich effect. In the concluding portion of chapter five, Barrigar speculates about the relation of the *imago Dei* to the evolutionary emergence of humanity. His suspicion is that the emergent forces of genetic and cultural coevolution operative in the evolution of *Homo sapiens* established them (*Homo sapiens*) as responsible agents whom God elected to bear the divine image as agapic agents in charge of overseeing the well-being of their home bio-niches.

Chapters six and seven lay out Barrigar's version of the life that *agape*-capable beings are called to enact: lives of agapic freedom as *imago*-bearing individualities and as image-bearing makers of society and culture. These two chapters offer stimulating discussions of how "agapic freedom" differs from "autonomous freedom," how form and boundaries can actually enhance existential freedom, and how the implications of agapic freedom should shape the intellectual life of human cultures.

The final chapter (chap. eight) returns to the original issues of meaning and nihilism discussed in chapter one. Barrigar argues here that in reality, the materialists' battle with impending nihilism is more problematic than the theists' struggles with the inevitable sufferings in the world. He contends that the *agape*-probability account laid out in chapter two and the notions of freedom-all-the-way-up, *imago*-bearing individuality, and agapic freedom discussed in chapters four through seven reveal that God and science belong together as the basis for humanity's flourishing and deepest realization of meaning.

In the remaining space apportioned to this review, I will offer what I consider the most important failures of this significant and provocative book before I conclude with some praise.

I think that Barrigar's book would have benefitted enormously from an early, if only brief, discussion of (1) the degree of realism with which he takes scientific and mathematical theories; (2) how he conceives of the distinction between God's creating and God's sustaining of the universe[s] brought into being; and (3) how these distinctions articulate the relation of divine causation to causations arising within creation. Setting up his positions on these matters early on would enable the reader to discern the conceptual coherency (or its absence) of many of the scientific, philosophical, and theological speculations making up the core of this book, for example, his claims that God frontloaded creation with all the forces, fields, laws, and entities that populate contemporary scientific theories' ontologies; that human first-person agency emerged from third-person physical mechanisms; that robust human freedom is ultimately based on randomness; and that moral evil and natural evil are the same because they both arise from natural goods. Philosophically and theologically, all of these claims merit careful interrogation to underwrite their credibility, which is not really possible without knowing the broader theological and metaphysical commitments that Barrigar presumes.

The foregoing discussion does not do justice to the originality of Barrigar's integration of materials from all over the cognitive map, nor to his rich array of examples, speculations, and breath-taking inferences deployed to impress the plausibility of his narrative on the reader. His book is not limited to the abstract and airy concerns of science-religion integration, but also provides the reader with much practical and wise pastoral import to savor. For these reasons alone, the book merits attention from Christians who wish to dig deeper into their faith's relationship to the contemporary scientific consensus and its implications for a meaningful life well lived.

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MADNESS: American Protestant Responses to Mental Illness by Heather H. Vacek. Waco, TX: Baylor University Press, 2015. xii + 271 pages. Hardcover; $39.95. ISBN: 9781481300575.

Heather Vacek is a professor of church history at Pittsburgh Theological Seminary. Her volume on Protestant reactions to mental illness in America is part of a new series: Studies in Religion, Theology,

and Disability, edited by Sarah J. Melcher and Amos Yong. Vacek aims to inform Christians about mental maladies through a historical examination of such; in particular she desires to dispel the myths that mental illness is a sin and that it is not the church's problem. Madness (the title representing only one of many historical appellations) focuses on five diverse individuals who exemplified a Christian response to mental illness, in contrast to the indifference or theological misunderstanding that has typically characterized American culture.

The book is well researched and the author's attention to detail and inclusion of personal accounts enhances its readability. Vacek examines the efforts of two clergy, one social activist, and two physicians; situates each individual in their complex and evolving social, religious, and medical contexts; and considers both historical and theological perspectives on mental illness. She incorporates views of illness causation, definitions of mental illness, and the changing relationship between church and state.

The first figure Vacek discusses is Puritan minister Cotton Mather (1663–1728). Influenced by American Colonialism and Calvinist theology, he believed sickness to be a result of sin and that all illness had a divine purpose, encouraging people to turn to God. Prayer and conversion to Christ could heal the mind. Nevertheless, Mather also encouraged care for one's own and others' health and even endorsed vaccination against smallpox. His book, *The Angel of Bethesda*, detailed remedies for multiple types of illness including madness.

The second individual is revolutionary-era physician Benjamin Rush (1746–1813), whose work in categorizing and proposing treatments for mental illness is legendary. He wrote one of the first scientific books on mental illness, *Medical Inquiries and Observations upon the Diseases of the Mind*, and founded the Philadelphia Humane Society to educate the public on preventive health. A Presbyterian, his faith guided his action, but Rush challenged the prevailing Christian view, arguing that biology, not sin, could better explain mental illness. He also argued that kindness and compassion were better treatments than being chained in a cold filthy cell, for example.

The third individual is social activist Dorothea Dix (1802–1887). This educated woman was appalled by the squalid conditions she found in mental asylums and, like Rush, advocated for change, travelling widely to educate others and to encourage Christians to be empathetic and work to ameliorate the suffering of the insane. Dix continued to see a role for sin and religious meaning in illness, but focused on cure, not cause. Her efforts in social reform, not always easy, are laudable. Vacek describes her as "part prophet, part moral authority, part civic expert" (p. 75).

The fourth figure is Presbyterian minister Anton Boisen (1876–1965), who personally experienced mental illness and was hospitalized (despite previous efforts, these institutions had deteriorated, were still stigmatized, and were more custodial than curative in nature). He reflected on his experience in *The Exploration of the Inner World: A Study of Mental Disorder and Religious Experience*. Boisen divided mental illness into two classes, organic and functional, and criticized psychiatrists for failing to recognize this difference. The church was equally culpable for failing to care for the suffering, ceding this role to medicine. He believed that some illness had religious meaning, but noted that when spiritual conflict was resolved well, it was labeled religious experience, but when it was not, it was labeled insanity. Boisen made inroads for clergy working in hospitals and began the Clinical Pastoral Education program.

The final person Vacek examines is psychiatrist Karl Menninger (1893–1990). A pioneer in his field and the author of several books, Menninger's medical work was fueled by his sense of Christian vocation and his belief in God's loving work in the world. With his brothers, he founded the Menninger sanatorium and clinics, and contributed to the new field of pastoral counseling. Menninger argued against the current medical use of diagnostic labels and viewed mental malady as a "state of functioning or way of behaving" (p. 141), not illness. And, against some Christian views, he rejected the supernatural and immorality as the cause of such suffering. Menninger, along with many others, championed both church and state to increase awareness of mental suffering, improve conditions in institutions, treat mental problems at an early stage, and exemplify compassionate care.

Of particular interest to those interested in the dialogue between science and faith are the threads evident in these individuals of the beginnings of a positive relationship between the two. Mather's desire to understand creation explained his interest in medicine. Dix viewed "science as a study of God's handiwork and providence" (p. 59). Boisen sought a new relationship between the church and psychiatrists. Menninger saw psychiatry and religion as part of a same whole, encouraged cooperation between church and state, and worked on integrating the two. He noted similarities in that both psychiatrists and clergy were aware of suffering and used similar tools, such as listening, reassuring, and correcting. In the centuries that witnessed the evolution of a separation between medicine and religion, these pioneers

argued for and exemplified a collaborative and mutually beneficial relationship between the two.

Vacek laments that despite the biblical calling to "love your neighbor," the church generally has not done better than society in understanding and caring for those who suffer mentally. There is often a gap between belief and practice; this is exacerbated by stigma, which not only limits care but is also contrary to biblical teachings on inclusion. In her concluding chapter, Vacek suggests using the concept of hospitality (e.g., Rom. 12:13), implied by the five individuals studied, as a way forward. A practical theology approach considers God's redemptive mission and informs a Christian response. We need to be conscious of suffering and work in solidarity with those who suffer. Hospitality includes welcoming and incorporating all people into fellowship, showing compassion, and exercising patience.

Vacek's work is thorough and thoughtful, but at times her conclusions extend beyond the evidence she presents. In particular, she neglects the many developments that have occurred in mental health care and the medicine-religious dialogue in the last few decades. Despite this weakness, *Madness* is a fascinating read and of particular interest to historians, mental healthcare practitioners, and those researching the intersection between medicine and religion. And, since the "poor in spirit" will always be with us, it also calls for action on the part of all Christians.

Reviewed by E. Janet Warren, MD, PhD, President of the Canadian Scientific and Christian Affiliation. ✦

Letters

Old Age at Lake Suigetsu, Japan, and Glacial Tillites, Geologic History, and Biblical Chronology

The fine article by Gregg Davidson and Ken Wolgemuth explains how we can have confidence in age dating, based on comparisons of independent data sets ("Testing and Verifying Old Age Evidence: Lake Suigetsu Varves, Tree Rings, and Carbon-14," *PSCF* 70, no. 2 [2018]: 75–89). It takes a unique approach of comparing raw carbon-14 data (no use of calibration curves) with tree-ring counts back to 14,000 years (most from Europe), and annual sediment layer (varve) counts covering 50,000 years of sediment deposition in Lake Suigetsu, Japan, to show how assumptions such as constant radioactive decay rates, annual growth of tree rings, and annual deposition of layered sediments can be tested and verified. Lake Suigetsu is well suited for radiocarbon studies, because storm water first enters an adjacent lake where the coarser sediment deposits, and then water flows into Lake Suigetsu with mostly very fine sediment. Bits of leaves and twigs washed in and deposited with these sediments contain carbon-14 derived directly from the atmosphere, preserving a historical record of atmospheric carbon-14 in each successive layer.

The article is simply fabulous for effectively communicating the reliability of radiocarbon dating to a reader interested in science. Instead of using a logarithmic scale for exponential decay of carbon-14, the authors used a graph with the scale of percent modern carbon: it shows visually the decrease of carbon-14 with the passage of time, due to radioactive decay (see fig. 1).

To my knowledge, no one else has ever plotted these data in this visually dramatic way to communicate with nonscientists. These tree-ring data and varve data from leaves are simply excellent to tie together the varve data to tree-ring data, because there are 4,000 years of overlap. The alignment of tree-ring and varve carbon-14 with conventional expectations, and the utter failure to align with young-earth expectations, is stunning. Furthermore, the research team found an ash from a known volcanic eruption at the depth where the carbon-14 content was equal to that of tree rings ~10,200 years. The Ar-Ar age of the ash was 10,000 ± 300 years, an excellent confirmation from a completely different radiometric dating method.

Then the authors went above and beyond merely writing a paper for a journal, by adding six call-out sections, referred to as "Casting Doubt," such as the topic of Circular Reasoning. Young-earth writers and advocates typically do not appreciate or understand radiocarbon dating correctly, so they can only raise doubt about the reliability of the results. These six sections address the various doubts and claims made

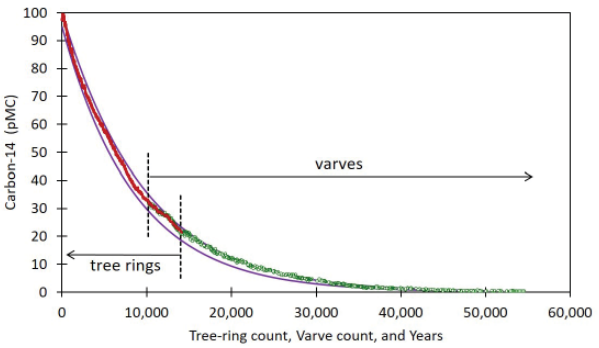

Figure 1. Tree ring and varve count vs. carbon-14 content. Solid lines represent the window for conventional expectations.

by young-earth advocates, and demonstrate why the conventional understanding is more in keeping with the nature of God. If I knew of a journal that offered an award for the paper with the most effective communication written for a most difficult target audience, I would submit this paper!

The above carbon-14 old-age dating is also consistent for very old ages as are obtained from U/Pb radiometric age dating that has been applied to glacial tillites that occur in the recent Ice Age, in the Paleozoic Era, and then farther and farther back in the Precambrian to very old ages. See http://www.csun.edu/~vcgeo005/Nr40tillites.pdf. Early life on Earth had anaerobic bacteria that produced methane as a waste product, but when cyanobacteria evolved that had photosynthesis as part of their metabolism, oxygen was released as a waste product, which was a poison for the anaerobic bacteria. Therefore, the earth experienced its first mass extinction as increased amounts of oxygen killed the anaerobic bacteria. Life then evolved to produce organisms that could tolerate oxygen, but these organisms combined oxygen with carbon in their metabolism and produced carbon dioxide as a waste product. But this waste product had subsequent consequences. Methane in the early atmosphere absorbed the sun's heat and kept the earth warm, but when carbon dioxide began to increase in the atmosphere, cooling occurred that may have produced a "snowball" Earth because tillites can be found at the earth's equator. All these changes certainly cannot have happened in 6,000 to 10,000 years as is promoted for the age of the earth by young-earth creationists, if the natural laws that the Creator also produced are obeyed.

Davidson and Wolgemuth should be congratulated on demonstrating the trustworthiness of scientific dating methods, and showing that the young-earth creationists have no logical basis for claiming a very young age for the earth.

Lorence G. Collins
ASA Member

About the "Literal" Interpretation of Genesis Chapters 1 and 2

I have a suggestion, or request, for our ASA community's discussion of the interpretation of the creation accounts in the Bible, primarily, of course, Genesis 1 and 2. We often use the term "literal interpretation," referring to the opinion that the days of creation were consecutive 24-hour days, and therefore that the creation of the earth and the entire universe occurred only about 120 hours before the creation of Adam, a few thousand years ago. This is commonly called young-earth creation, or YEC.

Whatever we call this interpretation, I propose that we cease calling it "the literal" interpretation. This is what the advocates of this view claim for it, thus implying that all other interpretations are not literal, but are something else, and claiming a sort of high ground in the competition for legitimacy. We do not need to concede this mantle to them.

What does the account literally tell us? It says God caused the earth to sprout. How long does that ordinarily take? Is there any indication in the text that this was done nearly instantaneously, in a few hours at most, with a mature botanical ecosystem and soil appearing from nowhere on top of previously bare inorganic rock? Can this be called literal interpretation? It says God planted a garden, again sounding somewhat slower than instantaneous completion.

If the sun, moon, and stars were not created until the fourth day, how was there light and dark, evening and morning on the first three days? And what does "the heavens and the earth" mean in verse 1? At what point on the globe was evening and morning observed? All these points have been debated for centuries, and I am not advocating any particular conclusion, only pointing out that whatever conclusions have been proposed, have all been heroic exercises of logical gymnastics. Such explanations may be right or wrong, but they cannot be called simple literal interpretation.

On this account, Adam had a prodigiously busy and productive first few hours of existence. From a blank slate of memory, he learned a language, learned to care for the garden, observed a large number of animals and formed meaningful names for them, and observed that they came in pairs and he did not. This is equivalent to a whole series of doctoral dissertations. Then he had to learn to fix his own lunch. No wonder he needed a nap in the afternoon and was happy to acquire a wife to help him. Is this seriously what we think Moses thought and meant when he wrote this account? Is this what the contemporary first-generation Israelite listeners thought when they heard it in the wilderness? Can we call this "literal" interpretation with a straight face?

So, whatever our various preferred interpretations are, and what we call them, let's stop conceding to the solar-day recent-creation viewpoint the claim of "literal" interpretation. There is no such thing as a simple, literal interpretation of the creation accounts, so let's retire this label. Of course, that raises the question of what label to replace it with.

Is there another term that is suitable, respectful, and avoids any pejorative feeling? That rules out "naïve," "wooden," and "unscholarly," and such terms are no more accurate than literal, so these cannot be considered as progress. We already commonly refer to YEC, and the advocates themselves use that label; will that do? However, YEC carries extensive baggage of the entire young-earth scenario, including Flood geology and claims of scientific verification of all this. We need a term that refers specifically to the interpretation of the biblical creation texts. Is there a better suggestion? Perhaps there really is nothing more compact and intelligible than "seven solar-day interpretation."

I hope this simple suggestion can clarify our discussion of this topic.

David Newquist
ASA Member

What Was Missing

I wish to suggest what was missing in Keith Miller's excellent article, "Doubt and Faith in Science and Religion," (*PSCF* 70, no. 2 [2018]: 90–100). Only in the last paragraph is the Holy Spirit briefly mentioned. Essentially every church service mentions the Holy Spirit, but it is too rare that much is said about what the Holy Spirit actually does. There is the belief that a discussion of this is subjective and mysterious. Yes, it is mysterious but definitely not subjective. I think that because of the Holy Spirit the rise of modern science was dominated by Christian scientists.

The primary function of our having the Holy Spirit is to better see what is God's will and purpose for us, and to strengthen our faith. In addition the Holy Spirit gives us better insight and understanding of both the Bible and God's work in creation. This is critical in the study of science and religion, and I am certain this helped me in my scientific research. We can see things around us much more clearly. I can see the Holy Spirit at work when I am on the same wavelength with my fellow Christian, as we understand and identify with every word spoken. When there is disagreement and conflict I wonder if I am out of tune with the Holy Spirit, or is it my fellow Christian, or both of us. We should never force our ideas upon our fellow Christian, but be humble and receptive, letting the Holy Spirit work in each of us.

William Wharton
ASA Fellow

Author Response

I want to thank William Wharton for his comments. My article was intended to address the comparison of science and religion with regard to faith and doubt more broadly than a consideration of Christianity alone. I agree fully that the Holy Spirit is essential in guiding us into spiritual truth and providing correction from error. l also believe that one of the primary ways in which the Holy Spirit does that is through the Body of Christ—that is, through the spiritual gifts and witness of the Christian community.

Keith B. Miller
ASA Fellow

An Appreciation

I am just sending you a short note to thank you for this journal. I look forward to receiving it each quarter. It is so well done and full of compelling articles that really provide comprehensive insight into the faith-science conversation. Information from each issue enriches my research and lectures. And thank you as well for the valuable book reviews.

Scott Flaig
ASA Member ✧

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