FEATURE ARTICLE

# Origin of Life: An Update on New Evidence & Theories

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### Abstract

*The origin of life is one of the most interesting and challenging questions in biology. This article discusses relevant contemporary theories and hypotheses about the origin of life, recent scientific evidence supporting them, and the main contributions of several scientists of different nationalities and specialties in different disciplines. Also discussed are several ideas about the characteristics of the most recent common ancestor, also called the "last universal common ancestor" (or LUCA), including cellular status (unicellular or community) and homogeneity level.*


**Key Words:** *ancestor; origin of life; LUCA.*

## ○ Background

The origin of life is one of the most challenging questions in biology and probably in all of science (Pross & Pascal, 2013). Perhaps more than most scientific areas, it is a question that takes us to the limits of what we know and probably to the limits of what we can know (Harold, 2014). Several explanations of the origin of life coexist at present, and different approaches have been taken, such as the "from geochemistry up" approach (e.g., studying first the environmental conditions that would have to occur in the beginning, then the biochemical reactions involved in the increase of complexity up until the first cell) and the "from biology down" approach (e.g., studying the simpler components of any complex cellular entity; phylogenetic studies that compare organisms with different levels of complexity) (Sutherland, 2016, p. 105).

The date of the appearance of the first common ancestor cannot be precisely determined, but recent studies have made a huge contribution to dating the most recent universal common ancestor of all living beings, also called the "last universal common ancestor" (or LUCA). Although the date of LUCA's appearance cannot be precisely determined, Weiss et al. (2016) consider LUCA to have existed 3.5–3.8 billion years ago (Ga), while Tashiro et al. (2017), using evidence of carbon isotope signatures in Eoarchean rocks, consider 3.95 Ga more accurate.

*"The contemporary studies included here illustrate the present lack of a consensus on the origin of life."*

Recently, Betts et al. (2018) proposed a novel timescale of life, using multiple lines of evidence, including fossils, biomarkers, new molecular clock analyses, and isotope geochemistry suggesting that the last universal common ancestor of cellular life appeared before the end of the late heavy bombardment, >3.9 Ga (4.519–4.477), with the emergence of Eubacteria and Archaebacteria occurring <3.4 Ga.

Of course, the date for the origin of life is constrained by the age of Earth itself – approximately 4.56 billion years (Arndt & Nisbet, 2012) – and the time point of ~4.4 Ga, when temperatures were still very high and the mantle was largely molten, following a Moon-forming impact (Arndt & Nisbet, 2012). Additionally, according to some authors, 4.2–4.3 Ga is the earliest possible date for the presence of liquid water (Mojzsis et al., 2001).

## ○ Contemporary Evidence about the Origin of Life

New analyses of the Murchison meteorite, which fell in 1969 in Murchison, Australia, revealed several organic compounds (Schmitt-Kopplin et al., 2010) that could support panspermia, Svante Arrhenius's theory that meteors or cosmic dust could have brought spores of "germs" to Earth (Arrhenius, 1908, p. 226). In a recent study, scientists described evidence of several organic compounds, such as hydrocarbons and N-rich organic compounds (e.g., amino acids) and water in the composition of two meteors that fell in 1998, one near Morocco and another in Texas (Chan et al., 2018). These pieces of evidence – in salt crystals inside the meteors – might represent the early solar system's organic composition (Chan et al., 2018).

In a recent study, an international team of researchers, including NASA scientists, presented evidence that meteorites may have contributed to the synthesis of important prebiotic molecules such

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as RNA: they found ribose and other sugars in three primitive meteorites (Furukawa et al., 2019).

In the 1950s, Stanley Miller tested the ideas of his mentor, chemistry Nobel laureate Harold Urey, regarding the composition of the early atmosphere and Oparin's primordial soup theory, which states that the early atmosphere of Earth was composed of hydrogen, carbon dioxide, methane, and ammonia (Harold, 2014). Miller constructed an imaginative and creative experimental apparatus in which he introduced the gases hydrogen, water, methane, and ammonia, subjected them to electric discharges (simulating lightning), and collected the products in a water container, simulating the ocean (Harold, 2014). Over a few days, organic matter was accumulated and then analyzed, and several small molecules were found, including glycine, alanine, and glutamic and aspartic acids (Harold, 2014). In 2011, a research team headed by one of Miller's former students identified, in Miller's original samples, a higher diversity of amino acids ($N = 23$) and four amines (Parker et al., 2011). These data suggest that life arose in the ocean in areas adjacent to volcanoes, where the proposed early-atmosphere gases could be found.

In 2010, biochemist Helen Hansma suggested the muscovite mica hypothesis for the origin of life, according to which confinement between muscovite sheets constitutes a form of entropy reduction, whereby molecules between mica sheets are able to interact, forming biopolymers that are selected through a Darwinian evolutionary process, while molecules outside the mica sheets are lost in solution (Hansma, 2010). This hypothesis is supported by evidence from atomic force microscopy that mica is able to interact with biomolecules, such as proteins, lipids, and short-length DNA molecules (Hansma et al., 1996), and by the description of some samples of mica ~3.8 billion years in age (Hansma, 2010). This hypothesis is included in a larger hypothesis of the origin of life on mineral surfaces, first suggested in 1951 (Hansma, 2010). This hypothesis is also supported by the work of a research team headed by Peter Coveney, who are using supercomputers to perform simulations of interactions of DNA molecules with clay minerals. Their results suggest that strong electrostatic forces act between mineral sheets and intercalated DNA (Thyveetil et al., 2008). They also tested conditions of increasing temperature and pressure in their simulations and concluded that the variations observed support the theory of the origin of life in hydrothermal vents (Thyveetil et al., 2008).

John Sutherland, in 2009, reported that simple precursor compounds (acetylene and formaldehyde) could produce two of RNA's nucleotides in the primordial soup under ultraviolet light (Service, 2015). According to Service (2015), this evidence supports the theory of panspermia (since hydrogen cyanide is abundant in comets) as well as the theory of the primitive soup. Recent results by Sutherland's team showed that key intermediates of both RNA and DNA could have arisen, ~4 Ga, under UV radiation (Xu et al., 2019). Thus, Sutherland's results support that life likely arose on the surface or in shallow water. He added, in an interview, that the presence of UV radiation was important to the assembly of monomers (Peretó & Marco-Casanova, 2015).

## ○ A Brief Update on New Evidence & Theories of LUCA

Allen Nutman and collaborators, studying metacarbonate rocks in the Isua supracrustal belt in southwest Greenland, published the evidence of the oldest known stromatolites (macroscopically layered structures produced by microbial activity), with an age of 3.7 billion years (Nutman et al., 2016). They suggest that the origin of life occurred in shallow marine environments and that ancient organisms were responsible for an autotrophic $CO_2$ inclusion in the ocean (Nutman et al., 2016). In Labrador, Tashiro et al. (2017) found evidence of the oldest biogenic graphite, ≥3.95 billion years old, corresponding to autotrophic organisms in seawater mixed with hydrothermal fluid. This team, led by Japanese geologist Tsuyoshi Komiya, studied carbon isotope values of graphite and carbonate in metasedimentary rocks. Recently, Nutman has been challenged by another team of scientists who studied the same structures present in rocks of Greenland, using a sample close to the original sample site. They concluded that these structures are abiogenic, probably deformed metasediments (Allwood et al., 2018). Recently, Nutman et al. (2019) presented additional examinations supporting the conclusions in their previous study.

Weiss et al. (2016) analyzed 355 genes in bacterial and archaeal phyla. They conceptualized a tree of life as a protein tree representing monophyly of Bacteria and Archaea, from which they inferred the proteins probably present in LUCA, such as reverse gyrase, an enzyme specific of hyperthermophiles, and the Wood-Ljungdahl pathway. Therefore, they suggested that LUCA was an $H_2$-dependent anaerobic autotroph using $CO_2$ and $N_2$, which existed in a hydrothermal environment. Others, such as Dodd et al. (2017), have presented evidence supporting this theory of the origin of life in submarine hydrothermal vents, which occurred at least 3.77–4.28 Ga. The evidence includes fossils of tubes and filaments; remains of iron-oxidizing bacteria embedded in rocks of the Nuvvuagittuq belt in Quebec, Canada; and the fact that in modern hydrothermal Si-Fe vents, one can find microorganisms that form distinctive tubes and filaments like those in the fossils (Dodd et al., 2017). This idea of the hydrothermal origin of life was first proposed by Corliss et al. (1981) after the discovery of modern submarine hydrothermal vents.

New evidence has also been found in the Dresser Formation, Pilbara Craton, Australia, hot spring deposits within a low-eruptive volcanic caldera (Djokic et al., 2017), which would be a similar environment to the one found presently in Yellowstone National Park (Figure 1). Several "biosignatures" were found, such as evidence of gas bubbles, microbial filaments, and stromatolites (Djokic et al., 2017). The authors proposed a view of the origin of life as occurring in pools that repeatedly dry out and get wet (Djokic et al., 2017; Van Kranendonk et al., 2017). They also performed an experiment using compounds probably available in the prebiotic Earth (nucleic acids) that were put through wet and dry cycles in conditions similar to the hot springs and obtained longer polymers, similar to RNA, encapsulated in protocells (Van Kranendonk et al., 2017). These authors suggest an early environment similar to Darwin's 1871 hypothesis, noting that "a number of scientists from different fields now think [Darwin] had intuitively hit on something important" (Van Kranendonk et al., 2017, p. 31). Indeed, their evidence supports Darwin's hypothesis of the origin of life in a warm little pond (Darwin, 1871).

Commenting on the Mars 2020 project, Tara Djokic said: "The deposits in the Pilbara [formation of Australia] are about the same age as the deposits on Mars [Columbia Hills], so if life ever developed on the red planet, there is a strong possibility that it would be preserved in hot springs just like here on Earth" (Zoric, 2017). Recently, evidence provided by Djokic et al. (2017) has been challenged by another team of scientists (Wacey et al., 2018) who suggest that, at the same geological formation, some microstructures might be vesicular volcanic rocks, nonbiological, pseudo-fossils.

**Figure 1.** Modern environment, similar to the one suggested to have occurred 3.5 billion years ago, in Yellowstone National Park (Grand Prismatic Spring). Source: http://bit.ly/2w6gDnA. Photo credit: Brocken Inaglory (CC BY-SA 3.0).

## ○ Final Remarks

The contemporary studies included here illustrate the present lack of a consensus on the origin of life, although the notion that life arose from nonlife to a complex system of organic molecules is well accepted by biologists. The date when and the environment where the LUCA occurred are not fully agreed on by all scientists, and one cannot discard the possibility that there may have been multiple origins in various environments that have contributed to the ancestral genotype.

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