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

Hugh Norman Ross

Reasons to Believe, Covina, CA 91724, USA; hross@reasons.org

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).

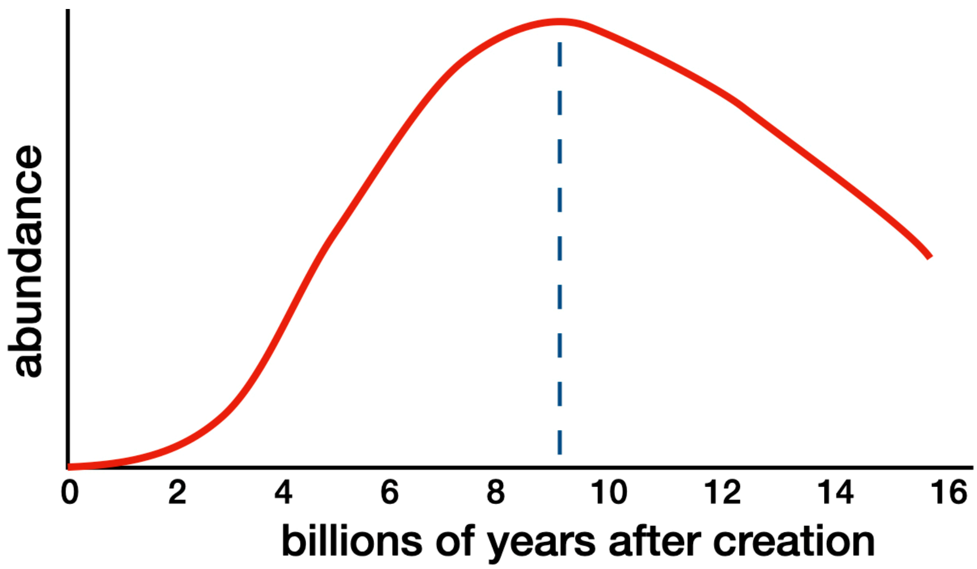

Figure 1. Abundance of Uranium and Thorium Throughout Cosmic History. Uranium and thorium are exclusively manufactured during supernova eruption events and merger events of neutron stars. As the universe expands and stars disperse, these events become progressively less frequent. Meanwhile, thorium-232, 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.

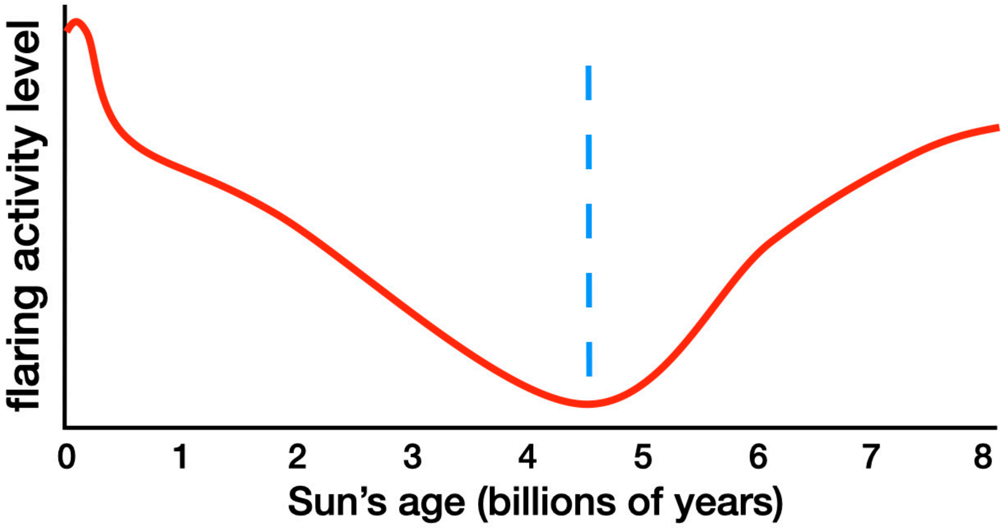

Figure 2. Sun's Flaring Activity and X-ray Radiation Levels Throughout Its History (Maehara et al. 2012, 2015; Notsu et al. 2013, 2019; Shibayama et al. 2013; Metcalfe 2018; Reinhold et al. 2020; Zhang et al. 2020). The *y*-axis is logarithmic. The dotted line indicates the present. During its first 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 $\pm$ 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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