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Special Issue Reprint

Exploring Science from a Biblical Perspective

Edited by
John A. Bloom

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About the Editor

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Editorial

Introduction to the *Religions* Special Issue, "Exploring Science from a Biblical Perspective"

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Christianity and science have a long and deep relationship which, in recent decades, has generated stimulating dialogue among scientists, theologians, philosophers, and historians. The focus of this Special Issue is to highlight one aspect of this discussion: the influence of biblical perspectives on science, both historically and in contemporary culture. It is intended to complement an earlier Special Issue of *Religions* which I was privileged to edit, "Christianity and Science: Fresh Perspectives" published in 2020–2021.

How does a biblical perspective influence science? For starters, it proposes God as the answer to the question, "Why is there something rather than nothing?" From a biblical perspective, matter and the universe are not eternal, but were created *ex nihilo* (from nothing) "in the beginning" (Genesis 1:1, John 1:3, Hebrews 11:3). The temporality of the universe created by an eternal, spiritual God clashed with ancient Near Eastern and Greek thought positing that matter is eternal, since in polytheistic worldviews, matter is a manifestation of the gods. When the eternity of matter concept was re-introduced in the West through the teachings of Aristotle around 1100 AD, this eternal/temporal matter debate became the greatest tension point between early science and theology, continuing well into the 20th Century. In fact, a survey taken in 1959, just prior to the discovery of cosmic microwave background radiation, found that less than one-third of U.S. scientists thought the universe had a beginning (Brush 1992). Robert Jastrow's classic *God and the Astronomers* (Jastrow 2000) documents the strong resistance that the Big Bang theory received from secular scientists in its early days, largely because of its theological implications.[1]

The notion that our universe has not always been here is better established today, but it is not without its detractors. Those wanting an accessible and extensive discussion of this topic should consult John C. Lennox's *Cosmic Chemistry* (Lennox 2021a) and *God and Stephen Hawking* (Lennox 2021b). To bring this discussion up to date, in this Special Issue, the astrophysicist Hugh Ross presents the most current evidence that our universe had a beginning (Ross 2023). It appears that this biblical perspective on the nature of matter and the universe has a strong warrant.

Another biblical perspective one can bring to a scientific question involves the origin of life: can life start merely from the interaction of chemicals, or does life require some type of causal agent as an influence to get it going? In his article, Hugh Ross argues that if the universe required an agent to form, it is not unreasonable to expect that an agent was also required for the origin of life (Ross 2023).

Does a biblical perspective in science only look for cases where God needs to act miraculously? By no means, and the next two articles in this Special Issue address this point historically. In addition to presenting God as the Creator of the universe and of life, the scriptures note in many places that God has established patterns and laws so that the world follows a predictable course (Genese 8:22, Jeremiah 33:20–21).[2] Edward Davis shows how this biblical expectation of regular patterns led Robert Boyle to develop some of the foundational ideas of chemistry (Davis 2023), and Michael Keas traces this expectation in the thinking of early scientists like Johannes Kepler, who solved the riddle of planetary orbits (Keas 2023).[3] Note the two-fold nature of a biblical perspective: we expect ordinary,

repeatable events to follow fixed laws, because God established these natural patterns, yet for *origin-* or *miracle-related* questions, we should be open to God working in a creative (non-patterned) manner. In fact, Keas shows that the leading 19th-century scientist-philosopher William Whewell helped to pioneer the new professional term "scientist" to refer to those who study nature with an openness to both kinds of explanation—miraculous design and non-miraculous design. Thus, exploring science from a biblical perspective affirms *both* the search for mechanical explanations—a key goal of science that leads to technological advances—*and* an openness to detecting direct divine creative actions. It is my hope that the necessity of this balanced approach to studying nature is better recognized as a result of this Special Issue.

The remaining articles in this Special Issue focus on contemporary discussions of how best to explore science from a biblical perspective. Kenneth Keathley discusses the range of ways that science and faith can interact and notes that many of the challenges in relating them are fundamentally ethical in nature (Keathley 2023). Since much of the science–scripture overlap centers on the early chapters in the Book of Genesis, Joseph Miller looks at the similarities and differences between Genesis 1–11 and ancient Near Eastern creation myths (Miller 2022), while Ted Cabal discusses the strengths and weaknesses of various attempts to find parallels between scientific discoveries and scripture (Cabal 2023). Garrett DeWeese responds to challenges that a biblical perspective in ecology is hostile to the environment (DeWeese 2023), and Casey Luskin provides a helpful review of the various models for human origins that are being discussed today in evangelical Christian circles (Luskin 2023). Stephen Dilley et al. further discuss how standard evolutionary theory may or may not be reconciled with design/creation approaches (Dilley et al. 2023).

To complete this Special Issue, two articles examine cases where it is argued that science clashes with a biblical perspective. Titus Kennedy surveys the archaeological artifacts recovered from ancient Jericho and finds that they are compatible with the biblical conquest narratives; thus, a breezy dismissal of their historicity may not be warranted (Kennedy 2023). Stephen Dilley offers an in-depth analysis of Stephen J. Gould's famous "Panda's Thumb" argument and notes that it, like many arguments commonly made for macro-evolution, hinges on *theological* premises that misrepresent a biblical perspective (Dilley 2023). While macro-evolution may be true, to argue that it must be true for theological reasons (such as "God would not do it that way") is simply an invalid approach.

I hope that the readers of this Special Issue will enjoy these articles as much as I have. I found it intriguing that a biblical perspective encourages the scientific search for mechanical, natural explanations for regular, repeating events, yet recognizes that God, as Creator, is not limited to using only natural processes. Thus, science, to the extent that it seeks to discover truth, should be open to both explanations. I also found that so-called "biblical perspectives" can vary from "Straw God" misrepresentations of a traditional Christian position (often by using words from the text in a woodenly literal manner) to situations where Christians themselves argue for a position that is not in fact biblical (misunderstanding "dominion" ecology). However, by continuing to study what historically has been seen as the "two books" of God's revelation, His Works and His Word, my hope is that we will all get a better handle on truth.

Conflicts of Interest: The author declares no conflict of interest.

Notes

1 For example, see (Maddox 1989).

2 For an introduction to this point, see (Bloom 2015).

3 I hoped that Rodney Stark would contribute an article on this point for this special issue, but he passed away before being able to do so. I refer readers to his excellent chapter, (Stark 2003).

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Article

Biblical Perspectives as a Guide to Research on Life's Origin and History

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Abstract: The more than thirty spacetime theorems developed over the past five decades establish that the universe and its spacetime dimensions have emerged from a cause/causal agent beyond the cosmos. Thus, to infer that this cause/causal agent may have intervened in the origin and history of Earth and Earth's life resides well within the bounds of reason. Meanwhile, proponents of each of the three prevailing naturalistic models (abiogenesis, panspermia, and directed panspermia) for the origin and history of Earth's life have marshaled arguments and evidence that effectively undermine and refute the other two models. A biblical perspective and approach to Earth's life can help resolve this impasse. While a superficial and pervasive appeal to divine intervention thwarts scientific advance, so does a rigid adherence to naturalism. A productive way forward is to identify which models (or parts of models), whether naturalistic, theistic, or a combination, most effectively narrow, rather than widen, knowledge gaps, minimize anomalies, offer the most comprehensive and detailed explanation of the data, and prove most successful in predicting scientific discoveries.

Keywords: spacetime theorems; origin of life; history of life; abiogenesis; hand of God dilemma; panspermia; quasi-steady-state models; habitable zones; process structuralism; Cambrian explosion

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1. Introduction

Naturalism is the belief that the laws of physics governing the universe and natural processes are fully sufficient to explain all that exists in the universe. Its proponents claim that it can explain the origin, dynamics, operations, and evolution of all the universe's components, including all forms of life. In other words, physics and chemistry alone explain everything we can detect and measure in the universe.

For the past century, naturalism has dominated scientific research on the origin and history of Earth's life. Such near-complete dominance is evident in the leading scientific journals on the origin and history of life. Examples include *Origins of Life and Evolution of Biospheres*, *Current Biology*, *Astrobiology*, *Proceedings of the National Academy of Sciences USA*, *Science*, and *Nature*.

The success of a naturalistic approach to scientific research is undeniable. Much of what scientists observe in the natural realm can, indeed, be explained from a strictly naturalistic perspective. This success, however, owes much to a biblical worldview. The biblical doctrines that the laws of physics are unchanging (Ecclesiates 1:4–11, Jeremiah 33:25, and Romans 8:20–22) and that the book of nature can be trusted to reliably reveal truth (Psalm 19:1–4 and Romans 1:18–20) provided the foundation for the scientific revolution that was birthed in Reformation Europe (Torrance 1965, 1985, 1996).

Does it follow from this success that naturalism explains everything we observe in nature? In light of the well-established laws of thermodynamics, gravity, and electromagnetism, which imply that the universe and everything in it is proceeding toward ever-increasing disorder and decay, is it reasonable to assert that life comes from non-life and that simple, primitive life inexorably progresses to more complex and advanced life? Is it reasonable to conclude that organisms possessing mind, will, and emotions naturalistically arise from life forms that lack mind, will, and emotions? Is it realistic that intelligent

life capable of launching and sustaining high-technology civilization arose through strictly natural means from species of life that possessed no innate intelligence?

2. Spacetime Theorems

In 1970, physicists Stephen Hawking and Roger Penrose published the first of the cosmic spacetime theorems (Hawking and Penrose 1970). Based on only two primary assumptions, Hawking and Penrose demonstrated that under classical conditions (without significant quantum spacetime fluctuations), the cosmic beginning is not just the beginning of matter and energy but also the beginning of space and time as well. That is, space and time began to exist when the universe began to exist.

The first assumption, that the universe contains mass, is undisputed. The second assumption, that general relativity reliably describes the dynamics, or movements, of massive bodies in the universe, has since been confirmed by astronomical observations to better than a trillionth of a percent precision (Penrose 1994; Weisberg and Huang 2016; Silva et al. 2021). Today, general relativity ranks as the most exhaustively tested and firmly verified principle in all of physics (Ross 2018; Do et al. 2019; Kramer et al. 2021).

In 1994–2003, theoretical physicists Arvind Borde and Alexander Vilenkin published five extensions of the spacetime theorems, culminating in what is now known as the Borde–Guth–Vilenkin theorem (Borde et al. 2003). These extensions demonstrate that, regardless of the homogeneity, isotropy, and energy conditions of the universe, the universe must be subject to the relentless grip of an initial spacetime singularity. Any cosmic model in which the universe obeys an average past expansion (a necessary requirement, as pointed out by Borde and Vilenkin, for physical life to possibly exist in the universe) must be traceable back within finite time to an actual beginning of space and time. In 2006, Vilenkin wrote, "With the proof now in place, cosmologists can no longer hide behind the possibility of a past eternal universe. There is no escape, they have to face the problem of a cosmic beginning" (Vilenkin 2006).

According to physicist Sean Carroll, an escape might exist. He explains that previous to 10^{-43} s after the cosmic origin event (the quantum gravity era where quantum mechanics competes with gravity in determining the dynamics of the universe), a possibility exists that quantum spacetime fluctuations could have been large enough to permit an escape from an initial spacetime singularity (Carroll 2008, 2010). However, quantum spacetime fluctuations during this first tiny split second of the universe's 13.8-billion-year existence would accumulate, that is, become "frothier," over long pathways through space. Such an accumulation would blur the images of distantly observed quasars and blazars, especially at short wavelengths. So far, observations at visual and ultraviolet wavelengths by the Hubble Space Telescope fail to reveal any blurring of distant quasar images (Tamburini et al. 2011).

Quantum gravity models with large quantum spacetime fluctuations, loop quantum gravity models, and many other quantum gravity models predict that Lorentz invariance (the proposition that the laws of physics are the same for all observers in the universe) will be violated at energy scales above the Planck energy of 1.22×10^{19} GeV (1 GeV = 1 billion electron volts) and that tiny deviations from Lorentz Invariance will occur at much lower energy levels.

Tests at energies above the Planck energy were widely presumed to be impractical, if not impossible. However, astrophysicists analyzed emissions from four bright gamma-ray bursts detected by the Fermi Space Telescope (Vasileiou et al. 2013). They found no violation of Lorentz invariance for energy levels less than 7.6 times the Planck energy at a 95% confidence level, assuming a linear dependence on photon speed with energy. In a subsequent article the astrophysicists declared, "Our results set a benchmark constraint to be reckoned with by any QG [quantum gravity] model that features spacetime quantization" (Vasileiou et al. 2015).

An analysis of optical polarization data from 72 active galactic nuclei and gamma-ray bursts placed a stringent limit on a major category of quantum gravity models (Kislat and Krawcynski 2017). This analysis established a lower limit on the energy scale of quantum

gravity that is a million times higher than the Planck energy, "severely limiting the phase space for any [quantum gravity] theory that predicts a rotation of the photon polarization quadratic in energy" (Kislat and Krawcynski 2017, p. 1).

Other quantum gravity models predict that at energy levels below the Planck energy, the propagation speed of very-high-energy gamma rays will deviate from the velocity of light. Specifically, photons of different energies emitted simultaneously from a source in a distant galaxy would arrive at different times. Through measuring the arrival times of the most energetic photons ever detected, those from the gamma-ray burst event, GRB 190114C, in a galaxy 4.5 billion light years away, the Major Atmospheric Gamma Imaging Cherenkov Collaboration determined that any departure from the velocity of light by GRB 190114C's gamma rays must be less than 1.7×10^{-17} (Acciari et al. 2020).

To eliminate all quantum gravity speculations seeking to avoid a cosmic beginning would require tests at infinitely high energy levels, an impossible quest for beings constrained by the laws of physics and the cosmic spacetime dimensions. However, without exception, all observations to date relevant to the quantum gravity era sustain a spacetime beginning to the universe (Tamburini et al. 2011; H.E.S.S. Collaboration et al. 2011; Vasileiou et al. 2013, 2015; Rovelli and Vidotto 2014; Perlman et al. 2015; Barceló et al. 2017; Kislat and Krawcynski 2017; Romoli et al. 2018; Acciari et al. 2020; Bartlett et al. 2021; Zhou et al. 2021; Abe et al. 2022; Bolmont et al. 2022). These observations illustrate the biblical principle that the more we learn about the natural realm, the more evidence we accumulate for the creation of the natural realm.

Given that all current observations and confirmed theories indicate that space and time came into existence at the cosmic origin event, we now can make reasonable inferences about where the universe has come from. It arose not from within spacetime but, rather, from an "entity" or "reality" beyond space and time. In coming to this conclusion, astrophysical researchers have echoed the biblical explanation for the origin of the universe and of spacetime. As Arno Penzias, who shared the Nobel Prize for Physics for the discovery of cosmic background radiation, commented, "Astronomy leads us to a unique event, a universe which was created out of nothing" (Penzias 1992). As Hebrews 11:3 declares, "We understand that the universe was formed at God's command, so that what is seen [detected] was not made out of what was visible [detectable]." According to 2 Timothy 1:9, Titus 1:2, and 1 Peter 1:18–20, time has a beginning and God was active "before the beginning of time." Physicists may have produced the spacetime theorems sooner had they started with the biblical assertion that time has a beginning.

The spacetime theorems establish that the Bible cannot be dismissed as scientifically irrelevant. Nor can scientists honestly assert that supernatural events never happen. Demonstrating that the universe—all that scientists can detect and measure—came into existence through the agency of a cause beyond space and time is the greatest supernatural event that any scientist can hope to uncover.

3. The Bible on the Origin and History of Life

In addition to crediting God with the origin of the universe, the Bible also points to God as the creator of Earth's life. Psalm 104:24 declares, "How countless are your works, Lord! In wisdom you have made them all; the earth is full of your creatures." Genesis 1 uses the Hebrew verbs *bara* (create) and *asa* (make) to describe God's action in bringing into existence different life forms. Genesis 1 also uses the Hebrew verbs *haya* (let there be) and *sharas* (teem) with respect to other life forms.

These biblical texts and others imply that God is responsible for *all* life on Earth. He brings different life forms on Earth throughout the history of life on Earth via supernatural acts that transcend the laws of physics (*bara*, when God is the subject), as well as supernatural acts performed within the laws of physics (*asa*, when God is the subject) and actions occurring through supernaturally or naturally guided physical processes (*haya* and *sharas*). Here, I define supernatural acts within the laws of physics as actions that do not violate the laws of physics but infer supernatural agency, akin to a Boeing 777 aircraft inferring human

engineers and humanly constructed assembly factories rather than naturally occurring windstorms blowing through aluminum, titanium, and copper ore deposits.

From a biblical perspective, therefore, research on the origin and history of Earth's life should not be closed to consideration of only natural causation or only supernatural causation. It should be open to both. It should also develop tests to determine which causation sources are most likely and/or best able to explain all the observational and experimental data. The Bible implies that strictly naturalistic mechanisms for the origin and history of Earth's life, where no mind or transcendent causal agent is involved, will fail to explain all the data. The Bible implies that the science of the origin and history of life may proceed more efficiently, generate more successful outcomes, and demonstrate greater explanatory and predictive power if both natural and supernatural causations are taken into account.

4. Origin of Life

The simplest known non-parasitic life form is the bacterium *Pelagibacter ubique*. Its genome consists of 1,308,759 base pairs, 1354 protein genes, and 35 RNA genes (Giovannoni et al. 2005; Kyoto Encyclopedia of Genes and Genomes 2023). This bacterium's genome is at the theoretical minimum size for an independently existing life form capable of long-term survival and reproduction (Itaya 1995; Maniloff 1996; Leslie 2021).

Proteins and functional RNAs are complex. Life-essential proteins range in size from 200 to 2000 amino acids. Transfer RNAs, messenger RNAs, and ribosomal RNAs are all life-essential. Transfer RNAs (about 15% of the total RNA in cells) contain between 75 and 95 nucleotides. Messenger RNAs (about 5% of the total RNA in cells) contain 400–12,000 nucleotides. Ribosomal RNAs (about 80% of the total RNA in cells) contain 1500–5000 nucleotides. Single cells contain between 50,000 and 3 billion proteins and RNAs (Milo 2013; Dolgalev et al. 2023).

Life, even in its simplest form, therefore, is intricate and complex to a mind-boggling degree. This intricacy and complexity pose a profound problem for naturalistic origin-of-life models. The chance of a living cell forming through the random, repeated shuffling of amino acids, nucleotides, lipids, and sugars is exceedingly remote to a point that is indistinguishable from zero. The chance that all the required amino acids, nucleotides, lipids, and sugars would be available in one place, with no contaminants, and where random shuffling can occur appears just as remote and indistinguishable from zero.

These improbabilities have reduced the number of naturalistic origin-of-life models still seriously considered viable by origin-of-life researchers to just three. These three include (1) abiogenesis, (2) panspermia, and (3) directed panspermia. Hundreds of scientists and several decades of concerted research effort have been dedicated to demonstrating the scientific feasibility of each. All these dedicated resources have yielded progressively more evidence to suggest that science is best and most successfully carried out if both natural and supernatural causes are considered and tested.

5. Abiogenesis Model

The central dogma of origin-of-life research is abiogenesis, the view that sometime in the past, favorable natural conditions occurred on Earth for the formation of complex organic molecules—the twenty bioactive amino acids, the five bioactive nucleobases, the two ribose sugars, and three categories of lipids—and that, in turn, these gave rise to the self-organization of proteins, DNA, RNA, and lipid membranes. Abiogenesis goes on to propose a naturalistic pathway whereby the proteins, DNA, RNA, and lipid membranes self-assemble into primitive living cells. The central dogma of biological evolution asserts that all life has naturalistically evolved from the first primitive living cells.

However, the abiogenesis model appears fraught with intractable problems. A sampling of just six is described, briefly, here:

Missing amino acids: Astronomers have yet to discover any of the twenty bioactive amino acids in interstellar molecular clouds (Snyder et al. 2005; Manna and Pal 2022). So far,

they have found only ten in meteorites and asteroids (Koga and Naraoka 2017; Potiszil et al. 2023). The twenty bioactive amino acids fall into four categories: nonpolar, polar uncharged, acidic (negatively charged), and basic (positively charged). The three basic (positively charged) bioactive amino acids are arginine, histidine, and lysine. Laboratory prebiotic synthesis experiments at both normal temperatures (0–200 °C) and high temperatures (200–700 °C) failed to produce any arginine or lysine. Reanalysis of products from normal temperature Miller–Urey-type spark discharge experiments detected neither arginine nor lysine (Johnson et al. 2008). Prebiotic hydrothermal synthesis experiments yielded no detectible level of amino acid production, where it would have been clearly discernible (Hennet et al. 1992; Aubrey et al. 2009).

The failure of any prebiotic synthesis experiment to produce either lysine or arginine under any remotely conceivable early Earth conditions led some astronomers to propose that comets, asteroids, and/or meteoroids and impact-shock synthesis brought these life-essential amino acids to Earth's surface (Chyba and Sagan 1992). However, the only basic amino acid reportedly detected in any meteorite is lysine, and it was identified only tentatively in just one chondrite (Kotra et al. 1979). The chondrites with the highest levels of amino acids, EET92042, GRA95229, and GRO 95577, contained no measurable lysine or arginine (Martins et al. 2007). In the words of two origin-of-life chemists, "a general consensus seems to have emerged that lysine and arginine are 'prebiotically implausible'" (McDonald and Storrie-Lombardi 2010).

Given the absence of lysine and arginine on the early Earth, biochemists sought to determine what biochemical functions can and cannot be achieved without these amino acids (McDonald and Storrie-Lombardi 2010). They discovered that while the lack of lysine and arginine did not halt the formation of proteins, it did prevent the formation of proteins that take any role in protein–nucleic acid biochemistry. Given that arginine- and lysine-containing proteins are essential for crucial protein–DNA interactions, naturalistic explanations for life's origin, on this basis alone, appear unlikely.

Homochirality: Amino acids cannot be linked together to make proteins in living organisms (in virtually all cases) without catastrophic consequences unless all the amino acids have the same "handed" configuration—in the case of known life, a left-handed configuration (Banreti et al. 2022). Nor can nucleosides be linked together in living organisms (in all cases) to make DNA and RNA unless they are connected by pentose sugars all with the same right-handed configurations. Outside of organisms, amino acids and pentose sugars exist in a racemic mixture, that is, random mixtures of left-handed and right-handed configuration.

No natural source exists on Earth for producing the homochiral molecules required for life's emergence. Organic chemist William Bonner writes, "I spent 25 years looking for terrestrial mechanisms for homochirality and trying to investigate them and didn't find any supporting evidence. Terrestrial explanations are impotent or nonviable" (Bonner 1995).

The only possible astronomical sources that could possibly drive a racemic mixture of amino acids toward a slight left-handed inclination are intense circularly polarized ultraviolet radiation (CPUR) emitted by either neutron stars or black holes and dense neutrino fluxes blasted from supernovae or neutron stars or Wolf–Rayet stars (high-mass helium-burning stars with surface temperatures ranging from 20,000 K to 210,000 K) in close orbits about massive stars. For both these radiation sources, the departure from a racemic mixture takes place through right-handed amino acids being destroyed at a faster rate than the destruction of left-handed amino acids.

Laboratory simulations show that, at best, CPUR from neutron stars or black holes would generate only a 1.34% excess of left-handed (relative to right-handed) amino acids (Takano et al. 2007; de Marcellus et al. 2011). Other laboratory simulation experiments demonstrate that, at best, dense neutrino fluxes from supernovae or neutron stars and Wolf–Rayet stars closely orbiting massive stars would produce only a 1% excess of left-handed amino acids (Boyd et al. 2018).

According to the Kuhn–Condon rule of quantum mechanics (Kuhn 1930; Condon 1937), one wavelength of polarized light will preferentially destroy right-handed chiral molecules while the adjacent wavelength will preferentially destroy left-handed chiral molecules. This rule implies that CPUR will destroy more left-handed than right-handed amino acids only if the CPUR is strictly monochromatic. Astronomers know of no astrophysical source of monochromatic CPUR.

In the Milky Way Galaxy, Wolf–Rayet stars and neutron stars in close orbits about massive stars are rare (Boyd et al. 2018). Thus, it is unlikely that they would populate our galaxy with a sufficient number of meteoroids containing amino acids with a slight preference for left-handed configurations.

Chemists in sophisticated laboratory experiments have been successful in amplifying an original tiny excess of left-handed chiral molecules that are closely analogous to bioactive amino acids (Shibata et al. 1998). However, any higher excess thereby achieved becomes unstable over time (Frank 1953). Furthermore, the greater the amplification of excess, the lower the remaining quantity of the original amino acid sample (Flores et al. 1977). All laboratory experiments are consistent with the conclusion that long before a sample of amino acids becomes 100 percent left-handed, the entire original sample is destroyed.

Insufficient time: In a short graduate astronomy course at the University of Toronto in 1970, astronomer Carl Sagan set forth three minimal requirements for abiogenesis (Sagan 1970):

1. A vast "soup" of prebiotic molecules, at least as vast as all Earth's oceans;
2. A rich abundance of exclusively homochiral (100% left-handed or 100% right-handed) prebiotic molecules;
3. A very long time, at least a billion years.

Research now shows that the time window for life's origin on Earth was much briefer than a billion years. Until 4.0 billion years ago, the Sun showered Earth in deadly radiation (Tarduno et al. 2014; Cranmer 2017). Earth's surface was, at least episodically, hellishly hot until 3.85–3.84 billion years ago (Schoenberg et al. 2002; Abramov et al. 2013; O'Neill et al. 2017). Permanent, stable liquid water oceans and permanent, stable rock masses did not appear on Earth's surface until 3.84–3.83 billion years ago.

When living organisms extract inorganic material from their environment, they preferentially choose the lighter isotopes of that material. For example, they choose carbon-12 at the expense of carbon-13, nitrogen-14 at the expense of nitrogen-15, and sulfur-32 at the expense of sulfur-34. The earliest undisputed multiple isotope evidence for life on Earth dates back to 3.825 ± 0.006 billion years ago (Manning et al. 2006). Ancient zircons discovered in western Australia (Bell et al. 2015) and northern Canada (Dodd et al. 2017) reveal brief episodes 4.1–4.0 billion years ago when liquid water, solid rocks, and the possible isotope signatures of life existed. Evolutionary biologist Niles Eldredge comments on this evidence: "One of the most arresting facts I have ever learned is that life goes back as far in Earth history as we can possibly trace it. . . . [I]n the very oldest rocks that stand a chance of showing signs of life, we find those signs" (Eldridge 2000).

The moment physical and chemical conditions permit life's existence on Earth, life appears. It appears not in just one form, as naturalistic models would predict. Different microbial lifeforms prefer slightly different carbon-12 to carbon-13 isotope ratios. Isotope evidence reveals the existence of a diversity of microbial species at the time of life's origin (Schidlowski 2001; Garcia et al. 2021).

Missing soup: The significance of evidence for multiple isotopes indicative of life in Earth's oldest rocks is this: despite the absence of a primordial prebiotic soup, life existed abundantly on Earth previous to 3.8 billion years ago. For many decades, scientists have scoured Earth's crust and oceans in a quest for evidence of prebiotics. Extensive research reveals none. Isotope ratios of carbonaceous molecules in Earth's oldest rocks show evidence of *post*biotics but not of *pre*biotics (Schidlowski 1988; Rosing 1999; Grassineau et al. 2005). If the latter ever existed, they must have been in such low abundance as to be of no use for abiogenesis.

Scientists now understand why Earth never had a prebiotic soup. The explanation comes from the "oxygen-ultraviolet paradox." If oxygen were present in the early Earth's atmosphere or oceans, even at a very low abundance level, that oxygen would have prevented any prebiotic chemistry from functioning. However, if there were no oxygen at all in Earth's atmosphere and ocean, ultraviolet radiation from the early Sun would have flowed to Earth's surface unimpeded and, in this case, too, halted prebiotic chemistry. For the early Earth, radiolysis of water by uranium, thorium, and plutonium isotopes produced sufficient oxygen to prevent what we know as prebiotic chemistry from occurring (Draganic 2005).

Deep-sea hydrothermal vents, far from damaging solar ultraviolet radiation, are widely touted sites for the synthesis of prebiotic molecules. A barrier to this synthesis is oxygen from the radiolysis of water. Another barrier is the vent temperature. The half-lives of nucleobases, amino acids, and pentose sugars at water temperatures of 200–300 °C measure just several days, minutes, and seconds, respectively (Miller and Bada 1988; Levy and Miller 1998; Islas et al. 2003). The vent conditions that produce amino acids and nucleotides just as efficiently destroy them.

With Earth essentially ruled out as a site for prebiotic chemistry, researchers committed to considering only naturalistic answers began to look to outer space. In several meteorites, they found eight of the twenty bioactive amino acids, though at abundance levels of only a few parts per million (Cronin and Pizzarello 1983; Burton et al. 2012; Lymer et al. 2021). In one comet, researchers discovered the simplest amino acid, glycine, but at less than one part per billion (Elsila et al. 2009).

The original sources of these amino acids are dense interstellar molecular clouds. To quote Carl Sagan, "We are made of star-stuff" (Sagan 1973). Molecular clouds in the Milky Way Galaxy's spiral arms and core possess a much higher abundance and diversity of carbonaceous molecules than any other known astrophysical sources. Astronomers have discovered over 140 carbonaceous molecules in interstellar molecular clouds so far. They have yet to find, however, any amino acids, nucleobases, or ribose sugars—critical building block molecules for proteins, DNA, and RNA (Kuan et al. 2003; Snyder et al. 2005; Manna and Pal 2022). While chemical conditions within the densest and largest interstellar molecular clouds permit limited production of nucleobases and simple amino acids, these same chemical conditions operate to destroy most of the nucleobases and amino acids produced. The remaining amounts likely fall below a few parts per billion, a quantity insufficient to support any conceivable naturalistic origin-of-life scenario.

Life as we know it? Recognizing the many intractable barriers confronting naturalistic abiogenesis models, some origin-of-life researchers began to speculate about the existence of alternatives to life as we know it, that is, life that is not carbon-based in its chemistry. The only elements in the periodic table other than carbon on which complex molecules might conceivably be based would be arsenic, boron, and silicon.

Arsenic and boron are rare, however. Compared to carbon, both are more than 5000 times less abundant in the solar system (Arnett 1996, pp. 14–15). When concentrated, both elements prove poisonous and deadly to life. Silicon is only 89 times less abundant than carbon in the solar system (Arnett 1996, p. 11). However, while carbon easily forms double and triple bonds, silicon rarely does. Because of silicon's very high affinity to oxygen, polymers of silicon will be built on Si–O chains rather than on Si–Si chains. Furthermore, as an MIT research team demonstrated, "The vast potential theoretical space of silicon chemistry is almost entirely unstable in water, and hence not available to a biochemistry based on water as a solvent" (Petlowski et al. 2020). Of all the elements in the periodic table, only carbon allows for the complexity and stability of chemical bonding that life molecules require. Any physical life in the universe must be virtually the same as "life as we know it." It must be carbon-based.

6. Hand of God Dilemma

Origin-of-life research chemists have achieved amazing outcomes in laboratory experiments that attempt to demonstrate how the components of life molecules potentially could be assembled. Their greatest success is the joining together of bioactive amino acids to construct short protein segments. However, for this success to be possible, the experimenters had to repeatedly intervene. They discovered that each chemical step needed a specific chemical environment and set of physical conditions (Orgel 2000, 2008; Schmidt-Kopplin et al. 2019). Nearly always, a subtraction reaction must occur simultaneously with an addition reaction, and both reactions must occur at specified rates.

In living cells, biochemical synthesis occurs through catalyzed reactions among different enzymes, each enzyme requiring a distinct, specified microenvironment at its active site for the reaction to run. In simulating an enzyme-free prebiotic scenario, experimenters have found that they must employ multiple, specifically ordered chemical steps that involve precipitation, crystallization, purification, and drastic changes in the chemical conditions to go from one synthesis step to the next. Even then, success is rarely achieved (Powner et al. 2009; Hänle and Richert 2018).

Origin-of-life chemist Clemens Richert, in a *Nature Communications* article, explains that the reputed goal of experimental origin-of-life biochemists is to re-enact what may have occurred when life arose from abiotic matter on the early Earth (Richert 2018). Richert noted, however, that the most successful origin-of-life experiments in the laboratory required numerous cycles of hydration and dehydration and/or cooling and heating. To be productive, these experiments necessitated repeated transitions from arctic to volcanic conditions in a single location then back to arctic again within only a few hours or days—an unrealistic natural scenario to say the least.

Richert has referred to these required experimenter interventions "the hand of God dilemma" (Richert 2018, p. 2). He recommended that in their publications, origin-of-life research chemists should state as accurately as possible how many times and exactly when and where in their experiments they commit the hand of God dilemma. His recommendation would help researchers in other disciplines, and especially the lay public, understand what has and has not been determined by origin-of-life laboratory experiments.

Experimenter intervention, Richert claims, is equivalent to asserting that God did it. In his paper, Richert acknowledges that, "yes, most of us [origin-of-life research chemists] are not comfortable with the idea of divine intervention in this context" (Richert 2018, p. 2). He and his peers may be uncomfortable with their finding, but what they have demonstrated in their experiments, nonetheless, is that an agent much more knowledgeable, intelligent, and capable than themselves is a more reasonable explanation for how life assembled on the early Earth.

7. Panspermia Models

The manifold failures of the abiogenesis model partly explain why since the beginning of the twenty-first century, origin-of-life conferences and research endeavors seem dominated by astronomers and astrobiologists. The current thinking of scientists committed to naturalism is that life's origin must have occurred on some extraterrestrial site and later transported to Earth's surface. Here are the two main panspermia scenarios put forward, interplanetary and interstellar:

Interplanetary panspermia: In the 1990s and first decade of the twenty-first century, astrobiologists speculated that life may have originated on Mars and piggybacked on a meteorite traveling from Mars to Earth. In 1996, U.S. President Bill Clinton famously danced around a Martian meteorite reputed to contain unmistakable signatures of microbial life. Later, however, that bold claim was refuted (Maniloff 1997; Bada et al. 1998; Kazmierczak and Kempe 2003; Weiss et al. 2004).

The piggybacking of life on meteorites certainly occurs, but the other way around. Meteorites have sent the fossil remains of Earth's microbial life to nearly all the solar system's planets and moons. While Earth's geologic activity has made the fossils of Earth's

first life unrecognizable, millions of pristine fossils of Earth's first life litter the landscape of the Moon, just waiting to be discovered (Armstrong et al. 2002; Ross 2007; Armstrong 2010). Once collected and closely examined, these fossilized remains of Earth's earliest life could go a long way to determining how life originated and whether its origin most closely aligns with a naturalistic or supernatural origin. One would hope astrobiologists would be motivated to send spacecraft to the Moon to recover these fossils, given their potential to answer crucial questions of life's origin, whichever direction the evidence may point.

All the conditions that stymie a naturalistic origin of life on Earth also exist on Mars. What is more, several other characteristics of Mars also serve to thwart a naturalistic origin of life. Mars' atmosphere always has been thinner than Earth's. Therefore, Mars' surface has been exposed to more ultraviolet radiation. Mars' soil/crust is more oxidizing and contains sixty times the concentration of sulfur and sulfur compounds. Mars' rotation axis tilt varies chaotically. Carbonate formation when Mars was warm and wet would have rapidly and permanently removed carbon dioxide from the Martian atmosphere, which quickly made Mars cold and dry (Carr 2000).

Interstellar panspermia: Conditions for a naturalistic origin of life on solar system bodies other than on Earth or Mars prove even more intractable. This recognition has turned naturalists' attention toward the consideration of interstellar panspermia. Adherents to this scenario have proposed several modes for transportation of the seeds of life from far-off regions of the cosmos to Earth:

(1) radiation pressure

Nobel Prize-winning chemist Svante Arrhenius developed the first scientific model for interstellar panspermia in 1907 (Arrhenius 1908). He reasoned that Earth was too young for life to have arisen here naturalistically. Therefore, he proposed that life arose over much more time on planets orbiting stars outside the solar system. He presumed that "spores" escaped from these planets and that interstellar radiation pressure wafted them to Earth. Astronomers later discovered that the required radiation pressure would have destroyed any such spores (Zagorski 2007).

(2) dust and meteoroids

The most popular candidates offered for transporting the seeds of life to Earth across the vast reaches of space have been interstellar dust and meteoroids. However, interstellar dust and meteoroids cannot protect microbes, genes, proteins, or life-essential amino acids and nucleotides from the deadly dangers of interstellar space. A dust grain massive enough to safely carry a microbe or spore across interstellar space would require propulsion by starlight at an intensity sufficient to destroy the microbe or spore and all its proteins, DNA, and RNA. The probability of an interstellar meteoroid of planetary origin large enough to protect a dormant microbe or spore during its trip to and landing upon Earth would be no greater than one chance in a hundred thousand over the entire history of Earth (Melosh 2003). For both dust grains and meteoroids, interstellar travel times range from the millions to tens of millions of years, a time scale much longer than the half-lives of the proteins, DNA, and RNA crucial for maintaining the viability of any such microbe or spore (Levy and Miller 1998; Larralde et al. 1995).

(3) comets

In 1981, astronomers Fred Hoyle and Chandra Wickramasinghe updated Arrhenius' model in their book *Evolution from Space* (Hoyle and Wickramasinghe 1981). They proposed that Earth was seeded with life by comets from other planetary systems.

In 2018, thirty-three astrobiologists extended the Hoyle–Wickramasinghe model to propose that comets 0.54 billion years ago seeded Earth with diverse genes, explaining the Cambrian explosion event, when 50+ phyla of life suddenly appeared (Steele et al. 2018, pp. 3–23). As recently as 2020, three astrobiologists further developed the Hoyle–Wickramasinghe model, claiming that interstellar comets seeded Earth with a community of diverse microbes 3.8 billion years ago (Wickramasinghe et al. 2020).

Astronomers estimate that about 20% of all stars in the Milky Way Galaxy possess comet belts (Trilling et al. 2008; Greaves and Wyatt 2010; Martin and Livio 2013). When stars experience close encounters with one another, they occasionally exchange comets. Such exchanges could potentially cut interstellar travel times from millions of years down to tens of thousands, conceivably even just thousands of years.

Nevertheless, for multiple reasons, comets make poor candidates for the transport of life or life's genes across interstellar space. First, the comets that are exchanged during stellar encounters are those orbiting distantly from their host stars. Such comets have an extremely remote probability of ever being close enough to a presumably "inhabited" planet to capture any of that planet's life or genetic material.

Second, any comet captured from another star has an extremely remote probability of making a close enough flyby (not a collision) with Earth, in less than a hundred thousand years, to safely deposit any microbes or genes on Earth. Third, even with a planet as heavily populated with microbes and viruses as Earth, the density of such microbes and viruses at distances where any comet could conceivably capture these microbes or viruses is very low. The density is far too low for a sufficiently large comet to realistically capture, encase, and protect a microbe or virus so that it can survive an interstellar trip, even a relatively short one (Wainwright et al. 2013).

8. Additional Challenges to Interstellar Panspermia

An obvious problem with appeals to interstellar panspermia is that it simply shifts the burden of explaining the naturalistic origin of life from Earth to some other planet orbiting some other star. The thirty-three astrobiologists who attempted to get around this problem did so by depending on two speculations. First, they asserted that the spacetime theorems and the big bang origin model must be incorrect. Both, they declare, must be replaced by some kind of quasi-steady-state cosmic (QSSC) model (Hoyle et al. 2000; Narlikar et al. 2003, 2007). Such models would allow infinite time for life to evolve from prebiotic chemicals. Second, they assert as fact the claim that "hundreds of billions of habitable planets exist in the [Milky Way] galaxy alone" (Steele et al. 2018, p. 5).

These astrobiologists are to be commended for acknowledging that only through a denial of decades of research findings about the origin and history of the universe—as well as long-standing biblical statements (Ross 2023)—can a naturalistic model for the origin and history of Earth's life be defended. However, as much as these astrobiologists favor alternatives to the big bang creation model and the spacetime theorems, the experimental and observational evidence sustaining them still stands strong in the face of thorough testing (Ross 2018). Likewise, the observational case against the QSSC model in all its modifications remains both overwhelming and pervasive.

According to the QSSC models, the spectral redshifts of quasars fail to establish their great distances. Until recently, this negative assertion could not be refuted by the direct trigonometric-distance-measuring methods used by surveyors to determine the distances and heights of buildings and mountains or by astronomers to determine the distances to nearby stars. However, by exploiting an intercontinental array of radio telescopes that yield the resolving power of an 8000 km diameter telescope, astronomers were able to achieve a direct distance measurement showing that the quasar 3C 279 must be at least 5.9 billion light years away (Homan and Wardle 2000). By use of this same technique, astronomers now confirm that the spectral redshifts of galaxies as far as 460 million light years away do, indeed, accurately indicate their distances (Kuo et al. 2013).

If the QSSC models were accurately describing cosmic reality, at least some of the spectra of quasars should be blue-shifted. Astronomers observe only redshifts, and the quasar redshifts always are proportional to their distances. The QSSC models also contradict the cosmic microwave background radiation (CMBR) evidence showing that the big bang creation event occurred only 13.8 billion years ago. By contrast, the QSSC models assert that there is enough dust in the universe to explain CMBR maps without a relatively recent big

bang. However, observations now establish that the quantity of intergalactic dust amounts to 100–125 times less than the minimum required by QSSC models (Thacker et al. 2013).

9. Number of Habitable Planets in the Milky Way Galaxy

Two teams of astrobiologists have calculated that there could be as many as 40 or 45.5 billion habitable planets in our galaxy (Guo et al. 2009; Petigura et al. 2013), a number shy of the QSSC's hundreds of billions. These numbers shrink still further if various habitability criteria are applied. The estimate of 40 or 45.5 billion habitable planets took into account nothing more than the possibility of a planet's orbiting a star in the zone where liquid water could conceivably exist on some part of the planet's surface for a limited time—"the liquid water habitable zone." It also included all host stars as candidates, regardless of their mass, age, and composition.

The liquid water planetary habitable zone was the first planetary habitable zone to be described by astronomers. Today, astronomers are aware of at least thirteen distinct planetary habitable zones (Ross 2016, pp. 81–93; 2019a, 2019b, 2022, pp. 132–81; Green et al. 2020). For a planet to be truly habitable, it must simultaneously reside in *all* the known planetary habitable zones. Of the 5369 planets that astronomers have discovered thus far and for which orbital features have been determined (Exoplanet TEAM 2023), only one (Earth) is known to reside simultaneously in even three of the thirteen known planetary habitable zones—the same one that resides in all thirteen such zones—not to mention in all the known galactic and intergalactic habitable zones as well (Lineweaver et al. 2004; Spitoni et al. 2017; Ross 2022, pp. 55–90).

10. Directed Panspermia Model

In 1999, the conference of the International Society for the Study of the Origin of Life (ISSOL), a triennial gathering of 300+ researchers, ended with a dramatic summation, but not by one of the official ISSOL speakers (Rana and Ross 1999). A conference participant stepped to the open microphone to offer his overview of the week's presentations. He noted that during the first day of the conference, Earth had been eliminated as the location where life originated. During the second day, Mars was eliminated. During the third day, the remainder of solar system bodies were ruled out. During the fourth day, interstellar panspermia was tossed out. The only possible explanation remaining, he said, was that an intelligent civilization from another planetary system must have sent a spaceship to Earth 3.8 billion years ago for the purpose of planting life on Earth.

This research scholar explained that his "directed panspermia" proposal was not a new one, nor was it original to him. None other than Nobel laureate chemist Francis Crick and famed origin-of-life researcher Leslie Orgel (present at the conference) had made such a proposal in 1973 (Crick and Orgel 1973). The directed panspermia model, said the speaker, held the advantage of explaining other events in the history of Earth's life that have proven intractable for all naturalistic models, events such as the Avalon and Cambrian explosions and other mass speciation events that occurred startingly soon after mass extinction events. He went on to propose that intelligent aliens visited Earth not only once but, rather, must have returned to Earth multiple times to rescue Earth from total extinction and to ensure life's steady progression from primitive to more advanced forms. With that comment, the man left the microphone and the conference was over.

The directed panspermia model he summarized clearly acknowledges the physical and chemical impossibility that life could have arisen on Earth apart from intelligent input. It frankly admits that the existence of life on Earth requires capable, intentional—thus personal—agency.

The model, however, suffers from several devastating flaws. First, it is not possible for physical intelligent aliens with advanced technology to have existed in the universe 3.8 billion years ago, or even 0.54 billion years ago (Snyder-Beattie et al. 2021; Song and Gao 2022). For such beings to exist and develop advanced technology, they would have had to be living on a planet with strong, enduring plate tectonics and a strong, enduring

magnetosphere. They also would have needed to live on a planet orbiting a star virtually identical to the Sun, and that star would need to be close to 4.57 billion years old (Katsova et al. 2016; Carlos et al. 2019; Reinhold et al. 2020; Zhang et al. 2020; Johnstone et al. 2021).

For these conditions to have been met, the host planet would have required an exceptionally high accretional heat (Labrosse 2015). That accretional heat would need to have been as great as what Earth gained from its collision (during its infancy) with the solar system's fifth rocky planet, Theia (Canup 2012; Wang and Jacobsen 2016; Steenstra et al. 2020). This interior planetary accretional heat by itself would not have been sufficient. It would have required precise augmentation by heat from the radioactive decay of a superabundant supply of thorium and uranium. To obtain this superabundance, the host planet would need to have formed when the cosmic supply of uranium and thorium peaked. That peak occurred when the universe was about 9 billion years old (see Figure 1).

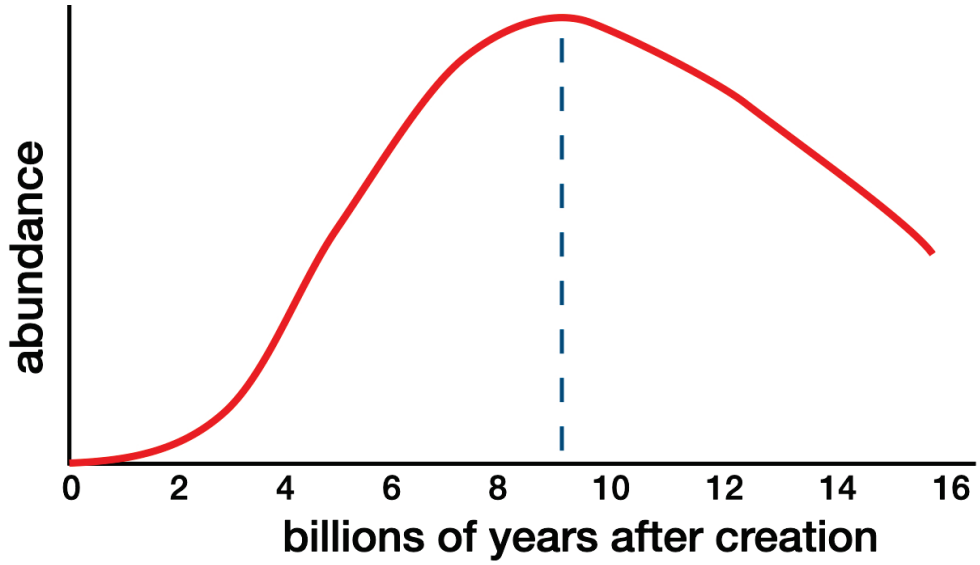

Figure 1. Abundance of Uranium and Thorium Throughout Cosmic History. Uranium and thorium are exclusively manufactured during supernova eruption events and merger events of neutron stars. As the universe expands and stars disperse, these events become progressively less frequent. Meanwhile, thorium-232, uranium-235, and uranium-238 decay with half-lives of 14.05, 0.704, and 4.468 billion years, respectively. Consequently, the concentration of uranium and thorium builds up during the first several billion years of cosmic history when star formation rates are high. Later, when star formation rates decline, the radioactive decay of uranium and thorium supersedes the production of uranium and thorium from supernova eruptions and mergers of neutron stars. One reason why Earth has such an enormous concentration of uranium and thorium is that it formed when the cosmic abundance of uranium and thorium had peaked (Yungelson and Livio 2000; Kobayashi and Nomoto 2009; Spina et al. 2016; Tsujimoto 2023). Diagram credit: Hugh Ross.

Our star, the Sun, has the lowest flaring activity level and the greatest luminosity stability among all known stars (Maehara et al. 2012, 2015; Reinhold et al. 2020; Zhang et al. 2020). However, during the Sun's history, this low flaring activity level and luminosity stability were lacking and will be lacking again in the future. Any star hosting a planet on which intelligent life has been able to launch and sustain high-technology civilization must be just like the Sun—with extreme luminosity stability and a very low level of flaring activity.

Figure 2 shows the Sun's past and present flaring activity levels and its future flaring activity levels, as determined from observations of the most Sun-like stars spanning ages from 0.1 to 9.0 billion years. Only when the Sun is about 4.57 billion years old is its flaring activity sufficiently low to permit the emergence of high-technology civilization.

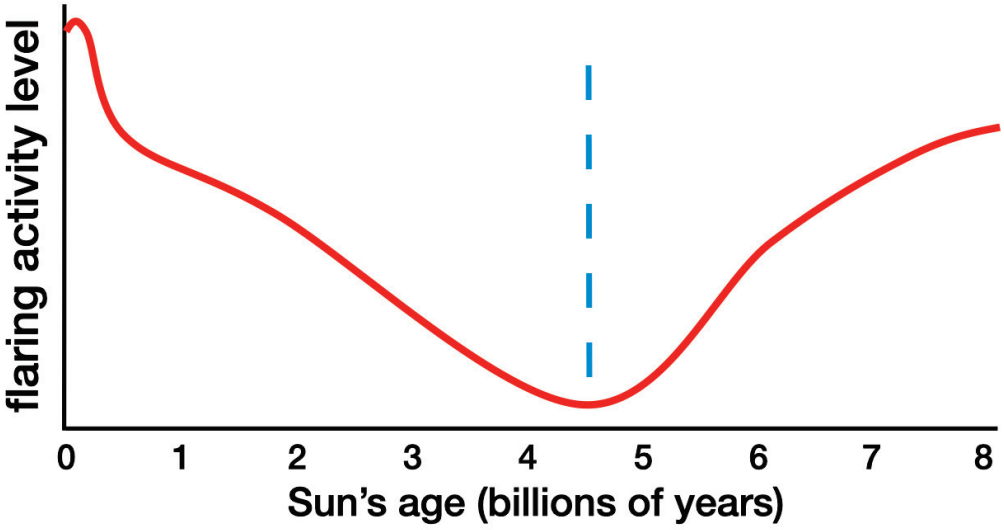

Figure 2. Sun's Flaring Activity and X-ray Radiation Levels Throughout Its History (Maehara et al. 2012, 2015; Notsu et al. 2013, 2019; Shibayama et al. 2013; Metcalfe 2018; Reinhold et al. 2020; Zhang et al. 2020). The *y*-axis is logarithmic. The dotted line indicates the present. During its first half-billion years, the Sun's flaring activity levels were more than 10,000 times greater than its present level. The Sun's intensity of particle radiation, gamma-ray, X-ray, and ultraviolet emission strongly correlates with its flaring activity level. Only for stars that are virtually identical to the Sun and about 4.57 billion years old is global high-technology civilization possible on one of its planets. Diagram credit: Hugh Ross.

The date for the peak cosmic abundance of uranium and thorium (plus 4.57 billion years) adds up to about 13.8 billion years. Therefore, while it is theoretically conceivable that other physical, extraterrestrial intelligent life could exist in the universe, that life could not predate us to any significant degree. It is wholly infeasible to suggest that physical intelligent aliens from another planetary system might have seeded life on Earth 3.8 billion years ago or seeded the Cambrian explosion 0.54 billion years ago.

As a second consideration, the laws of physics and the radiation, particles, gas, and dust in interstellar space present a huge challenge to the successful flight of spaceships across interstellar space. The damage to interstellar spacecraft from interstellar radiation, particles, gas, and dust increases with the square of the spacecraft's velocity. It also increases with the square of the spacecraft's cross-section. For these reasons, researchers intending to send spacecraft to the nearest planet outside our solar system, a planet only 4.25 light years away, recognize that spacecraft larger than 10 cm across and traveling at a fifth the velocity of light cannot survive the journey (Hoang et al. 2017). Thus, the latest plan calls for sending a thousand spacecraft, all much smaller than 10 cm across, at a tenth light's velocity (Clery 2016). Even so, more than half the spacecraft will most likely be inoperable on arrival and the other half, only partly operable. Clearly, no living organism, seed, or spore could survive the trip.

A third fatal flaw for directed panspermia is that the home planet for extraterrestrial physical intelligent aliens is either impossibly distant or non-existent. Astronomers have yet to discover a star that is sufficiently identical to the Sun such that it could be a candidate to host a planet on which intelligent physical beings can exist and develop a technologically advanced civilization. As noted already, the habitability requirements for a planet capable of hosting intelligent life are numerous. So far, everywhere astronomers have searched in our galaxy and the universe, they see only conditions hostile to intelligent physical life. At best, a planet capable of hosting extraterrestrial intelligent beings who have successfully launched high-technology civilization must be so distant—more than 10,000 light years away—as to make a life-seeding mission to Earth exceedingly impractical.

A remaining major problem with the directed panspermia model is the origin of extraterrestrial intelligent beings. Explaining the origin of an intelligent species bound by the laws of physics on some distant planet presents a challenge as big, if not bigger than, explaining life's origin on Earth.

It appears, therefore, that the origin of life on Earth should be sought within Earth's confines. It appears, too, that the cause or originator must be someone who is not constrained by the laws of physics governing the universe or by the universe's spacetime dimensions.

11. Process Structuralism

There is a growing acknowledgment among some evolutionary biologists that natural selection, mutations, gene exchange, and epigenetics are inadequate to explain the fossil record and the history of Earth's life. This recognition has given rise to a school of biological theory known as process, or biological, structuralism.

Process structuralists argue that there must exist one or more hidden natural physical or chemical forces in addition to natural selection, mutations, gene exchange, and epigenetics that shape and direct the development and the appearance of new species of plants and animals (Goodwin 2001; Morris 2003; Denton 2013). They also assert that these hidden forces play a more dominant role in the history of Earth's life than natural selection, mutations, gene exchange, and epigenetics. These forces, they claim, embody self-organizing principles that impact biological development in a major way.

Process structuralists cite the Avalon and Cambrian explosions of life and the mass speciation events that quickly follow mass extinction events as evidence for their hypothesis. They point out that the four known naturalistic mechanisms for generating change in life forms all make relatively small stepwise changes. Consequently, these four mechanisms all require long time periods and relatively stable or very gradually altering environments to produce significant change.

The known natural mechanisms predict a bottom-up development of taxonomic hierarchy (Ridley 1996; Schwartz 1999; Futuyma 2005). That is, the four known natural processes over time will first produce a proliferation of species, which, in much more time, will produce a proliferation of genera. The proliferation of genera will, eventually, produce new families. The proliferation of families over still more time will yield new orders. New orders will produce new classes, and, last of all, new phyla may be expected to appear.

The problem with the predicted bottom-up taxonomic development is that the fossil record of the Cambrian explosion reveals the opposite. As paleontologists have observed with respect to this explosion, "The major pulse of diversification of phyla occurs before that of classes, classes before that of orders, and orders before that of families" (Erwin et al. 1987).

The Cambrian explosion refers to the sudden appearance some 538.79 ± 0.21 million years ago (Linnemann et al. 2019) of animals with digestive tracts, circulatory systems, and skeletons, as well as internal and external organs. These animals require a minimum atmospheric oxygen level of 10%, and they appear in the fossil record at the geological moment this essential level is reached (Tatzel et al. 2017; Ye et al. 2020; Ross 2023).

The Cambrian phyla do not appear in a time-separated sequence of increasing complexity. The most advanced phylum, chordata, the phylum to which humans and all vertebrates belong, appears at the same time as the most primitive Cambrian phyla. It is the early, not the middle or the end, portion of the Cambrian Period. Furthermore, it is not just the non-vertebrate chordates that appear at the beginning of the Cambrian. Vertebrate fish also appear at that time (Hou et al. 2002; Shu et al. 2003; Morris and Caron 2014).

The problem with process structuralists' appeals to hidden natural self-organizing forces to explain the Avalon and Cambrian explosions is that the changes being attributed to such forces are far from trivial. They are, in fact, predominant. These proposed forces would be playing such dominant roles that it seems inconceivable that today's community of research scientists would have missed uncovering and identifying them if indeed such

forces are strictly natural. As paleontologists Kevin Peterson, Michael Dietrich, and Mark McPeek state in a review paper on the Cambrian explosion, "Elucidating the materialistic basis for the Cambrian explosion has become more elusive, not less, the more we know about the event itself" (Peterson et al. 2009). They are not alone among paleontologists in drawing such a conclusion (Wray 1992; Levinton 2008).

12. God-of-the-Gaps?

Ongoing scientific research has provided natural explanations for what many scientists in the past insisted were examples of God's supernatural interventions. It does not necessarily follow, however, that all scientific knowledge and understanding gaps will be answered by natural explanations.

In addition to God-of-the-gaps appeals, there are naturalism-of-the-gaps appeals. Gaps in our knowledge and understanding can never be totally eliminated. They can, however, be made smaller, less numerous, and less problematic. They also can become larger, more numerous, and more problematic.

What happens to the gaps, in light of more extensive research, determines whether or not we are on the pathway toward more comprehensive and detailed knowledge and understanding. What happens to the gaps will help better define where natural explanations and supernatural explanations best apply.

13. Biblical Approach to Researching the Origin and History of Life

The Bible offers a straightforward explanation for the "process structuralist forces" hidden from scientists. The process structuralists are correct that natural selection, mutations, gene exchange, and epigenetics remain inadequate to explain the history of Earth's life. They are correct, also, in noting that these four mechanisms play only partial, relatively minor, roles in explaining Earth's life history. However, the hidden self-organizing principles responsible for most of the changes in Earth's life over time are unlikely to be natural processes. If they were, it is difficult to imagine how they could be hidden from direct scientific investigation. More probably, they are not merely natural processes.

On the Bible's first page, we see a straightforward account of how life on Earth changed from primitive to progressively more advanced. For six creation "days," God intervened supernaturally within the laws of physics or through supernaturally or naturally guided physical processes to alter Earth's environment. During those days, he filled it with progressively more advanced life forms, either through supernatural acts transcending the laws of physics, supernatural acts within the laws of physics, or supernaturally or naturally guided physical processes. On the seventh day, God ceased his work of physical creation activity.

The description for each of the six creation days ends with the statement that reads in literal Hebrew: "evening was and morning was, day [X]." The Hebrew word for day, *yôm*, has at least four distinct definitions: part of the daylight hours, all the daylight hours, a calendar day of 24 h, and a long, finite time period (Brown et al. 1906, pp. 398–401; Harris et al. 1980, pp. 370–71). The Hebrew word for evening, *'ereb*, has alternate definitions of sunset or night (Brown et al. 1906, pp. 787–88; Harris et al. 1980, p. 694). The Hebrew word for morning, *boqer*, has alternate definitions of dawn, coming of dawn, end of darkness, or beginning of day (Brown et al. 1906, pp. 133–34; Harris et al. 1980, p. 125). Whichever definitions for *yôm*, *'ereb*, and *boqer* apply, the phrase "evening was and morning was, day [X]" infer that each of the six creation days had a start time and an end time within Earth's history. For the seventh day, the "evening and morning" phrase is absent. Its omission suggests that while the seventh day began, it has not yet ended. Rather, it continues. Both Psalm 95:8–11 and Hebrews 4:1–11 affirm this inference.

The cessation of God's creation work during the seventh day answers the fossil record enigma. It explains why naturalistic processes explain everything we see occurring in the life and physical sciences during the human era. It implies something more had to be going on during the eras predating humanity. God's supernatural interventions to

fill Earth with an abundance and diversity of life forms explain why scientists have been unable to identify current natural processes capable, by themselves, of explaining the origin of life, the increasing complexity of life, or such fossil record events as the Avalon and Cambrian explosions and other mass speciation following mass extinction events. God's supernatural interventions in the history of Earth's life leading up to the creation of the first humans—the re-creations mentioned in Psalm 104:29–30—also explain why new life forms that replace extinct life forms continually and perfectly compensate for the Sun's ongoing brightening by 19–23% over the past 3.8 billion years (Goldblatt and Zahnle 2011; Ross 2016, pp. 143–64).

Taking into account the possibility of both natural and supernatural causes for the origin and history of Earth's life, rather than limiting science to natural causes alone, avoids several conflicts with the thermodynamic properties of the universe and stars. Living organisms avoid the tendency of the second law of thermodynamics to generate increasing disorder and loss of complexity through an organized system of molecular machines, akin to how the machines in a factory locally decrease entropy by externally increasing entropy. Such avoidance is challenging for the assembly of simple prebiotic molecules into living organisms, since there are no pre-existing machines. Appeals to external energy sources such as the universe or the Sun face the difficulty that these sources are highly entropic. While the mechanical efficiencies of a diesel engine and the human body are about 40% and 1%, respectively, the mechanical efficiencies of the Sun and the universe are only about 0.00001% and 0.000000001%, respectively (Egan and Lineweaver 2010; Pavón and Radicella 2013; Spada et al. 2018; Valentim and Jesus 2020).

It is philosophically unrealistic and unnecessary to demand that all scientists performing research on the origin and history of life adopt a biblical worldview in conducting their research. However, scientists of all worldviews can and should participate in the endeavor to help establish the boundaries between unguided natural causation and supernatural guidance and/or causation, with the vitally important caveat that scientists can no longer pretend that no such boundaries exist. Some scientists in interpreting the data may tend to push the boundaries more firmly toward supernatural causation, while others will tend to pull the boundaries more toward natural causation.

Through this give-and-take endeavor along with careful, pervasive testing of competing models through ongoing experiments and observations, the boundaries between supernatural and natural causes are most likely to become more clearly defined. Through this approach, science and theology can most efficiently and rapidly advance. Once again, as was the case during the first two centuries of the Reformation and Counter-Reformation, scientists and theologians can become allies rather than enemies in the quest for a fuller understanding of reality.

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Article

Robert Boyle, the Bible, and Natural Philosophy

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Abstract: The great chemist Robert Boyle was also a serious student of the Bible and Christian theology, both of which profoundly influenced his natural philosophy. Christian beliefs and moral attitudes motivated him to extend human dominion over the creation by advancing scientific knowledge and giving medicines from his laboratory to the poor. His outspoken advocacy of empiricism, over and against those who believed that unaided reason was sufficient to probe the depths of nature, was rooted in the conviction that the free, wise, and powerful Creator knows the creation far better than we creatures ever will. He vigorously promoted what he called "the mechanical philosophy", partly because he found it far more theologically attractive than the pagan Greek conception taught in the universities, which conceived of "Nature" as a semi-divine being with a mind and powers of its own. It also underscored the great complexity of the world machine, requiring an intelligent Creator to have assembled it—thereby (he hoped) moving people not only to acknowledge God but to live piously and humbly.

Keywords: Robert Boyle; voluntarism; mechanical philosophy; intelligent design; piety; philosophy of science; accommodation

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1. Introduction

Few natural philosophers influenced the rise of modern science more than Robert Boyle. Usually associated today with a universal law about gases bearing his name, he neither discovered it nor claimed ownership, and he did not express it algebraically or even view it as valid under all conditions. Rather, he published in tabular form his carefully obtained data showing that pressure and volume of atmospheric air (not some theoretical ideal gas) are inversely related within the limits of his ability to test it, confirming (and crediting) Richard Townley's unpublished conjecture (*Works*, 3: 57–65; cf. MacIntosh 2020, pp. 99, 122–24). That major experiment earned Boyle more than a footnote in the history of science, but his most important contributions lay elsewhere. A superb experimentalist and diligent collector of information about many aspects of nature, Boyle did as much as anyone else to create the modern laboratory, the methods it employs, and the scientific papers it produces. His publications were read throughout Europe and in parts of North America because the subtlety and precision of his work were matched only by the range of his knowledge and the honesty and clarity of his reports. In short, Boyle showed the world how science ought to be done: we might even say that his most important discovery was the activity of science itself.

At the same time, Boyle also wrote extensively and thoughtfully about philosophy of science, piety, morality, theology, the Bible, and the relationship between science and religion. Attitudes and ideas inspired by Scripture and Christian beliefs shaped his understanding of how scientific knowledge should be obtained, the limits of that knowledge, and how it ought to be used. Claims about Christian beliefs playing a constructive role in the history of science were viewed with much suspicion more than forty years ago when my doctoral work began. The situation was not without irony. My advisor's first book was called *Science and Religion in Seventeenth-Century England*, another member of my doctoral committee later wrote a book arguing that medieval theologians nourished natural philosophy in the universities, and a third member was a leading authority on the

Reformation (Westfall 1958; Grant 2004; Strauss 1978). Nevertheless, when I proposed a dissertation about the influence of theological beliefs on conceptions of scientific knowledge in the Scientific Revolution, I was told it might make a good thesis in religion, but not in the history of science. After I cited similar ideas from Alexandre Koyré, Edwin Arthur Burtt, and other canonical authors in the discipline, they reconsidered.

What made that conversation necessary? The History of Science Society and its two journals, *Isis* and *Osiris*, had been started before the Great War by Harvard scholar George Sarton, who regarded the positivistic philosopher August Comte as the real founder of his new academic discipline. In the inaugural issue of *Isis*, Sarton named Andrew Dickson White—the most influential proponent of the "Conflict" view of the history of Christianity and science, though he had many predecessors in Europe and America—as the source of a central idea in Sarton's vision for the history of science. "The interactions between science and religion have often had an aggressive character", Sarton wrote. "There has been most of the time a real warfare. But as a matter of fact it is not a warfare between science and religion—there can be no warfare between them—but between science and theology" (Sarton 1913, pp. 330, 339; see Ungureanu 2019, pp. 250–54). Sarton's attitude, inspired by Comte and White, ruled the history of science largely unchallenged for much of the last century.

Although there had been dissenting voices all along, systematic deconstruction of White's false narrative of inevitable conflict between Christian theology and science did not really get underway until the 1970s and did not gather much steam until the 1980s. More recently, a parallel phenomenon to reverse a similar unhistorical secularization of the past has emerged in religious history and the history of ideas more generally (Coffey and Chapman 2009; Gregory 2009; Muller 2009; Firestone and Jacobs 2012). Today almost all historians of science reject the "Conflict" thesis as woefully unreliable, ideologically motivated garbage that tells us far more about White and Sarton as historical actors themselves than about the history they purported to relate. David C. Lindberg and Ronald L. Numbers, early advocates of the need to jettison the "Conflict" thesis, put it no less bluntly. "For more than a century historians of Christianity and science like White have wasted their time and dissipated their energies attempting to identify villains and victims, often with polemical or apologetic intent and always within a framework heavily laden with values" (Lindberg and Numbers 1987, p. 148). So far, no single, simple alternative has yet emerged to replace the conflict thesis. What Numbers and many others are now calling the "complexity thesis" is probably the best candidate. According to John Hedley Brooke, "Serious scholarship in the history of science has revealed so extraordinarily rich and complex a relationship between science and religion in the past that general theses are difficult to sustain. The real lesson turns out to be the complexity" (Brooke 1991, p. 5).

Showing much historical insight, Brooke identified a few "levels on which statements about nature and statements about God have coexisted". Religious beliefs have presupposed the uniformity and intelligibility of nature, sanctioned or justified scientific activity, motivated individual scientists, and influenced theory selection and views of scientific methodology—and sometimes offered theological explanations for otherwise inexplicable events that proved superfluous when science advanced (Brooke 1991, pp. 18–33, quoting 18–19). Table 1 summarizes most of these relations.

Table 1. How Religious Beliefs Can Influence Science (adapted from Davis 1999).

Why can science be done? (Why is a science of nature possible?)	The possibility question
Why should science be done?	The morality/motivation/justification question
How should science be done?	The methodology/epistemology question
What **sorts** of theories are acceptable?	The regulative question

Although these are not necessarily religious questions, scientists' answers often reflect religious or metaphysical beliefs, as well as philosophical beliefs about the nature of scientific knowledge. For example, Michael Faraday's Christian faith drove his search for the unity of forces in the universe, answering both the motivation and regulative questions. According to biographer L. Pearce Williams, his faith "gave him both a sense of the necessary unity of the universe derived from the unity and benevolence of its Creator and a profound sense of the fallibility of man". Furthermore, "the speculations and imaginings which led him to the experiments and the courage which permitted him to publish physical heresies owe something to his unquestioning belief in the unity and interconnections of all phenomena. This belief, in turn, derived from his faith in God as both creator and sustainer of the universe" (Williams 1970, p. 527). Robert Merton's famous thesis about the formative influence of the "Puritan ethos" on science in early modern England—ironically written and published under Sarton's sceptical supervision—answers the justification question: why was science worth doing? (Merton 1938). Interactions such as these are hardly surprising, especially during the Scientific Revolution. At that time, as Margaret Osler said, "the roots of European intellectual life grew from the seeds planted by both the biblical religions and the ancient Greeks". The former "emphasized the unrestrained will of an all-powerful God, while the Greek approach emphasized a world ruled by impersonal principles of unity and harmony" (Osler 2010, p. 1; cf. Hooykaas 1972; Davis 1984). In such a milieu, it seems almost inevitable that religious beliefs would shape science in important ways. For Boyle, as we shall see, biblically grounded attitudes and beliefs interacted with his scientific work mainly on the lower three levels in the diagram.

2. Boyle and the Bible

Following an intense encounter with God as an adolescent, Boyle vowed to live piously. According to some of his closest friends, he took that vow very seriously. His bearing, actions, and speech reflected a deep sense of God's immediate presence. He revered the Bible, which he studied not only alone but also sometimes in the company of his sisters, Katherine Jones and Mary Rich, both of whom were stuck in bad marriages (Davis 2007). From his own experience, he commended "daily and orderly" reading of "some set Portion or Chapters of the Bible", even passages that at first "we Understand not", committing them to memory "till our Understandings be grown up" (*Works*, 2: 442). Apart from his intense spiritual interest, he sought deep academic knowledge of the texts, perhaps ultimately owing to conversations with Jewish rabbis and scholars on the continent and in England, including the great Amsterdam rabbi Menasseh ben Israel who worked for the readmission of Jews to England; their interpretations of certain verses he found troublingly difficult to refute. Challenged by his father's close friend James Ussher to learn the biblical languages, he did, partly by studying with a rabbi, to such an extent that he could quote the Greek from memory and wrote his own Hebrew grammar (Hunter 2009, pp. 80–85). Out of a desire to evangelize the world, he underwrote or otherwise aided the preparation or publication of translations of the gospels, the New Testament, or the whole Bible into Gaelic, Irish, Lithuanian, Malay, Turkish, and Algonquian—this last project the famous work of John Eliot.

Theology was another keen interest. He spent his early teenage years with his older brother Francis in Geneva, under the tutelage of Isaac Marcombes, a Huguenot refugee related by marriage to the eloquent preacher and Bible translator Jean Diodati, a Calvinist theologian who helped write the Canons of Dordt, whom Boyle met. Marcombes guided the boys through both biblical testaments and Calvin's catechism, while saying prayers twice a day and attending church twice a week (Hunter 2009, pp. 44–47). As an adult, Boyle was very well-read in theology, especially Socinianism (which he opposed) and controversies over free will and predestination where he was ultimately content to leave the matter unresolved with an eye on God's sovereignty and superior knowledge. Indeed, he often functioned as a lay theologian, writing roughly one million words on biblical and theological topics, including natural theology, large parts of which were published in his

lifetime and much of the rest subsequently. However, he was typically careful to avoid committing himself to specific theological views that were contested among Christians. Contrary to what is sometimes said, there is no clear evidence that Boyle saw himself as a Calvinist, or even that Reformed theology *per se* influenced his natural philosophy (Anstey 2000).

A sophisticated reader of Scripture, Boyle did not regard the Bible as a scientific text and never used it that way. For example, his two large books containing experiments on light, colours, and cold—around a quarter million words altogether—include a grand total of just two biblical references. One mentions God's curse on Ham in Genesis 9: 25, a passage pertinent to his discussion of the dark complexion of sub-Saharan Africans. There Boyle rejected the traditional interpretation, "that the Curse meant by *Noah* to *Cham*, was the Blackness of his Posterity" (*Works*, 4: 89; in all quotations the original spelling, punctuation, and italics are retained). The word "God" appears just eight times in those two books, only once (in the place just mentioned) in a scientific context. This was business as usual in natural philosophy. For example, the first edition of Newton's *Philosophiae Naturalis Principia Mathematica* (1687) has just two references to "God", one of which disappeared in the second edition (1713) when the passage was reworded. Only in the "General Scholium" added to the second edition, an explicitly theological essay containing no mathematics, did Newton frequently mention God and cite Scripture (Snobelen 2017). The implication that Boyle placed his scientific work in a different conceptual category from his biblical and theological work is borne out by several catalogues of his writings prepared for his own use either by his servants, or Henry Oldenburg, "as were mentioned to me by the Honourable Robert Boyle" (BP 36, fols. 88–89; *Works*, 14: 337–39). Titles are listed under different headings, "papers of Divinity", "theological", or "philosophical [scientific]" (MS 185, fols. 1v and 3; *Works*, 14: 345–46; BP 36, fol. 72; *Works*, 14: 351–52), or else assigned by category to different storage boxes without headings (BP 36, fols. 59–60, *Works*, 14: 341–42; BP 36, fols. 119–20, *Works*, 14: 343–44; BP 36, fol. 121; *Works*, 14: 349–50; and BP 36, fols. 122–23; *Works*, 14: 353–55).

Overall, Boyle endorsed the classic notion, at least as old as Basil and Augustine, that nature and Scripture are both harmonious divine revelations. According to a manuscript snippet, "Right Reason and Divine Revelation being both of them Emanations from the Father of Lights: there is no likelihood that they should contradict one another" (BP 1, fol. 86, transcribed long after Boyle's death by Henry Miles on BP 7, fol. 252). He also believed that biblical language was accommodated to popular speech and human ignorance, so it should not be placed in opposition to scientific facts (Clericuzio 2008). Although he did not identify specific sources for these ideas, he was well acquainted with Augustine and Calvin. The latter especially had used accommodation frequently, especially in his biblical commentaries, where he was quick to seek an alternate interpretation if the literal sense of a text conflicted with the science of his day. For example, Calvin thought it was "opposed to common sense, and quite incredible, that there should be waters above the heaven" on the second day of creation (Gen. 1: 6–7), as Basil, Luther, and many others had thought. In his view, those waters must be "such as the rude and unlearned" perceived; he thought they were clouds. "He who would learn astronomy, and other recondite arts, let him go elsewhere", for "the history of the creation . . . is the book of the unlearned". On the fourth day of creation, when God made "the greater light, to rule the day, and the lesser light to rule the night" (Gen. 1: 16), we must keep in mind "that Moses does not speak with philosophical acuteness on occult mysteries, but relates those things which are everywhere observed, even by the uncultivated, and which are in common use". The text is not about "how great the sun is in the heaven, and how great, or how little, is the moon; but how much light comes to us from them". Calvin knew that "astronomers prove, by conclusive reasons that the star of Saturn, which on account of its great distance, appears the least of all, is greater than the moon", but "Moses wrote in a popular style things which without instruction, all ordinary persons, endued with common sense, are able to understand". Perhaps the most interesting comments accompany David's reference to

"the deaf adder that stoppeth her ear; Which will not hearken to the voice of charmers" (Psalm 58: 4–5). Since Calvin did not accept the validity of snake charming, he concluded that "David here borrows his comparison from a popular and prevailing error" (Calvin 1578 at verses cited; cf. Hooykaas 1972, pp. 117–19). Since Calvin (and virtually all of his contemporaries) accepted the Ptolemaic astronomy taught in all the universities, he never applied accommodation to the biblical texts about the Sun, Earth and Moon that were later scrutinized in the introduction to Kepler's *Astronomia nova* (1609) or Galileo's *Letter to Christina* (circulated in 1615, but not published until 1636). Modern commentators typically point out that the language in those texts is no more unscientific than references today to the rising or setting sun, and that verses in poetic books should not be read literally anyway. At that time, however, the earth's motion lacked proof, while solid scientific arguments contradicted it (Graney 2015). Consequently, as Cardinal Roberto Bellarmino told the priest Paolo Foscarini, all ancient and modern commentators "agree in expounding literally that the sun is in the heavens and travels swiftly around the earth, while the earth is far from the heavens and remains motionless in the center of the world" (Drake 1957, p. 163). It took the acceptance of Copernican astronomy to alter the situation.

Since Boyle was a Copernican, he would surely have agreed with the need for figurative interpretations, whether or not he read those two particular works by Kepler and Galileo (which he did not cite). He was in Florence when Galileo died and already realized the importance of his encounter with Rome (Hunter 1994, pp. 19–20). Although he did not apply accommodation to Joshua's prayer for the sun to stand still (the most famous text related to Copernican theory) in the two brief references to that passage in his published works, elsewhere he explicitly endorsed crucial components of the principle (*Works*, 5: 109–10 and 10: 529). In an early, unpublished "Essay of the Holy Scriptures", he said, "that God so condiscends to our inevitable Ignorance" (BP 7, fol. 9; *Works*, 13: 179). Therefore, as he stated in *The Excellency of Theology* (1674), we should not "deduce particular Theorems of Natural Philosophy from this or that Expression of a Book, that seems rather design'd to instruct us about Spiritual than Corporeal things", indeed "nobler and better Truths, than those of [natural] Philosophy". However, in the same passage, he rejected the "Opinion, that would so turn the first Chapters of *Genesis* into an Allegory, as to overthrow the Literal and Historical sense" (*Works*, 8: 21). In typical fashion, Boyle did not identify a specific target for this objection. Perhaps he was thinking of Calvin's rejection of Augustine's view that creation was instantaneous, and the creation "days" were literary devices, not ordinary days, an accommodation to our ignorance of the deeply mysterious creation process (Augustine 1982). Calvin "manifestly refuted" those "who maintain that the world was made in a moment. For it is too violent a cavil to contend that Moses distributes the work which God perfected at once into six days, for the mere purpose of conveying instruction. Let us rather conclude that God himself took the space of six days, for the purpose of accommodating his works to the capacity of men" (Calvin 1578). Regardless, Boyle believed we could learn the time, order, and "divers other Circumstances of the Manner, wherein the Fabrick of the World was compleated", only from revelation, "bare Reason being evidently unable to inform us of *Particulars* that preceded the Origine of the first Man". Where "those fabulous *Chaldeans* gave the age of the world as "up to 40,000 or 50,000 years", Boyle thought "the World is very far from being so old by 30 or 40 thousand years as they", no more than about 10,000 years old (*Works*, 8: 21). If he was thinking specifically of Ussher's number (4004 BC), he did not say. Apart from the account of creation, however, "in most other places of the Scripture, where the Works of Nature are mentioned but incidently, or in order to other purposes, they are spoken of rather in a Popular then Accurate manner", so the Bible should not be invoked "in the doubtful contentions of Naturalists, about such matters as may (though the History of the Creation cannot) be known by the meer Light of Natural Reason" (*Works*, 3: 219).

Of course, Boyle had no reason to doubt "the Literal and Historical sense" of the Genesis creation story, and no reason to think that very much could be known about the origin of the world and living things "by the meer Light of Natural Reason". Natural

history was not very advanced, knowledge of the ancient Near East and its literature was quite limited, and the Big Bang theory was still three hundred years down the road. There were no persuasive theories of biological, geological, or cosmological development, no one could read Egyptian hieroglyphics, and the Enûma Eliš and the Atrahasis Epic had not yet been discovered. For Boyle and most other early modern Christians, the world could not have been created in any other way than by the miraculous acts plainly narrated in Genesis. He also believed in miracles after the creation week, and that God still works miraculously all the time. In a manuscript from the 1680s not published until the twenty-first century, he wrote, "I do not deny but that there have been *Divine* Miracles properly so call'd. For I take the *Creation* of the *Rational Souls* that are daily United to Humane Embryo's to be a Work of an Almighty Power. And I take ‹also› the *Raising* of ‹*Jesus Christ* our *Saviour* & of› *Lazarus* from the *Dead*, to be Miracles of the same sort" (MS 198, fol. 22; MacIntosh 2005, p. 271; in quotations from manuscripts ‹angle brackets› surround words added above the line during revision). Not all miracles were of this type, however: his understanding of miracle texts was no less sophisticated than his handling of other biblical stories. In another manuscript from the same period, he confessed, "I am not ignorant that most men are wont to think, that *Miracles & Things contrary to the Laws of Nature* are of the same extent, & therefore they scruple not to employ those Terms promiscuously, as equivalent". Boyle thought that "they hereby confound Things that on divers occasions ought to be distinguish'd", since "there are divers Miraculous Operations recorded in the holy scripture, that are rather *Preternatural* or *Supernatural*, than (if I may so speak) *Contra-natural*". In his view, some miracles "were perform'd by the ‹direct or› immediate action of immaterial Spirits upon the Minds of Men", or by God himself, in ways that did not involve violations of natural law (MS 199, fol. 126v; MacIntosh 2005, p. 268). Although he did not believe that miracles proved God's existence, they had a crucial role in Boyle's apologetics—their sheer abundance in the New Testament, he believed, showed that Christianity was more likely to be true than Judaism, which had fewer miracles (*Works* 14: 253–54; MacIntosh 1994; MacIntosh 2005, pp. 200–15, 261–77, 301–15, and elsewhere; Davis 2020).

Nevertheless, Boyle rejected miracles in natural philosophy: there he accepted methodological naturalism. For example, the English Jesuit philosopher Francis Line sought to explain how a given quantity of air can expand without creating empty spaces between atoms, an idea that Line opposed. To preserve the Aristotelian principle that "nature abhors a vacuum", he proposed that God could give atoms a "virtual extension" by his absolute power, thereby filling thousands of times more space simply by increasing in size. Boyle replied,

> our Controversie is not what *God can do*, but about what can be done by *Natural Agents*, not elevated above the sphere of Nature. For though *God* can both create and annihilate, yet *Nature* can do neither: and in the judgment of true Philosophers I suppose our *Hypothesis* would need no other advantage to make it be preferred before our Adversaries, then that in ours things are explicated by the ordinary course of Nature, whereas in the other recourse must be had to miracles. (*Works* 3: 48)

Those "Schoolmen and Philosophers [who] have deriv'd [substantial] Forms immediately from God", Boyle protested in *The Origin of Forms and Qualities* (1666), have "put Omnipotence upon working I know not how many thousand Miracles every hour, to performe that (I mean the Generation of Bodies of new Denominations) in a supernatural way, which seems the most familiar effect of Nature in her ordinary course" (*Works* 5: 342). He responded similarly when Thomas Hobbes invoked God's absolute power in a discussion of the infinite divisibility of matter. "When Mr. *Hobbs* has recourse to what God *can* do, (whose Omnipotence we have both great reason to acknowledge) it imports not to the Controversie about Fluidity to determine what the Almighty Creator *can* do, but what he actually *has* done" (*Works* 3: 168).

Given that Boyle kept miracles out of his laboratory and maintained the age-old distinction between two divine revelations (nature and Scripture), where and how did science

meet biblical ideas? Mostly in his theological works, which did not report experimental results but often explored meta-level questions in natural philosophy. Many early modern natural philosophers engaged in serious theological speculation inspired by questions arising in natural philosophy, an activity that Amos Funkenstein called "secular theology" (Funkenstein 1986; cf. Davis 1984, 1999). They were doing what only professional theologians had been permitted to do in medieval universities. The arts masters who taught natural philosophy to undergraduates were forbidden from discussing theology (in most situations), but the theologians were free to discuss natural philosophy—as they often did (Grant 1996, pp. 174–76; Grant 2001, pp. 185–86). Galileo had this in mind, when in 1615 he told Monsignor Piero Dini, "Yet for all of me any discussion of the sacred Scripture might have lain dormant forever; no astronomer or scientist who remained within proper bounds has ever got into such things" (Drake 1957, p. 165). No other major early modern natural philosopher did secular theology more than Boyle, though Funkenstein mentions him only briefly, mostly in connection with his views on the plurality of worlds (Funkenstein 1986, pp. 192–94). In a full-length study of that topic, Steven J. Dick stated flatly that Boyle "did not specifically address himself to the question of other worlds", which indicates only that Dick did not realize how much attention Boyle gave to natural philosophical questions in his many theological works (Dick 1982, pp. 199–200, n18).

In fact, Boyle discussed multiple worlds—an early version of multiverse theory that he found plausible and attractive—in multiple places. He thought God might by his absolute power have made other worlds displaying his wisdom, circling other stars, that are very different from our world, having different arrangements of matter and laws of motion and therefore inhabited by creatures unlike the ones we know, with whom God might have different relations, perhaps even displaying divine attributes and excellencies unknown to us. We cannot deny that God could do such things (*Works*, 10: 162, 172–75, and 185–86; *Works*, 11: 122–23; *Works*, 12: 485 and 498). The bulk of that material is found in a treatise whose title indicates the theological context within which Boyle placed those ideas: *Of the High Veneration Man's Intellect owes to God; Peculiarly for His Wisedom and Power* (1685). The six paragraphs outlining his views on multiple worlds constitute two separate passages, each surrounded by square brackets. An advertisement at the front of the book advises readers that they "may with the Author's consent (or rather by his desire) be skip'd over; being but *Conjectural thoughts*, written and inserted for the sake of a *Virtuoso*, that is a great Friend to such kind of adventurous speculations" (*Works*, 10: 159). This almost certainly refers to his protégé David Abercromby, the Scottish physician and former Jesuit who in the 1680s translated *High Veneration* and four more books by Boyle into Latin (on Abercromby, see Davis 1994). The preface to the Latin edition, which bears the date 1684 and might therefore precede the English version, mentions "ideas scattered throughout with which the mind will not only be refreshed, but will also be rapt in wonder". Overriding Boyle's cautious attitude, Abercromby announced that Boyle "completely embraces certain subjects—the multiplicity of worlds, the creation of new creatures very different to those that now exist—which could fully satisfy even the most curious", admitting that he had "dared in this translation to act in one respect contrary to the author's opinion", by persuading Boyle not to omit those passages (*Works*, 10: 201–2). Nevertheless, the sheer joy and wonder Boyle displayed in contemplating the extent of God's creative power, even perhaps in worlds different from ours, was surely a powerful motive to study natural philosophy and to extend its explanatory scope to unknown realms.

Christian faith also provided other motives for doing natural philosophy. More than almost anything else, Boyle wanted people to serve others instead of their own pride and lusts. A lifelong desire to improve medicine and to make pharmaceuticals more widely available to the poor set the example. His very first publication, one of nine essays without the authors' names written for Samuel Hartlib, a disciple of the Czech educational reformer John Amos Comenius, was called "An Invitation to a free and generous Communication of Secrets and Receipts in Physick [medicine]". The opening paragraph did not pull theological punches. "Our Saviour assureth us, that it is more blessed to give than to

receive", so "the less selfish and mercenary our good actions are, the more we elevate our selves above our own, and the neerer we make our approximations to the perfections of the Divine nature". We all know "the strong obligation, that not charity onely, bare humanity layeth upon us to relieve the distresses of those, that derive their pedigree from the same father we are descended from, and are equal partakers with us, of the Image of that God, whose stamp we glory in" (*Works* 1: 3).

Boyle did what he could to follow through. According to the eyewitness testimony of the Florentine natural philosopher Lorenzo Magalotti, Boyle dispatched servants throughout London, bringing medicines from his laboratory, "helping poor epileptics with the comfort of very powerful remedies which they were accustomed continually to take with them for this very purpose alone" (*Correspondence*, 4: 266). We find extensive discussions of various treatments, including instructions for making and using medicinal substances, in both tomes of *Some Considerations touching the Usefulnesse of Experimental Naturall Philosophy* (1663–1664 and 1671). In the last decade of his life, Boyle expanded his reach to households throughout the English realm, especially settlers in New England, by publishing (at first for a limited private audience, but soon for wider circulation) recipes for fifty pharmaceuticals he believed to be efficacious. The original version was given for free "not only to physitians, & surgeons, but chiefly to divines & Ladyes, & other persons residing in the countrey that were wont out of charity to give medicins to the poor" (MS 186, fols. 119v-20; *Works*, 11: xxviii). Boyle's executor John Locke, who had studied and taught medicine at Oxford while Boyle was in residence there, was involved with publishing supplemental volumes after Boyle's death. Although there is no evidence of a direct influence, John Wesley's famous *Primitive Physick* (1747) is essentially the same thing, for the same charitable purpose.

According to Boyle's confessor Gilbert Burnet, who had substantial knowledge of his largesse, his donations sometimes exceeded GBP 1000 per year, at least one-third of his income, probably equivalent to several million dollars today. Burnet told the large crowd at Boyle's funeral that, "His Charity to those that were in Want" was "so very extraordinary", because "he considered himself as part of the Humane Nature, and as a Debtor to the whole Race of Men" (Hunter 1994, p. 20). This attitude arose from Boyle's Christian morality and strong sense of vocation, which were only enhanced by watching some of his older brothers violate their marriage vows and behave like wastrels. "A Convenient civil Calling" benefitting others, Boyle wrote before turning twenty-one, "is a sovveraigne Preservative agenst Idleness, (that mother of Vices) and an excellent prevention of a world of Idle, Melancholick and exorbitant thouhts, and un-warrantable Actions". One who lacks "som honest particular Calling" is "but an useless wastful Droane, and unworthy of the Benefits of Humane Society". The person who "make[s] Vacation his only Vocation, . . . must have a stronger Charity than Iudgement, that believes that God and Nature intended onely this for that man's Calling" (Boyle and Harwood 1991, pp. 85, 88).

The title of his largest single project, *The Usefulnesse of Experimental Naturall Philosophy*, declares a theme of great importance to Boyle for religious reasons. Taken together, its two long parts comprise about nine percent of his published work. Additional essays surviving only as Latin or English manuscripts that were originally intended for inclusion in the second tome would push the total word count past ten percent. The project's purpose, frequently stated in these or similar words, was "to advance the Empire of Man over other Creatures" (*Works*, 3: 193). The unpublished Latin essay on the usefulness of chemistry indicates that "creatures" included non-living created things, such as various forms of matter. It addresses how "the Empire of Man may be advanced by the skill of Physicists [or naturalists, *Physicorum*] in Chemical matters". Using "those arts by which Nature is more critically examined, such as geometry, mechanics, and those other parts of knowledge such as chemistry and trades", it was possible to "unfold Nature to us to her furthest extent, so she is stirred up, extended, and indeed finally subjected to man" (*Works*, 13: 321–22). The "Empire" references the mandate God gave humans in Gen. 1: 28, "Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth". With

Francis Bacon, Boyle thought the new post-Aristotelian science held the key to material and intellectual progress, enhancing our ability to obey this divine decree and therefore theologically superior to Greek science.

3. God and the Mechanical Philosophy

There were further theological reasons to jettison the Greek scientific legacy. Above all, the Aristotelian-Galenic conception of "Nature" as a wise, intelligent being—something not wholly unlike the modern Gaia hypothesis—was "prejudicial . . . to the Discovery of [God's] Works", because "the veneration, wherewith Men are imbued for what they call *Nature*, has been a discouraging impediment to the Empire of Man over the inferior Creatures of God", making it "something of *impious* to attempt, the removing of those Boundaries which *Nature* seems to have put and setled among her Productions. And whilst they look upon her as such a venerable thing, some make a kind of scruple of Conscience, to endeavour so to emulate any of her Works, as to excel them" (*Works*, 10: 450). However, the mechanistic alternative he favoured had a checkered history. Atomism in the ancient world, as taught by Leucippus, his student Democritus, and Epicurus, was associated with an atheistic philosophy in which "chance" rather than purpose reigned supreme, human souls disintegrated at death, and no role was allowed for any gods. Our universe, only the latest in an infinite series of worlds, was a chaos of uncreated atoms, moving randomly in an infinite space, blundering into one another from time to time to form larger bodies, including even the bodies of living things. Fortunately for Boyle, the French priest and theologian Pierre Gassendi had carefully cleansed atomism of its irreligious ties: matter and the laws of nature had been freely created by an omnipotent Creator whose actions were not bound by his creation (Osler 1992). The physician Walter Charleton adapted and popularized Gassendi's ideas in England. From reading both authors, Boyle concluded that Gassendi's position was solid biblical theology. For example, the axiom in natural philosophy, that necessary causes always do what they can, did not mean "that the Fire must necessarily burn *Daniel's* three Companions or their Cloaths, that were cast by the *Babylonian* King's Command into the midst of a Burning fiery Furnace, when the Author of Nature was pleas'd to withdraw his Concourse to the Operation of the flames, or supernaturally to defend against them the Bodies that were exposed to them" (*Works*, 8: 252). Passages such as this display Boyle's theological voluntarism, an emphasis on God's freedom in creating the universe and working within it now, unconstrained by our limited knowledge of God's purposes. This too was part of Gassendi's legacy, alongside nominalism, empiricism, and a love for design arguments—a combination that went together logically (Osler 1992, pp. 181–82).

As Dmitri Levitin has shown, initially Boyle accepted Gassendi's picture of Epicurus as an empirically oriented atomist, over and against the speculative Aristotle, as seen in "Of the Atomicall Philosophy" (*Works* 13: 227–35), an incomplete manuscript from the early 1650s. He also embraced Gassendi's peculiar view that Aristotle believed in a world soul (*anima mundi*). However, within a few years, Boyle and others involved with the early Royal Society came increasingly to view Epicurean atomism as dogmatic, reductionistic and no less speculative than Aristotelianism. Influenced by the German physician and chymist Daniel Sennert, Boyle became persuaded that there had been pre-Aristotelian proponents of a "corpuscularian", not necessarily atomistic theory that was more compatible with his own laboratory work. Then (as we shall see) he went even further, constructing a *theological* critique of both Epicurean and Aristotelian notions in his great treatise on God and the mechanical philosophy, *A Free Enquiry Into the Vulgarly Receiv'd Notion of Nature*, which he started writing in 1666 but did not finish until shortly before its publication twenty years later (Levitin 2014; Hunter and Davis 2007).

We have already seen Boyle's voluntaristic affirmation of God's freedom to create multiple worlds with different natural laws. We find a similar attitude in an unpublished Appendix to his treatise on final causes. "The Primordial System of the Universe" was

> arbitrarily Establish'd by God. Not that he created things without accompanying, and as it were regulating, his Omnipotence, by his boundless Wisdom; and consequently did nothing without weighty reasons: but because those reasons are *à Priori* undiscoverable by us: such as are the number of the fixt Stars; the collocation as well as number of the Planetary Globes; the Lines and Periods of their Motions; the Gyration of Jupiter and Mars about their Centers, compard with the Libration of the Moon; the paucity of Stars near the Antartick Pole; the bignesse shapes and differing Longævities of living Creatures, and many other Particulars: of which the only reason we can assigne, is, that it pleas'd God at the begining of things, to give the World and its parts that disposition. (MS 185, fol. 29; *Works*, 14: 168)

A nominalist view of natural laws resonated with his voluntarism. Scientific laws "did not necessarily spring from the Nature of Matter, but depended on the Will of the Divine Author of things" (*Works*, 11: 302). They were "collected or emergent" truths, "gathered from the settled *Phaenomena* of Nature", rather than "Axioms Metaphysical, or Universal, that hold in all Cases without reservation" (*Works*, 9: 414; cf. Davis 2020). Strictly speaking, a law is merely "a *Notional Rule of Acting according to the declar'd Will of a Superior*". Only "an Intellectual Being can be properly capable of receiving and acting by a *Law.* For if it does not understand, it cannot know what the Will of the *Legislator* is; nor can it have any Intention to accomplish it, nor can it act with regard to it; or know, when it does, in Acting, either conform to it or deviate from it". It makes sense that God "at the Beginning" would give motion to particles, "guide them, as he thought requisite, for the Primordial Constitution of Things", and then "by his ordinary and general Concourse, maintain those Powers" he gave mindless particles to transmit motion. However, "*I cannot conceive*, how a Body, devoid of understanding and sense, truly so call'd, can moderate and determine its own Motions; especially so, as to make them conformable to Laws, that it has no knowledg or apprehension of" (*Works*, 10: 457).

Contrary to Kepler, Galileo, and Descartes, who thought humans could attain at least some knowledge of nature that was objectively certain and equal to God's own understanding, Boyle stressed our vast ignorance of God's knowledge and the consequent need to construct science from the ground up by experience, not from the top down by abstract reasoning—and this attitude had a biblical warrant. "If we believe God to be the author of things, it is rational to conceive, that he may have made them commensurate, rather to his own designs in them, than to the notions we men may best be able to frame of them". According to Genesis, since the world was created before humans, "the author of nature consulted not, in the production of things, with human capacities; but first made things in such manner, as he was pleased to think fit, and afterwards left human understandings to speculate as well as they could upon those corporeal, as well as other things" (*Works*, 12: 397–98).

Just as he saw empirical science as theologically and biblically sanctioned, Boyle found the "mechanical philosophy", as he called it, theologically and biblically superior to the prevailing concept of nature based on the Greeks—according to which, a reified "Nature" did nothing in vain, abhorred a vacuum, and always did what was best. "This Belief, that the World and divers of its Principal Parts, as the Sun, Moon, Stars, *&c.* were animated and endowed with Intelligent Minds, was so Contagious", that it "help'd to seduce the Emperor *Julian* from Christianity to Heathenism" and "Mis-lead such Great Persons" as Moses Maimonides and even Boyle's friend Menasseh ben Israel. Against this notion, Boyle raised a significant objection from the Bible, which lacks any "Hebrew word that properly signifies *Nature*, in the sense we take it in". The Greek notion was frankly idolatrous. "Instead of the True *God*, they have substituted, for us, a kind of a Goddess, with the Title of *Nature*: Which, as they look upon as the immediate Agent and Director in all excellent Productions, so they ascribe to Her the Praise and Glory of Them". The mechanical philosophy, on the other hand, "does much better than its Rival comply with what Religion teaches us, about the *extraordinary* and *supernatural* Interpositions of *Divine*

Providence". Whenever "it pleases God to over-rule, or controul, the establish'd course of things in the World, by his own Omnipotent Hand, what is thus perform'd may be much easier discern'd and acknowledg'd to be *miraculous*", by those who "admit, in the ordinary course of Corporeal Things, nothing but Matter and Motion, whose Powers Men may well judg of". Those holding that "there is besides, a certain *Semi-Deity*, which they call *Nature*", are unable to estimate "how great [its powers] are, and how far they may extend". Thus, "the Miracles of our Saviour and his Apostles, pleaded by Christians on the behalf of their Religion", were "very differingly look'd on by *Epicurean* and other Corpuscularian Infidels, and by those other Unbelievers who admit of a Soul of the World, or Spirits in the Stars, or, in a word, think the Universe to be Governed by Intellectual Beings, distinct from the Supream Being we call *God*" (*Works*, 10: 474–75, 459, 487, and 448–49). By helping us identify genuine miracles, especially those found in the Bible, the mechanical philosophy supported Christianity.

According to Dmitri Levitin, Boyle's emphasis on the idolatrous character of pagan notions of nature and the need to combat them with design arguments was heavily influenced by *Tentamina physico-theologica de Deo*, a book published in 1665 by Samuel Parker, later Bishop of Oxford. The following year, Parker became a Fellow of the Royal Society and Boyle began writing *Notion of Nature* (Levitin 2015, pp. 349–50). There he compared the world to "a rare Clock, such as may be that at *Strasbourg*, where all things are so skilfully contriv'd, that the Engine being once set a Moving, all things proceed according to the Artificers first design". There was no need for "the peculiar interposing of the Artificer, or any Intelligent Agent imployed by him", because the various parts "perform their functions upon particular occasions, by vertue of the General and Primitive Contrivance of the whole Engine" (*Works*, 10: 448). Here and elsewhere, Boyle frequently spoke of the universe and its parts in mechanical terms, but he hardly originated the metaphor. Mechanical planetariums existed in the ancient world, including the device found near the Aegean island Antikythera in 1900 and those made by Archimedes and Posidonius that were known to Cicero, who emphasized that "these contrivances are the work of reason". Comparing them to the heavens, he concluded that the "marvelous velocity" and "perfect regularity" of the heavenly motions leaves no "doubt that all this is effected not merely by reason, but by a reason that is transcendent and divine" (Cicero 1933, pp. 207–19). At the University of Paris during the Middle Ages, astronomer John of Sacrobosco and natural philosopher Nicole d'Oresme described the world as a "machine" or "clockwork". A former philosophy student at Paris, John Calvin, spoke of "the machine of the world" (*mundi machina*) in the *Institutes of the Christian Religion* (Calvin 1559, book 1, chp. 10). A generation later Huguenot apologist Philippe de Mornay used the clock metaphor prominently in a work that profoundly influenced Boyle's intellectual development, *A Woorke Concerning the Trewnesse of the Christian Religion* (French 1581, English 1587). Do the heavens move randomly "by adventure", or do they move themselves? Neither, he argued, "for nothing moueth it selfe", and whenever things moved one another, "in the end men must be faine to mount vpto a first beginning". For example, "from the hammer of a Clocke wée come too a whéele, and from that whéele too another, and finally too the wit of the Clockmaker, who by his cunning hath so ordered them, that notwithstanding that he maketh them all too moue, yet he himselfe remoueth not". Similarly, he described the sky "as the great whéele of a Clocke", amounting to "the very instrument of tyme", needing "a Worker that putteth him to vse, a Clockkéeper that ruleth him, a Mynd that was the first procurer of his mouing (de Mornay 1587, pp. 5, 99). In the next century, Puritan divine John Robinson wrote, "it addes to the honour of the skilfull Artificer, so at the first to frame his Clocke or other works of like curious devise, as that the severall parts should constantly move, and order each other in infinite varietie, hee, as the Maker, and first Mover moving, and ordering all". Immediately after this, he pointed out a crucial difference that "must alwayes be minded, that the Artisan leaves his worke being once framed to it selfe; but God by continuall influx preserves, and orders both the being, and motion of all Creatures. Here also we except both unnaturall accidents; and specially, supernaturall, and miraculous

events; which are, as it were, so many particular creations, by the immediate hand of God" (Robinson 1638, pp. 31–32).

No less concerned than Robinson about the possibility of drawing a deistic inference from the clock metaphor, Boyle underscored the necessity of God's ongoing activity to maintain the universe and its creatures in existence and to guide matter as it moved. His invocation of the clock metaphor described only its created nature, not its very real creaturely dependence on the Creator. "If God should at any time withdraw his preserving Influence", he reflected on the sight of his shadow on the water, "the World would presently Relapse, or Vanish into its first Nothing", for "God is so the preserver of all his Creatures, that one may say of the rest, as the Psalmist speaks of many of them, where addressing himself to God, he says, *Thou hidest thy Face, they are troubled; Thou takest away their Breath, they Dye, and return to their Dust; Thou sendest forth thy Spirit, they are Created*". He went on to say, "that irresistible Agent finds as little more difficulty to produce the greatest changes among the Creatures, than to produce the least; as I find it harder to move the whole Arm of my Shadow, than to move its little Finger" (*Works*, 5: 109–10; cf. *Works*, 8: 23–24 and 28). In the last theological work published during his lifetime, *The Christian Virtuoso* (1690), he affirmed, "this most Potent Author, and (if I may so speak) Opificer of the World, hath not Abandon'd a Masterpiece so worthy of him, but does still Maintain and Preserve it". He regulates "the stupendiously swift Motions of the great Globes, and other vast Masses of the Mundane Matter", so they do not "disorder the grand System of the Univers, and reduce it to a kind of Chaos, or confus'd State of shuffl'd and deprav'd things" (*Works*, 11: 300). Perhaps echoing Boyle, a few years later Newton told David Gregory, "that a continual miracle is needed to prevent the Sun and the fixed stars from rushing together under gravity", a view briefly echoed in Query 28 of the *Opticks* (Newton and Trumbull 1959–1977, 3: 336; Newton 1718, p. 344).

Divine guidance of mindless matter was a crucial component of Boyle's natural philosophy. Knowing the "Intermediate Causes" of things did not "make it needless to admit a First and Supreme Cause", for "That Order of Things, by vertue of which these Means become sufficient to such Ends, must have been at first Instituted by an Intelligent Cause". It was "Irrational to Ascribe the Excellent Fabrick of the Universe, *such as it now is*, and the Actions that have manifest Tendencies to Determinate Useful Ends, To so Blind a Cause as *Chance*", and equally irrational to think, "that at the *First Framing of the World*, there was a *Sufficiency* in the Stupid Materials of It, without any *Particular Guidance* of a most Wise Superintendent, to Frame Bodies so Excellently Contriv'd and Fitted to their respective Ends" (*Works*, 11: 150–51). To hammer down that point, Boyle had his own version of monkeys with typewriters accidentally creating Shakespeare. It was "much more unlikely, that so many admirable Creatures that constitute this one exquisite and stupendous Fabrick of the World should be made by the casual confluence of falling Atoms", than that "a multitude of small Letters" in a printing shop, "being thrown upon the Ground, should fall dispos'd into such an order, as clearly to exhibit the History of the Creation of the World, describ'd in the 3 or 4 first Chapters of *Genesis*, of which History, it may be doubted whether chance may ever be able to dispose the fallen Letters into the Words of one Line" (*Works*, 3: 253).

An unpublished "Post-script" intended at some point as an appendix to his treatise on nature reveals precisely how Boyle baptized the mechanical philosophy (Hunter and Davis 2007). First, he distinguished between "the Epicurean ‹Corpuscularians› that wholly exclude the Diety from having any thing to do in the Makeing or ‹Preserving› the world & the Cartesian Mechanists, if I may so call them, who allow that God ‹have› Created the Matter of the universe but did ‹no more then› impress such a determinate quantity of Locall Motion upon the whole Mass, which he constantly preserves in it without increase or diminution". Then he defined a third group: those who are "far from thinkeing the Mechanicall affections of matter sufficient to have brought the parts of it into so goodly & admirably artificiall a frame as ‹that of› our world without the direction of a Most Wise & powerfull Agent that is in one word, of God". To the best of his knowledge, "Anaxagoras

was the first of the Mechanicall Philosophers that made [here there is a blank space; *noûs* is the word Boyle must have dictated to his amanuensis] or mind by which 'tis knowne he meant God to be that first cause that putt matter into motion & by those two principles fram'd the Corporeal universe". Therefore, Boyle announced, "I shall for distinction sake call ‹the› 3d sect of Mechanicall Philosophizers by the name of Anaxagoreans which sect ‹as to the maine› I ‹declare› myselfe to prefer to both the others". Although he admitted that the Cartesian hypothesis "is not Atheisticall", he considered it "not much more rational", since it is "utterly improbable (not to say altogether unconceivable) that a numberless multitude of fragments of ‹stupid› matter devoid of all knowledge sence & designe should ever be able to justle themselves into such admirably contriv'd Engines as the Bodyes of Men & other Animals & into those other ‹wonderfully differing› Master peices of workmanship that are yett all of them together but ‹small› parts of this great & stupendious Automaton the World". Overall, "the ‹impious› Errours of those that excluded God from the formation of the world are not to be imputed to the Mechanicall principles themselves but to the Personall arrogance of those Philosophers that rashly & unskillfully ‹misapply'd› those innocent principles by straineing them to do a work for which they were insuffitient" (BP 7, fols. 186–88 and 192v; *Works*, 14: 147–49 and 154).

For Boyle, then, a rational explanation of the world must include the activity of Anaxagoras' *noûs*, or mind. The clockwork universe requires a clockmaker, without which its intricate, interconnected mechanisms would not exist and could not function. Surely, they could not have assembled themselves by chance. Any other view was irrational. This is the final reason why Boyle accepted and promoted the mechanical philosophy: it gave us a powerful, seemingly irrefutable argument for a Creator from the self-evident design of the machines he had made. Yet, mere intellectual assent to God's existence was not enough. As he said in *A Disquisition about the Final Causes of Natural Things* (1688), he especially desired "that my Reader should not barely observe the Wisdom of God, but be in some measure Affectively Convinc'd of it". Affectively, not effectively, was the adverb deliberately chosen. Boyle's version of the mechanical philosophy demonstrated not only "the Greatness of God's Power" evident from the Cartesian version, but also his wisdom and goodness. In that way, Boyle believed, "Men may be brought, . . . both to *acknowledge* God, to *admire* Him, and to *thank* Him" (*Works*, 11: 145 and 95). The simple admission of God "may keep a man from being a downright atheist, yet it will not ordinarily suffice to make him a pious man", and he wanted to live in a world inhabited by pious men and women. Nevertheless, one's "piety, as well as his other virtues, will usually be proportionate to the firmness of the assent he gives to that fundamental article of religion, that there is a Divine Maker and Ruler of the world" (*Works*, 12: 483). At the same time, "Natural religion" was "the foundation, upon which revealed religion ought to be superstructed, and is as it were the stock, upon which Christianity must be ingrafted". Although natural religion was "*insufficient*, yet I think it very *necessary*". It is pointless "to press an infidel with arguments drawn from the worthiness" of Christian doctrine and biblical miracles "if the unbeliever be not already persuaded, upon the account of natural religion, that *there is a God*" (*Works*, 12: 432).

4. Conclusions

Biblical and theological ideas fundamentally shaped Boyle's natural philosophy. The sheer joy of uncovering the Creator's wisdom throughout the creation, the desire to imitate Christ by providing medical care to the poor, and the duty to obey the Genesis mandate were powerful motives for doing science. The intellectual humility proper to our status as mere creatures strongly encouraged an empirical approach to nature that was ideally suited to laboratory life. Finally, the mechanical philosophy was far more attractive than the impious Greek conception of "Nature". It focused our attention not on an immanent semi-divine being, but on properties and powers given to matter by the Creator, whose power, wisdom and goodness were clearly seen in the complex machines he had made, while advancing the "Empire of Man over the Creatures".

Boyle's influence on the Anglo-American conversation about science and religion down to our own day has been nothing short of profound. Newton's views on natural theology mirrored Boyle's. He and other great scientists such as James Clerk Maxwell held Boyle's view that natural laws are simply our descriptions of God's ordinary activities in the creation while affirming God's sovereign freedom to perform miracles. In his famous book, *Natural Theology* (1802), William Paley used Boyle's ubiquitous term "contrivance(s)" in identical contexts, stressing the apparent design of highly complex structures in the organic creation, especially one of Boyle's favourite examples, the eye. When authors today appeal to cosmological fine-tuning to argue for a Creator, they are effectively treating the whole universe as a contingently created contrivance, silently echoing Boyle. Proponents of "Intelligent Design" have lauded Paley for many years, but recently they have acknowledged their prior debt to Boyle (Behe 1996, pp. 211–16; Meyer 2021, pp. 31–6). They share his view that mechanistic science gives rise to powerful arguments for an intelligent designer, not "blind chance", as the ultimate author of nature. When they use current scientific knowledge of what mechanistic processes *can* do to identify aspects of nature that (in their view) *cannot* be explained by unintelligent causes alone, they employ Boyle's argument for recognizing the authenticity of biblical miracles—even though they try to keep the Bible at arm's length. As the late ID founder Phillip Johnson said, "the first thing that has to be done is to get the Bible out of the discussion" (Johnson 1999; cf. Meyer 2017, pp. 207–8). Unlike Boyle, who lived in an officially Christian nation that made blasphemy a crime, Johnson lived in a post-Enlightenment, increasingly post-Christian nation whose courts have banned explicitly religious practices in public schools—a form of education unknown in Boyle's day. This has not stopped Boyle's intellectual descendants from making his case as well as they can.

Religion and popular culture have also been substantially influenced by Boyle, especially in the eighteenth century. Puritan leader Richard Baxter admired Boyle's devotional work, *Occasional Reflections on Several Subjects* (1665), which was satirized by Jonathan Swift and remained in print until the mid-nineteenth century. The reflection (in that book) on recovering from a fever likened the complex, finely tuned human body to "so curious an Engine, that consists of so many pieces, whose Harmony is requisite to Health", might "have some or other of them out of order, it being no more strange that a Man's Body should be subject to Pain, or Sickness, than that an Instrument with above a thousand Strings (if there were any such) should frequently be out of Tune" (*Works*, 5: 63–64). This passage inspired the great hymn writer Isaac Watts to pen a four-line stanza about the wondrous creation of our bodies, including the lines, "Strange! that a Harp, of thousand Strings, / Should keep in Tune so long" (Watts 1766, book II, no. 19, v. 3). In 1794 the American composer William Billings set Watts' text as the fuging tune, "Creation", in *The Continental Harmony* (Davis 2002). Watts' poetic version of Boyle's prose is ubiquitous in shape-note singing since the late eighteenth century and on the internet today. Another musical by-product was Georg Frederick Handel's favourite oratorio, Theodora (1750). Now regarded as a masterpiece after centuries of neglect, since 1990 it has been recorded seven times and staged four times as an opera at Glyndebourne, Salzburg, Covent Garden, and the Barbican. Thomas Morell's libretto was based on Boyle's *The Martyrdom of Theodora, and of Didymus* (1687), a work that Samuel Johnson described as the first "attempt to employ the ornaments of romance in the decoration of religion", although "*Boyle's* philosophical studies did not allow him time for the cultivation of style" (Boswell 1934, 1: 312). Boyle's best-known artistic influence is the magnificent painting by Joseph Wright of Derby, *An Experiment on a Bird in the Air Pump* (1768), closely based on the description of a demonstration in which a bird was subjected to a partial vacuum created by his air pump until women witnessing the experiment made him stop (*Works*, 1: 286–87). Cotton Mather's *The Christian Philosopher* (1721), which brought the new science from Europe to America, was originally to be called *The Christian Virtuoso* after Boyle's book of that name, which had been devoted to "*Shewing*, That by being addicted to *Experimental Philosophy*, a Man is rather Assisted, than Indisposed, to be a *Good Christian*" (*Works*, 11: 281).

Boyle's voluntarist conceptions of nature and natural law may not be widely accepted, but they still come to the surface, especially when scientists debate the nature of nature. When Albert Einstein said that he "really" wanted to know, "whether God could have made the world in a different way; that is, whether the necessity of logical simplicity leaves any freedom at all" (Holton 1978, p. xii), he unwittingly asked one of Boyle's greatest questions. Cosmologists, environmentalists, philosophers, and theologians continue to debate answers to other questions about God, nature, and humanity that Boyle formulated more than three hundred years ago. Silly claims by a few prominent scientists that philosophy is useless and irrelevant notwithstanding, science remains a form of natural *philosophy*. Boyle's legacy is still with us.

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Abbreviations

BP Royal Society Boyle Papers
MS Royal Society Manuscripts

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Correspondence = *The Correspondence of Robert Boyle*. 2001. Edited by Michael Hunter, Antonio Clericuzio and Lawrence M. Principe. 6 vols. London: Pickering & Chatto.

Works = Boyle, Robert. 1999–2000. *The Works of Robert Boyle*. Edited by Michael Hunter and Edward B. Davis. 14 vols. London: Pickering and Chatto.

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religions

Article

Christianity Cultivated Science with and without Methodological Naturalism

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Abstract: Many people assume ceaseless conflict between natural science and Christianity, but the real conflict has been between scientism and Christianity. Scientism is the view that only the sciences (especially not theology) generate knowledge or rational belief. I show how Christianity generated rational beliefs that contributed to the rise of science. This science-fostering rational belief included rationales for when to practice methodological naturalism, and when to study nature without that restriction. Both practices cultivated science, though in different ways. This historical difference is of enduring value for recent debates about metaphysical naturalism (atheism), creationism, theistic evolution, and intelligent design.

Keywords: methodological naturalism; scientific naturalism; medieval science; historical science; origin science; scientism; Darwinian evolution; theistic evolution; intelligent design; William Whewell; X Club

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1. Introduction

"The idea of a ceaseless conflict between" natural science and religion "seems to be an integral part of the public consciousness." (Elsdon-Baker and Lightman 2020, p. 3). So observe two scholars in a recent academic anthology about science and religion. These historians argue that this conflict thesis substantially misrepresents the facts, while at the same time, noting that it is "more ingrained in the scholarship than previously imagined", and the "only way to root it out is to pursue a multidisciplinary reenvisioning" of science and religion studies (Ibid., p. 10). I contribute to this multidisciplinary reenvisioning within the domain of the history and philosophy of science. It has already been shown that the real conflict has not been between *science* and Christianity, but between *scientism* and Christianity (Plantinga 2011; Keas 2021). Scientism is the view that only the sciences (especially not religion) generate knowledge or rational belief.[1] I show how Christianity generated rational beliefs that contributed to the rise of science. This science-fostering rational belief included rationales for when to practice methodological naturalism, and when to study nature without that restriction. Both practices cultivated scientific progress, though in different ways. This historical difference is of enduring value for recent debates about metaphysical naturalism (atheism), creationism, theistic evolution, and intelligent design.

"Nothing has come to characterize modern science more than its rejection of appeals to God in explaining the workings of nature. Numerous scientists, philosophers of science, and science educators have made this claim". So announced the leading historian of science Ronald Numbers 20 years ago. He argued that this *science without God* principle, commonly called methodological naturalism, is a widely practiced "method of choice for understanding nature" that owes much to a long line of devout Christians who helped formulate it and prove its utility in the growth of science since the Middle Ages (Numbers 2003). According to some recent studies, ancient Christians began with *God without science*, or not much science, and ended up producing—in concert with other factors—late medieval *science without God*.[2] Unlike the old conflict thesis, the *science without God* thesis debunks the popular claim that Christianity produced 1000 years of medieval anti-science—the so-called "Dark Ages".

Many will cheerfully accept the new view's trade-in offer: Christianity is absolved of alleged Dark Ages anti-science, in exchange for recognition of Christianity's contribution to methodological naturalism and other features commonly associated with modern science. Many Christian theistic evolutionists especially recommend this historiography when it is attached to a particular lesson.[3]

The lesson is this: Enlightened Christians will methodologically, not philosophically, join hands with the majority of scientists (including atheists) in reconstructing the history of earth's organisms in a manner similar to Charles Darwin, who still believed in God when he published his *Origin of Species* in 1859 (he later converted to agnosticism) (Brooke 2010b). Embracing such methodological naturalism, regardless of your religious or non-religious worldview, allegedly puts you on the right side of history—to best practice science.[4]

To evaluate the merits of this lesson, and to better understand the history of science-Christianity relations, we will study the development of methodological naturalism—and its negation—in a few prominent phases of the history of science. We begin with recent analyses of methodological naturalism offered by philosophers of science. With these distinctions in hand, we will examine history to see methodological naturalism, and its denial, playing various intellectually virtuous roles in science.

2. Methodological Naturalism

There are multiple versions of methodological naturalism to recognize. Philosopher of science Sandy Boucher clarifies the important distinction between intrinsic methodological naturalism (IMN) and pragmatic methodological naturalism (PMN) (Boucher 2020), which he traces back to the Belgian atheist philosopher Maarten Boudry.[5] Here is my definitional summary of Boucher and Boudry:

> IMN: Science, as a way of knowing nature, excludes supernatural explanations of nature.
>
> PMN: Because scientists, *qua* scientists, have evaluated supernatural explanations of nature and found them inadequate, scientists no longer consider supernatural explanations as live options for scientific theory.

Boudry and his coauthors recommend PMN due to IMN's "failed strategy of ruling the supernatural out of science by philosophical fiat"—mere stipulation. They define supernatural as "processes and causes that transcend the spatio-temporal realm of impersonal matter and energy, and to phenomena arising from the interaction of those entities with the material universe." (Boudry et al. 2012, p. 1152). Given that Boudry and his co-authors would identify *themselves* as "phenomena arising from the interaction" of "impersonal matter and energy", they should allow for Richard Dawkins' admission (to Ben Stein in the documentary *Expelled*) (Expelled: No Intelligence Allowed 2008) of the possibility of smart aliens as the creators of earth's life. Such *naturalistic intelligent design* should be a legitimate scientific hypothesis within the methodological restrictions of IMN and PMN. However, if *intelligent design* (ID) means *God did it*, then ID is beyond science, if we accept the boundaries provided by IMN and PMN. We will return to ID because of its frequent mention in relation to methodological naturalism by many of my fellow historians-philosophers of science.

Boudry and his coauthors make an observation that is part of their rationale for preferring PMN over IMN.

> Not surprisingly, IMN is typically embraced by philosophers sympathetic to religion, by theistic evolutionists and religious liberals intent on safeguarding an epistemic domain for religious faith . . . , as well as by atheists who try to disarm the perceived conflict between religion and science . . . . In a way reminiscent of Stephen Jay Gould's principle of non-overlapping magisteria (NOMA) . . . , IMN seems to embody the modern *modus vivendi* between science and religion (Boudry et al. 2012, p. 1153).

However, Boudry and his coauthors argue this strategy for keeping religion safely separate from science by means of IMN is illegitimate because it amounts to "ruling

the supernatural out of science by philosophical fiat"—mere stipulation. There are yet other worries.

Philosopher of science Timothy (Tiddy) Smith (Smith 2017) argues that although IMN and PMN have merit, neither gets the full story correct. Methodological naturalism (MN) merely stipulates that "only natural cognitive faculties may be used" to justify theories about nature. Appeal to divine revelation or other "supernatural methods" is off-limits within science. In sum, MN "construed as an epistemological thesis, is a commitment to public methods, and this commitment is no kind of metaphysical prejudice". I call this MN version *epistemological methodological naturalism* (EMN). Smith argues that such an understanding of MN "is not a thesis about what may or may not be conjectured [as an explanation] by scientists [as is the case with IMN and PMN], but about how scientists may or may not justify their theories". Based on Smith's work, we may define epistemological methodological naturalism.

> EMN: Only publicly accessible methods using natural human faculties can justify theories of nature.

Theories of nature refer to explanations within the natural sciences. Smith's EMN aims to describe a central methodological trait of natural scientific inquiry, not to function as a rigorous demarcation between the natural sciences from other disciplines. EMN expresses a minority viewpoint of the meaning of MN, but considering this view is illuminating. Smith summarizes his argument for the incompleteness of IMN and PMN—and the superiority of EMN.

> To recap, the pragmatic defense is correct that supernatural explanations are testable, have been tested and have often failed in the scientific arena. Yet on the other hand, the pragmatic defense gets wrong the historical claim that methodological naturalism was eventually adopted as a rule of thumb [after the progressive failure of supernatural explanations]. The intrinsic defense also gets something right, insofar as science is a discipline with an explicit, a priori, anti-supernatural bias. But, the intrinsic defense doesn't square with the observation that science apparently can test and has tested supernatural explanations (Ibid., p. 327).

Smith's *history of science* critique of PMN is largely in tune with the most persuasive arguments to date—the majority historical interpretation as advanced by scholars such as Ronald Numbers and Peter Harrison, which I partly accept, and contest, below.

Smith's EMN, and coordinated critique of other versions of MN, give intelligent design (ID) more latitude to be recognized as a *scientific* research tradition. In his words: "Yet in the minimal sense of being publicly justified only by appeal to public methods, ID is, by the lights of the thesis argued here, scientific." Smith considers ID a "failed research program" within science, although he does not endeavor to demonstrate this. While the "motivation for defending ID is almost always religious", this "does not entail that the defenses of the theory must themselves be." (Ibid., p. 335). This is a nuance about ID that many historians and philosophers of science have overlooked. It is one way ID can be distinguished from creationism.[6] To appreciate Smith's EMN permitting ID to be scientific due to its non-religious defensibility, digest this recent description of ID.

> Intelligent design—often called "ID"—is a scientific theory which holds that some features of the universe and living things are best explained by an intelligent cause rather than an undirected process such as natural selection. ID theorists argue that intelligent design can be inferred by finding in nature the type of information and complexity which in our experience arises from an intelligent cause (Luskin 2021).

In the following episodic historical survey of the foundations of science, we will search for these three major versions of MN: intrinsic, pragmatic, and epistemological. We will explore the relationship of MN, and its negation, to religion, non-origins science, origins

science, ID theory, Darwinism, and various shades of metaphysical naturalism (atheism) and agnosticism—approximately in that order.

3. Greco-Roman Thinkers Cultivated Science with and without MN (Mostly without)

Until recently, many scholars have long claimed that a wide array of ancient Greek and Roman philosophers rejected the relevance of the gods and anything capricious or unpredictable in their study of nature, thus establishing the principle of MN, and thereby also giving birth to natural science. That is the historiography of science promoted by an influential group of 19th-century (Victorian) British scientists and polemicists. According to this now-discredited story, natural science was invented by ancient pagan Greeks, declined in medieval Christian Europe, and then was restored in the scientific revolution of the 16th and 17th centuries (Harrison and Roberts 2018; Stanley 2014b, p. 244).

In contrast to this view, Daryn Lehoux documents how most ancient Greco-Roman theories of the natural world included divinities interacting with nature in various governing and shaping roles. Most of the Presocratic natural philosophers took this approach, as did Plato and Aristotle. Lehoux further notes that the most influential ancient physician-philosopher Galen detected "a purposive divine agency behind the flawless design of human and animal bodies". Seneca posited "divine rationality as central to how the world works", and Ptolemy wrote in his *Almagest* (the most influential pre-modern science book) "that 'the first cause of the first motion of the universe . . . can be thought of as an invisible and motionless deity', gesturing back, one suspects, to Aristotle's account of the prime mover." (Lehoux 2019, p. 24). Some of these ancient thinkers traced the world's history back to a primordial stage that included uncreated matter, but that approach still does not fit the Victorian naturalistic stereotype of the history of science, as Lehoux explains.

> If the matter from which the cosmos is formed is sometimes said, as in Plato, to have been pre-existing, that does not entirely "naturalize" the account, at least insofar as divine agency is still responsible for the shape and characteristics of the world. A supernatural entity of one sort or another is clearly interacting with the system, and "the natural order" itself is seen to be non-self-starting. The chain of natural physical causation, that is, is seen as insufficient to explain its own beginning (Ibid., p. 27).

Lehoux concludes that "some of the biggest names in early science unabashedly" touted "divine causation in the cosmos, not just coincidentally or metaphorically, but deeply and centrally" in the practice of nature studies (Ibid., p. 29). He gives a prominent example. In the *Physics* Aristotle argues daily star motion is caused by the prime mover, which contains the cosmos. Stellar motion, in turn, causes the four terrestrial elements (fire, air, water, and earth) to move in ways that, along with the internal tendencies of each terrestrial element, largely explain natural changes—generation and corruption—in our immediate natural environment. In the *Metaphysics*, Aristotle explicitly identifies the prime mover of the *Physics* as divine—a conception that had been lurking in the *Physics* (Ibid., pp. 28–29). Thus, Aristotle's main account of natural causation invokes divine agency. Aristotle, like the vast majority of ancient pagan Greek thinkers, did not restrict their study of nature by an MN-like rule, Lehoux concludes. He documents this conclusion by reference to great thinkers such as Plato, Aristotle, Galen, and Ptolemy.

What about the few ancient cases in "science where naturalism in our sense seems to be more clearly and explicitly" displayed? Even here, the 19th-century MN science origin narrative is faulty. Lehoux's analysis of the ancient atomists makes this point well.

The Epicurean atomists argued all of nature could be explained by the interaction of invisible atoms. Their interactions—triggered by a random uncaused *swerve* mechanism—are due to collision and rebound. All of this was conceived to be independent of the gods, whose only role was to passively provide us with moral exemplars. Although this godless scientific theory had no role for capricious unpredictable anthropomorphic deities, ancient atomism traded personal capriciousness for impersonal capriciousness. The outcome, ex-

plains Lehoux, is that the "universe becomes unpredictably arbitrary in ways no naturalist should be willing to bear". He elaborates:

> Where the ancient philosophers who invoke divinities do so, nearly universally, to account for nature's regularity, complexity, and beauty, the one school we have found to be pure naturalists, the Epicureans, are the one school who allow for just this kind of capriciousness—the random, uncaused swerve—in the cosmos. It may not be a personalized kind of capriciousness (just the opposite), but for all that it is exactly the kind of explanation that "pure naturalism"—if such a thing even exists—was designed to avoid (Ibid., p. 36).

At the beginning of this section, we asked whether ancient Greek and Roman philosophers rejected the relevance of the gods and anything capricious or unpredictable in their study of nature, and thereby established the principle of MN, and thus also gave birth to science. This Victorian *MN origin of science* story fails to fit the overall pattern of Greco-Roman natural philosophy. Epicurean atomism, the closest case for a match to MN, turned out to be very unusual and also an awkward fit for the *MN origin of science* narrative traditionally aimed at *eliminating unpredictability* in nature.[7]

As we transition from Greco-Roman to Judeo-Christian perspectives, we will encounter an expanded set of options for rational progress in the study of nature. This will include a new kind of MN, which despite—or because of—its differences from modern MN, was much more friendly to science than the ancient pagan MN that had produced the Epicurean view of unpredictable natural events. Even so, there is some continuity in that both the non-Epicurean Greco-Roman and the Judeo-Christian traditions appealed to divinity in ways that often supported a view of predictable natural regularities that encouraged scientific investigation.

4. Medieval Christians Cultivated Science with and without MN: Progress, Diversity

Had he known the corrective historiography in Section 3, physicist Stephen Hawking might have been prevented from misconceiving some of the early stages of science in relation to Greco-Roman and biblical religion. He claimed that the earliest explanations of the cosmos invoked capricious and unpredictable divinities as the cause of events in nature. Although this is true of many cultures, there are many components of the Greco-Roman and Judeo-Christian traditions that did not promote this science-inhibiting perspective. Hawking claimed: "Gradually, however, it must have been noticed that there were certain regularities." (Hawking 1998, p. 188). Hawking seems to have been unaware that belief in the Judeo-Christian God actually supported the idea of the cosmos as a knowable and predictable lawful system, which is foundational to science. Here is one of the key texts:

> Thus says the LORD, who gives the sun for light by day and the fixed order of the moon and the stars for light by night . . . If this fixed order departs from before me, declares the LORD, then shall the offspring of Israel cease from being a nation before me forever (Jeremiah 31:35–36, ESV).

Christopher Kaiser's analysis is helpful.

> The term translated here as "fixed order" (NRSV) is the Hebrew word, *hoq*, meaning a royal decree or law. It is translated as *nómos*, the Greek word for law, in the Septuagint, and as *lex* in Jerome's Latin translation, the Vulgate. The biblical and theological use of these terms played a huge role in the development of the idea of cosmic natural law inherited by modern science (Kaiser 2007b, p. 48).

Building on this Judaic foundation, Theophilus, the Christian bishop of the Syrian city of Antioch (died ca. 185), recognized that "an earthly king is believed to exist . . . by his laws". Although most people never personally encounter a king, they can infer his existence by observing the orderly society such a king governs. By analogy, Theophilus argued, God is known "by his works", including "the timely rotation of the seasons . . . the various beauty of seeds, and plants, and fruits", and various "species of quadrupeds, and birds, and . . . the instinct implanted in these animals." (Dembski et al. 2008, pp. 91–92). Drawing

from their Jewish roots, ancient Christians recognized that lawful nature reflects a God who reigns as the maker and ruler of all. Medieval Christians developed this science-fostering idea further.

The standard Victorian MN story of science's origin, reflected in Hawking's misconceptions above, has been recently challenged by historians of science who have focused on the European Middle Ages and subsequent developments. These scholars have documented Christianity's important contribution to MN and other features of science (Harrison and Roberts 2018). Some of these medieval Christian science-fostering rational beliefs approximately constituted MN, but often they were importantly different, as I will now show.

4.1. Adelard of Bath (ca. 1080–ca. 1150)

One of the earliest candidates for a Christian advocate of MN is the Englishman Adelard of Bath. He is particularly remembered for his book *Natural Questions*, a dialogue with his skeptical "nephew", which constitutes a study of plants, animals, meteorology, astronomy, and human anatomy-physiology-psychology. He opens his book with an investigation of how plants routinely sprout from the soil *without* humans planting seeds or any known seeds existing in the soil, even after putting the soil through a sieve and placing it in a bronze pot. He ignores the possibility of plant seeds *unknown* to the investigators as the cause of this reoccurring sprouting phenomena, which is how his contemporary Peter Abelard (and we) solve this puzzle. Instead, Adelard of Bath addresses only two possible causes for such sprouting: (1) It is the immediate "effect of the wondrous divine will" (miracle),[8] and (2) it is the effect of an elemental capacity within soil that has existed ever since God first created this natural capacity. He argues for the second option with this proviso:

> I am not slighting God's role. For whatever exists is from him and through him. Nevertheless, that dependence [on God] is not [to be taken] in blanket fashion, without distinction. One should attend to this distinction, as far as human knowledge can go; but in the case where human knowledge completely fails, the matter should be referred to God. Thus, since we do not yet grow pale with lack of knowledge, let us return to reason.[9]

Adelard thought God miraculously created the original natural order of plant life. Once in existence, God maintains this natural order in such a way that, using our God-given human reason, we discover natural causes for these routine effects. However, when, after persistent effort, human reason fails to find natural causes for something, then we "should" (*epistemic*, not moral, "should") *reasonably* conclude that we have encountered the foundation of that natural order—the point at which God miraculously created it. In this study, Adelard is not focusing on the origin of plants, but on the routine causes of plant sprouting. Thus he says, "let us return to" reasoning about such ordinary natural causation.

Supernatural explanations are appropriately invoked at the edge of such nature studies, where we can reasonably infer the origin of a natural system. However, supernatural causes are inappropriate for explaining routine causal relationships within the ordinary operation of nature. This perspective about when to—and when not to—invoke supernatural causation, helped cultivate natural science, as seen in Adelard's *Natural Questions* dialogue.

The natural order examined in this part of his dialogue is not the whole cosmos, but only plant life. Adelard argues that we can rationally discern (at the edge of this domain of study) that God miraculously created plant life long ago. He also acknowledges that we can discover how plants routinely grow out of the soil without the direct intelligent action of God or humans. If Adelard had been addressing here the entire universe as a natural order, then his deliberations would have more resembled adherence to MN. However, Adelard only addressed reoccurring plant processes here. Later, he investigates other domains of reoccurring natural phenomena. Because he was *not* investigating *origins* in the "day of creation" (as Adelard expressed it), his investigative guidelines are quite different from MN. Typically MN only makes a significant difference in regard to the study of how things originate, rather than how things routinely operate. So we see a Christian frame

of mind contributing to science-fostering belief without MN as the majority of scholars now conceive it (IMN or PMN). Adelard of Bath's contemporary Peter Abelard also largely avoided MN as he developed a different approach to nature in its relationship to God, which nevertheless also laid some of the foundations for science.

4.2. Peter Abelard (1079–1142)

Peter Abelard's essay on God's creation of the world in "six days" (*Hexaemeron*) interprets the opening chapter of Genesis as communicating fundamentally different kinds of creative work organized in a six-day literary format that was not intended as strictly chronological teaching. Day one is about the origin of the cosmos in its initial primordial condition, full of potentiality for further specification by subsequent divine action. Historian Richard Dales observes: "Abelard posits an absolute beginning, a creation by God in which He first planned rationally in His own Mind what He was going to do, and then without any intermediaries He did it." (Dales 1992, p. 268). Consequently, humans, because they are made in God's image, are capable of knowing the order of nature that God created and sustains. Abelard further explicates this science-friendly belief by arguing humans can *rationally discern* the difference between God's initial creation of things (miracles) and our detection of ordinary natural causes (how things are sustained by God).

> When we now seek or assign a force of nature or natural causes in any outcomes of things, in nowise do we do it according to that first work of God in the disposition of the world, where the will of God alone had the power of nature in those [things] then to be created or arranged; but only after the work of God completed in six days. We usually identify a force of nature in the aftermath, when those things are in fact already so prepared that their constitution or preparation would be enough to do anything without miracles. Hence we say that those things which occur though miracles are rather against or beyond nature than according to nature, since that former preparation of things could not suffice for doing it, unless God were to confer some new power on these things, just as he was also doing in those six days, where his will alone worked as the force of nature in each thing to be made. If indeed he were also to work now [miraculously] as he did then, we would say at once that this is against nature, as for instance if the earth were spontaneously to produce plants without any sowing [of seed]. . . . Hence we call nature the force of things bestowed on them since that former preparation, sufficient thenceforth for something to be born, that is, to be made [non-miraculously].[10]

Notice Abelard makes similar points as his contemporary Adelard of Bath about the present natural order (in contrast to its original creation), but he disagrees with Adelard with regard to the natural cause of routine plant sprouting. This is due to seeds, not the elemental properties of soil. That was a reasonable step forward in nature studies, even though it took place within a theological treatise on the six days of creation, in conversation with God's subsequent sustaining of natural regularities. In the absence of later sharp university disciplinary boundaries between theology and nature studies, Abelard laid the foundation for *reasonably inferring the difference* between God's initial creation of particular natural things and our detection of ordinary natural causes that reflect God's faithfulness.

Recall Adelard of Bath asserted that when "human knowledge completely fails" to detect a natural cause of some effect, then "the matter should be referred to God", declaring it a miracle. This sounds as if the inference to direct divine intelligent causation is an argument from ignorance—when human reason "completely fails". However, Adelard of Bath's point here was subtly different. He argued that when, in a particular case, human reason completely fails (*after much effort*) to identify a natural cause, then it is *reasonable* to infer divine intelligent causation. Peter Abelard had a more explicitly positive way of framing the ability of human reason to distinguish between an event that is directly caused by God's intelligent action (miracle) and an effect that is caused by the ordinary course of nature as sustained by God. Both of these medieval explications of nature in relation to

God were science-friendly, and both fell outside the strict parameters of MN as typically conceived today.

Adelard and Abelard productively studied nature without MN restrictions, perhaps in part because they worked before the rise of universities with institutionalized disciplinary boundaries that sharply separated theology, natural philosophy, and other academic disciplines.

4.3. Boethius of Dacia (Late 13th Century): Did the Universe Have a Beginning?

Boethius of Dacia was a leading philosopher at the University of Paris liberal arts faculty about 1270–1275. Reflecting his university environment, he strongly demarcated academic liberal arts reasoning (including mathematics and natural philosophy) from Christian theology in his treatise *On the Eternity of the World.* He argued there is no way within natural philosophy, or the other liberal arts, to prove or disprove the universe came into existence a finite time ago. Some of his reasoning to this end appears identical to the MN-constrained study of nature.

To appreciate Boethius' argument, realize that he employed largely Aristotelian natural philosophy to conclude something comes into being *naturally* only when pre-existing matter acquires what Aristotle called a *form*. Such an event is generation, not creation. The natural world has within itself the capacity for only generation, not creation, Boethius argued.[11] He also briefly recognized other kinds of liberal arts reasoning beyond natural philosophy, such as mathematics and metaphysics. However, he concluded that these other disciplines in the university liberal arts program, like natural philosophy, are incapable of definitively establishing whether or not the universe had a beginning (Ebbesen 2020; Boethius of Dacia 1987, pp. 46–67). Part of his rationale for this conclusion was the following restrictive rule internal to Aristotelian natural philosophy: "Whatever the natural philosopher denies or concedes *as* natural philosopher, this he denies or concedes from natural causes and principles." (Boethius of Dacia 1987, p. 52). This sounds like an early Christian articulation of MN, especially if one identifies MN as either IMN or EMN,[12] but not PMN.

Let us see why from the Section 2 definitions.

> IMN: Science, as a way of knowing nature, excludes supernatural explanations of nature.
>
> PMN: Because scientists, *qua* scientists, have evaluated supernatural explanations of nature and found them inadequate, scientists no longer consider supernatural explanations as live options for scientific theory.
>
> EMN: Only publicly accessible methods using natural human faculties can justify theories of nature.

Boethius' restrictive rule corresponds fairly well with IMN. As to EMN, consider this: The "natural causes and principles" Boethius adopted from Aristotle, thanks to Church-funded university education, were *publicly accessible methods* made operable using *natural human faculties* that had been trained by the natural philosophy masters in universities across Christendom (Europe). Thus, Boethius' rule internal to Aristotelian natural philosophy might also be said to fit within EMN parameters.

However, doubts remain about the medieval MN thesis that identifies Boethius' rule as MN—understood as IMN, and perhaps also EMN. Although Aristotle's ahistorical theory of non-origins (the eternity of the world) belonged to natural philosophy as partly Christianized within medieval universities, most Western intellectuals since the time of Newton, for progressively good experimental and other rigorous empirical-conceptual reasons, have *not* recognized much of Aristotle's natural philosophy as legitimate scientific knowledge. So Boethius' exercise in natural philosophy regarding Aristotle's eternal world argument has long been regarded, for excellent reasons, as failing to measure up to the basic standards of the natural sciences—the very standards baked into the definitions of MN, whether IMN, PMN, or EMN. All three major versions of MN are about scientific theories of nature that are radically different from, and vastly superior to, Aristotle's

natural philosophy. Such doubts about the medieval MN thesis are expressed in the title and content of Michael Shank's recent essay "Naturalist *Tendencies* in Medieval Science" (title emphasis is mine). He identifies medieval natural philosophy approaches that are "akin to"—not identical to—"what we now call methodological naturalism." (Shank 2019, p. 38). Such a qualification should be seriously considered because it comes from a leading historian of medieval science.

Philosopher of science Stephen Dilley, who recognizes Boethius' restrictive rule as MN, offers additional criticism of Boethius' approach, including a point about the absence of a pragmatic justification for MN—the very thing insisted upon by PMN.

> Why not ... provide an argument for his definition [of MN] or adopt a more supple pragmatic justification for methodological naturalism? After all, it appears as if Boethius has simply displaced, rather than solved, the problem: the heart of his view is that natural philosophy doesn't conflict with revelation because it is constrained in scope, but this constraint—which allegedly solves his problem—stands as a brute, unjustified assertion. So Boethius has cloaked rather than dispelled the difficulty (Dilley 2007, p. 45).

Dilley concludes Boethius asserts MN without pragmatic justification. This is part of the historical evidence against the historical-philosophical PMN thesis. Such historical criticism shows that early articulations of MN-like rules, such as the one from Boethius, did not surface due to a perceived inadequacy of competing supernatural explanations of nature, as PMN alleges. Indeed, medieval Christian intellectuals virtually never suggested that the routine operation of nature should be explained by miracles. This respect for the God-sustained integrity of natural regularities was an important ingredient for the growth of natural science.

However, given Aristotle's ahistorical conception of nature, the natural principles assumed to be governing the routine operation of nature *also* implied a beginningless account of nature—although Boethius wisely argued natural philosophy is incapable of either proving or disapproving Aristotle's beginningless cosmos. Because medieval academics largely adopted Aristotle's ahistorical non-origins conception of nature for the purposes of carrying out natural philosophy, they typically also sharply demarcated such natural philosophy from theology in order to maintain the independent integrity of both academic fields—a demarcation that sometimes resembled MN. Aristotelian natural philosophy implied a beginningless cosmos (though this was debated in medieval natural philosophy), but Christian theological discourse supplied good reasons for believing in the creation of the cosmos "by reason of a higher cause which is the cause of the whole of nature", as Boethius expressed it (Boethius of Dacia 1987, p. 52). This bifurcated academic landscape was reflected by, and further reinforced by, the newly constructed university regulations that sharply distinguished the professional duties of natural philosophers from those of theologians.[13]

Thinking outside the Aristotelian philosophical box, Boethius acknowledged as factual that the cosmos had a beginning due to the action of the *first cause*, namely God's creative command. Boethius and the vast majority of medieval university faculty accepted the putative biblical teaching of a cosmic beginning. Some also developed philosophical arguments for nature's origin, which some considered beyond reasonable doubt, such as those associated with the cosmological argument for God's existence. Regardless, medieval intellectuals did not typically experience great pressure to reinterpret the Bible so as to accommodate a beginningless universe. Counterfactually, we could imagine such interpretive pressure due to the influence of the deliverances of natural philosophy operating within the confines of strict MN, but this does not well represent what happened in the Middle Ages.

By contrast, MN in the modern study of biological origins *did* create cultural pressure to reinterpret the Bible to accommodate Darwinism or some other version of naturalistic origins.[14] Part of the medieval–modern difference is due to the fact that, in the late 18th and early 19th centuries, there arose empirical scientific methods to reconstruct the history

of nature. However, the medieval study of the eternity or beginning of the world lacked empirical methods, and it also did not possess any sense of nature having had an empirically detectable history, due to the medieval tradition of closely following Aristotelian philosophy.

The eternity of the world controversy was mainly an exercise in what *we* would now call philosophy, rather than natural science (although some Aristotelian natural philosophy was adapted and integrated into modern science). So MN as a major science-difference-making rule of *empirical origin (historical)* science did not exist in the Middle Ages. Nevertheless, we have encountered an early MN-like rule that fostered the growth of science by establishing some of the disciplinary features distinguishing natural philosophy from the other liberal arts, and from theology.[15]

However, for the purposes of long-term scientific growth, disciplinary distinctions needed to be held in creative tension with rational progress through *unification*, which is a widely recognized trait of reputable scientific theories—a theoretical virtue (Keas 2018). From antiquity until the time of Johannes Kepler (1571–1630) and Isaac Newton (1642–1727), astronomy had been considered a branch of mathematics (the liberal art of geometry), *not* a branch of natural philosophy. Drawing from intellectual resources for the unity of the heavens (planets and fixed stars) and earth in Judeo-Christian theology, early modern scientists decisively integrated astronomy into a more unified successful science as indicated by the title and contents of Newton's 1687 book: *The Mathematical Principles of Natural Philosophy*.[16] Newton's grand unification was built on Kepler's earlier partial unification of the heavens and earth, which had appealed to observational and theological challenges to Aristotle's immutable (ahistorical) heavens. The documented appearance of new stars (subsequently recognized as supernovae explosions) in Kepler's lifetime supplied one of the observational challenges. As to theology, Kepler in his Copernican astronomy textbook, proclaimed the "truth concerning the mutable nature of the heavens." (Kepler 1952). He alluded here to Psalm 102:25–26, in which both heaven and earth are said to "wear out like a garment".

4.4. Jean Buridan (ca. 1295–1358)

Let us consider another teaching master at the University of Paris arts faculty, Jean Buridan. Did he practice or promote MN? He is considered one of the greatest natural philosophers of the Middle Ages. In his *Questions on Aristotle's Meteorology*, he outlines the appropriate way to reason about events in (roughly) what we today call earth's atmosphere.

> There are several ways of understanding the word "natural." The first [is] when we oppose it to "supernatural" (and the supernatural effect is what we call a miracle) . . . . And it is clear that meteorological effects are natural effects, as they are produced naturally, and not miraculously . . . . Consequently, philosophers explain them by the appropriate natural causes. But common folk, ignorant of these causes, believe that these phenomena are produced by a miracle of God, which is usually not true (Zupko 2008, p. 215).

Buridan thought meteorological phenomena are usually, but *not always*, natural (non-miraculous) events. Notice the *absence* of *strict* MN within his meteorology. However, natural philosophers, due to an academic division of labor specified in university regulations,[17] focused on what Buridan and many other academics called the "common course of nature" (*communis cursus naturae*), rather than "supernatural cases" (*casus supernaturalis*) (Biard 2001, p. 80). University theologians were officially tasked with studying the latter. In practice, these professional boundaries were somewhat flexible.

Buridan, as a master in the faculty of arts (not theology), reasoned (emulating Aristotle) "that the heavens are not naturally (*naturaliter*) generable or corruptible." (Ibid., p. 79). This meant that the part of the universe beyond the terrestrial region is incapable of major natural change (generation or corruption), and even more so incapable of a natural origin. In short, there are natural limits to what is possible in the common course of nature. Based partly on this reasoning, Buridan could make a reasonable inference to an intelligent cause, as opposed to a natural unintelligent cause, of the origin of the cosmos. In his scientific (not

theological) treatise *Questions on the Physics*, Buridan argued the natural order we observe originated from the designing choices of God the creator.

> Every order that is good and right in the operations and dispositions of natural beings arises primarily, principally, and originally from that best end for the sake of which everything else exists and acts or is acted upon in its first intention, viz., from God himself (Buridan (1509) as cited in Biard (2001), p. 82).

Besides noting the order of nature is contingent on God's original choices in creating, Buridan also analyzed how the choices of free intelligent agents such as humans are beyond (but interact with) mere bodily instinctual behavior and other natural events (Biard 2001, pp. 87–90). So Buridan crafted a nuanced view of how intelligent agency—both divine and human—is distinguished from nature but interacts with it. Such interaction of intelligent agency with nature sometimes does not fit well within MN constraints.

However, there is yet an additional MN-relevant pre-modern Western tradition of distinguishing two major classes of natural events—a deep distinction now unfamiliar to us. Buridan, like most medieval intellectuals (following Aristotle), did not consider rare or unique events in nature to be part of the common course of nature. Due to their alleged high degree of unintelligibility, such unusual events were thought to be beyond the domain of natural philosophy (Grant 1993, p. 89; Daston and Park 1998). This is part of the reason why medieval natural philosophers were not inclined to develop a discipline devoted to reconstructing the sequence of unique and rare events that constitute nature's history, as geologists would do in the late 18th and early 19th centuries. Medieval university theologians, most of whom had studied natural philosophy before theology, had a similar Aristotle-induced disinterest in nature's history, except notably for an interest in the origin of the cosmos. However, such cosmic origin discussion, which routinely arose while debating Aristotle's case for an eternal universe, did not attempt to *empirically* detect event sequences in the history of nature. Aristotle's cosmos had *no* history because any change in nature was thought to be cyclical, rather than leading in any particular direction. Aristotle's eternal universe was an ahistorical theory of non-origins.

Divine action in salvation history (e.g., prophecy and the mission of Jesus) and human action in the sequence of civilizations both produced lingering effects (e.g., extant documents and artifacts) that medieval intellectuals thought they could examine in order to reconstruct *human history*. However, there was no parallel development in medieval natural philosophy to reconstruct *nature's history*. The first empirical origin science, geology, did not arise until the late 18th and early 19th centuries. This modern development in science can be partly explained by a methodological crossover from the perspectives of *human history* to the task of reconstructing *nature's history.*

Medieval MN-like rules, such as in the work of Boethius, helped foster natural philosophy as a discipline that typically addressed different subjects than theology, and usually used different methods. Some of medieval natural philosophy would count for what we now call science, and so the MN question legitimately arises here. MN in this context did not challenge theology, but rather insured professional space for natural philosophers to love God with the exercise of their God-given cognitive capacities. Although foundational for science in its distinction from theology in this period, medieval MN-like restrictions made only a modest difference in the actual practice of science. This conclusion will make more sense when we compare it with the far greater difference that MN, and its negation, have been making in scientific practice since the 19th century. This has taken place in the empirical origin (historical) sciences, especially in biology (Sections 5 and 6).

Let us return to the observation that medieval intellectuals, following Aristotle, were not inclined to develop the origin sciences partly because they did not consider rare or unique events in nature to be part of the common course of nature that natural philosophers typically studied. However, some medieval intellectuals did study rare events in nature, but in a manner that was not embedded within the science of nature's history. Let us examine one of the most influential studies of this sort.

4.5. Nicole Oresme (ca. 1320–1382)

Buridan's younger contemporary, the natural philosopher and theologian Nicole Oresme, wrote *On the Causes of Marvels* (*c*.1370), which is about unusual and puzzling events and entities in nature. Oresme opens his book with this aim:

> To show the causes of some effects that seem to be marvels and to show that the effects occur naturally, as do the others at which we ordinarily do not marvel. There is no reason to have recourse to the heavens, the last refuge of the wretched, or to demons, or to our glorious God as if he would produce these effects directly, more so than those effects whose causes we believe are well known to us (Hansen (1985), pp. 136–137 as cited with an improved translation in Shank (2019), p. 54).

Oresme recognizes *some* (he does not say *all*) unique events or rare human experiences of sight, hearing, taste, touch, etc., are demonstrably the result of ordinary natural causes, which are subject to God's providence. Astrological influences or supernatural interventions (miracles beyond divine providence) are not appropriate explanations for the "marvels" he chooses to study, so he insists. This resembles MN, though not as strongly as Boethius articulated it.

As to unique events, he writes: "we should properly assign to particular effects particular causes, but this is very difficult unless a person looks at effects one at a time and their particular circumstances." He gives examples of such singular events: "Why Sortes [Socrates] is poor and Plato is rich, why an animal died at such a time, . . . why the crop failed in this field." (Hansen 1985, pp. 136–137). However, in this treatise, he mainly focuses on how to explain rare experiences of human sensation. "People marvel at such things only because they rarely happen," he explains (Ibid., pp. 160–61). For example, he explains how in rare circumstances "a thing can appear to our sight as larger or smaller than it is," and "a thing at rest can appear to be moving or vice-versa." (Ibid., pp. 138–39). In his later commentary on Aristotle's *On the Heavens*, Oresme used the reasoning in the last example to show how experience and reasoning cannot determine whether the sun revolves daily around earth, or the earth rotates daily on its axis to generate the equivalent appearance (Grant 2001, p. 200). Galileo Galilei (1564–1642) later extended this argument to make a case for the latter. So Galileo made productive use of earlier Church-funded research.[18]

Oresme's study of natural oddities largely avoided nature's history. He knew God created us with the sensory capabilities and rational capacities needed to detect and explain the optical and other illusions treated in his book. However, he did not aim to gather facts about nature that would enable him to reconstruct and explain the historical sequence of the first appearance of humans on earth relative to the first appearances of other life forms. If he had done so, and if he had insisted upon the methodological rule of invoking only unintelligent natural causes for explaining such sequential biological history, then that would have clearly constituted MN as most scholars now conceive it. Nevertheless, like most medieval European intellectuals, Oresme understood that the ordinary natural causes of nature's routine operations glorify God, because he initially created this natural order, and constantly sustains it. Consequently, Oresme recommended something like MN as an appropriate guide for much of nature studies. However, he never stated MN as a universal rule for the study of natural philosophy, as Boethius appears to have done. Nevertheless, he studied nature using some of the approaches now considered scientific.

Part of the reason for this difference between Oresme and Boethius lies in the fact that Oresme did not demarcate natural philosophy from theology as sharply as did Boethius. Historian Edward Grant notes Oresme's conclusion that "many things in the Gospels and in the articles of faith are no less reasonable than are many things in philosophy." (Grant 1993, p. 94)." Grant further observes that for Oresme "the world had a beginning not only because God had created it, but also because the attribution of a beginning to it was compatible with reason." (Ibid., p. 104). This exercise of reason to infer a cosmic beginning resembles the *absence* of MN. Although medieval university faculty generally acknowledged the rationality of Aristotle's case for a beginningless universe, they concluded that the cosmos began as a creation of God from nothing (ex nihilo) physically prior to our cosmos. Drawing

from Aristotle, they understood that nature does not have the capability to bring itself into being. Thus, the cosmic beginning was not considered part of the "ordinary course of nature", and so supernatural causation—alongside Aristotle's beginningless view—was on the table for rational deliberation by the lights of Oresme and most other medieval university faculty. In short, medieval Christian intellectuals sometimes contributed to the study of nature without MN in this manner.

Peter Harrison argues for the Christian contribution to MN and natural science broadly conceived during the Middle Ages and beyond. He is the editor of a recent anthology aimed at establishing this thesis. Although I have already shown some of the ways in which the medieval-MN part of that project is somewhat problematic, this volume contains much valuable historical analysis. For example, in the introduction, Harrison declares the following about some recent philosophical analyses of MN (specifically PMN) with misconceived appeals to the history of science.[19]

> Recent philosophical discussions that stress the historical failure of "supernatural explanations" when compared with "naturalistic explanations" [of nature] fail to take cognisance of the way in which this distinction functioned in the past. No significant medieval natural philosopher ever argued that supernatural explanations might offer an account of how nature usually operates. Indeed one reason for making the distinction was to make possible the identification of miraculous events, which become visible only against the background of the regularities of nature which were themselves attributable to divine providence (Harrison and Roberts 2018, p. 9).

The medieval study of how nature usually operates came with the expectation that theorists would routinely invoke natural causes operating under God's providence—not miracles. However, the origin of the cosmos, the origin of humanity, and certain other episodes were understood to have involved, in addition to God's providence, direct miraculous acts of God in history. However, natural sciences capable of empirically reconstructing nature's history, did not arise until the late 18th and early 19th centuries. It then became possible to entertain MN as a science-difference-making, though debatable, guide to inquiry.

Many of my arguments for how medieval Christians contributed to natural science with and without MN also pertain, with qualifications, to early modern scientific developments prior to the first empirical origin sciences of the late 18th and early 19th centuries.[20] For example, see Edward Davis' essay on Robert Boyle (1627–1691) where he identifies Boyle's allegiance to MN in the non-origin sciences of his day while allowing for the even more major difference-making effects of MN (and its repudiation) in the origin sciences since the 19th century.[21] Given space limitations we will proceed immediately to the late 18th and early 19th centuries. We will skip over the intermediate stages in order to focus on the *earliest mature* empirical origin (historical) sciences, and the eventual rise of MN as the majority view within those scientific disciplines.

5. Geology: The First Science to Detect Nature's History with and without MN

Natural science has come to be devoted to two kinds of knowledge: *how things work* and *how things originated.* Each of these aims is achieved through a somewhat different set of investigative tools. The first concern, how things work, was mostly the focus of nature studies before the late 18th century when geology became the first scientific discipline to acquire rigorous empirical methods for investigating how things originated.[22] Christian intellectuals contributed to this remarkable development in ways that sometimes were, and sometimes were not, accompanied by MN.

Although James Hutton (1726–1797) is often called the father of geology, historian Martin Rudwick has shown that the formation of geology as a reliable study of earth's history required a break from Hutton's eternalistic ahistorical Aristotelian approach. Hutton is remembered for his belief that earth has "no vestige of a beginning, no prospect of an end". This expression captures Hutton's Aristotelian-deistic perspective according to which

earth only shows signs of being subject to endless cycles that go in no particular direction, rather than going through unique phases of history leading up to the present. However, geology required a directionalist (developmental) view of history to get started. Rudwick received the History of Science Society's highest award in 2007 for his scholarship that tells how Christianity provided some of the key ingredients that enabled the origin of geology.[23] The Judeo-Christian idea of history was especially influential.

A Judeo-Christian view of history includes an absolute beginning followed by unique stages of development toward a purposeful end. In the Western tradition, this understanding of history largely replaced the ancient Greek idea of endless repeating cycles, which was especially associated with Aristotle. This Christian view informed the study of religious and secular history, both of which provided patterns of inquiry that guided early modern attempts to reconstruct earth's history. For example, early geologists used fossils as markers of earth's historical record in much the same way as human artifacts, such as coins, were important chronological indicators in archaeology. Fossils became known as nature's coins (Rudwick 2005, pp. 7 and 642).

Rudwick identifies Jean-André de Luc of Geneva (1727–1817) as a pivotal character in the rise of geology. De Luc called himself a Christian philosopher in contrast to Enlightenment deists and atheists. He realized many possible histories of the earth are consistent with the natural laws God created, so in order to discover the actual history one must engage in field observation of the earth's layered formations, not merely experimentation aimed at detecting natural laws. He called this kind of study *geology*. Rudwick concludes: "It is no coincidence that de Luc's system was the most strongly geohistorical, because of all these *savants* he was the one most explicitly committed to the historical perspective of biblical religion, a perspective he aspired to extend to the whole of geohistory." (Ibid., p. 643).

More recently Rudwick has noted that the Judeo-Christian scriptures,

> far from obstructing the discovery of the Earth's deep history, positively facilitated it. To borrow a metaphor from biology, they *pre-adapted* their readers to find it easy and congenial to think in similarly historical terms about the *natural* world that formed the context of human action and, so believers claimed, of divine initiative (Rudwick 2021, p. 4).

Epistemological methodological naturalism (EMN) was ignored at a fundamental level by the influence of the Judeo-Christian view of directional history (a meaningful unrepeated sequence of contingent events) on the formation of geology as a discipline. According to EMN, only publicly accessible methods using natural human faculties can justify scientific theories, including their deeper conceptual content. However, it is also possible to conceive of multiple secular and religious worldviews converging on a similar public idea of directional history, so as to detach geology from a specifically Judeo-Christian version of this idea in a rational reconstruction of the history of geology. However, this rational reconstruction would not change the actual historical pathway by which the Judeo-Christian vision of directional history shaped geohistorical theory. So at least some of the major participants in the foundation of geology did so without the restrictions of EMN.[24]

Early reputable geologists such as De Luc might retrospectively be said to have practiced IMN (science as a way of knowing nature excludes supernatural explanations of nature) for the purposes of geohistory, but often not in regard to the origin of life and major new kinds of life (where miracles were often deemed reasonable explanations). Rudwick summarizes De Luc's general view of geology: "The causes of physical events were assumed to be natural throughout, yet those natural causes were set in a context of overarching divine 'providence' (Rudwick 2021, p. 76)."

He notes further that De Luc's contribution to geology has been

> grossly neglected by historians. The reason for this is no mystery. De Luc's system has been ridiculed and dismissed because he admitted, indeed emphasized, that his geotheory was an integral part of a Christian cosmology that he set against

> the deism or atheism of other Enlightenment *philosophes*. But he was not an intellectual lightweight, nor was he a biblical literalist; he deserves to be treated as seriously by modern historians—even if they do not share his religious beliefs—as he was by his contemporaries (Rudwick 2005, p. 151).

So De Luc is a prominent example of a modern scientist who worked largely within the parameters of IMN for the purposes of geology, but who did not observe the restrictions of EMN in how he appropriated the Judeo-Christian idea of developmental history to shape geohistorical theory. Many other early geologists likewise followed this pattern. Knowing when, and when not, to follow various versions of MN, was one of the keys to this episode in scientific progress. Thanks in part to this wisdom from the Judeo-Christian tradition, geology came into being as a distinct discipline of the natural sciences.

6. Biological Origin Sciences with and without MN: The Big Difference This Makes

"But with regard to the material world, we can at least go so far as this—we can perceive that events are brought about not by insulated interpositions of Divine power, exerted in each particular case, but by the establishment of general laws." This is the first sentence in Charles Darwin's *On the Origin of Species* (Darwin 1859). This frontispiece quotation is from the prominent scientist and Anglican priest, William Whewell. Based on such evidence, we might expect that these two towering intellectuals were strong public advocates of MN throughout their careers. The real story is more complex and interesting.

6.1. William Whewell (1794–1866)

William Whewell helped pioneer the integrated study of the history and philosophy of natural science and was one of the first scholars to deeply understand scientific progress by means of the theoretical virtue of unification (Section 4.3).[25] He also was a leading expert in tide theory,[26] and was deeply conversant in scientific fields such as geology, mineralogy, physics, and astronomy (he pioneered the *circumstellar habitable zone* to assess the feasibility of extraterrestrial life based on a planet's temperature, derived from its distance from its host star).[27] He was a founding member (1831) and president (1841) of the British Association for the Advancement of Science (BAAS), he served as president of the Geological Society (1837–1839), and he made broad academic contributions as a long-time Master of Trinity College in the University of Cambridge. Leading Whewell scholar Laura Snyder has noted that at the 1833 Cambridge meeting of the BAAS, at which time Whewell dramatically announced his pioneering meaning of the word *scientist*, the BAAS was "firmly established" as "a scientific force in the nation. It also helped seal Whewell's reputation as a leader of the scientific establishment." (Snyder 2011, p. 147). It is no wonder Darwin appropriated Whewell.

Darwin's *Origin* quote was from Whewell's *Astronomy and General Physics Considered with Reference to Natural Theology* (Whewell 1833), which was the most successful book in the Bridgewater Treatises. This handsomely endowed book series was devoted to excavating the evidence for God in nature. Appropriately, Whewell's Bridgewater Treatise featured a frontispiece with this famous utterance from Isaac Newton: "This most beautiful System of the Sun, Planets, and Comets, could only proceed from the counsel and dominion of an intelligent and powerful being." Two years before Whewell's Bridgewater, "Brewster's *Life of Newton* had introduced the British reading public to the religious side of Newton, which had been downplayed by French writers on Newton (who tended to be atheists themselves)." (Ibid., p. 200). Darwin similarly aimed to opportunistically adapt the natural theology tradition of Newton and Whewell for his own purposes. Leading historian of science John Hedley Brooke concluded that "there was opportunism in Darwin's appropriation of this passage since Whewell would have balked, and did so, at its application to the creation of human beings." (Brooke 2010a, p. 265). I will go further than Brooke and show how Whewell did not promote MN in the biological origin (historical) sciences. Neither did Darwin in print, until later editions of his *Origin*.

Whewell argued for both the collective unity and individual peculiarity of various branches of knowledge such as the social sciences, human history (including the origin of Gothic architecture addressed in his monograph (Whewell [1830] 1842), geology, and biology. As to their individuality, each discipline "in a great measure" has "its own peculiar fundamental principles." (Whewell 1847, vol. 2, p. 19). Historian-philosopher of science Richard Yeo summarized Whewell's overall analysis as identifying "unity of epistemological process, while recognizing the integrity of different areas of inquiry," such that, in the progress of knowledge, "new domains of knowledge were associated with new fundamental ideas." (Yeo 1993, pp. 242–43, 252–53). Accordingly, Whewell argued that just as chemistry cannot legitimately be reduced to physics, likewise biology cannot be reduced to these more basic disciplines. To attempt such a reduction would obscure many instances of the reasonable inference to *final cause* in biology, he maintained.

Whewell argued certain arrangements of organismal parts point to a scientifically detectable intelligence that guided their construction. This is an inference to "design and intention" (Whewell 1833, p. 342), which he also called final causes (Ibid., pp. 307–19)—echoing Aristotle and citing the "Christian Virtuoso" (and chemistry pioneer) Robert Boyle (1627–1691). Edward Davis, a leading Boyle scholar, recognizes Boyle as "the father of modern intelligent design" theory because Boyle had argued that "design principles—what Aristotle had called 'final causes'—have a proper place within natural philosophy"[28] (i.e., what Whewell often called *science*). Whewell went further than Boyle because he more fully articulated the logic of design inferences, and the repudiation of MN, within the newly emerged biological origin sciences.

Whewell acknowledged that since Francis Bacon (1561–1626) it had become clear that sometimes "reasoning from final causes had been pushed too far". However, "it is certain" that the inference to purposeful design (final causes) in "the structure of animals" is well founded because the "most eminent physiologists in all ages" have converged on this conclusion (Whewell 1866, p. 357). Furthermore, this majority-acknowledged design inference outside the parameters of MN helped them make yet other key discoveries. Whewell cites examples such as "Harvey's discovery of the circulation of the blood"[29] and "Cuvier's restoration of extinct animals" from fossil evidence, which established the reality of extinctions for the first time. "These authors tell us that" they were guided by design-theoretic reasoning outside MN restrictions, Whewell argued. Critics of the design inference to purposeful origins in biology would have to face this question posed by Whewell: "Was it a false, an unreal principle that thus led them to some of the most important scientific truths which we possess?" (Whewell 1866, p. 357). In short, working outside the restrictions of MN can be, and often has been, a useful avenue to progress in the life sciences.

To further substantiate the scientific legitimacy of the inference to intelligent design in biological origins, Whewell pointed to the work of Marie François Xavier Bichat (1771–1802), a French pathologist and anatomist who pioneered the study of tissues in human anatomy. Bichat showed that each kind of tissue is susceptible to particular dysfunctions or diseases. Building on Bichat's work, Whewell argued that biology is the only natural science in which we encounter disease (studied in pathology) in the sense of failure to actualize a purposeful function that certain anatomical parts were designed and intended to perform. Whewell quoted Bichat: "Physiology is to the movements of living bodies, what astronomy, dynamics, hydraulics, &c., are to those of inert matter: but these latter sciences have no branches which correspond to them as Pathology corresponds to Physiology."[30] Whewell clarified Bichat by writing regarding non-biological processes that "we have no conception of what they *ought to do*". Gravity, for example, never "acts in a *diseased* manner." Echoing Bacon's caution regarding final causes, Whewell observes that gravity and other non-biological processes never fail "in their purpose" because "we do not conceive them as having any purpose which is answered by one mode of their action rather than another". However, anatomical parts studied in biology act "for the preservation and development

of the system in which they reside. If they do not do this, they fail, they are deranged, diseased." (Whewell 1858, p. 247).

Animal anatomy is quite different from crystals, Whewell emphasized. The law-governed physical processes that produce the regular repetitively angled surfaces of crystals are never said to be diseased or dysfunctional. He then showed how this difference supports the inference to intelligent design in biology.

> The regular form of a crystal, whatever beautiful symmetry it may exhibit, whatever general laws it may exemplify, does not prove design in the same manner in which design is proved by the provisions for the preservation and growth of the seeds of plants, and of the young of animals (Whewell (1840), vol. 1, p. 629 as cited in Yeo (1986), p. 277).

Although Whewell thought God created the general laws governing crystallization, natural laws capable of generating radically new biological structures are insufficiently supported by evidence. MN more appropriately applies to the physical sciences than to biology. Darwin's opportunistic quote of Whewell obscured this difference. Whewell, unlike Darwin, thought that natural science legitimately invokes direct divine intelligent intervention to account for the origin of biological organisms that possess fundamentally new anatomical and physiological features. Whewell did evaluate the alternative hypothesis that these events occurred by natural unintelligent causes but announced:

> It may be found, that such occurrences as these are quite inexplicable by the aid of any natural causes with which we are acquainted; and thus, the result of our investigations, conducted with strict regard to scientific principles, may be, that we must either contemplate supernatural influences as part of the past series of events, or declare ourselves altogether unable to form this series into a connected chain (Whewell 1858, p. 277).

Notice how Whewell framed the comparison between intelligent design and natural causes as a legitimate scientific evaluation process within the study of biological origins. In so doing, Whewell clearly articulated and promoted the scientific study of biological origins without MN.

Despite the extensive evidence to the contrary, some have suggested that Whewell embraced MN within all the origin sciences, including biology. In support of this view, they cite the following Whewellian passage: "The mystery of creation is not within the range of her [geology's] legitimate territory; she [geology] says nothing, but she points upwards."[31] Some quotations of this passage supply *nature* rather than *geology* in brackets, but given the context, her/she refers to geology.[32] This passage has a more limited meaning within the field of geology, echoing De Luc's view (Section 5). Michael Ruse makes a similar mistake about this passage when he claims it is about "science on origins" generally—expressing MN even in the study of biological origins.[33]

Let us dive deeper into Whewell's recommended pursuit of biological origins without MN. Following the pattern of how the founders of geology appropriated ideas from the study of human history,[34] Whewell analyzed biological origins by adapting methods that he extracted from his own technical monograph on the development of Gothic architecture. In that monograph, he was able to rigorously reconstruct some of the key steps in the origin of Gothic architecture. For example, he noted that a square area within a building can be covered with a vaulted ceiling by constructing intersecting *semicircular* vaults of equal height (see Whewell's Figure 1).[35] However it is impossible to cover a rectangular space with a vaulted ceiling in this same manner. The Romanesque churches that had preceded Gothic churches used only semicircular arches and thus were limited to square spaces and other associated architectural constraints. A vaulted ceiling over a rectangular space, with openings of equal height, is made possible by using *pointed* arches on at least two sides (Figure 2).[36] This new step in the logic of architectural design was a key event that helped trigger the origin of Gothic churches. In this innovation physical-spatial principles worked in tandem with aesthetic principles.[37] Whewell described Gothic churches and

their architectural precursors as a series of systems of interdependent parts. He explained that the sequence of coordinated changes that occurred made possible the new Gothic style, noting some changes would necessarily have preceded other changes.

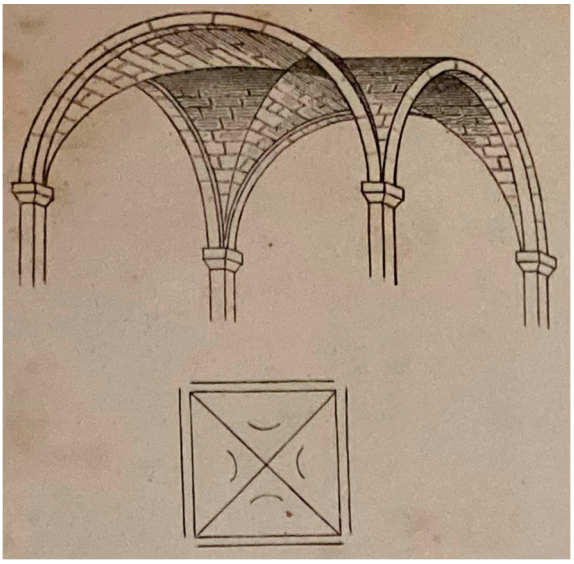

Figure 1. Square floor space covered by four semicircular vaults. Figures 1 and 2 are courtesy History of Science Collections, University of Oklahoma Libraries.

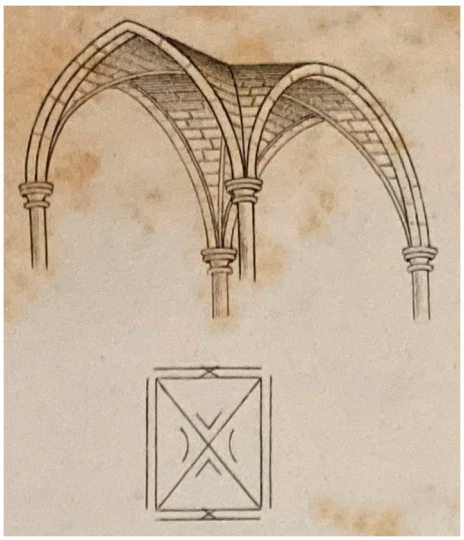

Figure 2. Rectangular floor space covered by two semicircular vaults and two pointed vaults. In the top-down view sketch the two shorter sides enabled by pointed arches are highlighted with Xs in Whewell's book as reproduced here.

A recent study of Whewell's architectural history in relation to the foundation of biological origins science shows how Whewell established that the "story of a historical lineage is a story of transmission and alterations of a coherent set of possibilities." (Quinn 2016, p. 15). In so doing, Whewell showed how to engage in causal reasoning in "historical science in the absence of general laws about contingent historical claims." (Ibid., p. 11). General laws sometimes play a role in reconstructing natural and human history, but it is a subsidiary role according to Whewell. Philosophers of science today typically agree with Whewell on these points about historical reasoning in biology.

Using this framework of historical reasoning, Whewell concluded that many historical events in the appearance of organisms on earth had intelligent (and more specifically

supernatural) causes (Whewell 1840, vol. 1, p. 164). These events differ from "the common course of nature"[38] Whewell proclaimed, employing the science-fostering medieval Christian concept tracked in Section 4. Even so, Whewell insisted that origin hypotheses in biology be evaluated on scientific, not theological, grounds (Quinn 2016, p. 14). The logic of these biological design inferences enabled scientists to "ascend to a past state, by considering what is the present state of things, and what are the causes of change." (Whewell 1845, p. 97).

Whewell explained how our present empirical experience of the cause-and-effect structure of the world provides clues that enable us to reconstruct the history of nature. He further developed the logic of the inference to intelligent design in biological origins by an analysis of how one human infers the existence of other intelligent agents, especially other humans.

> How are we led to elevate, in our conceptions, some of the *objects* which we perceive into *persons*? No doubt their actions, their words induce us to do this. . . . We feel that such actions, such events must be connected by consciousness and personality; that the actions are not the actions of things, but of persons; not necessary and without significance, like the falling of a stone, but voluntary and with purpose like what we do ourselves . . . (Whewell 1833, p. 345).

Whewell explains that belief in the existence of other persons is warranted because it is based on one's own experience of how thought, purpose, and choice operate. Note further how Whewell relates such intelligent agency detection to the inference to intelligent design in biological origins. In reference to the coordination of physical requirements for earth's habitability in conjunction with the coordination of anatomical parts necessary for biological functions in organisms, Whewell concluded that this system points to the "intention, wisdom, and goodness of a personal creator". Whewell also emphasized that such intelligent design inferences in biology are not "unphilosophical" (an archaic way of saying unreasonable or unscientific). He justified the reasonable status of these biological design inferences by noting that the "process corresponds most closely with that on which rests the most steadfast of our convictions, next to that of our own existence, the belief of the existence of other human beings." (Ibid., p. 346).

Whewell explained that the design inference is also well supported by the evidence for natural limits to biological change.

> There may thus arise changes of appearance or structure, and some of these changes are transmissible to the offspring: but the mutations thus superinduced are governed by constant laws, and confined within certain limits. Indefinite divergence from the original type is not possible; and the extreme limit of possible variation may usually be reached in a brief period of time (Whewell 1857, p. 479).

Whewell never dismantled his own account of the legitimacy of design inferences in biology, even in the wake of Darwin's *Origin*. In his last publication that addresses this topic, he responded to the memorable passage in Darwin's *Origin* in which Darwin had speculated about how a nerve might become sensitive to light, and how, coordinated with other related changes, this unguided process could produce an eye.[39] Whewell called this Darwin's "gigantic fabric of hypotheses, of which the basis is a *suspicion* that any nerve may become sensitive to light." (Whewell 1866, p. 358). Notice below how his criticism of Darwin's eye origin speculation shows how Whewell exhibited no obedience to MN in his reasoning to intelligent design in biological origins.

> The inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, for the correction of spherical and chromatic aberration, are all on the imaginary road from a bit of nerve to a complex eye; and therefore Nature has travelled on this road to the complex eye. This, it is confessed, seems absurd, but yet this is the doctrine insinuated. But the difficulties are not yet half stated. For, besides all this, and running parallel with these gradations of the optical adjustments, we have a no less complex system of muscles for

> directing the eye: some of them, as the pulley-muscle, dwelt on by Paley, such as resist the tendencies of their neighbours; and the numerical expression of these correspondencies of the gradations of the optical and the muscular adjustment of the eye is to be multiplied into itself for every organ of the animal, in order to give the number of chances of failure to success in this mode of animal-making (Ibid).

For this to have occurred without intelligent design is scientifically unreasonable, he concluded. Scientists would have to muster "a large swallow that can gulp down" (Ibid). Darwin's eye origin story, because of the absence of sufficient reasons to embrace it. This was Whewell's final assessment of Darwin's theory. Sadly, before this essay went to press, Whewell died after he fell from his horse (Snyder 2010, p. 323).

6.2. Charles Darwin (1809–1882)

Let us return to the intriguing connection between Whewell and Darwin in regard to MN. After reading John Herschel's June 1841 review of Whewell's *Philosophy of the Inductive Sciences*, Darwin made this note to himself in his private notebook: "I MUST STUDY Whewell on Philosophy of Science." Despite Darwin's "MUST STUDY" all-capitalized emphasis, several historians think he never read any of the three editions of Whewell's masterpiece that appeared from 1840 to 1858 (those available before Darwin's 1859 *Origin*)—nor any later editions of Whewell's multivolume book.[40] This means Darwin failed to read Whewell's most extensive contribution to how scientists can legitimately reconstruct the history of life on earth—without MN.[41] We have seen how Whewell, a pioneering philosopher of science and widely respected science practitioner, did not promote MN in the biological origin sciences. Rather he promoted *methodological pluralism*: openness to both natural and intelligent causes for explaining the history of the appearance of life on earth.

Methodological *pluralism*, not methodological *naturalism*, appears to have been the leading view in the life sciences on the eve of Darwin's *Origin*. Whewell, who was familiar with the work of a huge number of scientists, states that "the best naturalists" had rejected the "transmutation" theory of the origins of species due to the evidence for "rigorous limits" to natural biological change (Whewell 1857, pp. 477–78). This understanding of biological origins entailed detecting *both* unintelligent natural causes for limited transmutation, and intelligent causation for the origin of major new kinds of life. This is methodological pluralism, not MN.

Nineteenth-century methodological pluralism in the biological origin sciences is a remarkable achievement of meta-theoretical freedom and tolerance for intellectual diversity within Western culture.[42] The present essay highlights some of the Judeo-Christian and specifically Whewellian underpinnings of this legacy. Its enduring value for recent debates about biological origins is this: Follow the evidence wherever it leads, rather than prejudge the range of possible outcomes by MN. Darwin thought otherwise, first affirming MN privately, and then in broad public daylight—bucking majority methodological pluralism.

Although Darwin broke ranks with the methodological pluralism majority, few scholars have noticed that the first three editions of Darwin's *Origin* did not explicitly advocate MN—though private correspondence shows Darwin had already embraced it.[43] Stephen Dilley has located Darwin's first printed explicit invocation of MN in the fourth edition of the *Origin* (Dilley 2013), which was published in June 1866, about three months after Whewell died on March 6, 1866. Darwin would likely have known of the death of his highly influential acquaintance [44] and intellectual opponent with respect to origins. In 1866 (in the fourth edition of the *Origin*), Darwin advocated MN in his discussion of homologous organismal parts.

> On the ordinary view of the independent creation of each being, we can only say that so it is—that it has pleased the Creator to construct all the animals and plants in each great class on a uniformly regulated plan; but this is not a scientific explanation (Darwin 1866, p. 513).

This passage is rendered similarly in the first three editions,[45] but they lack the final phrase—"but this is not a scientific explanation".

Dilley's most striking conclusion about Darwin's increasing deployment of MN in the later editions of the *Origin* is that he thereby aimed mainly at winning evolution converts and ostracizing special creation, "rather than making a strong empirical and philosophical case per se for his position." (Dilley 2007, p. 20). In other words, Darwin's explicit invocation of MN was more rhetorical than epistemic. In support of this point, Dilley identifies a glaring inconsistency in Darwin's treatment of special creation: "A theory that is genuinely immune from scientific analysis [because it breaks the MN rule] cannot be rendered more or less probable by scientific analysis"—both of which Darwin incoherently attempted to do (Dilley 2013, p. 28). Finally, Dilley observes that "Darwin did not entirely cleave God from his science, including in later editions of the *Origin*. Several scholars have argued the *Origin* relied on theology in significant ways."[46] So the later editions of the *Origin* were inconsistent in their adherence to MN in multiple ways.

The timing of Darwin's first explicitly published use of MN is significant. He adopted this new public polemic in 1866 shortly after the death of Whewell—a world-class expert on what counts as a scientific explanation. This campaign may have been Darwin's second highly consequential opportunistic act in regard to Whewell (and the X Club likely influenced Darwin's MN proclamation, as shown below). As noted above, Darwin's first major opportunistic move with regard to Whewell was to quote Whewell's Bridgewater Treatise in a way that was out of sync with Whewell's overall contribution to the philosophy of science, especially as it pertains to origin of species by means of natural events and/or by means of intelligent causation. Whewell clearly opted for a methodological pluralism that embraced both kinds of causation for reconstructing the history of earth's organisms. MN was for Whewell an unjustified artificial constraint on theory construction and evaluation within biological origin science. How did this majority pluralistic methodological stance become a minority position in biology? We turn to that story next: the rise of MN to majority status during the late 19th century.

6.3. Darwin's Bulldogs: The X Club from 1864 to 1882, and the Rise of MN to Majority Status

MN gained many new adherents through the efforts of Darwin and a network of friends known as the X Club. The most influential X Club member, Thomas Henry Huxley (1825–1895), was also known as "Darwin's bulldog". Huxley acquired this whimsical title due to his polemical efforts in support of Darwin, though he disputed some of Darwin's evolutionary mechanisms. The X Club's evolution advocacy was part of a larger Victorian social reform movement Huxley retrospectively called scientific naturalism in 1892. Huxley thereby rehabilitated the earlier history of the movement, when it was known by terms such as "scientific materialism".[47] Victorian *scientific naturalism*, the softer term many recent historians favor,[48] promoted MN, MN-structured science education (Stanley 2014a, pp. 243–48), scientism, and often metaphysical naturalism (atheism) or more modest "agnosticism"—an ambiguous we-lack-knowledge-of-God label Huxley coined in 1869 (Dockrill 1971, pp. 461–77; Lightman 2002, pp. 271–89). The X Club, which met in London restaurants from 1864 to the 1880s, was at the center of this movement.

Historian Ruth Barton discovered that in the 1860s the X Club was "sometimes described as a clique, indicating that their power was not regarded as legitimate." (Barton 2018, p. 448). She also found that sometimes they were "secretive and conspiratorial." (Ibid., p. 214). The X Club's last major Darwin-bulldog achievement was to have Darwin buried beside Issac Newton in Westminster Abbey in 1882.[49] Stephen Hawking's body was added to the Abbey collection in 2018 as a symbol of the importance of "science and religion work[ing] together."[50]

The X Club's advocacy of scientific naturalism aimed to decouple the synergy between natural science and Christianity documented above and in Section 7. Matthew Stanley, a leading Huxley scholar, put it this way: "The triumphalist story of scientific naturalism—that science only became modern once it cast off the albatross of dogmatic

theology—was precisely the story promoted by the X Club." (Stanley 2014b, p. 244). Its leaders emphasized that in origin science one should disregard the possibility of supernatural causation. That is clearly MN. So the X Club functioned as Darwin's and MN's bulldogs.

Stanley further explains:

> The key to this naturalization strategy was for Huxley to tell a new story about the history of science. By naturalizing theistic science, he was able to argue that science had *always* been naturalistic. That is, by naturalizing the tradition of theistic science, he was able to remove it from history completely, making naturalism the obvious and solitary way to do science (Stanley 2014a, p. 256).

Huxley attempted to tell the story of the rise of natural science without any positive contributions from Christianity. He also helped eclipse the legacy of William Whewell, who had cultivated the integrated field of the history and philosophy of science to show that methodological and metaphysical naturalism have not been the only guides to science.

Until recently, historians have largely assumed that by the 1870s Christian intellectuals had mostly ceded scientific authority to the promoters of scientific naturalism. From the point of view of that flawed historiography, the debate appeared to be between scientific and religious authorities. However, Bernard Lightman has recently shown how the

> historical actors saw the debate as taking place between two sets of scientific authorities. In other words, Christian intellectuals were not willing to give up "science"—they refused to recognize Huxley and his allies as the sole scientific authorities who alone could speak on behalf of "science" and who alone defined its boundaries and determined its larger implications (Lightman 2016, p. 189).

Despite such thoughtful Christian critique, scientific naturalism and its core MN mode of inquiry, achieved majority status by the turn of the century. Part of the reason for this transformation was that some members of the X Club and its larger network of friends composed an account of the history of science that made it appear as if they were on the right side of history.[51] What important patterns in the history of science and Christianity did they miss? Let us highlight a few examples beyond what we have already encountered in Sections 3–6.

7. Christianity Generated Other Rational Beliefs That Contributed to Natural Science

The highly influential Church Father Saint Augustine (354–430) expressed confidence in our ability to read the "book of nature" because it is the "production of the Creator".[52] He instructed we should proceed "by most certain reasoning or experience" to discern the most likely way God established "the natures of things". This latter phrase became a popular medieval book title for works following Augustine's investigative approach.

For example, the English monk Bede (673–735) studied astronomy in the tradition of Augustine and Ptolemy. Historian Bruce Eastwood called Bede's book *The Nature of Things* (ca. 701) "a model for a purely physical description of the results of divine creation, devoid of allegorical interpretation, and using the accumulated teachings of the past, both Christian and pagan." (Eastwood 2013, p. 307). Note how Bede's Christian worldview was compatible with the analysis of the natural world as a coherent and knowable system of causes and effects.

The institution in which scholars have investigated nature for many centuries is also noteworthy—the university. This medieval invention began with the University of Bologna in 1088, followed by Paris and Oxford before 1200, and more than 50 others by 1450. The papacy supported this remarkable intellectual development. Universities provided additional stimulus to the medieval translation movement already under way, in which Greek and Arabic texts were rendered in the common European intellectual tongue of Latin. This movement greatly outperformed the comparative trickle of imperial Roman translations. If European Christians had been closed-minded to the earlier work of pagans, as the Dark Ages myth alleges, then it would be difficult to explain this huge appetite for translations.

The Franciscan cleric and university scholar Roger Bacon (ca. 1220–1292) read much of the newly translated work of earlier Greek and Islamic investigators, including Euclid, Ptolemy, and Ibn al-Haytham (ca. 965–1040). By evaluating them and introducing controlled observations (now called experiments), Bacon substantially advanced the science of light (Lindberg and Tachau 2013, pp. 503–4). Subsequent authors summarized and reevaluated Bacon's work, transmitting it through books used in university instruction. That is how it came to the attention of the Lutheran polymath Johannes Kepler (1571–1630), whose account "helped spur the shift in analytic focus that eventually led to modern optics."[53]

Christianity played a significant part in the development of such experimental methods aimed at disclosing the nature of things. The Christian belief in the divine freedom of the creator undercut the view, established by Plato and Aristotle, that the structure of the cosmos is a necessary one. Christians insisted that God could have created a universe quite different from the one Aristotle imagined, and so testing multiple hypotheses by experiment was an effective way to determine which set of natural laws God actually created to govern our cosmos (Davis 1999, pp. 75–95; Hannam 2009).

As we peer deeper into the foundations of natural science, we see Christianity cultivated a balance of both humility and confidence in human knowledge. Our confidence is derived from the orderliness of God's world, designed for discovery by his human image bearers. Belief in God as the universal lawgiver encouraged investigation of nature to discover natural laws, as the monumental achievements of Kepler, Galileo, and Newton demonstrate.

At the same time, human fallibility was one of the most persistent themes in the Bible. The Christian doctrine of the Fall of Adam and Eve, and our status as finite creatures, provided an explanation for the difficulty of human reason in achieving certainty about the cosmos, with a consequent emphasis on the testing of hypotheses. Many medieval and modern scientists embraced this balance of confidence and humility (Harrison 2007).

Galileo, Kepler, and many other early modern scientists were guided by the traditional Christian metaphor of the "book of nature". They sought to convey the idea that God wrote two books that are consistent with one another: nature and the Bible. Nature is largely written in the language of mathematics, many of these scientists argued, and so it can be read only by those who know this language. Galileo argued this in his book *The Assayer*. He wrote:

> Philosophy [natural science] is written in this all-encompassing book that is constantly open before our eyes, that is the universe; but it cannot be understood unless one first learns to understand the language and knows the characters in which it is written. It is written in mathematical language (Finocchiaro 2008, p. 183).

Similarly, Kepler believed mathematical ideas exist eternally in God's mind. God selected some of these principles to govern his creation. Because God created humans in his image, we have the intelligence needed to discover those natural laws, and in so doing, humans "share in his own thoughts".[54] Such Christian beliefs contributed to the foundations of science.

Darwin and his X Club supporters did not recognize the history we just outlined. They also ridiculed the miracles of the Judeo-Christian tradition as intrinsically anti-scientific. Such criticism failed to recognize the very notion of a miracle—understood as a rare supernatural event that is *only detectable* against a *backdrop of regularity*—would be inconceivable without the companion science-fostering idea of nature's regularity, to which the Judeo-Christian tradition had substantially contributed. A notable example of this misconceived materialist critique of miracles is in Darwin's autobiography, where he declared his belief "that the more we know of the fixed laws of nature the more incredible do miracles become." (Darwin 1959, p. 86). Had Darwin heeded his own private notebook declaration ("I MUST STUDY Whewell on Philosophy of Science"), he would have been better equipped to avoid this misconceived critique of miracles and to recognize the positive influence of theistic ideas on science that Whewell had documented.

8. Methodological Naturalism: Then and Now

Let us reassess Tiddy Smith's recent proposal to transcend some of the historical-philosophical inadequacies of intrinsic and pragmatic methodological naturalism (IMN and PMN), which prompted him to recommend epistemological methodological naturalism (EMN). MN, as conceived within the EMN perspective, stipulates that "only natural cognitive faculties may be used" to justify theories about nature. Recall that Smith had proposed: "Methodological naturalism is not a thesis about what may or may not be conjectured [as an explanation] by scientists [as is the case with IMN and PMN], but about how scientists may or may not justify their theories."

Smith's MN (EMN) seems to exclude from natural science the seminal work of Galileo and Kepler (and many others) who developed their theories of nature on the foundational idea that God wrote two books that are consistent with one another as complementary modes of divine revelation: nature and the Bible. Nature is largely written in the language of mathematics, they proposed, and so it can be understood by theory-making crafted by those who know this quantitative language of divine revelation. Conversely, if we conceive of the human ability to decode the mathematical structure of nature as merely "natural cognitive faculties" at work, then that would justify including the work of Galileo and Kepler within the boundaries of natural science as conceived within MN (especially EMN).

However, this move disregards the categories of the actors themselves—the self-conception of leading early modern scientists such as Galileo and Kepler. These scientists understood their cognitive faculties as created by God so as to enable them to decode the mathematics of nature as the revelatory language of God. Kepler specifically understood it this way: Because God created humans in his image, including our ability for mathematical conceptualization, we have the cognitive tools needed to discover the mathematically-structured laws of nature, and in so doing, humans "share in [God's] own thoughts." Accordingly, in the dedication to his *Epitome of Copernican Astronomy*, Kepler identified himself as a "priest of God, the creator of the book of nature."[55] Kepler understood his scientific discoveries, such as of the three laws of planetary motion (as they are now called in science textbooks), to have been episodes of receiving divine revelation.[56] Smith's account of MN (EMN) prohibits divine revelation as a source for scientific theorization (Smith 2017, pp. 322, 327, 329). Kepler violated Smith's MN!

What about the other two major versions of MN: IMN and PMN? Darwin inconsistently vacillated between IMN and PMN.

> IMN: Science, as a way of knowing nature, excludes supernatural explanations of nature.
>
> PMN: Because scientists, *qua* scientists, have evaluated supernatural explanations of nature and found them inadequate, scientists no longer consider supernatural explanations as live options for scientific theory.

Today many scholars remain stuck in Darwin's dilemma as identified by Dilley and further developed in the present essay. This dilemma is summarized by restating with bracketed interpolations a previous quotation of Dilley aimed at Darwin's treatment of creationism: "A theory that is genuinely immune from scientific analysis [because it breaks MN understood as IMN] cannot be rendered . . . less probable by scientific analysis [that allegedly justifies rejection of creationism by MN understood as PMN]." Darwin and many of his ideological successors have incoherently attempted both. They have engaged in such inconsistent critiques of creationism and intelligent design.

This inconsistency is less surprising given Darwin's use of MN had both epistemic and *rhetorical* functions. As we have seen in Dilley's analysis, Darwin's increasing deployment of MN in the later editions (1866 and beyond) of the *Origin* was aimed mainly at winning evolution converts and ostracizing creationism, "rather than making a strong empirical and philosophical case per se for his position." (Dilley 2013, p. 20).

Because intelligent design theory does not violate Smith's MN (EMN), EMN is unlikely to become the leading version of MN in the present climate of opinion. Nevertheless,

Smith's historical-philosophical critique of the two other major versions of MN (IMN and PMN) will be difficult for scholars and scientists to ignore—once exposed to Smith's formidable rationale, as enhanced in the present essay.

Another under-appreciated scholar in today's MN debate is the Canadian philosopher Robert Larmer. Echoing important distinctions I have made above for historical-philosophical analysis of MN, Larmer observes that "appeals to supernatural agency are not typically found regarding how things work, but rather how they come to exist in the first place." The former branches of science are *nomological* (explicating the repetitive common course of nature as medieval Christians conceived it), while the latter is *historical* (reconstructing unique contingent origin events in the history of nature). With this distinction in mind, Larmer quips:

> The fact that turtles are easy to catch hardly provides warrant for thinking that cheetahs will be easy to catch, and the fact that natural explanations in nomological science have enjoyed great success, scarcely warrants the assumption that explanations in terms of natural causes in historical science will enjoy the same degree of success (Larmer 2019, p. 19).

Emulating William Whewell's logic of intelligent design inferences in biology, SETI scientists since the 1960s have aimed to detect signals from space that display a pattern requiring alien intelligence to explain. Given Richard Dawkins' openness to a space alien intelligent cause of life's origin on earth (Section 2), this illustrates how SETI cannot legitimately be characterized as an *agent*-oriented inquiry that is totally separate from the *natural* (especially chemical-biological) origin sciences. This point strengthens Larmer's observation that potential alien design inferences are widely deemed acceptable in science "because they are not presumed to challenge a naturalistic account of how conscious intelligent agents originated." Only when the "design would have to be attributed to a supernatural intelligent agent" is the inference to design "judged to be only apparent and not genuine." (Ibid., p. 20). Larmer rightly identifies this argumentative move as arbitrary and unconvincing, despite the various campaigns to dignify it with the MN label.

9. Conclusions

We have seen how Christianity generated rational beliefs that contributed to the rise of natural science. This science-fostering rational belief included rationales for when to practice MN, and when to study nature without that restriction. Medieval Christian intellectuals sometimes promoted MN, or something like it, in the study of how things work in nature. The main difference this made was to more clearly distinguish theology from natural philosophy (roughly natural science). This promoted scientific progress. In most cases, MN did not make a big difference in the practice of science itself until its use, and its negation, competed for adherents in the biological origin sciences since the 19th century.

Whewell, speaking for the majority of scientists before Darwin's 1859 *Origin*, recommended methodological pluralism, not MN, in the study of biological origins. Methodological pluralism positioned scientists to remain open to detecting both natural and intelligent (even supernatural) causes in the history of life's appearance on Earth. Darwin and the X Club led the effort to replace methodological pluralism with MN. This campaign, in combination with other factors,[57] succeeded in making MN the majority view in the study of biological origins by around the turn of the century.

MN became a big difference-making methodological proposal within the study of biological origins ever since theorists developed rigorous empirical techniques for reconstructing this domain of nature's history in the 19th century. However, the big difference MN makes here is contestable—whether it promotes, or hinders, the discovery of the truth about biological origins.

If the majority of scientists today were to push aside MN as illegitimate in biological origin science, as a minority of them currently do (embracing instead methodological pluralism), this would not prohibit or discourage scientists from searching for natural

causes of the progressive appearance of organisms on earth. This point is illustrated well by the work of Whewell—a proxy for the majority view among scientists prior to the X Club's influential MN lobby. The current majority status of MN with regard to biological origins is a contingent fact of history, not the inevitable result of rational progress. The illusion of the latter owes much to the faulty historiography disseminated by the X Club, which has been subsequently perpetuated in popular science writing.

The present essay has excavated and repaired the historical-philosophical playing field so it no longer illegitimately predisposes us to accept the MN metanarrative as inevitable rational progress in all domains of the natural sciences. In light of this accomplishment, Larmer's diagnosis shines all the brighter.

> The issue is not whether it is legitimate to look for natural causes of phenomena, but rather whether science must or should in all circumstances confine itself to attempted explanations in terms of natural causes, no matter how inadequate such attempted explanations prove (Larmer 2019, p. 21).

William Whewell, the eminent scientist-scholar who helped pioneer the very term *scientist*, would agree.

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Dedication: For the admirable fellow historian of science Ronald Leslie Numbers (1942-), whom I have known since our first phone conversation in 1983 concerning my placement in a Ph.D. program. I owe much to Ron for his encouragement and advice at many junctures in my career over the past 40 years. Here is one memory: enjoyable conversation with Ron and other historians of science who were invited to the 2014 conference he organized, which was aimed at preparing the essays subsequently published in *Newton's Apple and Other Myths About Science* (Harvard University Press, 2015). Due to circumstances, he was unable to comment on the present essay, which interacts with his influential essay (Numbers 2003) on the same topic. In a 7 June 2023 personal email, he wished me "good luck" on my essay.

Notes

1 For purposes of this essay, I identify science without reference to any theological premises that may have been used within explanations of nature. Such theological premises, depending on their characteristics, might conflict with Christianity, or certain branches of Christianity. For example, Cornelius Hunter has argued that a theological form of naturalism, which he calls theological naturalism, operates internally within some scientific arguments, particularly in origin science. He defines theological naturalism as a set of theological traditions mandating naturalistic explanations in science. For example, he identifies a utilitarian theological premise: God would create to ensure optimal utility in *each* kind of organism *without* tradeoffs due to other design criteria such as aesthetics (including whimsical beauty) or ecological integration for higher level order (the ecological tradeoff example is mine, not Hunter's). This utilitarian theological premise is found in a leading evolutionary biology argument influentially expressed by Stephen Jay Gould: "Odd arrangements and funny solutions are the proof of evolution—paths that a sensible God would never tread but that a natural process, constrained by history, follows perforce," (Gould 1980, p. 20), as cited in (Hunter 2022, p. 7). See also the following works: (Hunter 2002, 2007, 2021).

2 (Harrison and Roberts 2018). This anthology updates and expands Numbers' seminal "Science without God" essay (2003), arguing that Christian intellectuals contributed to science and methodological naturalism (or its rough archaic science-without-God equivalent), but that this largely occurred within a Christian theological framework. So, the essayists generally aim to show that this admirable medieval and early modern achievement was *not* "without God" in a broad sense.

3 Such a lesson justified by a similar historiography is in (Bishop 2013). Bishop argues that in nature studies, methodological naturalism has been, for good reasons, the typical orientation of Christians since the Middle Ages.

4 For a longer lesson in allegedly good science in the same issue of the Christian journal that published Bishop, "God and Methodological Naturalism," see (Applegate 2003). Applegate offers practical and theological reasons for methodological naturalism.

5 (Boudry et al. 2010). On 18 February 2017, Boudry tweeted his atheism colorfully: "No self-respecting university should have a Faculty of Theology. Even a Faculty of Astrology would make more sense. At least stars exist." Accessed on 13 March 2023 at https://twitter.com/mboudry/status/835817310141235200. Boudry underappreciates the university as a medieval invention within Christendom in which about a third of the undergraduate curriculum was devoted to the study of nature (and mathematics) as a means to cultivate reasoning more broadly. The Church funded this towering cultural achievement, as documented in (Grant 2001).

6 At least in the recent American context, creationism is largely understood to be an endeavor to correlate particular understandings of the first chapters of Genesis in the Bible to the findings of modern science. As Stephen Meyer explains, "Creationism or Creation Science, as defined by the U.S. Supreme Court, defends a particular reading of the book of Genesis in the Bible, typically one that asserts that the God of the Bible created the earth in six literal twenty-four hour periods a few thousand years ago." By contrast, "The theory of intelligent design does not offer an interpretation of the book of Genesis, nor does it posit a theory about the length of the Biblical days of creation or even the age of the earth. Instead, it posits a causal explanation for the observed complexity of life." (Meyer 2006).

7 One reviewer suggested that Neo-Darwinian random mutations are just as impersonally capriciousness as Epicurean randomly swerving atoms, and so it is inconsistent to argue that Epicureans (but not also Darwinians) do not fit the *MN origin (and progress) of science* narrative, which traditionally aimed at celebrating the *elimination (or reduction) of unpredictability* in nature. However, in evolutionary theory since Darwin, the capriciousness of random variation is counterbalanced by non-random mechanisms such as natural selection and other natural laws. So Lehoux's argument still has merit even after qualifying it in response to this reviewer's insightful comment. One might also note two opposing inclinations within evolutionary theory today: (1) emphasize frequent convergence on similar molecular-anatomical structures due to non-random natural law constraints, or (2) emphasize the overall contingency and unpredictability of evolution as famously expressed by Stephen Jay Gould in his book *Wonderful Life* (Gould 1989, p. 45) in which he said evolution is "a staggeringly improbable series of events, sensible enough in retrospect and subject to rigorous explanation, but utterly unpredictable and quite unrepeatable. Wind back the tape of life to the early days of the Burgess Shale; let it play again from an identical starting point, and the chance becomes vanishingly small that anything like human intelligence would grace the replay." A similar tension between random and non-random accounts of nature is seen among ancient Greek thinkers.

8 (Adelard of Bath 1998, p. 93). This text of *Questions on Natural Science* (*Quaestiones naturales*) is based on more manuscripts than previous editions. The other dialogues addressed to his "nephew" are a treatise on the liberal arts that constitute philosophy (*On the Same and the Different*) and a manual on the upbringing and medication of hawks (*On Birds*).

9 (Ibid., pp. 97–98); the translator supplied the interpolations in brackets.

10 (Abelard and Zemler-Cizewski 2011, p. 55). Zemler-Cizewski supplied all the interpolations in brackets, except for my two interpolations: miraculously and non-miraculously.

11 (Boethius of Dacia 1987). Boethius interacts with Aristotle's idea of an eternal uncreated cosmos.

12 (Dilley 2007, p. 41), concludes regarding Boethius: "The proscription of references to supernatural causes or principles from natural philosophy just *is* methodological naturalism." Dilley largely identifies MN as IMN, though he appears to see the utility of engaging EMN.

13 For a similar argument see (Shank 2019).

14 (Turner 2010). Turner on p. 104 concludes that, by the late 19th century, many religious writers thought it necessary to promote "a new theology compatible with the new science" of biological origins driven by MN. This development "fostered conflict, as more traditionally minded religionists attempted to defend older opinions that stood in contradiction" to MN-guided biological origins science. (Moore 1979), gives a prominent example of a theological novelty that traditional theologians contested: The Catholic scholar Saint George Jackson Mivart (1827–1900), one of the most influential theological commentators on evolutionary theory, believed that the "human body was derived from" a natural God-guided evolutionary process, "but the soul, the source of mankind's rational and ethical nature, appeared de novo by creative fiat." Moore further notes that five years after Mivart published this conclusion, Pope Pius IX conferred on Mivart the degree of doctor of philosophy (1876).

15 Grant, *The Nature of Natural Philosophy*, pp. 49–90, argues that some of the Aristotelian philosophical principles condemned by the bishop of Paris in 1270 and 1277 stimulated non-Aristotelian conceptions of nature that produced scientific progress in the medieval and early modern periods. Boethius' career at the University of Paris was in its final stages around the time of these condemnations. In this controversial milieu, he framed his MN-like rule to protect his professional space as a natural philosopher, while also affirming his theological orthodoxy.

16 Newton's title in its original Latin was *Philosophiae Naturalis Principia Mathematica*. For the helpful role of Christian theology in this development, see (Kaiser 1997).

17 Natural philosophers were tasked with studying natural, not supernatural, events. In view of this university requirement, Buridan wrote: "In natural philosophy, we ought to accept actions and dependencies as if they always proceed in a natural way." However, Buridan in practice did not strictly follow this advice. Buridan, *Questions on the Heavens (de caelo)*, book 2, question 9, as cited in (Grant 2012, p. 42).

18 This point is extensively documented in (Heilbron 1999).

19 Prominent among such misguided literature is Boudry et al. (2010, 2012) discussed in Section 2. For a response to these essays, see (Harrison 2018).

20 For an assessment of the presence of MN during the scientific revolution, see (Harrison 2019). On p. 70 he writes: "One of the shortcomings of early modern natural philosophy was its limited capacity to shed light on the origins of the earth, the geological changes that it had undergone in the past, and those that would befall it in the future. Newton, for example, insisted that the scope of natural philosophy extended only to 'the present frame of nature' and not the creation of the world, nor its eventual destruction."

21 (Davis 2023). Referring on p. 6 to natural philosophy *not* focused on *origins*, Davis writes that "Boyle rejected miracles in natural philosophy: there he accepted methodological naturalism." However, Davis also notes on p. 14 that Boyle's work has legitimately provided the basis for what is now called the theory of intelligent design (ID) with regard to *biological origins*. Such ID proponents, Davis observes, share Boyle's "view that mechanistic science gives rise to powerful arguments for an intelligent designer" when "they use current scientific knowledge of what mechanistic processes *can* do to identify aspects of nature that (in their view) *cannot* be explained by unintelligent causes alone . . . ." This entails the repudiation of MN in the study of biological origins, which was implicit in Boyle's work and explicit in ID today.

22 Earlier natural philosophers addressed some origins questions (e.g., the cause of the cosmos, earth, and life), but with only rudimentary investigative techniques.

23 (Rudwick 2005, p. 171), "No naturalist could now [about 1825] claim, with any credibility, that life had maintained an ahistorical stability or steady state, still less a recurring cyclicity, of the kind that Hutton, long before, had conjectured for its physical environment." Rudwick's book is a comprehensive study of the origin of geology, not just a treatise on geology and religion.

24 A possible objection to this conclusion would be to identify the Christian contribution to geohistory as science-engaged philosophy rather than an *argument within science* and to argue that only the latter is legitimately restricted by any form of MN. However, this objection misses the mark. In this case, the scientists structured their *arguments within* science by means of emulating a Christian view of directional history.

25 Whewell used the term consilience to roughly refer to what is now more commonly called unification. (McMullin 2014). For an elaboration of unification in contrast with other theoretical virtues, see Keas, "Systematizing the Theoretical Virtues."

26 (Ducheyne 2010). Ducheyne notes that Whewell was a respected practicing scientist (especially in tide theory) in addition to his main expertise in the history and philosophy of science.

27 (Crowe 2016). Here on pp. 437–45, and in a forthcoming essay, Crowe shows how Whewell pioneered astrobiology's *circumstellar habitable zone* (Whewell called it the "Temperate Zone of the Solar System"). Whewell established this life-friendly zone on the physics of the rapid diminution of heat at further distances from a host star—the inverse square law for stellar radiation discovered by Whewell's close friend, the leading astronomer John Herschel. In our solar system, the inner planets are too hot for complex life, and the outer planets are too cold. Whewell recognized this is based on natural laws governing all solar systems, making potentially habitable planets (based on temperature for liquid water) *rare* compared to what had been imagined previously.

28 (Davis 2013). Davis notes that Boyle contributed to "'Boyle's Law,' the inverse relation between the pressure and volume of gases that is a standard part of a basic chemistry course."

29 For an assessment of Harvey that is similar to Whewell's, see (McMullen 1998).

30 (Whewell 1858, p. 246). Whewell quotes Bichat's *Anatomie Générale*.

31 (Whewell 1857, p. 488, this is identical in the 1st ed. of 1837, p. 588).

32 Ibid. Here is the context for the quotation. Whewell writes of "the impossibility of accounting by any natural means for the production of all the successive tribes of plants and animals which have peopled the world in the various stages of its progress, as **geology** teaches us. That they were, like our own animal and vegetable contemporaries, profoundly adapted to the condition in which they were placed, we have ample reason to believe; but when we inquire whence they came into this our world, **geology** is silent. The mystery of creation is not within the range of her [geology's] legitimate territory; she [geology] says nothing, but she points upwards." (emphasis is mine).

33 (Ruse 2010). See https://todayinsci.com/W/Whewell_William/WhewellWilliam-Quotations.htm (accessed on 11 March 2023) or an example of the error of *nature*, rather than *geology*, in brackets.

34 Similar to the historian of geology Rudwick, Whewell declares that "the geologist is an antiquary [historian] of a new order," due to "a real and philosophical connexion of the principles of investigation" of human history and geology. "The organic fossils which occur in the rock, and the medals which we find in the ruins of ancient cities, are to be studied in a similar spirit and for a similar purpose . . . . The history of the earth, and the history of the earth's inhabitants, as collected from phenomena, are governed by the same principles . . . . In both we endeavor to learn accurately what the present is, and hence what the past has been. Both are *historical* sciences in the same sense." (Whewell 1857, pp. 398–402).

35 (Whewell [1830] 1842, plate I, Figure 1).

36 Ibid., plate I, Figure 3.

37 Whewell considered the aesthetic criterion of *highly coordinated vertical* lines (as opposed to Romanesque *horizontal* orientation with a lower degree of coordination) to be the main "formative principle" of Gothic architecture, "which gave unity and consistency

to the new style, and disclosed a common tendency in the changes which had been going on in the different members [i.e., physical components] of the architecture. And the very fact of this character being, when once applied, so manifest and simple a mode of combining the parts of the structure into a harmonious whole, shows how much of genius there was in the discovery" (Ibid., pp. 10–11). He hinted at an underlying aesthetic theory to this aesthetic judgment: "Now in order to consider a work of art as beautiful, we must see, or seem to see, the relations of its parts with clearness and definiteness. Conceptions which are loose, incomplete, scanty, partial, can never leave us pleased and gratified, if we are capable of full and steady comprehensions" (Ibid., p. 9). Given that Whewell deployed much of his architectural history logic to the history of life on earth, he would have surely appreciated the subsequent discovery of both the *aesthetic* and *physical survival* value of compact seed arrangements in certain flowers which exhibit Fibonacci (or similar mathematical regularities) in their spiral arrangements of seeds. (A Fibonacci sequence is one in which each number is the sum of the two preceding ones: e.g., 1, 2, 3, 5, 8 . . .). There are multiple beautiful Fibonacci or Fibonacci-like arrangements that embody mathematically elegant solutions to seed arrangements that cannot be fully reduced to mere Darwinian physical survival value. The scientific theories that recognize this in flowers exhibit beauty as a trait of a good theory (theoretical virtue), which has recently been defined: A theory that "evokes aesthetic pleasure in properly functioning and sufficiently informed persons." Keas, "Systematizing the Theoretical Virtues," 2762. Beautiful mathematical relations in our theories of natural laws (e.g., gravity) and biological structures (e.g., Fibonacci seed arrangements) have often been taken to have epistemic value in scientific reasoning itself (Ibid., pp. 2772–75).

38 (Whewell 1845, p. 62). Whewell considers here detecting events "out of the common course of nature; acts which, therefore, we may properly call miraculous."

39 (Whewell 1866, pp. 357–58). He roughly quotes Darwin's *Origin*, 1st ed., pp. 186–87, omitting the words in brackets, and paraphrasing a few tiny portions—all without altering Darwin's essential meaning: "Several facts make me suspect that any sensitive nerve may be rendered sensitive to light"; "[Reason tells me, that if] numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade [being] useful to its possessor, can be shown to exist; [if] further, the eye does vary, if only slightly, and its variations are unlimited; and if any variation or modification in the organ be ever useful to an animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection [, though insuperable by our imagination,] can hardly be considered real."

40 Darwin, "Books to be Read" list, as cited in (Ruse 1975); Quinn, "Whewell's Philosophy of Architecture," 17, notes the "absence of any discussion" of Whewell's *Philosophy* "from Darwin's correspondence and notebooks." He concludes that this "is strong evidence that Darwin did not read the book."

41 Darwin thoroughly annotated his copy of Whewell, *History of the Inductive* Sciences (1837), so he likely read it carefully. This is documented in footnote 29 of Ruse, "Darwin's Debt to Philosophy." Whewell's (1837) *History* had much less coverage of MN-defying biological design inferences than Whewell's (1840) *Philosophy*.

42 I thank Kerry Magruder for noting some affinities between my account of methodological pluralism and Charles Taylor's treatment of *secularism* as *pluralism* rather than naturalism or materialism (Taylor 2007). Magruder highlighted for me how Taylor successfully argues *against* the historiography of secularism as a relentless increase in materialism, which amounts to a *subtraction account*, in which religion is progressively marginalized and subtracted from public visibility.

43 In an 1856 letter to the prominent theistic evolutionist Asa Gray, Darwin dismissed special creation as unscientific: "For to my mind to say that species were created so and so is no scientific explanation, only a reverent way of saying it is so and so." (Darwin 1897, p. 437).

44 (Quinn 2016, p. 17) mentions that "Darwin and Whewell were on good terms and discussed scientific matters. Many of these conversations occurred as the two walked home from J. S. Henslow's weekly scientific gatherings. Additionally, Whewell and Darwin would have met regularly through the Geological Society from 1837 to 1838."

45 (Darwin 1859, p. 435, 1860, p. 434, 1861, pp. 466–67). These first three editions render the passage: "On the ordinary view of the independent creation of each being, we can only say that so it is;—that it has so pleased the Creator to construct each animal and plant."

46 (Dilley 2013, p. 24). See Dilley's footnotes for examples of such scholarly judgments.

47 (Lightman and Dawson 2014, p. 1). Dawson and Lightman establish that "in the prologue to his *Essays upon Some Controverted* Questions (1892), Thomas Henry Huxley offered a retrospective defense of what he called the 'principle of the scientific Naturalism of the latter half of the nineteenth century.'" They note that Huxley's term, which he refashioned from earlier usage, was "certainly preferable to the considerably more contentious term *scientific materialism* coined by his close friend [and prominent X Club member] John Tyndall twenty years earlier."

48 Dawson and Lightman, *Victorian Scientific Naturalism*; (Harrison and Roberts 2018; Lightman and Reidy 2016; Brooke 2018).

49 (Barton 2018, p. 282). Barton notes that the honorific Abbey burial of Darwin was pulled off principally by X Club connections to the Royal Society and the official science representative to parliament.

50 This was announced by the Dean of Westminster at https://www.westminster-abbey.org/abbey-news/professor-stephen-hawking-to-be-honoured-at-the-abbey, accessed on 30 January 2023.

51 Another related factor was the rise of liberal Christianity, which minimized the supernatural within Christianity. See (Ungureanu 2019).

52 St. Augustine, *Contra Faustum Manichaeum* 32.20, as cited in (Harrison 2006).

53 (Smith 2014), inside jacket synopsis.

54 *Johannes Kepler Gesammelte Werke*, 13:309, letter no. 117, lines 174–9, as cited in (Kaiser 2007a, p. 175). See also (Keas 2019, chp. 10).

55 Kepler's textbook dedication, as translated in (Kepler and Baumgardt 1951).

56 Kepler's conception of receiving divine revelation while doing science is articulated in passages such as these: "For He Himself has let man take part in the knowledge of these things and thus not in a small measure has set up His image in man. Since He recognized as very good this image which He made, He will so much more readily recognize our efforts with the light of this image also to push into the light of knowledge the utilization of the numbers, weights and sizes which He marked out at creation. For these secrets are not of the kind whose research should be forbidden; rather they are set before our eyes like a mirror so that by examining them we observe to some extent the goodness and wisdom of the Creator." Johannes Kepler, *Epitome of Copernican Astronomy*, as cited in (Caspar 1993, p. 381). Kepler recognized "a divine ravishment [being cognitively carried away by God] in investigating the works of God." (Kepler 1952, pp. 849–50).

57 For some of the other factors (especially liberal Christianity that diminished the role of supernatural causation), see (Ungureanu 2019).

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Article

The Ethics of Integrating Faith and Science

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Abstract: Both faith and science can be defined in three ways: (1) a methodology; (2) a body of knowledge; and (3) an institution. In other words, each can be understood in terms of what it is, what it does, and who does it. The third way of understanding science—as an institution—seems to be often overlooked. Thus, the ethical underpinnings and implications are also underappreciated. In the 21st century, any model of the interaction between science and faith must include an ethical component. This essay briefly surveys significant areas of disagreement in which the conflicts are demonstrated to be essentially ethical in nature.

Keywords: Christianity; science; ethics; philosophy of science

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1. Introduction

Ian Barbour spent the better part of his life writing about the integration of science and faith. Over the years, he presented several models. He settled on a three-fold categorization: Enemies, Strangers, or Friends.[1] I affirm this taxonomy and I will argue that the Friends Model is the best characterization of the relationship between faith and science. However, most discussions leave out an important feature. The institutional aspect of both fields is often ignored, and thus the ethical elements are not addressed.[2] *In the 21st century, any model of science and faith must include an ethical component*. This essay briefly surveys certain areas of disagreement in which the conflicts are demonstrated to be essentially ethical in nature.

2. The Challenge of Definitions

This week I saw a fellow wearing a T-shirt that said, "Science is real!" I think I know the point the person was trying to make, but the statement is incoherent. Science is not real in the sense that persons, places, and things are real. However, the slogan helps to highlight one of problems facing discussions about faith and science—multiple definitions and the tendency to equivocate between them.

Both faith and science can be defined in three ways: (1) A body of knowledge; (2) A methodology; and (3) an institution. In other words, each can be understood in terms of what it is, what it does, and who does it. The third way of understanding science—as an institution—seems to be often overlooked. Thus, the ethical underpinnings and implications are also underappreciated.

Each of the three definitions has problems. For instance, neither faith nor science use just one methodology or approach to knowing. Nor is there a clear line of demarcation about the proper realm or range for the body of knowledge. Similarly, the institutional communities engaged in the process of gathering and affirming the respective bodies of knowledge are complex, variegated, and multileveled. So, these definitions will have to be simply working definitions, approximations that have exceptions and caveats. But they should operate sufficiently for the task at hand.

3. Defining Faith

Let us start with a definition of faith. First, I do not mean religion or all faiths in general. *The Faith—the body of knowledge—I have in mind is the Christian faith as expressed in*

the Apostle's Creed. Those who affirm the Triune God, Jesus Christ, and his saving work are brethren, walking together on the journey of faith. Within this community, I identify as a conservative evangelical (in the non-political sense of the term). I teach at a Southern Baptist school, affirm the *Chicago Statement on Biblical Inerrancy*, and also affirm the *Baptist Faith and Message* (2000) (including its declaration that humanity is the special creation of God, made in His image). For the purposes of this paper, faith refers to the body of beliefs that could be held by someone who affirms what C.S. Lewis called "mere Christianity," (Lewis 2015), though I personally write from the perspective of someone who is a member in good standing in the Evangelical Theological Society.

The second way to define faith is by its approach to gathering knowledge. *Christian theology attempts to understand and summarize what God has revealed*. Revelation comes to us through the world, Scripture, and ultimately His Son, Jesus Christ. Christians engage in theology by means of Scripture, tradition, reason, and experience—with priority given to Scripture.

Third, this activity of knowing and affirming the resulting body of knowledge is done in community. *This community is the Church*. The Church is simultaneously a divinely ordained and humanly populated institution. As a human institution, the Church—the community of faith—is flawed and fallible. However, we Christians are on a journey, one in which we believe we have the Bible as an infallible authority, the Holy Spirit as an indwelling reality, and the providential hand of God as our guide. We move forward, often stumbling, but still progressing.

So, in this paper faith refers to (1) the body of historic Christian beliefs (2) assembled by Christian theology and (3) affirmed by the universal Church in general.

4. Science

Science also needs defining. As noted above, science is not as easy to define as often popularly believed. In fact, generally accepted definitions have significant exceptions and vocal opponents (Zimring 2019).[3] Again, we will take a three-fold approach to defining science in terms of what it is, what it does, and who does it.

First, science can be defined as a field of study, namely the natural world. This definition is problematic because it excludes disciplines that historically have been understood to be scientific endeavors. For example, there was a time when theology was considered the queen of the sciences. Personally, I still think that. However, when people reference science without qualifiers, typically they are referring to the natural sciences.

Second, science can be defined as a method of learning, primarily by means of observation and experimentation. However, what exactly those methods are, is a matter of debate. Some, such as Paul Feyerabend, reject the notion that science can be defined in terms of method, since there is no universal method that all scientific fields use or accept.[4]

Third, science is also an institution. One of Thomas Huxley's goals in life was to create and establish science as a stand-alone profession (See Ruth Barton 1990, pp. 53–81). By any measure, he succeeded. However, institutional science, by definition, is composed of human beings, and they bring all the foibles and limitations of humanity with them. A major source of trouble has been the practice of cloaking institutional science with the respectability of science as a discipline (Paul Scherz 2017, pp. 11–17).

Still, though a perfect definition of science or the scientific method does not seem to be possible, a reasonably good approximation can be given, or perhaps a galaxy of definitions can be recognized. Imperfect as they are, we will define science as (1) a highly specialized method of learning, (2) a specific field of study, and (3) an immense institution of human endeavor.

5. The Three Models

Thus armed with sufficiently working definitions, we can proceed to the three primary models for relating faith and science. As noted above, these models present faith and science as enemies, strangers, or friends.

6. Enemies

The Enemies Model, which is also often called the conflict or warfare model, was first formulated during the Enlightenment but came to the fore during the Victorian era. Two notable books laid out the conflict theses: *History of the Conflict between Religion and Science* (1874) by John William Draper and *A History of the Warfare of Science with Theology in Christendom* (1896) by Andrew Dickson White. Thomas Huxley, who was often called "Darwin's Bulldog", epitomized this attitude when he famously likened theologians to "strangled snakes":

> *Extinguished theologians lie about the cradle of every science as the strangled snakes beside that of Hercules, and history records that whenever science and dogmatism have been fairly opposed, the latter has been forced to retire from the lists, bleeding and crushed, if not annihilated; scotched if not slain.* (Huxley 1860)

Today, one would be hard-pressed to find a serious philosopher or historian of science who advocates the conflict model. But the Enemies Paradigm can be found at the popular level, in modern culture, and, unfortunately, among a majority of those engaged in the STEM fields.[5]

Unfortunately, on the other side of the theological aisle from Huxley, a significant segment of evangelicalism confuses the Protestant affirmation of *Sola Scriptura* with a form of naïve biblicism. Thus, they understand the doctrine of the sufficiency of Scripture to mean that Christians do not need to use the resources afforded by tradition, reason, and experience. In fact, some of the worst attacks that evangelical scientists such as Hugh Ross have had to endure have come from these fellow believers (See for example, Sarfati 2004).

Proponents of naïve biblicism view any attempt to relate faith and science as a slippery slope that results in an inevitable denial of biblical authority. In May of 2022, the Sexual Abuse Task Force of the Southern Baptist Convention gave its report and recommendations at the annual meeting. One recommendation was to provide professional counseling services to victims of sexual abuse. One SBC pastor took to Twitter to oppose the recommendation, tweeting, "The church doesn't need 'trauma counselors.' We need BIBLICAL counselors. Scripture is sufficient!" (emphasis original). Though the pastor is not an academic, his tweet expresses the viewpoint of many evangelicals (as evidenced by his nearly 40,000 followers).

7. Strangers

Barbour presents a second approach, the Strangers Model, which he also calls the independence model. This viewpoint avoids conflict between faith and science by keeping them separate in "watertight compartments". (Barbour 2013, p. 27). Stephen Jay Gould referred to this approach as "Non-Overlapping Magisteria" (NOMA). Gould explains that the two cannot conflict because they operate in entirely distinct domains.[6] Science provides facts; religion expresses values. Never the twain shall meet.

Scientists are not the only ones to advocate the Strangers Model. It can also be seen in the work of the preeminent theologians of the 20th century. Neo-orthodoxy reigned through the writings of Karl Barth, Paul Tillich, and Reinhold Niebuhr. From reading their works one could get the impression that science didn't exist. They "virtually ignored science in their theological writing." (Larson and Ruse 2017, p. 11). Barth's *Church Dogmatics* is over six million words long, yet he never finds space to discuss science.

Advocates of the Strangers Model are correct when they point out the distinctions between faith and science. They have different frames of reference, different lines of enquiry, and different methodologies. But it does not follow that they have no areas of overlap or engagement. In fact, it is generally recognized that the opposite is true. It is an historical fact that Christianity provided the conceptual, epistemological, and ontological frameworks for modern science as a discipline.[7] The Christian worldview gave the moral sanction for engaging in science and still provides the ethical norms for how science should be

conducted. Not only do science and faith interact—they do so necessarily. Which brings us to the Friends Model.

8. Friends

The opening claim of the Bible is that the God who gave us the Scriptures is the God who created the heavens and the earth. Both Scripture and creation reveal God, albeit in different ways. The Friends Model is the deliberate, thoughtful attempt to interpret properly both communications of God. Throughout the history of the Church, most Christians have affirmed some version of the Friends Model. The Belgic Confession gives one of the best expressions of this model in its presentation of the "two books metaphor", which declares that we know God by two means:

> *First, by the creation, preservation, and government of the universe; which is before our eyes as a most beautiful book, wherein all creatures, great and small, are as so many letters leading us to perceive clearly God's invisible qualities—His eternal power and divine nature, as the apostle Paul says in Rom 1:20. All these things are sufficient to convict men and leave them without excuse.*
>
> *Second, He makes Himself more clearly and fully known to us by His holy and divine Word as far as is necessary for us in this life, to His glory and our salvation.* (The Belgic Confession 1561)

In affirming the two books, the Confession follows the clear teaching of Scripture that there is a general revelation in nature and a special revelation deposited in the Bible (Ps 19; Acts 14 & 17; Rom 1). The Friends Model attempts to properly relate the two modes of revelation. This involves the careful study and interpretation of both. Today, we call the careful study of God's creation the "natural sciences".

There are limits to both fields of study. On the one hand, science can tell us how the universe works, but it cannot tell us what it all means. On the other hand, the Christian faith tells us what it means, but typically it does not tell us how it works. As C.S. Lewis puts it, "Christianity does *not* replace the technical. When it tells you to feed the hungry it doesn't give you lessons in cooking. If you want to learn *that*, you must go to a cook rather than a Christian" (Lewis 1970). To give another example, the Bible tells us that the universe was created ex nihilo, out of nothing. It doesn't tell us that it happened 13.7 billion years ago.

Evangelicals almost universally affirm some version of the Friends Model. However, it must be noted that conservative evangelicals tend to veer into the Enemies Model while more progressive evangelicals at times flirt with the Strangers Model.[8] How to relate faith and science with epistemological virtue and intellectual integrity is very much an ethical endeavor.

9. The Ethical Challenges

The Christian view of the world tells us what is true, what is good, and what is beautiful. Too often, modern apologetics simply addresses intellectual questions about truth. But humans are not merely brains in a vat, dispassionately thinking rational thoughts. We must also address ethical concerns—the good and the beautiful. To address ethics is to deal with science as a communal effort, an institution comprised of human beings.

10. The Institutional Nature of Scientific Enterprise

The size of scientific institutions. Science, institutionally speaking, is the new leviathan. Compared to most networks of human endeavor, science is a behemoth. Scientific research universities continue to grow while colleges that emphasize the humanities are experiencing a steep decline.[9]

In terms of money, the latest estimates put worldwide investment in scientific research and development at over $2.2 trillion annually (2019).[10] As for the number of people engaged in scientific endeavors, the figures are equally impressive. Worldwide there are 8.8 million scientists, 7.5 million engineers, and 27 million software developers. Throughout

the world, the best and brightest minds are entering the STEM fields, with over 10 million STEM graduates every year.[11] There are political ramifications. The United States, along with all other major countries, see the STEM fields as essential for economic progress and even political survival. Science, institutionally speaking, plays a central role economically, agriculturally, militarily, and in every area imaginable in modern society and culture.

Science as the new priesthood. In popular culture, scientists are the new magicians, and science is the new priesthood. I believe it was Arthur C. Clarke who said that "Any sufficiently advanced technology is indistinguishable from magic" (Clarke 1964). The role of scientists as the new priesthood in some ways has had a similar effect that the Catholic priesthood had during the Medieval period.[12] The Roman Catholic Church taught that Scripture is revelation from God, but only qualified specialists could interpret it properly. Thus, the common man had to have the Catholic priest tell him what the Bible really means. A similar thing has now happened concerning general revelation in nature. The heavens declare the glory of God, but only a scientist can explain what it really means. Only someone trained in quantum or particle physics, genetics, or paleoanthropology, or perhaps climatology, can decipher what the world is really telling us. Luther and a significant part of 16th-century Europe suspected that the Roman Catholic hierarchy was abusing its position of privilege and power. Similar suspicions hang over the scientific clerics of today. (see Oreskes 2017).

11. The Role of Trust in Religion and Science

Both faith and science depend on a culture of trust. But trust can operate only in an ethical system. This is why the NOMA approach of the Strangers Model is unworkable.

The Christian faith provides ethical boundaries. Of course, science ventures into areas of ethics and values. How could it not? Ethics informs science as to what proper areas of study are and what the boundaries for research should be. Let us recall what the popular television show *Breaking Bad* was all about. Chemistry teacher Walter White decides that, before he dies of cancer, he will obtain his family's financial security by going into the business of making crystal meth. His street name was "Heisenberg". Let us just say he was ethically challenged.

The Christian faith provides the ethical scaffolding for doing science. There's another way that science and ethics overlap and interact. In his book, *Science and Christian Ethics*, Paul Scherz reports that according to one study, 70% of all results published in scientific journals were not able to be reproduced by other scientists (Scherz 2017, pp. 14–20). Some of the unreproducible results were due to malfeasance, fraud, and incompetence, but even more were due to unique facilities and resources. Others were unreproducible because of the level of skill or expertise required. Scherz was not simply claiming that 70% of all scientists are duplicitous. Rather, he was making the point that science, both as a discipline and as an institution, is highly dependent on an environment of trust. I believe we are seeing what happens when trust is eroded. Scherz warns that science cannot survive, much less thrive, in a culture of suspicion.

As a human institution, science is subject to all of the foibles, distortions, biases, and limitations of the human condition. Science as a discipline—as a methodology—was developed for the very purpose of rising above and remedying human shortcomings. For that matter, that is also supposed to be one of the primary purposes of religion. In both cases, the institutional expressions fall egregiously short of the disciplines.

By and large, Creationists who are accused of inadvertently slipping into the conflict model will often respond that they are not at war with the practice of science. They say that their bone of contention is with science as hegemonic leviathan. This distrust of scientific claims and science as a guild is showing up in evangelical culture as an overall rejection of scientific expertise. In the past few years, this skepticism for some has become almost total and has manifested itself in some very surprising arenas. In the eyes of many, establishment science is the intellectual Great Whore of Babylon.

12. The Crisis of Expertise

The ethics of managing risk. One area where ethical concerns become clear is in the field of risk management. As Steven Osterlind points out, science can often do a reasonably good job of quantifying risk (Osterlind 2019, pp. 7–8). What it cannot do is make the moral judgment as to what constitutes an acceptable risk. In January 2022, the Federal Aviation Administration (FAA) and the Federal Communications Commission (FCC) were in open dispute about 5G networks operating next to airports (Duncan and Aratani 2022). The Pilots Association advised against flying; thousands of international flights into the US were cancelled. Experts with the FCC said the 5G networks were safe; those in the FAA disagreed. They did not disagree about the level of risk. Rather the dispute primarily centered on what amount of risk was tolerable. It was a debate about dealing with uncertainty, with managing risk. "Acceptable risk" and "moral hazard" are not scientific terms; they are ethical concepts.

The ethics of defining scientific knowledge. What level of confidence constitutes "scientific knowledge"? Consider, for example, recent pronouncements about the Higgs boson. Scientists announced that the Higgs boson had been "discovered" and that the prediction about its existence had been "proven". Zimring points out that the more accurate claim would be that evidence consistent with the existence of the Higgs boson had been observed (Zimring 2019, pp. 9–10). But that does not make for a very compelling headline, does it?

Scientists disagree among themselves about what level of confirmatory evidence is required. Just as important, they disagree about what to do with results that seem to go against ones' hypothesis. For example, in Hugh Ross's book *Dual Revelation, Inerrancy and Concordism*, he sometimes makes this same point. In the chapter on the scientific evidence concerning an original couple, he responds to those who argue against the possibility of Adam and Eve as the sole progenitors of humanity. They argue that the genetic evidence does not indicate that the human population could ever have gotten below a few thousand. Ross does not challenge the data; he challenges their interpretation of it. He states that their assumptions are "fatally flawed . . . Mutation rates throughout humanity's history are impossible to determine with any accuracy. All . . . methods depend on a chosen mathematical model . . . [Genetic arguments are] subject to statistical and systemic uncertainties" (Ross Forthcoming, pp. 288–89). Since I know Hugh as a friend, I am inclined to take his opinions seriously. But in the broader scheme of things, the scientific layperson is in a dilemma. Whom are we to trust?

The spectacle of dueling experts. When James Shapiro published *Evolution: A View from the 21st Century*, in which he challenged the standard neo-Darwinian paradigm, Jerry Coyne dismissed it, saying that Shapiro didn't "understand how evolution works" (Shapiro 2011; Coyne 2012). Shapiro is a recognized expert in genetics who teaches molecular biology at the University of Chicago. If he can't understand evolutionary theory, then what hope do I have?

In *Redeeming Expertise*, Josh Reeves shows that throughout church history, Christians generally have been willing to "rethink traditional interpretations of Scripture when they conflict with the demonstrated truths of science." He then expresses well the dilemma facing the scientific layperson:

> *But how can nonscientists know when a scientific theory has been demonstrated? How can nonscientists distinguish between truth and scientific overreach, especially when someone attempts to use the prestige of science to further an anti-religious viewpoint? Questions about the validity of science and expertise are a primary element in the current culture wars . . . . What are the reliable indicators of specialist knowledge and what are not?* (Reeves 2021, p. 7)

An example of this dilemma can be seen in the book, *Four Views on Creation and Evolution*, in which the leaders of four major creationist organizations presented their respective views. At nearly the end of the book Deb Haarsma, president of BioLogos concluded, "For any of the scientific disagreements, the lay reader is put in the challenging

place of judging between two expert authors who each assert that the other is wrong. It may come down to which voices a reader trusts . . . " (Haarsma 2017, p. 175).

No doubt she accurately describes the present situation, but I hope that that is not the final word on the matter. If scientific discussions have degenerated to "my scientist is smarter that your scientist," then it will not matter what model of science and faith we employ. As Reeves points out, man cannot live by skepticism alone (Reeves 2021, p. 7).

13. The Current Climate

I wish I could say that the situation is improving, but we all know that it is not. In fact, evangelicals are in the middle of a great polarization in our culture today and are, in truth, playing a significant part. Many evangelicals display an intense distrust in scientific expertise, with some exhibiting outright hostility. I speak as an evangelical who loves evangelicals, and I will remain an evangelical—come what may—because I am an evangelical by conviction. But many of my brothers and sisters in Christ—whom I know personally; whom I love dearly; who I know love Christ, the Church, and the gospel—exhibit a radical animosity towards science that I find distressing and bewildering.

During the pandemic, debates about best practices concerning prevention or about the efficacy of vaccines became toxic due to misinformation and distrust. Speaking of distrust, just try having a calm, reasonable discussion about climate change. My point is this: in the 21st century any viable model of science and faith is going to have to take the cultural milieu into account.

I can imagine at this point that some of my evangelical brethren might respond by saying that it is always the child who counterpunches that gets in trouble with the teacher. The bully who started it all by tormenting and taunting the poor child, and who actually threw the first punch, often gets off scot-free. And they would have a point. Evangelicals didn't become the way they are in a cultural vacuum. Many of them lash out like a child cornered in the school bathroom because that's exactly how they feel. Just say out loud, in public, that children should not be subjected to medical sex change therapies. See what happens.

14. Conclusions

The Christian faith informs us about the true, the good, and the beautiful. I have argued for a Friends Model of science and faith that *includes an ethical component*. Evangelical apologetics has done a job of defending the truth. In the 21st century, we are going to have also to proclaim the good and the beautiful. We are going to have to display both epistemological and moral virtue to move beyond the "dueling experts" approach so that science and faith together can establish better ethical boundaries for managing the risks of technology and enabling the layperson to discern the limits of scientific (and religious) truth claims.

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Notes

1 (Barbour 2013). Barbour presents four models: conflict, independence, dialogue, and integration. He makes clear that the last two—dialogue and integration—are two ways of understanding the partner model. At times, he admits that "there is no clear line between Dialogue and Integration". (p. 200). Instead of using the term "partners", I prefer the term "friends", because it indicates not only a capacity for cooperation but also a positive disposition.

2 Barbour was perhaps the premier scholar in the field of integrating faith and science, and he wrote numerous books about the subject. As *When Science Meets Religion* illustrates (which was published the year he died), Barbour typically treated the two disciplines as two fields of intellectual endeavors. The institutional aspects of both and resulting ethical ramifications are not

addressed. His approach typifies the approach taken by most scholars on the subject as the field developed in the latter half of the 20th century.

3 Zimring argues that a universal definition of science does not exist. "Despite the weight that the label of science may carry with many people, it is an utter fiction that there is (or ever has been) a uniform consensus among scientists (or anyone else for that matter) as to what precisely defines science. This question has been tackled over the years by many great scholars and yet there is not a clear and unequivocal answer." (p. 3) For other philosophers of science who agree with Zimring's assessment see (Ladyman 2001, p. 1; Van den Brink 2009, pp. 25–29).

4 See, for example, (Feyerabend 2010, p. 6). Zimring explains, "For the reasons just stated, most modern attempts at defining science have focused on *methods* or *modes of thinking* that distinguish scientific activities from nonscientific activities rather than the specific content of scientific knowledge claims. However, while one often encounters discussions of 'the scientific method' and its application to investigation, there is a lack of agreement about what precisely this method entails, and there are those who argue that the very notion of a scientific method is itself an utter myth." (Zimring 2019, p. 6) (emphasis original).

5 (Larson and Ruse 2017). "Most historians agree with Peter Harrison, John Brooke and Ronald Numbers that the story is much more complex. Western Christianity birthed modern science, and many of the leading figures of science were men of devout faith. Lord Kelvin, John Clerk Maxwell and Michael Faraday are just three examples." (p. 5–9) STEM stands for "science, technology, engineering, and math".

6 (Gould 1999). A current advocate of the Strangers Model would be Michael Ruse. See (Ruse 2021).

7 Historians of science have provided a remarkable body of work that overwhelmingly demonstrates this point. A sampling would be (Lindberg 1992; Pearcy and Thaxton 1994; Huff 2003; Harrison 2009; Hannam 2011; Ungureanu 2019).

8 Henry Morris and Ken Ham are examples of the former while Peter Enns and Karl Giberson are examples of the latter. See (Morris 2000; Ham 1987; Enns 2012; Giberson 2015).I am not saying that all young-earth creationists (YEC) adhere to the Enemies Model, nor am I saying that all evolutionary creationists (EC) hold to the Strangers Model. Some YEC advocates, such as Marcus Ross and Todd Wood, display a deep love for science, while some EC proponents, such as Darrel Falk, Jeff Schloss, Jeff Hardin, and Michael Murray, care deeply about theological commitments.

9 (Larson and Ruse 2017, pp. 9–10). "Housed in ever-expanding research universities and fueled by unprecedented amounts of public funding, American science has assumed global leadership in terms of the sheer number of peer-review articles published and Nobel Prizes received in virtually every scientific discipline. The technological payoff has transformed American industry, agriculture, and warfare. The world (or at least much of it) has taken note."

10 https://sgp.fas.org/crs/misc/R44283.pdf (accessed on 1 May 2022.)

11 https://sciencebusiness.net/news/number-scientists-worldwide-reaches-88m-global-research-spending-grows-faster-economy (accessed on 1 May 2022).

12 Jim Stump makes this point. See (Stump 2017, pp. 57–59).

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Article

What Makes Genesis Different?

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Abstract: In contrast to those who read Genesis 1 through 11 as myth, the story of Genesis is historical narrative with a theological purpose (theo-history). The Hebrew theo-history of creation was undergirded by a worldview that did not converge with her neighbors but significantly diverged from the surrounding nations. While the literary style of Genesis has elements common to other ancient mythologies, the content itself is quite distinct. Unlike other ancient cosmologies, the Hebrew worldview perceived the people, places, and events of Genesis as historical and not merely religious symbols. The divergence of the Hebrew worldview from all ancient Near East (ANE) cultures is illustrated in three observations: (1) Genesis is monotheism not polytheism/panentheism, (2) Genesis is special revelation not cultic theology, and (3) Genesis is theo-history not myth or mytho-history. These three distinctives of Hebrew cosmology reflect a unique worldview shaped by divine revelation, and because Genesis was written in the genre of theo-history, Hebrew cosmology offers us a dependable foundation for knowing something true about our material origins, shaping ethical priorities, safeguarding the sacredness of human life, directing moral decision making, recognizing the significance of historical progress, and guiding scientific inquiry into the book of nature.

Keywords: genesis; cosmology; ethics; ancient near east; myth; science; genre; Hebrew creation; history

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1. Introduction

> In the beginning, God created the heavens and the earth. The earth was without form and void, and darkness was over the face of the deep. And the Spirit of God was hovering over the face of the waters. (Genesis 1:1–2, ESV)

What should we make of Genesis and the Hebrew story of creation? Is it myth? Is it history? Is it a story just like every other story of cosmic origins from the ancient world? Or, if Hebrew cosmology is not the same, what makes Genesis different?

In the study of literature from the ancient Near East (ANE), a significant number of scholars over the past sixty years (both secular and religious) have argued that the creation story of Genesis is mythology akin to, and shaped by, the shared cultural perspective of the ancient world. The most recent scholar to go down this path is William Lane Craig in his book, *In Quest of the Historical Adam*. Those who share in Craig's claim that Genesis is mytho-history see Genesis as a point of convergence between the Hebrew worldview and the worldview of the typical person living in the ANE, but is this the best way to view the Hebrew creation account? Before I answer that question, let me define a few key terms.

In this article, cosmology and cosmogony are used to describe any system of thought that attempts to explain the origins of the universe in scientific, philosophical, and/or theological terms. The term worldview is used to describe the lens we use to interpret the world and focus our observations into a clear narrative that answers the questions of origin, meaning, morality, and destiny. A worldview answers these six questions: (1) How did I come into being? (2) How can I know the meaning for my life? (3) What is the right thing to do? (4) How can I fulfill my moral purpose? (5) What happens when I die? and (6) How will my legacy be judged?

Given a particular worldview, we apply it to various fields of inquiry such as cosmic and human origins through what is called a paradigm. A paradigm, then, functions

inside our worldview to provide a field-specific framework to determine what counts as knowledge. These concepts of worldview and paradigm are important for understanding what makes Genesis different from other ANE mythologies.

Scholars who accept what I call a convergent worldview paradigm treat the people and events of Genesis 1 through 11 as literary symbols with little or no relationship to history or to the material realities of the cosmos. Like every other people group of the ANE, the Hebrew priests and scribes used the mythologies of Genesis to teach important religious truths and justify Israel's temple practices. In this sense, scholars who advocate for the convergent worldview paradigm see a clear unity between Genesis and all ancient cosmologies.

In contrast to those who read Genesis 1 through 11 as myth, my own study leads me to the conclusion that the story of Genesis is historical narrative with a theological purpose (or what I call theo-history). Yet, we should not assume that the synergy of theology and history in Genesis undermines the historical accuracy of the text. As Eugene H. Merrill notes, "one cannot seriously lay claim to a theological history of the Old Testament that does not draw upon actual historical events that took place precisely as the biblical texts describe them (Merrill 2008, p. 26)." In this sense, we can approach Genesis with confidence knowing that neither the theological purpose nor the literary style of text isolates us—the modern reader—from the historical events of Genesis.

The Hebrew theo-history of creation was undergirded by a worldview that did not "converge" with her neighbors but significantly diverged from the surrounding nations. Scholars such as John Oswalt, in his book *The Bible Among the Myths*, share in this view, which I label the divergent worldview paradigm. Scholars in this camp argue that while the literary style of Genesis has elements common to other ancient mythologies, the content itself is quite distinct. The essential elements of the Hebrew origin stories are dissimilar from other ancient mythologies and similar only in their secondary (or what philosophers call accidental) elements. Specifically, there is broad agreement that the genre of Genesis has clear points of stylistic unity with many ancient mythologies. However, these common elements do not outweigh the contrasting elements of style that define the genre of theo-history. Unlike other ancient cosmologies, the Hebrew worldview perceived the people, places, and events of Genesis as historical and not merely religious symbols.

Hebrew cosmology—written by Moses in an ancient language for ancient peoples—reflects the unique Hebrew worldview, which was shaped through the direct revelation of YHWH. The inspired nature of Moses' historical narrative gives the modern reader confidence that we can understand the meaning of the text. The uniqueness of Genesis as theo-history means that Hebrew cosmology offers a dependable foundation for knowing something true about our material origins, shaping ethical priorities, directing moral decision making, and guiding scientific inquiry.

To understand how Genesis is unique from ANE mythologies, let us look at three elements that are essential to the Hebrew worldview: (1) Genesis is monotheism not polytheism/panentheism, (2) Genesis is special revelation not cultic theology, and (3) Genesis is theo-history not mytho-history.

2. Genesis Is Monotheism Not Polytheism/Panentheism

How much of Hebrew cosmology was shaped by ANE religions and how much was shaped by YHWH's self-revelation? Most scholars agree in principle that the Hebrew writings were influenced by the religion, culture, and politics of the ancient world. Numerous references to foreign kings, gods, and cultic practices make clear the necessity of understanding biblical cosmology within both its literary and historical contexts. However, the fundamental difference between scholars is what they accept as essential versus what they accept as secondary (accidental) to the Hebrew worldview.

One clear line of distinction between Genesis and other ancient myths is the revelation that YHWH alone sits as the sole creator and only God. Still, some critics note that the Old Testament uses language that implies there are many gods and not just one. Against this

charge, John Currid explores the polemical nature of the Old Testament as one explanation for this polytheistic imagery. Psalm 82 provides one such example. Noting the psalmist's imagery of God (Elohim) taking a stand against El in the midst of the gods, Currid observes:

> This reference to Canaanite literature, in particular the meeting of the gathered council of gods before El, is not indicative of the God of Israel being part of the Canaanite pantheon. Rather, it is employed to picture the God of Israel as assaulting the pagan pantheon, or as Dahood comments, it is 'where God passes judgment on the pagan deities.' Here is seething hostility by the psalmist against Canaanite theology, as he claims instead that the one true God has deposed the pagan gods and that he is the only ruler of the earth (v. 8). (Currid 2013, p. 160)

While Currid concedes that an appeal to polemical theology does not address every parallel between the Old Testament and other ancient religions, the use of polemical language does reaffirm the assertion made here that Israel's resolute monotheism was an essential quality of their cosmology.

Unlike Israel, the creation stories written by the peoples of the ANE were steeped in polytheism; a belief that the world is inhabited by many finite gods (driven by their many human-like desires, such as sexual pleasure) who ruled over their own special domain. In the Pyramid texts of Teti, first king of Egypt's Sixth Dynasty (ca. 2323–2291 BC), the reader encounters the *Spells for entering the womb of Nut*. In this story, the goddess Nut recounts the glory of her son when she says, "Teti is my son, whom I caused to be born and who parted my belly; he is the one I have desired and with whom I have become content (Allen and Der Manuelian 2005, p. 67)." In addition to sexual intercourse, the birth of the ANE gods was attributed to a variety of bodily emissions from bleeding to masturbation—specifically from the gods Amun, Amenapet, Atumi, and Min—because the Egyptians saw the world as made of divine-beings married to the natural elements.[1]

Another useful word suited to the discussion of ancient mythologies is panentheism or finite-godism. Panentheism, as defined by Norman Geisler, describes well the finite-godism of the various ANE religions whose gods were limited in power and existed simultaneously both in the human world and outside the human world.[2] We can see an example of this finite-godism in the West Semitic storm god Hadad who battled against the cosmic "Sea", which itself was thought to be another god.[3] The Akkadian epic *Enuma Elish*, offers another example. In this tale, Marduk volunteers (at the prompting of Ea) to serve as the champion of the gods to defeat Tiamat. Anshar convenes a special council of the gods who, after a feast, transfers authority to Marduk who later tears apart the dead carcass of the defeated goddess Tiamat to fashion the heavens and the waters:

> (135) [Marduk] calmed down. Then the Lord was inspecting [Tiamat's] carcass,
>
> That he might divide (?) the monstrous lump and fashion artful things.
>
> He split her in two, like a fish for drying,
>
> Half of her he set up and made as a cover, heaven.
>
> He stretched out the hide and assigned watchmen,
>
> (140) And ordered them not to let her waters escape.
>
> He crossed heaven and inspected (its) firmament,
>
> He made a counterpart to Apsu, the dwelling of Nudimmud.
>
> The Lord measured the construction of Apsu,
>
> He founded the Great Sanctuary, the likeness of Esharra.
>
> (In) the Great Sanctuary, (in) Esharra, which he built, (and in) heaven,
>
> He made Ea, Enlil, and Anu dwell in their holy places. (Smith and Parker 1997, pp. 398–99)

These limited examples illustrate why panentheism is a useful word alongside polytheism in the sense that it reminds the modern reader that, unlike Israel, the peoples of the

ANE believed in a collection of gods who existed above the material world and yet in some way remained interconnected with the very fabric of nature itself.

Moreover, with the exception of Israel, the peoples of the ancient world did not perceive history as an arrow of progress from a past moment in time toward some fixed end. Human history for these peoples was a drama played out in the cycle of life and death among the gods. The Gods of the ANE were limited in power, lived in a nearly constant state of battle, and the death of any one god was meaningless to the existence of the cosmos. The people of the ancient world saw themselves as creatures in the service of these finite gods and goddesses: humans whose earthly existence reflected the same cycle of life and death. Humans—forever bound to their gods—were servant warriors in this eternal drama, and, as a consequence, the lives they extinguished in battle or the people they took as slaves had no moral significance.

Monotheism led Israel to see the cosmos, history, and human life in a very different way. Monotheism was foundational for Israel's understanding of history as linear with a fixed beginning in time and space.[4] YHWH was not a cosmic warrior trapped in the natural cycle of life and death. YHWH stood alone as the eternal immaterial God and nature was His finite material creation. The story of Genesis, therefore, was accepted by the Hebrews as a revelation of the cosmic past, human present, and promised future.

For the Hebrews, their commitment to monotheism and their participation in God's linear history meant that from beginning to end both the cosmos and their lives had purpose. The land, plants, and animals had inherent value. Humans were created in the image of YHWH and as stewards of God's good creation. Human life was made with a sacred purpose and not something to be extinguished at the whim of the gods or of other humans. The choices Israel made each day to love God and love their neighbor had transcendent meaning. Israel's earthly obedience to YHWH was predicated on the revelatory knowledge that He alone was good and that He alone created humankind and the earth for a good purpose.

3. Genesis as Special Revelation Not Temple Theology

A cross-section of scholars within the unified and divergent worldview paradigms accept, at a minimum, that the Hebrews believed Genesis was given to Moses by God. Yet this modest concession that the Hebrews *believed* in special revelation is insufficient. The Old Testament is more than a story perceived by Israel as God's self-revelation. The Old Testament is not Jewish natural theology used to justify their temple worship. The Old Testament was and is God's transcendent self-revelation for yesterday, today, and tomorrow. This distinction between Israel's perception of the text as God's self-revelation and the truth of the text as God's actual revelation in space and time is significant. Carl F.H. Henry rightly observes:

> The source of evangelical theology, then, is God made known in his own Word and deed. The Protestant Reformers rightly honored the Word of God as revelationally given not only above experience but also above the church as the control-point for every facet of Christian doctrine. God's revelation has been conveniently classified in two main types: general revelation, or the disclosure of God's eternal power and glory through nature and history; and special revelation, or the disclosure of God's redemptive purpose and work. (Henry 1999, p. 223)

Henry goes on to explain how this view of special revelation impacts the relationship between special and general revelation:

> The Bible openly publishes man's predicament and God's redemptive remedy in the form of objectively intelligible statements. The scriptural revelation takes epistemological priority over general revelation, not because general revelation is obscure or because man as sinner cannot know it, but because Scripture as an inspired literary document republishes the content of general revelation objectively, over against sinful man's reductive dilutions and misconstructions of it. (Ibid.)

Given this understanding of special revelation, Scripture cannot be spiritualized as a cultic blend of myth and history. Scripture is, at its core, a book of objectively intelligible statements about cosmic history, human origins, and redemption. The objective reality of YHWH's revelatory knowledge—which transcended the general knowledge of God found in creation—enabled Moses to speak above the din of cultural influence and provide Israel with knowledge, purpose, and moral significance. Still, there are some evangelical scholars who question, "Did God reveal truth only about spiritual matters, or did His revelation through Moses also reveal truth about our material origins?"

As the twentieth century turned into the twenty-first, the seeds of the scientific revolution germinated among scholars who rejected as anti-scientific and anti-intellectual any view of special revelation which overlapped with the domain of science. For scholars who embrace the unified worldview paradigm, the concept of special revelation was applied only to the spiritual or non-material teachings of the Bible. Specifically, they claim, the special revelation of Genesis only applies to the immaterial world of spiritual truths. Regarding the material world, they conclude, Genesis was a product of the cognitive environment (worldview) shared by all the peoples of the ANE.

Scholars such as John Walton argue that the only way the modern mind can properly understand Genesis is to understand the ANE cosmologies which shaped the Hebrew worldview. Walton concludes:

> As a result, we are not looking at ancient literature to try to decide whether Israel borrowed from some of the literature that was known to them. It is to be expected that the Israelites held many concepts and perspectives in common with the rest of the ancient world. This is far different from suggesting literature was borrowed or copied. This is not even a case of Israel being influenced by the peoples around them. Rather we simply recognize the common conceptual worldview that existed in ancient times. We should therefore not speak of Israel being influenced by that world—they were part of that world. (Walton 2009, pp. 11–12)

Walton, then, does not see the need to look for a common Babylonian, Hittite, or Egyptian source document but concludes that the fundamental worldview (what he calls the shared cognitive environment) of the Hebrews is the same: therefore, their basic cosmology in Genesis was the same. Walton reinforces his point in the following:

> From the idea that the temple was considered a mini cosmos, it is easy to move to the idea that the cosmos could be viewed as a temple. This is more difficult to document in the ancient world because of the polytheistic nature of their religion. If the whole cosmos were viewed as a single temple, which god would it belong to? Where would temples of the other gods be? Nevertheless it can still be affirmed that creation texts can and do follow the model of temple-building texts, in this way at least likening the cosmos to a temple. (Ibid., p. 82. See also, Walton 2011, p. 190)

This concept of a structural parallelism between the Jewish temple and Hebrew cosmology are explored in depth by Margaret Barker who concludes, "the mythology and symbolism of the ancient temple are the key to understanding of this symbolism, for when the meaning of these symbols is lost, the meaning of Christianity will also be lost (Barker 2008, p. 181)." Tom McLeish, citing Barker's work, argues that this thesis may not be sustainable yet accepts the underlying point that Genesis 1 is written to connect cosmology and worship. McLeish writes:

> Brown and independently the Orthodox scholar Margaret Barker both suggest a structural parallelism of the Genesis 1 text with the architecture of the temple, but, whether this suggestion can be sustained or not, what the 'priestly' account does is surely to enshrine the purpose and nature of creation within the repeated acts of worship of the community. . . . so, in Genesis 1, a context of communal

> remembrance and worship provides the grounding of the text that the lack of a continuous history fails to. (McLeish 2014, pp. 72–73)

While these scholars have differences on the connection between cosmology and temple, they are each driven to some degree by a rejection of a hermeneutic which takes Genesis as a literal account of historic events.

Kyle Greenwood, in his book *Scripture and Cosmology*, builds on the same basic themes as Walton and argues that the only way to understand the meaning of a text is to learn its ancient Near East context. "Biblical cosmology," he argues, "is ancient Near Eastern cosmology. Through the biblical authors, God spoke in the language of the common folk (Greenwood 2015, p. 204)." Greenwood concludes that because the Tanakh (the Jewish term for what Christians call the Old Testament) relies on the language of Divine accommodation, it is only possible to understand the meaning of Genesis as a product of the cultural, geographical, historical, and literary context.[5] Greenwood's assumption is that the Hebrews had a unified worldview with their ancient neighbors and, like their neighbors, the Israelites used the Genesis myth as a paradigm to justify their temple practices.

Greenwood points out that one possible definition of worldview comes from Kant's use of *Weltanschauung* in his *Critique of Judgment*. In this work, Kant argued that humans observe the phenomena (the natural world) but may not have a right sense of its true noumena (reality). Greenwood modifies Kant's concept of worldview using Walton's "cognitive environment" and adopts this premise for his book. To make his argument, Greenwood cites on the following quote from Walton:

> The Israelites received no revelation to update or modify their "scientific" understanding of the cosmos. They did not know that stars were suns; they did not know that the earth was spherical and moving through space; they did not know that the sun was much further away than the moon, or even further than the birds flying in the air. They believed that the sky was material (not vaporous), solid enough to support the residence of deity as well as to hold back waters.[6]

Greenwood, building on Walton's idea, asserts that the Hebrew scientific worldview was shaped wholly by the cognitive environment of the ANE, whose cosmology formed the basic structure for how they perceived and interpreted the world around them. Greenwood postulates that just as it was for all ANE cultures, "the ancient Hebrews' only knowledge of the world around them was limited to what their parents told them, what they had seen for themselves and what they imagined it must be like (Greenwood 2015, p. 24)." In short, Greenwood believes that Hebrew cosmology was grounded in the phenomena, with no insight into the noumena. In much the same way, Walton asserts that in order to properly interpret Genesis, one must recognize that it "pertains to functional origins rather than material origins and that temple ideology underlies the Genesis cosmology."[7]

The distinction modern scholars like Walton and Greenwood make between the material and non-material world was not shared by the writers of ANE myth or by the writers of the Old Testament. Egyptian theology, for example, merged the divine and physical worlds in the story of Anum.[8] In this tale, Anum started the creation process but left it for the other "Eight Great Gods" to finish. Anum does not create from nothing, but his own body forms the substance of the material world:

> You began Becoming—
>
> there was no Being, there was no Void:
>
> The world was from You, in the Beginning;
>
> all other gods came after. (Foster and Hollis 1995, p. 75)

While the Old Testament never merged the physical reality of God with nature, it is evident that Hebrew creation was deeply concerned with material origins. God's answer, beginning in Job 38:4, to Job's complaint makes clear that God, as the creator of the material world, had ultimate moral authority. Another example that undermines Walton and Greenwood's theory is the preservation of the Old Testament in its written form. The effort

to preserve the writings of the Old Testament speaks to an essential characteristic of the Hebrew understanding of special revelation. The immaterial word spoken by YHWH was connected to the material word through both the voice of the prophet and ultimately in the inspired text itself. The Creator God not only made the material world, He revealed to Israel a set of texts that gave them a concrete understanding of their historical origins, religious practices, and moral obligations. The Hebrew story of creation made no epistemological distinction between the material and immaterial worlds. Genesis was accepted as a special revelation concerning both the material origin of the cosmos and of God's spiritual purpose for humanity.

General revelation—what we see in the world around us in the book of nature—then was accepted by the Hebrews as physical evidence of YHWH's creative power and holiness made visible to every nation in every generation. As the Psalmist wrote, "For YHWH is the great God, the great King above all gods. In his hand are the depths of the earth, and the mountain peaks belong to him. The sea is his, for he made it, and his hands formed the dry land (Psalm 95:3–5, ESV)." The material world was God's general revelation to every nation and the truth of His good work was enshrined in His special revelation. YHWH's special revelation recorded in the Tanakh served, therefore, as the authoritative record of God's activity in history and through creation. Special revelation was given by YHWH to advance Israel's knowledge about general revelation and provide unique insight beyond their senses. In this way, Genesis is theo-history, a theology that reveals the truth regarding the origins of both the cosmos and human life itself.

4. Genesis Is Theo-History Not Mytho-History

Similar to scholars such as John Walton, Peter Enns believes that, "The reason the opening chapters of Genesis look so much like the literature of ancient Mesopotamia is that the worldview categories of the ANE were ubiquitous and normative at the time (Enns 2015, p. 53)." When God then chose Abraham to be the patriarch of Israel, writes Enns, He also chose to adopt "the mythic categories within which Abraham—and everyone else—thought (Ibid)." Therefore, Enns concludes, the cosmology of Genesis has the same essential qualities of other ANE mythologies. While Genesis can still be used to teach us about metaphysical reality, he argues, it cannot speak to the modern scientific conceptions of cosmology. Once Enns' definition is accepted, Genesis is determined to have no meaningful connection to history or material origins but serves only as a literary vehicle for conveying spiritual origins. Critical to this conclusion (shared in some fashion by scholars such as Enns, Walton, and Craig) is how they define myth.

The term myth is used by different scholars with a range of meanings across a philosophical and phenomenological spectrum. Many define myth using broad sweeping categories which include all ancient stories of creation. Others, such as William Lane Craig, argue that it is a fool's errand to offer a concise definition of myth. Instead, Craig relies on the work of Ludwig Wittgenstein to offer ten literary elements which he believes demonstrate a "family resemblance" between Genesis and all ANE mythologies. These are:

1. Myths are narratives, whether oral or literary.
2. Myths are traditional stories handed down from generation to generation.
3. Myths are sacred for the society that embraces them.
4. Myths are objects of belief by members of the society that embraces them.
5. Myths are set in a primaeval age or another realm.
6. Myths are stories in which deities are important characters.
7. Myths seek to anchor present realities such as the world, mankind, natural phenomena, cultural practices, and the prevailing cult in a primordial time.
8. Myths are associated with rituals.
9. Myths express correspondences between the deities and nature.
10. Myths exhibit fantastic elements and are not troubled by logical contradiction or incoherence (Craig 2021, pp. 45–46)."

However, unlike Craig's overly-broad criteria for labeling Genesis as mytho-history, other scholars have suggested more exclusive definition of myth. T.H. Gaster suggests that, "Myth is a story of the gods in which results of natural causes are accounted for supernaturally (Gaster 1962, p. 481)." Joseph Fentenrose, quoted by Robert Oden, defines myth as "the traditional tales of the deeds of *daimones*: gods, spirits, and all sorts of supernatural or superhuman beings." (Fontenrose 1966, pp. 54–55. Quoted in Oden 1992, p. 949).

Despite the different approaches from scholars like Craig, Gaster, and Fentenrose, it is important to ask, what do these scholars have in common? Hugh White's simple criticism of Fentenrose applies to Craig and Gaster equally when he writes, "The simple labeling of a story as a myth in this sense, though helping genre identification, does not necessarily advance our understanding of it (White 1989, p. 144)." Consequently, these different approaches to defining myth ultimately fail for several reasons:

1. These definitions of myth use genre identification as a tool to justify the modern bias against the supernatural.
2. These definitions of myth offer no objective criteria for distinguishing between essential and non-essential elements within any given set of creation stories.
3. These definitions of myth do not advance our understanding of how each creation story reflects the divergent worldviews among ANE civilizations.

Turning back to Enns, he avoids some of these problems by defining myth as, "an ancient, premodern, prescientific way of addressing questions of ultimate origins and meaning in the form of stories: Who are we? Where do we come from? (Enns 2015, p. 50)" Craig makes a similar move by suggesting that Genesis 1 through 11 is mytho-history because these stories, he claims, are simply too fantastical and inconsistent for the modern rational mind to believe.[9] The Tree of Life serves as one such story that, for Craig, if taken literally, is simply absurd. The idea of a magic tree planted by God in space and time with the power to give knowledge is a legend that no serious reader—today or in the ancient world—can take as historical (Craig 2021, p. 113). And while these rationalizations offered by Enns and Craig may to some degree eliminate the bias against the supernatural, they serve only to replace the old bias with a new bias against pre-scientific history. Genesis, it is assumed by such scholars, cannot speak about the material origins of humanity because the ancients did not have access to our modern scientific forms of investigation. In this way, scholars who embrace the unified worldview paradigm improperly treat modern science as the magisterial authority of interpreting Genesis. So where can we turn to find a better definition of myth that does not beg the question of history?

John Oswalt defines myth as "a form of expression, whether literary or oral, whereby the continuities among the human, natural, and divine realms are expressed and actualized. By reinforcing these continuities, it seeks to ensure the orderly functioning of both nature and human society (Oswalt 2009, pp. 45–46)." A myth was a story used to maintain the status quo of political and religious order. ANE mythologies reinforced the worldview that events and people were meaningless pawns in the cosmic cycle. These mythologies were rooted in the assumption that human experience is nothing more than a physical analog for the metaphysical drama of the gods. Based on this definition, Oswalt writes, "whatever the Bible is, it is not myth (Ibid., p. 14)." In other words, regardless of the literary style or what genre we assign to Genesis 1 through 11, the substance of the stories it contains was meant to be read as an historical account of material origins. Oswalt makes this important observation, "Ultimately, the unique worldview of the Old Testament undergirds its claims of historical reliability (Ibid., p. 14)."

Although Moses certainly wrote in a style that was understandable to his ANE readers, his use of so-called mytho-genre does not justify the claim that the content itself is poetic, figurative, uninspired, or void of historical accuracy. On the contrary, Genesis is neither mytho-history or mythology but a theological history of origins (or theo-history). The use of poetic or figurative language should also not be conflated with the use of mythical language. Both myths and the Bible use poetic, figurative language, but they use the

language for very different purposes. That is to say, the cosmology of Genesis 1—given the divergent worldview paradigm of the Hebrews—did not function as a fictional or cultic myth but as a theo-history meant to connect YHWH's eternal purposes with real events that happened in space and time.

Hebrew theo-history was a roadmap of human progress from our past in Genesis 1, through the daily experience of Israel, and toward a future kingdom of God. In Hebrew theo-history, events and people were not meaningless characters in some primordial drama, but essential players in time and space used by God to advance His eternal plan. Hebrew theo-history was rooted in the presupposition that human experience is understood primarily through the special revelation of the one true God and secondarily through the natural order and progress of time. For the Hebrews, God was, and is, separate from His creation. The power of God's spoken word recorded in Scripture not only brought the material world into existence and formed human life, but God's spoken word shaped the worship practices and ethical mandates that set Israel apart from the surrounding nations (Ramm 1954, p. 26).

5. Conclusions

The Hebrew story of creation told in Genesis is neither myth nor mytho-history. Genesis 1 through 11 is a form of theological storytelling (theo-history) that God used to reveal the material origins, moral duties, and destiny of humankind. The divergence of the Hebrew worldview from all ANE cultures was illustrated in these three observations:

1. Genesis is monotheism not polytheism/panentheism,
2. Genesis is special revelation not cultic theology, and
3. Genesis is theo-history not myth or mytho-history.

While much more must be written to properly establish these three distinctives, it is sufficient here to note that these three aspects of Hebrew cosmology reflect a unique worldview among the Jews which was shaped by YHWH's divine self-revelation. Consequently, because Genesis was written in the genre of theo-history, Hebrew cosmology offers us a dependable foundation for knowing something true about our material origins, shaping ethical priorities, safeguarding the sacredness of human life, directing moral decision making, recognizing the significance of historical progress, and guiding scientific inquiry into the book of nature.

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Notes

1 Walton's (2003, p. 162) source for this conclusion is noted as Allen (1988). See also, Wyatt (2001, p. 57). I use Walton here because his recognition that ANE myth married the divine to nature undermines his claim that ancient myths did not explain material origins.

2 (Geisler 1976, pp. 173, 193). Stated in metaphysical terms, in panentheism the existence of any one god is not essential to the existence of the cosmos. This theology is distinct from absolute pantheism, which identifies the cosmos and god as mutually essential qualities. Outside of Geisler's usage of panentheism, which is herein applied to ANE polytheism, the term panentheism is more often associated with platonic forms of monotheism, German idealism, and modern process theology. "However, Baltzly finds evidence in the *Timaeus* of a polytheistic view that can be identified as panentheistic." See, Culp (2021).

3 (Smith and Parker 1997, p. 86). It is important to note that scholars have divergent views on how much the typical ancient Near East view of the cosmic seas influenced Hebrew cosmology. Clines says that Hebrew cosmology presupposes "the earth floating on the cosmic sea." (Clines 2006, p. 635), whereas Greenwood says that unlike their ancient Near East neighbors, there is "no indication that the Hebrews had a notion of the earth floating on the cosmic sea." (Greenwood 2015, p. 79). Some scholars associate Hadad with Baal, and the original name of the West Semitic storm god later referred to as "Lord" was "Bel." See Herrmann (1999, p. 132).

4 Wyatt believes this concept of the linear progress of time is a modern paradigm, wrongly foisted upon the Old Testament, foreign to the Hebrew worldview, invalidated by modern scholarship, and an "embarrassment" to the serious study of ANE literature. See Wyatt (2001, pp. 305–6). In contrast to this view, a study of the A-Theory of time provides a viable integration point for a

coherent view of time, modern physics, and biblical theology, where time is not cyclical but linear in the progress of becoming. For a fuller discussion, see Craig (2001).

5 This article is focused on the cosmology of Genesis within the context of the Hebrew Bible which covers תּוֹרָה (Tôrâ, Law), נְבִיאִים (Nəḇîʾîm , Prophets), and כְּתוּבִים (Kəṯûḇîm, Writings). When refrencing the entire collection of Hebrew Scripture, the acronymn Tanakh is used in as a synonym for the term Old Testement, which is the familiar Christian designation. Tanakh is the most common term used in the Talmud and Midrash, and possibly modern Judaism and its use in this book helps draw a clear distinction when referencing the Hebrew Scripture from the Christian Scripture which includes both the Tanakh and the New Testament. When the term Scripture is used herein without qualification, it will be assumed to refer to both the Christian Old and New Testaments. For a history of Hebrew canon and the use of Tanakh, (Sanders 1992, pp. 837–52).

6 (Walton 2009, p. 16). For a robust critique of this quote from Walton, see Lennox (2011, pp. 139–48).

7 (Walton 2011, pp. 198–99). Wyatt's book on ANE mythology is commensurate with Walton's concept of shared cognitivie environment. However, the assertion that ancient cosmologies had no concern for material creation is rejected as Wyatt's book assumes these various mytholgies were inextricably linked to beliefs about the material universe—specficially, their understanding of space and time. Wyatt writes, "The organization of space at all these levels was also vital to the smooth running of a community on any scale. In practical terms this might be called secular, but it was never entirely separated from the sacred in the ancient world, and ritual was the means by which both space and time were organized and harnessed to a community's use (Wyatt 2001, p. 55)." This does not mean the myths are compasection with modern science, but it does undermine Walton's premise that cosmogenic myth had no relation to the material genesis of the universe.

8 Johnston notes that "Egyptian religion featured four major versions of the same basic mythic cycle of creation, each represented by rival sanctuaries: Heliopolis, Hermopolis, Memphis, and Thebes." (Johnston 2008, pp. 180–81). While a complete study of each of these unique mythologies is beyond the scope of this study, Johnston's short article provides an excellent starting place for further investigation of the Egyptian literature.

9 (Craig 2021, p. 101). For a critique of Craig's mytho-history, see Miller (2021).

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Article

Concordism and the Importance of Hybrid Models

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Abstract: Concordism functioned as the consensus view in Protestant circles until the rise of Darwinism. Darwinism upended evangelical beliefs about the relationship between the Bible and science, and concordism began to fall out of favor. Subsequently, theologians began formulating statements which collated doctrines and definitions in attempts to delineate boundaries for orthodox belief. Yet while definitions and doctrines are necessary for belief, they are not sufficient for fruitful discussion and discovery of how the early chapters of Genesis could accurately depict the Earth's early history. With this realization, scholars began developing "hybrid models" which proposed intertwined theological-scientific theories in hopes of explaining both the known scientific evidence as well as the import of Scripture. Thus, even as concordism was disdained by theologically liberal academics, hybrid models multiplied, responded to new evidence, and achieved varying levels of adoption. Analysis of older hybrid models (as well as the recent hybrid model proposed by William Lane Craig) results in insights applicable to models more broadly as well as concordism in particular.

Keywords: concordism; scientific models; evolution; creationism

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1. Introduction: Defining *Concordism*, Describing Its Practice and Its Abandonment

Since contrary definitions of concordism abound, we shall begin with one from the *Dictionary of Christianity and Science*, a current authoritative source for evangelicals: "Concordism refers to the position that the teaching of the Bible on the natural world, properly interpreted, will agree with the teaching of science (when it properly understands the data), and may in fact supplement science . . . Because the concordist holds Scripture to be entirely truthful, there cannot be any ultimate contradiction between Scripture rightly interpreted and nature rightly interpreted" (Soden 2017). This definition reflects the longstanding Christian understanding of the relation of the Bible and creation as two readable harmonious books.[1] The article also notes that concordism dominated from the rise of modern science with Copernicanism until the nineteenth century. But without specifying what led to the decline of concordism, the article states an "alternative view" has arisen holding that Genesis in its ancient context affirms no position on modern science.

What brought about the change? Historians agree that the Darwinian revolution dramatically changed late nineteenth century intellectual perspectives, including theologians' attitudes toward concordism.[2] Theological liberals promptly identified religious doctrine, even revelation itself, as based on an evolving process rather than divinely inspired Scripture. Evangelicals recognized that the transmutation of species had become scientific consensus. Instead of seeking to undermine the theory, these theologians began highlighting Christianity's incompatibility with the materialistic implications of Darwinian evolution. Evangelical apologetics shifted from the design argument, its longstanding mainstay, to defending rather than assuming biblical inerrancy. Eventual reassessment and even the abandonment of concordism by many evangelicals stemmed from the Darwinian intellectual transformation (Roberts 1988; Livingstone 1984).

Evangelicals had previously practiced concordism as evidenced historically in a process we might call the conservatism principle. Theologians historically resisted the abandonment of traditional biblical interpretations when new scientific theories seemed to

conflict. Only straightforward scientific evidence, accepted after long periods of debate, led to cautious amendment of longstanding biblical interpretation. Even then, central Christian doctrines were not at stake. Somewhat surprisingly, conservative theologians never developed a standardized hermeneutic relating the Bible's authority to scientific discoveries (Lindberg 2003). But the key figure in the most famous science-theology conflict, Galileo, offered a proposal which presciently described the historical practice of concordism until the nineteenth century.

Galileo's approach employed two fundamental assumptions and two interpretive steps in resolving science-theology clashes. Assumption 1: Assume biblical inerrancy but never inerrant interpretation. He argued "that Holy Scripture can never lie, as long as its true meaning has been grasped" (Galilei 2008b). Galileo also stressed "though Scripture cannot err, nevertheless some of its interpreters and expositors can sometimes err in various ways" (Galilei 2008a).

Assumption 2: Nature and Scripture cannot disagree. As God is the author of both books, correct interpretations cannot conflict. Theology is the queen of the sciences because it deals with salvation, "which, surpassing all human reason, could not be discovered by scientific research or by any other means than through the mouth of the Holy Spirit himself" (Galilei 2008b). But in matters such as geometry, astronomy, music, and medicine, theologians are not more expert than specialists in those fields.

Interpretive Step 1: Traditional biblical interpretations govern unproven science. Biblical statements pertaining to nature have authority over "any human works" supported by only "probable reasons" (Galilei 2008b). Such scientific theories, when apparently contrary to Holy Scripture, "must be considered indubitably false" if not demonstrably proven (Galilei 2008b). Galileo's position assumes that scientific theories can be errant interpretations of nature. Galileo's Interpretive Step 2: Proven scientific theory requires biblical reinterpretation. Obviously if God's two books, rightly interpreted, cannot contradict each other, and a debated scientific theory is eventually proven, the former biblical understanding is wrong.[3]

Galileo's approach describes the often-unrecognized practice of concordism from the outset of modern science (sixteenth century) until the late nineteenth century. Biblical inerrancy stood as the fundamental assumption even when influential scientific theories seemed to undermine Scripture. Biblical interpretation and scientific theories, however, even when difficult to reconcile, were viewed as allies. The arrival of Darwinism, however, presented a different challenge altogether for most evangelical theologians. Certain of its features were and still are theologically recalcitrant to many evangelicals. We shall return to address those features later. For now, it is sufficient to note that some evangelicals, having embraced contemporary evolutionary theory, have abandoned not only concordism but biblical inerrancy, too.

2. The Insufficiency of Definitions and Doctrinal Statements in the Concordism Debate

"The beginning of wisdom is the definition of terms."[4] Culture wars can be ignited over who gets to define terms (e.g., "woman"). Terms such as evolution, creation, history, myth, and literal illustrate the need for careful definitions among Christians. Confusion in the concordism debate often results when a Christian leader defines it such that it does not correlate well with something like the "standard" definition above from the Dictionary of Christianity and Science. But necessary as starting points in the larger discussion, establishing definitions is not sufficient for the analysis of competing understandings of the Scripture/creation relationship.

Doctrinal statements have long served the vital role of setting theological boundaries. Confessional statements allow for more precise comparison of competing theologies and, as Philip Schaff noted, they contribute to clarity in polemics and irenics (Schaff 1877).[5] Less comprehensive statements enlarge theological boundaries but may leave the boundaries blurred. For example, the Evangelical Theological Society's two sentence doctrinal basis

intentionally lacks detail to allow a variety of traditions which endorse biblical inerrancy. But just how inerrancy is understood by various ETS members is debatable.[6]

So, the more propositionally detailed, the more precise are doctrinal statements. For example, compare the Apostles' Creed with the Nicene with the Chalcedonian. On the other hand, the more detailed and analytic the doctrinal statement, the less accessible it is to non-theologians and the harder it is to see its obvious correlation with the Bible (again, cf. the Apostles' with the Nicene with the Chalcedonian creeds). Even necessary doctrinal statements are not sufficient for revealing the full implications of one's understanding of the Bible/science relationship.

3. The Necessity of "Hybrid" Models for the Scripture and Science Relationship

In his famous 1884 Baltimore Lectures on Molecular Dynamics and the Wave Theory of Light, Lord Kelvin maintained that "the test of 'Do we or do we not understand a particular subject in physics?' is 'Can we make a mechanical model of it?'" (Duhem 1996). Yet some early twentieth century philosophers of science thought scientific models not only subsidiary to theories, but that models are even dispensable altogether. Those philosophers noted that theories contain propositions whereas models do not. But today philosophers typically reject the notion that models have nothing to add to theories.[7] A given theory might produce different models, revealing that the theory provides a less than complete understanding, and a model (e.g., the billiard ball model of a gas) might also provide insights which an abstract theory cannot.

Twentieth century theologians noticed the affinities between scientific and theological models.[8] Theological models seek to flesh out the abstract descriptions of doctrines (e.g., Augustine's psychological model of the Trinity). Theological models also promote understanding of complex doctrines (e.g., the two minds Christological model) and allow scrutiny for biblical justification.

If we combine scientific and theological/biblical models, we then have what we might call hybrid models. Hybrids are especially complex because of the Church's longstanding approach to Scripture and creation as God's two books. Though different in purpose, both books must be read carefully because they are divine revelation. For this reason, when seemingly contradictory scientific theories are related to the Bible, hybrid models both multiply and are hotly debated. Yet, hybrids have traditionally helped sort through such challenges when definitions and doctrinal statements may not. Hybrids expose and flesh out the implications of particular understandings of the Bible in relation to controversial scientific theories.

4. An Analysis of Representative Historical and Contemporary Hybrid Models

To illustrate the construction of hybrid models, we shall examine several which highlight different aspects of model construction, their controversial nature, errors, and usefulness. The first two illustrate the eventual acceptance of debated scientific discoveries. Frequent adjustments of hybrid models are seen in these examples. And the second example illustrates how established but erroneous hybrid theories affect laypersons long they have been scholarly abandoned.

4.1. Calculating the Water Volume of the Oceans: How Early Hybrid Models Attempted to Reconcile the Discovery with the Biblical Flood

Once heliocentrism became especially controversial (sixteenth century), hybrid models multiplied. Even the Jesuits adopted the Tychonian helio-geocentric version (Cabal and Rasor 2017, pp. 27–49). The conservatism principle/concordism/two books approach was assumed by Western intellectuals with the rarest of exceptions. Many scholars began thinking about the history of the formation of the earth. During the seventeenth and eighteenth centuries, the most influential theory of the earth was diluvialism, explaining geological phenomena in view of the Flood (Cabal and Rasor 2017, pp. 99–120).

But in calculating the water volume of the oceans, scholars discovered the oceans did not contain enough water to cover all the mountains of the earth's current geography during the Flood. The earliest and most widely held hybrid theory suggested a subterranean reservoir of water was released during the flood. Thomas Burnet (1635–1715) argued for this model but eventually faced harsh criticism for suggesting the Flood account was not to be understood literally. John Woodward (1665–1728), accepting the subterranean reservoir hybrid theory, earned the title "Grand Protector of the Universal Deluge" for condemning Burnet's failure to maximize the Flood's earth shaping effects (Gohau 1990). Edmund Halley (1656–1742) modified the model by surmising a comet had once traveled perilously close to the earth, tilting it on its axis. But Halley's theory dropped the subterranean reservoir notion, suggesting instead that the tilting sloshed the oceans out of their basins over the continents. William Whiston (1667–1752) adopted Halley's comet model but coupled it with the original interior water model. He theorized that the earth's tilting on its axis produced the release of the deadly interior waters (Gohau 1990; Ellenberger 1999). Assessing these early hybrid models reveals adherence to concordism, because they believed the Bible was true even when a scientific discovery presented a challenge. The water issue still underlies various Flood hybrid theories to this day.[9]

4.2. Discovery of Differing Ancient Climates: A Hybrid Model Outlives Its Usefulness but Dies a Slow Death

William Buckland (1784–1856), was both a pioneering Oxford geologist and theologian. He practiced concordism and created hybrid models in relation to his geological discoveries.[10] The study of volcanoes led him to abandon his earlier view that internal rock formations were Flood related. But he made a bold announcement in 1823 that he had discovered evidence of the universal Flood. Buckland identified recently discovered fossils in Kirkdale Cave (North Yorkshire, England) as hyena, elephant, and hippopotamus. He originally believed the Flood had swept them there. Eventual evidence, however, convinced him the animals had lived there before being destroyed by the Flood. His revised hybrid theory was an early version of paleoclimatology, that Great Britain had once featured a vastly different ecological system. But his model was quite controversial, especially with a small group called the Scriptural Geologists. They especially opposed Buckland and the majority of Christian geologists in the early nineteenth century for believing the previous century's evidence had revealed an old earth.

Eventually, however, even some of the Scriptural Geologists accepted the evidence for an earlier "warmer" England. Such evidence contributed to the hybrid model known as the vapor canopy theory. Henry Morris did not invent the model, but he greatly popularized it (Morris 1980). Genesis 1:6–7 is supposed to refer to a protective water vapor barrier over the earth, protecting it from the sun's radiation. This biblical interpretation explained the gigantism of certain fossil plants and animals, the longevity of antediluvian human life, the source of the Flood's rainwater, and more.

Eventually most young earth creationist leaders rightly realized the model was indefensible biblically and scientifically. Russell Humphreys (Humphreys 1994) wrote: "the idea of a canopy atop the atmosphere did not come down from Sinai with Moses, engraved by the finger of God on the back side of the stone tablets. Instead, it was a human interpretation of scripture which was, for a time, the best understanding we could come up with. I think that time has passed. In spite of the large emotional investment some of us may have put into the canopy model, I suggest that now is a good time to re-evaluate the model, to see if it is worth any further effort."

I have often surveyed my students to find many still believe the vapor canopy to be integral for a sound doctrine of creation. They are unaware that most young earth leaders have abandoned it and are having a tough time explicitly convincing followers to abandon the model.[11] The Kirkdale Cave example reveals the difficulty in understanding new scientific evidence, especially when it is not easy to see how it coheres with the Bible. In this case, the hybrid model changed regarding the scientific understanding of the evidence

(fossils were Flood-swept vs. a warmer paleoclimate produced the fossils). The biblical hybrid model of a vapor canopy remains resistant to popular abandonment.

4.3. Discovery of the Vast Number of Land Animal Fossils: Today's Most Influential Hybrid Model and the Problem of Representational/Realist Models

Roughly about the middle of the seventeenth century, the organic origin of fossils began to be accepted regularly. But the discovery of so many fossilized land species raised questions as to how they could all fit on the Ark. In response, the nineteenth century Scriptural Geologists offered several young earth hybrid models. One proposed that God only commanded Noah to receive local animals onto the Ark and the rest perished. Some suggested reptiles (or their eggs) floated on trees outside the Ark. One model proposed that God recreated new species after the Flood (as evidenced by animals unique to specific continents); therefore, not all animals today have descended from those only on the Ark.[12]

By far the most widely known hybrid model of the Flood today is offered at the Ark Encounter of Answers in Genesis. The full-size wooden Ark in northern Kentucky is more than five hundred feet long. Surprisingly, its explanation for the land animal problem is to utilize a restricted version of evolutionary common descent.[13] The Ark Encounter webpage asks: "Two of Every Species? Was every species on the Ark? No. Species is a term used in the modern classification system. The Bible uses the term 'kind.' The created kind was a much broader category than the modern term of classification, species" ("How Many Animals" n.d.). Here is not the place to discuss the popular young earth creationist theory termed baraminology upon which the species vs. "kind" distinction is based.[14] Instead, the concern here has to do with the Ark Encounter presenting itself as if its major details are the established hybrid model (even in the young earth community).[15] As a representational model it misleads on this point and several others.

Representational models[16] such as the Ark Encounter present a special problem to non-specialists. Whereas specialists (in this case, scientists or biblical scholars) realize the model invites critique, the same is not true for the non-specialist. Science students themselves struggle with sorting multiple models of the same phenomenon/theory. In some cases, students consider more than half of the models equally plausible. Such students become frustrated with the inability to discern the "right" model and are unable to describe how to falsify any of the models, "the hallmark of a scientific question" (Ruebush et al. 2009). How much more acute is the problem for layfolk thinking the Ark Encounter is the only faithful biblical model.[17] Most are likely unaware that some of its major details are highly debatable.

For example, Andrew Snelling, Director of Research at Answers in Genesis, holds a very different view of ancient human/dinosaur interaction. Though agreeing that humans and dinosaurs must have lived at the same time, "they didn't live spatially together in the pre-Flood world." His reasoning is based on the "spatial separation of the fossil remains" of humans and dinosaurs. Thus, his model suggests dinosaurs and humans lived on separate island continents in the pre-flood world (Snelling 2009a). Yet perhaps the most noteworthy aspect of the hybrid model on display at the AiG Creation Museum and its Ark Encounter is that it portrays dinosaurs living together with humans. Most visitors to these exhibits do not realize that since no human and dinosaur fossils have ever been discovered in the same strata, AiG's lead scientist does not believe they lived in proximity.

Non-informed visitors to the Ark Encounter will likely perceive the exhibit to represent a biblically faithful witness against evolution.[18] Yet, few will be aware of a critically important problem surrounding AiG's understanding of the subject. As mentioned above, AiG solves the old problem of getting all the land species on the Ark by restricting them to "kinds," not species. They argue perhaps there were less than 7000 animals on the Ark to satisfy the Bible's teaching on the subject. The notion requires "hyperevolutionary" speciation rates beyond imagination (Duff 2019). One former young earth creationist notes that "for the most part, radical creationists are quite comfortable with the fact of evolution. In fact, some believe in the power of evolution to an extent that would make Richard Dawkins blush . . . Radical creationists have entertained every taxonomic level short of

the kingdom as marking the approximate limits of evolvability for the various 'kinds' of organisms" (Peters 2009).[19]

So, AiG practices concordism, but the Ark Encounter's ultra-realist hybrid model presents special problems for non-specialists. And AiG's doctrine of biblical inerrancy is deeply concerning with its revision to include the young age of the earth, Flood geology, and more. This eccentric and divisive approach excludes most framers of the Chicago Statement on Biblical Inerrancy, members of the Evangelical Theological Society, and even some leading young earth creationists (Ham 2013, 2015).[20]

4.4. Evangelical Evolution: A Question-Raising Hybrid Proposing New Answers

William Lane Craig's *In Quest of the Historical Adam* represents an especially important development in the trending evangelical adoption of human evolutionary theory (Craig 2021). Craig's role as a generational evangelical philosopher is well established. Thus, the influence of this book in evangelical circles will be substantial. A brief look at his definitions, doctrines and potential hybrid model may help grasp some of the implications of his proposal.

Craig regards as "one of the worst forms of concordism" any attempt to employ "contemporary science to guide one's interpretation of the text" (Craig 2021, p. 16). He describes the appeal of the approach as "the sirens of concordism" (Craig 2021, p. 18). His preferred version of concordism is "to integrate the independently discovered findings of contemporary science and biblical theology into a synoptic worldview" (Craig 2021, p. 16). His independence approach is quite different from the Dictionary of Christianity and Science definition as well as the approach which dominated until Darwin.

Craig's quest for the historical Adam is not due to theological significance. "It is . . . dubious that the doctrine of original sin is essential to the Christian faith" (Craig 2021, p. 5). Craig finds our proclivity to sin as sufficiently explained by our selfish evolutionary animal nature and the corrupt environment of our raising (Craig 2021, p. 231). Instead, Craig's quest for Adam has to do with biblical inspiration. Since Paul, under divine inspiration, teaches an historical Adam, the doctrine of inspiration would have to be revised were it not so. Similarly, Craig notes that Jesus believed in an historical Adam, and Jesus' omniscience guarantees its truth. The denial of this would be "to destroy orthodox Christian faith" (Craig 2021, p. 8).

To avoid, then, the type of concordism which allows Bible/science interplay, Craig first sets out to determine the genre of Gen 1–11 before examining the relevant science. He desires "to understand the text as the original author and his audience would have understood it," but fears "the terrifying possibility that the young earth creationist" interpretation is correct (Craig 2021, p. 16). He hopes his genre study will reveal Gen 1–11 does not support that type of literal interpretation.

Craig concludes the genre of Gen 1–11 is "mytho-history." In brief, by myth he does not mean falsehood. One of his most controversial proposals is that Gen 1–11 is recognized as myth due to its "fantastic elements . . . which, if taken literally, are so extraordinary as to be palpably false" (Craig 2021, pp. 104–5). Craig notes he is not rejecting the miraculous, but instead the "palpably false" elements such as a walking/talking serpent, vegetarianism, trees of life/good and evil, the rivers of Eden, cherubim, long lifespans, the Flood, the Table of Nations, the Tower of Babel, and the "most fantastic element," the young age of the earth (Craig 2021, p. 13). Craig describes God's anthropomorphic portrayal in Gen chapters 2–3 "as a humanoid deity worthy of polytheistic myths" (Craig 2021, p. 102). Yet one of Craig's "family resemblances among myths" is they "are objects of belief by members of the society that embraces them" (Craig 2021, p. 45). Even if some of the original audience believe the myths true, this does not mean "the truth of the accepted myths is somehow expected or intended" (Craig 2021, p. 158). And though Craig reckons Gen 1–11 to be mytho-history, he concludes it is "probably futile to try to discern to what extent the narratives are to be taken literally, what parts are historical and what parts are not" (Craig 2021, p. 201).

Craig devotes the last third of the book to the scientific evidence for Adam and its empirical equivalent, "namely, when did human beings first appear in the evolutionary process … The historical Adam may then be located around that time" (Craig 2021, p. 245). Craig identifies Homo heidelbergensis as that time when humans emerge either gradually from a multispecies event or a single species mutational event, or perhaps combining something from both. Craig argues for a genealogical single couple (not sole genetic progenitorship) before 550kya. "The radical transition effected in the founding pair that lifted them to the human level plausibly involved both biological and spiritual renovation, perhaps divinely caused" (Craig 2021, p. 376). Craig thinks a de novo creation of Adam unlikely due to our genetic similarity to chimps or the prospect of "considerable interbreeding with nonhumans" (Craig 2021, p. 376n.20).

So, Craig provides a hybrid model of Adam and Eve, synchronizing his theological understanding of the biblical/historical Adam with evolutionary theory.[21] He envisions an initial population of approximately five thousand hominins who look like human beings but are animals without capacity for rational thought. God chooses two and renovates their brains and endows them with souls. "At some point they become aware of God's moral requirements, which renders them responsible moral agents" (Craig 2021, p. 378). But misusing their free will, they commit "a (the original) sin" (Craig 2021, p. 379), thus becoming morally guilty and separated from God, but not alienated from God's offer of forgiveness.

Evangelicals holding to de novo creation of Adam and Eve will rightly be concerned by Craig's rather standard "fall upward" evolutionary-theological move. He argues that humans have an evolutionary propensity to selfishness which derives ultimately not from Adam but from the first living things on earth (Craig 2021, p. 231). Human proclivity to sin whether in Adam or humanity generally stems from living in a morally corrupt environment with "our self-seeking animal nature" (Craig 2021, p. 231) with its "natural biological tendency toward survival and hence selfishness" (Craig 2021, p. 232).[22]

Regarding definitions, Craig not only defines concordism non-standardly, but one might wonder whether Craig interprets Gen 1–11 in view of modern science anyway. Does his fear of young earth literalism, or does contemporary evolutionary doctrine influence his mytho-historical conclusion? Craig offers neither definition nor discussion of biblical inspiration, which is surprising since it grounds the justification for his quest. He examines in depth the literary nature of Genesis 1–11. Why not at least a brief treatment of the nature of biblical inspiration? Craig engages all manner of historical biblical criticism. So, then why should we trust we have the words of Jesus? Or why not assume Paul simply erred?

The issue of inspiration for many of Craig's traditional, theologically conservative followers is especially important in view of his mytho-history conclusion. Craig writes much on myth but little on history. His readers may rightly wonder how to interpret Gen 1–11 since he considers it at "some level historical," but concludes it "probably futile to try to discern … what parts are historical and what parts are not" (Craig 2021, p. 201). He does provide a list of central truths from Gen 1–11 which "come readily to mind" (Craig 2021, pp. 201–2), but neither cites nor exegetes texts from which the original audience would have learned them.

For Craig's traditional followers, what might be said of how they will read the early chapters of Genesis? He writes that, although "the classification of Gen 1–11 as mytho-history is prone to misunderstanding, I do not think that we should revert to vague euphemisms that tend to conceal rather than elucidate the literary character of Gen 1–11. Scholars simply need to be careful to explain our meaning to laymen" (Craig 2021, p. 157). I suspect that might be more difficult than Craig supposes. Many might wonder how to interpret the texts at all. What is fantastic and what is historical? Are all anthropomorphisms to be regarded as fantastic? Is it now fact that the Fall mythically describes our experience of evolutionary descent? Perhaps some will wonder why biblical texts outside Genesis should not also be regarded as fantastic/mythical.

J. P. Moreland's cautionary counsel is pertinent. He writes that when leaders teach theistic evolution, Christians are robbed of confidence in the Bible. (Moreland 2017) He contends theistic evolution not only places "Christianity outside the plausibility structure," but also has made it much easier to revise other biblical teachings "when there is cultural pressure on us to do so." (Moreland 2017).

5. Conclusions

Concordism remains controversial due to continuing pressures on biblical interpretation from the evolutionary revolution. Debates about fossils, ice ages, continental drift, and expansion of the universe now seem trivial in comparison. But hybrid models of necessity will continue to spring from the two books understanding, even when some evangelicals revise or abandon the tradition.

Hybrids reveal attitudes toward science and scripture which definitions and doctrines might not. Easily identifiable errors in past models make current scholars understandably nervous to offer new ones. *But one obvious lesson should be that testable models protect both those offering them and their followers from conferring models with infallibility.*

If the evolutionary whirlwind has presented a stiff challenge to the two books tradition, it has obviously not ended the tradition for evangelicals. Whereas theological liberals feel no pressure to practice any version of concordism, evangelicals, by nature of their commitments to Christ and the Bible, will continue to present some version of hybrid models, even if restricted ones, until the day dawns.

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Notes

1 On the use of the two books concept from the outset of the rise of modern science see (Howell 2002).

2 What follows in the rest of this section is based on (Cabal and Rasor 2017, pp. 39–49, 79–81).

3 Regarding when a scientific theory is "demonstrated" has been far more controversial than Galileo could have imagined.

4 Though the aphorism is widely attributed to Socrates, no citation from Plato's dialogues has ever been produced to substantiate the claim.

5 Schaff elegantly noted that "Polemics looks to Irenics—the aim of war is peace."

6 "The Bible alone, and the Bible in its entirety, is the Word of God written and is therefore inerrant in the autographs. God is a Trinity, Father, Son, and Holy Spirit, each an uncreated person, one in essence, equal in power and glory." See ("ETS Constitution" n.d.). On the other hand, ETS has adopted bylaw 12 which refers to the Chicago Statement on Biblical Inerrancy as specifying "the intent and meaning of the reference to biblical inerrancy in the ETS Doctrinal Basis . . . ." See ("Bylaws" n.d.). One may debate whether those who sign the doctrinal basis are adequately made aware of the "intent and meaning" of the ETS Doctrinal Basis.

7 For an excellent overview of scientific models see (Frigg and Hartmann 2020).

8 For example, see (Ferre 1963).

9 e.g., Andrew Snelling of Answers in Genesis utilizes the model of "catastrophic plate tectonics" to explain many features of the Genesis Flood such as the forty days and nights of rain resulting not from clouds (or a vapor canopy) but from the earth's cleaving open and releasing heated jets of water shooting high into the atmosphere that condensed into rain. See (Snelling 2009b, vol. 2, pp. 471–73). The understanding of divine action in these models assumes divine providence directs scientifically observable natural processes. Catholic thinkers, on the other hand, eschewed physical explanations of the Flood and emphasized the miraculous so as to not repeat the mistakes of the Galileo affair. See (Ellenberger 1999, vol. 2, p. 141).

10 On this section see (Cabal and Rasor 2017, pp. 108, 114, 117, 154n29).

11 For examples see especially the comments section of (Sarfati 2022). See also (Hodge 2009).

12 See (Cabal and Rasor 2017, pp. 123–33).

13 Andrew Snelling (2009a, vol. 1, p. 132), Director of Research for Answers in Genesis, credits modern biology, specifically the past "hundred and fifty years of investigations in zoology and genetics," for revealing "the amazing potentialities for diversification with which the Creator endowed the Genesis kinds."

14 See (Cabal and Rasor 2017, pp. 137, 144, 146, 162–67).

15 On the serious concerns of some other young earth scholars regarding AiG's model, see (Cabal and Rasor 2017, pp. 168–70).

16 As noted earlier, scientific models come in a variety of types, including representational models believed to be approximations of the truth like the Ark Encounter (as opposed to, say, exploratory models). In contrast, Reasons to Believe has long offered a testable model, realizing the need for correction as further truth comes to light. The history of (scientific/hybrid) modeling reveals the importance of this approach since our fallibility invariably results in distorted representations.

17 Visitors are told they are experiencing "Bible history at the life-size Noah's Ark!" ("Ark Encounter" n.d.). One Trip Advisor reviewer wrote: "I must admit both my wife and I had tears in our eyes when we first gazed up at the structure, knowing that this was real" ("Ark Encounter Williamson" 2017).

18 For instance, with one's paid admission they are entitled to lectures such as: "Creation vs. Evolution: Why it Matters with Dr. Terry Mortenson" see (Mortenson n.d.). On the misleading nature of AiG's definitions and partial acceptance of *evolution*, see Cabal and Rasor 2017.

19 On AiG's attempt to distance itself from whale evolution, see (Belknap 2019).

20 Young earth creationist Kurt Wise who endorses whale evolution is excluded in AiG's view from a proper understanding of inerrancy. See ("Affirmations and Denials" n.d.). This material is also one of the appendixes in (Mortenson and Ury 2008).

21 One might wish Craig had also treated well-known problems with evolutionary theory such as how God might superintend evolution, or standard evolutionary explanations for human consciousness, morals, and religious beliefs.

22 Craig agrees with Daryl Domning that behaviors sinful for humans are not so for animals because they "did not acquire their sinful character until the evolution of human intelligence allowed them to be performed by morally responsible beings" (Craig 2021, pp. 378–79n.26), quoted from (Domning 2001).

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A Theocentric Environmental Ethic

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Abstract: An influential view among environmentalists and ecologists is that religion, in general, and Christianity, in particular, not only have nothing to offer to environmental ethics but are actually hostile to the environment. I argue that a biblically informed theocentric environmental ethic of stewardship offers rich resources for duty-based environmental ethics in general and, in particular, for establishing grounds for restoration, conservation, and preservation of the environment.

Keywords: environmental ethics; Genesis; dominion theology; stewardship; conservation; preservation; restoration

1. Introduction: Historical Perspective

In 1967, Lynn White, professor of medieval history at UCLA, delivered an influential address to the American Association for the Advancement of Science, later published in the journal *Science* with the title "The Historical Roots of our Ecological Crisis."[1] According to White, the Western Judeo-Christian tradition in general and the Bible in particular bear "a huge burden of guilt" for the contemporary environmental crisis.

Six years later, in 1973, the eminent historian Arnold Toynbee, in an essay entitled "The Genesis of Pollution," made a similar claim:

> The thesis of this essay ... is that some of the major maladies of the present-day world—in particular the recklessly extravagant consumption of nature's irreplaceable treasures and the pollution of those of them that man has not already devoured—can be traced back to a religious cause, and this cause is the rise of monotheism. (Toynbee 1973)

Noted landscape architect Ian McHarg echoes this viewpoint: "In its insistence upon dominion and subjugation of nature, [the biblical creation story] encourages the most exploitative and destructive instincts in man rather than those that are deferential and creative." (McHarg 1969; cited by Wright 1989). Feminist theologian Rosemary Radford Reuther maintains that the Christian tradition, as heir of Neoplatonic dualism, presupposes a thoroughgoing alienation of humanity from nature. Consequently, she assigns Christianity considerable blame for "this debased view of nature, as the religious sanction for modern technological exploitation of the earth." (Reuther 1972). Examples of this view of the Judeo-Christian tradition as perpetrator of, or at least willing accessory to, the rape of nature, could be multiplied. So, it is no surprise that since the birth of the environmental movement some six decades ago,[2] most attempts to offer a systematic ethical framework for human interaction with nature, presupposing as they do something like White's or Toynbee's thesis, have seemed to many Jews and Christians to be deeply flawed.

I will argue that a theocentric ethic of environmental stewardship is able to answer criticisms such as White's and Toynbee's by offering a constructive way to make sense of values in nature, and also to speak to the central issues in environmental ethics: preservation, conservation or sustainability, and—perhaps more problematic—restoration.[3] I will also briefly argue that a theocentric ethic overcomes deficiencies in each of the four most popular contemporary approaches to environmental ethics.

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2. Contemporary Perspectives: A Brief Summary

To simplify somewhat, there are four contemporary approaches to environmental ethics that are widely influential but, I believe, are also seriously deficient. Briefly summarizing these approaches will serve to put in sharper relief the theocentric stewardship ethic that I will present. The four approaches are (1) *biocentric*, (2) *ecocentric*, (3) *"deep ecology"*, and (4) *minimalist* environmental ethics.

2.1. A Minimalist ethic

I will begin with this last approach, a *minimalist* environmental ethic. Those holding to this view assert that we simply have no moral responsibility for how we use—or abuse—nature itself; our moral relations with the natural world are conceived in purely anthropocentric terms.

John Stuart Mill, for example, was skeptical about an ethic of nature:

> In sober truth, nearly all the things which men are hanged or imprisoned for doing to one another, are nature's everyday performances . . . . Nature impales men, breaks them as if on the wheel, casts them to be devoured by wild beasts, burns them to death, crushes them with stones like the first Christian martyr, starves them with hunger, freezes them with cold, poisons them by the quick or slow venom of her exhalations, and has hundreds of other hideous deaths in reserve . . . . Everything, in short, which the worst men commit either against life or property, is perpetrated on a larger scale by natural agents. (Mill 1874)

William James uses even stronger language:

> Visible nature is all plasticity and indifference,—a moral multiverse . . . and not a moral universe. *To such a harlot we owe no allegiance*; with her as a whole we can establish no moral communion; and we are free in our dealing with her several parts to obey or to destroy, and *to follow no law but that of prudence* in coming to terms with such of her particular features as will help us to our private ends.[4]

The views of Mill and James are reflected in contemporary indifference to environmental concerns such as air and water pollution and even hostility towards the whole notion of climate change. As the evidence for the anthropogenic nature of climate change grows, such indifference to environmental concerns seems misguided.

Some Christians also embrace a minimalist environmental ethic, apparently believing that God will never allow his world to be destroyed by humans fulfilling the mandate to "subdue and rule" the earth.[5] They believe that acknowledging any moral duty with respect to creation must, in a zero-sum game, inevitably detract from more salient biblical commands such as evangelism. However, just because the care of creation is not the primary duty of Christians, it does not follow that it is not a duty at all. I will not say more about the rejection of environmentalism by some Christians; I believe the positive case for stewardship of creation is sufficient to rebut the rejection of environmental concern. I do want to note before moving on, though, that those most directly affected by any environmental degradation are more often than not the poorest of the earth's peoples, and that should deeply concern Christians.

2.2. A Biocentric Ethic

The other three approaches seem misguided to me. A *biocentric* environmental ethic grounds values and duties to the environment in a generalized respect for life or nature.[6] Biocentrism stands on certain principles: (1) Humans are members of Earth's Community of Life on the same terms as other species. (2) All species, including humans, are integral elements in a system of interdependence. (3) Each organism has its own good, which it pursues in its own way. Finally, (4) Humans are not inherently superior to other species.

Unfortunately, for Christians, biocentric approaches suffer from an impoverished anthropology, failing to recognize that God's image in every man, woman and child sets humanity off from the rest of nature in a very important way. However, this approach

is problematic for secularists as well. For the very abilities that enable humans to think inductively, to use language to express causal relations and not merely correlations, and above all, to make moral judgments about the value of life—those abilities do indeed confer on humans a status superior to other life. In other words, the biocentric approach asks humans to use the capacity of moral judgment unique to humans to deny that humans are morally unique.

2.3. An Ecocentric Ethic

An *ecocentric* environmental ethic grounds values and duties in the natural world itself, for example, ecosystemic homeostasis—a sustainable balance between plant and animal species in ecosystems.[7] Holmes Rolston III, a Christian scholar often regarded as the "father of environmental ethics," argues cogently that the natural world has value just because it is "value-able", that is, has value in itself in some way not necessarily tied to human valuers, and this avoids the so-called "naturalistic fallacy", the attempt to derive a moral "ought" from a non-moral "is". Rolston writes, "Tourists in Yosemite do not value the sequoias as timber, but as natural classics, for their age, strength, size, beauty, resilience and majesty. This viewing constitutes the trees' value." (Rolston n.d.). But it seems that an ecocentric approach generally ignores wild fluctuations in the Earth's natural history, fluctuations which would seem to erase previous values. How ecosystemic homeostasis is then a value remains unclear. And the adaptive ability of organisms evidenced when ecosystems change would seem to demand fluctuating values, and it is not clear how such unstable values ground environmental concerns.

Further, it also ignores the many purposes for which God can *use* his creation. If maintaining balance in ecosystems is a moral obligation, then the many biblical references to God's use of nature in blessing or in judgment on humans would be quite problematic. An ecocentric ethic thus places creaturely values above the Creator's, and so is problematic for Christians.

2.4. A "Deep Ecology" Ethic

"Deep ecology" and "eco-feminism" are closely associated with a resacralizing approach that draws on Native American, Wiccan and Eastern traditions to ascribe some sort of sacredness primarily to non-human species and landscapes.[8] Resacralization is often grounded in James Lovelock and Lynn Margulis's Gaia hypothesis, in which all the Earth's living matter, air, oceans, and land surface form a complex, self-regulating and self-directing system *that can be seen as a single organism*.[9] Gaia, this single vast system itself, is deified, and "Mother Earth" becomes "Mother Goddess Earth," more than a metaphor. Relying less on quasi-religious concepts, some "deep ecology" advocates argue that "Massive human diebacks would be good. It is our duty to cause them. It is our species' duty, relative to the whole, to eliminate ninety percent of our numbers." (Aiken and Regan 1984).

The shortcomings of this approach should be clearly apparent and not just to Christians. If the "elimination" of ninety percent of humanity involves genocide, then it is calling for a gross violation of human rights. And if it is calling simply for a natural reduction of the population, it is up to the advocate of the position to show how this can be achieved without vast human suffering and rights violations.

Much more could be said, of course, about all four of these approaches to environmental ethics, but this is not the place. The popular approaches either devalue nature or denigrate humanity. I will now argue that an ethic of creation care that is theocentric at its core is able to avoid these deficiencies and offer a constructive way to make sense of values in nature.

3. Stewardship as the Theocentric Ethical Category

Naturally, the arguments of White and Toynbee did not go unchallenged. Beginning perhaps with the publication of Francis Schaeffer's book, *Pollution and the Death of Man: The Christian View of Ecology* in 1970 (Schaeffer 1970), many Christians challenged the

hostile view, developing differing theological and ethical grounds for "creation care." A salient theme stressed the biblical image of *stewardship* as the proper Christian attitude toward nature.[10] Perhaps because White and successive critics harshly denounced the "dominion theology" of Genesis 1:28 (which reads, in the language of the King James Version, "Be fruitful, and multiply, and subdue the earth, and have dominion over it"), Christian response has focused on the more positive biblical theme of stewardship.

James Nash, for example, writes,

> According to one popular conception—actually, a misconception and stereotype—of "dominion," humankind is a distinctive creation designed for dominion . . . Nature is simply matter, resources waiting to be reformed for human utility. This viewpoint embodies the fundamental failures at the roots of the ecological crisis . . . Without doubt, Christian traditions bear some responsibility for propagating these failed perspectives. Consequently, the ecological crisis is a challenge to Christians to eradicate the last vestiges of these ecologically ruinous myths. (Nash 1993, p. 19)

But Nash, one of the few to carefully analyze the history of the ecological movement, concludes,

> Thus the ecological complaint against Christianity appears to be a serious historical oversimplification . . . [Dominion] became isolated from the moderating and controlling influences of the whole corpus of Christian thought and served as a license for elimination with extreme prejudice. The practices under the rubric of dominion were alien to the biblical and most traditional understandings of the concept. (Nash 1993, pp. 77, 79)

In surveying the growing literature on creation care coming from Christian writers, it appears to me that, with only a few exceptions, Christians have tended to avoid the dominion passages, and so their presentations of biblically-based environmental ethics are somewhat unbalanced. Certainly, stewardship is a more prevalent image in the Bible than subduing or having dominion. Yet if we are to do justice to a theocentric environmental ethic, we must take into account both the positive connotations of "stewardship" and the negative connotations of "dominion," since both are aspects of the biblical witness.[11]

In the following section, I will unpack the notion of God as "owner" and humans as "stewards" of creation and explore the category of stewardship as it applies to our relationship with God's creation. Next, I will pay attention to the alleged negative connotations of subduing and having dominion looking at three specific environmental duties of stewardship: restoration, conservation, and preservation. Stewardship is a deontological category and stresses the steward's duty to the sovereign. I have chosen to develop this account in deontological terms to contrast to what, in my view, is a misguided attempt to explicate duties to species, ecosystems, future generations, and such. In my view these are not the sorts of things to which we can have duties. As will be shown, a theocentric ethic can make sense of duties to God *with respect to* such things.[12]

3.1. Stewardship and Ownership

The biblical record is clear. "In the beginning God created the heavens and the earth" (Genesis 1:1), and the act of creation implies the right of ownership: "The earth is the Lord's, and everything in it" (Psalm 24:1). God as creator—and therefore owner and master of creation—is a salient concept throughout the Bible. Many implications flow from this fundamental affirmation of God as creator and master of all; two in particular are relevant here. First, if God is Creator, then he must impart something of himself to his creation.[13] In Psalm 19:1, David sings, "The heavens declare the glory of God; the skies proclaim the work of his hands," and the Psalmist can call on creation to praise its Creator:

> Praise the Lord from the earth, you great sea creatures and all ocean depths,
>
> lightning and hail, snow and clouds, stormy winds that do his bidding,
>
> you mountains and all hills, fruit trees and all cedars,

wild animals and all cattle, small creatures and flying birds,
kings of the earth and all nations, you princes and all rulers on earth
young men and maidens, old men and children. (Psalm 148:7–12)

The writers of the Psalms imbue their songs with nature parables illustrating God's goodness, beauty and faithfulness. Jesus used the birds and flowers to illustrate God's goodness (Matthew 6:27–30). The Apostle Paul as well maintains there is revelation of the character of God in creation (Romans 1:20). Nature is God's handiwork, and in it, we can see reflected something of his character, even though finitely and imperfectly.

Second, as his possession, nature is God's to employ as he pleases. Psalm 78 records God's use of nature for his purposes:

He divided the sea and led them through; . . .
He guided them with the cloud by day and with light from the fire all night.
He split the rocks in the desert and gave them water as abundant as the seas; . . .
He gave a command to the skies above and opened the doors of the heavens;
He rained down manna for the people to eat, he gave them the grain of heaven . . . .
He rained meat down on them like dust, flying birds like sand on the seashore. . . .
Again and again they put God to the test; they vexed the Holy One of Israel. . . .
He sent swarms of flies that devoured them and frogs that devastated them.
He gave their crops to the grasshopper, their produce to the locust.
He destroyed their vines with hail, their sycamore-figs with sleet . . . . (Psalm 78 *passim*)

The biblical perspective is that just as nature was created by God and can reveal his character, so also nature belongs to God and can reveal his purposes for blessing or punishment. This perspective alone could well be sufficient to ground an ethic of respect for nature, just as understanding who is the owner of new construction and what his purposes in the project could (one hopes) be sufficient to prevent vandalism, pilfering and graffiti at the project site.

Thus, as we revel in extravagant displays of wildflowers in the mountains of the High Sierra or thrill to the bugling of elk in the Rockies, as we smile at the anhinga hanging its wings out to dry in the Everglades or delight in a sunset behind the haystack rocks of Rialto Beach, as we watch in wonder the elephant seals at Piedras Blancas or the lurking alligators in Okefenokee Swamp, we will express gratitude to the Owner of this planet for allowing us to enjoy what he has made and to learn what we can from his creation, and we resolve to the best of our ability to refrain from marring his property. We feel privileged to be a part of the same creation as the delicate blossoms of the columbine or the awesome humpback whale, and the experience of the wild arouses within us a feeling of something like kinship with nature.

However, in recognizing we are guests on another's property, albeit tacitly, we acknowledge that the owner is the sovereign lord of their land. And so it comes as a sobering realization, heavy with responsibility, to find that we are designated the caretakers, or stewards, of this vast and varied world.

Just here we must draw clear and distinct lines of demarcation between the theocentric concept of humans as stewards of creation and the deficient concepts of humanity contained in biocentric, ecocentric, or deep ecology environmental ethics. While a theocentric ethic takes seriously the conception of humans as one with the environment in terms of their nature as creatures, it further recognizes that these creatures are endowed by the Creator with the capacity to bear a special delegated responsibility. In regards the transcendent infinity of the Creator, humans stand on the same side of a gulf as the humblest earthworm. We are *in and with* nature. However, in regards the immanent personality and moral agency of the Creator, humans stand on his side of the gulf, over against the rest of creation. For as bearers of the image of God, as being created with the purpose of rulership (more on which

below), humans are in a relevant sense *over* nature. This may sound like speciesism to some, but it is perhaps the only view of human beings that does justice both to our nature as rational, moral agents capable of seriously affecting our environment and responsible for those effects, and at the same time as fellow-creatures of the biosphere with all other life. And it seems that virtually everyone, either explicitly or implicitly, recognizes this in both their thinking and their acting. The concept of humans as stewards of creation, and hence over creation, is not an anthropocentric but a theocentric concept. This delightful, wonderful, extravagantly furnished world reveals God's character and serves his purposes, and he has placed us in it and made us stewards over it.

3.2. Stewardship and Responsibility

The English word "steward" entered the language sometime in the eleventh century as

> *stigwaerd*, *stig* probably referring to a house or some part of a house or building, and *waerd* [later, *ward*] meaning of course "warden" or "keeper." The first meaning offered by the *Oxford English Dictionary* is this: "An official who controls the domestic affairs of a household, supervising the service of his master's table, directing the domestics and regulating household expenditures; a major-domo." (Hall 1990, p. 40)

The most common use of 'steward' in English Bibles is to translate the Greek word *oikonomos*, and that of 'stewardship' is to translate *oikonomia*. These words are composed of *oikos*, "house, household," and *nomos*, "rule, law." So it follows that the steward is one charged with the rule of the household, responsible for the great natural wealth of the master's estate.

And there is still more to the conceptual reach of "steward." A century ago, the biologist Ernst Haeckel coined the word *ecology* to mean

> [T]he knowledge of the sum of the relations of organisms to the surrounding outer world, to organic and inorganic conditions of existence; *the so-called "economy of nature,"* the correlations between all organisms living together in one and the same locality, their adaptation to their surroundings, their modification in the struggle for existence. . . . [14]

Haeckel formed *ecology* from *oikos*, "household," plus *logos*, "study." Thus the relationship between stewardship and ecology is a very close one conceptually.

Clearly, the steward was not charged with responsibility over valueless bric-à-brac, and neither does a stewardship model of environmental ethics regard non-human creation as valueless. Rather the owner or monarch would place the most trusted servant as steward over the most valuable parts of the estate. But that value is derived from its relation to the owner, not to the steward. The steward values *what* the master values, values *just as* the master values, and manages the estate *in the manner* the master would want it managed were they present. That is why the Christian concept of stewardship is, at its core, thoroughly theocentric rather than anthropocentric. Wilkinson writes,

> [T]hough the value of things must comport with God's principles for correct valuing, humans are still the Creator's agents for this task. . . . The candidates for such principles put forward by the world around us—purely subjective valuations, usefulness for human purposes, and intrinsic values—are all deficient by Christian standards. The missing element is transcendence: valuing of the creation ought to be grounded in the Creator's norms. (Wilkinson 1990, p. 239)

In this way, a theocentric ethical system solves the problem of valuation that troubles naturalistic ethical systems. The concept of intrinsic value is contested because it seems, at least intuitively, that value in nature can never be more than instrumental.[15] But in a theocentric ethic, all aspects of the natural world have intrinsic value because of who their Creator is, irrespective of their instrumental value for humans or other creatures. Since "The heavens declare the glory of God" (Psalm 19:1), a clear night sky is of value in order that

the glory of the creator might shine regardless of the wishes of observational astronomers, lovelorn poets or aspiring natural theologians. The abiotic lunar landscape has value, even though only twelve humans have ever set foot on the moon, simply because it is a part of creation that God put in place (Genesis 1:16). That God will, in the last days, use it as a "billboard" (Luke 21:25) only adds instrumental value to the moon's antecedent intrinsic value as God's handiwork.

So the Creator determines the value of creation, and the steward is the one in charge of what is valuable. The picture is vice-regency, orderly management, not exploitation. (The concept of vice-regency, familiar to biblical theologians, has recently received more prominence in discussions of the *imago dei*.) The Psalmist, rhapsodizing on the creation, echoes the teaching that rulership is part of the purpose for which God created humanity.

> When I consider your heavens, the work of your fingers,
>
> The moon and the stars, which you have set in place,
>
> what is man that you are mindful of him,
>
> the son of man that you care for him?
>
> You have made him a little lower than God
>
> and crowned him with glory and honor.
>
> You made him ruler over the works of your hands;
>
> you put everything under his feet:
>
> all flocks and herds, and the beasts of the field,
>
> the birds of the air, and the fish of the sea,
>
> and all that swim the paths of the seas. (Psalm 8:3–8)

Commenting on this psalm, theologian Henri Blocher writes,

> Psalm 8, which sings the paradox of the smallness of man, and the glory of his position, may be read in line with this thought. . . . This royal capacity does not authorize any tyranny: the reign of the creature-image cannot be other than a lieutenancy; man is a vassal prince who follows the directives of the Sovereign and is accountable to him. On the other hand, the king serves as mediator for blessing the land: thus, the man is for the earth; as a shepherd, he dominates the animals with a view to their good as his own.[16]

Blocher's reading is supported by such Old Testament commands as "Do not muzzle an ox while it is treading out the grain" (Deuteronomy 25:4) and "A righteous man cares for the needs of his animal" (Proverbs 12:10). So it is clear that a biblical stewardship ethic grounds environmental responsibility.

3.3. Stewardship and Duty

There is one last corollary of the concepts of ownership and stewardship, which is pertinent to environmental ethics. The steward's duty to the owner is to fulfill the owner's mandate, to act in their stead, and to maximize the owner's good in relation to the stewardship. As an analogy, consider the medieval stewardship of a sheriff over a county (the politics of Robin Hood's era, for example). The sheriff was responsible not only for such matters as collecting taxes and conscripting a quota of soldiers for the monarch's army but also for matters such as securing the county from marauders, enforcing justice in the county, and "promoting the general welfare." But notice that these duties are owed by the sheriff to the king; the people of the county have only a "third-party interest" in the duties and do not themselves have rights against the sheriff.

This analogy helps clarify one persistent problem in environmental ethics: the question of whether nonhuman living things possess rights. A number of ethicists and jurists have grave worries about granting rights to nonhuman creatures. (For example, Taylor 1986, p. 219ff). However, from a theocentric—but not from a biocentric or ecocentric—point of view, we see that we *do* owe duties to God *with respect to* our treatment of creation. Thus, in

a theocentric environmental, ethical system, both future generations and even species, the extinction of which is attributable to human action or inaction, might have just claims. But the claim would not be brought by either future generations or by animal species (whatever that would mean), but rather by God himself on behalf of the third party whose welfare was violated by the steward.

4. Stewardship as Restoration

Restoration, roughly, is concerned with what moral considerations guide us in determining what and how much humans should do to repair damage caused to natural areas and, further, whether and to what degree we should seek to repair natural areas that have become harmful. For example, should we eliminate harmful species if that decreases biodiversity or put up dams to control flooding and generate electricity if that endangers the migration of salmon?[17] Should we drain malarial swamps and mitigate forest fire danger?

As we saw above, those who charge Christian theology with the responsibility for ecological problems usually attack the "dominion theology" of Genesis 1:28: "God blessed them [humans—male and female, vs. 27] and said to them, 'Be fruitful and increase in number; fill the earth and subdue it. Rule over the fish of the sea and the birds of the air and over every living creature that moves on the ground.'"

The most controversial concepts in this verse are expressed in the words "subdue" and "rule." In Hebrew, these are *kabash* and *radah*, respectively. To understand properly what Genesis 1:28 is saying, we must understand these Hebrew words. *Kabash* (the verb and its derivatives) occurs fifteen times in the Hebrew Bible. The Hebrew meaning can be expressed as "to subdue, bring into bondage."[18] The word is inescapably a harsh one. Typical of its use in the Hebrew Bible is to describe the conquest of the Canaanites in Palestine (Numbers 32:20–22); of forced servitude (Nehemiah 5:5); and even of rape (Esther 7:8).

> Despite recent interpretations of Gen 1:28 which have tried to make "subdue" mean a responsibility for building up, it is obvious from an overall study of the word's usage that this is not so. *kabash* assumes that the party being subdued is hostile to the subduer, necessitating some sort of coercion if the subduing is to take place. . . . Therefore "subdue" in Gen 1:28 implies that creation will not do man's bidding gladly or easily and that man must now bring creation into submission by main strength.[19]

The second word, *radah*, is somewhat less harsh but still a strong word. Its literal meaning in Hebrew is strong as well ("Come, trample the grapes, for the winepress is full," Joel 4:13). The meaning was extended figuratively in Hebrew to "have dominion, rule, dominate."[20] The word occurs twenty-two times in the Hebrew Bible with this meaning, although "Generally *radâ* is limited to human rather than divine dominion," for which the much more common word *mashal*, "to rule," is generally used.[21]

What then is the import of Genesis 1:28, and the strong verbs in it, especially remembering that the command was given before the Fall and before a curse was pronounced on the ground? To answer this, we must take account for two considerations, one exegetical and the other theological. The exegetical consideration comes from the immediately preceding context.

> Then God said, "Let us make man in our image, in our likeness, and let them rule over [*radah*] the fish of the sea and the birds of the air, over the livestock, over all the earth, and over all the creatures that move along the ground." So God created man in his own image, in the image of God, he created him; male and female he created them. God blessed them and said to them, "Be fruitful and increase in number; fill the earth and subdue it. Rule over the fish of the sea and the birds of the air and over every living creature that moves on the ground". (Genesis 1:26–28)

So contextually, there is a strong connection between "the image of God" and having dominion. While exegetes and theologians have offered a wide array of explanations for the meaning of the *imago Dei*, at a minimum, the meaning must be in the same semantic range as the idea of ruling. God is Maker, and therefore Ruler of Creation. In making humans in his image, God conferred on humans the status of vice-regents over creation, and this concept of delegated rulership lies at the heart of human stewardship of nature. Of all created things, living and non-living, only humans are endowed with the *imago dei*, and only humans are said to be "blessed" with the responsibility of dominion.

Many biblical texts support this view, for example Psalm 115:16: "The highest heavens belong to the Lord, but the earth he has given to man." Stewardship entails dominion. But we may immediately question why God placed human beings in a position of dominion over the rest of creation. Why should humans not live in complete *shalom* in nature, as the prophet's vision of the peaceful future kingdom celebrates?[22] What in creation needed subduing, given that God's verdict on what he created was "very good" (Genesis 1:31)?

The question brings us to the second consideration, the theological point of view on stewardship as restoration, and it has two aspects. First, Genesis tells us that evil is already present actively, not merely potentially, in the world *prior* to the fall of humanity. The serpent is already in the garden; the verdict that creation is "very good" is now contested. Whatever an interpreter makes of the serpent in Genesis 3, it is indisputable that the text presents it as figurative for or an embodiment of Satan. So the first theological point is that nature must be subdued to eliminate natural evil.[23] God is never portrayed as being threatened by Satan, but rather than eliminate the source of evil outright, God created men and women who, by their obedience to his rule, by their faithful exercise of their duties as stewards, would prevail over evil (both moral and natural) on God's behalf. It may seem that this aspect of stewardship has more to do with the restoration and care of the soul than the restoration and care of creation. But we understand from Job, for instance, or from many stories in the Gospels, that Satan and his hordes are permitted by God to have limited negative effects on the natural world. So combating natural evil is a theological duty bound up in having dominion.

The second aspect of the answer is this. Although "very good," creation is not said to be perfect. Nature itself—indeed the very matter out of which it has been built—is constituted of structures which, in the language of chaos theory, exhibit sensitive dependence on initial conditions. The world seems to be such that a minor mutation in a benign bacterium may result in a deadly strain that strikes down many. Random forces acting over time place irresistible pressure on a fault line, and the resulting earthquake kills thousands. The "butterfly effect" changes weather patterns, bringing drought or deluge, tornados or hurricanes. Seemingly innocuous errors in DNA replication result in tragic birth defects. A world such as this needs subduing and restoring.

And. in fact, in just those countries where a genuine biblical dominion theology has informed culture, much good has been done that falls under the rubric of "restoration."[24] Yes, critics are correct in pointing out that abuses of nature have been initiated based on a dominion theology, but I would argue, with others, that these are in fact instances of dominion abused. The critics must admit that human actions have cured polio and smallpox and many other disabling diseases and conditions. Though earthquakes, like weather, cannot be precisely predicted, they both can be planned for, and their effects mitigated. Reforestation in Niger can halt the advancing Sahara sands, preserving homes and preventing famine; agricultural research can produce hybrid corn, multiplying yield and feeding millions. Genetic research can greatly increase our understanding of our bodies, opening powerful new approaches to the prevention, diagnosis, and treatment of diseases. These are aspects of a true exercise of dominion, and cases where subduing nature can only be regarded as good. And if these examples all seem to beg the question by illustrating utilitarian results measured in human terms, then consider the examples of breeding endangered species in captivity and reintroducing them into their native ecosystems; of

restoring polluted lakes and rivers and coastlines; of rescuing beached whales or oil-soaked waterfowl.

To sum up: Because the natural world in which God placed Adam and into which we are born contains natural evil, and is a world in which the goodness of nature often hangs in precarious balance, responsible exercise of dominion is a duty, not an option, for humans made in God's image—whether believers or not.

This aspect of stewardship—having dominion, seeking restoration, or, as Francis Schaeffer called it, "substantial healing"—is alone sufficient, in my view, to legitimate much of natural science, engineering and technology. We should respect professional scientists and engineers, or science and math teachers, and take opportunities as we have them to encourage young people who have promise in these areas to become outstanding scientists for the glory of God and for the good of the world he made.

The harshness of the Hebrew words is not to be avoided, for the nature of the tasks of subduing and exercising dominion is not soft or easy; yet the harshness does not militate against the positive results of the tasks when properly carried out by God's stewards fulfilling their duty.

This restorative aspect of stewardship is one that naturalistic ethics has difficulty justifying. The popular "man-on-the-trail" environmentalist is likely to regard any human intervention as unnatural. But there is something fundamentally flawed with a view of the place of humanity in nature, which regards all human activity as somehow unnatural, and all technology as an intrusion to be resisted. A house built for human habitation is no more unnatural than a termite's mud castle or a beaver's lodge. That our shelters sometimes acquire Olympian proportions of wasteful opulence or grow into impersonal steel and glass highrises, or degenerate into dehumanizing urban slums is deplorable but no more "unnatural" than a series of beaver dams turning a free-flowing stream into a marsh, with the result that the stream no longer can support native trout or even a beaver population. (The difference, of course, is that humans have moral responsibility for such consequences while beavers do not.)

There is a twistedness in humanity that causes us to deploy our dominion over nature with fierce and destructive delight, and the true character, limits and purpose of dominion are easily forgotten. Humanity has frequently set itself up as a rival to God, usurping God's sovereign reign and arrogating absolute dominion for itself, often creating what God could never accept, unleashing on creation what God despises.

But a truly theocentric understanding of stewardship will ask questions about the legitimate employment of technology. It will weigh projected profits and efficiency benefits against environmental costs. Consequently, a theocentric ethic will not stop with the dominion aspect of stewardship, for conservation and preservation are equally features of stewardship.[25]

In sum, restorative stewardship is a rich and productive occupation when done aright. As men and women responsibly fulfill the stewardship duty to have dominion and subdue the earth, much good and great good can result.

5. Stewardship as Conservation

The difference between conservation and preservation may be illustrated by the comparison of the philosophies of the National Forest Service and the National Park Service respectively. Conservation, as practiced by the NFS, allows for a wide range of human activities on NFS lands; hence the motto, "Land of many uses." Conservation is conceived as management. The NPS, on the other hand, conceives its task as preservation, that is, maintaining the National Parks in a state as close as possible to their state prior to the arrival of humans (or, at least, the kind driving recreational vehicles). Overall, though, it seems reasonable to all but the most virulent anti-development environmentalist that both conservation and preservation are desirable and necessary features of a coherent environmental ethic. How does a stewardship ethic ground these two?

The conservation model of stewardship is initially supported in Genesis 2:15: "The Lord God took the man and put him in the Garden of Eden to work it and take care of it." The words translated "work" and "take care" are, respectively, the Hebrew words *'abad* and *shamar*. *'abad* is a common Hebrew word, generally translated "to work, serve." In reference to things, it is generally followed by an accusative of the thing upon which labor is to be expended; in Genesis 2:15 the accusative of reference is a feminine pronoun, while the word for garden is masculine. The most likely antecedent for the pronoun, then, is not the garden itself but the feminine word *adamah*, translated "ground" or "earth," that Adam was expected to "work."[26] The point then is that this service was not restricted to the Garden of Eden but was extended to the earth as a whole.

There is another important concept involved as well, for not only is *'abad* the most common Hebrew word for serving, but it is also a priestly word, the most common word for worshipping. For the Hebrew, worship consisted in doing what God commanded. Hence Adam's task in the Garden of Eden was, first of all, religious, not horticultural. By working the land he was serving God.[27]

The second word, *shamar*, while indeed meaning "take care of," often has about it the idea of guarding or preserving.[28] (I will return to this word below when considering stewardship as preservation.) In both serving and preserving the garden, then, Adam was exercising his delegated stewardship over God's domain. As beings made in God's image and serving as God's stewards of creation, humans subdue and have dominion *just so far as they serve creation.* The stewardship task is theocentric: humans serve—and worship—God *by* caring for creation!

Serving overlaps with, and helps define, the meaning of subduing. Serving in this sense is properly seen as conserving. The duty of serving clearly involves work; the idea is not simply to let things go wild. Here's one significant difference between conservation and preservation. Conservation values farmlands and pastures as sources of food and green spaces and gardens as places of beauty. In no way does a stewardship ethic encourage letting all land revert to its natural state. We can and must use natural resources, but prudently, with an eye to sustainability. Thus the nation of Israel is commanded to give a sabbatical to their farmlands by letting the land lie fallow every seventh year (Leviticus 25:1–7), and their failure to do this is cited as one of the reasons for the Babylonian captivity: "The land enjoyed its sabbath rests; all the time of its desolation it rested, until the seventy years were completed" (2 Chronicles 36:21). Of course, the obedience of the sabbatical year command demonstrated deep trust in the Lord's provisions, but it also would have had a very healthy restorative effect on the marginal soil of much of Palestine.

Not only farmlands, but farm animals were incorporated in Old Testament stewardship, as demonstrated by the commands already cited: "Do not muzzle an ox while it is treading out the grain" (Deuteronomy 25:4), and "A righteous man cares for the needs of his animal" (Proverbs 12:10). Louis Regenstein recounts in great detail the many biblical injunctions which lead to a conservation ethic and to caring for animal life, and then goes on to trace these ideas in the saints and thinkers of both the Eastern and the Western church.[29]

Of course, stewardship as conservation presupposes that the steward knows what to conserve. Here again the theocentric nature of stewardship becomes apparent, for the steward must value what the Creator values. Only by focusing theocentrically rather than biocentrically or ecocentrically can stewards ensure that they value what the Creator values and thus practice proper conservation. Still, the point is clear. A theocentric environmental ethic will certainly be sufficient to ground and justify ethical claims regarding conservation practices, and it is under the concept of stewardship as conservation that we can best understand and work out the value and means of sustainability.

While I cannot say much more here, it is under the rubric of sustainability that much of our practical decision-making must be considered. Are we consuming at an unsustainable rate—both with respect to our income levels, and with respect to our use of renewable and nonrenewable resources? Is our lifestyle a zero-sum affair, where our consumption means someone else's scarcity, where our overuse of resources means we leave our progeny a

depleted planet? Such issues should, I believe, be much more at the forefront of our day-to-day thinking than they have been in the past, and the answers surely involve questions of ethics.

6. Stewardship as Preservation

Preservation generally is taken to mean setting aside lands where naturally-occurring processes are allowed to unfold naturally, where human intervention is minimal and non-permanent. It might seem difficult to demonstrate that a biblically-based theocentric environmental ethic could ground the value of preservation. Although there are biblical texts which support restoration and conservation, there are no texts which clearly support the conception of stewardship as preservation. However, two lines of evidence do point this way.

First, there is the meaning of that word in Genesis 2:15, *shamar*, "to exercise great care over, guard, preserve."[30] It is clear, in the context of Genesis 1–2, that *shamar* must be consistent with *kabash*, *radah* and *'abad*, so the resulting concept cannot be restricted to preservation as the sole duty ethical with respect to creation. Rather, *shamar* must be seen as implying the care and preservation of that in God's creation which is worth preserving. But this, of course, returns us to the question of valuation. We must assign value in theocentric, not instrumental, terms. How does God value nature *simpliciter*? Listen to, as God speaking to Job, from the whirlwind (Job 38–39, *passim*):

> Where were you when I laid the earth's foundation? Tell me, if you understand.
>
> Have you journeyed to the springs of the sea or walked in the recesses of the deep?
>
> Have you entered the storehouses of the snow or seen the storehouses of the hail?
>
> Do you hunt the prey for the lioness? Who provides food for the ravens?
>
> Do you know when the mountain goats give birth?
>
> Do you watch when the doe bears her fawn?
>
> Who lets the wild donkey go free? Who untied his ropes?
>
> I gave him the wasteland as his home, the salt flats as his habitat.
>
> He laughs at the commotion in the town; he does not hear a driver's shout.
>
> The wings of the ostrich flap joyfully, but they cannot compare with the pinions and feathers of the stork.
>
> She lays her eggs on the ground and lets them warm in the sand,
>
> unmindful that a foot may crush them, that some wild animal may trample them.
>
> She treats her young harshly, as if they were not hers;
>
> she cares not that her labor was in vain,
>
> for God did not endow her with wisdom or give her a share of good sense.
>
> Yet when she spreads her feathers to run, she laughs at horse and rider.

In these verses, God fairly exults in the wild nature he has created, so it seems reasonable to conclude that any human attempt to completely domesticate or destroy wild places and wild things would amount to sacrilege.

Of course, not all of nature can or should be preserved in its wild state. But since God values the wild, so should his stewards. Preservation, deriving from an understanding of the value God places on his creation and his command to humanity to guard or keep creation, will find in wildness both a reflection of God's nature and a tonic for the human soul. Those of us who venture into wild country, where "man himself is a visitor and does not remain,"[31] would surely recommend it to all who are able. We find tranquility, and our souls are refreshed in the serene beauty of Yosemite Valley or Crater Lake. Our problems shrink to size, as do our egos, as we struggle up the rocks of Mt. Whitney or the glaciers of

Mt. Rainier. We gain perspective on our limited powers as we feel the force of the waves under a sea kayak or surfboard and come to understand God's blessing of nature—his command to living things to be fruitful and multiply—in the fertility of Monterrey Bay or the Everglades.

It is within the aspect of stewardship as preservation that we can locate duties with respect to endangered species: Humans are to preserve the wild creation, which God values as the product of his creative activity, and this would include the rich diversity of species. We could also locate duties to preserve wilderness areas that reflect "raw nature" to protect wild and scenic rivers and coastlands, tall-grass prairies, and rain forests. Here too, we would find duties to guide us in regulating human activity to avoid practices and products deleterious to wild nature, such as certain methods of crude oil transportation which risk spillage or unmitigated production and release of greenhouse gasses that contribute to global warming. Yet such stewardship must be carefully reasoned and based on the best science available rather than an emotional response to headlines.

Admittedly, discerning a balance between preservation, conservation, and restoration is very often quite difficult. Knowledge of nature, foresight of consequences, and humility in intervening—that is, wisdom—is necessary. But it is clear that all three duties can be grounded in a stewardship ethic.

7. Conclusions

I have shown that the criticisms of Christianity by White, Toynbee, and others can be met from the perspective of a biblical theocentric environmental ethic. But I have attempted to show more: The central concept of stewardship is rooted in an understanding of God as Creator and Master of the world, and value in nature derives from the relationship God maintains with his creation. I suggested that understanding our role as stewards of creation helps clarify moral judgments concerning the environment and supports a consistent structure of rights and duties with respect to nature. Specifically, a theocentric environmental ethic seems quite well suited for grounding the three general aspects of environmental ethics: restoration, conservation and preservation.

I claim, then, that a theocentric environmental ethic is worthy of closer examination regardless of one's religious views. Interestingly, Lynn White concluded his AAAS address by saying, "Since the roots of our troubles are so largely religious, the remedy must also be religious, whether we call it that or not. We must rethink and refeel our nature and our destiny." (White 1967) The noted environmental ethicist J. Baird Callicot agrees:

> The Judeo-Christian Stewardship Environmental Ethic is especially elegant and powerful. It also exquisitely matches the requirements of conservation biology. The Judeo-Christian Stewardship Environmental Ethic confers objective value on nature in the clearest and most unambiguous of ways: by divine decree. (Callicott 1994)

It seems then that the shift in ethical thinking required to embrace adequate environmental ethics may be, at its root, essentially religious. A theocentric stewardship environmental ethic shows us the way.

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Notes

1 (White 1967). It has been enormously influential and reprinted in many anthologies.

2 A convenient date for the birth of an organized environmental movement is the publication of Rachel Carson's *Silent Spring* in 1962.

3 That these are indeed the right issues on which to focus is illustrated by one of the most popular textbooks on the subject (Light and Rolston 2003). Part VI is titled "Focusing on Central Issues: Sustaining, Restoring, Preserving Nature." See also (Bassham 2020).

4 (James 1896); emphasis mine.

5 Illustrated, for example, by Beisner (1990). Beisner dismisses most environmental concerns as "ideologically influenced hysteria." Beisner is a founder of and the national spokesman for the Cornwall Alliance for the Stewardship of Creation; see www.cornwallalliance.org (accessed on 7 March 2023).

6 A *biocentric* ethic was laid out, for example, by Singer (1979). See also Taylor (1986).

7 An *ecocentric* environmental ethic is developed by Leopold ([1949] 1987) and by Rolston (1989).

8 Roots of the *resacralizing* approach are in (Lovelock 1979; McFague 1987; Naess 1986).

9 Lovelock (1979, p. vii); emphasis mine.

10 Among the many titles, see (Bouma-Prediger 2001; Hall 1990), hereafter *Steward*; (Nash 1993; Santmire 1985; Wilkinson 1990). See also "An Evangelical Declaration on the Care of Creation," originally signed by over one hundred evangelical leaders in 1994, available at http://www.creationcare.org/resources/declaration.php (accessed on 7 March 2023).

11 Like Nash, Paul Santmire clearly sees both sides, and his work is therefore somewhat richer than much writing from a Christian standpoint. Yet, as the subtitle to his book ("The Ambiguous Ecological Promise of Christian Theology") suggests, Santmire sees the subdue/have dominion theme as negative, in contrast to my more positive interpretation explained below.

12 An alternative to this deontological account is a virtue ethics approach. See Bouma-Prediger (2020). The appendix to this book is an extensive bibliography of works applying Christian virtue ethics to creation care. Of course, seeing and doing one's duty is a virtue.

13 See, for example, St. Thomas Aquinas, *Summa Contra Gentiles*, I.8.

14 Cited in Wilkinson (1990, p. 319); my emphasis.

15 See (Rolston n.d.) for an alternative approach.

16 (Blocher 1979); my translation.

17 The notion of restoration is contentious in environmental ethics. See (Elliot 1982; Katz 1992). My understanding of 'restoration' is somewhat different than that of Elliot or Katz.

18 (Brown et al. 1907), s.v.; hereafter cited as BDB.

19 (Harris et al. 1980), s.v. *kbš*; hereafter TWOT.

20 BDB, s.v. *rdh*.

21 TWOT, vol. 2, s.v. *rdh*.

22 "The wolf will live with the lamb, the leopard will lie down with the goat, the calf and the lion and the yearling together; and a little child will lead them. The cow will feed with the bear, their young will lie down together, and the lion will eat straw like the ox. The infant will play near the hole of the cobra, and the young child put his hand into the viper's nest. They will neither harm nor destroy on all my holy mountain" (Isaiah 11:6–8).

23 On natural evil, see DeWeese (2013).

24 See, for example, Stark (2003), who notes that both Whitehead and Oppenheimer are among those modern scientists who have emphasized, regardless of their personal religious beliefs, that modern science could only be born in a historic Christian cultural consensus with its belief that a reasonable God created the universe outside himself, and its principles therefore could be discovered by reason.

25 Santmire sees dominion not as restoration but as indifference to nature, and the eschatological posture of much of Christianity as deeply and emotionally opposed to devoting much effort to saving this world, which will be destroyed anyway as preparation for the new heavens and the new earth. Hence his subtitle, "The Ambiguous Ecological Promise of Christian Theology." His sociological observations about Christianity may, unfortunately, be justified, but I do not feel that his exegetical conclusions are adequate. I believe that restoration, conservation and preservation are equally a part of the larger stewardship model.

26 (Hamilton 1990), s.v. 2:15. Although not universally accepted as a correct interpretation, I am reading Genesis 2 as an amplification of Genesis 1. See Hamilton (1990, pp. 150–52).

27 (Cassuto 1961), s.v. 2:15.

28 Interestingly, in the Babylonian Creation Epic, commonly called the *Enuma elish* (after its first two words), the two concepts of serving and guarding are closely linked to the creation of man. See Pritchard (1968, Tablet VI).

29 (Regenstein 1991), passim.

30 TWOT, vol. 2, s.v. *šmr*.

31 The phrase is from the definition of 'wilderness' in the *Wilderness Act* of 1964.

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Review

Comparing Contemporary Evangelical Models Regarding Human Origins

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Abstract: Multiple viewpoints exist among Protestant Evangelical Christians regarding human origins, with each offering different answers to questions regarding the existence of Adam and Eve and their relationship to humanity, common human–ape ancestry, evolution and intelligent design, humanity's relationship to other members of the genus *Homo* (e.g., Neanderthals and Denisovans), and the timing of human origins. This article will review eight models for human origins which have recently received attention: (1) the Classical Theistic Evolution/Evolutionary Creationism model, (2) the *Homo divinus* model, (3) the Genealogical Adam and Eve model, (4) the *Homo heidelbergensis* model, (5) the Unique Origins Design model, (6) the Classical Old Earth Creationist model, (7) the Classical Young Earth Creationist model, and (8) an Old Earth/Recent Humans Hybrid model. Key features of each model will be described, and critical responses will be discussed in light of agreement or disagreement with traditional Judeo-Christian theological views and the scientific evidence. Most of these models maintain that science does not force one to abandon belief in core tenets of a traditional Adam and Eve, though they resolve the relevant scientific and theological questions in different ways and with varying degrees of success.

Keywords: human origins; Adam and Eve; evolution; theistic evolution; evolutionary creationism; creationism; intelligent design

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1. Introduction

Traditionally, Christians have believed that humanity began when God created Adam and Eve, who are typically considered to be the initial sole progenitors of all living humans. This view is important to many Christians who view Adam and Eve's fall into sin as theologically crucial, because that sinful nature then spread into all of their descendants, spurring the later coming of Christ to die on the cross and atone for the sins of humanity (Reeves 2009; Grudem 2017a, 2017b; Waters 2017). However, this view is not universally accepted among Christians, some of whom do not see Adam and Eve as necessary to central Christian theological doctrines.

While the debate among Christians over human origins and Adam and Eve is nothing new, it reached a renewed intensity in 2011 when *Christianity Today* (*CT*) published a cover story titled, "The Search for the Historical Adam." The article did not insist on a traditional view of Adam and Eve, and highlighted evangelical thinkers who accept modern evolutionary biology and are skeptical that Adam and Eve existed. For example, *CT* highlighted the views of Francis Collins, the evangelical Christian geneticist who headed the Human Genome Project and wrote the 2006 bestselling book *The Language of God*, stating that he "reported scientific indications that anatomically modern humans . . . originated with a population that numbered something like 10,000, not two individuals" (Ostling 2011).

Four years before that article, Collins had founded the BioLogos Foundation to promote theistic evolution, or evolutionary creationism (TE/EC), aiming to show that an evolutionary scientific viewpoint is generally correct and fully compatible with Christianity (Luskin 2014). The *CT* article featured the viewpoints of BioLogos-affiliated scientists. "Dennis R. Venema, the BioLogos senior fellow for science and the biology chairman at

Trinity Western University, is among the BioLogos writers who are not only advocating theistic evolution but also rethinking Adam," explained the story. Venema and then-BioLogos president Darrel Falk co-wrote an informational document on Adam and Eve, which *CT* quoted: "The BioLogos paper by Venema and Falk declares it more flatly: The human population, they say, 'was definitely never as small as two . . . . Our species diverged as a population. The data are absolutely clear on that.'" Other evangelical scientists were quoted as saying things such as Adam and Eve "do not fit the evidence," or although there was "wiggle room in the past" to believe in Adam and Eve, "human genome sequencing took that wiggle room away" (Ostling 2011). Some years later Venema appeared to concede that the issue was more complex and that there were in fact ways to reconcile the latest genomic evidence with a literal Adam and Eve (Venema 2018; see also Section 2.1.1). However, that is to get ahead of the story. Here, suffice to say that in the years following the *CT* article, multiple novel viewpoints on human origins were articulated, refined, and promoted within the Christian community—with most aiming to reconcile the latest scientific findings with some form of belief in Adam and Eve.

2. Results

If there is one space where standard evolutionary models come into sharpest conflict with traditional Christian beliefs, it is within human origins (Collins 2011). Traditionally, Christians have believed that humanity began when God created Adam and Eve. All humanity is thus descended from these two individuals—and they are usually described as not only our universal progenitors (i.e., progenitors of all living humans), but as our initial and *sole* progenitors (Collins 2011, 2013; Barrett and Caneday 2013; Barrick 2013b; Walton 2013). Their initial sole progenitorship of humanity is important to many Christians who view Adam's sin as spreading through the entire human race (Reeves 2009; Collins 2011). Moreover, historically Adam and Eve were not said to have evolved or descended from apelike ancestors or more-primitive non-human species, but were believed to have been specially and miraculously created by God *de novo* in their present human form (Ostling 2011; Walton 2013; Barrick 2013b). Old Testament scholar John Walton explains the traditional understanding of human creation:

> *Formed from dust.* The most obvious statement about Adam—and the one most important to this discussion—is the statement that God formed (*yaṣar*) him from the dust (*'apar*) of the earth. Is this intended to be a statement about the material origins of the first human being? Traditionally, it has been common to think about this statement as describing a material process of special creation characterized by discontinuity with any previously existing creature. (Walton 2013, p. 92)

It was also traditionally believed that Adam and Eve lived just a few thousand years ago (Lamoureux 2009, pp. 77–78; Barrett and Caneday 2013; Barrick 2013a, 2013b). As Barrett and Caneday (2013) explain, major Protestant authorities have historically held this traditional view:

> The Christian view of creation that Darwinism rivaled was not monolithic, even if the popular belief among Christians was that God created the cosmos approximately 4000 years before the coming of the Christ. This belief preceded the publication of The Annals of the World by James Ussher, Archbishop of Armagh, who attempted to identify the time of creation's beginning with precision. For example, both leading church Reformers Martin Luther and John Calvin believed that creation was not yet 6000 years old and that God created all things within six twenty-four-hour days. Calvin is thoroughly conversant with Augustine, agreeing with him at several points, but also rejecting his belief that God created all things instantaneously. (Barrett and Caneday 2013, p. 15)

Likewise, biologist and theologian Denis Lamoureux states that "Generations of Christians have firmly believed that the creation of Adam and Eve in Gen 2 is an elaboration of the brief account of human origins on the sixth creation day in Gen 1. This traditional

literal interpretation asserts that human history begins with the events in the garden of Eden" (Lamoureux 2009, pp. 77–79).

In contrast to the traditional view, the standard evolutionary viewpoint holds that modern humans evolved from a population of thousands of individuals which traces back to the most recent common ancestor (MRCA) we share with living apes, and the human population was never reduced to a mere two individuals. Moreover, under the standard evolutionary viewpoint, the ancestral lineage of modern humans leading back to the MRCA with apes is one of descent with modification where purely natural evolutionary mechanisms—e.g., random mutation, natural selection, genetic drift, etc.—were responsible for human evolution. Other models have been developed which propose different variations and mixtures of traditional theological views and mainstream scientific viewpoints regarding human origins.

2.1. Classical Theistic Evolution/Evolutionary Creationist Model

Proponents of theistic evolution/evolutionary creationism (TE/EC) seek to reconcile Christianity with the standard evolutionary model of human origins. As such their view is essentially indistinguishable from the standard evolutionary model, described above, although they believe that somehow God oversaw the evolutionary process. They generally believe that "scientific evidence is irrelevant to the Bible," because the Bible "is simply not a science book" (Davis 2012), and are frequently willing to reshape theology when necessary to fit within an evolutionary context.

TE/EC proponents frequently accept that humans "are utterly unique and distinguished from the rest of creation because only they bear the Image of God and have fallen into sin" (Lamoureux 2009, p. 28). However, they typically reject the idea that humanity is descended from merely two individuals such as Adam and Eve, normally doubting their existence as historical individuals. Biologist and theologian Denis Lamoureux, a self-described "evolutionary creationist," notes that evolutionary creationists "do not accept the existence of Adam and Eve" (Lamoureux 2009, p. 71), and summarizes this perspective on human origins:

> The greatest problem with evolutionary creation is that it does not embrace the traditional literal interpretation of the opening chapters of the Bible. Church history shows that nearly all Christians have understood Gen 1–3 to be a basic record of actual events in the past. Specifically, most have believed that Gen 2 reveals that human history began with Adam and Eve. (Lamoureux 2009, p. 31)

Instead, TE/ECs opt for the view that modern humans are descended from a hominid population that never dipped below a size of thousands of individuals. Under this view, all living humans are also descended from a common ancestor we share with apes. Humans are said to have historical evolutionary relationships with all other living species, including relatively recent humanlike hominids such as the Neanderthals or Denisovans, and also with earlier apelike hominids such as the australopithecines. Some of these species may even have been our direct ancestors (e.g., the australopithecines).

Moreover, because humanity evolved via natural mechanisms, a full-throated TE/EC view holds there was no miraculous or special creative activity from God involved in the origin of humanity. Even if God somehow guided this process, as Francis Collins explained, under TE/EC there would be no observable evidence for design in the biological history of human origins, because "from our perspective, limited as it is by the tyranny of linear time, this would appear a random and undirected process" (Collins 2006, p. 205). Although TE/EC proponents believe God oversaw the process of human origins, by accepting a standard evolutionary model they effectively believe our biological origins were the result of strictly natural and mechanistic causes, and reject the idea that intelligent design is scientifically detected in nature (Luskin 2014). One possible exception to natural causation could be God creating the human soul (Collins 2006, p. 207), although some TE/EC proponents maintain that human psychology—including our religious impulses—arose via natural evolutionary mechanisms (Rossano 2010; Luskin 2011).

TE/ECs commonly cite certain specific lines of scientific evidence in favor of their views. This often includes fossil evidence for human evolution from apelike ancestors (Falk 2017), such as claims that australopithecine hominids had "transitional features" between apelike creatures and humans, including jaws, teeth, and a combination of "an ape-like rib cage and human-like hip bones" (Lamoureux 2009, pp. 125, 131). Genetic evidence is also cited to claim that "chimpanzees are our closest 'cousins'" with "99%" similar DNA (Lamoureux 2009, p. 126). Another common genetic argument for human–ape common ancestry cites shared "junk" DNA between humans and apes (especially pseudogenes or endogenous retroviruses), and general genetic similarities between humans and apes (Falk 2004; Collins 2006; Alexander 2008; Lamoureux 2009; Venema and McKnight 2017). Under a classical TE/EC view, it is unlikely that God would place non-functional DNA into the same locations of the genomes of separate species, and a more likely explanation is that we inherited this "broken" or "junk" DNA from a common ancestor. For example, in *The Language of God*, Francis Collins maintained that some "45 percent of the human genome" consists of "genetic flotsam and jetsam," making "the conclusion of a common ancestor for humans and mice . . . virtually inescapable" (Collins 2006, pp. 134–37).

The 2011 *CT* article highlighted a new TE/EC argument—that modern day human genetic diversity is so great that it could not be explained by humans descending from a mere initial pair of two individuals. Many thousands of initial ancestors to modern humans would be necessary to account for the genetic diversity observed in humans today. TE/ECs have placed great confidence in this argument. In their book *Adam and the Genome*, Venema and McKnight (2017), wrote that the existence of Adam and Eve is as decisively refuted by the data as the geocentric model of the solar system:

> [W]e can be confident that finding evidence that we were created independently of other animals or that we descend from only two people just isn't going to happen. Some ideas in science are so well supported that it is highly unlikely new evidence will substantially modify them, and these are among them. The sun is at the center of our solar system, humans evolved, and we evolved as a population. (Venema and McKnight 2017, p. 55)

This population genetics argument against the existence of Adam and Eve has become one of the most forceful arguments advanced for human evolution.

2.1.1. Responses

An obvious benefit of this model is that it is fully compatible with mainstream evolutionary science. However, in denying the existence of a historical Adam and Eve, it explicitly rejects major traditional theological beliefs about human origins, which will not be acceptable to many seeking to preserve those beliefs (Grudem 2017a, 2017b). Before accepting the TE/EC model, those who value these major traditional theological beliefs may wish to first consider the extent to which scientific evidence against the existence of Adam and Eve and in favor of human evolution is as open and shut as is being claimed.[1]

Fossil evidence: First, the fossil record shows a distinct break between the apelike australopithecines, which are supposedly directly ancestral to our genus *Homo*, and the first humanlike members of the genus *Homo* (Luskin 2022). Such evidence has led to observations from mainstream evolutionists conceding that there is a "large, unbridged gap" between humanlike members of *Homo* and the australopithecines (Mayr 2004, p. 198), which required a "genetic revolution" since "no australopithecine species is obviously transitional" (Hawks et al. 2000, p. 4), and implies a "big bang" model of human origins (University of Michigan News Service 2000). While evolutionary paleoanthropologists generally believe that "the transition from *Australopithecus* to *Homo* was undoubtedly one of the most critical in its magnitude and consequences," they admit that "many details of this transition are obscure because of the paucity of the fossil and archaeological records" (Lieberman et al. 2009, p. 1). This lack of fossil evidence for the evolution of the humanlike body plan in the fossil record weakens the necessity of adopting standard evolutionary explanations of human origins.

Genetic evidence: Genomic comparisons between humans and chimpanzees are becoming more sophisticated, with recent proposals proposing lower estimates of human–chimp genetic similarity estimates to between 84% and 96% (Buggs 2018c; Seaman and Buggs 2020). It is also unclear how any percent similarity between human and chimp DNA yields an argument that requires common ancestry (Luskin 2022).

Junk DNA genetic arguments for common human–ape ancestry have also come under significant critique in recent years due to the discovery of mass-functionality for non-coding or "junk" DNA in the human genome. A major 2012 *Nature* paper by the ENCODE consortium reported "biochemical functions for 80%" of the human genome (ENCODE Project Consortium 2012, p. 57). Lead ENCODE scientists predicted that with further research, "80 percent will go to 100" since "almost every nucleotide is associated with a function." (Yong 2012). In the wake of this research, the journal *Science* published an article titled "ENCODE Project Writes Eulogy for Junk DNA" which stated that these findings "sound the death knell for the idea that our DNA is mostly littered with useless bases" (Pennisi 2012, p. 1159). Evidence of functions for non-coding DNA has continued to mount at a high pace. A 2021 article in *Nature* reported that over 130,000 specific "genomic elements, previously called junk DNA" have seen specific functions identified (Gates et al. 2022, p. 215), followed by a paper in *Genome Biology and Evolution* which concluded, "The days of 'junk DNA' are over" (Stitz et al. 2021, p. 11). There is still much we do not understand about the genome and there are many specific genetic elements for which no function has yet been discovered. Nonetheless, this evidence suggests a strong trendline in the research literature away from non-functionality for "junk" DNA.

One frequently mentioned example of junk DNA is pseudogenes, which TE/EC advocates commonly cite as "the mutated remains of once-functional genes" (Venema and Falk 2010) that show our common ancestry with apes. Yet, a 2012 paper found pseudogene function is "widespread," and since "the study of functional pseudogenes is just at the beginning" it predicted "more and more functional pseudogenes will be discovered as novel biological technologies are developed" (Wen et al. 2012, p. 31). Indeed, the literature is now replete with papers reporting functions for pseudogenes (Hirotsune et al. 2003; Pain et al. 2005; Zhang et al. 2006; Tam et al. 2008; Piehler et al. 2008; Poliseno et al. 2010; Muro et al. 2011; Rapicavoli et al. 2013; Ji et al. 2015; Hayashi et al. 2015; Prieto-Godino et al. 2016; Suzuki et al. 2018; Fiddes et al. 2018; Habib et al. 2019), including producing functional RNA transcripts or performing functions without producing any RNA (Poliseno 2012). A 2012 paper notes that although "pseudogenes have long been dismissed as junk DNA," recent advances have established that "the DNA of a pseudogene, the RNA transcribed from a pseudogene, or the protein translated from a pseudogene can have multiple, diverse functions," concluding that "pseudogenes have emerged as a previously unappreciated class of sophisticated modulators of gene expression" (Poliseno 2012, pp. 1, 10). Indeed, many pseudogenes are known to produce proteins, with a study in *Nature* reporting "more than 200 peptides that are encoded by 140 pseudogenes" (Kim et al. 2014, p. 579).

There are good reasons to understand why DNA labeled a "pseudogene" is now turning out to have a function. Pseudogenes are often identified by comparison to some other similar gene sequences encoding a functional protein from which the pseudogene is thought to have been derived and subsequently degenerated. However, regulatory functions of pseudogenes often require them to have some sequence similarity (homology) to their protein-coding counterparts so their RNA transcripts can interact with transcripts from the protein-coding gene, thereby regulating protein production (Salmena et al. 2011). Therefore, the reason our genomes contain sequences that resemble protein-coding-genes but do not produce proteins is not because they are discarded evolutionary "pseudogenes," but because they are designed that way as important genomic regulatory and control elements.

Many papers have criticized the assumption that pseudogenes are functionless junk DNA and now suggest abandoning the term (Pink et al. 2011; Poliseno 2012; Wen et al. 2012; Kovalenko and Patrushev 2018; Troskie et al. 2021). A 2020 paper in *Nature Reviews Genetics* observes, "Where pseudogenes have been studied directly they are often found to

have quantifiable biological roles," and warns that "the dominant limitation in advancing the investigation of pseudogenes now lies in the trappings of the prevailing mindset that pseudogenic regions are intrinsically non-functional." It cautions that pseudogene function is "prematurely dismissed" due to "dogma" (Cheetham et al. 2020).

There are prominent examples of prematurely dismissing pseudogene function, only to be proven wrong later. During the 2005 *Kitzmiller v. Dover* trial, biologist Kenneth Miller testified that our beta-globin pseudogene is "broken" because it has "molecular errors that render the gene non-functional," indicating humans share a common ancestor with apes (Miller 2005, p. 79). Two years later, leading evolution advocate Eugenie Scott claimed this pseudogene "isn't going to do diddly. It's just going to sit there" and "not do a thing" (Scott 2007). However, a 2013 study reported that this precise pseudogene *is* functional (Moleirinho et al. 2013), and a 2021 study found it is "essential" and has "indispensability" for human red blood cell formation (Ma et al. 2021, pp. 478, 490).

Endogenous retroviruses (ERVs) are another class of "junk" DNA commonly cited by TE/ECs in favor of human/ape common ancestry. The structure of the arguments here is similar to those used for pseudogenes: ERVs also show widespread evidence of function, particularly gene regulatory roles (Conley et al. 2008; Jacques et al. 2013; Chuong 2018; Robson and Mundlos 2019; Jönsson et al. 2021; Sakashita et al. 2023), and their similarity to viral DNA may exist for functional reasons, as they are involved in immune-functions to repel viral infections (Badarinarayan and Sauter 2021).

Again, it is true that there is still much we do not know about junk DNA and there are many specific genetic elements (including pseudogenes and ERVs) for which specific functions have not yet been discovered. However, recent trends in research show that far more functionality is being discovered than was anticipated, leading to the possibility of mass functionality for junk DNA. As a 2023 academic book on RNA states:

> While the story is still unfolding, we conclude that the genomes of humans and other complex organisms are not full of junk but rather are highly compact information suites that are largely devoted to the specification of regulatory RNAs. These RNAs drive the trajectories of differentiation and development, underpin brain function and convey transgenerational memory of experience, much of it contrary to long-held conceptions of genetic programming and the dogmas of evolutionary theory. (Mattick and Amaral 2023, p. vii)

If noncoding/junk DNA is in fact functional, then genetic similarities could be the result of common design due to the need to meet similar functional requirements. Even Francis Collins has acknowledged that shared genetic similarity "alone does not, of course, prove a common ancestor" because "such similarities could simply demonstrate that God used successful design principles over and over again" (Collins 2006, p. 134).

Population genetics: Third, arguments against Adam and Eve based upon human genetic diversity and population genetics seem to have been undermined by subsequent modeling analyses. One of the first scientific responses to this population-genetics argument against Adam and Eve was published in 2012, when biologist Ann Gauger, a senior fellow with the Discovery Institute (a pro-intelligent-design think tank, where this author also works), reported that genetic diversity in HLA genes—some of the most diverse genes in the human genome—could still be explained if we originated from an initial couple (Gauger et al. 2012, p. 120).

After the publication of *Adam and the Genome* in 2017, biologist Dennis Venema was engaged on the BioLogos discussion forum by Richard Buggs, a geneticist at Queen Mary University London. During the discussion Venema acknowledged that various papers he had cited as having refuted the existence of Adam and Eve had not actually addressed the question of whether humanity descended from an initial couple (Buggs 2017). From this discussion emerged a consensus among various Christian biologists that if an initial pair of humans lived far enough in the past, then modern human genetic diversity could in fact be accounted for by natural biological processes. Eventually, Buggs stated to Venema: "You would do your readers a service if you wrote a blog to tell them now, as far as you

are able, that present day genomic diversity in humans does not preclude a bottleneck in the human lineage between approx 700 K and 7myr ago. I think you owe this to them" (Buggs 2018b). (The bottleneck he refers to is the human population being reduced to two individuals—effectively the same as humanity descending from Adam and Eve.) Venema then publicly acknowledged the veracity of Buggs's critique, replying: "I've already agreed with this . . . .You're welcome to publicize it" (Venema 2018). Buggs later summarized this conversation on his blog with *Nature Ecology and Evolution*, reporting that the question was no longer whether a historical Adam and Eve could have existed, but rather at what point in time they lived (Buggs 2018a).

Gauger along with Ola Hössjer, a professor of mathematics at the University of Stockholm, had already begun a project to address how deep into the past an initial couple had to live in order to account for modern human genetic diversity. They published a series of papers developing and testing a population genetics model which allows for an initial pair of humans to be given "designed variants" of genes representing "primordial diversity" built into the initial genomes of Adam and Eve. Under their model, natural biological processes then govern the subsequent genetic history of the human race. They showed that modern-day human genetic diversity can be explained by a single pair of ancestors—e.g., what one might call Adam and Eve—provided that they lived at least 500,000 years ago (Hössjer et al. 2016a, 2016b; Hössjer and Gauger 2019). S. Joshua Swamidass, a Christian scholar and professor of computational biology at Washington University in St. Louis, performed an analysis that yielded a similar result, finding that Adam and Eve could have lived 495,000 years ago as our sole genetic progenitors (Swamidass 2017).

There is another population genetics argument relevant to human origins—but this one is posed as a mathematical challenge to unguided evolutionary models. The MRCA of humans and chimpanzees is said to have lived approximately 4 to 6 million years ago (Wood and Harrison 2011). Though estimates vary, a reasonable accounting proposes that the genetic differences between humans and chimps amount to some "35 million base-pair changes, 5 million indels [sequences of multiple nucleotide bases] in each species, and 689 extra genes in humans" (Cohen 2007). Yet, a population genetics study in the journal *Genetics* found that if just two specific mutations were required to provide some evolutionary advantage in the line that led to humans, then "this type of change would take >100 million years," which was determined to be "very unlikely to occur on a reasonable timescale" (Durrett and Schmidt 2008). This "waiting times" problem (Hössjer et al. 2021) suggests there may be far too little time available from the fossil record for standard unguided evolutionary mechanisms to generate observed genetic, morphological, and behavioral differences between humans and chimps. Some have proposed intelligent design as a possible explanation for the rapid appearance of biological information necessary to overcome the waiting times problem and generate these complex traits (Thorvaldsen and Hössjer 2020).

2.2. Homo Divinus Model of Denis Alexander

The term "*Homo divinus*" was coined by theologian John Stott, who viewed Adam as a possible descendant of *Homo erectus* that was chosen by God to be the "first man to whom may be given the specific biblical designation 'made in the image of God'" (Stott [1972] 1999, pp. 55–56). This model built upon the ideas of Old Testament scholar Derek Kidner, who proposed that Adam was given "federal headship" over humanity, meaning that Adam's original sin spread to both his "offspring" and his "contemporaries" (Kidner 1967, p. 29). Under this view, therefore, Adam may not be genetically or genealogically ancestral to all humans, but his sin impacted the whole of humanity, whether descended from Adam or not. This view is said to be consistent with "covenant theology," where Jesus Christ saves all of humanity even if he is not their biological ancestor, but because he is their "federal head" (Kidner 1967, p. 30).

In more recent discourse, TE/EC proponent and biologist Denis Alexander has also promoted the *Homo divinus* model as a possible way to reconcile evolution with some

form of a historical Adam and Eve. Alexander's model essentially adopts the standard evolutionary view of human origins, but then proposes that at some point in the Neolithic period, God "chose a couple of Neolithic farmers in the Near East, or maybe a community of farmers, to whom he chose to reveal himself in a special way." This "marked the time at which God chose to reveal himself and his purposes for humankind for the first time" (Alexander 2008, pp. 236–37).

2.2.1. Responses

This model fully adopts an evolutionary perspective on the origin of humans, and proposes that Adam and Eve were real people chosen by God for a special purpose who lived just a few thousand years ago. However, this is where its similarity to traditional theological beliefs ends. The "Adam and Eve" in this model are natural-born descendants from earlier hominids that evolved through standard evolutionary mechanisms, and they are in no way proposed to be specially created by God nor are they said to be the progenitors of all humans.

In fact, under this model Adam and Eve have no necessary genealogical or ancestral relationship to any other humans and play essentially no role in the physical or biological origins of humanity. Rather, their role is strictly spiritual: it is a model "about spiritual life and revealed commands and responsibilities, not about genetics" (Alexander 2008, p. 238). Thus, although the *Homo divinus* model allows for a recent Adam and Eve, this version of Adam and Eve does not seem genealogically connected to later humans in a manner that fulfills traditional biblical views of human descent.

This model also raises theological concerns. In proposing an Adam and Eve that are in no way biologically connected to the rest of the human race, some may feel this model does not satisfy Old Testament doctrines about Adam and Eve somehow transferring the "image of God" to the rest of humanity, nor New Testament doctrines about Adam's sin and death somehow spreading through all humanity (Donald 2009, p. 21; Reeves 2009, p. 48; Collins 2011, p. 127; Waters 2017).

2.3. Genealogical Adam and Eve Model of S. Joshua Swamidass

Like the TE/EC model, the Genealogical Adam and Eve (GAE) framework fully adopts a standard evolutionary model of human origins, with one important exception: the special creation of Adam and Eve. In the GAE view, modern humans are descended from a population composed of tens of thousands of hominids who arose via standard evolutionary mechanisms, plus two individuals who were miraculously created. "The genealogical hypothesis, with details filled this way, is entirely consistent with the findings of evolutionary science," writes S. Joshua Swamidass, who developed the model. "The DNA of our ancestors, their genetics, would still arise from a population, not a single couple. We would all still share common ancestry with the great apes" (Swamidass 2019, p. 10).

Thus, Swamidass evokes standard evolutionary mechanisms, but allows an important exception to them: he proposes that Adam and Eve could have been "*de novo* created. God creates Adam and Eve by a direct act, *de novo* from dust and a rib (or Adam's side)" (Swamidass 2019, p. 25). Swamidass then immediately hedges on this point, stating that *de novo* creation is possible but "is not required" under his model (Swamidass 2019, p. 26). He further proposes that "Adam and Eve's lineage eventually interbreed with people outside the Garden" (Swamidass 2019, p. 26). However, he makes it clear that the people "outside the Garden"—from whom all humans are descended—evolved via standard evolutionary mechanisms:

> *No additional miracles allowed.* No appeals to divine action are permitted to explain the data or increase confidence in the hypothesis. Yes, one direct act of God is included in the hypothesis itself, but the evidential evaluation of the hypothesis cannot infer or rely upon divine action in any way. (Swamidass 2019, p. 26)

He continues:

> *The two findings of evolutionary science.* The people outside the Garden would share common descent with the great apes, and the size of their population would never dip down to a single couple. (Swamidass 2019, p. 26)

Apart from the potential *de novo* creation of Adam and Eve, Swamidass's model of human origins is thus equivalent to the standard evolutionary model and involves no other miraculous or non-natural events.[2] Under this view, therefore, Adam and Eve could have been specially created and eventually became the genealogical ancestors of all living humans today. Humans are also descended from thousands of other hominid ancestors who evolved via standard evolutionary mechanisms from apelike ancestors.

2.3.1. Responses

The GAE model aims to retain space for both an orthodox view of the special creation of Adam and Eve, and possibly also their recent origin, alongside a standard evolutionary view of human origins. Swamidass even states that the GAE hypothesis supports a "traditional" version of Adam and Eve (Swamidass 2019, p. 6). However, under the GAE model, Adam and Eve are not the sole progenitors of humanity—far from it. Under GAE, the ancestral contributions of Adam and Eve to humanity (in terms of both genealogy and genetics) are likely dwarfed by the ancestral contributions of a much larger population of fully evolved hominids.

The GAE model also raises profound questions about universal human equality. Swamidass splits humanity into two groups. First, there are "textual" humans who are directly descended from Adam and Eve (as well as other hominids), are made in the image of God, inherited Adam's sin, and are those for whom Christ died. These are the people who are referenced in Scripture. Then, there's a second category of "biological humans" who evolved from apelike ancestors, whom Scripture never references, but who make up the great bulk of our ancient ancestral stock and perhaps even represent a large proportion of humanity throughout much of historical human history. Swamidass is unclear about whether the non-textual people had "human worth and dignity," were made in the image of God, sinned, or had "need for a Savior" (Swamidass 2019, pp. 149–50). However, his model leaves open the possibility that they possessed none of these things, thereby potentially undermining the Judeo-Christian foundation for universal human equality, and the inherent dignity and worth of all humans.

Within Swamidass's model, textual humans included "everyone alive across the globe by, at latest AD 1" (Swamidass 2019, p. 134), such that when Christ died all living humans were descended from Adam, inherited his sinful nature, and needed salvation. Prior to this point in human history, however, there may have lived many non-textual humans—people whom Scripture never mentions, who did not necessarily inherit Adam's original sin, and for whom Christ did not necessarily die. Evolutionary biologist and Christian apologist Jonathan McLatchie is troubled by this proposal:

> Swamidass' view would seem to suggest logically that those individuals who were biological (but not textual) humans are qualitatively indistinct from other animals. However, in that case it makes no sense to call their deeds evil, or to postulate that they had a sense of right and wrong. Moreover, if they, as Swamidass suggests, "do wrong at times", then does this not suggest that Adam's fall is but one of many falls that have occurred in human history? The theological ramifications that accompany this scenario are too severe for me to entertain Swamidass' proposal. (McLatchie 2020)

Similarly, theologian and medical doctor Hans Madueme is concerned about the polygenetic implications of Swamidass's model:

> Swamidass zealously distances his position from earlier racist polygenetic theories. According to those accounts, racial groups that (allegedly) didn't descend from Adam weren't full human beings. I agree that his position is a vast improvement. However, the genealogical hypothesis remains polygenetic, at least to some

> degree. Swamidass defines all those outside the garden as biologically but not textually human.
>
> This move, however, raises a host of questions: for example, in what sense are non-Adamic biological humans fully human? If these biological humans have a different origin from Adam and Eve, do they participate in original sin and salvation? Did Christ live and die for them, and were they able to experience justification by faith? And, if human beings are natural kinds—as Christians have always believed—then how is interbreeding even possible? In chapter 14, Swamidass speculates that these biological humans are made in God's image, with minds and souls, but "they are not yet affected by Adam's fall. They have a sense of right and wrong, written on their hearts (Rom. 2:15), but they are not morally perfect. They do wrong at times. They are subject to physical death, which prevents their wrongdoing from growing into true evil (Gen. 6:3)" (175). Although Swamidass is only speculating here, the notion of other people outside the garden, in my view, is nowhere in Scripture. In traditional Christianity, being human and being a descendant of Adam are co-extensive. As far as I can see, Swamidass's revisionism lacks a convincing exegetical or theological basis. (Madueme 2020)

Scriptural questions are also raised about this division between "textual" and "biological" humans. In Genesis 3:20, Eve is called "mother of all the living," but a core element of Swamidass's model is that Eve was certainly *not* the "mother of all the living" at the time she was created, nor did she become an ancestor of all living humans until millennia after her creation. Swamidass concedes that passages such as Acts 17:26 ("from one man, [God] made all the nations") and Romans 5:12–18 ("all sinned" after Adam's fall, so Christ died for "all people") seem to "presume universal ancestry of Adam," but dismisses them with the casual, "They do not specifically deny mixing with other lines in the distant past" (Swamidass 2019, p. 114). William Lane Craig worries that this mixing of Adam and Eve's descendants with evolved humans (who were not necessarily created in the image of God) is tantamount to massive amounts of "bestiality, contrary to God's will for humanity" occurring throughout human history (Craig 2021, p. 378).

Lastly, there are reasons to wonder whether this model is necessary. Its primary goal seems to be to marry the possibility of *de novo* creation of Adam and Eve with a standard evolutionary model. However, if the fossil and genetic evidence does not demand or support key tenets of an evolutionary model (such as common human–ape ancestry; see Section 2.1), is this marriage necessary? Moreover, Ann Gauger and Ola Hössjer's research—as well as Swamidass's own modeling—show that if Adam and Eve lived far enough in the past, then modern human genetic diversity is compatible with an initial pair who were our *sole* initial ancestors. This seemingly eliminates a major argument for invoking thousands of evolutionary ancestors outside the line of Adam and Eve, thus rendering moot a central motive for adopting the GAE model.

2.4. Homo Heidelbergensis Model of William Lane Craig

William Lane Craig is a Christian philosopher and theologian who has written extensively on adapting the *Kalam* cosmological argument for the existence of God to modern scientific evidence, and other arguments for cosmic design (Craig and Smith 1995; Craig 2000, 2001; Craig and Moreland 2012). In 2021, he addressed biological origins with his book *In Quest of the Historical Adam*, which proposes that Adam and Eve were real historical people who could have been members of *Homo heidelbergensis*, a hominid species that lived about 750,000 years ago (Craig 2021, p. 330). His model of human origins allows Adam and Eve to be ancestors of other members of the genus *Homo* including not just our species *Homo sapiens*, but also the Neanderthals and Denisovans, which he argues are so similar to humans genetically (including neurogenetically), morphologically, and behaviorally that they ought to be considered as bearers of the *Imago Dei*. He describes his model as follows:

> Adam and Eve may therefore be plausibly identified as members of *Homo heidelbergensis* and as the founding pair at the root of all human species. Challenges to this hypothesis from population genetics fail principally because we cannot rule out on the basis of the genetic divergence exhibited by contemporary humans that our most recent common ancestors, situated more than 500 kya, are the sole genetic progenitors of the entire human race, whether past or present. The challenge of the wide geographic distribution of humanity is similarly met by situating Adam and Eve far in the past, prior to the divergence of *Homo sapiens*, Neanderthals, and other species, and allowing multispecies cultural evolution to proceed thereafter in response to environmental changes to produce modern human behaviors wherever their descendants are to be found. (Craig 2021, p. 359)

Thus, unlike the GAE model, Craig's model allows and even prefers that Adam and Eve were the "sole genetic progenitors" of humanity. That said, at times he seems open to limited interbreeding or admixture between Adam and Eve's descendants and other evolved hominids, as in the GAE model—but this "admixture hypothesis" is not his preferred view and is not necessary to his approach[3] (Schaffner 2021). As noted, Craig views interbreeding between Adam and Eve's descendants and other hominids as a rare event—equivalent to "bestiality" and "contrary to God's will for humanity" (Craig 2021, p. 378).

Craig's model aims to be compatible with modern evolutionary science. In an interview with *Christianity Today*, Craig stated that he aspires to show "there is no incompatibility between contemporary evolutionary science and the affirmation of a single human pair at the headwaters of the human race, [so] we can prevent that obstacle to faith." (Travis 2021). Likewise, a review of Craig's model in the journal *Science* observes that he "takes evolution as a given" (Schaffner 2021). However, for Craig "evolution" seems to imply common ancestry but not necessarily an entirely unguided evolutionary process. He is open to the *de novo* creation of Adam and Eve, but sees this as creating a dilemma:

> One can . . . postulate instead a *de novo* creation of Adam and Eve. But then one faces a difficult dilemma. One must explain our genetic similarity to chimps either on the basis of repetitive divine use of a similar design plan or on the basis of considerable interbreeding with nonhumans. The first has difficulty explaining broken pseudogenes that we share with chimps . . . The second looks as if God condones bestiality for our forebears. (Craig 2021, p. 376)

Because Craig eschews the idea of massive amounts of bestiality in human history, he seeks to account for modern human genetic similarities to apes by proposing that Adam and Eve may ultimately descend from a common ancestor shared with apes. However, he argues that this does not preclude them from having been the sole progenitors of subsequent members of humanity—Adam and Eve essentially represented a bottleneck of two individuals who were derived from a population that evolved from apelike ancestors:

> No such appeal to interbreeding [between humans and non-human hominids] is necessary if we envision Adam and Eve as emerging from a hominin population that shared common ancestry with chimpanzees and other great apes. Indeed, on the view proposed here, Adam and Eve could be our sole genetic progenitors, whose descendants never fell into bestial relations with nonhuman hominins or at least produced no descendants from such liaisons. (Craig 2021, p. 378)

What seems to be driving Craig's model is a conviction that Adam and Eve were real historical people who could have been our sole genetic progenitors, creating a race of humans untarnished by interbreeding with other hominids, yet sharing genetic properties with apes. His model requires a very ancient Adam and Eve in order to accommodate them being ancestral to other humanlike members of the genus *Homo* (again, Neanderthals or Denisovans), whom he believes were so morphologically, genetically, and behaviorally advanced that they were probably made in the image of God. Another key reason Craig requires an ancient Adam and Eve is that he desires them to be "our sole genetic progenitors."

He cites studies showing that modern human genetic diversity can be accounted for only if humanity traces to an initial pair that lived at least 500,000 years ago (Craig 2021, p. 353).

2.4.1. Responses

Craig's model seeks to posture Adam and Eve as an initial pair of progenitors—a bottleneck of two—from whom all subsequent humanity descended, and allows humanlike members of the genus *Homo* such as the Neanderthals and Denisovans to be descendants of Adam. His model accomplishes this by placing Adam and Eve hundreds of thousands of years in the past, a position which also can account for modern-day human genetic diversity. However, an ancient Adam and Eve who lived hundreds of thousands of years ago could be viewed as problematic by some who would cite biblical genealogies as requiring a more recent Adam and Eve. If these genealogies are incomplete (Kitchen 1966, pp. 37–39; Henry and Dyke 2012; Keathley and Rooker 2014, pp. 169–77; Collins 2018, p. 200), however, then this problem might be avoidable.

Craig's model is compatible with either the *de novo* creation of Adam and Eve or an Adam and Eve who evolved from apelike ancestors, sharing a common ancestor with apes. Craig prefers the latter position—human–ape common ancestry—because it explains human–ape genetic similarity and the presence of what he calls "broken pseudogenes" shared in the genomes of humans and apes. He believes this genetic evidence is incompatible with the *de novo* creation of Adam and Eve. However, if pseudogenes are in fact functional genetic elements and not merely "junk" DNA (see Section 2.1.1), then there could be functional reasons for the fact that humans and apes share them in similar locations. That is, functional genetic similarities between humans and apes would be the result of common design rather than common descent, and would not require an evolutionary origin. Thus, the genetic evidence does not necessarily refute the *de novo* creation of humans as Craig seems to think it does.

Another issue raised by Craig's model is that Adam, Eve, and the entire human race are arising hundreds of thousands of years before there is definitive evidence for modern human intelligence in the archaeological record. Many researchers have recognized an "explosion" or "revolution" (Bar-Yosef 2002; Mellars 2004; Nowell 2006) of modern humanlike culture in the archaeological record showing the abrupt appearance of human creativity (White 2003, pp. 11, 231), technology, and art (Rice 2007, pp. 104, 187, 194)—even including paintings (Kelly and Thomas 2010, p. 303)—and the rapid emergence of self-awareness, group identity, and symbolic thought (Bar-Yosef 2002). One review of Paleolithic archaeology dubbed this the "Creative Explosion" (Toth and Schick 2015, p. 2459). However, this explosion of modern humanlike creativity does not appear until about 100,000 years ago—hundreds of thousands of years after Craig places the origin of Adam and Eve.

This is not to say that there is no evidence for high intelligence among earlier hominids such as the Neanderthals. Studies have found that Neanderthals had the morphological capability for human speech (Arensburg et al. 1989; D'Anastasio et al. 2013), and Neanderthal remains have reportedly been found associated with signs of culture including art, burial of their dead, and complex tools (Stringer 1992; Trinkaus and Shipman 1993; Folger and Menon 1997; Chase and Nowell 1998; Alper 2003; Wong 2003)—including musical instruments like the flute (Chase and Nowell 1998; Folger and Menon 1997). Morphological mosaics—skeletons showing a mix of human and Neanderthal traits—suggest "Neandertals and modern humans are members of the same species who interbred freely" (Trinkaus and Duarte 2003). Even among the earlier *Homo erectus*, there is direct and circumstantial evidence that they may have controlled fire (Wrangham and Carmody 2010; Zhong et al. 2014; Chazan 2017; Hlubik et al. 2017) and traveled by boat (Bednarik 1997; Gibbons 1998)—activities which presumably required high intelligence and even speech (Everett 2018).

However, not all experts agree with these claims and the evidence for the technological, artistic, and cultural abilities of Neanderthals, *Homo erectus*, and other contemporary hominids is debated (Rana and Ross 2015). Uncontested evidence of high human intelligence

and cultural activity in the archaeological record does not exist until long after Craig's proposed date for Adam and Eve.

2.5. Unique Origins Design Model of Ann Gauger and Other Intelligent Design Advocates

As noted earlier, after the 2011 *CT* article various intelligent design (ID) proponents collaborated on a project to ask whether human genetic diversity could be explained if we descended from an initial pair. Intelligent design is a scientific theory which holds that some features of the universe and life are best explained by an intelligent cause rather than an undirected cause such as natural selection (Meyer 2009, p. 4). The leaders of this project were design theorist and biologist Ann Gauger and mathematician Ola Hössjer who co-published three papers from 2016 to 2019 showing that modern human genetic diversity could be resolved back to just two individuals. (Hössjer et al. 2016a, 2016b; Hössjer and Gauger 2019). Their population genetics model found that if these two individuals lived at least 500,000 years ago then modern-day human genetic diversity could be accounted for with humanity arising from an initial couple. The assumption in their model is that this initial couple had "designed variants" of genes representing "primordial diversity" built into their genomes and so did not need to descend from previous hominids via natural evolutionary processes to provide the requisite genetic diversity (Hössjer and Gauger 2019). According to this model, the pair did not share common ancestry with apes and would have been the sole genetic progenitors of modern humans—the couple from whom all humanity descended.

If this couple lived hundreds of thousands of years ago, such a model would enjoy some benefits of William Lane Craig's *Homo heidelbergensis* model in that it would allow other humanlike members of the genus *Homo* (e.g., Neanderthals or Denisovans) to also belong to a monophyletic group of hominids made in the image of God. Depending on how far back this initial couple lived (e.g., 1.5 million years), even earlier humanlike members of *Homo* such as *Homo erectus* could be viewed as "image bearers," potentially placing Adam and Eve synchronously with the first appearance of the humanlike body plan in the fossil record.

2.5.1. Responses

The Unique Origins Design model maintains that our human lineage was designed separately from apes at least 500,000 years ago,[4] and demonstrates that this can account for modern day human genetic diversity. Some evolution proponents might object that some genetic evidence remains unexplained, such as junk DNA, including what Craig calls "broken pseudogenes that we share with chimps." As noted in Section 2.1.1, however, there are good reasons to view pseudogenes and other forms of junk DNA as functional, and it is possible to explain their presence in humans and apes with common design rather than common descent and inheritance from a common ancestor with apes.

This model requires an ancient Adam and Eve and is thereby compatible with Craig's proposal that Adam and Eve could have belonged to the species *Homo heidelbergensis* or some similar contemporary member of *Homo*. This allows Neanderthals, Denisovans, and other humanlike members of *Homo* to be descended from Adam and Eve. It also allows Adam and Eve to have lived even earlier, potentially having been members of *Homo erectus*, thus aligning the creation of Adam and Eve with the first appearance of the humanlike body plan in the fossil record. Although there is circumstantial evidence that these earlier hominids had high intelligence, such a proposal implies that Adam and Eve and their descendants lived for hundreds of thousands of years before there is definitive evidence of humanlike intelligence and creativity in the archaeological record.

An ancient Adam and Eve could also trouble those who view biblical genealogies as requiring a more recent inception for humanity. It is important to note that the Unique Origins Design model was developed by intelligent design proponents in a series of three technical papers that were primarily asking the scientific question of whether human genetic diversity could be derived strictly from an initial pair, and those papers did not

develop a full-fledged theological model of Adam and Eve. One response to concerns over an ancient Adam and Eve could be that the biblical genealogies are incomplete (Kitchen 1966, pp. 37–39; Henry and Dyke 2012; Keathley and Rooker 2014, pp. 169–77; Collins 2018, p. 200). However, even if incomplete, the ability of the genealogies to be stretched to accommodate an Adam and Eve that lived, say, 1.5 million years ago seems to have not yet been adequately investigated. Another possible response is that a much more recent Adam and Eve might still be compatible with human genetic diversity.

Gauger and Hössjer's model essentially assumed that normal genetic/evolutionary processes occurred after the initial design of the human species, and that these processes work very slowly to allow mutations to accumulate and generate observed human genetic diversity. Hence, Adam and Eve had to live hundreds of thousands of years ago to allow for enough time for modern human genetic diversity to naturally appear. However, if additional evolutionary assumptions are questioned and the genetic history of humanity did not follow standard evolutionary rates, then human genetic diversity could be compatible with a much more recent Adam and Eve (see Sections 2.6–2.8). A more recent Adam and Eve might not allow other humanlike forms in the hominid record such as Neanderthals, Denisovans, or *Homo heidelbergensis*, to be descended from Adam and Eve. However, it could bring the timing of Adam and Eve into alignment with the explosion of modern humanlike creativity observed in the archaeological record at about 100,000 years ago.

2.6. Classical Old Earth Creationist Model of Reasons to Believe

Two of the primary expositors of a highly mature Old Earth Creationist (OEC) model of human origins are Fazale Rana and Hugh Ross, both scientists affiliated with the OEC advocacy organization Reasons to Believe (RTB) (Rana and Ross 2005; Rana and Ross 2015). OECs accept the conventional view that the earth and universe are billions of years old; however, they are generally skeptical that unguided evolutionary mechanisms are responsible for life and typically believe that God progressively and specially created various groups of organisms during the history of life. OECs also seek to find harmony between a literal reading of the book of Genesis and conventional chronology and ordering of major events in natural history. Their human origins model maintains that Adam and Eve were historical persons, the sole progenitors of humanity, and specially and miraculously created by God, separately from apes, sometime between 55,000 and 130,000 years ago (Rana and Ross 2015, p. 252; Ross 2016; Rana 2020a, p. 70; Rana 2018; Rana 2021).

An important component of the OEC model is that other members of the genus *Homo* such as Neanderthals or Denisovans were not descended from Adam and Eve, and were not made in the image of God, and thus they do not need to place Adam and Eve far enough back in time to be ancestral to those groups. This is important to their model, which includes a typical OEC view of a "local biblical flood," where Adam and Eve's descendants (apart from Noah's family) were universally killed off in the flood because they all lived in a localized region in Mesopotamia that was impacted by this small-scale flood. If Neanderthals or other non-human hominids were descended from Adam, their widespread geographic distribution would require a much larger "global" flood to fulfill the apparent biblical requirement that all humanity was wiped out in the flood, and they do not want to postulate a global flood in their model.

Rana and Ross cite archaeological evidence as highly consistent with their model, and have argued that a creation date for Adam and Eve of roughly 70,000–80,000 years ago fits closely with the explosion of humanlike creative activity in the archaeological record around this same time (Rana and Ross 2015, p. 274). Their model is flexible, however, and finds that the "most likely" creation date of Adam and Eve is between 55,000 and 120,000 years but could be "stretched as far back as 230,000 years ago" (Ross 2016). Based upon the more recent evidence, a creation date for Adam and Eve of about 130,000 years has been proposed (Rana 2018; Rana 2021). In light of these modestly varying estimates, a rough date of ~100,000 years for the creation of Adam and Eve will be assigned to this model throughout the rest of this paper.

2.6.1. Responses

Those who desire a more recent Adam and Eve based upon biblical genealogies might find this model more palatable than Craig's *Homo heidelbergensis* model or the Unique Origins Design model, which proposes they lived at least 500,000 years ago. However, this model is still unlikely to satisfy those who seek a very recent Adam and Eve based upon strictly complete biblical genealogies. OECs often maintain that the genealogies are incomplete (Henry and Dyke 2012) in attempts to avoid such problems.

On the other hand, proposing that Adam and Eve lived much less than 500,000 years ago could complicate efforts to account for modern human genetic diversity. However, as noted in Section 2.5, if the genetic evolution of humans after their creation proceeded faster than presently observed rates, these problems could be avoided. Ironically, help on this point for this OEC model may come from Young Earth Creationists who believe the earth is only a few thousand years old. Sanford et al. (2018) constructed a model which predicted that if Adam and Eve lived for hundreds of years and had dozens of children, and if Adam and Eve had genetic diversity built into their gametes, then modern human genetic diversity could be accounted for in just 200 generations—i.e., a few thousand years. This suggests that the scale of modern human genetic diversity may not be a problem for a traditional Adam and Eve specially created by God as our sole progenitors regardless of whether one adopts the Unique Origins Design model, the Old Earth Creationist model, the Young Earth Creationist model, or the Old Earth/Recent Humans Hybrid model.

OECs are skeptical on fossil and genetic grounds of evolutionary arguments that humans descend from apelike ancestors (Dykes 2020a, 2020b). Since the OEC model is a non-evolutionary model for the origin of humans, it, like the Unique Origins Design model, must account for shared "junk" DNA between humans and apes. This does not seem to be highly problematic, however, given the abundance of evidence of function for non-coding DNA (Section 2.1.1).

Another challenge to the OEC model is that many would prefer that other humanlike members of the genus *Homo* such as Neanderthals or Denisovans should be related to modern humans and descended from Adam and Eve. These other groups have body plans which are highly similar to modern humans and also have very high genetic similarity to modern humans. William Lane Craig notes that they share genetic traits which are thought to be required for human cognition and speech, raising the possibility that they were highly intelligent (Craig 2021, pp. 302–29). There is also genetic evidence that *Homo sapiens* interbred with both Neanderthals and Denisovans (Villanea and Schraiber 2018; Teixeira et al. 2021), a finding suggestive of their being part of a common human family traceable to Adam and Eve. Proponents of the OEC human origins model would reply that it is difficult to make any firm conclusions from genetics, and would cite the paucity of clear-cut archaeological evidence for high intelligence within Neanderthals, Denisovans, or any hominid that predates modern humans (Rana and Ross 2015; Dykes 2020c, 2020d). However, while the OEC model holds that Neanderthals and Denisovans were created separately from humans, it does allow for evidence of interbreeding between humans and these other groups, though this evidence was unexpected (Rana 2020b). They see their placement of Adam and Eve at ~100,000 years ago as closely aligned with the evidence for advanced human creativity appearing in archaeological records, and a major point in favor of their model.

2.7. Classical Young Earth Creationist Model

The classical Young Earth Creationist (YEC) model is perhaps the oldest model in terms of having been developed many decades ago, and it will be familiar to many readers. In general, Young Earth Creationism adopts an interpretation of the book of Genesis where God created the universe, earth, and all "kinds" of life in six 24-hour days. Under this view, on the sixth day God specially and miraculously created Adam and Eve as the sole progenitors of the human race (Morris 1976, 1977). Because all of creation is typically said to be only 6000 to 10,000 years in age, YECs would hold that Adam and Eve lived only a

few thousand years ago (Jeanson 2017, pp. 191–92). Under this model, there is no physical death before the fall of Adam and Eve, and physical (and spiritual) death entered the world just a few thousand years ago when Adam and Eve committed the first sin.

After their creation, Adam and Eve (and their descendants) lived for hundreds of years and gave birth to many children, leading to rapid expansion of the human population. The YEC model holds that a few thousand years after the creation of Adam and Eve, the Earth experienced a worldwide "global flood" which killed off all humanity except for Noah and his family—a second genetic bottleneck. Other humanlike members of the genus *Homo* such as the Neanderthals are typically said to simply be members or subraces of the human species and were fully human.

2.7.1. Responses

Historically, many Protestants, including early reformers such as Martin Luther and John Calvin, believed in a recent creation (Barrett and Caneday 2013); however, at various points old Earth viewpoints have also enjoyed popularity among Evangelicals.[5] The YEC model is not only compatible with traditional theological views of Adam and Eve, it essentially defines the traditional theological view. In addition to satisfying interpretations of the Bible which indicate a recent creation of Adam and Eve, many YEC proponents will point out that their model is distinguished because it alone accommodates the traditional view that there was no physical death prior to the creation (and subsequent fall) of Adam and Eve.

Apart from the Hybrid model (Section 2.8), any model which accepts an old Earth would require that there was physical death prior to the creation of Adam and Eve. Thus, the theological view that there was 'no death before sin' is a driving force for many who accept the YEC model.[6] However, OECs reply that when God warned Adam and Eve not to eat from the Tree of Life, He said "in the day that you eat of it you shall surely die." (Genesis 2:17, ESV). Yet, Adam and Eve did not "die" that very same day when they ate the fruit—but they did immediately realize they were naked, felt shame, and hid from God. Thus, OECs would argue that the warning of Genesis 2:17 speaks of "spiritual death" rather than "physical death." (Ross 2001, p. 94; 2014, p. 110). YECs would reply that at the fall Adam and Eve experienced "the commencement of a process of physical dying" (Ham 2006, p. 99)—a plausible supposition, but the rejoinder from OECs has severely blunted the conclusion that only the YEC model can make sense of such passages. Alternatively, some proponents of an old Earth argue that Adam and Eve's sin did in fact "cause" physical death, but the curse was applied by God retroactively to earlier periods of creation: "effects of the Fall can be retroactive as well as proactive (much as the saving effects of the Cross stretch not only forward in time but also backward, saving, for instance, the Old Testament saints)" (Dembski 2009, p. 19).

Various scientific challenges have also been posed to the YEC model, some of which are more easily answered than others. YECs would certainly see junk DNA and pseudogenes as functional genetic elements, thereby explaining their shared presence in ape and human genomes. The challenge of modern human genetic diversity being unable to arise in just a few thousand years initially seemed formidable to any model of Adam and Eve, especially one where they lived only a few thousand years ago. However, as noted in Section 2.6, work by Sanford et al. (2018) proposes that human genetic diversity could arise very rapidly if Adam and Eve were created with initial diversity not only within their own genome but also in the genomes of their gametes. If they had many offspring, then it is argued that human genetic diversity could increase to modern-day levels in a few hundred generations—within the timespan allowed by the YEC model. Other YECs have offered similar arguments that Adam and Eve were created with initial diversity in their genome, which can account for modern human genetic diversity (Jeanson 2017). They also maintain that mutational degradation of the human genome implies that the human species cannot be more than a few thousand years old (Sanford 2005).

At first blush, the YEC model seems to encounter a chronological problem when it proposes that Neanderthals and Denisovans are fully human members of our species, descended from Adam and Eve. Under conventional dates, these groups lived tens or hundreds of thousands of years ago—long before the date YECs would give for the creation of Adam and Eve. However, YECs reject almost all standard dating methods which otherwise would place Neanderthals and Denisovans as living long before the date YECs give for the creation of Adam. Though there is not universal agreement, many YECs claim that fossil specimens of virtually all humanlike members of the genus *Homo*—from *H. erectus* to *H. heidelbergensis* to Neanderthals to Denisovans to modern humans—represent post-Flood human fossils that probably lived concurrently, just a few thousand years ago. Moreover, YECs admit no discrepancy between the appearance of the modern humanlike body plan in the fossil record (approximately 1.5 million years ago under conventional dates) and the first clear-cut evidence of modern humanlike intelligence in the archaeological record (approximately 100,000 years ago under conventional dates) because they reject the methods used to obtain those dates. Yet, this approach to resolving certain chronological problems by proposing near-wholesale rejection of scientific dating methods thus substitutes one set of problems for another, and generates major hurdles related to rejecting mainstream science which this model must overcome.

2.8. Old Earth/Recent Humans Hybrid Model

As the GAE model shows (Section 2.3), belief in a recent Adam and Eve who lived only a few thousand years ago does not necessarily entail belief in a young Earth. The Old Earth/Recent Humans Hybrid ("Hybrid") model accepts a conventional age of the universe and earth of billions of years old, but proposes that God specially and miraculously created Adam and Eve very recently, perhaps as recent as 6000 to 10,000 years ago (Daae 2010, 2012). Unlike the GAE model, however, the Hybrid model does not hold that Adam and Eve's progeny interbred with other pre-existing hominids. Rather, the Hybrid model postulates that there were no humanlike hominids prior to the creation of Adam and Eve, and that Adam and Eve are the sole progenitors of all humanity—which would include the Neanderthals and Denisovans as subraces of normal human beings.

The Hybrid model thus resembles the YEC model in virtually all respects except that it allows that the universe and earth (and potentially also non-human forms of life) predated the creation of Adam and Eve by millions if not billions of years. This model generally accepts conventional dating techniques for natural features other than hominid fossils, but holds that many humanlike hominid fossils are far younger than is conventionally believed. Proponents of this model would emphasize that fossil and archaeological remains of humans and humanlike hominids are so fragmented, sparse, and obscure that it is difficult to date them definitively.

2.8.1. Responses

The main motive underlying this model is to attempt a merging of traditional theological beliefs about Adam and Eve with a conventional view of the age of the universe and earth. Because it proposes a very recent Adam and Eve, the responses to the Hybrid model are thus virtually identical to responses to the YEC model—with the exception that the Hybrid model does not require challenges to the ages of the earth, universe, or other natural features (apart from humanlike hominid fossils).

It should be noted that some versions of the Hybrid model propose that all animal life was created recently (e.g., Gray 1997), but it seems possible to hold to an ancient Earth and ancient creation of non-human life, but then hold that only the human species was created very recently. Either viewpoint would therefore hold that there was no human death before sin. The version which holds that all animal life was created recently can claim that there was no death whatsoever prior to the fall of Adam and Eve. However, the position that non-human life existed long before Adam and Eve must accept that animal death existed

prior to Adam and Eve's sin. Defenses of this position from old Earth proponents are reviewed in Section 2.7.

While some details of this model can therefore vary, this model could allow that some early hominid fossils distinct from humans (e.g., the australopithecines) may in fact be much older than just a few thousand years in age. However, whenever a hominid species is related to humans (e.g., Neanderthals, Denisovans, etc.), this model holds they must descend from Adam and Eve and thereby have lived only within the last few thousand years. This model would therefore propose that the conventional dating of some, if not many, humanlike hominid fossils is inaccurate, as these fossils are said to be far younger than is typically believed. Whether it is feasible to reduce the ages of known humanlike hominid fossils to just a few thousand years is a major scientific hurdle this model must overcome.

3. Discussion

The eight models reviewed here have various strengths and weaknesses with regard to their respective approaches to incorporating traditional theological beliefs about human origins and scientific evidence regarding fossils, genetics, population genetics, archaeology, and chronology. Arguably, four of the models (TE/EC, *Homo divinus*, GAE, and *Homo heidelbergensis*) are evolutionary in that they involve humans evolving from apelike ancestors and sharing a common ancestor with apes, while the other four models (Unique Origins Design, OEC, YEC, and Hybrid) reject those evolutionary points.

Comparison of the Models

Table 1 below summarizes how these models interface with important traditional theological beliefs about Adam and Eve. The TE/EC model satisfies none of these beliefs, whereas only the YEC and Hybrid models satisfy all of them. The *Homo divinus* model, also an evolutionary model, proposes a historical Adam and Eve who lived recently, but because Adam and Eve are detached from any genealogical relationships to subsequent humans in this model, this recent origin is of unclear value. Some of the other models perform considerably better, as the *Homo heidelbergensis*, Unique Origins Design, and OEC models each satisfy four or five of the seven theological points—all of them missing a recent timing of the origin of Adam and Eve and no physical death before the fall. This latter point is only satisfied by the YEC and Hybrid models. Ironically, a recent origin of Adam and Eve is satisfied by the *Homo divinus* and GAE models—both evolutionary models. The GAE model is the only model to postulate that Adam and Eve are genealogical ancestors of all humans, but are not their sole initial progenitors.

Table 2 below summarizes how these models interface with mainstream scientific positions on human origins. Here, the TE/EC, *Homo divinus*, and GAE models perform best and satisfy all of the mainstream scientific points. The *Homo heidelbergensis* model satisfies at least five of the points, but diverges from mainstream science when it proposes that humanity went through a bottleneck of two individuals at the time of Adam and Eve, as mainstream science recognizes no such event. The Unique Origins Design model scores three points—two related to dating and one for recognizing that humans are related to Neanderthals and Denisovans. The OEC model also scores three points—two related to dating, and one for being the only non-evolutionary model to recognize that the human body plan appears before human intelligence in the fossil record. The YEC model scores only one point, related to humans and Neanderthals/Denisovans being related. The Hybrid model also scores this latter point, as well as a second point for an old age of the universe/earth.

Table 1. Comparison of model interaction with traditional theological beliefs about Adam and Eve.

Model	Adam and Eve Were Real Historical People Who Fell into Sin.	Adam and Eve Were Ancestral to All Living Humans.	Adam and Eve Were the Sole Initial Progenitors of All Humans.	Adam and Eve Were Specially and Miraculously Created "*de novo*."	Adam and Eve Lived Recently (<10,000 Years) as Genealogies Typically Suggest.	No Physical Death before the Fall of Adam and Eve	Humans Only Interbreed with *Imago Dei* Humans (i.e., Bestiality Not Required).
Classical Theistic Evolution/Evolutionary Creation Model							
Homo divinus Model	X				X		
Genealogical Adam and Eve Model	X	X		Possible, if not favored, but not required.	Quite possible, but not required.		
Homo heidelbergensis Model	X	X	Strongly preferred, but not required.	Probably not.			Strongly preferred, but not required.
Unique Origins Design Model	X	X	X	Allowed, if not favored.			X
Classical Old Earth Creationist Model	X	X	X	X			This was initially strongly preferred, but was rejected after evidence of human–Neanderthal interbreeding.
Classical Young Earth Creationist Model	X	X	X	X	X	X	X
Old Earth/Recent Origin Hybrid Model	X	X	X	X	X	Possible, but not required.	X

Table 2. Comparison of model interaction with mainstream scientific positions on human origins.

Model	Humans Evolved via Standard/Unguided Evolutionary Mechanisms from Apelike Species.	Humans Share a Common Ancestor with Apes.	Humans Had Thousands of Primordial Ancestors and Never a Bottleneck of Two.	Humans (*Homo sapiens*) Are Related to Neanderthals and Denisovans.	Human Body Plan Appears before Human Intelligence.	Dating (Old Age) of Hominid Fossils Is Accurate.	Dating (Old Age) of Earth and Universe Is Accurate.
Classical Theistic Evolution/Evolutionary Creation Model	X	X	X	X	X	X	X
Homo divinus Model	X	X	X	X	X	X	X
Genealogical Adam and Eve Model	X	X	X	X	X	X	X
Homo heidelbergensis Model	Not clear, but seems to be possible.	X		X	X	X	X
Unique Origins Design Model				X		X	X
Classical Old Earth Creationist Model					X	X	X
Classical Young Earth Creationist Model				X			
Old Earth/Recent Origin Hybrid Model				X			X

Darwin skeptics have proposed many scientific arguments regarding human origins that might differ from the mainstream scientific consensus. However, they would argue that these points are nonetheless supported by peer-reviewed scientific papers and evidence. As such, these points ought to be considered in any evaluation of these models, even if they diverge from the standard scientific "consensus." This evaluation is shown in Table 3. Here, the TE/EC, *Homo divinus*, and GAE models score zero points, underscoring the commitment of these models to never diverging from the scientific consensus. The *Homo heidelbergensis* model recognizes that population genetics models have found that human genetic diversity could arise from an initial pair, and also recognizes evidence of the full humanity of Neanderthals and Denisovans. The remaining four models (Unique Origins Design, OEC, YEC, and Hybrid models) all recognize the possibility of intelligent design in human history. Indeed, the Unique Origins Design, YEC, and Hybrid models recognize all of these alternative scientific points except for aligning the timing of the origin of humans in the fossil record with the first archaeological appearance of humanlike intelligence. Only the Unique Origins Design model accepts dating methods, yet proposes Adam and Eve could have been created when the humanlike body plan first appears, while only the OEC model accepts dating methods and proposes that Adam and Eve coincided with the first archaeological evidence of humanlike intelligence. These are important points distinguishing the OEC and Unique Origins Design models from other viewpoints.

Table 4 and Figure 1 present the totals from each of these tables. Table 4 also includes a subtotal from only Tables 1 and 2, such that each models' performance strictly from the vantage of mainstream theological views (Table 1) and mainstream scientific views (Table 2) can be evaluated.

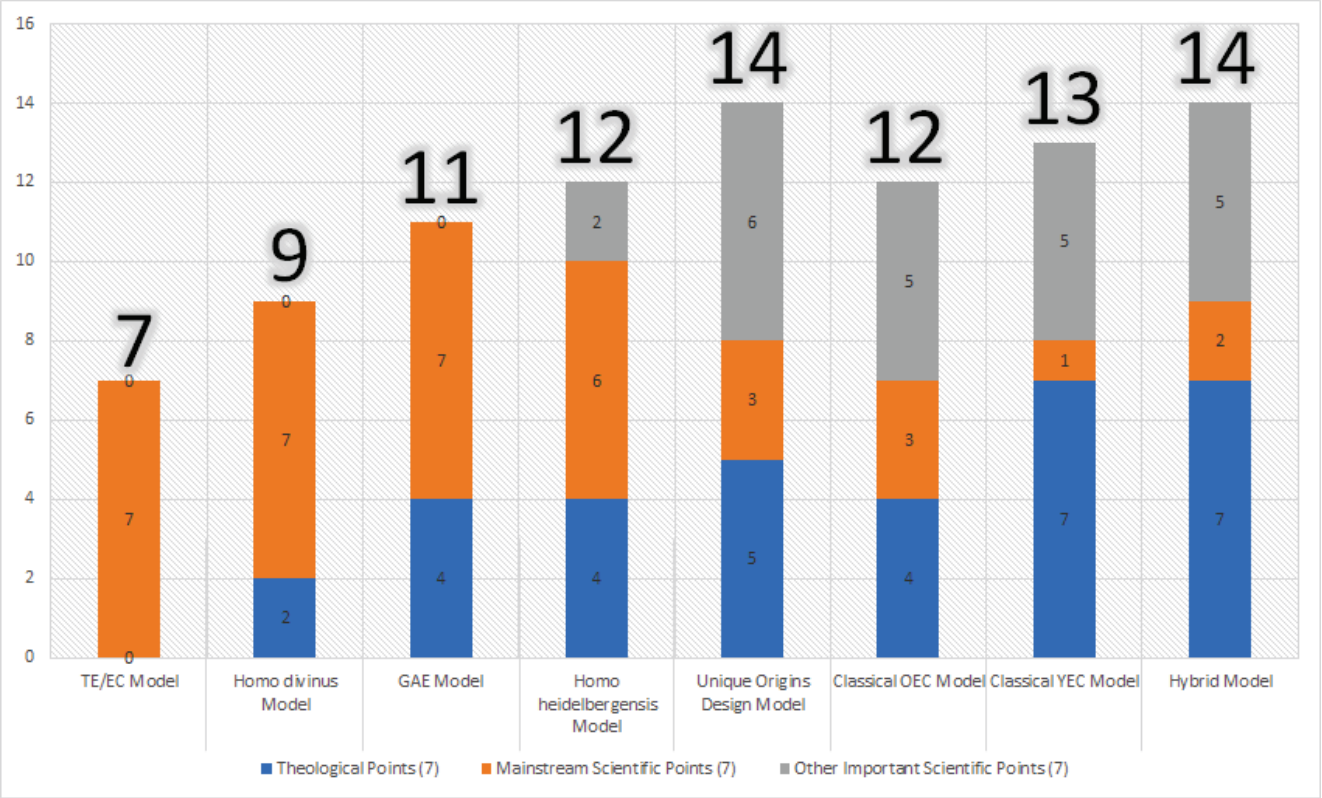

Figure 1. Comparison of scores and point totals of the models.

Table 3. Other important scientific points.

Model	Acknowledges Waiting Times Problem for Evolving Complex Traits and the Possibility of Design.	Incorporates Population Genetics Modeling Showing Humans Can Come from an Initial Pair.	Incorporates Evidence of Pseudogene Function.	Accepts Evidence of Full Humanity of Neanderthals/ Denisovans.	Acknowledges Fossil Gap between Human and Apelike Species.	Adam and Eve Aligned with First Appearance of Fossil Evidence of Humanlike Body Plan.	Adam and Eve Aligned with First Appearance of Archaeological Evidence of Humanlike Intelligence.
Classical Theistic Evolution/Evolutionary Creation Model							
Homo divinus Model							
Genealogical Adam and Eve Model							
Homo heidelbergensis Model		X		X			
Unique Origins Design Model	X	X	X	X	X	Possible.	
Classical Old Earth Creationist Model	X	X	X		X		X
Classical Young Earth Creationist Model	X	X	X	X	X	Not if standard dating methods are adopted.	Not if standard dating methods are adopted.
Old Earth/Recent Origin Hybrid Model	X	X	X	X	X	Not if standard dating methods are adopted.	Not if standard dating methods are adopted.

Table 4. Point totals for the models.

Model	Theological Points (7)	Mainstream Scientific Points (7)	Subtotal (14) of Tables 1 and 2	Other Scientific Points (7)	Grand Total (21)
Classical Theistic Evolution/Evolutionary Creation Model	0	7	7	0	7
Homo divinus Model	2	7	9	0	9
Genealogical Adam and Eve Model	4	7	11	0	11
Homo heidelbergensis model	4	6	10	2	12
Unique Origins Design Model	5	3	8	6	14
Classical Old Earth Creationist Model	4	3	7	5	12
Classical Young Earth Creationist Model	7	1	8	5	13
Old Earth/Recent Origin Hybrid Model	7	2	9	5	14

In the subtotals, the GAE and *Homo heidelbergensis* models perform best because they incorporate mainstream scientific views about common ancestry and human evolution from apelike species in contrast to the other non-evolutionary models, while also acknowledging Adam and Eve as real historical people. The GAE model also allows for their *de novo* creation and recent origin, while the *Homo heidelbergensis* model allows them to be the sole ancestors of humans and denies interbreeding with non-human species. In the grand total analysis (Table 4, Figure 1), however, the Unique Origins and Design and Hybrid models tie for the highest scores, followed closely by the YEC model, which is followed closely by the OEC and *Homo heidelbergensis* models. The TE/EC model scores lowest, largely because it rejects traditional theological beliefs and other important scientific points worth considering in the conversation.

As noted, four of the models (TE/EC, *Homo divinus*, GAE, and *Homo heidelbergensis*) are evolutionary in that they involve common human–ape ancestry, while the other four models (Unique Origins Design, OEC, YEC, and Hybrid) favor or require the *de novo*/miraculous creation of humans. It is thus useful to compare the performance of evolutionary models vs. non-evolutionary models: Considering only Tables 1 and 2 (i.e., the Subtotal in Table 4), the evolutionary models outperform, scoring an average of 9.25 points to 8 points for the non-evolutionary models. When Table 3 is incorporated into the totals, the non-evolutionary models outperform, scoring an average of 13.25 points compared with 9.75 points. This reflects the fact that the evolutionary models tend to score many mainstream scientific points but few theological points, whereas the non-evolutionary models tend to score both theological and scientific points.

The value of this scoring method is unclear, as the various theological and scientific points evaluated may not all have equivalent value. The alternative scientific points (Table 3) could also be selected differently. Which models a person prefers will likely depend upon whether they find it more important to align with certain traditional theological beliefs (Table 1), mainstream scientific beliefs (Table 2), other scientific beliefs (Table 3), or a combination of various beliefs from any of those broader categories. For example:

- If one cares very little about traditional theological beliefs regarding human origins and is convinced that mainstream evolutionary biology is correct, then the TE/EC model may be appealing.
- Conversely, if one places the highest priority upon traditional theological beliefs about Adam and Eve, then the YEC or Hybrid models may be most attractive.

For those incorporating both theological and scientific considerations into their positions, some of the newly conceived models incorporate multiple traditional theological

views about Adam and Eve and also perform fairly well when compared with the scientific evidence. For example:

- If one finds evolutionary science persuasive but desires a form of historical Adam and Eve, then the *Homo heidelbergensis*, GAE, or *Homo divinus* models may be persuasive.
- If one finds evolutionary claims to be scientifically weak but accepts standard dating methods, then the Unique Origins Design or OEC models seem most viable. The Hybrid model is also available to those who accept an old Earth, though it requires rejecting dating methods as regards many hominid fossils.

A key scientific question distinguishing these models is how they resolve a potential discrepancy in the timing of the appearance of the humanlike body plan in the fossil record (conventionally dated to about 1–2 million years ago) versus the appearance of unambiguously modern humanlike intellectual activity in the archaeological record (conventionally dated to about 100,000 years ago). The TE/EC and GAE models accept these dates by adopting the standard evolutionary view that hominids experienced "mosaic" evolution, where the humanlike body plan evolved prior to the evolution of modern human cognitive and intellectual capacities. Under the GAE and *Homo divinus* models, Adam and Eve might even have lived long after modern human intelligence evolved.

The OEC model provides a simple solution to this conundrum by proposing that Neanderthals, Denisovans, and other hominids are not descended from Adam, allowing them to place the origin of Adam at the exact time of this archaeological "explosion" of humanlike creativity. Another potential resolution is to propose that humanlike creativity actually extends further back into the archaeological record than is commonly believed—a position supported by evidence of high intelligence in Neanderthals and other humanlike hominids, but not explored in detail here.[7] Such a conclusion would lend support to both the *Homo heidelbergensis* and Unique Origins Design models, both of which propose an ancient Adam and Eve—though only the Unique Origins Design model allows Adam and Eve to potentially coincide with *Homo erectus*, when the humanlike body plan first appears in the fossil record. A final potential avenue for reconciling this apparent discrepancy is to question the dating of various hominid fossils and tools. Such a position would be found in the YEC model or Hybrid model. The YEC model is skeptical of not just evolutionary science, but virtually all dating methods. The Hybrid model questions the dating of very recent hominid fossils, but otherwise accepts the conventional ancient age of the earth.

A key outstanding theological question is whether the biblical genealogies can potentially allow for an Adam and Eve that lived 100,000, 500,000, or 750,000 years ago (or even earlier). This hinges on the incompleteness or extent of incompleteness of the genealogies. Such an ancient Adam and Eve would be required by the OEC, *Homo heidelbergensis*, and Unique Origins Design models. At present, the primary models which allow for a very recent Adam and Eve are the GAE, YEC, and Hybrid models. The GAE model, however, raises additional theological questions by postulating huge numbers of biologically modern humans that lived throughout much of human history but were not descended from Adam and Eve. The *Homo divinus* model also allows for a recent Adam and Eve; however, because it is divorced from genetics or genealogies, this is of unclear theological importance.

4. Conclusions

If recent decades are any indication, new models will likely be constructed in the future that adopt and refine the strongest elements that these current models have to offer. Whatever the final resolution to these questions, it seems clear that a variety of options already exist for Protestant Evangelicals and other Christians seeking to understand human origins and harmonize traditional theological beliefs with the scientific evidence. Although some models appear more successful than others at achieving a reconciliation, one need not jettison traditional beliefs about Adam and Eve in light of the findings of science.

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Notes

1 The intent of this section is not to discuss or critique all aspects of modern evolutionary biology, but simply to provide scientific commentary on specific common arguments from evolutionary creationists on the specific topic of human origins.

2 Swamidass's (2019) descriptions of the GAE model contains various other statements which indicate the close association of his GAE model with an attempt to retain a standard evolutionary viewpoint:

- "evolutionary science does not require us to reject the Genesis narrative" (p. 7);
- "evolutionary science could be true, even as our loyalties remain with Scripture" (p. 7);
- "I offer a speculative narrative of origins that contains the traditional *de novo* account of Adam and Eve alongside evolutionary science" (p. 13);
- "Nothing in this book is outside mainstream science." (p. 23);
- "The full story of human evolution is that of populations across the globe linked into a common evolutionary fate by pervasive interbreeding everywhere. We can now see the genealogical hypothesis is far more plausible than we might have first imagined. If Adam and Eve were real people, very quickly, in just thousands of years, their lineage would mix with everyone outside the Garden." (p. 55);
- "Yes, our ancestors appear to rise as a population, and it appears that we also share ancestry with the great apes." (p. 102);
- "The scientific account of evolutionary science plays out in the mystery outside the Garden of the traditional account." (p. 174);
- Swamidass anticipates a potential response to his model as "Why did God make Adam and Eve *de novo*, without parents, when everyone else was created through a process of common descent?" (p. 205);
- He also acknowledges that his model leaves a tension between evolutionary science and traditional theological views of Adam and Eve: "The only way evolutionary science presses on a traditional reading of Genesis is by suggesting, alongside Scripture, that there were people outside the Garden." (p. 215).

3 Schaffner (2021) stated: "we eventually learn that his [Craig's] model allows for an unspecified amount of admixture from other hominin lineages into the descendants of Adam, eliminating the need for such a tight bottleneck. A more clearly stated hypothesis in this section would have saved the reader time and frustration."

4 The concept of intelligent design entails an infusion of information that came from an intelligent mind. In the context of this model, intelligent design could inolve *de novo* origin/special creation, but it could also include taking the body plan of a pre-existing organism and infusing information into the genome such that a new type of organism suddenly emerged. Thus, at the very minimum, intelligent design requires some input of information which changes the genotype and phenotype of an organism. Again, this could mean *de novo* origin/special creation, but it does not necessarily require this. However, even in the case that design does not involve *de novo* origin/special creation, something special is still happening—namely the infusion of information into the genome which produces an informational discontinuity that is beyond the abilities of natural mechanisms to produce.

5 For example, the Scofield Refererence Bible, highly influential in American Evangelicalism and Fundamentalism, advocated the gap theory and day/age theory, which accept an ancient age of the earth. However, the Scofield Bible did not place a date on Adam and Eve, and seemingly allowed or assumed a recent Adam and Eve. Its theology of origins would probably be most compatible with the Hybrid model (Section 2.8).

6 See, for example, reasons cited in various entries in Ashton (2000), *In Six Days: Why Fifty Scientists Choose to Believe in Creation*.

7 This evidence is controversial to some, including proponents of the classical OEC model. See Rana and Ross (2015).

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On the Relationship between Design and Evolution

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Abstract: A longstanding question in science and religion is whether standard evolutionary models are compatible with the claim that the world was designed. In *The Compatibility of Evolution and Design*, theologian E. V. Rope Kojonen constructs a powerful argument that not only are evolution and design compatible, but that evolutionary processes (and biological data) strongly point to design. Yet Kojonen's model faces several difficulties, each of which raise hurdles for his understanding of how evolution and design can be harmonized. First, his argument for design (and its compatibility with evolution) relies upon a particular view of nature in which fitness landscapes are "fine-tuned" to allow proteins to evolve from one form to another by mutation and selection. But biological data run contrary to this claim, which poses a problem for Kojonen's design argument (and, as such, his attempt to harmonize design with evolution). Second, Kojonen appeals to the bacterial flagellum to strengthen his case for design, yet the *type* of design in the flagellum is incompatible with mainstream evolutionary theory, which (again) damages his reconciliation of design with evolution. Third, Kojonen regards convergent evolution as notable positive evidence in favor of his model (including his version of design), yet convergent evolution actually harms the justification of common ancestry, which Kojonen also accepts. This, too, mars his reconciliation of design and evolution. Finally, Kojonen's model damages the epistemology that undergirds his own design argument as well as the design intuitions of everyday "theists on the street", whom he seeks to defend. Thus, despite the remarkable depth, nuance, and erudition of Kojonen's account, it does not offer a convincing reconciliation of 'design' and 'evolution'.

Keywords: evolution; theistic evolution; design; intelligent design; laws of nature; protein evolution; science; theology; bacterial flagellum; irreducible complexity; convergent evolution; fitness landscapes; fine tuning; evolutionary creation

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1. Introduction

A perennial question in discussions about biological origins is whether or not design is compatible with evolutionary theory. Are the two friends or foes? Was Richard Dawkins correct when he claimed that "Darwin made it possible to be an intellectually fulfilled atheist" (Dawkins [1986] 1991, p. 6)? Or is evolution simply the means by which a Creator brought about his divine plan? These are important and challenging questions for those interested in the intersection of science and faith.

Yet a more difficult question concerns whether *mainstream* evolutionary theory is compatible with *biology-based* design. Is it possible, say, that the wing of a hummingbird and the blush of an orchid provide empirical evidence for design, while at the same time being fully explained by natural selection, random mutation, and other natural processes? Can one have full-blooded versions of both design and evolution simultaneously?

These are much more difficult questions. A host of fine thinkers past and present have weighed in on one side or the other. In 2005, for example, 38 Nobel Laureates signed a statement which declared that evolution is "an unguided, unplanned process of random variation and natural selection" (Elie Wiesel Foundation 2005). Yet other scientists disagree, including those who state that "evolution is not in opposition to God,

but a means by which God providentially achieves his purposes. Therefore, we reject ideologies that claim that evolution is a purposeless process or that evolution replaces God" (BioLogos Foundation n.d.) Indeed, the co-discoverers of natural selection—Charles Darwin and Alfred Russell Wallace—held opposing views about the relationship between design and evolution.

Adjudicating this long-standing disagreement is no easy matter. But progress can be made by analyzing in detail the best current treatment available. Such a treatment has been rendered by E. V. Rope Kojonen, a theologian at the University of Helsinki, in a thoughtful and serious book, *The Compatibility of Evolution and Design* (hereafter, CED), published by Palgrave-MacMillan/Springer-Nature (Kojonen 2021). Kojonen argues that evolution and design can be harmonized. Indeed, he contends that mainstream evolutionary biology is fully compatible with design arguments (or design perceptions) that are based on biological phenomena. The wing of the hummingbird displays evidence of design even while being the product of natural selection, random mutation, and other processes—all *without* the need for divine intervention or supervision per se.

We will explore Kojonen's view in more detail below. For now, it is important to note that his analysis is formidable and wide-ranging, covering literature across several subdisciplines of biology and philosophy. Philosophically, the work is remarkably sophisticated, engaging current discussions of causation, explanation, determinism, theodicy, and so on. Kojonen also ably engages current scientific discussions, from the bacterial flagellum to fitness landscapes to evolutionary convergence; he is also highly conversant in the literature of proponents of intelligent design (ID). Throughout the book, Kojonen offers nuanced arguments, appropriate qualifications, and respectful engagement with both mainstream evolutionary theory and contemporary notions of design. In short, CED is a fine work of scholarship.

Indeed, we regard CED as the *best* current treatment of the compatibility of design and evolution from a theistic evolutionary point of view. A careful analysis of this work is highly relevant to making headway on the broader question of the relationship between evolution and design. Thus, our analysis here will have wider application to the literature as a whole, *mutatis mutandis*.

To this end, we provide an extended examination of CED. While the strengths of the book are remarkable, we nonetheless contend that the book's overall thesis is flawed: Kojonen's attempt to draw together mainstream evolutionary theory with a biology-based design argument (or perception) does not succeed.

Our analysis proceeds in four steps. First, we provide a summary of CED. Second, we argue that the success of Kojonen's proposal depends in part on the scientific details in question. Third, we give an extended analysis of these scientific details and argue that they run contrary to Kojonen's model; we focus in particular on protein evolvability, the bacterial flagellum, and convergent evolution. Finally, we round out our article by raising epistemological concerns about Kojonen's fundamental understanding of how to detect design in the natural world.

Importantly, in this article, we do *not* contend (or assume) that evolutionary theory is false or implausible per se. Even in our examination of scientific details, our point is either to critique Kojonen's view of 'design' or to illuminate tensions between 'design' and 'evolution' in his model. Thus, in this article, we are interested in Kojonen's view of design and its compatibility with evolution rather than the truth or falsity of evolutionary theory itself. (We should note, however, that because of the way Kojonen frames the matter, our criticisms of his view of design do have negative implications for the feasibility of evolutionary theory as he understands it. But, as we will see, this is an *implication* of our argument based on *his* own framing. It is not the focus of our argument itself).

Definitions and Qualifications

A definition or two will help keep matters straight along the way. The word 'evolution' has been defined in many different ways (Meyer and Keas 2003). In some contexts, it means

'change over time', whereas in others, it means 'common ancestry'. Elsewhere, it refers to the mechanism of natural selection acting on random mutations. Still elsewhere, it means the selection-mutation mechanism plus supplemental natural processes such as genetic drift (neutral evolution), natural genetic engineering, phenotypic plasticity, niche construction, and so on. In this article, we follow Kojonen's use of the term to refer to mainstream evolutionary theory, which is a combination of common ancestry, the mutation-selection mechanism, and other natural processes (as necessary).

In general, by 'design', we mean an intentional act of an agent in accord with a plan, pattern, or purpose. Having said that, our use of the term 'design' in this paper will usually refer to Kojonen's particular version of design rather than to a general idea of design (as just defined). The context in each case will make clear which definition is in use. Kojonen's version of design is a strain of 'intelligent design', the idea that (i) certain features of the natural world are best explained by mental agency rather than by mindless processes or forces, and (ii) the design of these features is detectible, whether through direct intuitive perception or careful scientific analysis. In short, design is real and detectable. As noted, Kojonen is particularly interested in ID in biology.

It is important to mention that there is much controversy surrounding the notion of 'intelligent design'. There is also much ferment about its relationship to evolutionary theory. Strictly speaking, ID minimally holds that *at least one* physical feature of the universe is best explained by mental agency (as opposed to mindless causes), and that the design of this feature can be empirically detected. As defined, ID is compatible with many definitions (or versions) of evolution. For example, ID is compatible with 'evolution' defined as 'change over time', 'change in the frequencies of alleles in a population', 'common ancestry of a certain taxonomic group', or 'universal common ancestry of all (or most) taxonomic groups'. ID is also broadly compatible with the idea that evolutionary mechanisms (e.g., natural selection acting upon random mutation) can explain at least some features of the universe. Importantly, ID is *incompatible* with the idea that all features of the universe can be explained by non-mental causes or that, even if some features are caused by mental agency, such agency is not detectable from apprehension of the effects (or features) in question.

Having clarified this point, we emphasize that the aim of this article is not to provide a definitive statement about ID and evolution, but rather to evaluate Kojonen's specific proposal on these matters. As noted, in our view, Kojonen's model stands as the finest current model on offer from an evolutionary point of view. Future discussions will need to grapple with Kojonen's careful account.

2. Summary of The Compatibility of Evolution and Design

In their simplest form, CED's main theses are as follows (Kojonen 2021, pp. 6–10, 205–13):

1. Evolutionary theory, properly understood, is both scientifically correct and compatible with a certain type of biological design argument.
2. The biological world itself provides notable grounds for belief in a purposeful Creator, and evolutionary theory does not defeat these grounds.
3. For those worried about so-called natural evil, there is a way to join evolution with a biological design argument that actually *adds* credibility to evolution-based theodicies, rather than raising additional hurdles for them.

In order to defend these primary claims, Kojonen carefully constructs an argument for the harmony of evolution and biological design. We will refer to this argument as Kojonen's evolution-friendly biological design argument (or KEBDA). Importantly, one of the unique features of Kojonen's proposal is his contention that, even with the acceptance of standard evolutionary theory (and, hence, no need to appeal to design-based alternatives to evolution), biological phenomena *still* provide notable grounds for belief in a Designer (see point 2 above). Kojonen argues that this is true not just for a scholar who can follow the nuances of KEBDA, but even for an everyday theist (the "theist on the street") who relies on intuition and common sense to apprehend design in biological

phenomena (Kojonen 2021, pp. 32, 145–204). Thus, in Kojonen's evolutionary vision, flora and fauna don't simply reveal God 'through the eyes of faith' but rather in a more robust and substantial way.[1]

This is a unique and provocative contribution to the literature on this topic, and Kojonen has broken new and stimulating ground. We will return to this interesting feature of CED in due course. For now, however, we will focus on summarizing the first thesis above—the compatibility of evolution with design—which forms so much of the impetus behind, and substance of, Kojonen's endeavor in CED.

As is evident, Kojonen is clear from the outset that his argument takes mainstream evolutionary theory as a *given* (Kojonen 2021, pp. 7, 98, 105). He states, for example, that "the validity of the essential scientific claims of evolutionary biology will be accepted as the starting point of my inquiry" (Kojonen 2021, p. 7).[2] On this view, there are no causal 'gaps' in evolutionary processes, and as such, no divine interventions are needed.[3] Evolution is a settled matter. Accordingly, CED does not seek to provide a scientific defense of evolution per se but rather to give a philosophical account of how evolution and design are (or can be) compatible (Kojonen 2021, pp. 5–8). Supposing that full-orbed evolutionary theory is true, does it dovetail with detectable biological design?

Having taken evolution as a starting point, Kojonen carefully builds his case for its compatibility with design. The details of his proposal are manyfold, but the basic idea is straightforward: the locus of design is at the origin of the cosmos (or the laws of nature) (Kojonen 2021, pp. 164–67). God acts at the beginning of the universe, granting to it all that is necessary for biological complexity to eventually unfold. The deity creates the laws of physics and chemistry, which then give rise to preconditions—including "the library of forms"—that enable evolution to produce complex entities.[4] Random mutations and natural selection alone are insufficient for the emergence of biological complexity; preconditions are required, and God ultimately stands behind these preconditions (Kojonen 2021, pp. 97–143).

2.1. Why Bother with Design?

Naturally, a critic might wonder, "Why bother with design if Kojonen has already granted evolutionary theory? That is, if evolutionary explanations are fully adequate to explain biological diversity and complexity—as Kojonen assumes—then what is left for design to explain?" As Kojonen himself puts it, "Evolutionary processes are supposed to provide an explanation for precisely the same features of biology that design arguments also attempt to explain—therefore making design unnecessary". (p. 9).

Kojonen recognizes the power of this objection. The worry, in short, is that a critic might claim that Kojonen's model violates Ockham's razor. As David Glass puts it:

> In most cases design is compatible with the alternative explanation, but if this is so, why not accept both design and the alternative explanation? The obvious answer is that there is no need to infer two explanations when one will do. When I learn that my children were playing in the study, the hypothesis that there has been a burglary becomes redundant as an explanation for the untidiness. (Glass 2012)

Kojonen draws upon a number of resources to respond to this objection. Indeed, one of the very fine features of CED (and Kojonen's other writings) is his use of "conjunctive explanations" in this regard (Kojonen 2021, pp. 148–55, 2022a).[5] He notes that his burden is to show that the conjunction of 'design *and* evolution' has greater explanatory value (or goodness) than simply 'evolution' on its own. Given that 'design and evolution' are less simple than 'evolution' (and so are a prima facie violation of Ockham's razor), Kojonen recognizes the need to show that the conjunction of 'design and evolution' provides an offsetting benefit that 'evolution' alone lacks. Kojonen's task is to show that the conjunction has enough explanatory gain so that 'design' is a *helpful*—rather than superfluous—addition to evolution's explanation of biological complexity and diversity (Kojonen 2022a).[6]

Kojonen takes up this challenge directly. He ultimately cites an array of considerations—the origin of proteins, the complexity of the bacterial flagellum, evolutionary algorithms, and the like—to show that it is implausible to think biological diversity and complexity *ultimately* arose without a designing mind. As he summarizes: "The cosmos must be special indeed to allow for the evolution of the kind of complex teleology and the large variety of creatures that we observe. And this feature of the cosmos . . . is explained better by a theistic view than by supposing that this feature is due to chance" (Kojonen 2021, p. 162, see also pp. 97–143). So, biological complexity and diversity are best explained by (ultimate) design rather than by random processes. In this sense, Kojonen believes that adding 'design' to 'evolution' provides an important explanatory *gain* over and above 'evolution' alone. Without *designed* preconditions, one cannot fully account for the extraordinary complexity and diversity of biological life.

One of Kojonen's thought experiments may help illuminate his line of reasoning. He asks readers to suppose that the first photos of the moon showed the text of John 3:16 written in craters on the surface (Kojonen 2021, p. 165). Suppose further that there was a natural explanation for each crater (and asteroid). Suppose also that we could trace these natural explanations all the way to the big bang. "In this case", writes Kojonen, "it seems that natural explanations simply do not explain the intelligibility of the pattern, even though they explain each individual crater". (Kojonen 2021, p. 165) The evidence of design remains clear, even if that design occurred at the beginning of the universe and was transmitted by natural processes across time and space. So it is in biology, he argues. The complexity of flagellar motors and other biological phenomena point directly to design; the fact that proximal (evolutionary) causes are in play does not preclude God as the ultimate cause. Indeed, positing a designer *adds* explanatory value: the appeal to a natural explanation to account for John 3:16 is not at all convincing on its own.

Note that Kojonen does not want to add just any 'design' hypothesis to 'evolution'. In fact, he wants to add a hypothesis that has three key elements: (i) *biological* design (Kojonen 2021, pp. 132, 157–74), that is (ii) empirically detectible (Kojonen 2021, pp. 132, 157–74),[7] and (iii) came about without divine intervention (Kojonen 2021, pp. 28, 109, 122, 146, 184, 185, 192). So, even though evolutionary theory is correct, there is still a real design argument here—one that is based on biological phenomena, not data from cosmology or physics per se. And this design argument does not include divine interventions; instead, organic creatures arise from the laws of nature over time—what one might call a full-throated "front-loaded" view of design.[8] It is this view of 'design' that Kojonen believes adds explanatory value to 'evolution'.

Notably, under Kojonen's model, evolution *per se* is not ultimately responsible for the impressive complexity and diversity of life we observe on Earth—at least not any more responsible than natural processes are for spelling out John 3:16. In the John 3:16 analogy, natural processes on their own are recognized to be impotent to spell out the message, and this is why we recognize that a Mind must have crafted the laws of nature (and initial conditions of the universe). In a similar way, Kojonen contends that evolution on its own is impotent to create much of the observed complexity and diversity of life, and what gives evolution its impressive creative powers are the "preconditions" that ultimately derive from the laws of nature (and initial conditions) that God designed at the beginning of the universe.

2.2. Which Version of Evolution?

Of course, careful thinkers will note that much of the discussion hinges on what the term 'evolution' means. It is one thing to say that God's initial creative act eventually produced biological diversity and complexity; it is quite another to claim that all of this is compatible with standard evolutionary theory, properly understood. Kojonen is well aware of this difficulty. In response, he canvasses an array of interpretations of evolution—everything from Stephen Jay Gould's 'contingency' view to Simon Conway

Morris's 'directional' view—and argues that each legitimate version is compatible with front-loaded design. He summarizes:

> If evolution is directional . . . then this directionality is contingent on the laws and constants of nature allowing this directionality. If evolution is highly contingent, so that running the "tape of life" again would cause a very different result, then this makes it surprising that such valuable outcomes have in practice been reached. (Kojonen 2021, p. 210)

He explains that, on the contingency side, the appeal to design (rather than to cosmic chance) explains the general possibility and existence of purposive organisms in biology, as well as the preconditions for both. On the directionality side, the appeal to design (rather than to undesigned processes) explains how evolution is able to instantiate platonic "laws of form", which in turn enable convergence and subsequent evolutionary outcomes. Either way, the (resulting) complexity of biological organisms makes more sense from a design perspective than from a non-design perspective (Kojonen 2021, pp. 152–53, 194).[9]

In this fashion, then, Kojonen has argued that evolution and design are not mutually exclusive, but rather can be harmonized. Indeed, evolution actually needs design (in the form of precise preconditions and fine-tuned natural laws), so evolution is not simply compatible with design but actually *supportive* of it.

We hope this brief summary draws attention to the considerable strengths of *The Compatibility of Evolution and Design*. As mentioned, Kojonen's treatment is nuanced, thoughtful, clear, and fair-minded. It is a model of fine scholarship and deserves serious attention in current and future discussions of the relationship between design and evolutionary theory.

Even so, we have significant concerns. We explore these in Sections 4–7 below.

3. Why Scientific Evidence Is Crucial

But first, the issue must be framed in the proper way. In particular, one must be clear about what Kojonen needs to do to succeed. In this section, we argue that, although KEBDA is *philosophical* argument, it nonetheless rises or falls in part on *scientific* evidence. In order to successfully harmonize 'design' and 'evolution', Kojonen needs to show that his case for design is strong and does not conflict with his acceptance of evolution. In Sections 4 and 5, we will argue that Kojonen's argument for design is scientifically implausible and also in tension with evolutionary theory. As a result, KEBDA is fundamentally flawed. For the moment, however, we contend that Kojonen's philosophical reconciliation of evolution and design hinges in part on scientific data, whatever that data happen to be.

3.1. Design and the "Preconditions" of Evolution

As mentioned, Kojonen attempts to show that the conjunction of 'design *and* evolution' has greater explanatory merit than 'evolution' alone. Given his particular version of design, Kojonen must show that 'evolution *and* empirically-detectible biological design that came about without divine intervention' help explain life in a way that 'evolution' on its own does not. He must show that this type of 'design' adds something helpful. Kojonen sees all of this clearly (Kojonen 2021, pp. 149–56). KEBDA is his attempt to rise to this challenge.

How does Kojonen go about this daunting task? In chapter four, Kojonen marshals various arguments to show that the *preconditions* of evolution must be designed if evolution is to be successful (as he believes it to be).[10] The deck must be stacked in advance. In particular, fitness landscapes must be finely tuned ahead of time in order for evolutionary processes to successfully produce biological complexity and diversity. Kojonen believes that it is implausible to think that evolutionary processes can account for flora and fauna *without* these special preconditions. To make his case, Kojonen cites the work of Andreas Wagner, William Dembski, and others on protein evolution, evolutionary algorithms, structuralism, and the like. For Kojonen, these thinkers' arguments powerfully show that evolutionary processes need prior "fine-tuning" of fitness landscapes (Kojonen 2021, pp. 97–143, esp. pp. 109–23). Thus, 'evolution and design' is superior to 'evolution alone'.

But two problems bubble up with Kojonen's depiction of design. The first is that scientific evidence strongly indicates that fitness landscapes are not "fine-tuned" in the way required by Kojonen's model. The work of ID theorists Douglas Axe, Ann Gauger, Stephen Meyer, and others is especially relevant in this regard (Axe 2000, 2004, 2016; Meyer 2009, 2013, 2021; Gauger et al. 2010; Gauger and Axe 2011; Reeves et al. 2014). We will analyze this research (and Kojonen's response) in the next section. Our basic argument will be that, on Kojonen's view, one of the key ways that 'design' adds explanatory value to 'evolution' is by setting up fine-tuned fitness landscape that enable evolution to search and find biological forms.[11] But if empirical evidence indicates there are *no* such landscapes, then Kojonen's conception of 'design' is poorly grounded and, thus, has little explanatory benefit to add to evolution.

The second problem also concerns Kojonen's case for design. He supports his case by citing biological phenomena that, upon closer inspection, actually display a *type* of design that is incompatible with mainstream evolutionary theory. This harms his philosophical attempt to harmonize 'design' and 'evolution'. In particular, Kojonen cites the bacterial flagellum, a molecular propulsion apparatus that propels bacteria through liquid. Yet, as we will argue, the type of design found in the flagellum runs contrary to evolutionary theory, which (again) hampers Kojonen's attempt to harmonize 'design' and 'evolution'. We will examine the bacterial flagellum (and Kojonen's response) in more detail below.

Thus, in summary, the landscape is as follows: in order for Kojonen to succeed at showing that the conjunction of 'evolution and design' is explanatorily superior to 'evolution' alone, he needs to show that adding 'design' increases evolution's explanatory value in a way that offsets the liability of violating Ockham's razor. Two explanatory entities are better than one only in certain conditions. What kind of 'design' does Kojonen believe fits these conditions? The kind of design he has in mind is the type in which God created the laws of nature, which ultimately lead to fine-tuned "preconditions" (including smooth fitness landscapes) that enable evolution to occur. Kojonen gives several lines of evidence for this view, including research on fitness landscapes, the bacterial flagellum, evolutionary algorithms, structuralism, convergence, and so on. His task is to show that this evidence makes his view of 'design' sufficiently robust and plausible to add explanatory merit to 'evolution'.

By way of response, we will focus on the critical question of whether Kojonen's articulation and justification of design is convincing. Though we do not have space to examine every line of evidence that Kojonen raises, we will analyze three key areas: fitness landscapes, the bacterial flagellum, and convergence.[12] With respect to these areas, Kojonen must accomplish the following: First, he must justify his empirical claim about fitness landscapes. Without smooth landscapes, his concept of 'design' cannot augment 'evolution' in a way that helps explain evolution's ability to search and find viable biological forms. 'Design' would thus add little explanatory value on this score. Second, Kojonen must show that the bacterial flagellum counts as evidence for 'design' but in a way that does not conflict with 'evolution'. If the flagellum manifests a type of design inconsistent with evolution, then, in effect, Kojonen would have accepted evidence that creates an internal tension in his conjunction of 'design and evolution'. Third, Kojonen must similarly show how convergence supports his view of 'design' in a way that also avoids conflict with 'evolution'. Thus, in sum, Kojonen needs to articulate and justify his conception of design in a way that augments the explanatory value of evolution rather than undercuts it.

We take up these matters in the next section. But before doing so, it is crucial to realize that the point of our (upcoming) scientific analysis is *not* to criticize evolutionary theory per se. Although we believe that the scientific evidence in question counters mainstream evolution, we nonetheless set this aside for the sake of the argument. Instead, our criticisms are aimed at Kojonen's conception of *design*. We will contend that he does not offer sufficient empirical support for it—and so it adds little explanatory merit to 'evolution'—and that some of the evidence he does offer actually conflicts with his commitment to evolution. (Of course, it ought to be noted that, because Kojonen concedes that evolution needs the

help of design, our criticisms of his view of design have broader implications for whether evolution, as he understands it, can successfully produce biological complexity. But that particular implication follows from *his* way of framing the issue; it is not the focus of our argument itself.)

3.2. The Importance of Scientific Evidence

Why make such a big deal about scientific evidence? Here's why this point is worth emphasizing: in the face of scientific criticisms of Kojonen's model, proponents of Kojonen's view may be tempted to defend it in the following ways:

- Kojonen's proposal is a *philosophical* model, not a scientific one. Scientific evidence is of secondary importance.
- KEBDA is primarily an exercise in harmonizing two distinct views ('design' and 'evolution'), not in the evaluation of the empirical evidence for these views, whether individually or jointly.
- Kojonen's model shows that evolution and design are compatible, whatever the scientific details may be. Having established this harmony, it is now just a matter of working out the details over time.

It is true that KEBDA is a philosophical argument. And, of course, the conceptual and epistemological elements of the argument are important. But some philosophical arguments also depend in part upon scientific evidence. In this case, much depends on whether there is a good case for fine-tuned preconditions and suitable fitness landscapes (as Kojonen envisions them). Indeed, Kojonen situates design precisely in those fine-tuned preconditions which yield smooth fitness landscapes that allow evolution to succeed. His case for marrying design with evolution therefore depends on the existence of this fine-tuning. So, it is crucial to assess whether this fine-tuning is real. And this question can be assessed scientifically: are fitness landscapes smooth? Are there open pathways between functional proteins, for example? Or are there impassible barriers between such proteins?

Scientific data are also crucial to assessing the internal harmony of Kojonen's conjunction of 'design and evolution'. For example, do empirical studies show that the bacterial flagellum embodies a type of design that is in tension with Kojonen's acceptance of evolution or not?

These empirically oriented questions help determine whether Kojonen's conception of 'design' adds explanatory value to 'evolution' in a way that makes his model plausible. This is why scientific evidence is essential to assessing Kojonen's 'philosophical' design argument. Philosophically, KEBDA has many strengths indeed. But the great temptation here is to think that its philosophical merits carry the day, and that KEBDA is basically a success because of its impressive conceptual and epistemological content. (Having said that, we do have significant epistemological concerns, which we will explain in Section 7 below.) Yet in any case, if the scientific data do not support KEBDA, then it suffers a serious blow. It struggles to meet its own standard of showing that 'design and evolution' are superior to 'evolution' alone.

So, what do the scientific data indicate?

4. Scientific Problems for Kojonen's View of Proteins

Unfortunately, the scientific evidence runs strongly contrary to KEBDA. In what follows, we argue that empirical challenges posed by Axe, Gauger, Meyer, and others severely damage Kojonen's account of design. In Section 5, we contend that research on the bacterial flagellum likewise raises difficulties for Kojonen's reconciliation of design and evolution. If we are correct, then the scientific details—so important to the justification of Kojonen's model—damage the central thesis of his book.

First, we begin with proteins, which are the subject of the research of Axe and others.

4.1. Rarity and Isolation of Proteins

4.1.1. The Work of Andreas Wagner

As noted, Kojonen proposes that divinely created laws of nature ultimately gave rise to "preconditions", a "library of forms", and the like, which eventually enabled natural selection and random mutation (and other natural processes) to produce all manner of flora and fauna. With this preset advantage, evolutionary processes can find viable biological forms, including—most notably—new proteins.[13] The key question, then, is whether there is good empirical evidence that proteins (or 'primitive' proteins of whatever kind) can evolve into other proteins, including into more complex proteins. Or are viable proteins too different to allow an evolutionary transition from one to another? Following Wagner (2014, p. 100), Kojonen notes that if "viable protein forms" are like "stars in our universe, islands separated by vast expanses of dark empty space", then "we would be in the situation described by . . . ID proponents, and evolution by natural selection would be impossible" (Kojonen 2021, p. 121). So, are proteins isolated from each other? Or are they connected by evolutionary bridges?

To his credit, Kojonen acknowledges that the weight of empirical evidence affirms that functional proteins are often exceptionally rare—an exceedingly small percentage of amino acid sequences in sequence space fold into complex three-dimensional structures that can perform biological tasks (Kojonen 2021, pp. 119–20). (Sequence space is the multi-dimensional map of all possible amino acid sequences.[14]) Finding a viable protein sequence is akin to finding a needle in a haystack. Yet Kojonen then argues that protein rarity is not a barrier for evolution because functional proteins are sufficiently close to each other in sequence space such that one protein could plausibly transform into another. He argues that, because of the fine-tuning of natural laws, there are otherwise unexpected functional pathways through sequence space to link up functional amino acid sequences such that one protein sequence could traverse to another through sequence-space via evolutionary mechanisms. Proteins might be *rare*, but they are not *isolated*. There is a proverbial cluster of needles lumped together in the haystack: when one is found, another is close at hand.

Kojonen states:

> If functional forms are close to one another, then producing a new protein form or function would not require evolution to search through the entire vast realm of all possible arrangements of amino acids. Rather, evolution would only need to search through the adjacent space of possible forms to find viable new forms. This is a far easier task, and if functional forms are arranged in such a way, then this would explain how evolution is possible despite the rarity of functional forms. (Kojonen 2021, pp. 120–21)

Kojonen justifies this assertion by citing the research of Andreas Wagner (and his team).[15] Wagner claims to have demonstrated that proteins can evolve into one of their nearest neighbors through a tractable number of mutations. Every protein in biology is thus interconnected through a continuous series of traversable steps.

4.1.2. Limitations of Wagner's Research

Yet Wagner's research is significantly limited. In particular, Wagner never directly studied the feasibility of one protein evolving into another. Instead, he compared the metabolic pathways of different organisms and identified enzymes (a type of protein) that are present in multiple pathways, and he also identified enzymes that are missing (Rodrigues and Wagner 2009). In addition, Wagner studied how mutations can change the regulatory regions of proteins to alter when (and to what extent) proteins are expressed (Aguilar-Rodríguez et al. 2017, 2018; Oxford Academic 2017). Wagner argued that such changes could direct proteins to enter or leave metabolic pathways. But he did not study the more fundamental question of the plausibility (or implausibility) of the evolutionary origin of proteins in the first place.

To be sure, Wagner has performed notable research that bears some (limited) relevance on protein evolvability. For example, in addition to the studies above, he surveyed numerous proteins' relative locations in sequence space (Ferrada and Wagner 2010). He identified which proteins with the same structures perform different functions and which functions could be performed by proteins with different structures. He also tallied the functions performed by proteins in pairs of local regions in sequence space, noting these regions' specific sizes and distances from each other. In addition, he mapped the percentage of functions performed in paired local regions as a function of the regions' size and separation (i.e., amino acid differences) (Ferrada and Wagner 2010). Based on this analysis, Wagner extrapolated the conclusion that mutations could change a protein (with a particular function) into another protein (with a different function) in the same region. In Wagner's view, this allowed proteins to evolve in organic history. Yet again, he did not actually empirically demonstrate that such transformations were ever possible. Instead, he simply mapped interesting correlations between protein sequences, functions, and structures.

In fact, Wagner's own research suggests that protein evolution is exceedingly difficult. He acknowledged, for example, that many proteins correspond to extremely rare sequences. Moreover, he identified highly separated regions of sequence space where the proteins in the different regions possessed *different* structures and performed *different* functions. This observation suggests that many proteins are not simply rare but also isolated—they are strikingly different from all other proteins in distant regions of sequence space. Wagner did not demonstrate that a series of short steps (or smooth evolutionary pathways) connect these distinct types of proteins. Even if mutations might transform *some* proteins into other close-at-hand proteins—which Wagner did not show—his own data strongly indicate impassable chasms between many other types of proteins. To borrow Wagner's metaphor: many proteins appear to be separated from each other like stars in the universe.

4.1.3. Axe, Gauger, and Others on Protein Rarity and Isolation

Though Wagner's own research is insufficient to answer whether natural processes can give rise to proteins, *other* scientific research does address this question. This research strongly indicates that proteins are rare and isolated, and that viable evolutionary pathways between them are highly unlikely.

To appreciate the centrality of this problem, consider, first, the importance of proteins to life on earth. The advent of new complex proteins occurs in major transformations throughout organic history. These transformations include the origin of life, the origin of eukaryotic cells, the origin of complex animal body plans, and the origin of new plant phyla. Each of these events requires the genesis of highly complex novel proteins (Hutchison et al. 2016; Paps and Holland 2018; Heger et al. 2020). So, explaining biological complexity and diversity requires explaining the origin of *many* new complex proteins.

Second, empirical evidence indicates that proteins are rare, isolated, and difficult to achieve by evolutionary means. Kojonen's own way of framing the matter helps make this clear. He writes:

> The more crucial point that needs to be made in response [to Axe et al.] is that what matters is not just the rarity of functional forms, but also their closeness in the "biological hyperspace" of functional forms, meaning the "distance" in mutations that is required to traverse between these forms. (Kojonen 2021, p. 120)

So, in Kojonen's view, a "crucial" issue is the "distance" in mutations from one functional protein to another. That is, protein evolution hinges in part on how many mutations must be changed to produce a new function, the rate at which mutations can occur, the probabilities of the required number of mutations arising in the amount of time available, and the like. Current research provides striking data on this score. For example, Axe (2010) performed a population genetics study which found that when a feature requires more than six mutations before giving any benefit, this feature is unlikely to arise in the whole history of the Earth—even in the case of bacteria that have large population sizes and rapid generation times. Additional research by Gauger and Axe (2011)

found that merely converting a particular metabolic enzyme to perform the function of a closely related enzyme—the kind of conversion that evolutionists claim can readily happen—would require *a minimum of seven* mutations. Yet this exceeds the limits of what Darwinian evolution can produce over the Earth's entire history, as calculated by Axe (2010). A follow-up study by Gauger, Axe, and biologist Mariclair Reeves bolstered this finding by attempting to mutate additional enzymes to perform the function of a closely related protein (Reeves et al. 2014).[16] After inducing all possible single mutations in the enzymes, and many other combinations of mutations, they found that evolving a protein to perform the function of a closely related protein would take over 10^{15} years—over 100,000 times longer than the age of the Earth. Collectively, this research indicates strong barriers to protein evolution, and that evolving a protein from a *similar* protein often requires more time (and mutations) than is available. Evolutionary processes simply have neither the time nor resources to 'search' and find the right mutations to produce even a basic transformation, much less the hundreds of thousands of transformations necessary to produce all known proteins in organisms on Earth. Once again, viable proteins appear to be as isolated as stars in the universe.

Moreover, the empirical data on protein rarity poses a *quantifiable* challenge to KEBDA. Several studies demonstrate that, for many proteins, functional sequences occupy an exceedingly small proportion of physically possible amino acid sequences. For example, Axe (2000, 2004)'s work on the larger beta-lactamase protein domain indicates that only 1 in 10^{77} sequences are functional—astonishingly rare indeed. Such rarity presents prima facie evidence that many proteins are very difficult to evolve by a blind evolutionary process of random mutation and natural selection.

Of course, a common rejoinder to this data is to claim that 'protein rarity' is only true for select proteins; many others are not so rare. That is, many proteins might have sequences with functions that are more common in sequence space and are thereby easier to evolve. As Kojonen (2021, p. 119) puts it, "others argue that functional proteins are much more common". He specifically cites Tian and Best (2017) as a rebuttal to Axe (2004) on this point. Similarly, Venema (2018) objects to Axe (2004)'s research because he believes "functional proteins are not rare within sequence space". Importantly, Kojonen is correct that some proteins are easier to evolve than others, and this point is pressed by some scientists[17]—but nonetheless, a very large proportion of proteins seems beyond the reach of mutation and selection.

Indeed, Tian and Best (2017) present much data that actually support Axe's general thesis for protein rarity. They reported that the functional probabilities for ten protein domains range from 1 in 10^{24} to 1 in 10^{126}. Yet even if we grant generous assumptions towards evolution, additional research indicates that only three of the ten domains studied by Tian and Best could have possibly emerged through an undirected evolutionary search of sequence space. Specifically, Chatterjee et al. (2014) calculated that there are at most 10^{38} trials available over the entire history of life on Earth to evolve a new protein. Therefore, if a protein domain has a probability of less than 10^{-38}, then it is unlikely to emerge via a process of random mutation and natural selection. Seven of the ten domains studied by Tian and Best (2017) had probabilities below 10^{-38}. Thus, even though Kojonen (2021, p. 119) cites Tian and Best (2017) to argue that the "specificity required for achieving a functional amino acid sequence" may be less for some proteins, their research provides strong empirical evidence that many proteins have functional sequences that are so rare as to be beyond the reach of standard evolutionary mechanisms.

Kojonen (2021, p. 119) also cites Taylor et al. (2001) to counter (or mitigate) Axe's results on protein rarity. Taylor et al. (2001) reported that the probability of evolving a chorismate mutase enzyme is 1 in 10^{23}, which Kojonen (2021) takes to suggest that functional protein sequences can be "more common than in the case of the protein studied by Axe". Yet the fact that chorismate mutase represents less rare sequences is unsurprising given that its function requires a simpler fold than typical enzymes such as beta-lactamase studied by Axe (2004).[18] Could chorismate mutase evolve? If it could, this still does not

demonstrate the feasibility of Kojonen's thesis: the possibility that *some* simpler proteins could evolve does not mean that *all* (or even most) more complex proteins could evolve. But for KEBDA to succeed, evolutionary mechanisms must be up to the task in all cases, not just some.

The possibility of evolving relatively simpler proteins, however, raises another objection. Hunt (2007) asks: If a simple protein could evolve in the first place, might it also evolve further into a more complex protein? More specifically, if one assumes that a comparatively simple protein such as chorismate mutase could evolve, why could it not also evolve into a more elaborate protein, including one with a functional sequence that is as rare as those studied by Axe?[19] Like Kojonen, other thinkers (e.g., Hunt 2007; Venema 2010; Matheson 2010) have argued that rarity in sequence space does not necessarily imply *isolation* in sequence space to a degree that would pose a barrier to evolution.[20] This line of thinking accepts (or allows) a continuous path of functional sequences from a simple protein to a more complex protein. Under this view, even if proteins are rare, they are (or could be) clustered together. As such, the mutation-selection mechanism would not need to search a large region of sequence space; it would only need to find the continuous pathways close at hand.

Yet a simple analogy shows why this objection is wrong. Imagine a spacecraft lands on the north pole of a planet, and the astronauts wish to drive to the south pole. Their ability to do so depends on the percentage, p, of the planet's surface that is navigable. If p is 70.0%, a continuous path likely exists between the poles. If p is 0.1%, a path most likely would not exist. The lower the percentage, the less likely a path.

Let us now consider how this analogy would apply to the evolution of new proteins. The rarity of the beta-lactamase domain studied by Axe (2004) would correspond to a planet the size of our entire galaxy, and the total amount of navigable land would correspond to the surface area of an atom. If we extend our analogy to a protein whose rarity is 1 in 10^{23}, this would still be akin to a planet the size of Jupiter with a total area of traversable land the size of a postage stamp.[21] A navigable path from one pole to the other would almost certainly not exist. In other words, even for the protein that Kojonen claims has a sequence probability that is "more common", the possibility of a continuous functional path leading from it to a typical protein is exceedingly remote.[22]

Complex proteins appear to be overwhelmingly isolated, including from simple amino acid sequences that can perform basic functions. Collectively, the data show that proteins of typical complexity are beyond the reach of natural selection, random mutation, and other standard evolutionary mechanisms.

4.2. The State of the Field

Stepping back, broader trends in the field of protein science have confirmed this formidable picture. In particular, protein evolution studies have consistently demonstrated that the evolvability of complex proteins is highly constrained, contrary to evolutionary expectations. Consider, for example, the perspective of Dan Tawfik, a leading researcher in this field until his recent death. Tawfik (2016) summarized the field as follows:

- An enzyme could only be altered experimentally to perform a new function if its structure and active site were not substantially changed. Such "micro-transitions" could never accumulate to transform an enzyme into something fundamentally different.
- Proteins in different superfamilies have no connection to those in other superfamilies in terms of their sequences and structures. The different superfamilies represent "isolated galaxies". (A "superfamily" is one of the broadest categories under which one can group similar proteins.)
- Researchers have "zero knowledge" of how the superfamilies are related or could have originated.

Yet an even more compelling result from Tawfik's own research shows the isolation of fundamentally different protein structures, called "protein folds".[23] (The generation of a

stable "protein fold" is a necessary condition for protein function.) Tawfik's experiments showed that between 3 and 15 mutational changes destroyed the structural and thermodynamic stability of numerous kinds of protein folds (Tokuriki and Tawfik 2009; Tokuriki et al. 2007; Meyer 2021, pp. 319–20). But to transform a given protein fold into another one requires *many more* than just 15 mutations. Thus, as mutations accumulate, they will destroy the stability of a protein fold *long before* a novel protein fold arises. In short, degradation occurs more rapidly than innovation. This implies that there are no evolutionary pathways between fundamentally different protein folds. Mutating one stable protein fold into another generates thermodynamically unstable intermediates. These intermediates cannot perform any function and thus will not be preserved by natural selection. This experimental result once again highlights the isolation of viable protein structures from each other.

Tawfik himself operated within the philosophic framework of scientific materialism, so he simply assumed that novel proteins must have evolved through some undirected evolutionary process. He proposed models for their origin but acknowledged that he could not justify the plausibility of any of these models. In an article for the American Society for Biochemistry and Molecular Biology, molecular biologist Rajendrani Mukhopadhyay interviewed Tawfik, who said:

> "Once you have identified an enzyme that has some weak, promiscuous activity for your target reaction, it's fairly clear that, if you have mutations at random, you can select and improve this activity by several orders of magnitude", says Dan Tawfik at the Weizmann Institute in Israel. "What we lack is a hypothesis for the earlier stages, where you don't have this spectrum of enzymatic activities, active sites, and folds from which selection can identify starting points. Evolution has this catch-22: Nothing evolves unless it already exists." (Mukhopadhyay 2013)

Currently, the field of protein evolution lacks plausible, solid hypotheses about how natural processes transformed random sequences of amino acids (peptides) into the sophisticated entities that we recognize today as proteins. Until that happens, the origin of proteins will remain, as Tawfik says, "something like close to a miracle" (Mukhopadhyay 2013).

In the end, evolving new proteins is quite difficult to envision under known laws of nature. This is because a continuous path of functional sequences in sequence space is not plausible—primarily due to both the rarity of functional sequences and the isolation of proteins with entirely different structures and functions. A key point here is that extremely rare functional sequences entail *isolation* in sequence-space. This hurdle poses a fundamental challenge to Kojonen's thesis that nature was designed to evolve life. Proteins, like stars, are separated by vast distances.

Recall that Kojonen himself noted that if "viable protein forms" are like "stars in our universe, islands separated by vast expanses of dark empty space" then "we would be in the situation described by . . . ID proponents, and evolution by natural selection would be impossible" (Kojonen 2021, p. 121). This is exactly what the empirical evidence indicates.

Yet the point here is not to criticize evolutionary theory—although clearly, there are formidable problems with Kojonen's understanding of protein evolution. Instead, for present purposes, our target is Kojonen's account of *design*. Recall that, in his proposed model, preconditions (and smooth fitness landscapes) are fine-tuned so that evolution can successfully search and build viable biological forms. Yet empirical evidence shows that no such preconditions or fine-tuned fitness landscapes exist. Kojonen's view of design is, thus, at odds with the data itself. As such, it is poorly situated to add explanatory value to evolution.

5. Scientific Problems for Kojonen's View of the Bacterial Flagellum

Recall our earlier (brief) discussion of the famed bacterial flagellum, a microscopic rotary engine that helps propel bacteria through an aqueous environment. Kojonen believes that the flagellum actually *strengthens* his model. He holds that the complexity of the flagellum shows that there must be fine-tuned "preconditions" that ultimately point to

design in the laws of nature (Kojonen 2021, p. 122). The bacterial flagellum not only indicates design, but Kojonen believes it does so in a way that is fully compatible with mainstream evolutionary theory. He contends that the organelle arose by a stepwise process of exaptation and so is fully consistent with evolution. All told, then, the flagellum not only fits with evolution but *also* bolsters the case for design. Thus, in Kojonen's hands, the bacterial flagellum shows that 'evolution and design' is better than 'evolution' alone.

We will argue below, however, that *type* of design embodied in the bacterial flagellum is incompatible with mainstream evolutionary theory. This harms Kojonen's philosophical attempt to harmonize 'design' and 'evolution'. In effect, Kojonen's conjunction of 'evolution and design' is at odds with itself: one of the conjuncts undermines the other. That is, the bacterial flagellum provides evidence of 'design' in a way that damages 'evolution'. To show this, we first define "irreducible complexity". Next, we illuminate the underlying engineering and design principles of the bacterial flagellum, showing its astonishing complexity. Third, we raise problems with Kojonen's account of the bacterial flagellum, arguing that its particular design contradicts evolutionary theory. This analysis shows, once again, that the scientific details do not support Kojonen's model, and that it is internally conflicted in a significant way.

5.1. Irreducible Complexity Defined

An initial definition will start matters. In his 1996 book, *Darwin's Black Box*, biochemist Michael Behe defines "irreducible complexity" as follows:

> In *The Origin of Species* Darwin stated: "If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down". A system which meets Darwin's criterion is one which exhibits irreducible complexity. By irreducible complexity I mean a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning. (Behe 1996, p. 39)

Behe provides a mousetrap illustration that is helpful in this regard. He notes that a mousetrap is an irreducibly complex system: it is composed of five parts (a platform, spring, hammer, catch, and trigger), each of which is essential for the trap to work. A mousetrap with 80% of the parts does not catch 80% as many mice. Without a hammer, for example, the trap catches *no* mice. It simply does not work. *All* parts have to be in place for the trap to be functional.

The Irreducible Complexity Argument in a Nutshell

Behe's broader argument is that IC systems are best explained by a mind rather than by mindless physical processes. We know from our repeated experience that intelligent agents create irreducibly complex systems—they can bring together an array of parts in order to achieve a particular outcome, whether that be a radio to catch soundwaves or a rocket ship to travel to space. By contrast, we know that stepwise physical processes, such as natural selection, must move towards immediate function (or else they wander stochastically, or perhaps even fail). For a process like natural selection to build some new feature, *each* step must confer a functional advantage that enhances the organism's survival and reproduction. If not, the step is "blind" to natural selection, and there is no selective way to pass the trait on to the next generation. So, in human experience, gradual natural processes do not produce IC systems. But intelligent agents do. Thus, intelligent agency is a superior explanation for the origin of irreducibly complex systems.

Of the many examples of irreducible complexity that Behe cites, the most prominent is the bacterial flagellum. This organelle is a "true rotary engine" (Minnich and Meyer 2004) that propels a bacterium through liquid by rapidly spinning a whip-like tail. It operates much like an outboard motor. Indeed, both comparative biology and knockout experiments on the flagellum show that it requires many coordinated protein parts in order to function

(Macnab 1987; Pallen and Matzke 2006). A machine of this intricacy—in which all essential parts must be in place prior to any function—requires explanation. Kojonen sees the power of Behe's argument:

> Since the core function of an irreducible complexity emerges only after all necessary parts are in place, it cannot plausibly be evolved in this direct way. After all, natural selection cannot select for a function that emerges only after all of the parts are in place, because selection cannot look to the future. Instead, the gradual evolution of the parts of a system like the flagellum would have to be favored by natural selection for some other reason, not because of increases in mobility. (Kojonen 2021, pp. 116–17)

Moreover, Kojonen acknowledges that even the claim of "indirect" evolution of the bacterial flagellum faces severe challenges and would even require some measure of "serendipity":

> Behe admits that an irreducibly complex system could in principle evolve in the tinkering, indirect fashion that Behe's critics point to. However, he claims that, as the complexity of the system increases, the probability of such evolutionary accounts decreases. Because the proteins must fit together, the parts must be modified before serving in the new function. Thus, "analogous parts playing other roles in other systems cannot relieve the irreducible complexity of the new system; the focus simply shifts from 'making' the components to 'modifying' them" (Behe 2006, pp. 112–13). Orr (1996), who is otherwise critical of Behe's work, surprisingly agrees with this criticism: "we might think that some of the parts of an irreducibly complex system evolved step by step for some other purpose and were then recruited wholesale to a new function. But this is also unlikely. You may as well hope that half your car's transmission will suddenly help out in the airbag department. Such things might happen very, very rarely, but they surely do not offer a general solution to irreducible complexity". Here, the appeal to our common human experience of designing things supports the inference that creating complex teleological order is difficult. There is, indeed, quite a bit of serendipity in parts useful for one purpose being so easily adaptable to another role. (Kojonen 2021, pp. 117–18)

How does Kojonen rise to the challenge? In the main, he cites protein homology, co-option (or exaptation), and protein evolvability. We will analyze each of these below.

But to appreciate the *type* of design manifest in the flagellum—and whether or not it is compatible with evolution, as Kojonen believes it to be—let us first consider the exquisite characteristics of this organelle.

5.2. The Exquisite Bacterial Flagellum

5.2.1. General Features

Harvard biologist Howard Berg has deemed the bacterial flagellum "the most efficient machine in the universe" (quoted in Dembski 2004, p. 324). It is not difficult to see why. It is a true machine, having some 35–40 protein parts, each of which has an individual function, and which together perform an integrated function—complete with short-term memory, self-assembly, and an efficiency that surpasses human engineering. The flagellum has a highly efficient proton-powered rotary engine that operates at up to 100,000 rpm. It is one of the best understood molecular machines in science (Minnich and Meyer 2004).

5.2.2. The Engineering Logic of the Bacterial Flagellum

The engineering logic of the bacterial flagellum has been detailed by engineer and computer scientist Waldean Schulz (2021a, 2021b, 2021c). He has demonstrated that rotary propulsion requires several tightly integrated systems: a flagellar motor and a filament, part delivery mechanisms, an assembly process, and a navigation system. Each is essential

for the flagellum to function, each is composed of multiple proteins, and each must meet very tight constraints dictated by an overarching design logic.

Subsystems of the flagellum include:

- A rotary engine with stators that generate greater torque in more viscous environments using an ingeniously engineered adaptive response strategy. The motor also has a clutch to suspend propulsion when doing so is advantageous (National Science Foundation 2008; Guttenplan et al. 2010).
- A propellor-like filament (Ikeda et al. 1996).
- Maintenance processes for the motor and filament (Schuhmacher et al. 2015; Ribardo et al. 2019; Zhuang and Lo 2020).
- An assembly process that incorporates an export gate which moves target proteins outside the bacterium in the right amount at the right time to construct the hook and filament (Waters et al. 2007; Minamino et al. 2014; Tan et al. 2021).
- Processes that suspend operations and eject flagellar proteins in threatening or low-nutrient environments as a form of risk management (Ferreira et al. 2019; Nedeljković et al. 2021).
- Chemotactic navigation that employs sensors which send a chemical signal to the motor to change direction when the bacterium is moving in a direction that is not favorable (Hamadeh et al. 2011; Othmer et al. 2013).

Numerous articles have been written on the ingenuity of each of these mechanisms, some of which have even served as models for human innovation (Mohammadi et al. 2017; Jiang et al. 2021; Tachiyama et al. 2022). One biologist observed that, " . . . the flagellum is so well designed and beautifully constructed by an ordered assembly pathway, even I, who am not a creationist, get an awe-inspiring feeling from its 'divine' beauty" (Aizawa 2009).

Recall Kojonen's earlier statement that the "crucial" issue concerning the evolution of proteins turns on "mutations", including the number, timing, and rate needed to traverse from one functional protein to another. The challenge increases dramatically when assessing the origin of even one of the essential flagellar subsystems. For instance, undoubtedly, many mutations would be required for the 'evolution' of the flagellum's navigation system (aka chemotaxis). To yield a functional system that provides an advantage to the organism, either all of these mutations would have to occur simultaneously—akin to a miracle—or each mutation (or set of mutations) would have to confer a functional advantage (or at least inflict no harm) at every step toward a fully operational system. Of particular note, the proteins composing the navigation system serve no other purpose in the bacterium, nor do they closely resemble any other proteins (see below). A partially materialized propulsion/navigation system, on the other hand, would not simply be "neutral" but rather disadvantageous to the cell given that the production of malformed proteins or some non-functional system would require energy to produce, yet would provide no offsetting benefit. In fact, because useless parts or proteins provide no advantage to the organism, they would likely be quickly degraded if not deleted (Gauger et al. 2010).

More generally, a plausible evolutionary explanation of the bacterial flagellum must explain not just the flagellum-chemotaxis propulsion/navigation system but its array of other characteristics, including its delivery system of individual parts, maintenance cycle, feedback loops, and performance efficiencies. In particular, indirect evolutionary accounts (such as co-option or exaptation) must explain how the 35–40 protein parts of the flagellum evolved from parts that originally served different functions in the cell. It must also account for their assembly instructions. The insurmountable barrier to any scenario is the numerous tight constraints identified by Schulz (2021a, 2021b, 2021c) that must be met before the system could function at all. Recall H. Allen Orr's assessment of co-option (cited by Kojonen above):

> We might think that some of the parts of an irreducibly complex system evolved step by step for some other purpose and were then recruited wholesale to a new function. But this is also unlikely. You may as well hope that half your car's transmission will suddenly help out in the airbag department. Such things

> might happen very, very rarely, but they surely do not offer a general solution to irreducible complexity. (Orr 1996)

So, just how does co-option plausibly explain the origin of the most efficient machine in the universe?

5.3. Indirect Evolution, Co-Option, Exaptation

Kojonen takes the challenge of irreducible complexity head-on. He frames the problem as follows:

> Draper (2002) homes in on the crucial question: Are the requirements for each individual part really as strict as Behe claims? If biological parts are more malleable than Behe assumes, so that less specificity is required for fulfilling their roles, then Behe's argument against co-option fails. Debunking Behe's argument, then, depends on the details of how proteins work and how difficult it is to transition from one form to another, somewhat similar, form. Then, a continuous series of functional forms, leading from no flagellum to a flagellum, must exist so that no change is too large for natural selection to cross, and all modifications can be made. As with Dembski's argument, it does seem plausible that evolving such complex systems is difficult, and the existence of such an evolutionary pathway has stringent conditions. But difficult or not, it is possible that nature does allow it. Behe thinks that the existence of such pathways is unlikely, but the existence of such pathways is fundamentally an empirical question.[24] (Kojonen 2021, p. 118)

Notice two key elements of this passage. First, Kojonen states that the matter is "an empirical question". Indeed, it is. Once again, the scientific details are paramount. Is there evidence of smooth evolutionary pathways between viable forms or not? This is a fundamentally scientific question. Kojonen's model hinges in part on empirical evidence.

Second, Kojonen also states that "[d]ebunking Behe's argument, then, depends on the details of how proteins work and how difficult it is to transition from one form to another, somewhat similar, form". So, Kojonen believes that successfully countering Behe's argument depends on how proteins work and the prospects for a protein-to-protein transformation. This makes sense. The flagellum, for example, is made of protein parts. The function of each part, as well as the likelihood of a given part evolving into its present form from an ancestral form, is highly relevant. In short, Kojonen believes that his counter to Behe—an attempt to show that the flagellum's 'design' is compatible with mainstream 'evolution'—rests upon the plausibility (or implausibility) of protein evolution.

This is significant. We have already examined strong evidence against fine-tuned preconditions and fitness landscapes that are 'designed' to enable proteins to evolve. *This means that the calculations above (Section 4) directly impact the viability of Kojonen's response to Behe*. If these calculations are correct, then it is safe to say—by Kojonen's own lights—that he has not met the challenge of irreducible complexity. The flagellum, thus, appears to display a type of design that conflicts with evolution. Thus, to the extent that Kojonen accepts the bacterial flagellum as evidence of 'design', he faces an internal coherence problem for his conjunction of 'design and evolution'.

5.3.1. Co-Option on Its Own Terms

Having raised this crucial challenge to Kojonen's reply to Behe, we will now take co-option *on its own terms* for the sake of argument. Yet even on these terms, it still fails to be plausible. Kojonen cites authorities that invoke exaptation (also called "co-option" or "indirect evolution") to explain the evolutionary origin of the bacterial flagellum. Under this model, evolution proceeds by borrowing parts from different systems, retooling them to change their functions, and then combining them into a new system to perform a new function. Philosopher Angus Menuge lists five elements that any co-option account must provide to explain an irreducibly complex system:

(1) Availability of parts.
(2) Synchronization, in which parts are available at the same time.
(3) Localization, in which parts are available at the same location.
(4) Coordination, in which part production is coordinated for assembly.
(5) Interface compatibility, in which parts are "mutually compatible, that is, 'well-matched' and capable of properly 'interacting'". (Menuge 2004, pp. 104–5)

Typically, exaptation or co-option accounts do not explain anything beyond part of element (1). In this vein, Kojonen claims that 90% of flagellar parts have homologues that perform functional roles outside the flagellum. As we will see, this is an inaccurate claim—and co-option/exaptation accounts of the evolution of the flagellum face this and additional obstacles.

5.3.2. Problem 1: Confusing Sequence Similarity with an Evolutionary Pathway

In the context of biochemical evolution, the primary evidence for homology between two proteins is typically said to be similarity between amino acid sequences. An initial mistake made by proponents of co-option is therefore to confuse sequence similarity between two proteins with evidence for an evolutionary pathway. Even if other systems have proteins similar to each component of an irreducibly complex system, at most, this suggests homology, which might reflect common ancestry. Mere sequence similarity does not constitute a stepwise evolutionary explanation. Kojonen seems to miss this important nuance. He states that "parts of the flagellum are similar (or homologous) to parts that have other uses, and this gives grounds for constructing a plausible evolutionary explanation for its evolution" (Kojonen 2021, p. 117). He also writes, "The existence of similar parts in other systems, for example, does provide supporting evidence for evolvability" (Kojonen 2021, p. 118). But similarity does not itself indicate a viable evolutionary pathway. As Behe explains:

> Although useful for determining lines of descent . . . comparing sequences cannot show how a complex biochemical system achieved its function—the question that most concerns us in this book. By way of analogy, the instruction manuals for two different models of computer put out by the same company might have many identical words, sentences, and even paragraphs, suggesting a common ancestry (perhaps the same author wrote both manuals), but comparing the sequences of letters in the instruction manuals will never tell us if a computer can be produced step-by-step starting from a typewriter . . . Like the sequence analysts, I believe the evidence strongly supports common descent. But the root question remains unanswered: What has caused complex systems to form?[25] (Behe 1996, pp. 175–76)

Behe points out that a single author (or mental agent) could be the cause of two different manuals. Accordingly, mere similarity is not evidence that *mindless* processes can bring about the system in question.

5.3.3. Problem 2: Overstating Protein Homology

But the problem runs deeper than incorrect reasoning about sequence similarity: many parts of the bacterial flagellum are *dissimilar* to parts of other biological systems. Thus, a second problem facing the co-option model of evolution is that biological parts are often unique and unavailable to be borrowed from other systems (Khalturin et al. 2009; Beiko 2011). But Kojonen claims this is not a problem for the flagellum:

> Though a complete evolutionary explanation for the bacterial flagellum is still missing, critics of Behe have argued that approximately 90% of the parts of the flagellum are similar (or homologous) to parts that have other uses, and this gives grounds for constructing a plausible evolutionary explanation for its evolution. The type III secretion system, for example, has been argued to represent a viable

> precursor system to the flagellum. (Musgrave 2004; Pallen and Matzke 2006). (Kojonen 2021, p. 117)

Kojonen cites two sources for his claim that 90% of flagellar parts are homologous to "parts that have other uses". (Presumably, he is referring to parts that exist elsewhere besides the flagellum itself.) But this claim is highly problematic. One of his sources, Musgrave (2004, p. 81), provides no comprehensive analysis of flagellar homologues but simply asserts, via citations to other sources, that "between 80 and 88 percent of the eubacterial flagellar proteins have homologs with other systems, including the sigma factors and the flagellins"—but those sources (discussed below) do not substantiate this claim. Kojonen's other source, Pallen and Matzke (2006), does provide a comprehensive study of flagellar proteins that are homologous to other proteins, but they too do not substantiate a claim that "90%" of flagellar proteins are homologous to proteins outside of the flagellum.

According to Table 1 of Pallen and Matzke (2006), 15 of the 42 flagellar proteins they studied did not have known homologues.[26] So, at best, they only identified homologues for only about 64% of the flagellar proteins they studied (27 out of 42)—significantly less than 90%. Moreover, the vast majority of the remaining 27 proteins for which they reported homology are highly suspect and/or do not support an evolutionary pathway leading to a flagellum:

- Two of the claimed flagellar proteins with detected similarities to other proteins are regulatory proteins with unsurprising similarity to other regulators, yet they are not structural components of the flagellum that contribute to its motility function.[27]
- Three of the allegedly homologous proteins had only slight sequence similarity; they were claimed to be homologous based on "structural or functional considerations".[28] Yet because evolution proceeds by modifying sequences of DNA and proteins, a lack of sequence similarity suggests these other proteins are *not* a viable source that could have been utilized via an evolutionary pathway.
- Seven of claimed homologous proteins are strictly homologous to other flagellar proteins,[29] what might be called "intraflagellar homology". One cannot explain the initial evolution of the flagellum by claiming it evolved from itself, so these examples are entirely unhelpful towards explaining the how the flagellum first arose from "parts that have other uses" (Kojonen 2021, p. 117) or from "similar parts in other systems" (Kojonen 2021, p. 118), as Kojonen puts it. This tenuous argument may have been derived from Musgrave (2004, p. 81), who argues that flagellar proteins find homologues in "other systems" including "flagellins"—but flagellin is a strictly flagellar protein that only forms a subunit of the flagellum's propellor.
- Eleven of the claimed homologous proteins were similar to proteins in the Type Three Secretory System (T3SS),[30] three of which were also claimed to show intraflagellar homology.[31] As quoted above, Kojonen cites the T3SS as a potential "viable precursor system to the flagellum", but this argument has been long-criticized by intelligent design proponents (Illustra Media 2003) as well as by other scientists. More on this below.

Kojonen's other source for his 90% statistic, Musgrave (2004), provides two citations for his claim that "between 80 and 88 percent of the eubacterial flagellar proteins have homologs with other systems"—Aizawa (2001) and Ussery (2004). Ussery (2004) does not discuss homology for flagellar proteins outside of the flagellum; he merely compares sequence diversity across other flagellar proteins that fulfill the same flagellar function in different species of bacteria. Aizawa (2001) does identify some non-flagellar homologues for flagellar proteins, but only finds homologues for four flagellar proteins that were not also identified by Pallen and Matzke (2006).[32] All four of these homologues are proteins used in the T3SS. Although there is clear homology between various flagellar proteins and the T3SS, we will explain below that such data are of limited value to account for the evolution of the flagellum.

Adding the four additional flagellar homologues identified by Aizawa (2001) to those identified by Pallen and Matzke (2006) brings the total to 31 out of 42 flagellar proteins that show sequence similarity to other proteins—74%—which is again moderately less than 90%. But as noted above, the vast majority of these homologues are unhelpful in constructing some kind of an evolutionary pathway. In the end, Kojonen's citations (and the sources of his citations) reveal at best only 4 out of 42 flagellar proteins (9.5%) are homologous to "similar parts in other systems" which could have potentially served as "precursors" to the flagellum, as Kojonen says. Nine-and-a-half percent is strikingly less than his claimed statistic of 90%.

Excursus on T3SS

Because quite a few (perhaps up to 15) flagellar proteins appear homologous to proteins in the T3SS, the latter is often cited as a possible evolutionary precursor (or close relative) to the flagellum (Musgrave 2004; Miller 2008, p. 59). It is therefore worth exploring further why the T3SS could not serve as "a viable precursor system to the flagellum", as Kojonen believes it to be. The T3SS is part of the flagellum itself and is used to pump proteins from inside the cell to outside the cell where they self-assemble into the flagellum. For this function, the T3SS is simply a molecular pump involved in flagellar assembly. Even granting that it could have been co-opted for *some* function, it is nonetheless unrelated to the flagellum's motility function and so is unlikely to have been 'co-opted' to produce motility, the core function of the flagellum.

Once the flagellum is assembled, the T3SS provides an additional function: a structural component that anchors the flagellum in the cell membrane. Yet even here, it is not part of the motor portion of the assembled flagellum, but could be viewed as something akin to the bracket on an outboard motor. Again, the T3SS is a poor candidate for co-option (and modification) into the proteins that comprise the flagellum's propulsion function.

Notably, a different molecular machine (called an "injectisome") uses the T3SS as well (Diepold and Armitage 2015). In the injectisome, the T3SS is involved in both assembling the injectisome and in the injectisome's function. (The injectisome is used by certain predatory bacteria to inject toxic proteins into eukaryotic cells, which then kill the eukaryotic cells so they can be ingested by the bacterium.) But it is doubtful that the injectisome and its T3SS are useful in explaining the origin of the flagellum. First, there are ecological and phylogenetic considerations that strongly imply the flagellum *predates* the T3SS and the injectisome and, thus, could not have evolved from these systems (Abby and Rocha 2012a, 2012b; Deng et al. 2017; Coleman et al. 2021).[33] As *New Scientist* reported:

> One fact in favour of the flagellum-first view is that bacteria would have needed propulsion before they needed T3SSs, which are used to attack cells that evolved later than bacteria. Also, flagella are found in a more diverse range of bacterial species than T3SSs. "The most parsimonious explanation is that the T3SS arose later", says biochemist Howard Ochman at the University of Arizona in Tucson. (Jones 2008)

Second, even if the T3SS could have served as a precursor to the flagellum, it is not clear that this would provide anything close to a viable evolutionary pathway—a "continuous series of functional forms, leading from no flagellum to a flagellum", as Kojonen puts it. William Dembski nicely captures the essence of the evolutionary leap required to explain how a flagellum evolved from the T3SS:

> [F]inding a subsystem of a functional system that performs some other function is hardly an argument for the original system evolving from that other system. One might just as well say that because the motor of a motorcycle can be used as a blender, therefore the [blender] motor evolved into the motorcycle. Perhaps, but not without intelligent design. Indeed, multipart, tightly integrated functional systems almost invariably contain multipart subsystems that serve some different function. At best the T[3]SS represents one possible step in the indirect Darwinian evolution of the bacterial flagellum. But that still wouldn't constitute a solution to

> the evolution of the bacterial flagellum. What's needed is a complete evolutionary path and not merely a possible oasis along the way. To claim otherwise is like saying we can travel by foot from Los Angeles to Tokyo because we've discovered the Hawaiian Islands. (Dembski 2005, p. 52)

Moreover, further research indicates that the T3SS and flagellum are so distinct that they may in fact have independent origins (Tan et al. 2021)—a generally unexpected result on an evolutionary view.

5.3.4. Problem 3: Assembly Not Required?

Yet even if all the necessary parts were available and co-opted so that they could be constructed in the form of a flagellar motor, co-option does not explain the *assembly instructions* needed to construct complex systems. It is not just a matter of getting the parts; it's also putting them together in the right sequence, at the right time, and in the right orientation. Simply having all the ingredients for chocolate cake is not in itself sufficient to produce a cake. Something similar is true for a Corvette engine. So much the more for the most efficient machine in the universe. Microbiologist Scott Minnich and philosopher Stephen Meyer explain this challenge:

> [E]ven if all the protein parts were somehow available to make a flagellar motor during the evolution of life, the parts would need to be assembled in the correct temporal sequence similar to the way an automobile is assembled in a factory. Yet, to choreograph the assembly of the parts of the flagellar motor, present-day bacteria need an elaborate system of genetic instructions as well as many other protein machines to time the expression of those assembly instructions. Arguably, this system is itself irreducibly complex. (Minnich and Meyer 2004)

From beginning to end, the flagellar assembly process is "tightly controlled and regulated in a sequential genetic hierarchy mirroring organelle assembly from the inner membrane to the outer cell surface" (Minnich and Meyer 2004). Indeed, Behe has deemed the origin of flagellar *assembly* equivalent to "Irreducible Complexity Squared" (Behe 2007, p. 93), because, as he puts it, "not only is the flagellum itself irreducible, but so is its assembly system. The assembly process and the flagellum together constitute irreducible complexity piled on irreducible complexity" (Behe 2019, p. 286).

Yet in his most recent book, *Darwin Devolves*, Michael Behe observes that when it comes to explaining the evolutionary origin of the flagellum's assembly, one continues to hear very little from the evolutionary biology community:

> In 1996 [in *Darwin's Black Box*] I showed that, despite thousands of papers in journals investigating how that fascinating and medically important molecular machine worked, there were no papers at all that tested how the bacterial flagellum might have arisen by a Darwinian process. The scientific literature was absolutely barren on the topic . . . . Twenty years on, there has been a grand total of zero serious attempts to show how the elegant molecular motor might have been produced by random processes and natural selection. (Behe 2019, p. 287; see also Behe 2007, pp. 267–68)

Like many of his evolutionary colleagues, Kojonen simply elides this problem.

Stepping back, it is important to reiterate that our main point in this section is not to critique evolutionary theory per se. Though Behe's irreducible complexity argument does challenge mainstream evolution, our point instead is to critique Kojonen's *conjunction* of 'design and evolution'. Recall that Kojonen believes that complexity of the bacterial flagellum adds to his case for joining 'design' to 'evolution' (see esp. Kojonen 2021, p. 122). But Behe's argument shows that the *type* of design manifest in the bacterial flagellum runs contrary to evolution. Thus, Kojonen's marriage of 'evolution and design' has a major problem: the very system that provides strong evidence of design *also* undercuts evolution. One part of the model saws off the branch upon which the other side sits. Kojonen's model is internally conflicted.

6. Convergent Evolution

We now turn briefly to convergent evolution which, in our estimation, serves as the basis for Kojonen's most powerful positive argument for the laws of form (or "library of forms"). In Kojonen's model, these forms are a key element of the preconditions that make evolution possible. Notably, he regards them as "an emergent consequence of the laws of chemistry and physics" (Kojonen 2021, p. 123). That is, they arise from the laws of nature. Recall that in Kojonen's model, the laws of nature are designed. So, the laws of form play an important role in his conception of design *and* its explanatory value: evolution can only happen under certain conditions, and chief among these conditions are the laws of form, which are themselves the direct result of God's design of natural laws. Thus, the laws of form connect design and evolution in a way that shows the added explanatory merit of design to assist evolutionary searches.

As noted, we regard "convergent evolution" as the most formidable argument that Kojonen provides for the existence of the laws of form. In what follows, we argue that Kojonen's account of convergence drives a wedge between his acceptance of 'design' on the one hand and 'evolution' on the other. Once again, internal conflict comes to the fore.

To see this, some background on convergence is helpful. In Kojonen's view, convergence itself "refers to the independent evolution of the same biological outcome in two or more different lineages, beginning from different starting points" (Kojonen 2021, p. 125). He observes, for example, that "dolphins and sharks have similar streamlined bodies and dorsal fins, even though dolphins are mammals and sharks are fish". He also points out that paddle-shaped limbs for swimming "have evolved independently seven times, and a structure as complex as the eye has evolved independently 49 times…" (Kojonen 2021, p. 125). Kojonen interprets convergence as evidence for preconditions or, more specifically, that laws of form "play a significant role" in helping evolutionary processes cluster around similar solutions (Kojonen 2021, p. 125). He notes that the presence of similar features in the natural world, which are not explained by common ancestry, suggests to some thinkers that natural selection acting on random mutation may be directional or forced to move along certain fortuitous evolutionary pathways. Somewhat more modestly, Kojonen himself concludes that convergence shows "the evolution of Earth-like life is heavily influenced by functional constraints" (Kojonen 2021, p. 127). Put in the form of a rhetorical question, then, the general thought seems to be: if the same solutions independently arose over and over, doesn't that suggest that the deck was likely stacked to allow evolution to succeed? (Kojonen 2021, p. 125)

Unfortunately, notable problems arise for Kojonen's appeal to convergence. First, convergence relies on a great many improbable events. It not only requires the evolution of certain complex proteins, traits, and systems but the evolution of these things *independently more than once*. As just noted, Kojonen claims that the eye, in one form or another, independently evolved dozens of times. This means that the probabilities about protein rarity and isolation (described in Section 4) apply with even greater force. If the probability is prohibitively low of evolving even a single short protein one time in the entire history of the Earth, then, all things being equal, the probability of evolving this protein multiple times is proportionally greater.[34] So much the more with entire systems of proteins, cell types, tissues, and organs. So, Kojonen's appeal to convergence runs headlong into an a fortiori argument.[35]

Notably, this is a problem for Kojonen's case for *design*: on his view, convergence points to the laws of form, and these laws in turn arise directly from the designed laws of physics and chemistry. So, convergence is indirect evidence of design. Yet if an evolutionary origin of convergence is implausible, then Kojonen's case for design likewise suffers.

Second, and at a deeper level, Kojonen's model falls prey to the horns of a troubling dilemma. This dilemma is a version of what philosopher of biology Paul Nelson has deemed "Sober's Paradox" (Nelson 2022). The basic problem is that Kojonen's beliefs about common ancestry conflict with his belief in convergence. His attempt to accept both claims fractures the unity of his model.

To see this, consider the first horn of the dilemma. If Kojonen retains evolutionary convergence, then he de-fangs his co-option response to Behe's irreducible complexity argument. This is because co-option depends for its plausibility on *similar* protein parts in other systems serving as good candidates for modification into the specialized parts needed for the bacterial flagellum. As Kojonen explains about the flagellum, "The existence of similar parts in other systems, for example, does provide supporting evidence for evolvability" (Kojonen 2021, p. 118). But with 'convergent evolution', highly complex parts or systems—even more complex than the bacterial flagellum—can arise *without* similarity or common ancestry. Yet if that is plausible, what force does the co-option really have?

Moreover, Kojonen also undercuts his argument for protein evolution. His account hinges on mutation and selection's ability to traverse from one functional protein to another. Presumably, it is easier for evolution to forge a new protein from a similar one rather than from a vastly different one. Otherwise, if it is just as plausible to claim that evolution can produce major innovations as it can minor changes, why bother to talk about gradual change from one similar functional protein to another? The force of the argument has been lost.

More generally, Kojonen's acceptance of evolutionary convergence harms the justification of common ancestry in standard evolutionary thought. The received view is that similar structures are best explained by a common ancestor who also had a similar structure. On this view, it is more parsimonious to claim that a complex feature evolved once rather than twice. Whether this reasoning is correct or incorrect is irrelevant; the point is that it runs contrary to convergent evolution. If complex features are just as likely to arise independently multiple times as they are a single time, then it is extremely difficult to make the case for common ancestry (Luskin 2017). Once again, Kojonen has accepted a claim that renders his model internally unstable.

Matters do not get easier on the other side of the dilemma. If Kojonen retains his account of protein evolution, his co-option response to Behe, and the standard justification for common ancestry, then he harms the justification of evolutionary convergence. As we have seen, this is because each of these lines of argument (or reasoning) presupposes that it is more probable for biological complexity to have evolved once rather than multiple times independently. This crucial presupposition cuts the ground out from evolutionary convergence, which is committed to the idea that independent evolutionary lineages have produced similar features.

Moreover, Kojonen clearly regards convergence as important. Recall that he believes "[e]xamples of convergence are *ubiquitous* in biology" (Kojonen 2021, p. 125, emphasis added). The reason that these examples are said to be 'convergent' is because, in general, multiple lines of evidence—typically from genetics, paleontology, biochemistry, systematics, and the like—indicate that it is difficult to form a coherent phylogenetic account of their origin from a given common ancestor. These data count as anomalies under common ancestry. That is *why* evolutionary biologists regard them as the result of convergent evolution. Yet if Kojonen opts for the 'common ancestry' horn of the dilemma, then he must eschew convergence. But convergence is arguably his best argument for the laws of form and, indirectly, for the locus of design in the laws of physics and chemistry. This loss damages a significant feature of his model.[36]

In short, Kojonen is caught between a rock and a hard place. A familiar refrain sounds again: Kojonen's understanding of (and justification for) 'design' conflicts both with his own reasoning (about co-option, etc.) as well as with the justification of common ancestry, a mainstay of 'evolution'. His model is internally fragmented.

One of the most interesting features of Kojonen's treatment of design is his exploration of the laws of form. But this particular argument for them—perhaps the best of the book—comes at a very steep price.

7. Design Detection Damaged

In this final part of our argument, we raise concerns about the epistemology underlying Kojonen's model. In brief, our concerns are twofold: First, Kojonen's proposal severely damages his own design argument. And second, his model also significantly damages the legitimacy of an everyday theist's intuitive apprehension of design. This latter point is notable because Kojonen is keen to show that his model generally supports (or at least does not harm) the "theist on the street" who intuitively perceives design in the biological world (Kojonen 2021, pp. 32, 156, 162–64, 206).

In what follows, we first summarize key elements of Kojonen's view of design detection. Second, we explain why these elements are problematic both for the justification of Kojonen's biology-based design argument and for the "theist on the street".

7.1. Kojonen's View of Design Detection

In chapter five of CED, Kojonen lays out his views on design detection. He cites with approval the work of philosopher of science Del Ratzsch:

> According to Ratzsch (2001), design detection typically works by first identifying artifactuality through identifying *counterflow*, properties that are contrary to what would be expected based on natural processes. However, when analyzing artifactual objects, features like complex teleology then function as secondary markers identifying intentional production, as opposed to what can also be accidental artifactual products, such as footprints. Here Ratzsch identifies both *mind correlative* order, which suggests design, and *mind affinity*, which almost inescapably suggests mind. He then argues that while design is typically detected by first observing counterflow, these secondary marks of design can actually provide grounds for design beliefs even in the absence of counterflow. (Kojonen 2021, pp. 164–65, original emphasis)

This is a complex paragraph, but the basic idea is as follows: First, Kojonen seems to agree with Ratzsch that detecting design usually happens through a process that begins with "counterflow". In this context, "counterflow" is, to use Kojonen's language, that which runs "contrary to what would be expected based on natural processes". (For a formal definition, see Ratzsch 2001, p. 5.) The idea is that a key step in detecting design typically involves understanding what nature would do when left to its own devices and then contrasting that with what one actually sees. For example, we know that it is unlikely that nature on its own would produce a forest with trees lined up in perfectly straight rows. If we find such a thing, we can justifiably conclude that some kind of mind was at work. Kojonen seems to accept Ratzsch's point here.

But Kojonen also goes on to agree with Ratzsch that, even without counterflow, one can still reliably detect design. In some cases, we can justifiably say that something is designed even if it is the result of normal natural processes. This is why Kojonen speaks of "secondary marks" that include "mind correlative order" and "mind affinity". (Mind affinity is simply a special case of mind correlative order. Both are characterized by a special stamp of 'mind'—roughly, a deep connection with what minds do, operate, or produce (Ratzsch 2001, pp. 3–4, 14–15, 61–69, 134).) The basic idea is that, when a given object in nature exhibits a deep correlation with what minds (uniquely) do, a person can reliably believe that the object is designed—*even if it is a product of nature's normal operation*.

As noted earlier, Kojonen illustrates this idea with a 'moon crater' scenario, also from Ratzsch. Kojonen asks readers to suppose that the first photos of the moon showed the text of John 3:16 written in craters on the surface (p. 165). Suppose further that there was a natural explanation for each crater (and asteroid). Suppose also that we could trace these natural explanations all the way to the big bang. "In this case", writes Kojonen, "it seems that natural explanations simply do not explain the intelligibility of the pattern, even though they explain each individual crater" (Kojonen 2021, p. 165). The evidence of design remains clear, even if that design occurred at the beginning of the universe and was transmitted by natural processes across time and space. So, even when nature is acting

in her normal way (with no interruptions or counterflow), we can still detect design in certain cases.

This allows Kojonen to say that his proposal still preserves our ability to detect design despite the fact that, in his model, the locus of design is at the origin of the laws of nature (e.g., Kojonen 2021, pp. 164–67). Both the professional biologist and the "theist on the street" can discern God's handiwork even if nature has never been disrupted since its initial creation. In other words, if biological complexity arose via the laws of nature, we can still look at a given organism and reliably believe that it was designed—even if it is the direct result of unbroken laws going back to the big bang. In particular, this means that mainstream evolutionary theory's appeal to only physical causes poses no threat to a biological design argument or to the direct intuitive apprehension of design enjoyed by everyday theists.

7.2. A Looming Epistemological Conflict

But this account is flawed. Kojonen's understanding of design detection runs contrary to his acceptance of evolutionary theory and his placement of the locus of divine activity at the creation of the laws of nature. The tension is so significant that it undercuts his design argument and defense of the theist on the street.

To see this, consider how Kojonen replies to a key objection to his account of design detection. This objection asks: just how would we detect *biological* design if Kojonen's model were correct? That is, if God created the laws of nature (along with the initial conditions), and this led to all subsequent physical, chemical, and biological phenomena, how exactly can we say that biological phenomena point to design more so than mere physical objects do? How can we claim, say, that the eye of the eagle provides better evidence of design than a couple of rocks on the ground? The whole point of Kojonen's model is to show that *biological* design fits nicely with evolutionary theory.

Kojonen perceptively articulates the objection to his view as follows:

> Why, then, should we think that there is something special about biology that gives grounds for the perception of design, as opposed to ordinary rocks, which also require the existence of a Creator? (Kojonen 2021, p. 161, see also p. 167)

Kojonen's reply to this objection draws on his foundational understanding of how humans detect design. He provides several resources in this regard. One resource is, of course, his extended argument in CED. That is, Kojonen observes that someone who understands KEBDA can appeal to it in order to understand how biology in particular can evince design in a special way. In other words, if his long argument is correct, then biology points to design in a particular way because the biological data uniquely show the need for fine-tuned preconditions. And these preconditions are best explained by a Designer.

Of course, the problem with this response is that it only succeeds if Kojonen's argument itself succeeds. Insofar as one has reason to doubt Kojonen's argument, one likewise has reason to doubt his response to the objection. If our criticisms in this article are correct, then this line of reasoning is unconvincing.

Yet Kojonen also gives broader grounds for design detection. Notably, these grounds are available not just to specialists—who can follow the nuances of KEBDA's use of fine tuning in biology—but also "theists on the street" who apprehend design by direct intuition or perception. In particular, Kojonen writes:

> It seems to me that even if we did not know about the fine-tuning evidence, our experience of creating things, and observing the properties of life, should make us suspect that our cosmos must be fine-tuned to allow for the evolution of such properties. Assume a further principle that what requires most ability also best demonstrates the existence of that ability. Then, given that the production of complex biological organisms requires far more fine-tuning than the existence or something like rocks, biological organisms better demonstrate the fine-tunedness of the cosmos. (Kojonen 2021, p. 162)

So, the basic idea is that when we notice the complexity of biological life, our own experience of making things (including, presumably, complex things) should make us suspect that the complexity of life likewise requires fine-tuning. And if biological organisms require more fine-tuning than, say, rocks, it is reasonable to hold that these organisms manifest design in a more robust way.

Elsewhere, Kojonen states the matter more simply: "we can know based on our own experience (and through the testimony of others) that it is difficult to produce this type of [biological] order, and that designing an automated process [analogous to evolution] to produce such order is more difficult still" (Kojonen 2021, p. 163). Once again, he refers to "our own experience" as well as that of other human beings. We know based on our first-person experience, and the reports of others, that it takes a mind to create certain things. One does not produce iPhones by waiting until nature gets around to it. Instead, it takes work, creativity, and a lot of fine-tuning.

Kojonen also adds a final element to his account of design detection (and reply to the objection)—namely, that human's basic apprehension of design is grounded in certain prima facie intuitions. He writes in the next sentence:

> Moreover, as Nagel (2012, p. 6) points out, the design intuition (and resistance to Darwinism as an unguided process) is often based on an "untutored reaction of incredulity to the reductionist neo-Darwinian account of the origin and evolution of life. It is prima facie implausible that life as we know it is the result of a sequence of physical accidents together with the mechanism of natural selection". (Kojonen 2021, p. 163, citing Nagel 2012)

Here, Kojonen seems to say that our "design intuition" often arises from a basic sense that unguided evolution cannot create the complexity of life we see around us, and that there must instead be a mind behind it all.

Thus, the key aspects of design detection in Kojonen's model (and in his reply to the objection above) include: (i) our observations about the properties of life (including, presumably, its complexity), (ii) our own experience of creating things, including complex things, (iii) the experiences of others along these same lines, (iv) common sense reasoning about what it takes to build complex rather than simple things, and/or (v) our intuition of design in biology, which often arises from a basic sense of the creative limits of unguided nature. Put in the simplest way, these points collectively hold that, in our experience as agents, complex things require greater resources than simple things to make, and that nature can only explain so much. The complexity of life is better accounted for by mental agency rather than unguided nature—especially when it comes to, say, an eagle's eye rather than simple rocks on the ground.

7.3. Mind over Matter

At the heart of these points is the common-sense idea that humans can exercise creativity (and produce fine-tuned systems) in a way that nature cannot. Indeed, Kojonen's own design argument hinges on a similar idea. He writes, for example, "The cosmos must be special indeed to allow for the evolution of the kind of complex teleology and the large variety of creatures that we observe. And this feature of the cosmos . . . is explained better by a theistic view than by supposing that this feature is due to chance" (Kojonen 2021, p. 162). Theism explains complex teleology and biological diversity better than chance does. God's *agency* is a better explanation than chance, because agents can create things that nature (and its contingency) cannot.

This general line of reasoning lies at the center of Kojonen's attempt to unite 'design' and 'evolution'. As we have seen, Kojonen argues extensively that evolution on its own cannot search and find viable biological forms. It requires preconditions of just the right kind—a Goldilocks arrangement. He writes, for example, about "the kind of fine-tuning of the landscape of forms that seems to be required to evolve the kind of biological order described by Behe" (Kojonen 2021, p. 122).[37] And these 'fine-tuned' preconditions are best explained by a Designer. This whole line of thinking presupposes that some phenomena

are beyond the reach of unaided nature but can only be explained by a mind. Agents have powers to create (or fine tune) in ways that nature does not.

A similar presupposition informs the other cognitive resources that undergird Kojonen's understanding of design detection. He notes that "design intuition" is often based on deeper intuition about the limits of physical accidents and natural selection—the limits of nature acting on its own, more or less. A similar presupposition underlies Kojonen's appeal to "our experience" of building complex things, rather than simple ones. We know it takes mental effort to do so. And Kojonen believes this fact, coupled with our realization of nature's complexity, should lead us to suspect that there is a mind behind it all. Why? Because we know that minds can do things nature cannot.

Kojonen's own moon crater analogy nicely illustrates this point. Recall that the illustration was supposed to show that we can detect design even when we encounter unaided nature. That is, even without disruptions in the course of cosmic history, we can still reliably detect the activity of an original Designer. The analogy makes us think, "Yes, there would have been a mind that caused the message". Why? Because we have a lot of reliable experience of agents who have abilities different from (and beyond) the abilities of nature. We know that natural laws do not create messages. That is *why* we say the John 3:16 message is not fully explicable by natural law. We also know that agents possess the unique power to write messages. That is *why* we immediately recognize design. In our experience, only minds do that sort of thing, not nature. The analogy succeeds to the extent that we are justified in maintaining that minds exercise greater creative powers than nature does.

A similar point can be made about Kojonen's other analogies, illustrations, and metaphors about design and its detection (including the detection of indirect design). These include the VCR factory analogy, castle-building metaphor, Mats Wahlberg's fugues analogy, analogy to human technology, Asa Gray's mechanical loom, and so on. (Kojonen 2021, pp. 157–74, esp. 164–74; Kojonen 2022a). In all cases, the detection of design, including indirect design, depends upon the fundamental insight that the creativity of minds exceeds that of nature. The apprehension of complexity only reliably triggers a belief in (or inference to) design if minds can create complexity that nature cannot.

Collectively, then, Kojonen's formal argument, cognitive resources, and key illustrations all rest on the basic insight that minds have creative powers greater than that of nature. This is the heart of his understanding of design detection.

7.4. Kojonen's Model Undercuts Itself

But Kojonen's own model undercuts this pivotal insight. His particular views of 'design', along with his acceptance of mainstream 'evolution', harm his own understanding of design detection. His model damages the very foundation upon which it rests. Notably, our critique does *not* presuppose that evolution is false or that it occurs without design (see Kojonen 2021, pp. 145–46). Instead, we will assume for the sake of argument that Kojonen's model is correct in the sense that (i) evolution is true, and (ii) design is located at the origin of the laws of nature. From this vantage, we raise three epistemological worries, which collectively build on each other.[38]

7.4.1. Element 1: Direct vs. Indirect Design

The first concern centers on the distinction between 'direct design' and 'indirect design'. The former is due to the immediate action of an agent, whereas the latter is due to action of an agent that has been (or is) mediated by some other process, entity, or event. Direct design occurs when God creates a type of organism by His own hand; indirect design is when He organizes the big bang and lets natural laws take it from there, for example.

In our lived experience, humans readily attribute direct design to various types of biological phenomena. (This is not only true of "theists on the street", for example, but also of some other people as well.) For example, consider a person who sees a hummingbird for the first time. A natural reaction is to think that this type of bird was directly designed. ("Wow! That's spectacular. Somebody made that!") In fact, humans often experience things

like hummingbirds as *distinct entities*—what Axe (2016, pp. 65–86, esp. 71) calls "busy wholes" or what one might call "natural kinds". That is, humans often experience an entity like a hummingbird as a certain *type* of thing, and they naturally believe that this type is the result of direct design. By contrast, it is rarely the case that, upon seeing a hummingbird for the first time, a typical person would say, "Wow! That's specular. Somebody indirectly created that by a process of secondary causes over millions of years". Instead, many people believe that a designer directly crafted the first instance of a given specimen or feature. ("God made the first hummingbirds, then they reproduced".) Whether rightly or wrongly, human beings routinely apprehend (or infer) direct design when they encounter the power, beauty, and complexity of organisms or organs.

Yet in Kojonen's model, these beliefs in direct design are uniformly false. In his view, there is *no* direct design of biological phenomena. All biological diversity and complexity are the result of *in*direct design. The locus of design was billions of years prior to the advent of life on Earth. (Indeed, even if Kojonen were to locate direct design at the origin of life, all subsequent flora and fauna would still be the result of indirect design.) This simply follows from Kojonen's understanding of design (and of evolution). So, if Kojonen's proposal were true, human beings who accepted his view would have a serious defeater for their 'direct design' beliefs about biological organisms and features. They would realize that they have little or no grounds to trust their minds in this context. Indeed, if they had an intuitive belief, based on biological data, that the human species was directly designed, they would likewise be mistaken. Humans and their array of unique capacities ultimately came from the same event that gave rise to rocks and stardust. Again, a person in this situation would have a defeater for her belief in direct design.

Something similar is true of the common intuition that an eagle's eye appears to be more designed than a couple of rocks. But in Kojonen's model, both are the result of the *same* event. The eye of the eagle seems *directly* designed, but it is not any more so than a mere rock. This, too, is a defeater for such a belief.

But then how would a person in this general situation know that the laws of physics and chemistry were *directly* designed, as Kojonen believes them to be? Recall that his argument for design is supposed to be based on *biological* phenomena. But if his model were correct, humans would have *no* cases of biological things that seemed to be directly designed actually turning out to be directly designed. So, if there are no such cases—and these cases are the basis for believing that the laws of nature are directly designed—then the ground for believing that the laws are directly designed is very poor indeed. If a baseball player strikes out in his first 23 plate appearances, what basis does he have to believe that he will get a hit at his next at-bat?[39]

In effect, Kojonen's model undermines its own design argument. To succeed, Kojonen needs some basis in *biology* to say that the laws of nature were directly designed. (If he appeals to the big bang model in cosmology or fine-tuning in physics, as opposed to the data of biology, then he has essentially cast aside the heart of his model. See Kojonen (2021, pp. 131–32).) Unfortunately, in Kojonen's own proposal, biology itself ends up providing defeater after defeater for 'direct design' beliefs. This undercuts the basis for his claim that the laws of nature are directly designed.

This is our first concern. Two other concerns (below) build on this one and cover other aspects of Kojonen's account, including other resources he has for design detection.

7.4.2. Element 2: Continuity of Non-Agent Causes

In the previous section, we offered a counter to Kojonen's claim that, in his model, an informed person can know, based on apprehension of biological things, that the laws of nature are directly designed. In what follows, we expand our concern to whether a similarly informed person would know that *biological* phenomena were designed (again, granting Kojonen's model for the sake of argument). This second problem builds on the first problem. If Kojonen's model were true, not only would all cases of 'direct design' beliefs about biological phenomena be false, but a person who accepts the model would also

believe that non-agent causes are *proximately* sufficient to bring about any given biological phenomenon. (In this case, 'non-agent' causes would include evolutionary causes but not be limited to them. It would also include other physical causes as well as the causal effects of platonic "laws of form", appropriately interpreted, if any. A 'non-agent' cause does not reject agent causes per se; it simply does not invoke them.[40]) For example, if Kojonen's model were true, a person who accepted the model would believe that, despite her ostensible prima facie belief that, say, a designer directly crafted an eagle's eye or the first hummingbirds, it is actually the case that each of these phenomena are proximately explained by non-agent causes. For each biological organism or feature, there would be *continuity* of non-agent causes from *before* that entity's existence that led up to (and through) the advent of that entity. Indeed, this continuity would extend all the way back in time. (In fact, there might not be any particular reason, based in biology, to think there was a big bang.) A person who accepted this model would believe that non-agent causes gave (proximate) rise to case after case of biological complexity. The same would be true for human beings, too. An unbroken chain of non-agent causes from the ancient past would extend up to (and through) the rise of the first humans, whoever they happened to be.

The question, then, is: on what grounds would a person in this position believe that biological phenomena were designed? Or, put differently, on what grounds would a person in this situation believe that non-agent causes are insufficient to explain biological complexity? What grounds are there to invoke a designer? The *continuity* of non-agent causes from the inorganic realm to (and through) the organic realm makes this a difficult question. By contrast, *dis*continuity from the inorganic to organic realms (or from episode to episode in organic history) might suggest that a designing agent added new information or direction. But according to Kojonen, there is no such discontinuity.

Of course, Kojonen might point out that the whole point of KEBDA is to show that evolution on its own is insufficient to search and find viable biological forms. It needs fine-tuned preconditions, and these are best explained by a designer. But this response misses the point. What this response fails to consider is that, even if evolutionary processes *as such* are insufficient, in his model, there is still *continuity* of unbroken, non-agent causes from ancient cosmic history through the origin of life and through the advent of all instances of biological complexity, including of human beings. Evolutionary causes are only one type of 'non-agent' cause. There are other processes that are in play; all of these are non-agent causes. *None* of them are the direct action of an agent. A human being who apprehended and accepted this unbroken continuity would have no reason per se to believe that biological phenomena were the result of a designing agent at any time in the past. In fact, the strong continuity of non-agent causes might in fact suggest the opposite. (And again, to try to counter this by appealing to big bang cosmology or fine-tuning in astrophysics is to miss the point of Kojonen's *biology*-based model.) To be sure, on Kojonen's view, biological phenomena (and evolution) ultimately depend on a Designer. But even when we grant this claim, it does not follow that a person in this situation would have sufficient *evidence* to believe that (Kojonen 2021, pp. 145–46).[41]

7.4.3. Element 3: The Foundations of Design Detection

Despite our arguments above, a critic might wonder: "But what about Kojonen's other resources for detecting design, including the human experience of creating complex things? And doesn't the sheer complexity of biological phenomena justify design beliefs in *some* way, despite the negative implications Kojonen's model has for 'direct design' beliefs? For example, doesn't the moon crater illustration show that certain kinds of complexity reliably trigger design beliefs (or inferences to these beliefs) despite the concerns noted above?"

Alas, the answer is no. It is true, of course, that Kojonen's various illustrations are helpful and stimulating in this regard. These include the VCR factory analogy, castle-building metaphor, Mats Wahlberg's fugues analogy, analogy to human technology, Asa Gray's mechanical loom, and so on. (Kojonen 2021, pp. 157–74, esp. 164–74; Kojonen 2022a). And Kojonen's sophisticated KEBDA argument is also stimulating on this front as well.

But Kojonen's illustrations, as well as his design argument itself, are based on his more fundamental view of design detection. And his model undercuts this very foundation.

Recall that Kojonen's view of design detection was anchored on five elements: (i) our observations about the properties of life (including, presumably, its complexity), (ii) our own experience of creating things, including complex things, (iii) the experiences of others along these same lines, (iv) common sense reasoning about what it takes to build complex rather than simple things, and/or (v) our intuition of design in biology, which often arises from a basic sense of the creative limits of unguided nature. Collectively, these points hold that, in our experience as agents, complex things require greater resources than simple things to make, and that nature can only explain so much; design is needed to account for the complexity of life. These are the fundamental resources (and insights) that Kojonen marshals as the basis for humans' ability to detect design. *But Kojonen's model raises problems for each of these resources*.

To see why, note first that (i) above (about life's complexity) serves as the explanandum. It is not itself an explanation. The remaining four points attempt to provide an explanation. Second, consider points (ii) and (iii) above, humans' experience of creating complex things. As we have seen, a person who accepts Kojonen's view would lack evidence that humans were *directly* designed. Instead, they would believe that human beings and their cognitive abilities arose from the seamless continuity of non-agent causes that extend billions of years in the past. As such, it would be difficult to know whether human creativity (and design) is a legitimate category of explanation above and beyond the powers of natural processes and non-agent causes. For all one could tell, human creativity is simply another manifestation of non-agent processes that extend back indefinitely in time. 'Human creativity' *could* be suitably different than the 'creativity of non-agent causes', but the *evidence* of organic (and inorganic) history would not necessarily suggest anything of the kind.

For many human beings (including "theists on the street"), their creative experience helps show the limits of unguided nature as well as the need for a designer. Yet this is precisely what 'continuity' obscures: biological history (and inorganic history prior to it) no longer offer reason to think that nature (or non-agent causes) is limited in this way. As a result, for a person who accepts Kojonen's model, the idea that 'minds have creative powers that nature lacks' no longer has a substantial basis. For all she can tell, human creativity is simply a product of mindless forces, which extends back indefinitely. So, one's experience of creating complex things does not give her any particular reason to believe that design is necessary to explain complexity in biology.

Similarly, point (iv) above also falters: humans' commonsense reasoning about what it takes to build complex things would no longer serve as a strong basis to infer (or apprehend) design. That is because, again, a person who accepted Kojonen's model would realize that *every* case of the emergence of biological complexity in organic history is preceded by non-agent causes that, for all one could tell, are sufficient to account for the entity in question. For all one could tell, proximate non-agent causes have produced biological complexity that includes—and exceeds—the feats of human engineering. Our commonsense reasoning that 'complexity requires a mind' would not *per se* find support in organic (and inorganic) history.

Once again, the alleged merit of KEBDA is beside the point. Even if evolution on its own is insufficient, Kojonen still holds that non-agent causes run in continuity from the inorganic to the organic, and then through every episode in organic history. There is no discontinuity, and so it is unclear—based on biology—whether a designer is required.

Moreover, this same reasoning undercuts Kojonen's final element of design detection: a person who accepts Kojonen's model would no longer have grounds for her intuitive belief that unguided natural processes have only limited creative power. This is for the same reasons as those we have just explored. After all, her view of the organic world is one in which non-agent causes seem to account for complexity after complexity. They even apply to human beings and their unique cognitive and creative powers. The evidence available to her would not indicate, in itself, that nature is limited. Indeed, 'continuity' might rather suggest just the opposite.

This cuts the ground out from beneath Kojonen's many metaphors and illustrations of design and its detection (including indirect design and its detection). These include the moon crater example, Wahlberg's fugues, the VCR factory analogy, the castle-building metaphor, the analogy to human technology, Asa Gray's mechanical loom, and so on. In all cases, these examples depend upon one or more of the principles above, including the experience of creating complex things, common-sense reasoning about what it takes to make a complex (or fine-tuned) system, or intuitions about the creative limits of unguided nature. But Kojonen's model erodes these very foundations.[42]

7.5. Brief Conclusion

Thus, Kojonen's model harms each of the elements of his account of design detection, including humans' own experience of creating complex objects. If Kojonen's view of design (and of evolution) is true, then a person who accepts it is in trouble: the model undermines the very grounds it relies on. Kojonen's proposal undercuts the epistemological resources that it needs to enable design detection.

Moreover, a person who accepted Kojonen's model would have defeaters for her (intuitive) belief that the laws of nature are directly designed, biological organisms and organs are designed, and that some biological phenomena, such as the eye of an eagle, display greater evidence of design than simple rocks do. Whether such a person is a seasoned expert or an everyday "theist on the street", this same set of limitations applies to whoever accepts Kojonen's view.

7.6. The Theist on the Street and a Helpful Design Detection Analogy

An important goal of Kojonen's proposal is to affirm the rationality of "theists on the street" regarding their intuition that life was designed. Yet his model undercuts that intuition. To further appreciate why, consider this question: What if the universe really were as Kojonen describes? That is, what if humans (including theists on the street) were born into such a world and developed their cognitive abilities in it? Would they actually have the dispositions and beliefs that Kojonen thinks undergird our current ability to detect design? There are good reasons to believe the answer is "no".

An analogy may help in this regard. Imagine a jury being asked to try a court case about an allegedly fraudulent casino that was accused of rigging slot machines to yield winning jackpot combinations far less than they should, statistically speaking. On these particular slot machines, there are four reels with 10 symbols on each reel. The machines will pay out a jackpot when the symbols on all four reels line up with an identical symbol—a cherry—something that should happen, on average, 1 in every 10^4 spins, or 1 in every 10,000 spins.

The prosecution presents evidence that the casino's machines are producing jackpots far less than they ought to. In fact, the prosecution's team of experts tested the slot machines and found they only pay out a jackpot 1 in every 100,000 spins—an order of magnitude less frequently than they should.

The defense then takes its turn and makes a counterargument: "Actually, we live in a very special universe where the physical laws that govern slot machines (and their statistical odds) are fine-tuned such that things always happen about an order of magnitude less frequently than you'd expect. In fact, the 'weird' behavior of these slot machines proves our theory is true!".

But how did the defense know that in our "special" universe, "things always happen about an order of magnitude less frequently than you'd expect"? They could only know this based upon background knowledge of how often things *ought* to happen (in this case, that there *ought* to be a win 1 in every 10,000 spins) and then, on this basis, compare the behavior of the slot machines to show that winning was occurring actually far "less frequently than you'd expect".

The problem for the defense's argument is that if we if we really lived in their universe, then all our knowledge of physical laws and statistics and slot machines would be based

upon our experience in *that* universe. And if the defense's argument was true then, based upon our experience in that universe, we should "expect" a win 1 in every 100,000 spins—not 1 in every 10,000 spins—and thus the slot machines at stake in the case should appear to be behaving perfectly normal. Thus, in the defense's universe, we *could never know* that things were happening "an order of magnitude less frequently than you'd expect".

The defense must answer this question: *If we lived in their universe, how could they possibly "know" that the slots were producing wins less likely than they should?* In their universe, the slot machines should behave exactly as experience would suggest—so they could never argue that things were behaving in a weird way. But the fact that the slots are behaving weirdly suggests that the defense's "fine-tuned universe" argument cannot be true.

This analogy invites us to consider the epistemological effects of living in a universe described by Kojonen's model (in which evolution is true, design is confined to the advent of the laws of nature, and biological data are in view). In this universe, it is not clear that humans (including theists on the street) would have the basic epistemological dispositions or beliefs that Kojonen believes undergird our ability to detect design in biology. For example, people who grew up in this universe would not likely believe that nature (i.e., non-agent processes) have only limited ability to build biological complexity. After all, in this universe, the continuity of non-agent processes across the advent of everything from bacteria to blue whales seems to suggest that non-agent causes are quite creative. Similarly, people who grew up in this universe would not likely believe that our own experience of creating complex things is at all relevant to the claim that 'minds have greater creative power than nature does'. Instead, they would likely believe that our minds are simply a manifestation of nature's creativity (or the creativity of non-agent causes). A similar line of thinking applies to the other elements of design detection discussed above. The bottom line is that human cognition would likely be significantly different in Kojonen's universe than we actually experience it to be. Conversely, the fact that we have the particular cognitive dispositions and beliefs that we currently possess—instead of the ones we'd have in Kojonen's universe—suggests that we live in a world notably different than captured in Kojonen's model. Thus, in a particular sense, Kojonen's model is inconsistent with the lived experience of some humans, including some theists on the street. This seriously harms the plausibility of his proposal, including its defense of everyday theists.

8. Summary and Conclusions

We have come at last to the end. The salient question in this article is one that Kojonen himself addresses: Are two explanatory appeals better than one? Why bother with 'design' if one already accepts 'evolution'? Kojonen's task is to show that the conjunction of 'evolution and design' is explanatorily superior to 'evolution' alone. To succeed, he needs to show that adding 'design' increases evolution's explanatory value in a way that offsets the liability of violating Ockham's razor. Kojonen holds that the kind of 'design' that fits the bill is the type in which God created the laws of nature, which ultimately lead to fine-tuned "preconditions" (and smooth fitness landscapes) that enable evolution to occur. Kojonen gives several lines of evidence for this view, including research on fitness landscapes, the bacterial flagellum, evolutionary algorithms, convergence, and so on. His task is to show that this evidence makes his view of 'design' sufficiently robust and plausible to add explanatory merit to 'evolution'.

In this article, we argued that Kojonen's account of design is flawed. It requires fine-tuned preconditions (and smooth fitness landscapes) so that evolution can successfully search and build viable biological forms. Yet empirical evidence shows that no such preconditions or fitness landscapes exist. At precisely the place we would expect to find evidence of Kojonen's type of 'design', we find no such thing. Accordingly, his view of design is at odds with the evidence itself. As such, it is poorly situated to add explanatory value to evolution.

We also contended that Kojonen's conjunction of 'design' and 'evolution' is internally fragmented. Recall that Kojonen believes that the complexity of the bacterial flagellum

adds to his case for joining 'design' to 'evolution'. Yet Behe's irreducible complexity argument shows that the *type* of design manifest in the bacterial flagellum runs contrary to mainstream evolution. Thus, the very system that provides strong evidence of design *also* undercuts evolution. In effect, this drives a wedge between the two. Kojonen's conjunction of 'design and evolution' is at war with itself.

We also highlighted the internal tension in Kojonen's attempt to join 'design' and 'evolution' with respect to convergent evolution. Kojonen draws on convergence as a key argument for the "laws of form", which are an important element of fine-tuned preconditions and, thus, his case for design. Yet convergent evolution conflicts with Kojonen's use of co-option and approach to protein evolution. It also conflicts with the general justification of common ancestry. Thus, this element of Kojonen's case for design chaffs against his own reasoning as well as mainstream evolutionary thought. Internal discord surfaces once again.

In each of these criticisms, we have not targeted evolutionary theory itself. Although we believe that the scientific evidence we have covered counters mainstream evolution, we have set this concern aside in this article. Instead, our criticisms are aimed at Kojonen's conception of *design*. We have contended that he does not offer sufficient empirical support for it—and so it adds little explanatory merit to 'evolution'—and that some of the evidence he does offer actually conflicts with his commitment to evolution, producing incoherence within his model. (We should note, however, that because of the way Kojonen frames the matter, our criticisms of his view of design do have negative implications for the feasibility of evolutionary theory as he understands it. But this is an *implication* of our argument based on *his* own framing. It is not the focus of our argument per se. We will return to this point momentarily.)

Finally, we raised epistemological concerns aimed at the fundamental basis of Kojonen's understanding of design detection. If our concerns are correct, then they cut deeply against Kojonen's design argument as well as his defense of the theist on the street. In a nutshell, our worry is that a person who takes Kojonen's model seriously—or who lived in such a universe—would either have defeaters for her biology-based design beliefs or might not have the cognitive dispositions and beliefs that (in our experience) are foundational to the formation of such beliefs in the first place. Kojonen's reliance on evolution (and non-agent causes) undermines his basis for design detection, in short.

Stepping back, it is important to reiterate, once again, the many strengths of Kojonen's treatment. The extensive review we have given here is a credit to a book of remarkable sophistication, precision, and erudition. Only a venerable fortress is worthy of a long siege. *The Compatibility of Evolution and Design* is the best of its class.

Even so, we bring this article to a close on a poignant note: Kojonen's model may have devastating implications for mainstream evolutionary theory. Recall that the heart of his proposal is that evolution *needs* design (in the form of fine-tuned preconditions). Evolution on its own is insufficient to produce flora and fauna. But if we are correct that Kojonen's conception and justification of design are flawed, then it follows—by his own lights—that evolution is impotent to explain biological complexity. Kojonen's *own* account of the efficacy of evolution depends upon the success of his case for design. But if the latter stumbles, then so does the former. In a startling way, Kojonen has set the table for the rejection of evolution. If he has failed to make his case for design, then he has left readers with strong reasons to abandon mainstream evolutionary theory. The full implications of this striking result warrant further exploration.

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Notes

1 All of this depends, to a notable extent, on a given person's background beliefs.

2 To elaborate, for example, Kojonen writes: "[I]f the salvaging operation is to be successful, the evidence of biological teleology needs to be shown to provide at least some support for the rationality of religious belief, *even while accepting evolutionary explanations as true or probably true*" (Kojonen 2021, p. 5, emphasis added). And: "the biological design argument developed here should be understood as a primarily philosophical argument, rather than a scientific one" (Kojonen 2021, p. 6). "However, in this book, *the validity of the essential scientific claims of evolutionary biology will be accepted as the starting point of my inquiry*. I invite proponents of ID, as well, to *assume the plausibility of evolution for the sake of the argument*, and to join me in asking if the falsity of the conclusion of design really follows from it" (Kojonen 2021, p. 7, emphasis added).

3 As we understand him, Kojonen does not exclude divine interventions from organic history in the sense of prohibiting them or even as a supplement to evolutionary processes per se. Instead, he is simply interested in building an account that does not require any such inventions. See Kojonen (2021, pp. 28–30, 145–204) and Kojonen (2022b).

4 Kojonen states that the "preconditions" of evolution, including the "library of forms", are "an emergent consequence of the laws of chemistry and physics" (Kojonen 2021, p. 123).

5 For more on conjunctive explanations and (also) explanatory goodness, see Glass (2012, 2022), Glass and McCartney (2014), (Glass and Schupbach forthcoming), and Glass (2017).

6 Kojonen (2022b) outlines the problem and his general solution:Evolution is commonly understood to explain teleology (or the appearance of teleology) itself via reference to a non-teleological process. It is understood as an attempt to reduce teleology to non-teleological causes, and in this way explain the very same evidence that was the given as grounds for inferring design. Thus, once we already have an explanation for biological teleology by way of Darwinism, it is then argued that we no longer have a need for any further explanations. The traditional Darwinian claim is that the question "what processes are responsible for the apparent teleology of biological nature" has already been definitely answered by the theory of evolution, with no need for further explanations. However, if evolution is understood to depend on "laws of form" and to act more as a search engine than as an independent creator like the architect, then it seems to me that Darwinism pushes back the question of the general origin of biological teleology to the laws of nature, and does not yet fully explain this teleological order. If natural selection works, then it can be asked whether its functionality is better explained by reference to design or by reference to chance. This would leave room for a theistic conjunctive explanation of teleology, following Gray's line of argument on the dependence of evolution on design.

7 Kojonen believes that the detectability of design can be discerned by rigorous argument, common sense, and/or intuitive apprehension, given certain background beliefs and other considerations.

8 See Footnote 3.

9 Kojonen also holds that his model allows for elements of both contingency and directionality together in complementary ways (Kojonen 2021, p. 131).

10 Kojonen also cites the work of Wagner and others in support of his view (Kojonen 2021, pp. 123–35). See our discussion below.

11 Kojonen (2021, p. 122) frames the matter as follows: "It seems, then, that defending the power of the evolutionary mechanism requires assuming that the landscape of possible biological forms has some fairly serendipitous properties . . . . The ability of evolution to generate teleology appears to depend on teleology . . . " So, the need for preconditions, smooth fitness landscapes, and the like is part of Kojonen's case for design or "teleology". It is precisely the 'design' of these "serendipitous properties" that allows 'evolution' to succeed. But if empirical evidence shows that no such "properties" exist, then Kojonen's appeal to design (in this instance) does not add explanatory benefit to his account of how evolution can find biological forms.

12 A brief word about Kojonen's analysis of evolutionary algorithms is in order. Kojonen draws on the work of ID thinkers, such as William Dembski, to argue that evolution on its own is insufficient to explain the rise of biological complexity and diversity (Kojonen 2021, pp. 97–115). In his response to Kojonen's account, Jeavons (2022) focuses on Kojonen's argument that biological fitness landscapes were fine-tuned so that evolutionary searches would achieve predetermined outcomes. Although Jeavons (2022) does not frame it as such, his insightful analysis of evolutionary algorithms poses severe challenges to Kojonen's

premise that the landscapes could have been sufficiently fine-tuned solely due to fine-tuning of the laws of physics and the universe's initial conditions. Jeavons (2022) states that "additional feedback mechanisms must generally be added to modify the properties of the evolutionary algorithm in a goal-directed way during a run, based on some information about its current performance". He then states that the adjustments must be based on such variables as the current population and individuals' current fitness. Consequently, no fitness landscape resulting solely from the initial fine-tuning would allow for an effective evolutionary search in every biological context. For example, if a search was performed effectively for large populations of ants in the late Cretaceous period in one environment, it would likely not allow for successful evolutionary searches in many other contexts, such as the evolution of the first cetaceans. Instead, multiple infusions of *new* information would have been required to continuously tailor evolutionary searches to achieve desired outcomes. Jeavons (2022) states, "to achieve significant results, an evolutionary algorithm must be carefully tailored to the problem in hand, and the problem itself must have appropriate properties". Somewhat curiously, neither Kojonen (2022b) nor Jeavon himself acknowledge or solve these difficulties for Kojonen's model.

13 Proteins carry out the large majority of the work in a given cell, so they are crucial for virtually all forms of biological life.

14 More fully, 'sequence space' is roughly all the possible ways that amino acids can be linked together. Of these many different ways, only a small percentage actually produce a functional protein. By way of analogy: There are many ways that letters in the English alphabet can be arranged in, say, a one-hundred-letter sequence. But of all these ways, only a tiny fraction will form meaningful English sentences. Similarly, only a tiny fraction of the ways that amino acids can be combined will actually produce functional proteins. In short, it is a needle-in-a-haystack scenario.

15 Elsewhere in CED, Kojonen cites in support of his view of the "laws of form" the work of Michael Denton and others (Kojonen 2021, pp. 123–25). He also explores convergent evolution, drawing in particular on the work of Simon Conway Morris (Kojonen 2021, pp. 125–28). Our discussion below also applies to the work of these thinkers, *mutandis mutatis*.

16 Other experiments by Gauger et al. (2010) broke a gene in the bacterium *E. coli* required for synthesizing the amino acid tryptophan. When the bacteria's genome was broken in just one place, random mutations were capable of "fixing" the gene. But when just two mutations were required to restore function, Darwinian evolution became stuck, unable to restore the full function.

17 For example, Venema (2018) cites intrinsically disordered proteins (IDPs), noting they "do not need to be stably folded in order to function" and therefore represent a type of protein with sequences that are less tightly constrained and are presumably therefore easier to evolve. Yet IDPs fulfill fundamentally different types of roles (e.g., binding to multiple protein surfaces) compared to the proteins with well-defined structures that Axe (2004) studied (e.g., crucial enzymes involved in catalyzing specific reactions). Axe (2018) also responds by noting that Venema (2018) understates the complexity of IDPs. Axe (2018) points out that IDPs are not entirely unfolded, and "a better term" would be to call them "conditionally folded proteins". Axe (2018) further notes that a major review paper on IDPs cited by Venema (2018) shows that IDPs *are* capable of folding—they can undergo "coupled folding and binding"; there is a "mechanism by which disordered interaction motifs associate with and *fold* upon binding to their targets" (Wright and Dyson 2015). That paper further notes that IDPs often do not perform their functions properly after experiencing mutations, suggesting they have sequences that are specifically tailored to their functions: "mutations in [IDPs] or changes in their cellular abundance are associated with disease" (Wright and Dyson 2015). In light of the complexity of IDPs, Axe (2018) concludes:

> If Venema (2018) pictures these conditional folders as being easy evolutionary onramps for mutation and selection to make unconditionally folded proteins, he's badly mistaken. Both kinds of proteins are at work in cells in a highly orchestrated way, both requiring just the right amino-acid sequences to perform their component functions, each of which serves the high-level function of the whole organism. (Axe 2018)

Venema (2018) also argues that functional proteins are easy to evolve. He cites Neme et al. (2017), a team that genetically engineered *E. coli* to produce a ∼500 nucleotide RNA (150 of which are random) that encode a 62 amino-acid protein (50 of which are random). The investigators reported that 25% of the randomized sequences enhance the cell's growth rate. Unfortunately, they misinterpreted their results—a fact pointed out by Weisman and Eddy (2017), who raised "reservations about the correctness of the conclusion of Neme et al. that 25% of their random sequences have beneficial effects". Here is why they held those reservations: the investigators in Neme et al. (2017) did not compare the growth of cells containing inserted genetic code with *normal* bacteria but rather with cells that carry a "zero vector"—a stretch of DNA that generates a fixed 350 nucleotide RNA (the randomized 150 nucleotides are excluded from this RNA). Weisman and Eddy (2017) explain how the zero vector "is neither empty nor innocuous", since it produces a "a 38 amino-acid open reading frame at high levels" of expression. Yet since this "zero vector" and its transcripts provide no benefit to the bacterium, its high expression wastes cellular resources, which, as Weisman and Eddy (2017) note, "is detrimental to the *E. coli* host". The reason the randomized peptide sometimes provided a relative benefit to the *E. coli* bacteria is because, in some cases (25%), it was probably interfering with production of the "zero vector" transcript and/or protein, thus sparing the *E. coli* host from wasting resources. As Weisman and Eddy (2017) put it, it is "easy to imagine a highly expressed random RNA or protein sequence gumming up the works somehow, by aggregation or otherwise interfering with some cellular component". Axe (2018) responds to Neme et al. (2017) this way:

> Any junk that slows the process of making more junk by gumming up the works a bit would provide a selective benefit. Such sequences are "good" only in this highly artificial context, much as shoving a stick into an electric fan is "good" if you need to stop the blades in a hurry.

In other words, at the molecular level, this random protein was not performing some complex new function but rather was probably interfering with its own RNA transcription and/or translation—a "devolutionary" hypothesis consistent with Michael Behe's thesis that evolutionarily advantageous features often destroy or diminish function at the molecular level (Behe 2019). In any case, what Neme et al. (2017) showed is that a quarter of the randomized sequences were capable of inhibiting *E. coli* from expressing this "zero vector", but they provided no demonstrated benefit to unmodified normal bacteria.Finally, Venema (2018) cites Cai et al. (2008) to argue for the *de novo* origin of a yeast protein, BSC4, purportedly showing that "new genes that code for novel, functional proteins can pop into existence from sequences that did not previously encode a protein". However, the paper provides no calculations about the rarity of the protein's sequence nor its ability to evolve by mutation and selection. Rather, the evidence for this claim is entirely inferred, indirect, and based primarily upon the limited taxonomic range of the gene, which led the authors to infer it was newly evolved. Axe (2018) offers an alternative interpretation:

> The observable facts are what they are: brewers' yeast has a gene that isn't found intact in similar yeast species and appears to play a back-up role of some kind. The question is how to interpret these facts. And this is where Venema and I take different approaches. . . . Other interpretations of the facts surrounding BSC4 present themselves, one being that similar yeast species used to carry a similar gene which has now been lost. The fact that the version of this gene in brewers' yeast is interrupted by a stop codon that reduces full-length expression to about 9 percent of what it would otherwise be seems to fit better with a gene on its way out than a gene on its way in.

18 The function of chorismate mutase is to catalyze the conversion of chorismate to prephenate through amino acid side chains in its active site, thereby restricting chorismate's conformational degrees of freedom. Essentially, it is merely providing a chamber or cavity that holds a particular molecule captive, thereby limiting that molecule's ability to change. In contrast, beta-lactamase requires the precise positioning and orientation of amino acid side chains from separate domains that contribute to hydrolyzing the peptide bond of the characteristic four-membered beta-lactam ring. This function requires a more complex fold compared to chorismate mutase. Axe (2004) specifically compares beta-lactamase to chorismate mutase and notes that the beta-lactamase fold "is made more complex by its larger size, and by the number of structural components (loops, helices, and strands) and the degree to which formation of these components is intrinsically coupled to the formation of tertiary structure (as is generally the case for strands and loops, but not for helices)".

19 For example, Hunt (2007) argues that relatively short peptides that perform simple functions could first evolve, which could then in turn evolve into more complex proteins that have rarer sequences. Research has shown that some short polypeptides derived from a random library can frequently perform simple functions (see e.g., Keefe and Szostak 2001). However, their ability to further evolve into complex enzymes appears extremely improbable, because functional paths in sequence space would not likely extend to regions containing even modestly complex proteins. The planet analogy in the main text illustrates why: suppose a tiny region around one pole of our hypothetical planet contained a high percentage of traversable land. Even so, a continuous path to the *other* pole still would not likely exist if a much larger region around the other pole contained a miniscule percentage of traversable land.

20 Axe (2011) replies to this objection as follows:

> It's kind of like insisting that the height from which a person has an accidental fall has nothing to do with their chance of surviving because it's the speed of impact that really matters. One could equally insist that the speed of impact is irrelevant—it's the force of rapid deceleration that really matters. In truth they all matter, and they do so for closely related reasons. The confusion comes from overlooking the causal links between them. Yes, the Darwinian mechanism requires that the different protein folds and functions not be isolated, and yes the rarity of functional sequences has a great deal to do with whether they are isolated.

This objection is further rebutted by the planet analogy in the main text, which shows that extreme rarity directly correlates with isolation.

21 The area comparisons for the planet were calculated by comparing the proportion of functional sequences for each protein by the percolation threshold in sequence space as defined in percolation theory. The percolation threshold represents the proportion of randomly distributed occupied sites in a lattice below which long continuous paths of neighboring occupied sites become rare. The threshold has been identified for multi-dimensional lattices as approximately the reciprocal of the number of a site's nearest neighbors (Gaunt et al. 1976). In the context of protein sequence space, it is approximately the reciprocal of the average number of sequences accessible in a single mutation, which is typically less than 10,000. The planet's traversable land divided by the traversable land corresponding to the percolation threshold of a two-dimensional lattice was set equal to the protein's proportion of functional sequences divided by its percolation threshold.

22 Kojonen tries to overcome this problem by arguing that the physical properties of proteins are "finely-tuned" to bias the clustering of functional sequences such that a very narrow path could extend to complex proteins with rare functional sequences. The biasing would result in the prevalence of functional sequences along a path to a new protein being much higher than in other regions of sequence space. But such biasing could not possibly assist the evolution of most proteins. Biasing in the distribution

of functional sequences in sequence space due to physical laws is arguably subject to the same constraints as the biasing in play in the algorithms employed by evolutionary search programs. Consequently, protein evolution falls under "No Free Lunch" theorems that state that no algorithm will in general find targets (e.g., novel proteins) any faster than a random search. An algorithm might assist in finding one target (e.g., specific protein), but it would just as likely hinder finding another (Miller 2017; Footnote 12). Thus, although Kojonen acknowledges that proteins are sometimes too rare to have directly emerged from a random search, he fails to appreciate the extent to which rarity necessitates isolation and why this must often pose a barrier to further protein evolution. Different proteins have completely different compositions of amino acids, physical properties, conformational dynamics, and functions. Any biasing that might assist in the evolution of one protein would almost certainly oppose the evolution of another. In other words, the probability of a continuous path leading to some proteins would be even less likely than if the distribution of functional sequences were random.

[23] Proteins are chains of amino acids that fold into stable three-dimensional shapes determined by molecular interactions between their constituent amino acids. These "protein folds" determine the specific function that a given protein is then able to perform in the cell (Dobson 2003; Onuchic and Wolynes 2004; Dill et al. 2008). Due to their importance in determining biological functions, protein folds can be considered "the smallest unit of structural innovation in the history of life" (Meyer 2013, p. 191).

[24] The paragraph concludes with the sentence: "The existence of similar parts in other systems, for example, does provide supporting evidence for evolvability (Musgrave 2004; Pallen and Matzke 2006)". We will take up this particular claim below. Note also Kojonen (2021)'s appeal to co-option in his response to Behe on page 122.

[25] Behe (2007, p. 95) likewise notes: "modern Darwinists point to evidence of common descent and erroneously assume it to be evidence of the power of random mutation". See also a more recent discussion in Behe (2019, pp. 287–91).

[26] The proteins are: FlgD, FlgH, FlgI, FlgJ, FlgM, FlgN, FlhE, FliB, FliD, FliE, FliL, FliO, FliS, FliT, FliZ.

[27] The proteins are: FlhDC.

[28] The proteins are: FliK, FliJ, FliG.

[29] The proteins are: FlgE, FlgK, FlgL, FlgBCFG.

[30] The proteins are: FlhA, FlhB, FliF, FliP, FliQ, FliR, FliH, FliI, FliM, FliN, FliC.

[31] The proteins are: FliM, FliN, FliC.

[32] The four proteins are FlgH, FlgI, FliS, FliT.

[33] To elaborate, the injectisome is found in a small subset of gram-negative bacteria that have a symbiotic or parasitic association with eukaryotes. Since eukaryotes evolved over a billion years after bacteria, this suggests that the injectisome arose after eukaryotes, relatively late in the history of life. However, flagella are found across the range of bacteria, and the need for chemotaxis and motility (i.e., using the flagellum to find food) is thought to have arisen very early—perhaps being present as early as the last bacterial common ancestor. Most certainly, the need for chemotaxis and motility preceded the need for parasitism, which means we would expect that the flagellum long predates the injectisome. Indeed, given the narrow distribution of injectisome-bearing bacteria, and the very wide distribution of bacteria with flagella, parsimony suggests the flagellum long predates injectisome rather than the reverse.

[34] Presumably, the probabilities are independent in each case. The whole point of convergent evolution is that *independent* evolutionary lineages led to the same outcome in organic history.

[35] Of course, Kojonen could reply by trying to dissipate these probabilities by appealing to deeper laws of nature, laws of form, or other fundamental features of matter. If the deep structure of nature constrains the development of life by causing it to 'cluster' around similar biological forms, then perhaps the probability of the repeated emergence of these forms is higher than expected. But this response is problematic in two ways. First, it plainly runs against actual data we have on protein rarity and isolation, including the rates and time needed for mutations or other changes to produce new proteins. Second, Kojonen cannot take this line of thinking very far if he also wants his model to be compatible with versions of evolution that allow (significant) for contingency. Recall that, though Kojonen himself emphasizes the laws of form (and laws of nature that underlie them), he is nonetheless keen to claim that his model is compatible with mainstream interpretations of evolutionary theory, including ones that allow for a notable degree of contingency and chance.

[36] Of course, it is possible for Kojonen to reply that some clusters of similarities, such as nested hierarchies, are better explained by common ancestry, whereas *other* similarities, which appear to be isolated, are better explained by convergent evolution. But the problem with this possible reply is three-fold. First, it does not take seriously Kojonen's own claim that convergence is "ubiquitous". To the extent that Kojonen accepts the pervasiveness of convergence in biology is likewise the extent to which the proposed reply is untenable. If convergence is persuasive, is it plausible that convergent similarities *never* include similarities that are part of a nested hierarchy, for example? Second, the possible reply above also does not solve a deep problem in the other direction: to the extent that similarities are due to common ancestry is also the extent to which convergence does not explain these similarities. But this is a problem, because Kojonen's view of convergence is ultimately rooted in his understanding of design—it arises from the laws of form, which are themselves the result of designed laws of nature. So, to the extent that Kojonen wishes to use common ancestry to explain similarities (such as those in nested hierarchies) is also the extent to which his use of 'design' does not add explanatory value to 'evolution'. Third, and more generally, the burden is on Kojonen to make these matters clear. He assumes that similarity implies common ancestry (in his view of protein evolution and reply to Behe), yet

at other times, he seems to think (other?) similarities point to convergent evolution (and design). Kojonen should resolve this tension by providing a principled ground to demarcate the two that does not damage the explanatory value of 'design' and that also avoids internal tension between 'design' and 'evolution'.

37 The full quote is helpful. Kojonen (2021) writes:

> According to this view, then, the possibility of evolution depends on the features of the space of possible forms, where *all the forms must be arranged in a way that makes an evolutionary search through it possible.* This argument shows how the preconditions for the working of the "blind watchmaker" of natural selection can indeed be satisfied by nature in the case of protein evolution, despite an extreme rarity of functional forms. According to this view, then, *the possibility of evolution depends on the features of the space of possible forms, where all the forms must be arranged in a way that makes an evolutionary search through it possible.* This argument shows how the preconditions for the working of the "blind watchmaker" of natural selection can indeed be satisfied by nature in the case of protein evolution, despite an extreme rarity of functional forms. Behe (2019, p. 112) argues that Wagner does not yet solve the puzzle of evolving irreducible complexity, arguing that "it doesn't even try to account for the cellular machinery that is catalysing the chemical reactions to make the needed components. " However, suppose that, in the case of the bacterial flagellum, though the vast majority of possible arrangements of biological proteins are non-functional, there nevertheless exists a series of possible functional forms, little "machines" that happen to contain increasing numbers of the flagellum's vital parts while still serving some other function. This then would allow for the seamless transition from no flagellum to a flagellum over time, through small successive steps. In this manner, by moving through such a suitable library of forms, the blind process of evolution would have the ability to produce even the most complex structures without the intervention of a designer. *This is the kind of fine-tuning of the landscape of forms that seems to be required to evolve the kind of biological order described by Behe.*

It seems, then, that defending the power of the evolutionary mechanism requires assuming that the landscape of possible biological forms has some *fairly serendipitous properties*. (Kojonen 2021, p. 122, emphases added) Kojonen (2021) elsewhere writes:

> Suppose for the sake of the argument that Behe is partially correct: complex machinery exists in nature and is difficult to evolve. Nevertheless, suppose that his critics are also correct, and the evolution of such complexity through Darwinian mechanisms actually happened. Given these premises, a theistic evolutionist could well argue that the irreducible complexity argument merely shows how demanding the conditions for evolvability are, and how much fine-tuning evolution actually requires. In a universe designed to allow for evolution, such serendipity could be expected, rather than being unlikely. Hence, Behe's argument could simply reveal the extent to which fine-tuning is required by evolution. (Kojonen 2021, pp. 118–19)

38 Pretty clearly, we will not assume that Kojonen's argument for design (KEBDA) is correct given that such an assumption would beg the question at issue. Our epistemological concerns target *ways of knowing* that make this argument possible in the first place.

39 Kojonen draws on Mats Wahlberg's argument (or analogy) of "computer-generated fugues in order to argue that the products of a design process incorporating random elements can still evidence design" (Kojonen 2021, p. 169). Even if human agents were to listen to such a fugue and mistakenly believe that *every* element of it was designed (when, in fact, some elements are randomly generated), they are still correct that "the sounds they hear are expressive of intelligence and intent" (Kojonen 2021, p. 170). So, this example apparently shows that design might still be detectable even if humans are mistaken about certain aspects of it. Perhaps, then, Kojonen can reply to our argument by saying that even if humans are mistaken about 'direct design', they can still be said to reliably detect design in some notable sense. By way of reply: First, we will show below that Kojonen's model undercuts humans' ability to detect design in the way required by Wahlberg's argument (or analogy). Second, it is arguably the case that, relative to the justification of design beliefs, 'direct design beliefs' ("Someone made hummingbirds!") are more fundamental than 'detailed design beliefs', as we might call them ("Someone made every detail of hummingbirds!"). Thus, permissible mistakes about the latter may not be relevant to the epistemic permissibility (and troubling implications) of mistakes about the former. Third, it is not entirely clear that, in Wahlberg's example, fugues are "random" in a sense that would be relevant to the current discussion.

40 An 'agent' cause, by contrast, is the direct action of an agent.

41 Accordingly, our argument does not fall prey to Kojonen's critique of Dawkins's claim that evolution can produce design without a designer and is thus a "consciousness-raiser" that ought to prompt a person to be wary of design (see Kojonen 2021, pp. 145–46). Kojonen (2021, p. 145) responds to Dawkins by saying, "Suppose for the sake of argument that a divine designer is actually responsible for the laws of form (and other environmental factors) that enable evolution. In that case, evolution would be dependent on design, and therefore evolution would not actually show us that evolution can produce design without a designer". But this critique of Dawkins does not apply to our argument. First, Kojonen's line of thinking fails to address the larger points we are making about (i) the implications of evolution for 'direct design' beliefs and (ii) the broader continuity of non-agent causes that would be apparent to a person who accepted Kojonen's model. Second, in the quote above, Kojonen seems to move illicitly from ontology to epistemology: from the fact that there is a designer (and design of the type he proposes), it does not follow that evolution itself would not point human observers in the other direction. It is entirely possible that, in

some notable sense, evolution might obscure the signal of design. The *fact* of design does not entail *evidence* of design. (Similarly, the fact of design likewise does not entail the lack of defeaters to evidence of design.)

42 Of course, each of Kojonen's illustrations is not (simply) given to show that humans can detect design directly or indirectly. Kojonen deploys them for an array of purposes. But our point here is that, insofar as these illustrations support the idea that (on Kojonen's model) human beings can reliably detect design based on biological phenomena, these illustrations are instead undercut by the fact that Kojonen's model actually damages the foundational dispositions or beliefs involved in design detection that undergird (this use of) these illustrations. Moreover, Kojonen's illustrations do not seem to address our points about direct design and non-agent continuity. Biological complexity could in principle be designed (or compatible with design), but that does not mean there would be sufficient evidence of such, especially given some of the key elements of Kojonen's proposal. So, too, with Kojonen's view of human technology and the need for fine-tuning to make it possible (Kojonen 2021, p. 173–74). Even if such fine-tuning did exist, a person who accepted Kojonen's key claims (about evolution, non-agent causes, and so on) would likely have little evidence of it. Interestingly, in his discussion of human technology, Kojonen seems to move away from biological data and, instead, openly cites data from *other* areas, including mathematics and commonsense physics. Perhaps this is a tacit admission of one of our key points: in Kojonen's model, the biological evidence *on its own* may not in fact point to design.

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The Bronze Age Destruction of Jericho, Archaeology, and the Book of Joshua

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Abstract: The ancient city of Jericho, located at the archaeological site of Tell es-Sultan west of the Jordan River and adjacent to the Ein es-Sultan spring on the edge of modern Jericho, has often been associated with the biblical city of Jericho and the story found in the book of Joshua. The identification of Jericho with Tell es-Sultan is not disputed, and numerous excavation teams have affirmed Tell es-Sultan as Jericho. While excavations have also uncovered the fiery destruction of a walled city at Jericho, the date of the fall of Bronze Age Jericho and the association of this destruction with the narrative in the book of Joshua have been a point of disagreement among archaeologists for more than a century. The first excavations at Jericho (Tell es-Sultan) occurred in 1868 under the direction of Charles Warren, followed by soundings conducted by FJ Bliss in 1894, the expeditions of the years 1907–1909 and 1911 by Ernst Sellin and Carl Watzinger, the excavations of 1930–1936 directed by John Garstang, the 1952–1958 project of Kathleen Kenyon, brief excavations by Shimon Riklin in 1992, and the most recent excavations and restorations by the joint Italian–Palestinian team from 1997 to 2000 under Nicolo Marchetti and Lorenzo Nigro, followed by the 2009–2017 seasons directed by Jehad Yasin, Hamdan Taha, and Lorenzo Nigro. Although there is a significant deviation in views over the exact date of the destruction and abandonment, archaeological analyses of Jericho generally agree on the manner in which the city met its end, including a widespread fire, collapsed mudbrick walls, burning of the stored grain, and abandonment. However, assessing all of the archaeological data from Jericho IVc, both new and old, including pottery wares, Egyptian scarabs, a cuneiform tablet, stratigraphic analysis, and radiocarbon samples, allows a more definitive historical reconstruction concerning the chronology of the destruction of Jericho and its connections to the biblical narratives.

Keywords: Archaeology; Jericho; Bronze Age; Canaan; Biblical Archaeology; Levant

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1. Introduction

The ancient city of Jericho, located at the archaeological site of Tell es-Sultan, about 5 miles west of the Jordan River, adjacent to the Ein es-Sultan spring on the northwest edge of modern Jericho, has often been associated with the biblical city of Jericho and the story of its destruction as found in the book of Joshua. The identification of Jericho with Tell es-Sultan is not disputed, and the name of the city may even be attested on a Middle Bronze Age scarab discovered in Tomb D641 at Jericho, rendered as "Ruha" and perhaps deriving from an early Semitic word "Yareah" for the moon, connected to the name of the moon deity. Numerous excavation teams and archaeological investigations have not only identified Tell es-Sultan with Jericho but additionally uncovered the fiery destruction of a walled city. Yet, the date of the fall of the Bronze Age city of Jericho and the association of this destruction with the narrative in the book of Joshua have been points of disagreement among archaeologists for more than a century. The first excavations at Jericho (Tell es-Sultan) occurred in 1868 under the direction of Charles Warren, followed by soundings conducted by FJ Bliss in 1894, the expeditions of the years 1907–1909 and 1911 by Ernst Sellin and Carl Watzinger, the excavations of 1930–1936 directed by John

Garstang, the 1952–1958 project of Kathleen Kenyon, brief excavations by Shimon Riklin in 1992, and the most recent excavations and restorations by the joint Italian–Palestinian team from 1997 to 2000 under Nicolo Marchetti and Lorenzo Nigro, followed by the 2009–2017 seasons directed by Jehad Yasin, Hamdan Taha, and Lorenzo Nigro. These excavation projects used varying methods, excavated for differing amounts of time per season, and all came to unique conclusions regarding the details of the fall of the final Bronze Age city at Jericho. Although there has been a disparity of views regarding the interpretation of the data, including the exact date of the destruction and abandonment, archaeological analyses of Jericho generally agree on other specifics, such as the manner in which the city met its end.

The current, prevailing view amongst modern archaeologists regarding Jericho is that the narrative in the book of Joshua about the destruction of the walled city is a "romantic mirage," which contradicts the archaeological findings, and that "there was no trace of a settlement" around 1230 BC, "the suggested date of the conquest" (Finkelstein and Silberman 2002, pp. 76, 81–82; Joshua 6: 1–26).[1] This perspective is widely held in academia and asserts that the Jericho conquest is a later literary invention and mythical propaganda devoid of historical information, or at best a legendary historical core that might preserve loosely similar earlier events combined with reflections of later periods (Finkelstein and Silberman 2002, pp. 107, 118; Dever 2003, pp. 51–74; Na'aman 1994, pp. 280–81; Fritz 1987, p. 84; Killebrew 2005, p. 152; Finkelstein and Mazar 2007, pp. 61–62; Lemche 1985, p. 56; Thompson 1987; Van Seters 2001). However, many other scholars have argued that the conquest of Jericho was a historical event that archaeological data supports (e.g., Albright 1957, pp. 273–89; Bright 1981, pp. 129–43; Garstang [1931] 1978; Wood 1999, pp. 35–42; Younger 2009, pp. 237–41). Within this "historical" view are two main subdivisions: that the fall of Jericho occurred about 1230 BC in Late Bronze IIB or that the destruction happened around 1400 BC at the end of Late Bronze IB. Although the vast majority of scholars over the last few decades have placed the hypothetical conquest of Jericho in the 13th century BC, and that is primarily the view mentioned and summarily rejected by most modern scholars, the conclusions of Kenyon following her excavations at Jericho asserted that neither ca. 1230 BC nor ca. 1400 BC would be possible for the fall of Jericho, since allegedly the last Bronze Age city existed during the Middle Bronze Age in the 16th century BC, not anytime in the Late Bronze Age, and therefore the story contradicts archaeological findings at the site (Kenyon 1957, pp. 213–18, 257–58; 1967; 1970; 1975, pp. 562–64).[2] The debate between a conquest of Jericho in the 13th century BC versus around 1400 BC has been extensively discussed elsewhere and in relation to the Exodus and conquest generally, but it is almost universally acknowledged by archaeologists that there is no trace of the destruction of Jericho in the 13th century BC or an inhabited and walled city of Jericho at that time (Finkelstein and Silberman 2002, p. 76; Wood 2005, pp. 475–89; 2007, pp. 249–58; Hoffmeier 2007, pp. 225–47).[3] However, the dispute at Jericho revolves around archaeological data related to the date of the fall of Jericho city IV, the final Bronze Age city, and how closely the specifics of the Joshua narrative about the fallen walls, fire destruction, looting, timing, and subsequent abandonment and settlement match the findings at the site.

Archaeological excavations have shown that Jericho had a long history of occupation, but the city is first mentioned in the Bible during the period of the wilderness wandering (Numbers 22: 1). According to biblical descriptions of Canaanite cities, including Jericho, many of these settlements prior to the Joshua period conquest had walls, gates, and various fortifications (Numbers 13: 19–28; Deuteronomy 3: 5; Joshua 2: 5, 6: 1–5, 10: 20). Past evaluations of Canaan in the Late Bronze II and the 13th century BC, where some scholars have placed the conquest of Canaan, suggest that there was a dearth of fortified cities in the region. However, massive fortifications originally constructed in the Middle Bronze Age often continued to be used at least into the first part of the Late Bronze Age, and in some cases even later (Mazar 1992, p. 243). Subsequent archaeological excavations and surveys have demonstrated that specific cities mentioned in the conquest narratives were occupied

and fortifications were even present in the 15th century BC, or Late Bronze I (Hansen 2000; Kennedy 2013).

2. The Middle Bronze Age Wall at Jericho

Jericho is one of the many settlements in Canaan where a formidable fortification system was constructed during the Middle Bronze Age. During this period, the people of Jericho built a cyclopean wall around the city, which utilized a stone retaining wall and an upper wall of mudbrick. This city wall was rebuilt in Middle Bronze III around 1600 BC and encompassed an area of about 17 acres, although part of the site was destroyed in modern times due to road construction, so calculations are only approximate (Nigro and Taha 2009, pp. 731–34; Marchetti et al. 1998, p. 141). According to the early German excavations, when less damage had been done to the site, the stone retaining wall was approximately 4 to 5 m high, and the upper mudbrick wall on top of the retaining wall was approximately 6 to 8 m high and 2 m thick (Sellin and Watzinger [1913] 1973, p. 58; Marchetti et al. 1998, p. 141). Inside this was another wall, made of mudbrick, which, according to the Italian–Palestinian team, reached a height of 12.11 m above ground level outside of the fortifications (Marchetti et al. 1998, p. 142). Both a stone retaining wall and a rampart of debris piled on the MB I and MB II fortifications were built in MB III, or approximately 1650–1550 BC/1600-1500 BC (Marchetti et al. 1998, pp. 131, 138, 141; Marchetti 2003, pp. 311–12; Nigro and Taha 2009, p. 731; Nigro 2020, p. 201). Besides the ceramic typology indicating the date of the construction in Middle Bronze III, excavations have demonstrated that the Cyclopean Wall cuts through Tower A1, which was in use during Middle Bronze I and II (Nigro and Taha 2009, p. 734). A report about the 1952 excavations had come to similar conclusions, stating that the latest surviving defenses are Middle Bronze Age and that this system had been preceded by two previous Middle Bronze Age walls built prior (Tushingham 1952, pp. 8–10). Although these final city walls appear to have been constructed in Middle Bronze III, this does not mean that Jericho had no walls in the subsequent Late Bronze I period. Rather, as was the case at many other sites in Canaan, the massive fortifications could have remained in use into the Late Bronze Age or beyond. One of the clearest parallels for this comes from Hazor, where it was obvious that the city of the Late Bronze Age reused Middle Bronze fortifications and repaired or strengthened them, and this was perhaps also the case at Jericho (Yadin 1959, pp. 9–19; 1975, pp. 266–67; 1982, p. 22). Other sites, such as Gezer and Tell Jerishe, demonstrate the continued use of the Middle Bronze Age fortification system into the Late Bronze Age (Dever 1992, p. 17; Sukenik 1942, p. 199). It is therefore possible that the city wall built at Jericho in Middle Bronze III continued to be used into the subsequent period of Late Bronze Age I. However, whether or not the city was occupied in Late Bronze I can only be determined by an analysis of other data. (See Figure 1 below).

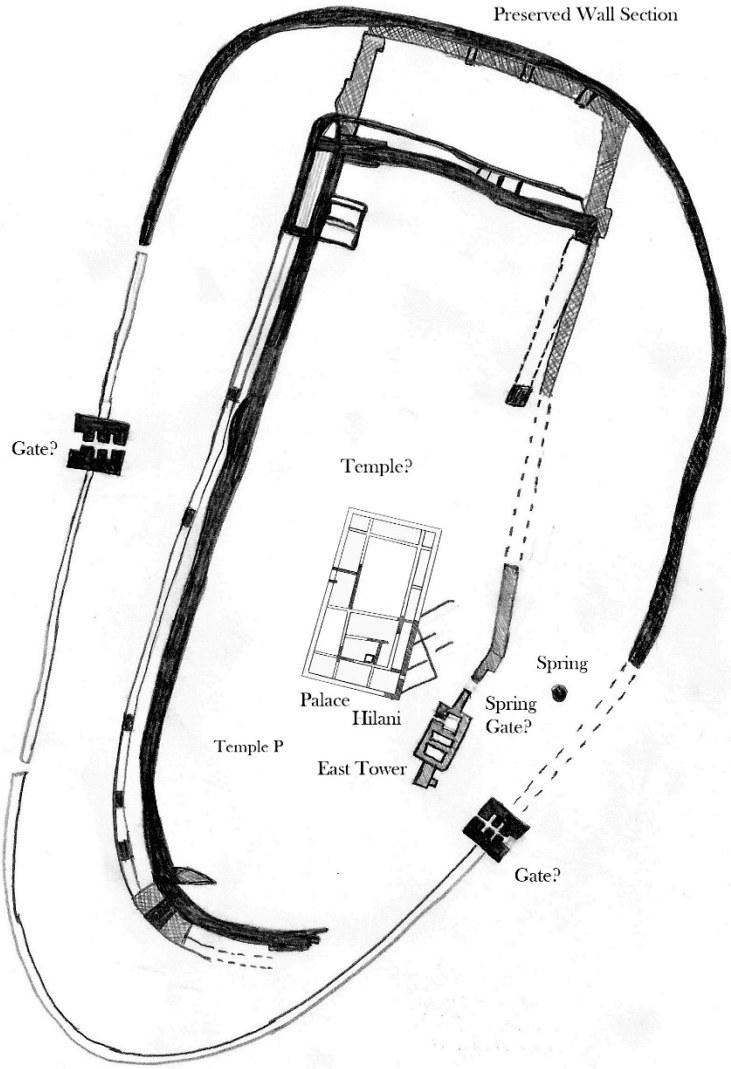

Figure 1. Composite map of the ancient city of Jericho based on multiple excavations.

3. Destruction of Jericho IVc

Temporarily setting aside the question of Middle Bronze III versus Late Bronze I for the fall of Jericho IVc, while acknowledging the possibility that the Middle Bronze Age fortifications could have continued in use into the Late Bronze Age, the correlation between the manner of destruction found in excavations at Jericho and the Joshua narrative about the conquest of Jericho should be examined. The book of Joshua records that not long after the spring harvest, the Israelites besieged Jericho, the walls of the city fell, the army walked up into the city, a restriction had been placed to not loot Jericho except for metals, and finally the city was burned (Joshua 3: 15, 4: 19, 5: 10, 6: 1–24). Additional information related to stratigraphy indicates that a city may not have been rebuilt at Jericho subsequent to its destruction until the 9th century BC, except for a briefly used residential building by Eglon of Moab during the Judges period (Joshua 6: 26; Judges 3: 12–30; 1 Kings 16: 34). Therefore, after the fall of Jericho, there should have been no city at the site until the Iron Age II and only a residence during the Late Bronze II.

According to archaeological excavations at Jericho, including the Kenyon and Italian–Palestinian excavations, the mudbrick wall on top of the stone retaining wall had collapsed and fallen in front of the retaining wall around most of the city and had essentially formed a pile of sloping bricks resembling a ramp (Marchetti et al. 1998, p. 143; Kenyon and Holland 1981, p. 110; Wood 1990b, pp. 54–56; 1999, p. 37). The outward falling of the city walls,

which was followed by a massive fire that engulfed Jericho and included the collapse of buildings in the city, was proposed by excavators as possibly being the result of an earthquake rather than a battering ram or other siege equipment (Garstang 1948, pp. 118, 138–139, 159; Kenyon 1957, pp. 179, 262; Kenyon and Holland 1981, pp. 110, 370).[4] This "terrible destruction" of Jericho by fire has been posited by various excavators and other researchers as the result of a violent attack by either a foreign enemy or another city-state, without agreement regarding the identity of the attackers (Nigro 2016, p. 15; 2020, p. 201). The falling or collapse of the wall was the first phase, while the destruction by fire was the second phase. The collapse of the city wall, which was constructed in the Middle Bronze Age III, and other associated architecture in the final Bronze Age City IVc Jericho is dated on the basis of its construction period. The finds sealed by the destruction layer on top of collapsed architecture and subsequently constructed architecture such as the "Middle Building" mean the falling of this wall, building collapse, and the destruction of the city must have occurred within the periods of either Middle Bronze III or Late Bronze I.

Although Kenyon separated the falling of the walls and the following fire destruction into separate phases, the two events need not be separated by vast amounts of time, and there is no indication that the city was abandoned or lay dormant in between the collapse and the fire. Perhaps it is more than a coincidence that the sequence is the same as that recorded in the book of Joshua—fallen city walls, then the intentional burning of the city by the attacking Israelites (Joshua 6: 20–24). Because battering rams would cause the walls to fall into the city at specific points of attack rather than outside and in front of the retaining wall all around nearly the entire city, this facet of the destruction has often been attributed to an earthquake, although other explanations may be possible. Indeed, rather than displaying the characteristics of a battering ram siege and forcing entry at a particular weak point or points of the city defenses, as would be expected from conventional warfare, an earthquake or another action with similar result might have caused wall sections to crumble both outside and inside the line of the stone retaining wall. However, perhaps more important than the specific cause of the collapse is that, according to archaeological observations, the walls of Jericho City IVc fell down the slope, resulting in the formation of a simple ramp up into the city. This phenomenon of a fallen mudbrick wall forming a pile that people could use to march over and past the walls and into the city accords with the description in the Joshua narrative about the wall falling upon itself and the army then walking up into Jericho (Joshua 6: 20). (See Figures 2 and 3 below).

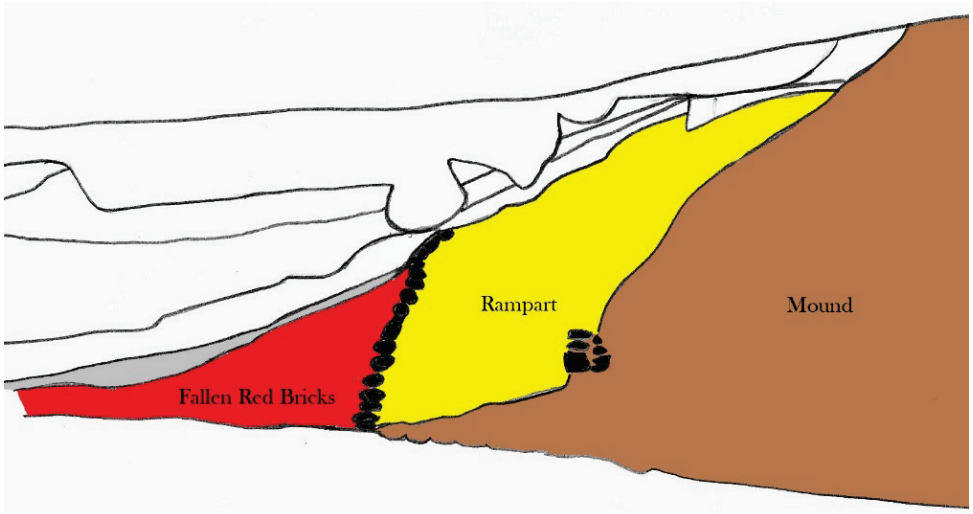

Figure 2. Cross section of Trench I showing the Jericho outer city wall built in Middle Bronze III. The pile of fallen mudbricks in the form of a ramp in front of the stone retaining wall originally comprised a mudbrick wall atop the stone retaining wall.

Figure 3. Houses of mudbrick built up against the outer wall at Jericho. Photo from the Sellin and Watzinger excavations.

After the walls fell, the next archaeologically observable event in the sequence was the burning of the city. The fire destruction of Jericho IVc was found in numerous excavation areas at the site, and it was a severe and complete destruction, including blackened walls and floors, fallen bricks and timber, burnt debris, collapsed roofs, and burned remains around the MBIII wall (Kenyon and Holland 1981, p. 370; Nigro and Taha 2009, p. 735). The fire was so intense and so widespread, including residential houses, the palace and the temple, that it appeared to indicate a deliberate burning of Jericho rather than an accidental or localized fire restricted to a particular building or section of the city (Garstang 1948, pp. 118, 136, 142). This is further supported by the long abandonment of the site, with the next architecture dating to Iron II except for the briefly occupied "Middle Building," indicating that significant death and destruction that occurred at Jericho. (Marchetti 2003, p. 317). This violent destruction brought an end to the stratum known as Jericho IVc (Jericho 1997–2000 Seasons Report: http://www.lasapienzatojericho.it/Results%201997-2000/res_sulIVc.htm, accessed on 22 February 2023). (See Figure 4 below).

Figure 4. Stratigraphic section of the final Bronze Age destruction layer at Jericho from a Kenyon excavated square on the eastern side of the city, showing collapsed building materials, pottery, charcoal, and ash.

However, the collapse of the walls and the city being engulfed in a destructive fire were not the only details found at Jericho that match the Joshua narrative. Prior to attacking the city, the Israelites had observed Passover (March/April), and then the Israelite army had been instructed to loot only the metals from Jericho but to leave everything else in the city to be destroyed (Joshua 5: 10, 6: 19–20). Excavations in the destruction layer at Jericho uncovered numerous ceramic storage jars containing significant amounts of grain, specifically barley, that had been burned along with the buildings rather than looted (Kenyon 1957, pp. 230, 261; Garstang 1931, pp. 193–94; 1948, p. 141). These finds indicate an attack on Jericho soon after barley harvest time in March/April and by an army that was not concerned with looting the food supplies of the city, matching the timing and methodology of the invading Israelite army in the Joshua narrative (Joshua 2: 6, 3: 15, 5: 10; cf. Gezer Calendar; Exodus 9: 31–32; Ruth 1: 22; 2 Samuel 21: 9). Although this would explain why there was so much burned grain found in the city at the time of its destruction, it also directly contradicts the typical military practice of the period, as the full grain jars indicate that the city was conquered while food stores were still abundant and the attacking army neglected to loot food from the city. Campaigns were usually launched before the spring harvest, when the city under siege would have the lowest amount of resources, and sieges were usually quite long, such as the 3-year siege of Sharuhen and the 7-month siege of Megiddo (Pritchard 1969, p. 246; Cline 2002, p. 21). Besieging a city in the spring season prior to harvest would not only starve out the defenders but also allow the attacking army to harvest and use the grain in the fields outside of the city for an additional food source (Lichtheim 1976, p. 34). At Jericho IVc, the attack was initiated after harvest, the siege was brief, and the invaders simply burned the food supplies inside the city. (See Figure 5 below).

Figure 5. Burned storage jars full of grain uncovered in the fire destruction layer of Jericho IVc. Found and photographed in the excavations under Garstang.

4. Pottery and the Date of Destruction

Although there may be general agreement about the basic manner in which Jericho IVc was destroyed and perhaps even acknowledgement that the events and sequence appear consistent with the Joshua narrative, there is much dispute concerning the exact date when the city was destroyed and if those events could connect to the fall of Jericho recorded in the book of Joshua. In order to establish a firm date for the destruction of Jericho, it is necessary to analyze the chronology of the ceramic remains, royal scarabs found at the site, a clay tablet discovered in excavations, and the various radiocarbon dates.

Ceramic remains are the most abundant material found from excavations in this region, and the chronology of pottery typology is widely used for establishing the date of excavated strata. At Jericho, thousands of sherds were excavated in association with the destruction layer and the final Bronze Age city, including local wares, imported wares, and locally produced exotic imitation wares. The types of pottery that are most distinctive are usually decorated wares, and excavations at Jericho have certainly uncovered much of this material.

Cypriot Bichrome Ware, with its characteristic painted red/brown and blue/black decoration along with fine clay, is one type of pottery that can indicate the occupation of the site in Late Bronze I or ca. 1500–1400 BC (Gitin 2019, pp. 339–41; Amiran 1970, pp. 152–57). Garstang excavated various bichrome fragments in the destruction layer of the final Bronze Age city (Wood 1990b, pp. 37, 53; 1990a, pp. 48, 49; Bienkowski 1986, pp. 128–30; Garstang 1934, pls. 29: 4, 7, 12; 34: 3; 36: 12; 39: 5; p. 111, pl. 34: 10; and pl. 31: 8). Chocolate on White Ware, which is another painted ware that was found in significant amounts at Jericho from numerous excavations, maybe even more indicative of Late Bronze I occupation around 1500–1400 BC (Fischer 1999, pp. 1–22; Gitin 2019, pp. 169–70; Amiran 1970, pp. 158–60). Another possible indicator of the fall of Jericho and its abandonment prior to Late Bronze II could be the lack of Western Anatolian Gray Ware imports, which appear in the Levant beginning in Late Bronze IIA (Gitin 2019, p. 381).

Although Kenyon argued for dating the destruction of Jericho IVc to around 1550 BC rather than slightly later in the 15th century BC due to an alleged absence of exotic wares such as Cypriot Bichrome and Chocolate on White, the excavation reports on Jericho tell a different story. Both Cypriot bichrome and Chocolate on White can be seen on plates

and descriptions in the Kenyon expedition reports, which were published posthumously, demonstrating that this type of pottery was in fact discovered (Kenyon and Holland 1983, pp. 436, 464–72). This exotic ware characteristic of Late Bronze I was also found in the Sellin and Watzinger excavations and can be seen in the excavation report of 1913, although ceramic chronology was not well understood and defined at that time (Sellin and Watzinger [1913] 1973, pp. 123–29, 142–46). However, Watzinger eventually argued that Jericho was unoccupied during Late Bronze I (Watzinger 1926, pp. 131–36). The Kenyon expedition did in many places mention the presence of Late Bronze pottery, even noting parallels to Late Bronze IB strata at other sites such as Megiddo Level VIII and Beth-Shean stratum IX (Kenyon 1951, p. 133; Tushingham 1953, p. 63). The excavations under Kenyon surely found Late Bronze I pottery, which is consistent with the findings from other expeditions at Jericho. However, because the Kenyon excavations focused on deep trenches rather than broad trenches, only a sampling of findings from each period was uncovered rather than extensive material culture from a single period. While using narrow excavation trenches encompassing only very small areas of the site may have been a pragmatic method to probe and discover an overall stratigraphic profile of the site, this technique also had major shortcomings for understanding any one occupational period at Jericho (Herr 2002, p. 53; Wood 1990a, p. 47).

The excavations at Jericho led by Garstang, which dealt extensively with Middle Bronze Age and Late Bronze Age structures, tombs, and materials, found considerable amounts of Late Bronze Age pottery, including local and imported wares. Among the distinctive Late Bronze I pottery types were Cypriot wares and imitations, but a lack of Mycenaean wares indicated that occupation of the city had ceased by Late Bronze II (Garstang 1941, pp. 369–71). However, the local wares excavated at Jericho were the most prolific of the pottery finds. It is therefore significant that these local wares have clear parallels to Late Bronze I strata at other sites in Canaan. Wood analyzed the local wares in detail and explained numerous parallels, refuting the idea that these local wares could all belong to Middle Bronze II or III (Bienkowski 1990, p. 46; Wood 1990a, pp. 45–49, 68–69). Among the numerous forms found at Jericho with clear parallels from other sites were "the flaring carinated bowl with slight crimp" from Late Bronze I contexts at the Lachish Fosse Temple 1 (Tufnell et al. 1940, pl. 42: 129), Megiddo IX (Loud 1948, pl. 53: 19), Hazor 2 (Yadin 1961, pl. 263: 3–16), Hazor cistern 9024 level 3 (Yadin et al. 1958, pl. 123: 1–9), and Hazor cistern 7021 level C (Yadin 1972, pl. 136: 1–7; Wood 1990a, pp. 47–48). Conical bowls with painted interior concentric circles, a typical Late Bronze IB form found all over the southern Levant, were also found at Jericho (Garstang 1934, p. 121). Parallels in Late Bronze I contexts come from Ashdod XVII (Dothan 1971, p. 81), Hazor 2 (Yadin 1960, p. 94; 1972), Lachish Fosse Temple 1 (Tufnell et al. 1940, pl. 37: 1), Shechem XIV (Toombs and Wright 1963, fig. 23: 2), Mevorakh XI (Stern 1984, fig. 5: 7) and Megiddo VIII (Loud 1948, pl. 61: 18). Another bowl form found at Jericho has Late Bronze I strata parallels from Rabud LB4 (Kochavi 1974, fig. 4: 3) and Shechem XIV (Toombs and Wright 1963, fig. 23: 1) (number 5), Lachish Fosse Temple 1 (Tufnell et al. 1940, pls. 41: 98, 104, 105, pls. 42: 127) (number 6), and Lachish Fosse Temple 1 (Tufnell et al. 1940, pls. 37: 3, 4, 7 and 38: 32, 33), Mevorakh XI (Stern 1984, fig. 5: 11–14), Megiddo VIII (Loud 1948, pl. 61: 13, 14) and Hazor 2 (Yadin 1961, pl. 288: 3) (number 7), although this has also been found in Middle Bronze III contexts and is probably a form that continued from MB into LB (Wood 1990a, p. 48). The storage jar type found at Jericho (number 8) is another typical Late Bronze I form, with parallels from Late Bronze I strata such as Lachish Fosse Temple 1 (Tufnell et al. 1940, pl. 57: 389), Rabud LB4 (Kochavi 1974, fig. 4: 10), Shechem XIV (Toombs and Wright 1963, fig. 23: 14) and Hazor cistern 7021, level C (Yadin 1972, pl. 141: 2). Oil lamps, which continuously changed over time and are quite distinctive by archaeological period, are another indicator from Jericho that the city was occupied during Late Bronze I, as the saucer form with a slightly pinched spout (number 9) is typical of Late Bronze I with a clear parallel from Lachish Fosse Temple 1 (Tufnell et al. 1940, pl. 45 186, 187). Cooking pots were prolific due to their common use and short lifespan, and they

are another pottery type that is quite distinctive by period. At Jericho, the everted rim cooking pots with a round bottom (numbers 10, 11, 12) have numerous parallels in other Late Bronze I contexts, such as Lachish Fosse Temple I (Tufnell et al. 1940, pl. 355: 361), Shechem XIV (Toombs and Wright 1963, fig. 23: 19, 20), Michal XVI (Herzog et al. 1989, fig. 5.6: 3), Mevorakh XI (Stern 1984, fig. 7: 9), Hazor 2 (Yadin 1972, pl. 138: 4), Lachish Fosse Temple 1 (Tufnell et al. 1940, pl. 55: 354), Rabud LB4 (Kochavi 1974, fig. 4: 6), Ashdod XVII (Dothan 1971, fig. 33: 7), Michal XVI (Herzog et al. 1989, fig. 5.6: 8), Hazor XV/2 (Yadin 1961, pls. 199: 19 and 289: 7), and Hazor 2 (Yadin 1972, pl. 139: 1–4). The water jar with painted stripes (number 13) was unique to the Late Bronze Age, and the type found at Jericho is also known from Late Bronze I strata at Ashdod XVII (Dothan 1971, fig. 33: 13), Hazor 2 (Yadin 1961, pl. 266: 15), and Hazor cistern 7021 level C (Yadin 1972, pl. 141: 12). The dipper juglet from Jericho (number 14), while occurring from Middle Bronze III to Late Bronze II, also appears to have a form consistent with Late Bronze I at the Lachish Fosse Temple 1 (Tufnell et al. 1940, pl. 52: 297, 303). The most recent excavations at Jericho have also affirmed Late Bronze IB pottery at the site from a building in the palace area near the center of the city (Nigro 2009, p. 362).

While the idea that Jericho was completely unoccupied during the Late Bronze Age is not accepted by archaeologists, a variety of ideas about the extent of the settlement and the dates of occupation have been proposed, ranging from only occupation at the "Middle Building" in the 14th century BC to a small settlement that allegedly lasted into the beginning of LB IIB before being abandoned until the Iron Age IIA (Nigro 2020, pp. 201–6). These discrepancies are mostly due to differing chronologies about 18th Dynasty Pharaohs, incorrectly placing LB I pottery into LB II (e.g., Chocolate on White Ware), and claiming that the evidence for the LB II settlement disappeared due to erosion, dumping, or leveling. While erosion can move archaeological material or cover it, pits and dumping can jumble the chronology of sections of strata, and leveling can cover or damage architectural remains, the evidence for entire strata does not simply disappear from archaeological sites and is not a phenomenon observed elsewhere in the region. The ceramic data from excavations at Jericho since 1907 indicate that the site was indeed inhabited during the Late Bronze I. (See Figures 6 and 7 below).

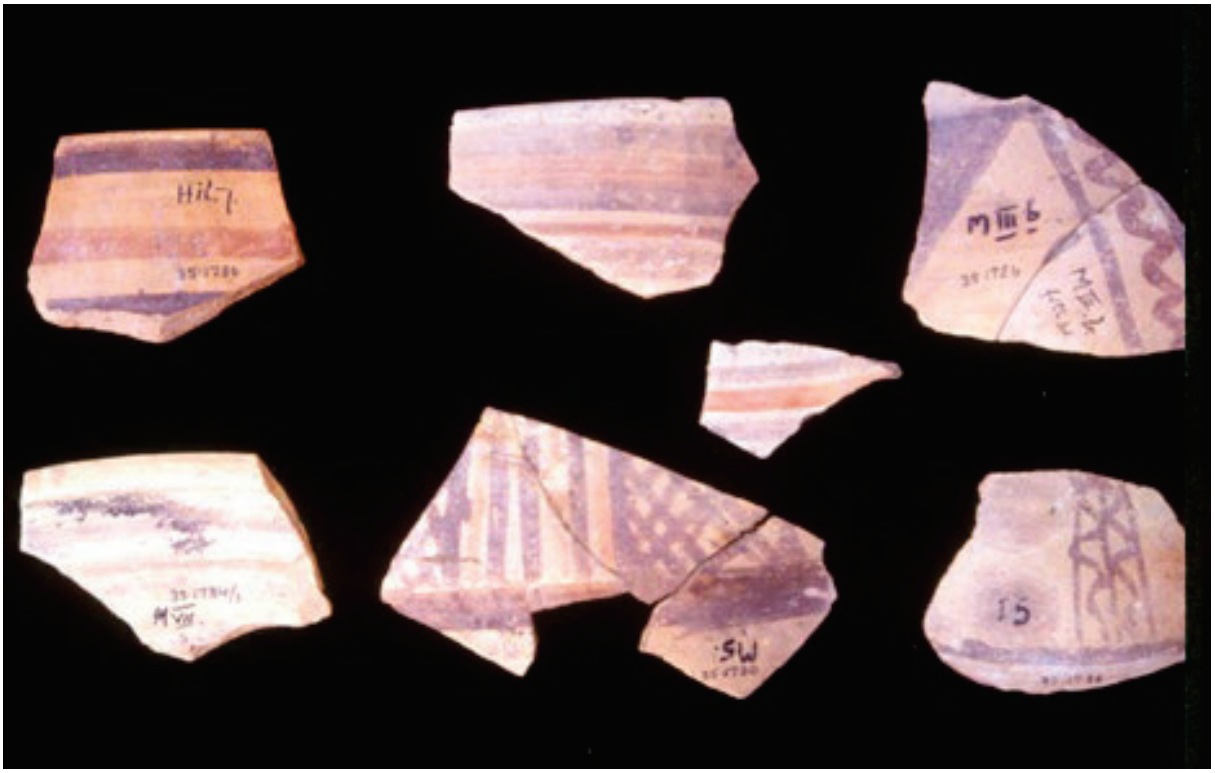

Figure 6. Cypriot Bichrome sherds excavated by Garstang at Jericho IV and shown in (Wood 1990b).

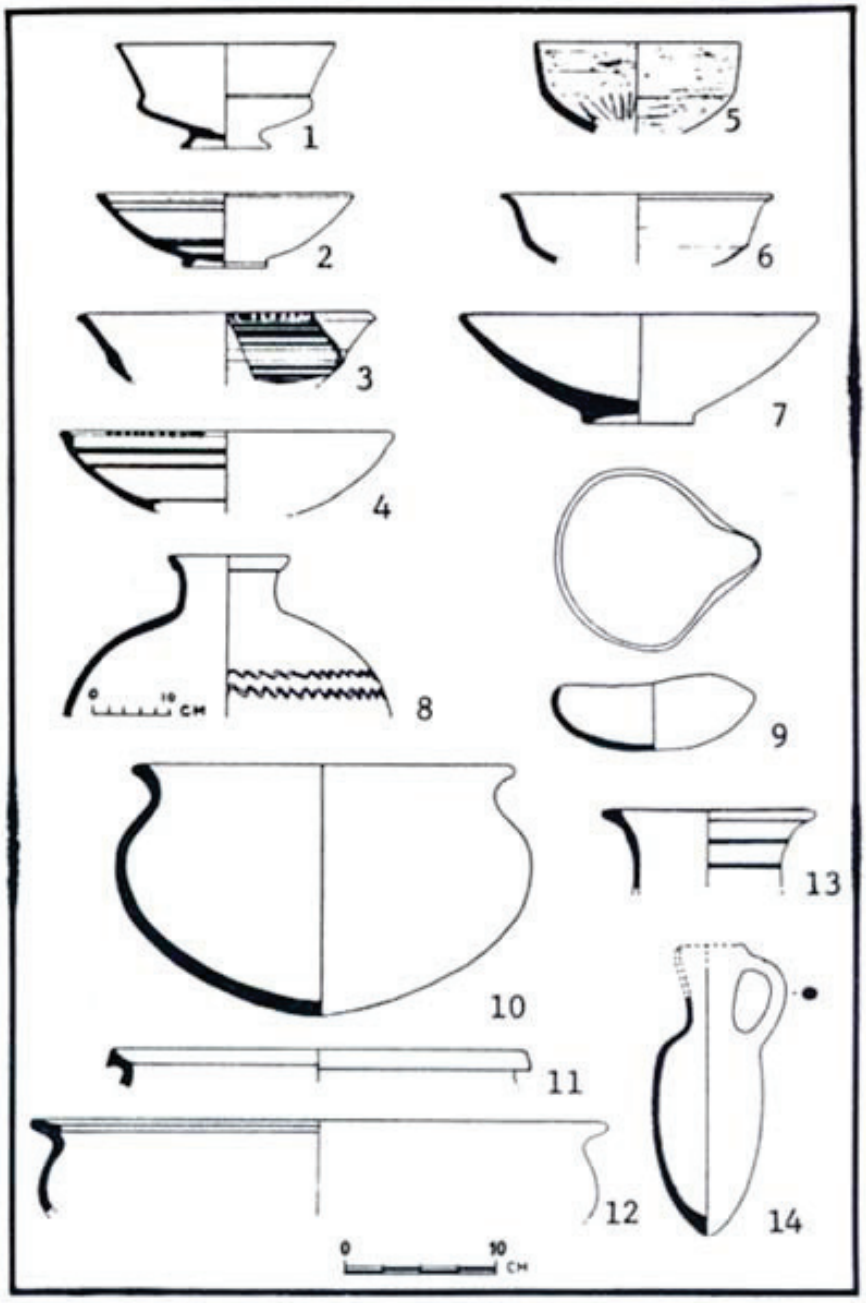

Figure 7. Pottery types from Jericho shown in Wood 1990a, p. 47. 1. flaring carinated bowl (*Jericho 4*, fig. 110: 1); 2 4. bowls decorated with internal concentric circles (*Jericho 5*, fig. 206: 2; *Jericho 4*, fig. 110: 8 and *Jericho 5*, fig. 206: 1); 5–7. bowls (*Jericho 5*, fig. 191: 16, *Jericho 4*, fig. 109: 34 and *Jericho 5*, fig. 189: 2); 8. storage jar (*Jericho 5*, fig. 199: 6); 9. lamp (*Jericho 5*, fig. 197: 2); 1012. cooking pots (*Jericho 5*, fig. 198: 10; *Jericho 4*, figs. 150: 22 and 121: 11); 13. decorated water jar (*Jericho 5*, fig. 206: 11); 14. dipper juglet (*Jericho 5*, fig. 196: 5).

5. Scarabs, Stratigraphy, and Radiocarbon Tests

While the ceramic data from Jericho indicates the occupation of city IV into Late Bronze I and, by extension, the destruction of this final city during Late Bronze I, the evidence from inscribed scarabs is an important secondary form of chronological information that can help pinpoint an accurate date for the fall of Jericho. During the course of excavations at Jericho, numerous scarabs have been discovered, some of which are stylistic and others that contain the names of rulers. For the purposes of unraveling the dispute about the date of the fall of Jericho, a series of Egyptian scarabs inscribed with the names of kings from the

13th Dynasty to the middle of the 18th Dynasty (18th to 14th centuries BC) are especially useful. The most important of these royal scarabs were those of the 18th Dynasty Pharaohs Hatshepsut, Thutmose III, and Amenhotep III (Garstang 1948, p. 126). The scarabs of Thutmose III, one of the most powerful and prestigious Pharaohs, are one of the few of Pharaohs whose scarabs may have been manufactured after his death or even handed down as an heirloom. In contrast, the scarab of Hatshepsut is a very unusual find, as Pharaoh–Queen Hatshepsut suffered *damnatio memoriae* after her reign in an attempt to wipe her name and image from history, and her scarabs would not have been reproduced or circulated later (Gardiner 1964, pp. 182, 198). Another artifact of note is a two-sided seal, not a scarab, of Thutmose III (Garstang 1948, p. 126). This seal, unlike the scarabs of Thutmose III, is a rare artifact and one that can be restricted to the years of his reign in the early to middle 15th century BC. The scarabs of Amenhotep III, a rather isolationist and insignificant Pharaoh, were also not reproduced after his reign nor held in high regard, so the idea that all of these scarabs were heirlooms or reproductions from centuries later is implausible. However, many scarabs of Amenhotep III have been found in stratified LB IB contexts from Canaan. The presence of scarabs of Hatshepsut and Amenhotep III at Jericho, after which no more Pharaohs are attested at Jericho, indicates that the occupation of the site ceased during the reign of Amenhotep III and at the end of Late Bronze IB around 1400 BC. Recent studies and discussion of 18th Dynasty chronology may have a slight bearing on the exact date of these connections, but would not change overall conclusions (e.g., Ramsey et al. 2010). Indications of Egyptian weakness in Canaan and the inability or refusal to send troops to help combat the invading "Habiru" in the region during the reign of Amenhotep III as described in the Amarna Letters should also be considered as related to the fall of Jericho during this period (cf. Johnson 1996, pp. 65–82; Moran 1992). The chronology from the inscribed royal scarabs, in agreement with data from pottery excavated at Jericho, therefore seems to indicate that the destruction of the final Bronze Age city of Jericho occurred during the reign of Amenhotep III at the end of the Late Bronze IB and near 1400 BC (Garstang 1948, pp. 135, 179; cf. Garstang 1944, p. 380). Indeed, even the most recent expedition at Jericho acknowledges the possibility that the city could have been destroyed in Late Bronze IB in the second half of the 15th century BC, although it attributes the attack to the Egyptians led by Thutmose III (Nigro 2020, p. 201). While it is possible that Thutmose III could have conducted a military campaign against Jericho, the city appears nowhere in Egyptian annals or topographic lists around this period, and the method of destruction and looting does not fit the typical military practice of the Egyptians. (See Figure 8 below).

Figure 8. Seal of Thutmose III (**left**) and the scarab of Amenhotep III (**right**) excavated at Jericho. Amemhotep III was the latest Pharaoh attested at Jericho and corresponds to the LBIb pottery.

In addition to the ceramic and scarab data indicating destruction of Jericho in Late Bronze IB ca. 1400 BC, the abandonment and reoccupation of the site in the following periods also suggests that the overall narrative about Jericho in the books of Joshua, Judges, and Kings spans Late Bronze IB to Iron IIA. Following the destruction of the city, although the city itself remained abandoned until Iron IIA, a lone residential structure on the site was later built and occupied in Late Bronze IIA during the 14th century BC, at what came to be designated the "Middle Building" due to its stratigraphic positioning beneath the Hilani and above the Palace storerooms of Areas H-I 6 (Bienkowski 1986, pp. 112–21; Garstang 1941, pp. 369–70; 1948, p. 180; Kenyon 1957, p. 261). After the destruction of Jericho IVc, the

final Bronze Age city, Jericho was vacant for a number of years. Dirt, pottery, and other material washed down from the higher areas of the mound and was called the "streak" or the "wash" (Wood 1990a, p. 49). When the Middle Building in Area H on the east side of the tell was built, this layer of wash was underneath its foundations. After the Middle Building was abandoned, along with the rest of the site, erosion again formed a wash layer over the stratum of the Middle Building. Because of this, the Late Bronze IIA material of the Middle Building was both above and below some Late Bronze I material (Wood 1990a, p. 49; Garstang 1934, pp. 106, 111; Bienkowski 1986, p. 112; Kenyon 1951, pp. 120–21). In the Iron Age, the Hilani structure was built over the Middle Building, but after its abandonment, erosion from the top of the mound again washed down and covered the stratum of the Hilani. Thus, material from the top of the mound, especially from the final Bronze Age city, is found in various strata because of erosion. However, the most important stratigraphic relationship to note is that the Late Bronze IIA Middle Building was constructed over the stratum of Jericho IVc (except where the "wash" brought materials from Jericho IV), and thus there is an indication of a short period of an occupational hiatus in between the two layers. This means that the last phase of Jericho City IVc precedes Late Bronze IIA, but not for a long period of time. The "Middle Building" is also significant because it can be linked to another phase in the history of Jericho, which is recorded in connection to Eglon of Moab and an event that occurs decades after the destruction of Jericho by Joshua (Judges 3: 13–26).[5] This Middle Building was identified as a large residence or villa associated with Eglon of Moab in the 14th century BC, measuring about 14.5 m by 12 m and being the sole occupied area at the previously destroyed city (Garstang 1948, pp. 177–80). (See Figure 9 below).

Figure 9. The "Middle Building" at Jericho, excavated and photographed by Garstang and dated to the Late Bronze IIA or the 14th century BC.

Another significant find associated with the Middle Building was a cuneiform clay tablet dated to the 15th century BC on the basis of epigraphy (van der Toorn 2000, p. 98; Bienkowski 1986, p. 113; Garstang 1934, pp. 116–17). Tablets in the Bronze Age southern Levant are rare, with very few examples coming from any city south of Ugarit. From Hazor, Tell el-Hesi, Taanach, Shechem, Jerusalem, Megiddo, and elsewhere in Canaan, only about 40 total tablets or tablet fragments from the Late Bronze Age have been discovered (e.g., Horowitz et al. 2002, pp. 753–66). Unfortunately, the Jericho tablet found in the Middle Building was in extremely poor condition, with few signs visible, and no plausible reading for the text has yet been determined. Although this tablet was found in excavations of the Middle Building, it was dated to the 15th century BC and may have been part of the "wash" material from the previous stratum, further indicating occupation at Jericho in Late Bronze I and the 15th century BC. (See Figure 10 below).

Figure 10. Damaged cuneiform tablet from Jericho dated to the 15th century BC.

After the abandonment of the Middle Building, the city of Jericho was not rebuilt until the Iron Age II, including the reuse of the MB III-LB I cyclopean wall and the construction of the Hilani building (Nigro 2020, pp. 204–6). During the 9th century BC reign of Ahab in Iron Age II, a small settlement was built over part of the ruins of Jericho, including tripartite pillared buildings associated with Israelite architecture. While slightly later, according to the biblical narrative, the city was also apparently occupied in the time of Elisha by "sons of the prophets," and LMLK ("for the king") imprinted jar handles likely dating to the reign of Hezekiah was also found at the site (1 Kings 16: 34; 2 Kings 2: 4–18).

Radiocarbon samples from Jericho have also been an important subject of discussion, but unfortunately, the radiocarbon dates from the Jericho IV destruction have been inconsistent and therefore have not yet been able to support a particular date for the fall of the city. Initial radiocarbon samples taken from Jericho were eventually analyzed by the laboratory at the British Museum, and a date was published as 1410 BC +/− 40 (Kenyon and Holland 1983, p. 763). However, due to a problem with equipment calibration that affected many samples for the years 1980–1984 and caused uncertainty of the results, BM-1790 from Jericho was revised to 3300 +/− 110 BP (Bowman et al. 1990, p. 74).[6] Another analysis of 18 samples from the Kenyon excavations at Jericho yielded results ranging from 3393 +/− 17 BP (GrN-18368) to 3312 +/− 14 BP (GrN-18539), with an outlier of 3614 +/− 20 (GrN-18538) that may have been from an older and reused wooden beam; the calibrated probable dates given during the time of the study were 1601-1566 calBC or 1561-1524 calBC (Bruins and van der Plicht 1995, pp. 213–20). Using OxCal with IntCal20 and no adjustments for geographical location, these samples would yield calibrated dates ranging from 1699 to 1623 calBC 70.3% probability (GrN-18368) to 1617–1531 calBC 95.4% probability (GrN-18539), with the outlier (GrN-18538) 2031–1899 calBC 95.4% probability (https://c14.arch.ox.ac.uk/calibration.html, accessed 20 April 2023; cf. Christopher Bronk Ramsey 2009, pp. 337–60). These samples from the Kenyon excavations indicate that their calibrated radiocarbon dates are significantly higher than the historical dates when compared to the proposed dates of destruction published by the various excavation teams. In 2000, the Italian–Palestinian expedition tested two samples that were excavated from a building that appeared to contain debris from the final destruction of the Bronze Age city that had washed down to the bottom of the mound. These two most recent samples yielded calibrated dates of 1347 BC +/−85 and 1597 BC +/−91, which could accommodate either proposed approximate historical destruction dates of around 1550 BC or 1400 BC if the calibration curves were accurate (Marchetti and Nigro 2000, pp. 206–7, 330, 332). However,

it is a known issue that the radiocarbon dates for Bronze Age sites in the Levant often conflict with the chronological information derived from ceramics and inscriptions and that some samples can be from burned wooden beams cut from trees that were harvested over 100 years before their destruction (Mazar and Ramsey 2008, pp. 159–80; Levy and Higham 2005; Ben-Tor and Rubiato 1999, p. 36). Thus, radiocarbon dates should be viewed with caution, and dating strata by means of pottery typology continues to be the primary and most reliable method employed by archaeologists. While a few radiocarbon samples from Jericho do fit a Late Bronze IB destruction of the city around 1400 BC, others match more closely to a 1600–1500 BC destruction timeframe. Essentially, the radiocarbon dates from Jericho at present appear to only rule out a ca. 1230 BC destruction hypothesis but have not been able to solve the dispute between a Middle Bronze III or Late Bronze I destruction of the city.

6. Conclusions

When all of the chronological data from Jericho IV is assessed and assembled, including specific pottery wares and forms of Late Bronze I, 18th Dynasty Egyptian scarabs concluding with Amenhotep III, a cuneiform tablet dated tentatively to the 15th century BC, and radiocarbon samples that would at least allow the possibility of a destruction around the Late Bronze IB period, the destruction of the final walled Bronze Age city of Jericho appears to have occurred near the end of the Late Bronze I period around 1400 BC. The mudbrick wall falling upon itself all around the city, similar to an earthquake rather than a specific point of entry, an apparently intentional fire that consumed the entire city, the many storage jars of grain that were not looted, and the timing of the attack soon after the spring harvest all agree with the specifics of the Joshua account regarding the methods of destruction. An abandonment of Jericho following its destruction until Iron IIA, except for a palatial residence briefly occupied in Late Bronze IIA, also matches the narratives and sequences in the books of Joshua, Judges, and Kings. Thus, archaeological excavations and analysis at Jericho appear to place the destruction of the final Bronze Age city ca. 1400 BC in a manner consistent with the account in the book of Joshua.

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Notes

1 The conquest of Canaan, the Holy Land, is also mentioned in the Quran (Surah 5 Al-Ma'ida, 20–26), although the city of Jericho is not specified.

2 The view of Kenyon that Jericho was destroyed around 1550 BC was based primarily on the expulsion of the Hyksos and the alleged lack of Cypriot pottery of the Late Bronze Age discovered in the Jericho excavations. Note that Watzinger thought that Jericho was destroyed by 1600 BC or even earlier in an evaluation of his excavations (cf. Watzinger 1926).

3 The view that the conquest of Canaan occurred during the 13th century BC or around approximately 1230 BC was promoted by Albright and prompted by his excavation findings of destruction at Tell Beit Mirsim which he dated to the 13th century BC and connected to the conquest of Canaan.

4 While there was also an Early Bronze Age II earthquake dated to around 2700 BC at Jericho which provides an example of such phenomenon, and many significant earthquakes throughout history are known to have occurred in the Jericho region, the events should not be conflated (Nigro 2020, p. 188).

5 The place where Eglon of Moab resided can be identified as Jericho by comparing the information in Judges 3: 13 with that of Deuteronomy 34: 3 and 2 Chronicles 28: 15, which both record that Jericho is the city of palm trees.

6 BP or "Before Present" and referring to the year 1950.

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Article

God, Gould, and the Panda's Thumb

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Abstract: The panda's thumb argument, championed by the late Stephen Jay Gould, stands as one of the most famous polemics for common ancestry. In this essay, I analyze Gould's argument in several steps. First, I attempt to reconstruct the argument in both deductive and likelihood formulations. I contend that both versions of the argument rest on a theological claim—namely, that God would not (likely) create or allow a suboptimal panda's thumb. I then argue that a wide range of people are not rationally obligated to accept this theological claim. Next, I give special attention to the likelihood formulation's emphasis on a contrastive argument for evolution over special creation. I contend that a great number of people are not rationally obligated to accept this formulation either. I next consider and reply to an objection that Gould never intended the panda argument as an apologetic for evolution (and an attack on special creation) but rather as a critique of adaptationism. Finally, I argue that the panda argument conflicts with Gould's broader views about the human mind and the relationship between theology and science. I also note along the way that the shortcomings of the panda argument apply to a number of other arguments for evolutionary theory. To be sure, I do not criticize evolution itself or the comprehensive grounds for it. Instead, my primary aims are to analyze the panda argument and suggest that caution is in order about similar arguments as well.

Keywords: Stephen Jay Gould; theology; evolutionary theory; common ancestry; panda's thumb; suboptimality; dysteleology; science and religion; special creation

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1. Introduction

Stephen Jay Gould was a towering, if controversial, figure in late 20th century evolutionary biology. Before he passed away in 2002 at age 60, his influence extended deeply into the professional guild and the public square. By the end of his career, he had published roughly 480 peer-reviewed papers, two dozen books, 300 essays, and 100 book reviews (Shermer 2002). As a skilled essayist, he arguably stood among the ranks of T.H. Huxley and J.B.S. Haldane. And his professional accomplishments were recognized with the highest honors, including the Linnean Society of London's Darwin–Wallace Medal, the Paleontological Society Medal, the MacArthur Fellowship, the Phi Beta Kappa Award in Science (twice), and others. In 2000, the U.S. Library of Congress deemed him a "Living Legend".

Whatever one makes of Gould's array of controversial claims,[1] his most famous argument for evolution—derived from the panda's thumb—has become something of an icon in its own right (e.g., Salesa et al. 2006, p. 381; Prothero 2007, pp. 37–38; Dawkins 1986, p. 91; Rice 2007, p. 2; Futuyma 2013, pp. 613–14).[2] Perhaps this is not surprising, given that Gould championed this argument for over twenty years, from his *Natural History* column in 1978 to his *magnum opus* in 2002 (Gould 1978, 1980, 2002). Of all his arguments for evolution based on a single structure, he considered this one the *summum bonum*, the best of the best (Gould 1980, pp. 28–29; 1991, p. 61; 2002, p. 104, 111–16).

In this essay, I analyze Gould's panda argument in several steps.[3] First, I attempt to reconstruct the argument in both deductive and likelihood formulations. I argue that both versions rely on God-talk. In particular, they hold that the Almighty would not (likely) create or allow a suboptimal panda's thumb. I canvass an array of worldviews

and claim that people who hold these views are not rationally obligated to accept this theological claim. Next, I give special attention to the likelihood formulation's emphasis on a contrastive argument for evolution over special creation. I likewise contend that a great number of people are not rationally obligated to accept this formulation either. I then consider the objection that Gould never intended the panda argument as an apologetic for evolution (and an attack on special creation) but rather as a critique of adaptationism. I argue that there are strong grounds, including textual grounds, to defuse this criticism. Finally, I argue that there are further reasons to reject the panda argument: it conflicts with Gould's broader views, including his doctrine of NOMA and his beliefs about the origin (and lack of design) of human cognition. Insofar as a person accepts these broader views, such a person has additional reasons to set aside the panda argument.

I also note along the way that problems with the panda argument apply to a number of other arguments for evolutionary theory. This is not to say that there is anything wrong with evolution in general or with the comprehensive case for it per se. Not all the grounds for evolution include God-talk, and such grounds are beyond the scope of this article.[4] Nonetheless, like Gould, a number of prominent biologists *do* offer theology-laden arguments for evolution, sometimes as their self-reported best stand-alone argument for the theory. These luminaries include Theodosius Dobzhansky, Niles Eldredge, Douglas Futuyma, Francisco Ayala, Jerry Coyne, Émile Zuckerkandl, Richard Dawkins, George Williams, Francis Collins, Kenneth Miller, and others. Their theology-laden arguments surface in major areas: molecular homology, embryology, biogeography, paleontology, gross anatomy, dysteleology, organic diversity, and the like. At least some of my criticisms of Gould's argument apply to others' arguments, *mutatis mutandis*[5] (Alexander 2014, pp. 234–51; Avise 2010; Ayala 2006, pp. 25–42, 71 85–89, esp. 34–36; 2007, pp. x–xi, 1–6, 22–23, 76, 88–92, 154–60; Barbour 2000, pp. 111–14; Collins 2006, pp. 130, 134–37, 139, see also pp. 176–77, 191, 193–94; Coyne 2009, pp. 12, 13, 18, 54–58, 64, 71–72, 81–85, 96, 101, 108, 121, 148, 161; Dawkins 1986, p. 93; 1995, pp. 95–133, esp. 105; 2009, pp. 270, 297, 332, 341, 351, 354, 356, 362, 364, 369, 371, 375, 388–89, 390–96; de Beer 1964, pp. 46–48, 55, elliptically; Dilley 2012, 2013, 2017; Diogo and Molnar 2016; Dobzhansky 1973; Eldredge 2000, pp. 99–100, 144–46; Forterre and Gadelle 2009; Futuyma 1995, pp. 46–50, 121–31, 197–201, 205, Futuyma 2013, pp. 53–54, 631–56, esp. 636–41; Gould 1977, pp. 91–96, esp. 91; 1980, pp. 20–21, 24, 28–29, 248; 1983, pp. 258–59, 384; 1986, pp. 60–69, esp. 63; Giberson and Collins 2011, pp. 34, 38, 55, 101–108, 161; Hunter 2001, 2007, 2014, 2019, 2020, 2021a, 2021b; Kitcher 1982, pp. 137–39; 2007, pp. 48–50, 57–58, 123–31; Kutschera 2007, pp. 90–91; Lents 2018; Lustig 2004; Mayr 2001; Miller 1999, pp. 80, 100–103, 267–69; Nelson 1996, pp. 12–39, esp. 31–34; cf. Numbers 2003; Pievani 2022; Prothero 2007, pp. 37–39; Radick 2005, p. 455; Shermer 2006, pp. 17–19, 42–44; Shubin 2008, pp. 173–98, elliptically; Wells 2010, pp. 67–88; Williams 1997, pp. 2, 4, 6–10, 104, 132–60; Zuckerkandl 2006, p. 10).[6]

2. Definitions

Before attending to the panda argument itself, some clarifications are in order. By 'evolution', I mean 'common ancestry', the view that all flora and fauna are the physical descendants of one (or a few) life forms that lived long ago. The term 'creationism' will primarily refer to contemporary young-earth creationism, the most prominent version of creationism in Gould's era. But because Gould also rejected intelligent design theory, I will also use the broader term 'contemporary design-based views' (or similar) to include not just contemporary young-earth creationism but also old-earth creationism as well as intelligent design theory. By contrast, I will use the term 'special creation' to refer narrowly to a version of creationism in which God is said to have created the structures and organs of each species well-matched to their respective environments.[7] (Readers should note that this term can have different meanings in other contexts.)

By 'theology', I mean propositions about a divine being. To be sure, I do not claim per se that Gould personally accepted the theological claims contained in the panda argument (although it is reasonable to think he did). Strictly speaking, Gould's personal beliefs are

irrelevant for present purposes. Instead, the present aim is to assess the panda *argument*. Doing so requires analyzing the theological (and non-theological) propositions in the argument and their justification. The truth or falsity of a proposition, like the soundness of an argument, stands or falls on its own. Thus, even when I use the phrase "Gould's theology", I simply mean his use of theology, regardless of what he personally believed. The same can be said of other thinkers who also use theology as part of their justification of evolutionary theory, *mutatis mutandis*.

In addition, I call attention to another feature of the God-talk in play. As mentioned, while Gould attacks 'special creation' (as I use the term), he also regards the panda argument as adjudicating between evolution and other design-based rivals. As I will argue below, however, these rivals do not necessarily hold the same view of God as 'special creation' does. With respect to these rivals, then, I argue that Gould uses what we may call "*positiva* theology" (Dilley 2012).[8] This theology tries to establish evolution and refute design rivals by drawing upon theology that is, in some sense, foreign to these rivals. If my argument is correct, Gould's contemporary adversaries are not rationally obligated to accept his partisan theology.[9]

A final preliminary, in the form of an objection, deserves a brief examination. A critic might say that Gould's interest in the panda's thumb and in suboptimality generally is actually a thinly veiled means of establishing exaptation and attacking adaptationism. Accordingly, it would be a mistake to hold that Gould's purpose for the panda argument is to support common ancestry and undermine creationism. I address this thoughtful objection later in the article. For the time being, I will proceed with my interpretation of Gould but will return to this point in due course.

3. The Panda's Thumb Argument

Now to the argument itself. While Gould's comprehensive defense of evolution includes many threads, at times he highlights imperfections as offering "the primary proofs that evolution has occurred" (Gould 1977, pp. 90–91; 1980, p. 13; 1983, pp. 55; see also pp. 131, 160, 258; 1991, p. 61). Of the many examples of imperfection Gould cites, he regards the panda's thumb as his "favorite" (Gould 1986, p. 210; 1991, pp. 66–67; 2002, p. 104). Gould's seminal essay, "The Panda's Thumb" and its companion "Senseless Signs of History", both published in the collection *The Panda's Thumb* (Gould 1980), provide the clearest exposition of the argument. Gould lays the initial groundwork in the title essay, framing the argument as a natural extension of Darwin's own emphasis on imperfections in the case for evolution. For Gould, Darwin's (1862) *On Orchids* exemplified this approach by detailing how orchids accomplish cross-pollination by using "jury-rigged" rather than ideal structures. Gould explains that orchids:

> evolved an astonishing variety of "contrivances" to attract insects, guarantee that sticky pollen adheres to their visitor, and ensure that the attached pollen comes in contact with female parts of the next orchid visited by the insect. . . . Orchids manufacture their intricate devices from the common components of ordinary flowers, parts usually fitted for very different functions. If God had designed a beautiful machine to reflect his wisdom and power, surely he would not have used a collection of parts generally fashioned for other purposes. Orchids were not made by an ideal engineer; they are jury-rigged from a limited set of available components. Thus, they must have evolved from ordinary flowers. (Gould 1980, p. 20)

Note the evident theology: "If God had designed a beautiful machine to reflect his wisdom and power, surely he would not have used a collection of parts generally fashioned for other purposes". God would not borrow parts that He had originally created for other functions; instead, He would manufacture novel parts for new purposes. Accordingly, orchids "were not made by an ideal engineer"—they are far too "jury-rigged" for that. Moreover, these theological claims immediately lead to Gould's conclusion in the next

sentence: "Thus, [orchids] must have evolved from ordinary flowers". Gould's convictions about the Almighty provide *direct* grounds for evolution.

On Gould's view, Darwin's theology-laden argument about orchids illustrates the more general insight that the oddities of nature—whatever they are—serve as prime evidence for evolution. As Gould explains in the next paragraph:

> Our textbooks like to illustrate evolution with examples of optimal design—nearly perfect mimicry of a dead leaf by a butterfly or of a poisonous species by a palatable relative. But ideal design is a lousy argument for evolution, for it mimics the postulated action of an omnipotent creator. Odd arrangements and funny solutions are the proof of evolution—paths that a sensible God would never tread but that a natural process, constrained by history, follows perforce. (Gould 1980, pp. 20–21)

Gould writes that "ideal design" (or "optimal design") makes "a lousy argument for evolution". (Hereafter, I will use the terms "optimal design" and "ideal design" interchangeably.) According to Gould, optimal design is exactly what one would expect of an "omnipotent creator" or "sensible God". If the Almighty does anything at all, He does it well. As such, Gould believes that optimal designs provide virtually no evidence for evolution. Hence, evidence will have to come from the opposite quarter—from 'suboptimal' designs, which Gould calls "[o]dd arrangements and funny solutions". As he explains at length in "Senseless Signs of History", the companion essay to "The Panda's Thumb":

> Scientists who study history. . . must use inferential rather than experimental methods. They must examine *modern results* of historical processes and try to reconstruct the path leading from ancestral to contemporary words, organisms, or landforms. . . . But how can we infer pathways from modern results?... How do we know that a modern result is the product of alteration through history and not an immutable part of a changeless universe?
>
> This is the problem Darwin faced, for his creationist opponents did view each species as unaltered from its initial formation. How did Darwin prove that modern species are the products of history? We might suppose that he looked toward the most impressive results of evolution, the complex and perfected adaptations of organisms to their environments: the butterfly passing for a dead leaf, the bittern for a branch, the superb engineering of a gull aloft or a tuna in the sea.
>
> Paradoxically, he did just the opposite. He searched for oddities and imperfections. The gull may be a marvel of design; if one believes in evolution beforehand, then the engineering of its wing reflects the shaping power of natural selection. But you cannot demonstrate evolution with perfection because perfection need not have a history. After all, perfection of organic design had long been the favorite argument of creationists, who saw in consummate engineering the direct hand of a divine architect. A bird's wing, as an aerodynamic marvel, might have been created exactly as we find it today.
>
> But, Darwin reasoned, if organisms have a history, then ancestral stages should leave *remnants* behind. Remnants of the past that don't make sense in present terms—the useless, the odd, the peculiar, the incongruous—are the signs of history. They supply proof that the world was not made in its present form. When history perfects, it covers its own tracks. (Gould 1980, p. 28, original emphasis)

Present-day oddities count as evidence for evolution because they are *expected* given evolution but *unexpected* given divine design. Evolution operates by historical contingency, cobbling together new form and function from available parts; this process sometimes produces useless and peculiar structures. By contrast, if a "divine architect" had made the world "in its present form", organs and structures would be perfectly suited for an

organism's current functional needs in its specific environment. Gould's argument is clearly comparative: either evolution or divine design. He attacks the latter as part of his attempt to establish the former.

But just what kind of creative deity does Gould criticize? Three features stand out. First, as mentioned, Gould thinks that God would create perfect (or optimal) designs. More than half a dozen times in the excerpt above, Gould associates "perfection" (or its cousins) with the deity's handiwork.

Perfect for what? This question leads directly to the second feature of God's creative activity: adaptation. Organisms are well suited to their habitat. The hallmarks of divine designs are "complex and perfected adaptations of organisms to their environments" including "the butterfly passing for a dead leaf, the bittern for a branch, the superb engineering of a gull aloft or a tuna in the sea". Perfectly designed organisms tightly correspond to their habitat. Their individual features successfully fulfill particular functions required by an organism situated in a specific environment. Suboptimal designs, as Gould says elsewhere, are "departures" from this fit (Gould 1986, pp. 60–68, esp. 66). An optimally designed wing enables a bird to fly; a poorly designed wing does not. Thus, on this view, God would create organisms with features that perfectly fulfill their biological functions, enabling the organism to thrive in its particular habitat.

Third, the Almighty would create organisms matched to their *present-day* environment. According to Gould, 19th century creationists held that "each species [was] unaltered from its initial formation". Following their lead, Gould invokes a similar notion in his imperfection argument. A bird's wing, he says, might have been "created exactly as we find it today". Thus, in making his case for evolution, Gould says scientists must examine "modern results" in order to reconstruct the past.[10] He highlights remnants of the past that "do not make sense in present terms". These oddities provide proof that "the world was not made in its present form". As Gould notes elsewhere, God would produce successful "coordination between an organism and its *current* circumstances" (Gould 2002, p. 104, my emphasis).[11] Thus, the divine would create organisms adapted to their present habitat.

Taking these three elements together, Gould conceives of God as a "divine architect" who creates flora and fauna with features perfectly suited to their present-day environments. This Being would not fashion "useless", "odd", or "peculiar" structures that inhibit an organism from fulfilling its extant biological functions. Instead, God would craft features "for current utilities" (Gould 2002, p. 104). The deity would do all things well for the present era.

Of course, from an evolutionary perspective, organs and structures are subject to the vicissitudes of historical contingency. Evolution cobbles them together from whatever parts are available, sometimes jury-rigging these parts in odd ways in an attempt to meet their current biological needs. Thus, evolution often produces imperfect designs for current environments.

Having explained why imperfection is, in general, supportive of evolutionary theory, Gould next turns to his beloved panda. The creature's thumb, he notes, is not really a true thumb at all. That is, the thumb is not a fifth-digit appendage (as on the human hand). Instead, the fifth digit on pandas is a standard-issue claw, suitable for scratching and digging rather than gripping. The 'thumb' is actually an elongated wrist bone called the radial sesamoid. The muscles surrounding this bone allow it to press against the panda's pad—making it opposable—and so enable the panda to manipulate bamboo. But while the thumb is "serviceable. . . for stripping leaves off bamboo shoots" it is nonetheless "highly inefficient" (Gould 1986, p. 63). For Gould (1980, p. 23), this "odd arrangement" provides strong evidence of an evolutionary origin:

> The panda's thumb provides an elegant zoological counterpart to Darwin's orchids. An engineer's best solution is debarred by history. The panda's thumb is committed to another role, too specialized for a different function to become an opposable, manipulating digit. So the panda must use parts on hand and settle for an enlarged wrist bone and a somewhat clumsy, but quite workable,

> solution. The sesamoid thumb wins no prize in an engineer's derby. It is, to use Michael Ghiselin's phrase, a contraption, not a lovely contrivance. But it does its job and excites our imagination all the more because it builds on such improbable foundations. (Gould 1980, p. 24)

And five pages later:

> The panda's 'thumb' demonstrates evolution *because* it is clumsy and built from an odd part, the radial sesamoid bone of the wrist. The true thumb had been so shaped in its ancestral role as the running and clawing digit of a carnivore that it could not be modified into an opposable grasper for bamboo in a vegetarian descendant. (Gould 1980, p. 29, original emphasis)

Two decades later, in his *magnum opus*, *The Structure of Evolutionary Theory* (2002, p. 104), Gould gives a fine summary of his panda argument:

> We observe a single object, but not enough relevant items to forge consilience about its status as the product of history. How can we work from unique objects? How shall we infer history from a giraffe? Darwin tells us to search for a particular form of discordance—some imperfection or failure of coordination between an organism and its current circumstances. If such a quirk, oddity, or imperfection—making no sense as an optimal and immutable design in a current context—wins explanation as a holdover or vestige from a past state in different circumstances, then historical change may be inferred. Call this, if you will, the orchid principle (though I have also designated it as the panda principle for my own favorite example, perforce unknown to Darwin, of the panda's false thumb, Gould 1980), to honor Darwin's argument (1862) for orchids as products of history. Their intricate adaptations to attract insects for fertilization cannot be read as wonders of optimal design, specially created for current utilities, for they represent contraptions, jury-rigged from the available parts of ordinary flowers. [12]

The reference to "Gould, 1980d" is *The Panda's Thumb* (Gould 1980). In the passage above, Gould reiterates his classic argument. Any "imperfection or failure of coordination between an organism and its current circumstances" suggests an evolutionary explanation rather than "optimal and immutable design".

As one might expect, Gould's argument about the panda's thumb draws upon detailed research. In particular, he examines a study by D. Dwight Davis (1964), who was at the time the curator of vertebrate anatomy at Chicago's Field Museum of Natural History. According to Gould, Davis's study "is probably the greatest work of modern evolutionary comparative anatomy" (Gould 1980, p. 22, 43–44). This study shows not just that the panda's 'thumb' is an elongated radial sesamoid but that its hypertrophy could have come about by "a simple genetic change, perhaps a single mutation affecting the timing and rate of growth" (Gould 1980, p. 23).[13] A longer bone would have, in turn, altered the muscles attached to the radial sesamoid so that the capacity for opposability would be a direct mechanical effect of the bone's growth. Thus, a minor genetic change may have ultimately produced the panda's 'thumb.' Such a change is more plausible given that ordinary bears, the giant panda's closest relative, already have a noted ability to manipulate objects with their forelegs and, relative to other carnivores, also have a slightly larger radial sesamoid and a favorable muscular arrangement in the wrist. Moreover, beyond the 'thumb' itself, Gould agrees with Davis that other associated, complex changes can be explained by natural processes. Such changes include, for example, alterations to the form and function of the skull, which are necessary for the transition from an omnivore diet to the panda's almost exclusive bamboo diet. Thus Gould, like Davis, concludes that "very few genetic mechanisms—perhaps no more than half a dozen—were involved in the primary adaptive shift from *Ursus* [bear] to *Ailuropoda* [panda]. The action of most of these mechanisms can be identified with reasonable certainty" (Gould 1980, pp. 43–44).[14]

Taking all of these passages into account, we may now attempt to reconstruct Gould's argument. Recall that he framed the argument as a contrast between evolutionary processes, on the one hand, and "an omnipotent creator", "sensible God", or "ideal engineer" on the other. Whereas God would make perfect adaptive designs for an organism's current environment, evolution would not necessarily do so. As it happens, the panda's thumb is *not* an ideal design for eating bamboo. And natural processes, like genetic mutations and natural selection, can in principle explain changes to the radial sesamoid.

4. The Deductive Formulation

In my view, there are two possible ways to construct Gould's argument. The first is deductive. The second is a likelihood argument. We will analyze each in turn.[15]

On the deductive front, one might articulate the argument as two complementary syllogisms, the first leading to the second:

Deductive argument 1:

1. If an omnipotent creator made the panda's thumb, he would have optimally designed it for its primary function in the panda's current environment; he would *not* have suboptimally designed it or allowed it to become suboptimal for its primary function in the panda's current environment.
2. The panda's thumb is not optimally designed for its primary function in its current environment.
3. Thus, it is not the case that an omnipotent creator made the panda's thumb [1, 2 modus tollens].

Deductive argument 2:

4. Either an omnipotent creator made the panda's thumb or it evolved from a common ancestor with a similar structure.
5. It is not the case that an omnipotent creator made the panda's thumb [3 above].
6. Thus, the panda's thumb evolved from a common ancestor with a similar structure [4, 5 disjunctive syllogism].

A Brief Commentary on the Deductive Formulation

It may help to clarify this reconstruction (cf. Nelson 1996, p. 499). Both arguments are deductively valid. As such, if the premises are true, then the final conclusion is guaranteed to be true. This would constitute "proof" of evolution, as Gould says.

In the first argument, I have articulated premise one using "an omnipotent creator" rather than a "sensible God" or "ideal creator". These terms are not equivalent per se, which suggests that an 'expansive' interpretation of Gould's text may actually support several versions of the panda argument, each involving a specific entity. I have chosen "omnipotent creator" because I think it best captures what Gould had in mind. Readers who disagree can modify the argument accordingly.

More importantly, recall Gould's block quotes (above), in which he emphasizes that God creates structures that match an organism to its current environment. Accordingly, premise one claims that if the Almighty made the panda's thumb, it would be optimally designed for its primary function in the panda's present habitat. I have included the phrase 'primary function' because Gould invariably focuses on the thumb's key function of stripping bamboo leaves rather than any secondary functions. Similarly, Gould's other examples in the same passages also highlight a given structure's key function—for example, a bird's wing for flight—rather than any secondary functions, like keeping a bird warm while nesting.

In addition, premise one includes the idea that God would not *allow* the thumb to become suboptimal vis-à-vis the panda's present-day habitat. Gould holds that if God fashioned the panda's thumb in the past, He would make sure the thumb functions

optimally in the "present" (Gould 1980, p. 28; 2002, p. 104). Thus, the deity's creative forethought ensures the thumb's tight adaptive fit with its contemporary environment.

Premise two portrays Gould's judgment that the panda's thumb is "clumsy" and "highly inefficient" for its key function (Gould 1980, p. 24; 1986, p. 63).

Premise four articulates Gould's characterization of the argument as adjudicating between two main rivals, special creation and evolution: 'Either an omnipotent creator made the panda's thumb or it evolved from a common ancestor with a similar structure.' Unless otherwise qualified, most formulations of a disjunction ('either X or Y') use an inclusive "or", which can be interpreted as "and/or". In this case, however, it is best to read it as an exclusive "or", which means that only one hypothesis can be true, not both. As is transparent in his various writings, Gould held the conviction that 'evolution' and 'special creation' are mutually exclusive explanations rather than complementary accounts. For him, the choice was binary (Gould 1983, pp. 33–40, 42–45; 1977, pp. 11–17; 1991, pp. 309–24).

Evaluation

As one might imagine, most of the action centers on premise one. We will return to this shortly. For now, however, the salient point is that the main drawback of this particular reconstruction is that it does not fully capture Gould's positive case for evolution based on the suboptimality of the panda's thumb. That is, Gould seemed to hold the following: if evolution fashioned the panda's thumb, then it would not necessarily be optimally 'designed' for its primary function in the panda's current environment; we would be unsurprised if it were suboptimally 'designed' for its primary function in the panda's current environment.

This is a straightforward articulation of Gould's claim about the expected outcomes of evolutionary processes. Importantly, this claim does *not* say that evolution *entails* a suboptimal thumb rather than an optimal one. On Gould's view, evolution sometimes produces exquisite designs: "But what nature can do, she often does surpassingly well", he says (Gould 1980, p. 307). So, it is *possible* that evolution could produce an optimal (or nearly optimal) thumb. For Gould, however, evolution is also a tinkerer, and, thus, we would be unsurprised to discover the thumb was suboptimal even if we could not deduce this fact *a priori* from evolutionary theory itself. Even so, Gould gives some degree of positive evidence (or expectation) about the thumb given evolution. One weakness of the deductive reconstruction is that it does not quite capture this positive element.

In a similar way, the deductive reconstruction does not capture Gould's use of the empirical study by Davis. Recall that Davis thought the thumb could have come about by "a simple genetic change, perhaps a single mutation affecting the timing and rate of growth" (Gould 1980, p. 23).[16] As such, Gould believed that a major study had confirmed that the panda's thumb could have been made by evolution. This claim also functions as positive support for evolution. Empirical data confirms the expectations (or predictions) of the theory. Unfortunately, the deductive formulation of the argument does not capture this element clearly.

So, the deductive formulation may not be the best reconstruction. Perhaps, then, one ought to understand Gould's argument in terms of likelihoods?

5. Likelihood Formulation

Another possibility is to frame the panda polemic as a likelihood argument. Philosopher of science Elliott Sober sees it this way: "[Gould] claims that the hypothesis of intelligent design makes the panda's thumb very improbable, whereas the hypothesis of evolution by natural selection makes the result much more probable" (Sober 2008, p. 127). Although Sober misses Gould's particular focus on special creation—rather than on the more general notion of "intelligent design"—nonetheless, we can adapt his formulation accordingly.

As such, let 'E' be evolutionary theory, 'T' be the panda's thumb, and 'C' be special creation by an omnipotent creator. The argument is $Pr(T|E) > Pr(T|C)$. That is, given

evolutionary theory, the imperfect thumb is more probable than given special creation. Thus, the thumb supports evolution over special creation.

It may be helpful to spell out the argument point by point:

i. The probability is extremely low that "an omnipotent creator" made the panda's thumb suboptimal (or allowed it to become suboptimal) for its primary function in the panda's current environment.
ii. The probability is much higher that evolution fashioned the panda's thumb to be suboptimal for its primary function in the panda's current environment.
iii. The panda's thumb is suboptimal for its primary function in its current environment.
iv. If a datum is more probable on one hypothesis than on another hypothesis (and these hypotheses are mutually exclusive), then the datum supports the former hypothesis over the latter.
v. Thus, the suboptimality of the panda's thumb supports evolution over the claim that an omnipotent creator fashioned it.

A Brief Commentary on the Likelihood Formulation

Point (iv) above does much of the heavy lifting. It is an expression of the "law of likelihood", which articulates a way that a fact (or piece of evidence) can favor one hypothesis over a competitor. More precisely, it holds that datum D favors hypothesis H_1 over hypothesis H_2 if and only if D is more probable on H_1 than on H_2.[17] Suppose I have two friends, Ken and Henry, who independently enjoy stealing my vintage rum from time to time. Ken takes my rum fairly often, whereas Henry takes it very rarely. If my rum goes missing, I can safely conclude that this fact favors the 'Klepto-Ken' hypothesis over the 'Henry-heist' hypothesis.

This basic reasoning applies to point (iv) above. According to Gould, a suboptimal thumb is more probable given the 'evolution' hypothesis than given the 'omnipotent creator' hypothesis. These expectations are articulated in points (ii) and (i) above, respectively. Thus, given the fact that the panda's thumb is suboptimal (as in point iii above), it follows that this fact favors the evolutionary hypothesis more than the God hypothesis.

Evaluation

One of the nice features of the likelihood formulation is that it captures what was missing in the deductive formulation: Gould's belief in positive evidence for an evolutionary hypothesis. Recall that Gould drew on Davis's careful empirical study, which apparently showed that the thumb could have come about by a "simple genetic change". This result arguably raises the probability that the thumb arose through evolutionary mechanisms. (Or, more modestly, this result at least lessens the improbability that the thumb came about by evolutionary means.) This formulation captures this element.

The likelihood approach also allows a degree of flexibility in terms of the amount of support the thumb provides for evolution over special creation. That is, the more Gould (or anyone else) can show that the thumb is much more probable given evolution than given an omnipotent creator, the stronger the thumb favors evolution over its rival. And a similar result is true in the opposite direction: if one thinks the probabilities between the two hypotheses about the thumb are closer together, the likelihood formulation still provides a way to articulate that idea.

Yet this is also where the likelihood of formulation appears to differ from Gould's own understanding of the argument. Gould tacitly accepts an epistemic principle much stronger than the law of likelihood. He repeatedly uses the word "proof" in the context of the panda argument (Gould 1980, pp. 13, 20, 28), claiming that the argument "demonstrates evolution" (Gould 1980, p. 29). More generally, Gould asserts that imperfections are "the primary proofs that evolution has occurred" (Gould 1977, pp. 90–91; 1980, p. 13; 1983, p. 55, see also pp. 131, 160, 258; 1991, p. 61). Imperfections also disprove the creation hypothesis, supplying "proof that the world was not made in its present form" (Gould 1980, pp. 28–29).[18] Of course, *proving* one hypothesis and *disproving* another is quite different

than *favoring* one hypothesis over the other. 'Favoring' is much more modest; it only states that the evidence supports one claim more than another, to whatever extent. It typically comes in degrees. Both hypotheses could end up being false. Or a third hypothesis might be formulated that is favored by the evidence when compared to either of the previous hypotheses.

Proof, on the other hand, is ironclad. It establishes a given hypothesis with certainty. It is not degreed, not even settling for a very high degree of probability. It is also impregnable to being overturned by a (future) formulation of a rival hypothesis that might try to account for the data in a more convincing way. Proof is proof.

So, the likelihood version departs from Gould's own description of the argument. While a likelihood approach has many advantages over Gould's notion of "proof" and deductive certainty, it is important to note the marked difference. Commentators such as Elliott Sober have overlooked this exegetical point.

To this point, we have not yet visited the most controversial claim of the likelihood formulation. When it comes to evaluating the argument, much attention ought to be given to (i) above, the claim that the probability is extremely low that "an omnipotent creator" made the panda's thumb suboptimal (or allowed it to become suboptimal) for its primary function in the panda's current environment. We will turn to this idea in due course.[19]

Stepping back, I have formulated two versions of the panda argument. While much analysis remains ahead, perhaps this initial examination helps illuminate ways that a person might understand an argument that Gould himself prized. In his view, if ever there was a single artifact that could demonstrate descent with modification, the panda's thumb was it.

6. Critical Appraisal of Key Claims

In what follows, I will critically analyze several elements of the two formulations above. In each case, I will argue that, depending on a person's background beliefs, there may be good grounds for a wide range of people to reject both versions of the panda argument.

6.1. Only Two Options?

We begin with premise four of the deductive argument, which holds, "Either an omnipotent creator made the panda's thumb or it evolved from a common ancestor with a similar structure." For Gould, these two options were the *only* viable ones. In the immediate context of his seminal essays on the panda, he does not give any hint that there might be a third (or fourth) possible explanation worth considering. Elsewhere, he analyzes and rejects the thesis that God, rather than unguided nature, is the best explanation for suffering in the natural world and the improbable results of evolution (Gould 1991, pp. 309–24; 1983, p. 33–40, 42–45). In general, however, Gould more or less uncritically adopts the dichotomy allegedly laid out in the *Origin*: either descent with modification or special creation. Unfortunately, this neither captures the nuances of the *Origin* nor the contours of Gould's own era (Gillespie 1979, pp. 19–40; Hunter 2021a, 2021b).

The deeper question, however, concerns who is rationally obligated to accept premise four (cf. Nelson 1996, p. 502). Apparently, very few. William James' classic text, *The Varieties of Religious Experience*, for example, plausibly demonstrates the great diversity of religious beliefs worldwide—much more varied than Gould's simple dichotomy—and also indirectly implies that Gould's two 'viable' theories are hardly essential "characteristics of the religious life" (James [1904] 2002, p. 485). In fact, premise four elides a host of entities, processes, or deities found in pantheism, process theism, henotheism, polytheism, apophatic theism, religious pluralism, Confucianism, religious Taoism, Theravada Buddhism, Mahayana Buddhism, Nirguna Brahman-oriented Hinduism, Platonism, and the like (Dilley and Tafacory 2019, p. 47). While Gould may have good reasons to reject these possibilities, his premise makes a claim that many people worldwide would not

be rationally obligated to accept. Without further grounds from Gould, such people are (presumably) justified in denying premise four and, hence, the panda argument.

This is no fault of the premise, of course. One cannot reasonably expect Gould to exhaustively justify the premise with respect to every major worldview not covered by his two favored options. As such, the present point is *not* to criticize Gould's premise per se but rather to make an observation: the premise appeals to a circumscribed range of people.

6.2. Suboptimality?

Both the deductive and likelihood formulations claim that the panda's thumb is suboptimal. Oddly, Gould does not give strong reasons to accept this claim; nowhere in his writings does he provide a detailed empirical study that demonstrates the suboptimality of the panda's thumb. The major research that Gould relies upon, Dwight Davis's study, used a *dead* panda for its conclusions about comparative morphology; it did not examine how effective living pandas are at stripping bamboo leaves. Biologist John Gittleman notes that the analyses of both Davis and Gould arose "despite any real information on how the giant panda lives in nature" (Gittleman 1985, p. 524). The first major study of living pandas—focusing specifically on their adaptation to bamboo—was conducted by George Schaller's team, which published its results in *The Giant Pandas of Wolong*. They observed that pandas "efficiently bring food to the mouth with their forepaws" and "handle bamboo stems with great precision by holding them as if with forceps in the hairless groove connecting the pad of the first digit and pseudothumb" (Schaller et al. 1985, pp. 4, 215). Further:

> When watching a panda eat leaves, stem or new shoots we were always impressed by its dexterity. Forepaws and mouth work together with great precision, with great economy of motion, as the food is grasped, plucked, peeled, stripped, bitten and otherwise prepared for being swallowed. Actions are fluid and rapid. . . . (Schaller et al. 1985, p. 58)

Similarly, in 1999, a team of Japanese scientists used computed topography, magnetic resonance imaging, and live observation to analyze the structure and function of the panda's thumb. They reported that the "radial sesamoid" and its accessories enable the panda to "manipulate objects with great dexterity" (Endo et al. 1999, p. 309). In fact, the "way in which the giant panda, *Ailuropoda melanoleuca*, uses the radial sesamoid bone—its 'pseudo-thumb'—for grasping makes it one of the most extraordinary manipulation systems in mammalian evolution" (Endo et al. 1999, p. 309).[20] They conclude that "the hand of the giant panda has a much more refined grasping mechanism than has been suggested in previous morphological models", including Davis's model (Endo et al. 1999, p. 310).

In fairness to Gould, Schaller's team published its work in 1985, followed by the Japanese team in 1999, while Gould published his initial articles on the panda's thumb in 1978. However, Gould continued to champion the thumb as his premier example of imperfection until his death in 2002, never conceding the conclusions of these careful studies. As a curious aside, Gould positively praises the thumb's function in his original 1978 article. Recounting his trip to the Washington zoo as a boy, he writes, "I was amazed by their dexterity and wondered how the scion of a stock adapted for running could use its hands so adroitly" (1978, p. 24).

Thus, by way of an assessment of the 'suboptimality' claim: not only does Gould fail to offer empirical evidence for the suboptimality of the thumb, but key empirical studies of the thumb suggest quite the opposite.[21] Yet, because this claim is essential to both the deductive and likelihood formulations of the panda argument, a person who rejects the suboptimality claim would likewise reject the panda argument.

6.3. The Ways of the Almighty

Just what would an omnipotent creator do? Recall premise one of the deductive formulation: 'If an omnipotent creator made the panda's thumb, he would have optimally designed it for its primary function in the panda's current environment; he would *not* have

suboptimally designed it or allowed it to become suboptimal for its primary function in the panda's current environment.' Recall also a key claim in the likelihood formulation: 'The probability is extremely low that "an omnipotent creator" made the panda's thumb suboptimal (or allowed it to become suboptimal) for its primary function in the panda's current environment.'

These two claims are not identical, of course. The former specifies what God *would* do (or would not do); the latter gives only a probability. But they both share a common thread about what to expect (or not expect) from the deity. On both views, it is highly unexpected, at the very least, for God to create (or allow) a suboptimal thumb. For ease of reference, I will refer to this common thread as "premise one". (So, to be clear, in what follows, by "premise one", I do not just have in mind the first premise of the deductive formulation but also the first statement (i) of the likelihood argument. Thus, my statements about "premise one" will apply to each formulation *mutatis mutandis*.)

Premise one requires analysis. Just what is the justification for it? And who can rationally reject it? To approach these questions, it is important to recognize that Gould did not simply limit himself to claims about the alleged actions of an "omnipotent creator". He also referred to a "sensible God", "rational agent", and "ideal engineer" (Gould 1980, p. 20; 1983, p. 160). These terms are not all the same, and each one gives the panda argument a unique meaning. Consider: 'If a rational agent made the panda's thumb, he would have optimally designed it for its primary function in the panda's current environment; he would *not* have suboptimally designed it or allowed it to become suboptimal for its primary function in the panda's current environment.' The term 'rational agent' does not denote properties of omnipotence, benevolence, aseity, or the like. On some views, a 'rational agent' is a person who fundamentally maximizes self-interest, a notion with few implications about pandas or thumbs. Based on my reading of Gould, an "omnipotent creator" seems most in keeping with his intent; nonetheless, both the meaning and justification of the panda argument radically depend upon which agent one considers.

Having clarified the content of premise one, we may now ask: Who is rationally obligated to accept it? That is, who is rationally obligated to accept that God would not make (or allow) the panda's suboptimal thumb or that the probability is 'extremely low' that God would do so? These questions are more difficult to answer than one might think—in no small part because they breed a further array of queries. Given that Gould believes God would (probably) not allow a suboptimal thumb in the *present*, one might ask: on Gould's view, what should God do if the environment changes? Should God prevent change? If so, to what degree should He maintain stasis? Or should God create new animals, as the famous nineteenth century scientist Georges Cuvier believed? Perhaps He should instead act parsimoniously and limit Himself just to modifying extant animals?[22]

These are non-trivial questions, and Gould elides them. But more to the point, he gives no justification for the assumption he *does* make—namely, that it is highly unexpected (at the least) for God to create a suboptimal panda's thumb. Gould apparently assumes that an omnipotent Being would only behave in the manner purportedly specified by one particular version of creationism ('special creation'). Yet Gould provides no positive grounds for this assumption.

A lack of positive grounds would not be a problem if special creationist theology were obviously true. But it hardly seems to be. Alternatively, a lack of positive grounds would be fine if Gould simply borrowed his contemporary adversaries' background beliefs and, on that basis, showed how the natural world better accords with evolution than with their theories. In other words, the theology in the panda argument does not require independent justification if all parties in the conversation *already* accept this theology. But such is not the case. As we will see, the panda argument relies on *positiva* theology—propositions about God not necessarily held by contemporary design-based rivals.[23] As stated, Gould's argument is only attractive to thinkers who *already* believe that, if God made the panda's thumb, He would do so as premise one describes. Gould provides no positive grounds to sway any dissidents toward his partisan view.

None of this is to say that design-based rivals are correct. Nor is it to defend their views of God, intelligent agency, or related matters. But it is to point out that, unless rivals are given reasons to abandon their current views, they are not rationally obligated to accept Gould's God-talk and, hence, are not rationally obligated to accept the panda argument.

The point applies widely for the simple reason that, in light of *their* background beliefs, a number of thinkers do not appear to be rationally obligated to accept Gould's theology. Of course, some of them may be within their epistemic rights to accept this premise, but this does not mean they *must*. Instead, the relevant question is: who can sensibly reject Gould's theology? Consider, for example, a mainstream orthodox Christian view of premise one. This view may include difficulties for a generalized form of this premise. A generalized form holds that if God had created an organism or structure in the past, He would (almost surely) optimally design it for the organism's environment in the present. Many Christians do not accept this claim in part because they believe in the doctrine of the Fall, which holds that, due to creaturely rebellion against God, the natural world is no longer in its pristine state. This doctrine is arguably one of the most influential ideas in world history, affecting a wide range of human ideas and activities, including the rise of modern science itself (e.g., Harrison 2007). Genesis intimates the effect on the natural world:

> And to the man, [God] said,
>
> . . . cursed is the ground because of you;
>
> in toil you shall eat of it all the days of your life;
>
> thorns and thistles it shall bring forth for you. . .
>
> By the sweat of your face you shall eat bread
>
> until you return to the ground. . .
>
> you are dust, and to dust you shall return. (Genesis 3: 17–19)

Paradise lost; toil and death gained. In the Christian tradition, the majority of modern commentators as well as many Church Fathers believe Saint Paul spoke directly about the effects of the Fall on creation in his famous letter to the Roman church:

> For the creation waits with eager longing for the revealing of the children of God; for the creation was subjected to futility, not of its own will but by the will of the one who subjected it, in hope that the creation itself will be set free from its bondage to decay and will obtain the freedom of the glory of the children of God. We know that the whole creation has been groaning in labor pains until now. . . . (Romans 8: 19–22)[24]

And in his commentary on the Book of Isaiah, John Calvin contrasts the prophet's irenic vision of the natural world before the Fall with animal cruelty and violence after:

> [Isaiah] describes the order which was at the beginning, before man's apostasy produced the unhappy and melancholy change under which we groan. Whence comes the cruelty of brutes, which prompts the stronger to seize and rend and devour with dreadful violence the weaker animals? There would certainly have been no discord among the creatures of God, if they had remained in their first and original condition. When they exercise cruelty towards each other, and the weak need to be protected against the strong, it is an evidence of the disorder. . . which has sprung from the sinfulness of man. (Calvin [1550] 1892, p. 383)

While not all Christians accept this view, millions do. Whether or not this doctrine is correct, supported by the Bible, or endorsed by the Church Fathers is much beside the point. What matters is that, given *this* background belief in the Fall, these Christians are not rationally obligated to accept Gould's theology and, hence, his panda argument.

In light of this version of Christianity, one might be unsurprised to find that contemporary creationists and intelligent design theorists—Gould's specific adversaries—also typically reject premise one. This is not to say that their reasons for doing so are strong, but only to point out that Gould has given them no grounds to replace their own views of the divine (or of intelligent agency) with those of the panda argument.

In the present day, young earth creationists routinely claim that the Fall of man adversely affected the created order such that it is no longer optimal. In the seminal text of modern creationism, *The Genesis Flood*, Henry Morris and John Whitcomb argue that the original creation was without flaw, but "the Edenic curse had far-reaching effects upon nature" including physical changes to animals as well as predation and death (Whitcomb and Morris 1961, p. 459). Andrew Snelling argues a similar line in *Earth's Catastrophic Past* (2010), arguably the most comprehensive defense of creationism today.[25] He contends that creation was originally "complete and perfect. There was nothing out of order—no pain, no suffering, no disease, no struggle for existence, no disharmony, no sin or evil, and above all, no death" (Snelling 2010, vol. 1, p. 245). But "[m]an's fall from his created state of innocence" had a "pivotal effect upon. . . the whole earth" which adversely altered the animal kingdom, humankind, and even "the very elements of the ground itself" (Snelling 2010, pp. 253, 245–59). Snelling, Morris, and Whitcomb are hardly alone. To my knowledge, nearly all contemporary young-earth creationists affirm the existence of an omnipotent God *and* the adverse effects of the Fall on creation (Nelson 1996, p. 500). Given the degraded state of creatures and their environment, it is hardly surprising that some organisms are poorly adapted to their current ecological niche.

Likewise, intelligent design theory itself does not entail the acceptance of premise one. The theory holds that certain features of the natural world are best explained by detectable intelligent agency rather than mindless materialistic processes like natural selection and random mutation (Meyer 2013, p. 339). While ID theorists generally expect to find well-engineered systems or organisms in the natural world (Miller 2022), the theory is consistent with at least some degree of 'devolution' in the present day (e.g., Minnich and Meyer 2004, pp. 301–2). And the theory itself focuses on intelligent agency rather than the theology-rich concept of an "omnipotent creator". Thus, insofar as a person accepts ID theory, she has grounds (in principle) to refrain from accepting premise one.

Moreover, intelligent design theorists can accept additional claims that more directly run contrary to premise one. For example, William Dembski holds that "[i]f humans are indeed the crown of Creation", then "on theological grounds" it seems "entirely reasonable for human sin to have repercussions throughout the physical world" (Dembski 2009, p. 39). These repercussions include not just suboptimal designs but outright natural evil. In fact, Dembski accepts that God himself brought "about natural evil" in part to help human beings understand the seriousness of sin as well as their need for redemption (Dembski 2009, pp. 37, 150).[26] On this view, one can reject the notion that God created *only* optimal designs in the biological realm. Similarly, one can accept that God knew about the Fall (logically) prior to the moment of creation and thus *deliberately* created suboptimal organisms for punitive and redemptive purposes.[27]

More deeply, advocates of contemporary creationism, intelligent design, or related views can take matters one step further. Even aside from their own theories, there are independent (religious) reasons to think that suboptimal designs that have no purpose at all—not even salvific purposes—are fully compatible with the creative activity of an omnipotent creator. Philosopher Peter van Inwagen has argued that gratuitous evil poses no threat to God's existence (van Inwagen 1995, 2006). Evil is 'gratuitous' when it is unnecessary either for some compensating good *or* to prevent some worse (or equally bad) evil. If van Inwagen is correct, then an appendage that functions inefficiently and is not balanced by *any* compensating goods may be compatible with the claim that God created it. On this view, 'gratuitous suboptimality', as we may call it, is no objection to a creative deity.

Taking a step back, various thinkers have offered several ways to reject Gould's theology. In their view, God could have (i) created everything good but, for corrective and redemptive purposes, allowed the Fall to mar the biological realm, (ii) directly created suboptimal designs for divine purposes, or (iii) allowed suboptimal designs *sans* offsetting goods. By enumerating these three options, I do *not* mean to endorse any of them or to claim that any of them are plausible. Instead, the main point is that, in light of *these* views (taken on their own terms) and in light of Gould's lack of apologetic for special

creationist theology, a range of contemporary thinkers are not rationally obligated to accept premise one.

Even if we were to charitably confine Gould's argument to Darwin's era, problems still remain. Perhaps the most prominent creationists of that day—Louis Agassiz and William Paley—would *also* not be obligated to accept Gould's theology.[28] Take Louis Agassiz, for example. In his greatest theoretical work, *Essay on Classification* (1859), he defends what we might call 'taxonomic creationism.' Agassiz believes that species are incarnations of ideas in the mind of God, and their (taxonomic) relations reflect a grand divine plan. On this view, God created basic organismal types that allow variation, some of which are less functional than others. He did not create each species (or structure) optimally adapted to its (current) environment, a point Agassiz drives home early in the work:

> The argument for the existence of an intelligent Creator is generally drawn from the adaptation of means to ends, upon which the Bridgewater treatises, for example, have been based. But this does not appear to me to cover the whole ground, for we can conceive that the natural action of objects upon each other should result in a final fitness of the universe and thus produce an harmonious whole; nor does the argument derived from the connection of organs and functions seem to me more satisfactory, for, beyond certain limits, it is not even true. We find organs without functions, as, for instance, the teeth of the whale, which never cut through the gum, the breast in all males of the class of *mammalia*; these and similar organs are preserved in obedience to a certain uniformity of fundamental structure, true to the original formula of that division of animal life, even when not essential to its mode of existence. The organ remains, not for the performance of a function, but with reference to a plan, and might almost remind us of what we often see in human structures, when, for instance, in architecture, the same external combinations are retained for the sake of symmetry and harmony of proportion, even when they have no practical object. (Agassiz 1859, pp. 11–12)

Agassiz clearly rejects the notion that "an intelligent Creator" would (probably) create or allow only optimal biological designs.[29] On this view, God does not produce every structure for a function but rather creates according to a (taxonomic) plan in which aesthetic elements like "symmetry and harmony of proportion" sometimes take precedence over biological utility. Indeed, one might *expect* cases of inutility. The deity is an artistic architect rather than a spartan engineer.

Strikingly, William Paley also implicitly rejects Gould's theology. In *Natural Theology* (1809), he argues for the existence of an omnipotent deity based on organismal adaptation. Yet he thinks that limited cases of imperfection pose no difficulty because the sheer quality and quantity of exquisite adaptations provide a preponderance of evidence for the existence and traditional attributes of God (Paley 1809, pp. 56–58). As such, Paley points out that an ostrich's wings can be "reckoned an imperfection in the bird" because, "although they may greatly assist it in running, do not serve for flight" (Paley 1809, p. 220). Paley also allows "totally useless" structures as long as they are "extremely rare" (Paley 1809, p. 59). (Notably, Gould does not believe the panda's thumb is totally useless but rather "workable" (Gould 1980, p. 24)). So, Paley's creationism is consistent with the existence of a clumsy panda's thumb.

Stepping back, we see congruity between Paley and Agassiz, two of the most prominent figures in the 19th century debate about biological origins. Despite their starkly different approaches to natural theology, both hold that God's concern in creation is not exclusively aimed at optimal design at the species level, much less with respect to current habitats. For Agassiz in particular, the deity took other elements into consideration, such as beauty, symmetry, and cosmic-level harmony. Oddly, Gould himself was familiar with Agassiz's and Paley's views yet apparently did not realize that they raised difficulties for his panda argument (see Gould 2002, pp. 260–81).

To summarize, premise one claimed that an omnipotent creator (almost surely) would not have suboptimally designed the panda's thumb for its primary function in the panda's

current environment. Such a Being neither creates nor permits poor function. But not only does Gould fail to offer positive support for his view, quite a few thinkers in the discussion have ample reasons to reject it. Such thinkers include taxonomic creationists, Paleyian creationists, contemporary young-earth creationists, intelligent design theorists, mainstream Christians, and many others.

7. The Likelihood Formulation One More Time

As we have seen, a wide array of people are not rationally obligated to accept Gould's theology. That is, many people are justified in rejecting either (or both) premise one of the deductive formulation or statement one of the likelihood formulation. Naturally enough, this has significant implications for whether such people should accept the panda argument as a whole.

Having said that, it is also important to note that there is more going on in the likelihood formulation than just Gould's theology-laden claim. The point of the likelihood argument is to *contrast* special creation with evolution. That is, while an imperfect thumb is compatible with the activity of an omnipotent creator, nonetheless, it is said to be *less* expected on this view than on evolution. The deity tolerates a few screw-ups; evolution tolerates a lot. Thus, even if many people are not rationally obligated to accept the one-off claim that 'God would probably not create or allow the suboptimal thumb', the deeper point is to contrast evolution with special creation. The likelihood version holds that evolution fits the data *better* than creationism does. The point is to compare the two in light of the evidence; when that happens, evolution emerges as the victor.

The likelihood formulation is formidable, and evaluating it comprehensively involves a number of interesting issues. For now, however, I simply want to observe that the matter may be more difficult than it first appears. Just how much does the panda's thumb favor evolution over its rival? Once again, the extent depends in part on what an omniscient creator would do. Religious traditions set the boundaries in different places. Even *within* each of the monotheistic religions, different sects have varied ideas about the matter. Unsurprisingly, these sects also often disagree about the quality and quantity of (expected) disarray in the created order. Some believers regard this disarray as deep and pervasive. For example, Alvin Plantinga suggests that God may have allowed the incarnation, death, and resurrection of His Son as an unrivaled great-making property of the universe and as a remedy to the problem of creaturely rebellion. But "if the remedy is to be proportionate to the sickness . . . [our] world will contain a great deal of sin and a great deal of suffering and pain. Still further, it may very well contain sin and suffering, not just on the part of human beings but perhaps also on the part of other creatures as well" (Plantinga 2011, p. 59). Such sin and suffering may explain creaturely "predation, waste and pain" (Plantinga 2011, p. 59). On this view, we might be unsurprised to find *many* suboptimal designs—perhaps even as many as we would expect given evolution. If so, then such imperfections do not favor evolution over creation.

Whether Plantinga is correct or not is quite beside the point. Whether one is an atheist, agnostic, theist, or other, the deeper issue is that one's conception of God (and perhaps related matters, like creaturely freedom) radically shapes the extent to which the panda's thumb supports evolution over a given God-based view.[30] The likelihood formulation of the panda argument will have to engage serious theological issues in order to claim success. Perhaps this can be done, but the task is hardly trivial.

Why is this worth pointing out? First, expositions of the panda's thumb argument rarely, if ever, acknowledge these matters, much less address them. Second, as noted, some prominent biologists make theology-laden arguments for evolution, yet likewise fail to do so with theological substance. Indeed, theology-laden defenses of current evolutionary theory in technical literature, popular writing, and textbooks nearly always lack theological and metaphysical rigor.[31] In these contexts, the assertion that imperfection bolsters evolution over design-based rivals leaves much territory unexplored.

A second and deeper challenge concerns the claim that the panda's thumb is, in fact, suboptimal. The suboptimality of the thumb is essential to the argument, functioning as its crucial evidence. In the likelihood formulation, the argument claims that an imperfect thumb is more expected given evolution than given special creation. But to make this claim, one must determine what counts as an *imperfection*. And this is no small task given the theological context of the argument, especially with an "omnipotent creator" in view. As philosopher of biology Paul Nelson observes:

> Many philosophers and theologians take the creator's proper domain to be the entirety of time and space, and furthermore hold that issues of moral value figure ultimately in any theory of creation. If this is so then the necessary finitude or limits of scientific observation may lead us to infer mistakenly than an organic design (e.g., the panda's thumb) is imperfect, when its imperfection is only *apparent*, that is, *local*. On this view, any judgment of perfection or imperfection must be qualified with a proviso that perfection. . . can only be judged only on the scale of the whole creation. (Nelson 1996, p. 503, original emphasis)

The panda argument depends on the judgment that the panda's thumb is imperfect. If this judgment is to be sound, then the proper metric of evaluation must be utilized. But *what* is the proper metric—local biological adaptation, cosmic harmony, salvation history, eschatological redemption, or something else? Even if the thumb performs its biological function poorly, it may have a more important function in the divine economy. To claim that the thumb's primary function is *biological* implies that God is mainly concerned with, or only able to affect, a relatively narrow range of possibilities. But what is the evidence for this assumption? Human artists and inventors sometimes craft work for moral or aesthetic purposes rather than mere functional ones, for example.

Arguably, human cognition faces strenuous demands when assessing the proper metric for God's purposes with the panda's thumb, especially when cosmic harmony, salvation history, eschatological redemption, and divine aesthetics are live possibilities. Just how does Gould *know* what the deity had in mind for the radial sesamoid? Philosopher Elliott Sober summarizes the point:

> Creationists don't need to assert that *they* know what God would have had in mind if he had built the panda. All they need to say is that *Gould* does not know this. Gould adopts assumptions about the designer's goals and abilities that help him reach the conclusion he wants—that intelligent design is implausible and Darwinian evolution plausible as an explanation of the panda's thumb. But it is no good simply *inventing assumptions* that help one defend one's pet theory. Rather, what is needed is *independent evidence* concerning what God (or some other intelligent designer) would have wanted to achieve if he had built the panda. And this is something Gould does not have. (Sober 2008, p. 128, original emphasis).[32]

Thus, in order for the likelihood formulation to carry the day, serious theological work remains to be done. In particular, affirmation of the thumb's suboptimality requires analysis of divine purposes or goals at the relevant scale, whether local, cosmic, redemptive, aesthetic, or otherwise. But without a sound judgment of the thumb's imperfection, the argument loses its central evidence. This is not to say that such a judgment cannot be reasonably made, but only to make the modest point that any such judgment requires substantive theological reflection.[33]

A final problem with the likelihood argument includes a self-referential concern. (As it happens, this concern applies to the deductive version as well.) Those inclined toward the argument often agree with Gould that evolution is an unplanned and unguided process that leaves humans poorly equipped to discern the alleged purposes of a putative deity. As I will briefly explore in Section 10 below, those who accept this view may be unjustified in accepting the panda argument or indeed many *positiva* arguments for evolution.

8. An Objection and Reply

But scholars familiar with Gould's work might raise an objection. Some may worry about my characterization of the panda argument as a polemic for common ancestry and against special creation. A critic might suggest that Gould's aim was instead to establish exaptation and attack adaptationism.[34] Gould's interest in the panda's thumb might be viewed as a modest precursor to his more technical and developed arguments for these ends. On this view, the panda's thumb is a weird, unique, and exapted structure in the broader context of comparative morphology. The thumb is odd, peculiar, and incongruous by comparison to the thumbs of other organisms—such as those of apes, which have 'typical' thumbs rather than extensions of their radial sesamoids. It is "clumsy" in terms of where it has come from, not necessarily its present-day use. Thus, it would be wrong to think that Gould characterized the thumb as "sub-optimal" in the sense of having poor function. By contrast, he thought of it as an exaptation. Exaptations can function reasonably well but still be identifiable as odd, peculiar, clumsy, and incongruous in comparison to the features of other animals. So, it is a mistake to characterize Gould's argument as focusing on suboptimality and, by extension, as an argument for common ancestry and against special creation. Instead, it is better described as an argument for evolution as a messy, haphazard, improvising process—a process of contingency rather than one primarily marked by, say, the finely sculpting hand of natural selection.

I raise four points by way of reply. First, I quite agree that Gould's writings about the panda's thumb are part of his apologetic for exaptation and his critique of adaptationism. The textual evidence is clear that Gould had these ends in mind. In fact, I am even happy to concede, if need be, that these are his *primary* purposes. But it would be an overstatement to claim that these are his *only* purposes. Great thinkers can have more than one purpose for a given argument (or set of arguments). As I will show below, Gould had in mind more than just exaptation and anti-adaptationism.

Second, my primary concern is not with Gould's supposed purposes but, once again, with the *argument* as he straightforwardly presented it. Arguments and their premises stand or fall on their own. Moreover, as a de facto reality, the panda argument has been and remains widely deployed by other thinkers as a polemic for evolution and critique of creationism or intelligent design (e.g., Salesa et al. 2006, p. 381; Prothero 2007, pp. 37–38; Dawkins 1986, p. 91; Rice 2007, p. 2; Futuyma 2013, pp. 613–14, 639). Whether Gould intends it or not, the panda argument has played this role and continues to do so. It can be studied as such.

Third, but even setting this point aside, the objection above misses the common conceptual thread that, for Gould, tied adaptationism and special creation together. Both views emphasize optimal or near-optimal design. In one case, God is the craftsman; in the other, natural selection. In either case, species are well-adapted to their particular environment. (More so in the case of divine design.) But both views stand or fall on the level of optimality present in the natural world. For Gould, clear examples of suboptimal adaptation count as evidence against these views. In the case of adaptationism, Gould believes that suboptimality indicates that natural selection plays a lesser role in survival and reproduction than adaptationists believe. In the case of special creation, Gould thinks that suboptimality indicates that a divine explanation is less plausible than a tinkering, evolutionary one. For Gould, *both* views share similar internal logic, and so he marshals suboptimality as evidence against the duo. Thus, to claim that 'Gould has only one purpose in mind in his suboptimality arguments' misses his understanding of the conceptual connection between adaptationism and special creation.

Fourth, in any case, the textual evidence is unmistakable. Gould regards the panda argument as establishing common ancestry and upending creationism. He is also clear that sub-optimality is part of the picture. At the risk of being repetitive or pedantic, I have reiterated some of Gould's language in what follows. For example, Gould frames the panda argument as modeled on Darwin's argument about orchids. But it is clear that Gould regards Darwin's argument as a polemic against special creation and for evolution.

Paraphrasing Darwin, Gould writes: "If God had designed a beautiful machine to reflect his wisdom and power, surely he would not have used a collection of parts generally fashioned for other purposes" (Gould 1980, p. 20). After stating that orchids "were not made by an ideal engineer" but are "jury-rigged", Gould concludes, "Thus, [orchids] must have evolved from ordinary flowers" (Gould 1980, p. 20). The basic framing is clear: special creation by God versus evolution from a common ancestor.

It is also clear that sub-optimality is in view. Gould goes on to explain that:

> [P]erfection of organic design had long been the favorite argument of creationists, who saw in consummate engineering the direct hand of a divine architect. . . But, Darwin reasoned, if organisms have a history, then ancestral stages should leave remnants behind. Remnants of the past that don't make sense in present terms—the *useless*, the odd, the peculiar, the incongruous—are the signs of history. (Gould 1980, p. 28, emphasis altered)

'Uselessness' is a clear type of sub-optimality, a species of poor function. Moreover, the contrast with "consummate engineering" likewise implies less than perfect function. Well-engineered objects are typically marked by good function. Of course, they may have other fine features as well, such as aesthetic elegance. But they typically have these in addition to good function. It would be very odd to characterize an object as having "perfect" design and yet have *no* implications about its performance.

More to the point, Gould is clear that all of this framing and language about orchids applies directly to the panda argument. He makes this transparent in his *magnum opus*, his mature characterization of the panda argument:

> If such a quirk, oddity, or imperfection—making no sense as an optimal and immutable design in a current context—wins explanation as a holdover or vestige from a past state in different circumstances, then historical change may be inferred. Call this, if you will, the orchid principle (though I have also designated it as the panda principle for my own favorite example, perforce unknown to Darwin, of the panda's false thumb, Gould 1980), to honor Darwin's argument (1862) for orchids as products of history. Their intricate adaptations to attract insects for fertilization cannot be read as wonders of optimal design, specially created for current utilities, for they represent contraptions, jury-rigged from the available parts of ordinary flowers. (Gould 2002, p. 104).[35]

Notice the language of imperfect function. Gould states that "imperfection" makes "no sense as an optimal or immutable design in a current context". Orchids, like the panda's thumb, are not "specially created for current utilities". These are clear statements about suboptimality in the sense of poor *current* function. (This dovetails with Gould's language elsewhere that the thumb is "highly inefficient" (Gould 1986, p. 63).) Thus, Gould is not (simply) claiming that the thumb is clumsy or odd in comparison to the thumbs of other organisms. He is (also) making a statement about its functionality.

Moreover, the language of "specially created" features once again highlights the overall importance of creationism as Gould's adversary. In fact, the whole paragraph is framed as a contest between this adversary and evolution: "optimal and immutable design in a current context" cannot explain what appears to be "a holdover or vestige from a past state in different circumstances" and, thus, "historical change may be inferred". Gould's attack on adaptationism is no doubt close at hand. But it is difficult to say that creationism is not also in the picture: why else attack the idea of "specially created" features?

In summary, then, there are good reasons to accept my interpretation of Gould's panda argument. As mentioned, one can accept that Gould's *primary* purpose is to establish exaptation and criticize adaptationism, if need be. But there is also strong evidence that this was not his only purpose and that he also had in mind the argument that I have analyzed above.

9. A Brief Exposition of the Theological Elements of the Panda Argument

Given that God-talk is clearly in play, it may be helpful to recapitulate several theology-related features of the panda argument. The first notable feature of the argument is that it *requires* theology to be persuasive. In either formulation, the argument's non-theological claims on their own cannot substantiate their respective conclusions. So, Gould's argument depends on God-talk. Of course, a different version of the argument that focuses exclusively on the actions of a "rational agent" will not per se engage theology. But any version that invokes a divine being will do so.

Second, Gould's theology serves as part of his *positive* case for evolution. The scientist thinks "oddities" and "imperfections" count as strong grounds to favor evolution over creationism, not just to reject creationism alone (Gould 1980, p. 28). If Gould removes theology entirely from the panda argument or from his imperfection arguments generally, he loses "the primary proofs that evolution has occurred" (Gould 1977, pp. 90–91; 1980, p. 13; 1983, p. 5; see also pp. 131, 160, 258; 1991, p. 61).

Third, as we have seen, Gould's theological claims are partisan. Gould does not borrow the tenets of his various creationist rivals to show *on their own grounds* that the facts of the natural world support evolution more than them.[36] Instead, Gould imports his own *positiva* intuitions about what a "sensible God" would do. In short, Gould's theology is sectarian relative to a range of perspectives, including some, like young-earth creationism, that are heavily involved in origins discussions.

As mentioned, Gould is not alone. Some prominent biologists likewise use *positiva* theology in some of their arguments for evolution. This occurs not just in debates with creationists or intelligent design theorists but even in 'neutral' or 'purely scientific' contexts like encyclopedia entries or textbooks (Nelson 1996, pp. 497, 506–8). That is, even when the rhetorical setting is a straightforward description of the reasons for evolution, theological claims often surface. In fact, a 2019 study of 32 biology (and evolution) textbooks—including the top 12 in the United States—indicated that around 80% of them use theology in a tendentious way in their case for evolution (Dilley and Tafacory 2019). Thus, some of the challenges that plague the panda argument apply elsewhere too.

10. Still More Reasons

Additional considerations raise further reasons to reject the panda argument. These stem from tensions between the panda argument, on the one hand, and some of Gould's other claims, on the other. The crucial point here is not simply that Gould's own view is internally conflicted, however. The first tension explored below applies to *any* thinker, religious or non-religious, who adopts Gould's compartmentalized approach to science and theology. The second tension applies in particular to atheists, agnostics, or anyone who believes that evolution is an unguided and unplanned process. A person who accepts either Gouldian compartmentalism or that evolution is undirected cannot also accept the panda's thumb argument. Rationally speaking, a person in this situation must make a choice. These considerations provide additional grounds for people in this situation to reject the panda argument.

10.1. Tension 1

The first internal tension concerns Gould's 'compartmental' approach to the relationship between science and religion. This doctrine, which he calls Non-Overlapping Magisteria (NOMA), sequesters science and religion from each other. He explains:

> To summarize. . . the net, or magisterium, of science covers the empirical realm: what is the universe made of (fact) and why does it work this way (theory). The magisterium of religion extends over questions of ultimate meaning and moral value. These two magisteria do not overlap. . . . To cite the old clichés, science gets the age of rocks, and religion the rock of ages; science studies how the heavens go, religion how to go to heaven. (Gould 1999, p. 6)

But if science and religion "do not overlap", then how can Gould's argument about a biological phenomenon, like the panda's thumb, rest upon theological claims? Indeed, in the panda argument, theological claims are *essential*. Remove these claims, and the argument's conclusion no longer follows validly from the premises. More generally, all of Gould's imperfection arguments—from zebra stripes to marsupial animals—turn upon God-talk. But if NOMA ought to be observed, then these arguments illicitly mix science and religion; as a result, they are illegitimate.

More generally, anyone who accepts an epistemic barrier between science and religion faces the same dilemma. Both compartmentalists and complementarians do so. The former assent to NOMA, while the latter believe that science and religion offer complementary perspectives on at least some of the same natural phenomena. Both generally hold that the content of a scientific theory cannot raise or lower a person's epistemic justification for a religious claim. So, too, the content of a religious claim cannot raise or lower a person's epistemic justification for a scientific theory. Yet in the panda argument, a theological claim purports to provide readers with increased justification for belief in evolutionary theory. Accordingly, compartmentalists and complementarians cannot coherently deploy the panda argument—or *any* of the many theology-laden arguments currently in play.

A similar result applies to methodological naturalists who reject God-talk in scientific discourse at the level of salient background beliefs, evidence, or arguments (Nelson 1996, pp. 493, 495–96, 514–15). They cannot coherently regard theology-laden arguments for evolution as properly scientific. They must choose *either* methodological naturalism *or* theology-laden scientific arguments for evolution. One cannot have it both ways (Dilley 2017).[37]

10.2. Tension 2

A second internal tension concerns the epistemic basis of Gould's theology. On what grounds can he legitimately know true propositions about God? The question becomes pressing in light of Gould's view of human evolution, in which humans were not created by God in order to know Him but were produced by mindless evolutionary processes (cf. Darwin 1958, pp. 92–93; Churchland 1987, pp. 548–49; Crisp 2016). In the late 1970s, Gould claimed that "mind, spirit, and God . . . are just words that express the wondrous results of neuronal complexity" (Gould 1977, p. 13). And ". . . if mind has no real existence beyond the brain, can God be anything more than an illusion invented by an illusion?" (Gould 1977, p. 25). That is, the notion that our 'minds' apprehend 'God's nature and ways' is akin to the notion that one illusion can reliably apprehend another illusion. The point here is not so much Gould's implied atheism (Sheldon 2014, p. 143), as it is his view of the human species' ability to reliably do theology. As late as 1999, just three years before his death, he endorsed the "cold bath" theory of nature. In this view, "[n]ature. . . existed for eons before we arrived, didn't know we were coming, and doesn't give a damn about us" (Gould 1999, p. 195). I take this as a metaphorical way of saying that humans are the result of indifferent natural forces; they are surely not creatures designed to inhabit the Earth by a self-revealing God.

In this light, one might wonder how Gould can reliably know certain claims about the deity. Gould avers that God would not (likely) create or allow suboptimal designs, yet, in his view, the human mind was never specifically designed to apprehend such truths. At most, humans were fashioned by chance and selection to survive and reproduce on the African savannah. How likely is it that homo sapiens, having ultimately arisen from primitive organisms, evolved cognitive powers to *know* true subjunctive claims about a (proposed) omnipotent deity's intentions for a tiny sliver of the biosphere—the panda's thumb—which is far removed from human survival and reproduction?[38] Of course, it is *possible* that our lineage evolved this ability. But is it *probable*? Gould's "cold bath" perspective suggests that the answer is either no or inscrutable. Accordingly, a critic may reasonably claim that Gould's view of evolution presents an obstacle to the justification of the panda argument's God-talk.

This same result applies to atheists and agnostics, for example, who make similar claims about human origins and the limitations of human cognition with respect to theological knowledge of the relevant sort. Such thinkers apparently have a defeater for *any positiva* argument for evolution. Insofar as they bring their own theology to the table—not borrowed from design rivals—then they need to justify this theology within the context of using it in an argument for evolution (or against design).[39] In this case, the version of evolution they accept opposes the very grounds they give for its acceptance. This is a troubling internal tension.

11. Final Thoughts

To be clear, this essay has not critiqued evolutionary theory or made a comprehensive case for it. Even if the difficulties that plague the panda argument apply to other theology-laden arguments for evolution,[40] it does not follow that there aren't *other* good arguments for evolutionary theory. The failure of one argument, or of one class of arguments, does not rule out the presence or power of different types of arguments.[41]

Instead, I have argued that a number of people are not rationally obligated to accept the panda's thumb argument, in either the deductive or likelihood formulations. Among other problems, Gould's argument maintains that the thumb is suboptimal for its primary purpose of stripping bamboo leaves. Not only does Gould offer no evidence for this claim, but prominent empirical studies indicate quite the opposite. Second, Gould's argument hinges on a particular claim about what the deity would (likely) do. Yet he provides no justification for this theological claim. As it happens, many religious believers who regard the natural world as adversely affected by the Fall have reason not to accept Gould's contention. More poignantly, some key thinkers directly involved in the origins discussion in the past, like Agassiz and Paley, as well as in the present, like young earth creationists and intelligent design theorists, have grounds to reject Gould's assertion to one degree or another.

Moreover, deep theological waters must be navigated if Gould is to hold that an imperfect thumb is *more* expected given evolution than given an omnipotent creator. Establishing this claim may require a careful examination of creaturely agency, divine intentions, and, in some circles, even doctrines of eschatology and the Incarnation. More generally, it is also no easy matter to establish what counts as 'imperfection' in the context of an "omnipotent creator". Such a being has an array of purposes available to Him. Discerning these is not trivial, yet rarely do such matters surface in discussions of the panda's thumb.

Whatever the case, any thinker—religious, atheist, agnostic, or otherwise—who accepts NOMA, complementarity, or methodological naturalism cannot also justifiably accept the panda argument. Indeed, they cannot justifiably accept any theology-laden arguments currently given for evolution within the context of science. As noted, such arguments are not limited to imperfection arguments but also include polemics that draw on molecular homology, gross anatomy, embryology, biogeography, paleontology, organic diversity, and the like. They appear not just in popular-level works but also in textbooks and elsewhere.

Perhaps more worrisome is whether Gould can have the relevant kind of theological knowledge in light of his own non-theistic vision of evolution. That is, can Gould (or others) reasonably expect to know specific subjunctive claims about a divine being's relationship to select episodes in organic history when such a being had nothing to do with humans' cognitive development? Something like this question troubled Darwin and, arguably, remains worrisome to the present day (Darwin 1958, pp. 92–93; Dilley 2012, pp. 51–52).

Stepping back, the panda's thumb is one of the most iconic arguments for evolutionary theory. Discussion of it raises significant challenges, especially regarding the nature of imperfection and the ways of the Almighty. More generally, from Darwin to Gould, atheists, agnostics, and theists have all contributed to theology-laden arguments for evolution. This is a rich topic, and much conversation remains ahead.

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Notes

1 Most notably, this includes Gould's critique of adaptationism, gene selection, and gradualism, not to mention his advocacy of punctuated equilibrium. Also fascinating are his clever rhetorical maneuvers in the "Darwin Wars." For the latter, see Sheldon (2014).

2 In addition, the icon is the namesake of the well-known pro-evolution website www.pandasthumb.org, accessed August 4, 2023.

3 Paul Nelson's fine article (1996), which I draw on in this essay, first drew my attention to the theological elements of Gould's argument.

4 There are a number of ways that the grounds for evolutionary theory extend beyond the scope of this article. For example, if it were demonstrated that complex biological systems, such as the bacterial flagellum or vertebrate eye, could be built by stepwise physical processes, then all things being equal, such data might be plausibly taken to confirm evolutionary theory over, say, intelligent design theory. Moreover, if the version of ID theory under consideration specifies a non-divine designer, rather than a supernatural designer, then theology-laden claims would not be required to argue in favor of evolution over intelligent design. Thus, in certain contexts, the grounds for evolution do not require God-talk. As such, the comprehensive case for evolution is in principle much broader than the particular theology-laden claims addressed in this essay. It is also notable that the standard definition of 'evolutionary theory' as 'common descent brought about by the mutation-selection mechanism (and other natural processes)' does not per se include theological content. The theory *itself* is not theology-laden (in the relevant sense) and, as just noted, in some contexts, *arguments* for it are likewise not theology-laden. Thus, one can speak coherently about evolutionary theory and some of its grounds in non-theological terms.

5 Of course, some other thinkers' theology-laden arguments for evolution involve much different theological claims than those examined in this article. The extent to which the present study applies to these arguments depends on these differences as well as various other factors.

6 See also Dilley and Tafacory (2019) for an analysis of the role of theology in arguments for evolution in 32 biology (and evolution) textbooks, including the top 12 in the United States. Luskin (2009, 2015) is also relevant.

7 I use the term 'special creation' in part because, as I will note below, Gould's own language suggests that he had something like this term in mind. It is arguably the case that Gould was influenced by his reading of the *Origin*. In that work, Darwin's chief rival seems to have been the view that God created the structures and organs of each species to be well-matched to their respective environments. Yet Darwin engaged with other versions of creationism as well. Indeed, part of the point of my argument (below) is that some of the actual contours of 19th century creationism were much broader and more nuanced than Gould's critique of 'special creation' (so defined). See also Gillespie (1979) and Hunter (2021a, 2021b).

8 On a related note, Cornelius Hunter (2007) argues that contemporary evolutionists who use theology in their polemic for evolution do not invent their own theology but rather draw upon a centuries-old tradition of secularized theology, which he calls "theological naturalism."

9 As we will see, the same can be said for even some creationists in the 19th century.

10 Gould italicizes the phrase.

11 In the original passage, Gould emphasizes that imperfect design is the failure of coordination between an organism and its current circumstances.

12 Although Gould here summarizes Darwin's argument, it is clear that Gould agrees with its substance.

13 The quoted words are Gould's.

14 The brackets are Gould's. He is quoting Davis.

15 My thanks to a reviewer for helping me formulate both deductive and likelihood versions of Gould's argument.

16 The quoted words are Gould's.

17 That is, empirical datum D favors hypothesis H_1 over hypothesis H_2 if and only if $Pr(D \mid H_1) > Pr(D \mid H_2)$. And the degree to which D favors hypothesis H_1 over hypothesis H_2 is given by the likelihood ratio $Pr(D \mid H_1) / Pr(D \mid H_2)$.

18 One might wonder if Gould thinks imperfections collectively, rather than individually, disprove the creation-in-the-present-form hypothesis. But Gould repeatedly emphasizes our ability to draw strong conclusions from *individual* entities (see Gould 1983, pp. 131, 258; 1986, p. 63; 2002, p. 104).

19 Some readers may wonder whether Gould had in mind a Bayesian formulation of the panda argument. My own view is that he did not. I have just noted his use of "proof" language (as opposed to probability). And, in the context of the panda's thumb or other imperfection arguments, it is not clear that he attended to prior probabilities, a core feature of Bayesian reasoning. In any case, some of the considerations below (about likelihoods) may be relevant to a Bayesian formulation of the probability of evolution given the suboptimal thumb, especially its catch-all likelihood.

[20] Although the authors state that the thumb arose in "mammalian evolution," they do not argue for the thumb's evolutionary origin but rather assume it, as per standard decorum in technical biology journals.

[21] Gould tends to emphasize the thumb's function for stripping bamboo leaves. Empirical studies show that the thumb also routinely handles bamboo in a manner that allows the panda to strip bark and to eat shoots and stalks as well.

[22] My thanks to a reviewer for suggesting some of these helpful questions.

[23] As we will see, the same is true for some 19th century creationists as well.

[24] According to New Testament scholar Douglas Moo (1996, pp. 513–14), the majority of modern commentators believe Saint Paul spoke directly about the adverse effects of the fall on creation in (Romans 8: 19–22). See also (Schreiner 1998, p. 435) and (Murray 1968, vol. 1, pp. 301–2).

[25] John Morris (2010), son of creationist godfather Henry Morris and president of the Institute for Creation Research, regards Snelling's 1500 page work (2010) as the sequel to *The Genesis Flood* (1961).

[26] Dembski (2009, p. 150) accepts the traditional view of God, including His omnipotence.

[27] Perhaps God does so via middle knowledge. In *The End of Christianity*, Dembski is not keen on the idea (2009, p. 216). Nonetheless, the concept is compatible with the thesis of his book.

[28] I will briefly examine Agassiz and Paley. I leave it to the reader to consult the views of Cuvier and Owen, who also held background beliefs that, given these beliefs, would have presumably allowed them to reject premise one of Gould's argument.

[29] In fact, according to Agassiz, humans can infer the existence of an intelligent Creator by considering the harmony of the "universe" as a whole, which arises from the relations between objects generally rather than from the adaptation of particular organisms to local environments.

[30] Among other claims about the divine, atheists or agnostics can be justified, in principle, in holding *conditional* claims about God. For example, nothing in their worldview precludes them in principle from accepting that "if an omnipotent creator made the panda's thumb, He would not (likely) have created or allowed it to be suboptimal." Such a claim does not entail belief in the existence of God but rather belief in what would follow *if* God existed. Similarly, atheists and agnostics can also hold that "the existence of a suboptimal panda's thumb is more expected given evolutionary theory than given an omnipotent creator". This claim likewise does not entail belief in the existence of God but rather an expectation about the datum *were* God to exist (relative to an expectation *were* evolutionary theory to be true). The general point, then, is that atheists or agnostics can, in principle, coherently accept some kinds of theology-laden claims, including some relevant to the contest between evolution and special creation. The main text simply observes that, whatever one's worldview, justifying such claims requires substantial reflection on a range of topics, including theological topics.

[31] A happy exception to this superficiality is Kitcher's careful *Living with Darwin* (2007). Plantinga (2011, pp. 55–63) offers a thoughtful critique of Kitcher's view.

[32] For a discussion about whether Sober's view has harmful implications for the justification of evolutionary theory, see Elliott Sober (2011a, 2011b), Sahotra Sarkar (2011), and Hunter (2014).

[33] It is worth noting that Sober himself thinks that his point is a two-edged sword. He argues that proponents of the design argument have the same problem: they do not have independent grounds to know the powers or plans of an intelligent designer and so cannot establish their likelihood claim (that, say, the human eye is probable given an intelligent designer). As Sober says, "we must be careful not to beg the question. We cannot reason that since the eye was made by God, that God must have wanted human beings to have eyes with the features we observe. What is needed is evidence about what God would have wanted the human eye to be like, where the evidence does not require a prior commitment to the assumption that there is a God and also does not depend on looking at the eye to determine its features" (Sober 2008, p. 146). For criticisms of Sober's view, see Dilley (2017). More importantly, Stephen Meyer's *Signature in the Cell* (2009) and *Darwin's Doubt* (2013) are perhaps the best biology-based design arguments available, yet they both utilize "inference to the best explanation" rather than a likelihood formulation. The same is true of Meyer's extended design argument for theism in *Return of the God Hypothesis* (2021). Moreover, in these works, Meyer shows how to make predictions (or set expectations) from a design perspective (e.g., Meyer 2009, appendix) and how to render the design argument in a Bayesian form (Meyer 2021, pp. 231–35).

[34] My thanks to a reviewer for this version of the objection (see Gould and Lewontin 1979; Vrba and Gould 1986; Gould 1983, pp. 147–57; 1989; 1991, pp. 109–39).

[35] Although Gould here summarizes Darwin's argument, it is clear from the context that Gould agrees with its substance.

[36] Even when evolutionists invoke theological claims with which creationists agree, like "God would not deceive", they generally apply them in ways not consonant with creationist theology (e.g., Dilley 2013, pp. 776–77).

[37] Arguably, the use of theology in arguments for evolution—from the *Origin* to the present day—stands in tension with the 'standard view' of the rise and normative establishment of methodological naturalism in biology. For the standard view, see Numbers (2003, pp. 279–85). For a counter, see Hunter (2007, 2021a, 2021b) and Dilley (2017).

[38] Assessing this claim is a complicated affair in part because one must non-arbitrarily choose the initial conditions (or time) from which to make the assessment (see Sober 2008, pp. 362–63).

[39] See Note 30.

[40] Moreover, some of the other theology-laden arguments for evolution involve much different theological claims than those examined in this article. This, too, limits the scope of my study.

[41] See also Note 4.

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