Contents available at **PubMed**
www.aidsreviews.com

PERMANYER

Check for updates

AIDS Rev. 2024;26:80-91

On the origin of life on earth

Vicente Soriano[1]* *and Rubén Herce*[2]

[1]*UNIR Health Sciences School and Medical Center, Madrid;* [2]*Philosophy School, University of Navarra, Pamplona. Spain*

Abstract

The creation of the universe out of nothing (ex nihilo) is attributable to the eternal God. Would a direct divine intervention be needed for other singular events, such as the origin of life? Taking apart the human being, created to image and resemblance of God, we argue that current scientific knowledge allows us to rationally admit a continuity between the origins of the universe and the emergence of life on Earth. Although the irruption of living beings from inert matter is a leap or discontinuity in creation, a direct intervention of God would not be indispensable. The initial impulse of creation, with matter and energy in a space-time imbalance, could have triggered reactions between the different elements and a self-organization of metabolites, in accordance with natural physical-chemistry laws. This paradoxical increase of complexity ended with a transition from chemistry to biology. It happened when independence, metabolism, heritability, and life cycle took place in a protocellular unit. In this way, the emergence of life on earth could be part of an evolutionary dynamic of the timeless God's creative act.

Keywords

Origin of life. Creation. RNA world. Virus. Panspermia. Science and faith. Evolutionism. Synthetic biology. Prebiotic soup. Self-organization. Complexity. Contingency.

Introduction

The big questions about the existence, such as the creation of the universe, the origin of life, and the uniqueness of the human being, can be addressed in the light of both scientific advances and philosophical reflection. Science and philosophy (and theology) are distinct and complementary forms of knowledge. They are different ways of approaching the reality. Although some hard defenders of science have blamed religious belief systems for hindering understanding of the world[1], many others think that any worldview must consider both approaches[2].

The representation we make of God's acts is an approach to our reason in temporal and spatial coordinates. This anthropomorphism is certainly a reductionism. The way of acting of an eternal and infinite Creator ultimately remains elusive and is a mystery. In an unprecedented way, Ratzinger postulated that "the becoming of created matter is a moment in the history of the spirit"[3]. In a way, it could be expressed as a reformulation of Einstein's masterful equation $E = mc^2$, where this time "E" would not be energy but spirit; "m" would represent matter rather than mass, and the space-temporal becoming would correspond to "c^2".

Admitted that a direct divine intervention would explain the creation of the universe out of nothing, *ex nihilo*[4,5], how could other singular events, such as the origin of life have occurred? (Fig. 1). Could the emergence of life on earth be part of an evolutionary

***Correspondence to:**
Vicente Soriano
E-mail: vicente.soriano@unir.net

Received in original form: 28-05-2024
Accepted in final form: 04-06-2024
DOI: 10.24875/AIDSRev.M24000071

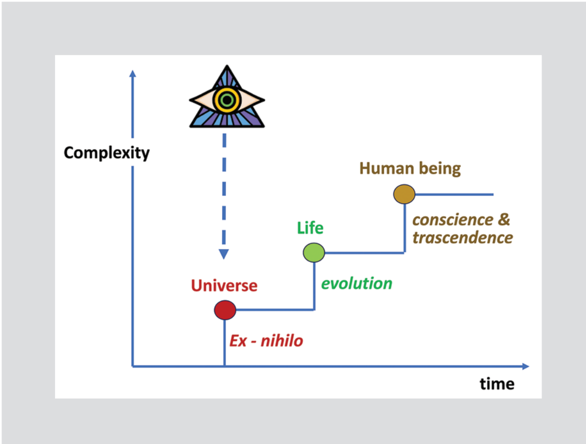

Figure 1. *Great moments in the history of creation.*

dynamic of the timeless God's creative act? In this article, we argue that current scientific knowledge may allow us to rationally admit a natural continuity between creation and the origin of life.

Although the irruption of living beings from inert matter is a leap and a discontinuity in creation[6], a direct intervention of God would not be indispensable. The initial impulse of creation, with matter and energy in a temporal-space imbalance, could have been enough for triggering reactions between different elements leading to a self-organization of metabolites[7,8]. Thereafter, self-production and replication could have happened feeding and stabilizing this independent metabolic unit[9]. This paradoxical increase in complexity[10] ended up with a transition from chemistry to biology. It could have happened when a protocellular unit acquired a life cycle of independence, metabolism, and transfer (replicative inheritance)[11,12].

When and how life emerged?

Scientific evidence describes the appearance of single-cell life on Earth 3.800 million years (My) ago, that is, about 10,000 My after the Big Bang, but only 700 My after the formation of the planet. For 1,000 My, there were only prokaryotic single cells. The first nucleated cells (eukaryotes) appeared 2,000 Myago and the first multicellular organisms 1,500 My ago[13,14].

The Cambrian explosion of life in the aquatic environment occurred about 541 My ago. It was followed by the appearance of plants on the surface and later, of terrestrial animals, including insects, dinosaurs, and mammals. Since then, there have been several mass extinctions, the last one 66 My ago after a large meteorite fell in the Yucatan, which wiped out the dinosaurs.

As shown in figure 2, a temporal evolution in creation is recognizable, with the formation of chemical elements, biomolecules, and increasingly complex organisms[6-8,10], including living beings and the most exclusive of them, the human species. The singular emergence of men, however, is out of the scope of this work.

In a way, the creative act is a universe in expansion and cooling that combines four dimensions, originally considered interdependent two by two, that is, matter and energy; and space and time. This was true until the relativity pointed out that our understanding of the world has reached an explanatory limit, as it happened with the concept of atom. A new more holistic explanation is needed. What strikes the most is that human beings, the most recent evolutionary product of creation, are capable of recognizing universal laws[13,15,16].

Several hypotheses have been proposed historically to explain how life began. Briefly, they can be grouped into four major theories, not all mutually exclusive: (i) creationism; (ii) spontaneous generation; (iii) panspermia; and (iv) abiotic physicochemical origin. Creationists claim that God is behind each single living species. Defenders of spontaneous generation considered that there was no boundary between the inert and life, being possible for living beings emerge from inert matter. Panspermia defends an arrival of living organisms from outside the earth, perhaps throughout meteorites. Finally, the abiotic origin hypothesis defends that organic biomolecules steadily were formed on earth and evolved to primitive unicellular beings, being the current biodiversity result of evolutionary dynamics.

The anthropic principle

Marco Bersanelli distinguishes between creation and origin. It is fascinating that we can know the laws of nature, physical and chemical, that explain the way the universe is. However, they do not account for creation or the appearance of the human being. Their explanation requires an approach from another level of knowledge, the philosophical one[17].

The conditions necessary for life in the universe are admirable. In fact, life could not have appeared if any of nature's constants had a slightly different value. For example, if gravity was a little more intense, the stars would burn out sooner and they would not be able to have planets that could support life, nor would there have been time for the synthesis of carbon, which is essential for life. Conversely, if gravity was weaker, the universe would have expanded more rapidly and galaxies and stars could not have formed, making life impossible.

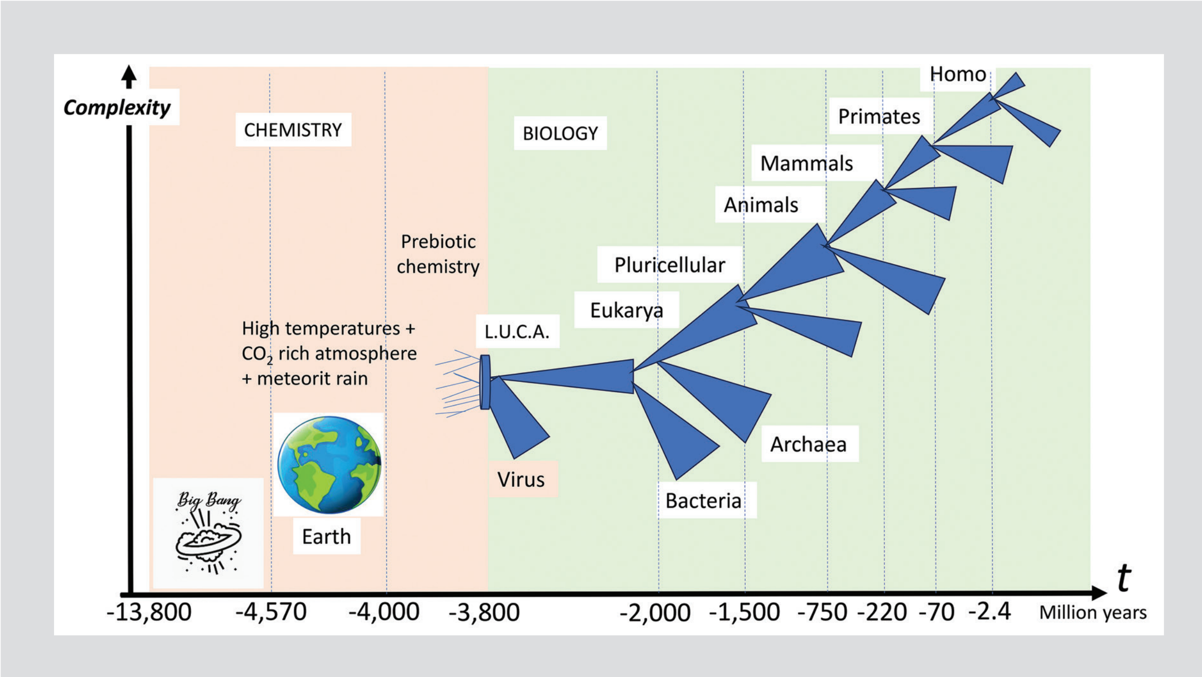

Figure 2. *Timeline for creation of the universe and tree of life.*

On the other hand, once the material elements were created, the dynamics of physics and chemistry laws (surface tension, gravity, electromagnetism, etc.) hypothetically could trigger an evolution toward more organized structures, first molecular and then supra-molecular, some of which acquired the properties that define life[18]. This negative entropy, however, which Schrödinger already highlighted as a major feature of living beings, is difficult (or impossible) to admit in a framework of exclusive chance. The perception of a purpose in the origin of life – and the biodiversity that followed – is a mystery and rejects any materialistic reductionism.

What is life?

In the 18th century, a French chemist, Antoine Lavoisier, pointed out that there are great chemical differences between inanimate matter and living organisms. Furthermore, it is striking that the unique composition and complexity of living beings are recognizable across all of them. In other words, there is an extraordinary similarity in the biochemical reactions across the different living beings, from the simplest to the most complex. As an example, there is only one biological energy currency, the adenosine triphosphate (ATP). This and other similarities shared among the living beings led the French Nobel laureate Jacques Monod to state: "what is true in *Escherichia coli* is also true in the elephant"[19].

Defining life is difficult and is best understood by describing its attributes. Differentiating the living from the inert might seem intuitive; pointing out that the living implies self-movement and a link with the organic[20]. The latter is understood as elements constituted by carbon and water. Up to 70% of the mass of living beings is water. However, the chemistry of living organisms is organized around carbon, which accounts for more than half of the dry weight of cells. No other element can form such a variety of crystalline forms and different sizes, nor functional groups with so many different elements.

From a chemical point of view, there are six major elements in the composition of living beings, which are different from those that make up the inanimate matter of the Earth's crust (Table 1). Oxygen is predominant and accounts for 66% of living organisms. Carbon follows, with 18%. Hydrogen accounts for 10%; then, nitrogen, phosphorus, and sulfur. Other elements are present only as traces. In contrast, half of the inert matter in the Earth's crust is made up of silicon (28%), aluminum (8%), iron (6%), calcium (4%), and sodium (3%).

There have been many historical figures who have spoken out about life. Aristotle (4th century b.C.)

Table 1. Main constituent chemical elements

Crust*	Living beings†
Oxygen (47%)	Oxygen (66%)
Silicon (28%)	Carbon (18%)
Aluminum (8%)	Hydrogen 10%)
Iron (6%)	Nitrogen (3%)
Calcium (4%)	Phosphorus (1%)
Sodium (3%)	Sulfur (0.3%)
Potassium (2.6%)	Traces
Magnesium (2%)	

*The earth's crust is 5 km thick in the oceans to 70 km in the continental mountainous regions.
†99% of living matter is made up of 6 elements. The remaining 1% are only present as traces.

Table 2. Main characteristics of the living being

1. Independence
   Membrane. Compartments
2. Metabolism
   Capture of matter and energy
   Increased internal complexity
   at the cost of increased external entropy
3. Information retained and evolution
   Step to descent and movement
   Replication and adaptive capacity
4. Life cycle
   To be born, to grow, and to die. Vital clock

pointed out that the main feature of a living organism is that it "nourishes, grows and dies by itself"[21]. One century ago, based on his well-known biosynthesis experiments, the Russian Alexander Oparin was one of the first to understand life as a complex system of inert entities. Going a step further, in 1943 Erwin Schrödinger, one of the fathers of quantum mechanics and winner of the Nobel Prize in Physics, defined life only from physics and chemistry: "life is a matter that repeats its structure as it grows, like a crystal."[22]. For the American Stuart Kauffman, life must be understood as the acquisition of autocatalytic capacity in a complex molecular system, as an inevitable self-organization[7,8].

In 1986, John Maynard Smith described living things as entities that multiply, vary, and inherit[10]. Another Nobel laureate, the Belgian Christian de Duvé, defined living organisms in 1991 as "chemical systems capable of maintaining themselves in a state far from equilibrium, growing and multiplying with the help of a constant flow of matter and energy with the environment"[23]. The United States National Air and Space Agency has adopted the definition of the biochemist Gerald Joyce: a living being is a "self-sustaining chemical system that evolves as a result of its interaction with the environment"[24].

Aristotle stated that there was nothing in nature that did not have an end. For Jacques Monod, only chance is behind the mystery of life, in the form of blind freedom. In his book "Chance and Necessity" (1970), he pointed out that "life would be one possibility among many, and it happened." Against this view, many scientists awoke, such as Stephan Jay Gould[25], Robert Shapiro[26], and Christian de Duvé[23], all of whom considered it impossible for life to be a simple coincidence. Among other problems, they stressed that the dynamism of evolution is contingent and that otherwise the appearance of life in such a short interval of time (~ 200 My) since the last great meteorite bombardment 4,000 My ago, could not be explained[14].

Efforts to define life and distinguish it from inert matter have concluded that there are four main characteristics of living beings (Table 2). First of all, independence from the environment, developing membranes, and a certain imbalance of internal and external elements. Second, inner metabolic reactions, with an increase in the complexity of one's own matter and entropy outside. Third, having the ability to retain information and pass it to offspring after dividing or replicating, with the possibility of adaptation. Finally, to have a biological cycle, meaning the experience of a movement by which the living being is born, grows, and dies.

Synthetic biology

There are two general approaches for examining the origin of life. The first is analytical and goes from top to bottom. It consists of identifying the minimum elements that support life. The second is constructive and goes from the bottom up. It seeks to elucidate how the first living being was produced from its inanimate constituents (Fig. 3).

Craig Venter and Francis Collins were the fathers of the Human Genome Project[27,28]. The complete description of genes of living things opened the possibility of identifying what is the minimum required for life.

Craig Venter has manipulated the simplest cells to see what is essential for life. He is one of the pioneers of synthetic genomics[29]. In 1995, he published the complete genome of Mycoplasma, the simplest cell with autonomous growth, which has 525 genes[30]. In 2016 he inserted a synthetic DNA molecule with 531 Kb into a mycoplasma, from which he had previously removed its nucleic acid. It had only 473 genes, which are essential for retaining the ability to survive and replicate autonomously[31]. Although the function of many of these genes remains unknown, only 206 genes seemed to be essential for life.

Multiple experiments have pursued the production of viruses, bacteria, or cells from nucleic acid molecules synthesized in the laboratory[32]. However, the construction of artificial genomes has not allowed empowering for life so far[12,33].

Prebiotic media and system chemistry

Another strategy for examining life formation is constructive, bottom-up, and pursues biosynthesis. It aims to achieve the production of a living being from its simplest constituent inert elements. In other words, elucidates the transition from chemistry to biology[34].

Alexander Oparin (1924) and John Haldane (1929) were the pioneers in abiogenesis. A prebiotic soup would be the substrate for the formation of life's constituents. The experiments of Stanley Miller[35], Miller and Urey[36] showed that biomolecules, including amino acids, could be obtained under certain conditions of temperature and pressure from water, methane, and ammonia, with electric discharges, which could mimic the earth's surface and early atmosphere[37-41].

The enthusiasm for artificial life led Richard Feynman (1918-1988), the American Nobel Prize in Physics, to say "*what I cannot create*, *I cannot understand*." The early atmosphere was rich in carbon dioxide and poor in oxygen, so early prokaryotes should have used a form of primitive photosynthesis before resorting to oxidation.

The fossil evidence of the oldest living organism dates back to 3,400 My, suggesting that sulfur may have been the source of energy at life's origin[42]. More recently, fossils of cyanobacteria have been identified from 1,750 My ago that produced oxygen, thanks to containing thylakoids with photosynthetic activity[43].

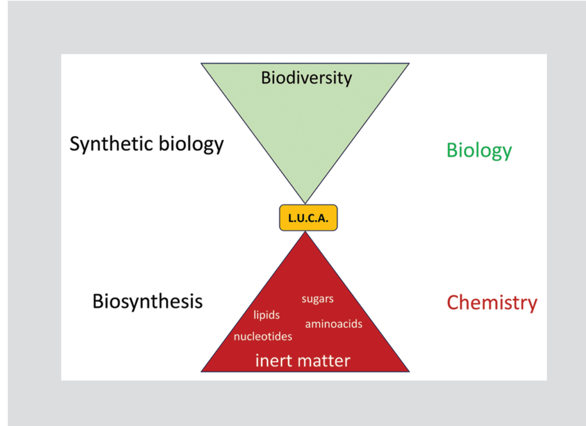

Figure 3. *Strategies for the study of the life's origin.*

A more recent push to explain the origin of life came in 2005 with systems chemistry. Briefly, animate beings should be understood as compartments where various chemical elements interact outside the thermodynamic equilibrium, in a stable and self-maintained way (metabolism), while evolving and being able to divide/reproduce[6,44-47].

Self-organization and complexity in living beings

It is fascinating to examine how subcellular constituents could be formed in natural dynamic processes (Table 3). The interaction of elements originally occurred around carbon, which characteristically has four binding bonds, forming the first biomolecules. These were able to polymerize, generating nucleic acids (nucleotides) and proteins (amino acids). Subsequently, macromolecules, such as the ribosome or chromosome were formed[6,12,14]. Finally, functional organelles such as mitochondria, cell membranes, the Golgi system, or lysosomes were produced[7,8,10,48,49].

One of the most striking features of life is the increasing complexity of living organisms. This negative entropy cannot be possible in a world that would have been left to chance alone[6-8,10]. The ability for self-organization and assembly in many biomolecules is extraordinary. Life evolves onward and upward as if it had a purpose[6-9,50,51]. The direction in which biological changes at different levels tend is a mystery, but it respects the natural laws of physics and chemistry. It leads to the generation of organelles from biomolecules; or the appearance of an extraordinary biodiversity in an evolutionary journey from the simplest prokaryotic cells[18,52]. This temporal trend in living beings has been seen as a proof of God's existence[5,53].

Table 3. Subcellular levels of complexity in living things

Elements	Examples
1. Atoms	Carbon
2. Molecules	Nucleotide, amino acid
3. Biopolymers	Nucleic acid, protein
4. Macromolecules	Ribosome, chromosome
5. Organelles	Mitochondria, cell membrane

The RNA world

The dogma of molecular biology, enunciated by Francis Crick in 1958, postulates that genetic information flows in only one direction, from DNA to RNA and from RNA to protein. At present, we know that protein synthesis can also occur in organisms that only have RNA[19]. The ribosome is a critical enzyme protein, as it translates the mRNA into a chain of amino acids. However, the synthesis of DNA or RNA molecules requires other enzymatic proteins, known as polymerases and ligases. The question is obvious: which came first, nucleic acids or proteins?[34].

The dilemma was apparently solved when ribozymes, RNA molecules with double duty, were described. On the one hand, they contain a nucleotide sequence that can be copied and passed on to offspring. On the other hand, ribozymes can adopt conformations that provide them with enzymatic activity, including self-catalytic, capable of producing copies of themselves[54].

In the 1980s, it was postulated that an RNA world would be at the origin of life[55]. The hypothesis became stronger when in 2009 the possibility of oligonucleotide formation under certain physicochemical conditions and ribozymes with self-replicating capacity were demonstrated[56]. The translation link between nucleic acids and amino acids was a further critical step when a protoribosome was built[57]. Finally, there was proof that the four essential molecules of life (nucleic acids, amino acids, lipids, and sugars) could be synthesized artificially[58-60].

The polymerization of biomolecules is a necessary step for the formation of living organisms. How could this happen? It has been postulated that submarine volcanic vents provided the ideal conditions for heat and cold cycles to allow the formation of macromolecules, such as RNA or DNA strands, peptides and proteins, lipids, and carbohydrates[57,61]. It occurred in the early nature of the Earth in a similar way to how it is currently produced in the laboratory with a thermocycler, amplifying nucleic acid fragments with the polymerase chain reaction methodology[62].

Viruses, viroids, and obelisks

One of the characteristics of evolution is its imperfection. This explains why many of the branches of different species on the life's tree have become extinct. They probably had room to expand at some point, but then disappeared as they competed with others better adapted to the changing environment[52].

Viruses are not considered living beings, although their existence is linked to them. They have no metabolic or replicative autonomy. Numerically, they outperform bacteria, *Archaea*, and eukaryotes. What is more, viruses can infect all living beings, releasing thousands of viral particles from each cell during its biological cycle. The enduring existence of viruses requires living cells, which provide the ribosomes for protein synthesis and sometimes replicative enzymes and the envelope[63].

Viruses are simpler than cells. They probably appeared shortly before them and in multiple prebiotic attempts coevolved with the first protocells (Fig. 2). It is important to note that they do not have a monophyletic origin, that is, they do not derive from a common ancestor[64]. It is also possible that during the opportunities provided for the emergence and initial evolution of protocells, some lost elements, having the chance of completing their biological cycle only by infecting other full bacteria. There are more than 80 different families of viruses and collectively the number of viral particles on Earth has been estimated at 10^{32}. They can be found in every conceivable habitat. By infecting and manipulating their hosts, viruses have probably influenced the evolutionary trajectories of all life.

A close observation of viruses, which are obligate parasites of bacteria or eukaryotic cells, has provided valuable information about the unique characteristics of primitive life. Although many viruses contain DNA as genetic material, more than 200 viruses, including those that cause flu, AIDS, Ebola, COVID-19, and hepatitis C bypass DNA, having genomes composed only of RNA. With their extraordinary capacity for mutation and genetic variability, RNA viruses have convincingly demonstrated the mechanisms of population diversity dynamics in a short time. They are an ideal model for studying adaptive

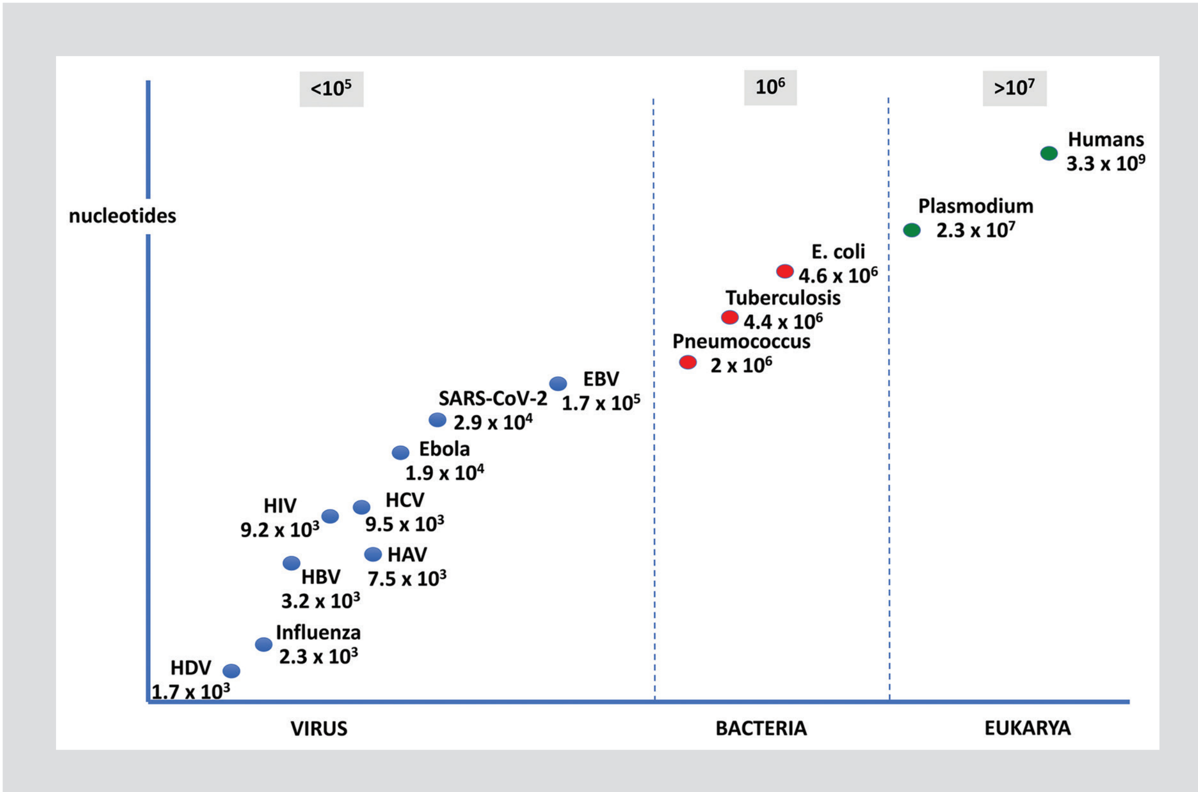

Figure 4. *Genome size of different organisms.*

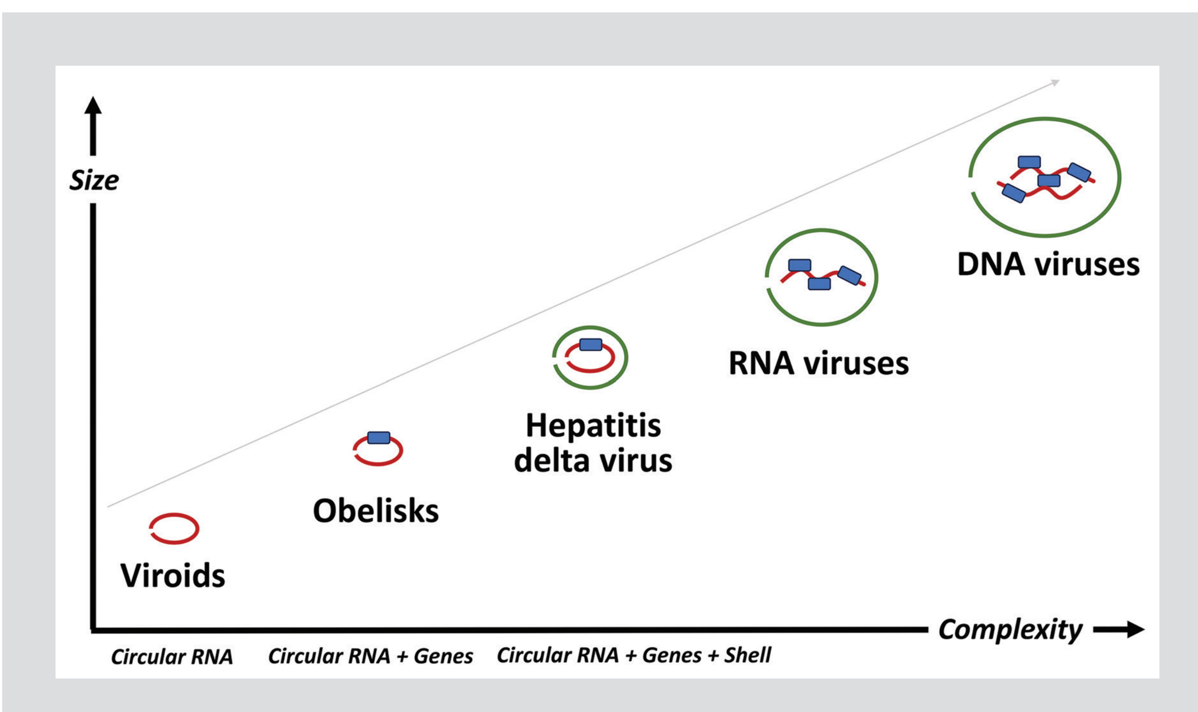

Figure 5. *Elements at the edge of life.*

phenomena by natural selection and large-scale competition[65,66]. Due to their ability to infect different cells, they have played a very important role in the horizontal transfer of genetic material across living beings[52].

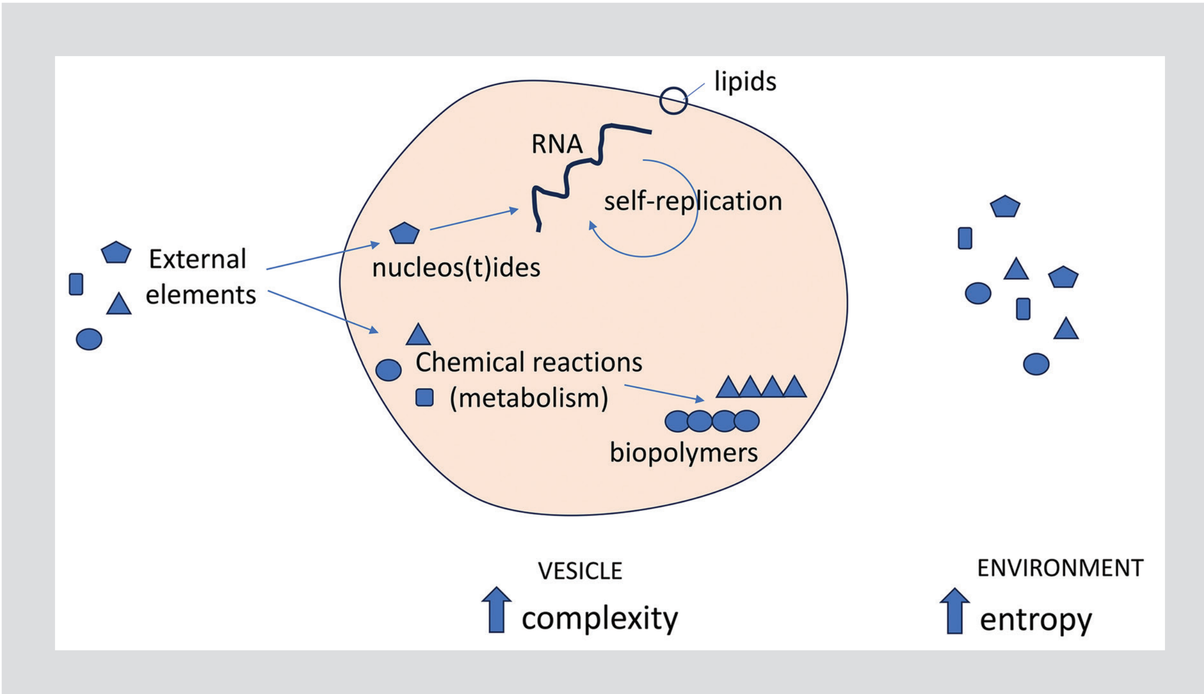

Figure 6. *Elements of the protocell.*

Some viruses, such as the hepatitis delta virus (HDV), are very simple organisms. HDV is the smallest human virus, with a short RNA molecule of 1,700 Kb (Fig. 4). Besides being a virus, it is also defective. HDV only exists associated with the Hepatitis B virus, which provides its envelope, as a parasite of another parasite[67]. HDV does not have its own replicative enzyme but uses a polymerase from the infected hepatocyte. Its RNA molecule shows auto-catalytic or ribozyme activity, which is essential for viral replication. That same molecule is the template for the synthesis of a single viral protein, the delta antigen. In the end, despite this fascinating existence, viruses are not living things.

Viroids are smaller and simpler than viruses. They are RNA molecules that can self-cleave and re-ligate their genome as part of the replication cycle, acting as ribozymes. Viroid genomes do not encode any proteins at all. They were first discovered in the 1970s when some were found to cause diseases in plants. Soon scientists discovered a similar element that can cause hepatitis in humans, the HDV discussed above. During the past 5 years, several studies have reported viroid-like circular RNA genomes amid databases of sequences from animals, fungi, and bacteria[68].

Researchers from Stanford have recently reported the discovery of new biological entities that they have called "obelisks," based on their shape. These small particles are circular single-stranded RNA molecules of around 1,000 bases that contain one or two genes and self-organize into a rod-like structure[69].

Obelisks fall somewhere between viruses and viroids (Fig. 5). They are more like RNA plasmids, which are genetic elements that reside inside bacteria and transfer between them. Like viroids, obelisks have a short circular single-stranded RNA genome and no protein coat. However, like viruses, their genomes contain genes that codify proteins. All 30,000 obelisks described so far in the gut and mouth of humans encode a single major protein known as obulin. Moreover, many obelisks encode a second smaller obulin. These proteins do not make a shell. Of note, obulins do not share any homology with any other known protein. So, no clue about their function.

Obelisks are not rare and must be widespread across multiple niches. They were detected in around 7% of microbiome datasets from the human gut and 50% of datasets from the human mouth. Different obelisk types were found in different body sites and distinct donors. Long-term data revealed that people can harbor a single obelisk type for around a year.

Experiments with obelisks are planned and could reveal truths about the origin of life itself. Because viroids and obelisks are small, simple, and have the capacity to self-replicate, they could be the precursors of all life on Earth. One big question is whether viruses evolved from increasingly complex viroids and obelisks, or emerged first and then degenerated into these simpler structures[70]. The long-term evolution of viruses on Earth starts to slowly emerge.

A pantetheine world

The molecules of life are fundamentally composed of the elements HCNOPS, which are the acronyms for hydrogen, carbon, nitrogen, oxygen, phosphorus, and sulfur. Miller and Urey's experiments in 1953 showed that organic molecules could be produced from inorganic ones, using electrical discharges and simulating what could have happened 4,000 My ago. However, life is more than biomolecules[34]. As French Nobel laureate Henri Bergson pointed out in 1907, an "élan vital" beyond mechanism is required to account for living things[71].

For many years, Miller tried unsuccessfully to obtain pantetheine, a subunit of coenzyme A, which all living things have and is necessary for multiple reactions of cellular metabolism, including the Krebs cycle, the synthesis and oxidation of fatty acids, and the synthesis of essential lipids and neurotransmitters.

A British team has recently obtained pantetheine in water at room temperature, from hydrogen cyanide, which was very abundant on the early Earth[72]. The authors postulated that it was the presence of aminonitriles, derived from amino acids that allowed the formation of pantetheine. Other key ingredients of life, such as peptides and nucleotides, could be easily generated from pantetheine and aminonitriles. Thus, a pantetheine world is a possible good alternative to the RNA world hypothesis as the origin of life. Alternatively, RNA and proteins could have interacted and behaved symbiotically at the very early stages coevolving synergistically to produce a protocell[73,74].

L.U.C.A., bacteria and eukaryotic protocells

Microspheres that envelop RNA and biomolecules would be the prototype of the most primitive cell, known as a "*cenancestor*" or "chemoton" (Fig. 6). In this hypothetical model, the formation of nucleic acids, which carry the minimum genetic information to be passed on to offspring, is a difficult step that would have occurred due to duplications, transfers, and genetic mutations (deletions, insertions, and nucleotide changes)[10-12,14].

The exchange of metabolites across a membrane and the production of energy – almost exclusively using a single molecule, ATP – would support internal reactions, giving the protocell autonomy from the environment[75].

The cell is the unit of life or minimum vital structure. The organic elements that make up the cell may have several vital functions, but they do not enjoy the autonomy that the cell unit does. In view of the similarity of reactions that the great diversity of living organisms has, a common cellular ancestor has been postulated in the backward chain that explains current biodiversity. It is known as L.U.C.A. (*Last Universal Common Ancestor*). Not only would it be the first but the only one that was viable, that is, capable of generating the current range of living organisms. Although many other predecessors could have been generated in different attempts, this was the one that prevailed.

All cells are grouped into three domains or kingdoms. First, those that do not possess enveloped or anucleated genetic material (or prokaryotes). Second, those that have nuclei with membrane-enveloped genetic material (eukaryotes). Of the simplest cells or prokaryotes, there are two types: *Archaea* and bacteria. The former live in extreme environments of temperature, pressure, and acidity. Bacteria occupy the rest of ecological niches, which are more favorable, both outdoors and in symbiotic coexistence with multicellular organisms. This is the case of the gut microbiome in mammals. Contrary to initial assumptions, phylogenetic studies have shown that *Archaea* (and not bacteria) are the closest to eukaryotic cells on the evolutionary scale[52].

The panspermia hypothesis

With regard to the place of life's origin, two mutually exclusive hypotheses have been proposed. The first postulates an immanent genesis, that is, on the Earth itself. Other points to provenance from another planet. In the second case, the arrival on Earth of organic material, biomolecules, or primitive unicellular organisms from outside could have occurred after meteorites collided with the Earth's surface. This hypothesis is known as panspermia. It was already suggested by the Greek Anaxagoras in the 5th century B.C. In more recent times, the description of amino acids and polycyclic and nitrogenous hydrocarbon compounds in some meteorites, such as Murchison or Winchcombe (which fell in England in 2021), has renovated the interest in this theory[76,77]. It supports that the first organic molecules might have arrived on Earth from the outside, facilitating the emergence of life at some point.

The panspermia hypothesis states that the building blocks of life (molecular panspermia) or life itself (transfer-based panspermia of living organisms) may have arrived interplanetary to facilitate the emergence of life on Earth. Although at the end of the XX century, many experiments were carried out in space flights, trying to discover possible terrestrial organisms that could have been seeds of Panspermia, it could never be demonstrated that they could "seed" new planets, even if they were able to survive space flights.

Instead of using living organisms, the use of abiotic chemicals as seeds has been proposed to test the molecular panspermia hypothesis. The biopolymer should be able to survive space flights and "function," that is, contingently drive chemical evolution toward some form of abiogenesis once it reaches an alien planet. Polymeric gels have been used as an example because they can be synthesized prebiotically on one planet (such as polyester gels) and could be transferred to another via meteorites[76,77]. On landing on a liquid-bearing planet, they could assemble into structures with cell-like characteristics and functions[78]. All this presupposes that these gels could be organized in compartments, through the separation of phases to fulfill relevant functions such as the encapsulation of primitive metabolic, genetic, and catalytic materials, exchange with the environment, movement, coalescence, and evolution. All these functions could lead to the gels' ability to alter local geochemical niches on other planets, hypothetically allowing chemical evolution leading to biology. It would be equivalent to the insufflation of the "breath of life" of the ancients[44].

Astronomical studies with the Hubble and James Webb large telescopes search for exoplanets and signs of extraterrestrial life. They are of great importance to questions about the origin and meaning of the universe and life. The evidence of a bacterium or plant outside the earth would suffice to give wings to the possibility of an origin of life from inert matter. It would make it easier to accept that life could have arisen from the inert spontaneously, without any divine involvement. However, would it be revulsion for the faith of believers? At this point, it would be worth to acknowledge that the discovery of any form of extraterrestrial life does not imply, by any means, that there could be intelligent life.

Final thoughts

Considering creation in the light of science provides an extraordinary view of the reality. The immensity and adjustments of the universe, the conformation of life, and the self-conscious and transcendent nature of the human being cannot be rationally understood as the result of chance.

The apparent discontinuity recognizable in creation for the origin of life and for the emergence of the human being are, for now, mystery to the human rational knowledge. In this work, the available information on the origin of life has been revisited. An incomplete path from inert matter to living beings has been glimpsed. Joseph Ratzinger acknowledged that it is reasonable to think that a single creative act would have sufficed to account for the cosmos, the origin of life, and perhaps, for the human being himself by the eternal God's Reason, who unfolds his timeless love[3].

Many authors have spoken out against vitalism, understood as a requirement for more than matter and physics-chemistry to explain life. However, current science allows us to recognize more and more laws of continuity in everything material, from the inorganic to the organic[46]. In contrast, the exclusivity of consciousness in the human being would make materialistic reductionism unacceptable. The human being remains an unfathomable mystery[2,53,79].

In one of his novels, Chesterton puts in the mouth of Father Brown, its protagonist that "we are on the bad side of the tapestry." We only see ropes and knots. Because the drawing can only be seen from the other side. However, there is a sense and logic in the tangle of the back of the tapestry. In this way, faith would become precisely the belief that all cosmic history makes sense. It does not happen randomly, or arbitrarily. There is logic and contingency due to the past, even if the future is unpredictable. Some mutations are more common than others. Some changes open up a range of possibilities and at the same time close others. Divine action is not an evolutionary history riddled with coincidences, but rather the unfolding of that history with imperfections. God's way of acting is on another plane, on the other side of the tapestry. He gives meaning to everything without being the craftsman who retouches each piece at different times[80].

Louis Pasteur, 150 years ago, refuted spontaneous generation. Every living organism proceeds from some previous living form. Although the production of some form of life in the laboratory has not yet been achieved, that possibility cannot be ruled out. In this paper, we have described a possible evolution without discontinuity between the inert and the living. The recognition of self-organization in biological matter and trends in life are fascinating facts. On a different plane from that of scientific empiricism, a creation from nothing that unfolds from the inert generating living organisms could be contemplated in a scenario of creative love[53,81]. At this point, one can only reason that God's designs are a mystery and their full understanding is unattainable to our intellect.

Funding

None.

Conflicts of interest

None.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article. Furthermore, they have acknowledged and followed the recommendations as per the SAGER guidelines depending on the type and nature of the study.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Use of artificial intelligence for generating text. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

References

1. White L Jr. The historical roots of our ecologic crisis. Science. 1967;155:1203-7.
2. Weber B. God and the world of signs: semiotics and the emergence of life. Zygon. 2010;45:361-6.
3. Ratzinger J. Introduction to Christianity. New York, USA: Ignatius Press; 2000.
4. Artigas M. The Mind of the Universe. Philadelphia, PA, USA: Templeton Foundation Press; 2000.
5. Bolloré MY, Bonnassies O. God: The Science and the Proofs. London, UK: Susanna Lea Associates; 2021.
6. Nitschke W, Farr O, Gaudu N, Truong C, Guyot F, Russell MJ, et al. The winding road from origin to emergence (of life). Life. 2024;14:607.
7. Kauffman S. The Origins of Order: Self-organization and Selection in Evolution. New York, USA: Oxford University Press; 1993.
8. Smolin L. The Life of the Cosmos. Oxford, UK: Oxford University Press; 1998.
9. Das K, Gabrielli L, Prins LJ. Chemically fueled self-assembly in biology and chemistry. Angew Chem Int Ed Engl. 2021;60:20120-43.
10. Szathmáry E, Smith JM. The major evolutionary transitions. Nature. 1995;374:227-32.
11. Weiss MC, Sousa FL, Mrnjavac N, Neukirchen S, Roettger M, Nelson-Sathi S, et al. The physiology and habitat of the last universal common ancestor. Nat Microbiol. 2016;1:16116.
12. Kalambokidis M, Travisano M. The eco-evolutionary origins of life. Evolution. 2024;78:1-12.
13. Müller GB. Evo-devo: extending the evolutionary synthesis. Nat Rev Genet. 2007;8:943-9.
14. Ricardo A, Szostak JW. The origin of life on earth. Sci Am. 2009;301:54-61.
15. Pross A. Toward a general theory of evolution: extending Darwinian theory to inanimate matter. J Syst Chem. 2011;2:1.
16. Novo FJ. The theory of evolution in the writings of Joseph Ratzinger. Sci Fides. 2020;8:323-49.
17. Bersanelli M. The age of the universe. In: Campo A, Gozzano S, editors. Einstein vs. Bergson: An Enduring Quarrel on Time. Berlin, Germany: De Gruyter; 2022.
18. Vanchurin V, Wolf Y, Katsnelson MI, Koonin E. Toward a theory of evolution as multilevel learning. Proc Natl Acad Sci USA. 2022; 19: e2120037119.
19. Nelson DL, Cox MM. Lehninger's Principles of Biochemistry. New York, USA: W. H. Freeman Editors; 2021.
20. Weber BH. Emergence of life. Zygon. 2007;42:837-56.
21. Aristotle. De Anima. London, UK: Penguin Classics; 1987.
22. Schrödinger E. What is Life? The Physical Aspect of the Living Cell. London, UK: Cambridge University Press; 1945.
23. De Duvé C. Vital Dust: Life as a Cosmic Imperative. London, UK: Basic Books; 1995.
24. Joyce G, Deamer DW, Fleischaker G. Origins of Life: The Central Concepts. New York, USA: Jones and Bartlett; 1994.
25. Gould SJ. Darwinism and the expansion of evolutionary theory. Science. 1982;216:380-7.
26. Shapiro R. The prebiotic role of adenine: a critical analysis. Orig Life Evol Biosph. 1995;25:83-98.
27. Collins FS. The Language of God. New York, USA: Simon and Schuster Inc.; 2006.
28. Collins FS. The Language of Life. New York, USA: Harper Collins Pub.; 2011.
29. Venter JC, Glass JI, Hutchison CA 3rd, Vashee S. Synthetic chromosomes, genomes, viruses, and cells. Cell. 2023;185:2708-24.
30. Fraser CM, Gocayne JD, White O, Adams MD, Clayton RA, Fleischmann RD, et al. The minimal gene complement of *Mycoplasma genitalium.* Science. 1995;270:397-403.
31. Hutchison CA 3rd, Chuang RY, Noskov VN, Assad-Garcia N, Deerinck TJ, Ellisman MH, et al. Design and synthesis of a minimal bacterial genome. Science. 2016;351:aad6253.
32. Adamata KP, Dogterom M, Elani Y, Schwille P, Takinoue M, Tang TY. Present and future of synthetic cell development. Nat Rev Mol Cell Biol. 2024;25:162-7.
33. Zwart H. The bioethics of synthetic cells. Nat Rev Mol Cell Biol. 2024;25:157-8.
34. Lane N, Xavier JC. To unravel the origin of life, treat findings as pieces of a bigger puzzle. Nature. 2024;626:948-51.
35. Miller SL. A production of amino acids under possible primitive earth conditions. Science. 1953;117:528-9.
36. Miller SL, Urey HC. Origin of life. Science. 1959;130:1622-4.
37. Johnson AP, Cleaves HJ, Dworkin JP, Glavin DP, Lazcano A, Bada JL. The Miller volcanic spark discharge experiment. Science. 2008;322:404.
38. Bada JL. New insights into prebiotic chemistry from Stanley Miller's spark discharge experiments. Chem Soc Rev. 2013;42:2186-96.
39. Walker SI. Origins of life: a problem for physics, a key issues review. Rep Prog Phys. 2017;80:092601.
40. Green NJ, Xu J, Sutherland JD. Illuminating life's origins: UV photochemistry in abiotic synthesis of biomolecules. J Am Chem Soc. 2021;143:7219-36.
41. Altamura E, Fiore M. The origin and early evolution of life: (prebiotic) systems chemistry perspective. Life. 2022;12:710.
42. Wacey D, Kilburn M, Saunders M, Cliff J, Brasier MD. Microfossils of sulphur-metabolizing cells in 3.4-billion-year-old rocks of Western Australia. Nat Geosci. 2011;4:698-702.
43. Demoulin CF, Lara YJ, Lambion A, Javaux EJ. Oldest thylakoids in fossil cells directly evidence oxygenic photosynthesis. Nature. 2024;625:529-34.
44. Goodman G, Gershwin ME. Physics, biology and the origin of life: the physicians' view. Isr Med Assoc J. 2011;13:719-24.
45. Sutherland JD. Studies on the origin of life - The end of the beginning. Nat Rev Chem. 2017;1:12.
46. Lopez A, Fiore M. Investigating prebiotic protocells for a comprehensive understanding of the origins of life: a prebiotic systems chemistry perspective. Life (Basel). 2019;9:49.
47. Freeland S. Undefining life's biochemistry: implications for abiogenesis. J R Soc Interface. 2021;19:20210814.
48. Kahana A, Lancet D. Self-reproducing catalytic micelles as nanoscopic protocell precursors. Nat Rev Chem. 2021;5:870-8.
49. Sajeev Y. Prebiotic chemical origin of biomolecular complementarity. Commun Chem. 2023;6:259.
50. Zimmer C. On the origin of life on earth. Science. 2009;323:198-9.
51. Service RF. The life force. Science. 2013;342:1032-4.
52. Koonin EV. Towards a postmodern synthesis of evolutionary biology. Cell Cycle. 2009;8:799-800.
53. Thomistic Evolution; 2024. Available from: https://www.thomisticevolution.org/disputed-questions/catholic-teaching-on-creation-and-on-human-origins
54. Lincoln TA, Joyce GF. Self-sustained replication of an RNA enzyme. Science. 2009;323:1229-32.

55. Cech TR. The RNA worlds in context. Cold Spring Harb Perspect Biol. 2012;4:a006742.
56. Benner SA, Kim HJ, Yang Z. Setting the stage: the history, chemistry, and geobiology behind RNA. Cold Spring Harb Perspect Biol. 2012;4:a003541.
57. Agmon I. On the re-creation of protoribosome analogues in the lab. Int J Mol Sci. 2024;25:4960.
58. Powner MW, Gerland B, Sutherland JD. Synthesis of activated pyrimidine ribonucleotides in prebiotically plausible conditions. Nature. 2009;459:239-42.
59. Hardy MD, Yang J, Selimkhanov J, Cole CM, Tsimring LS, Devaraj NK. Self-reproducing catalyst drives repeated phospholipid synthesis and membrane growth. Proc Natl Acad Sci USA. 2015;112:8187-92.
60. Podolsky KA, Devaraj NK. Synthesis of lipid membranes for artificial cells. Nat Rev Chem. 2021;5:676-94.
61. Patel BH, Percivalle C, Ritson DJ, Duffy CD, Sutherland JD. Common origins of RNA, protein and lipid precursors in a cyanosulfidic protometabolism. Nat Chem. 2015;7:301-7.
62. Saiki RK, Scharf S, Faloona F, Mullis KB, Horn GT, Erlich HA, et al. Enzymatic amplification of beta-globin genomic sequences and restriction site analysis for diagnosis of sickle cell anemia. Science. 1986;230:1350-4.
63. Trubl G, Stedman KM, Bywaters KF, Matula EE, Sommers P, Roux S, et al. Astrovirology: how viruses enhance our understanding of life in the universe. Int J Astrobiol. 2023;22:247-71.
64. Krupovic M, Dolja VV, Koonin EV. Origin of viruses: primordial replicators recruiting capsids from hosts. Nat Rev Microbiol. 2019;17:449-58.
65. Coffin JM. HIV population dynamics *in vivo*: implications for genetic variation, pathogenesis, and therapy. Science. 1995;267:483-9.
66. Domingo E, Sheldon J, Perales C. Viral quasispecies evolution. Microbiol Mol Biol Rev. 2012;76:159-216.
67. Asselah T, Rizzetto M. Hepatitis D virus infection. N Engl J Med. 2023;389:58-70.
68. Navarro B, Flores R, Di Serio F. Advances in viroid-host interactions. Annu Rev Virol. 2021;8:305-5.
69. Kuhn JH, Botella L, de la Peña M, Vainio EJ, Krupovic M, Lee BD, Navarro B, Sabanadzovic S, Simmonds P, Turina M. J Virol. 2024 Jun 10:e0083124. doi: 10.1128/jvi.00831-24.
70. Pennisi E. Tiny fossils upend timeline of multicellular life. Science. 2024;383:352-3.
71. Bergson H. Creative Evolution. London, UK: Dover Pub.; 2012.
72. Fairchild J, Islam S, Singh J, Bucar DK, Powner MW. Prebiotically plausible chemoselective pantetheine synthesis in water. Science. 2024;383:911-8.
73. Babajanyan SG, Wolf YI, Khachatryan A, Allahverdyan A, Lopez-Garcia P, Koonin EV. Coevolution of reproducers and replicators at the origin of life and the conditions for the origin of genomes. Proc Natl Acad Sci USA. 2023;120:e2301522120.
74. Agmon I. Three biopolymers and origin of life scenarios. Life (Basel). 2024;14:277.
75. Martin WF, Sousa FL, Lane N. Energy at life's origin. Science. 2014;344:1092-3.
76. Martins Z, Botta O, Fogel ML, Sephton MA, Glavin DP, Watson JS, et al. Extraterrestrial nucleobases in the Murchison meteorite. Earth Planet Sci Lett. 2008;270:130-6.
77. Vollmer C, Kepaptsoglou D, Leitner J, Mosberg AB, El Hajraoui K, King AJ, et al. High-spatial resolution functional chemistry of nitrogen compounds in the observed UK meteorite fall Winchcombe. Nat Commun. 2024;15:778.
78. Sithamparam M, Satthiyasilan N, Chen C, Jia TZ, Chandru K. A material-based panspermia hypothesis: the potential of polymer gels and membraneless droplets. Biopolymers. 2022;113:e23486.
79. Ayala FJ. Colloquium paper: the difference of being human: morality. Proc Natl Acad Sci U S A. 2010;107:9015-22.
80. Jacob F. Evolution and tinkering. Science. 1977;196:1161-6.
81. Ratzinger J. God and the World. A Conversation with Peter Seewald. New Yok, USA: Ignatius Press; 2002.