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Understanding Open Questions on the Origin of Life

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Abstract

Open, unanswered questions in the field of origin of life (OoL) describe the vast gaps in explaining the supposed historical, continuous, and naturalistic path from lifeless chemicals to cellular life that utilizes genetics and metabolism. At three recent international conferences, participants clarified dozens of open questions on the origin of life (OQ/OoL) and discussed possible scientific and philosophical resolutions. This paper examines a few important OQ/OoL from the perspective that a naturalistic OoL scenario contradicts the revelation of creation in Scripture and that scientific research is bringing into focus how difficult it will be to resolve these OQ/OoL, rather than converging toward explanations for a naturalistic, historical explanation of the OoL.

Introduction

Over the past few years, international conferences were held to discuss open questions on the origin of life (OQ/OoL) in Sicily (EMFCSC, 2006), Spain (Astrobiology Workship, 2009), and Leicester, UK (University of Leicester, 2012). A similar meeting held at the Royal Society in 2006 also noted, "The ubiquity of open questions [on the emergence of life on the early earth]" (Jortner, 2006, p. 1885). While this author did not attend these conferences, papers, presentations, and reports from the conferences are well documented in the peer-reviewed literature and on websites for each conference. These conferences gave evolutionary scientists, educators, and philosophers the opportunity (1) to gauge the overall progress on origin of life (OoL) research, (2) to identify and clarify "big-picture" unanswered areas within the OoL field, and (3) to facilitate collaboration and cooperation between diverse research efforts. These conferences were held because, as Luisi and Ruiz-Mirazo summarized (2010, p. 353), "The origin of life on Earth is still a mystery, one of the greatest mysteries in science today. … Our ignorance about the origin of life is profound—not just some simple missing mechanistic detail." Dozens of significant OQ/OoL span the disciplines of (1) philosophy—what is life? (2) chemistry—how did the prebiotic syntheses of macromolecular proteins and nucleic acids occur? (3) biology—how did metabolism and genetics become unified? (4) physics—how did catalytic cycles overcome thermodynamic and kinetic constraints? (5) astronomy—where did life begin? and (6) geology—what were the conditions on the prebiotic earth?

One significant OQ/OoL is the origin of homochirality for biochemical polymers. The difficulties of finding a naturalistic origin of homochirality for amino acids and polypeptides were

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recently reviewed in this publication (Murphy, 2013). Emergence is another common theme in OQ/OoL, including (1) how does biochemistry and biology emerge from chemistry, and (2) is life an emergent property? OQ/OoL span both top-down and bottom-up research approaches. Top-down research methodologies look for evidence of progressively simpler ancestors of modern cellular life toward the first "living" creature, often called the last universal common ancestor (LUCA), or the cenancestor. Bottom-up research methodologies strive to understand how lifeless inorganic chemicals formed the biochemical polymers necessary for life and how those components self-organized into the first "living" creature.

The overwhelming majority of OoL scientific research and philosophy is based on naturalistic and materialistic assumptions. Their efforts seek to contradict God's creation *ex nihilo* described in Holy Scripture, including in Genesis, Exodus, John, Acts, Hebrews, and Colossians. OQ/OoL continue to accumulate because naturalistic OoL research yields scientific contradictions and dead-ends, as the work is based on false assumptions that exclude the Creator. In mathematics, an "indirect proof" establishes the truth of a proposition by showing that if the proposition is false a contradiction will result. In the fields of SETI (the Search for Extraterrestrial Intelligence), archeology, cryptography, and forensics, once all natural explanations for the observations and evidence are eliminated, some other explanation for the observations and evidence must be pursued. Similarly, OQ/OoL should continue to accumulate over time, and these questions will become more difficult to overcome due to their false foundation of creation apart from God and contrary to biblical revelation. One proposed open question for the 2009 OQOL conference even wondered why the field of OoL research "has not progressed much since the early experiments of Stanley Miller [in the 1950s]". Lahava et al. (2001, p. 77) concluded, "After almost 50 years of modern research, there is no paradigm of the origin of life." The lack of progress in naturalistic OoL research is a shocking admission, especially when compared to the staggering and impressive advancements in other scientific fields in the past six decades.

The Significance of the Conferences for Open Questions on the Origin of Life

Just like other scientific communities, OoL researchers use societies (e.g., ISSOL, the International Society for the Study of the Origin of Life), journals (e.g., *Origins of Life and Evolution of Biospheres*), and conferences to network, to collaborate, to publish, and to seek research funding. Recent conferences on OQ/OoL fostered much debate since these OQ/OoL do not have any single plausible explanation and invariably have competing theories with limited experimental data, scant observed evidence, and no scientific consensus to convincingly answer many of the particular aspects of the naturalistic approach to the OoL. Thus, OoL researchers are each other's harshest critics. Scientists challenge competitors' research and ideas by peer-review to reject and criticize unwarranted assumptions, poor experimental methodology or data analysis, and unjustified conclusions and to propose alternative interpretations. These conferences on OQ/OoL clarified the gaps in their collective scientific knowledge and challenged each other's unverified theories, speculations, assumptions, and explanations.

Pearcey and Thaxton (1994, p. 21ff) wrote that "modern science arose within a culture saturated with Christian faith," and that the philosophical underpinnings of science include that (1) nature is real, (2) nature is good and of great value, (3) nature is worthy of study, (4) nature is not God, (5) events in the natural world occur in a reliable and predictable fashion, often characterized as the "laws of nature," (6) the "laws of nature" can be stated in precise mathematical formulas, (7) the order in the natural world is intelligible and can be interpreted and understood by a rational mind, (8) the order in the natural world must be found by observation and experiment rather than rational deduction, and (9) the ordered, intelligible, good world reflects the character of the God of the Bible. Modern scientists will nearly universally accept 1 through 8, but to the extent that scientists believe in 9, materialistic, naturalistic science excludes any role for God in the past, present, or future in the physical world. In other words, belief in God is acceptable so long as no active role is assigned to God. Researchers studying the OQ/OoL seek explanations for how lifeless earth, water, air, and fire became today's extremely complex living creatures in a way that is consistent with the known natural, scientific laws of physics, chemistry, biology, geology, astronomy, thermodynamics, etc.

OoL researchers fabricate compelling narratives for life's origin and subsequent evolution, interweaving scientific explanations with optimism and enthusiasm for future discoveries to fill in the missing gaps in their OoL scenarios. Advocates for the biblical account of Creation in Genesis must enter into the debates on the OQ/OoL with caution. Like picking up a 7–10 split in bowling, if we merely knock down one of the multiple naturalistic explanations or theories for some aspect of an OQ/OoL, then other naturalistic explanations remain and perhaps are even strengthened. Since divine creation did not proceed through a long evolutionary history of intermediate chemical and biochemical transitions toward living creatures, all naturalistic explanations for the OoL will ultimately be proved untrue by the standard of being consistent with known scientific laws. We can often accept the criticism OoL researchers shower on one another without accepting the incomplete evidence they provide for their own particular naturalistic explanations for OoL scenarios. What follows is a brief description of a few of the OQ/OoL addressed at the conferences in 2006, 2009, and 2012 and their significance as a means to strengthen our faith in the biblical account of Creation.

OQ/OoL #1: Where Did Life Begin?

Hazen (2005) has pointed out that since the 1980s, the OoL field began to transform from the search for the "Origin of Life" (singular) to the search for the "Origins of Life" (plural). This change reflects the beliefs and hopes of OoL researchers that the appearance of life in the universe is frequent and that many individual origin events occurred and coordinated to produce living creatures on earth. This change may be motivated by the need to keep our planet Earth from being unique in any sense—for example, alone being just right for life. In the 1990s, NASA funding drove the search for life both to extreme environments on earth and throughout the universe, thus expanding OoL research from the disciplines of chemistry and biology to the fields of astrobiology, astronomy, and geology. Conducting scientific research is expensive, and the pursuit of research funding is highly competitive among research groups. Since funding drives scientific research, which results in publications that build reputations and careers, the scientific consensus about where life began perhaps became more influenced by self-interest than by evidence alone. For example, Witze (2013) reported on the alarm among planetary scientists with NASA's announcement of a restructuring of how NASA research is funded. Currently there is no evidence (observed or replicated in a laboratory) that life exists or has ever existed anywhere in the universe (except here on earth) in its current form or in any intermediate or transitional lifelike form.

The naturalistic search for a continuous OoL path from lifeless chemicals to living creatures spans many terrestrial and extraterrestrial environments looking for individual biochemical materials, organic precursors, fossils, primitive cellular life, and other evidence of life's origins. On earth, OoL researchers pose scenarios for formation on mineral surfaces, at hydrothermal vents, or in aqueous environments ranging in temperatures from above boiling to below freezing. At the 2012 Leicester conference, various presentors argued that each location has potential advantages and disadvantages regarding energy availability, chemical composition, reaction rates, and molecular stability. Astrobiology expanded the search for chemical compounds synthesized under prebiotic conditions to meteorites and the cosmos, seeking to explain the origin of abiotic organic and bio-organic compounds, and ultimately life on earth. Pascal (2012) claims that extraterrestrial OoL research benefits from a wider range of chemical compositions, temperatures, and energy sources (chemical, electromagnetic radiation, mechanical, geothermal) than were ever possibly present on earth. So far, no complex biochemical materials (e.g., oligopeptides or nucleotides) have been detected in any cosmic material. As stated in regard to the Sicily conference, "What we learn from cosmic products is of limited interest regarding macromolecular prebiotic molecular evolution" (EMFCSC, 2006).

A lack of scientific consensus on "where life began" means that none of the explanations offered by naturalistic OoL research is even remotely close to offering a scenario where lifeless chemicals were transformed to living, cellular creatures in a way that is consistent with the known laws of nature. A few key problems with terrestrial OoL include the availability of chemical materials and energy sources, the dilution problem, and the thermodynamic constraints of an aqueous environment. A few key problems with extraterrestrial OoL include the stability of biochemical materials in the harsh cosmic environment, transport of organic materials to earth, and contamination of any extraterrestrial sample analyzed on earth. Genesis describes the creation of the heavens, the earth, and all living creatures—that is everything—as resulting from the decree of God. The enthusiastic pursuit of the extraterrestrial search for the OoL testifies to the futility of finding a naturalistic explanation of the OoL exclusively here on earth. When those extraterrestrial efforts also prove unsuccessful, the only scientific conclusion will be that the underlying assumptions of any naturalistic OoL were "indirectly proven" to be false and that life was the result of the special creation of God.

OQ/OoL #2: Was the Origin of Life Heterotropic or Autotropic?

Heterotrophic organisms use available complex organic compounds for growth and energy since they cannot produce these materials for themselves. Autotrophic organisms are capable of synthesizing their own food from inorganic substances, using light or chemical sources of energy. Early naturalistic OoL research focused on various heterotrophic scenarios in which organic and biochemical compounds supposedly accumulated in a prebiotic world by diverse processes until some self-organization processes culminated in life's origin (see Figure 1). More recently, a variety of competing autotrophic OoL scenarios have been theorized in which simple chemical processes (e.g., inorganic, C_1, C_2) progressively organized themselves and evolved toward life (OQOL, 2009, pp. 391ff). As Mansy (2010, p. 394) summarized, "The heterotroph sup-

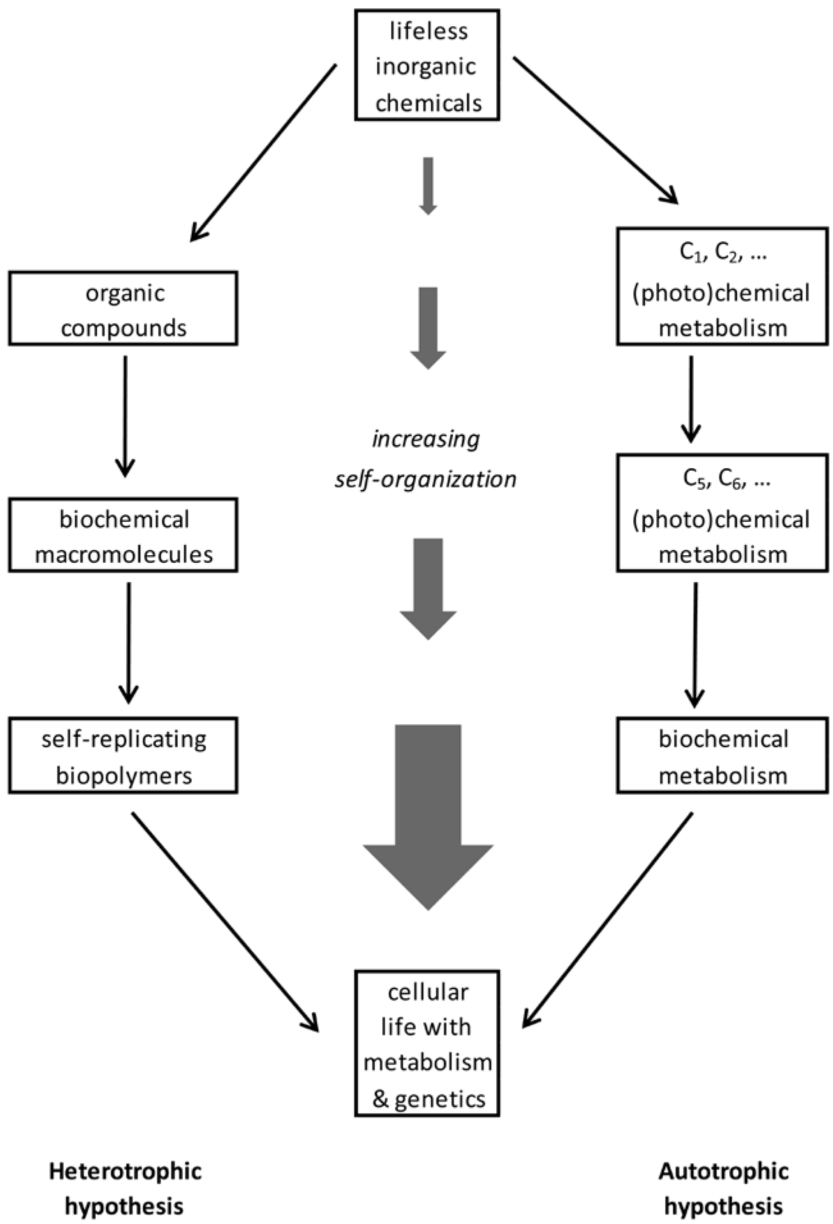

Figure 1. An overview of heterotrophic and autotrophic origin-of-life (OoL) pathways.

porters tend to focus on the creation of self-replicating systems dependent upon provided energy sources, and the autotrophic supporters often focus on geochemical cycles that mimic contemporary biochemical paths. In short, heterotrophy versus autotrophy emerges as replication-first versus metabolism-first arguments." Both the autotrophic and heterotrophic OoL approaches have large open questions concerning the vast difference in complexity between lifeless inorganic materials and living cellular organisms. Smith and Morwitz (2010, p. 398) concluded, "The problems for deciding between autotrophic and heterotrophic origins therefore come from uncertainty about mechanisms of organization."

Various naturalistic OoL scenarios lie along a continuum from heterotrophic to autotrophic. Ever since Oparin (1936) proposed a process for the evolution of life on earth, all naturalistic OoL schemes have lacked sufficient evidence to convincingly demonstrate a viable route from lifeless inorganic chemicals to cellular life. No one has found evidence of either autotrophic metabolic cycles or heterotrophic self-replicating biopolymers that would have served as intermediate or transitional stages in an OoL pathway toward cellular life. One common explanation for lack of evidence for the supposed steps from lifeless inorganic chemicals to cellular life is that any early OoL metabolic cycles or genetic replicators "ate the evidence" (Hazen, 2005, lesson 3). This incredible claim implies that once upon a time there was at least one continuous pathway from lifeless inorganic chemicals to cellular life that existed long enough for cellular life to become established, at which point the living creatures then consumed any and all evidence for any and all intermediates and transitional stages along the OoL path. This explanation is comparable to a bridge built between remote islands and after everyone finished traveling between the islands, all evidence of the bridge was removed, including any evidence that anyone ever knew how to build a bridge or had any other way to travel between these remote islands.

Autotrophic OoL schemes require somewhat simpler chemical environments and energy sources, but much more complex metabolic cycles to evolve toward self-replication. Pascal (2010, p. 393) noted, "Converting redox potentials into free energy available for a metabolism is a difficult task … the inorganic sources of energy [in a primitive earth environment] are not considered as able to deliver free energy in amounts … sufficient to induce biological self-organization." Smith and Morwitz (2010, p. 399) concluded, "We currently lack a principled, quantitative, chemically explicit theory of the requirements to stabilize a metabolic network and a self-generated control system far from thermodynamic equilibrium."

Heterotrophic OoL schemes postulate a somewhat simpler series of transitional OoL stages but require a much more complex environment in both quantity and variety of biochemical materials for progressive self-organization. As Zaia and Zaia (2008, p.1600) summarized, "The heterotrophic organisms need molecules (proteins, lipids, sugars, etc.) ready to be used as an energy source for other syntheses." Pereto (2005, pp.24–26) concluded:

> In this scenario, life would have started with very simple anoxygenic and heterotrophic primordial cells. Difficulties regarding prebiotic chemical reactions in the atmosphere (since we still lack any robust evidence of its … exact chemical composition and physical conditions) and uncertainties as to the accumulation of extraterrestrial organics have shifted the focus in search of other locations for primeval living processes.

Even if the open question of metabolism first or genetics first is ever resolved, OoL research would then face the significant open question summarized by Norris et al (2012, p. 487): "How did metabolism and genetic replication get married?" And this is not the only concerted merging of biochemical capabilities. The minimum essential characteristics of biological life include information (genetics), complexity, metabolism, growth, reproduction, irritability, and adaptation. Finding a means of self-replication of biopolymers, for example RNA or polypeptides, is only a miniscule first step toward the first hypothetical life-form.

The bottom line is that no evidence exists to show that either the heterotrophic or autotrophic OoL processes are occurring today. Nor has evidence been found to suggest that any complete heterotrophic or autotrophic OoL scheme was operative in an early earth environment. Today, we see lifeless chemical compounds, and we see living cellular organisms, but we see nothing in between, such as any series of transitional stages or OoL pathways from mere chemicals to living creatures. OoL research continues to reveal the enormous gap between the composition and complexity of these two aspects of God's created order. The vast gap between lifeless chemicals and living creatures is wonderfully expressed in Genesis 2:7: "The Lord God formed a man from the dust of the ground and breathed into his nostrils the breath of life, and the man became a living being" (NIV).

OQ/OoL #3: How Plausible Is the "RNA World" Origin-of-Life Hypothesis?

Luisi and Ruiz-Mirazo (2010, p. 420) concluded that for many OoL researchers, "the origin of life on the basis of a prebiotic family of RNAs is the preferred scenario." Ribonucleic acid (RNA) is the leading single-biopolymer model proposed for OoL that may have preceded the current two-biopolymer system, which is based on deoxyribonucleic acid (DNA) and proteins. In all observed living creatures, DNA is the genetic biopolymer that stores information and directs the biosynthesis of proteins. Proteins provide a diversity of structure, metabolism, and catalysis necessary for life. Modern biology has found that RNA molecules exhibit a wide range of self-replication and catalytic properties, which leads OoL researchers to see vast possibilities and potential (Luis et al., 1999; Vaidya et al., 2012). While DNA does not catalyze its own reproduction, one drawback for RNA is its high susceptibility to hydrolysis (Voet and Voet, 2004).

RNA is an unbranched polymer consisting of ribose sugars precisely joined together by phosphate bonds, with each ribose containing one heterocyclic base. Note the differences between RNA and DNA in Figure 2. A monomer unit of RNA or DNA, which consists of a base, a sugar, and a phosphate, is a nucleotide. While RNA is chemically similar to DNA, there are some important differences. In DNA, the sugar is deoxyribose (no OH group in the 2 position of the ribose). Both DNA and RNA use four heterocyclic bases: three in common (guanine, adenine, and cytosine), and uracil (only in RNA), and thymine (only in DNA). RNA polymers are generally single-stranded and lower molecular weight, while DNA is double-stranded and much higher molecular weight. This single strand (RNA) vs. double strand (DNA) difference is biochemically enormous in structure and functionality. Three kinds of RNA participate in protein synthesis from DNA: messenger RNA, transfer RNA, and ribosomal RNA. Many biochemistry textbooks and publications describe the remarkable details of the role of RNA in protein synthesis; see for example Hames and Harper (2000).

Shapiro (2010, p. 423) points out that, "the nucleotide components of RNA are substances of considerable chemical complexity, bearing four chiral centers, and the region-specific connection of the furanose form of the sugar ribose to a particular place on each of four heterocycle entities." Like many monosaccharides, ribose exists in equilibrium among five isomeric forms; one linear form, two five-membered rings (α- or β-ribofuranose), and two six-membered rings (α- or β-ribopyranose) (see Figure 3). The ribose in RNA consists only of the β-D-ribofuranose form of ribose, which is only about 18% of the equilibrium composition

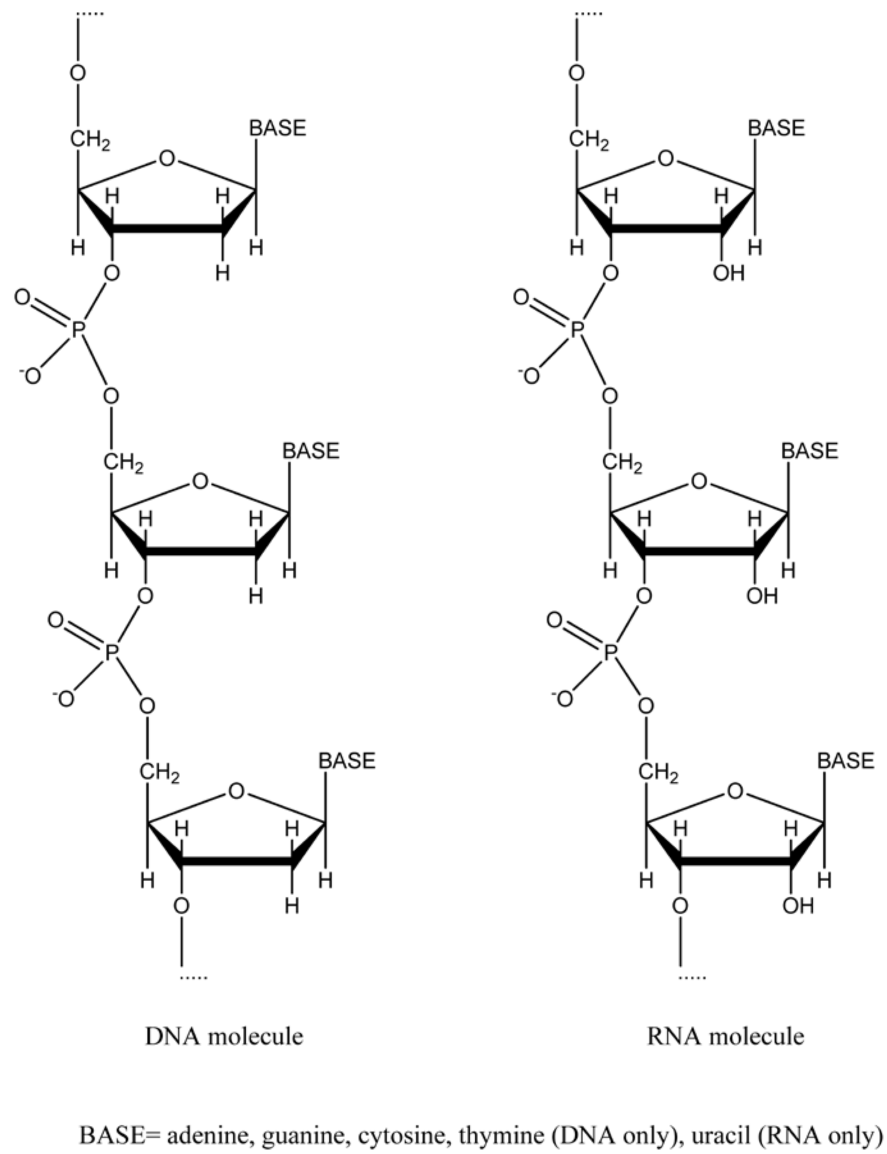

Figure 2. DNA and RNA nucleotide sequences

in solution among these five ribose isomers (Angyal, 1969). Shapiro (2010, p. 424) points out that too often "the progress that has been made by skilled chemists in this area [RNA world OoL hypothesis] more reflects an achievement [of organic chemists] in the total laboratory synthesis of RNA rather than any recapitulation of events on the early Earth." Failing to clearly distinguish a synthesis in a laboratory from either (1) possible prebiotic OoL chemistry or (2) what actually occurred in the history of the earth is a common practice among OoL researchers. The popular media also does not report or emphasize these differences. Equating the processes of laboratory syntheses and natural geochemistry does a disservice to the complexity of laboratory syntheses and downplays the practical impossibility of lifeless inorganic materials naturally combining within thermodynamic and historical constraints to form the complex biopolymers of life and ultimately to form cellular life. Shapiro (2010, p. 425) and many chemists "declare that the abiotic formation of RNA would constitute a near miracle."

Pross (2010, p. 435) argues against a metabolism-first OoL scenario based on proteins and argues for the RNA-first theory since incremental chemical evolution of polypeptides will pass through numerous transition or intermediate states, and any protein OoL pathway "cannot pass through non-functional intermediates." Pross's conclusion applies to the thermodynamic constraints and chemical stability of any OoL pathway from lifeless chemicals to observed cellular life, which presumably requires many transition states and intermediate materials.

While modern biochemistry and molecular biology continue to discover the amazing features and roles of RNA in living creatures, OoL researchers may be asking too much of one molecule in their quest for a pathway from lifeless chemicals to living cellular organisms. For example, Benner and Hutter (2002) concluded that the simultaneous roles of catalysis and information storage place incompatible demands on molecular structure of RNA. DNA has essentially the same chemical properties independent of its nucleotide sequence; a requirement of genetic information storage. But proteins provide a diverse range of chemical properties and functions specifically based on a particular amino acid sequence. RNA world proponents are searching for an OoL scenario where RNA accomplishes more genetic information storage, more catalysis, and more functionality than has been observed for RNA in living biochemical systems. A related OQ/OoL is the origin of the universal genetic code for all living creatures: the encoding of each

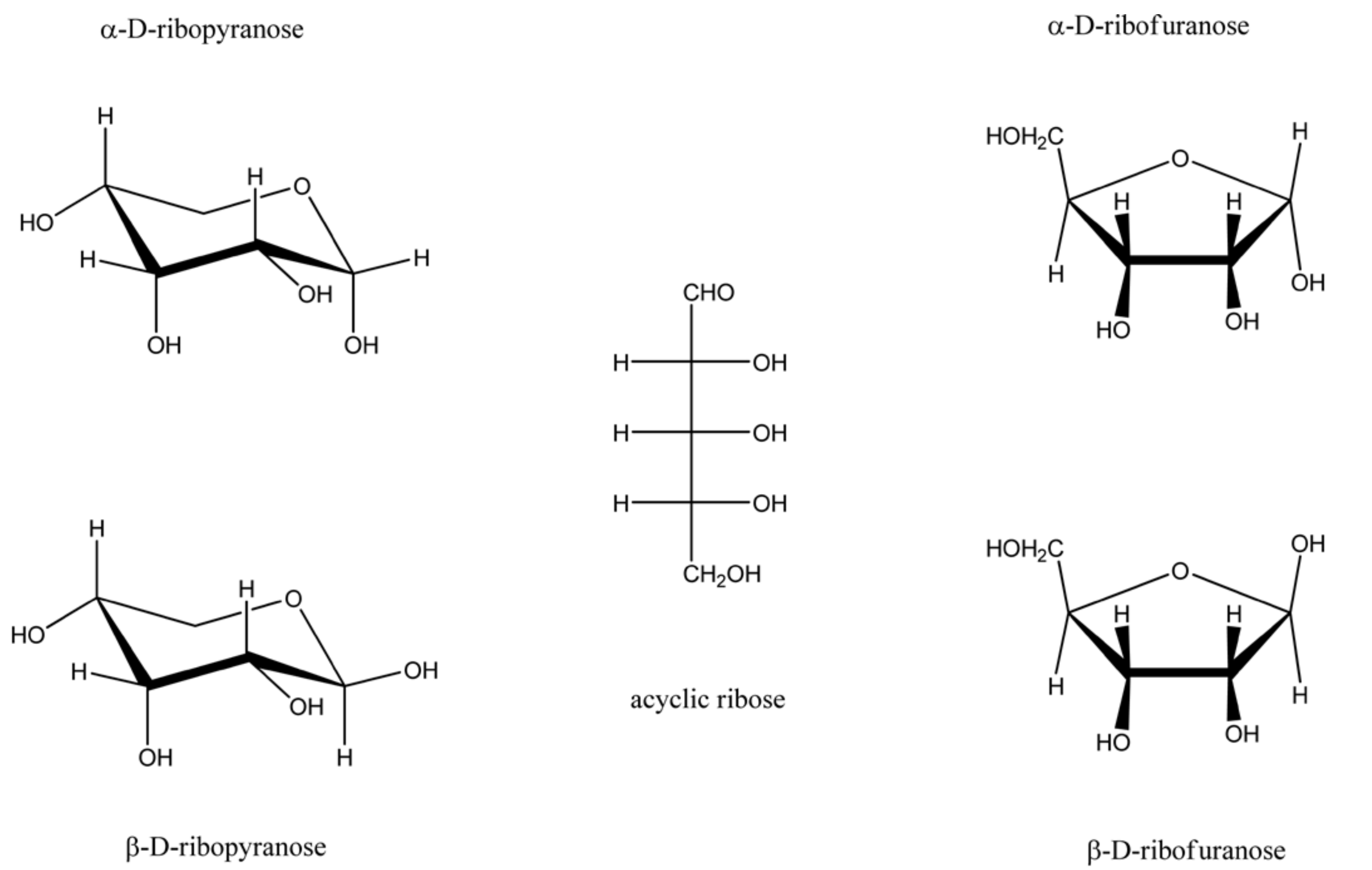

Figure 3. Isomeric forms of ribose

amino acid by one or more nucleotide triplets and the synthesis of all proteins (primary, secondary, tertiary, and quaternary structures) from sequences of DNA nucleotides.

Perhaps the greatest challenge to the RNA world OoL scenario is the stability of the nucleotides and the component sugars, phosphates, and heterocyclic base pairs. For example, Levy and Miller (1998, p. 7935) reported that "calculation of the half-lives for the rates of decomposition of the individual nucleobases A, U, G, C, and T clearly shows that these compounds are not stable on a geologic time scale at temperatures much above 0°C." Furthermore, Li and Breaker (1999, p. 5371) reported that "the rate constant for RNA transesterification [i.e., internal chemical rearrangements] under representative physiological conditions is ~100,000-fold greater than … for the hydrolysis of DNA under similar reaction conditions." Many factors affect RNA stability including pH, temperature, inorganic catalysts, UV radiation, etc. In a fallen world experiencing death and decay, every biopolymer is vulnerable to and eventually undergoes various degradation reactions. Our Creator has provided living organisms with numerous systems for protecting, repairing, and replacing critical proteins, DNA, and RNA that have been damaged. No OoL scenario has postulated the synthesis, storage, protection, and organization of biopolymers into living cellular creatures in the absence of these God-given protection, repair, and replacement strategies.

Critical unanswered scientific questions remain for the RNA world OoL scenario, including the following: (1) What prebiotic syntheses produced RNA or any mononucleotides? (2) What prebiotic mechanism achieved coupling the RNA units only in the 3'–5' configuration? (3) How were specific RNA macromolecular sequences synthesized in many identical copies in sufficient concentrations? (4) Within thermodynamic constraints, how could self-replication occur for a single molecular system? (See University of Leicester, 2012; EMFCSC, 2006.) Without a viable solution to any one of these four questions, the RNA world OoL hypothesis seems nearly impossible. Taken together, all the open, unanswered questions about the RNA world OoL hypothesis have led many researchers to abandon the RNA world OoL hypothesis and to conclude that a metabolism-first OoL scenario is more plausible.

Much of the RNA world hypothesis is driven by theoretical models. Science is anchored in actual observations in the real world (Pearcey and Thaxton, 1994). No mere rational deduction or prediction, no matter how sophisticated, can replace actual observed evidence. Vast computing power has been harnessed to produce incredible models, predictions, and forecasts, but in the absence of actual experimental evidence and real observations, models remain mere scientific prophecy subject to falsification or validation as soon as evidence is gathered and data is collected. All scientific evidence points to RNA as an essential part of all cellular life, but little to no evidence points to the abiogenesis of RNA apart from living creatures, which makes the RNA world OoL scenario an impossible route from lifeless chemicals to living cellular organisms.

OQ/OoL #4a: Is Life an Emergent Property?

OQ/OoL #4b: How Does Biology Emerge from Chemistry?

Traditionally, science seeks to reduce complex systems to their component parts and processes and then discover the "laws of nature" that describe those components in order to understand the whole complex system (Pearcey and Thaxton, 1994). Emergence is the scientific and philosophical idea that order, coherence, and complexity (which are not evident at the microscopic level) can arise at a macroscopic level far from equilibrium. Self-organization emerges from a disordered system through a myriad of individual interactions under a narrow range of constraints in energy, time, and space. Common examples of emergence in nature include snowflakes, sand dunes, clouds, flocking birds, and schooling fish. Emergence is a common theme in OoL research spanning, as Pohorille (2010, p. 384) concluded, "at least four types of emergent traits that are particularly relevant to the origins of cellular life: 1. organic/synthetic chemistry, 2. macromolecular and sub-cellular structures and functions, 3. metabolic and regulatory networks, 4. cellular behavior." While the scientific aspects for the "emergence" of chemistry from physics is well understood, OoL researchers have passionately (but unsuccessfully) pursued a similar understanding of the emergence of biology from chemistry.

With so many OQ/OoL and so little consensus on any aspect of the OoL pathway from lifeless chemicals to cellular life, the variety of individual emergence problems from chemistry to biology/cellular life is overwhelming. Pohorille (2012, p.429) succinctly described just one gap in the emergence of biochemistry: "The emergence of protein functions is a puzzle. … Structure (folding) is a prerequisite for function. Function … is a prerequisite for evolution. … Compact folds are rare among random amino acid chains. Then, how did protein functionality start?" Solving any one OQ/OoL on the emergence of biology and cellular life from chemistry and physics barely begins to comprehend the complexity of metabolic cycles and genetic systems of biopolymers. Pohorille (2012, p. 430) continues, "Explaining how [protocellular functions] originated, operated and evolved in a concerted, tightly regulated fashion is a major challenge."

All aspects of emergence in OoL scenarios have essentially no experimental data or scientific evidence to resolve these OQ/OoL on emergence. Nevertheless, emergence in OoL has attracted the attention of researchers from the disciplines of astronomy, biochemistry, biology, biophysics, chemistry, informatics, mathematics, philosophy, and physics. Prigogine (1972, p. 27) is perhaps the best-known contributor to theories on the nonequilibrium thermodynamics of "order through fluctuations," for which he won the Nobel Prize in Chemistry in 1977. Prigogine's work has inspired many to search for a fourth law of thermodynamics that would span the gaps between physics and biology and would explain the emergence of life. El-Diasty (2011, p. 30) concluded, "Present postulates on the origin of life do not satisfy the criteria of a scientific immensity theory … so is a fourth law needed for thermodynamics about the self-organizing phenomena observed in biology?" Critics of Prigogine's thermodynamic analysis on the origin of life, including Morris (1978) and Gish (1978), emphasize the speculative nature of emergent hypotheses on the OoL and the lack of experimental evidence or verification.

At the recent conferences on the OQ/OoL, presenters sought inspiration for and explanations of emergence from (1) Darwinian evolution, (2) nonlinear, chaotic, and random systems, (3) Gödel's theorems and algorithms, (4) autocatalytic sets, and (5) competitive coherence. The clear conclusion is that while the problems of emergence in OoL are vast, the scientific inquiry on these OQ/OoL is in its infancy and is dominated by conjecture, supposition, and hypotheses. In Genesis 1, Scripture reveals that biology, chemistry, physics, and all creation emerged when "God said, 'Let there be.…'" Since Creation was a discontinuity in history, the OoL search for a continuous, naturalistic path from lifeless chemicals to cellular life, including the emergence of biology from chemistry and physics, will continue to be a futile and unsuccessful quest.

Conclusion

While many OoL contributors danced around the issue, one conference directly asked—but failed to answer—the OQ/OoL: What evidence is necessary to prove how life originated? (University of Leicester, 2012). As with evolution, a detailed theory of OoL remains elusive, but scientists overwhelmingly, enthusiastically, and optimistically still persist in the belief that naturalistic answers will eventually be found. Wieczorek (2012, p. 7) described the goal of OoL: "[A] proper theory for the origins-of-life should propose a logical chain of events that would start with prebiotic soup and end with a living organism." Such vague descriptions of the OoL goals are sufficient to gain consensus but not comprehensive enough to risk falsifiability. Falsification remains a widely accepted criterium for valid scientific theories and explanations. Alpermann et al. (2010, p. 404) raised an inconvenient truth for the modern study of naturalistic OoL: "Does this impossibility of falsification of any [OoL] hypothesis mean that there is a philosophical hypothesis left, the hypothesis of a supernatural Creator, who brings the process of origin of life into being?"

Perhaps the only agreement within the naturalistic OoL community is that science does not have a naturalistic or materialistic answer to the origin of life on earth and that modern science may never provide an answer. Pizzarello (2010, p. 378) candidly captured the limited progress in the field of OoL research: "There is exceedingly little knowledge about the actual origin(s) of life." Stano (2010, p. 454) seconded the conclusion, when he stated, "We simply do not know and perhaps we will never know the exact historical sequence of the events that lead to living cells." Many conference participants proposed, postulated, and speculated on a wide range of answers to the interrelated OQ/OoL, each providing more research possibilities than actual evidence or experimental results. At this point in the history of their research endeavors, OoL scientists may need more humility. For example, in the 1950s, after Miller presented the results of the experiments synthesizing organic compounds under supposed primitive-earth conditions at a seminar at the University of Chicago, Nobel Prize winner Harold Urey was asked by Enrico Fermi, "I understand that you and Miller have demonstrated that this is one path by which life might have originated. Harold, do you think it was the way?" Urey replied, "Let me put it this way, Enrico. If God didn't do it this way, he overlooked a good bet!" (Arnold, et al., 1995). Currently, most OoL researchers do not accept the reducing atmosphere in the early earth assumed by Miller and Urey. With the myriad of OQ/OoL, future researchers may come along and discover answers and explanations that everyone else missed, including that no naturalistic pathway could have possibly ever existed from lifeless chemicals to living, cellular organisms. As their naturalistic assumptions lead to more scientific contradictions and as the "modern" answers to how life originated become increasingly impossible to believe, the account of Creation in Genesis and throughout Scripture will prove to be the only viable explanation for the origin of all living creatures and the created world.

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