Origin of Life – Miller-Urey Reading

When did the chemicals of life arise?

- The solar system formed about 4.6 Ga ("giga ago" = billion years ago).
- Isotopic evidence of life based on ratios of Carbon-12 and Carbon-13 in graphite from Labrador dated 3.95 Ga and Jack Hills dated 4.1 Ga.
- Oldest known cell fossils are found in rocks dated 3.5 Ga.

It is probable that chemical evolution began around 4 Ga and resulted in cells by 3.5 Ga.

Testing the 'primordial soup' hypothesis

In the 1920s, Alexander Oparin and JBS Haldane independently proposed the idea that simple chemicals could have combined into more complex molecules of life in the 'primordial soup' of early Earth. This idea intrigued many people and in 1953 a young graduate student, Stanley Miller, decided to test the hypothesis.

Miller was working in the lab of Harold Urey, recipient of a Nobel Prize in Chemistry. Urey thought the experiment was risky and probably would not work. He gave Miller a maximum of one year to get results.

Miller filled his apparatus with the gases thought to be present in Earth's early atmosphere: water, hydrogen, ammonia and methane (remember these with the acronym WHAM). He added heat and a spark of lightning to simulate the turbulent conditions of early Earth.

Miller started the experiment. The water became pink after a day and red by the end of a week. A yellow streak of new compounds was stuck to the glass. It was clear that chemical reactions had occurred.

Miller was able to identify five amino acids: aspartic acid, glycine, alpha-amino-butyric acid and two versions of alanine. Further analysis revealed other organic compounds. However, Miller could not detect small amounts of compounds.

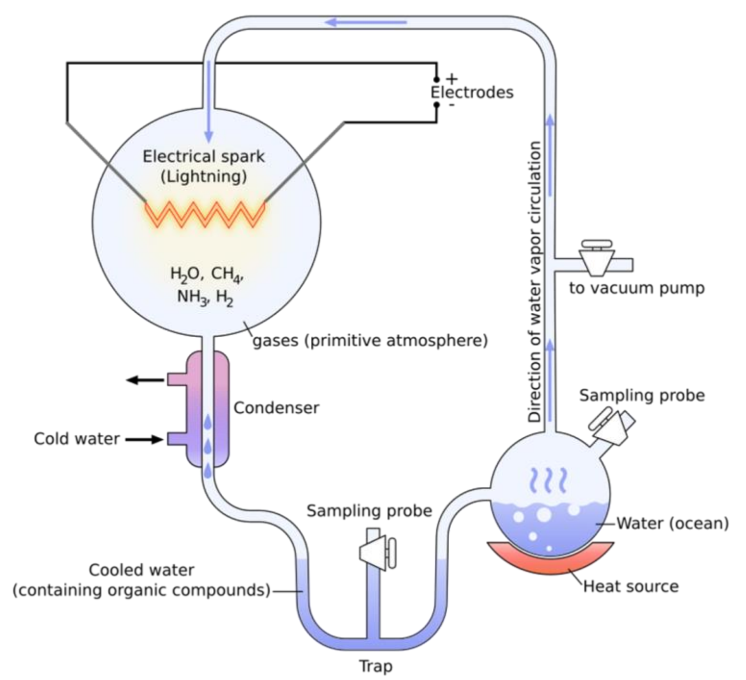

Diagram of Miller's apparatus. (Y Mrabet 2008 modified by AJ Hunter 2014, Wikimedia Creative Commons)

Refining Miller's original experiment

Miller's experiment was criticised as scientists drew new conclusions about the early atmosphere. The original mixture of gases created a reducing atmosphere. Scientific consensus changed to favour a more inert atmosphere with carbon dioxide and nitrogen. When Miller repeated the experiment in this atmosphere in 1983, he created a colourless solution with few amino acids.

Jeffrey Bada, a former student of Miller, repeated Miller's second experiment with some new additions. Rather than just modelling the atmosphere, Bada added chemicals to duplicate the minerals present on early Earth. When Bada re-ran the experiment he also got a watery liquid. However, this liquid was full of amino acids.

After Miller's death in 2007, Bada inherited Miller's old sample jars from the original experiment and other unpublished experiments. Using modern techniques that are a billion times more sensitive than those used by Miller, Bada and colleagues found that Millers original experiment had produced not six, but 14 amino acids. An unpublished experiment with higher air flow yielded 22 amino acids.

Miller also performed a variation of his experiment with hydrogen sulfide, methane, ammonia and carbon dioxide in the mixture. Hydrogen sulfide and carbon dioxide are common volcanic gases. Bada's team analysed the vials from this experiment and found 23 amino acids, some of which contained sulfur and are involved in protein synthesis.

Implications of the experiment

Miller's experiments suggest that Earth's early atmosphere could have produced the chemicals necessary for life. This result spawned an entire field of research into how simple organic molecules (e.g. amino acids) could form more complex compounds (e.g. proteins) without a living cell for assembly. The evolution of living cells took place over millions of years on early Earth. Scientists have not managed to create life in the laboratory but have made great strides into understanding the chemistry that would lead to the first cells.

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