Origins of life*

Charles Darwin in 1871 suggested that microbial life originated in some 'warm little pond' full of 'ammonia, phosphoric salts, heat and electricity'. In light of recent discoveries on the origin of life, Charles Darwin's theory appears prescient. In the first half of the 20th century, Alexander Oparin established the 'metabolism first' hypothesis to explain the origin of life. Aligning with this hypothesis, most scientists believe that the first forms of life evolved in the warm vents of ancient seas.

In 1977, scientists discovered biological communities living in and around seafloor hydrothermal vents, far from sunlight. These communities thrive on a chemical soup rich in hydrogen, carbon and sulphur spewed from geysers. There is also extreme heat and pressure around the vents. Since sunlight cannot reach the depths of these structures, the organisms create their own energy through chemosynthesis (similar to photosynthesis) using chemicals instead of sunlight. The main problem with this theory is that owing to lot of water present in the ocean, the molecules may spread out too quickly to interact to form cell membranes and primitive metabolisms.

In a recent discovery, Tara Djokic and Martin J. Van Kranendonk (University of New South Wales, Australia) have found evidence of microbes living in hot springs of Western Australia as early as 3.48 billion years ago. Until now the earliest evidence for microbial life on land came from South Africa between 2.7 and 2.9 billion years ago. In contrast, fossils dating back 4 billion years were found in ancient seabeds. The new fossils dating around 3.5 billion years ago were found at the Dresser Formation in Pilbara, Western Australia in rocks containing geyserite – a mineral deposit that only formed in terrestrial hot springs. Fossilized stromatolites of different shapes and sizes were discovered indicating that the small life forms which created them were already well diversified and had been evolving there for a long time. The new findings imply that life inhabited land 580 million years earlier than known so far. According to the recent discovery, land pools that get repeatedly dry and wet again are better places for the formation of primitive life forms.

Prior to this discovery, David Deamer (University of California, Santa Cruz, CA, USA) had shown that volcanic pools could help assemble compartments through membranes which are the essential boundaries of cell life. The idea was that simple molecules join into polymers like nucleic acids when exposed to wet and dry cycles of hot springs. Peptides also form under the same conditions with lipids protecting the information-carrying polymers. Deamer tested this idea by mixing nucleic acids with lipids and putting them through wet and dry cycles under acidic conditions and high temperatures. Simple molecules called protocells were formed using this experiment. On introduction of an intermediate stage (moist phase) between wet and dry, the surviving protocells crowded together resulting in more complex protocells that would have better chances of survival. The composition found in the Dresser Formation made it a likely spot for the three-part cycle to occur. Also, since the Dresser had been filled with surface hot springs, it contained key ingredients and organizational structures for the origin of life. Example of such ingredients include boron for nucleic acids like RNA, phosphate for nucleic acids and also used in the form of adenosine triphosphate (ATP), zinc and manganese in the cytoplasm of cells, and clay which functions as a catalyst for creating complex organic molecules.

The deep-sea vent hypothesis has been developed into an alternate yet unproven model by Mike Russell (NASA's Jet Propulsion Laboratory, CA, USA). According to this theory, the pH gradient between alkaline hydrothermal vents and the acidic ocean provides free energy that can be tapped. Modern bacterial cells do this to generate ATP. There is another source of energy in the vents. The transfer of electrons from hydrogen in the vents to carbon dioxide in the ancient sea water could synthesize more complex organic molecules. Hence the energy of pH gradients and transfer of electrons from hydrogen to carbon dioxide could evolve into a primitive metabolism required by the earliest forms of life.

Both theories have a long way to go before they can be proved correct. Also, the two theories have different implications in terms of exploring life forms on other planets. The deep-sea vent theory is applicable for the exploration of life in the icy ocean worlds of Enceladus and Europa, while the hot spring theory is applicable for exploration of life on Mars.

*This write-up is an excerpt from a recent article by Djokic *et al.*[1].

1. Djokic, T., Van Kranendonk, M. J. and Deamer, D., *Sci. Am.*, 2017, **317**(2), 30–35.

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