The Origin of Life on Earth

Recent discoveries of **prebiotic** conditions on other planets and their moons has rekindled interest in the origin of life on primeval Earth. Experiments demonstrate that both peptides and nucleic acids may form polymers naturally in the conditions that are thought to have existed in a primitive terrestrial environment. RNA has also been shown to have enzymatic properties (**ribozymes**) and is capable of self-replication. These discoveries have removed some fundamental obstacles to creating a plausible scientific model for the origin of life from a prebiotic soup. Much research is now underway and space probes have been sent to Mercury, Venus, Mars, Pluto, and Pluto's moon, Charon. They will search for evidence of prebiotic conditions or primitive microorganisms. The study of life in such regions beyond our planet is called **exobiology**.

Steps Proposed in the Origin of Life

The appearance of life on our planet may be understood as the result of evolutionary processes involving the following major steps:

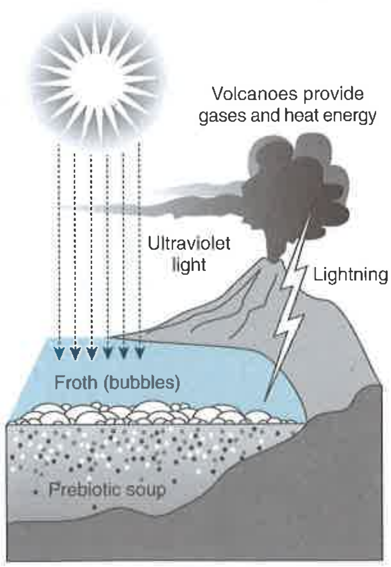
1. Formation of the Earth (4600 mya) and its acquisition of volatile organic chemicals by collision with comets and meteorites, which provided the precursors of biochemical molecules.
2. Prebiotic synthesis and accumulation of amino acids, purines, pyrimidines, sugars, lipids, and other organic molecules in the primitive terrestrial environment.
3. Condensation reactions involving the synthesis of polymers of peptides (proteins) and nucleic acids (probably RNA) with self-replicating and catalytic abilities.
4. Synthesis of lipids, their self-assembly into double-layered membranes and liposomes, and the 'capturing' of prebiotic (self-replicating and catalytic) molecules within their boundaries.
5. Formation of a **protobiont**; this is an immediate precursor to the first living systems. Such protobionts would exhibit cooperative interactions between small catalytic peptides, replicative molecules, proto-tRNA, and protoribosomes.

Photo: Ron Lind

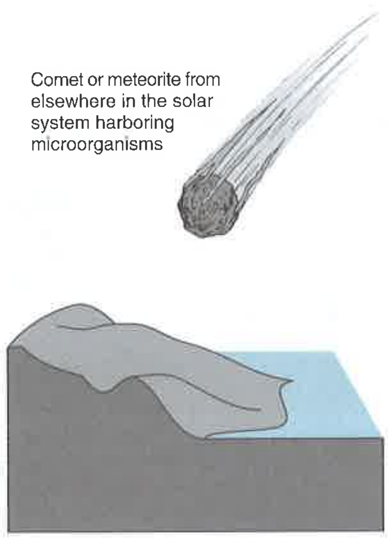
These living **stromatolites** from a beach in Western Australia are created by mats of cyanobacteria. Similar, fossilized stromatolites have been found in rocks dating back to 3500 million years ago.

Where Might Life Have Originated?

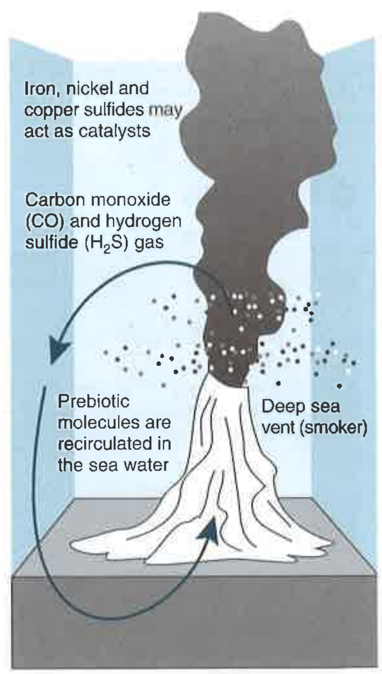
Scientists continue to speculate about where life might have originated. Three alternative views of how the key processes occurred are illustrated below.



Ocean Surface (Tidal Pools)
This popular theory suggests that life arose in a tidepool, pond or on moist clay on the primeval Earth. Gases from volcanoes would have been energized by UV light or electrical discharges to form the prebiotic molecules in froth.



Panspermia
Cosmic ancestry (panspermia) is a serious scientific theory that proposes living organisms were 'seeded' on Earth as 'passengers' aboard comets or meteors. Such incoming organisms would have to survive the heat of re-entry.



Undersea Thermal Vents
A recently proposed theory suggests that life may have arisen at ancient volcanic vents (called smokers). This environment provides the necessary gases, energy, and a possible source of catalysts (metal sulfides).

1. Summarize the steps hypothesized for the appearance of life on Earth: ______________________

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2. Explain why ocean surfaces and undersea thermal vents are likely environments for the origin of life on Earth:

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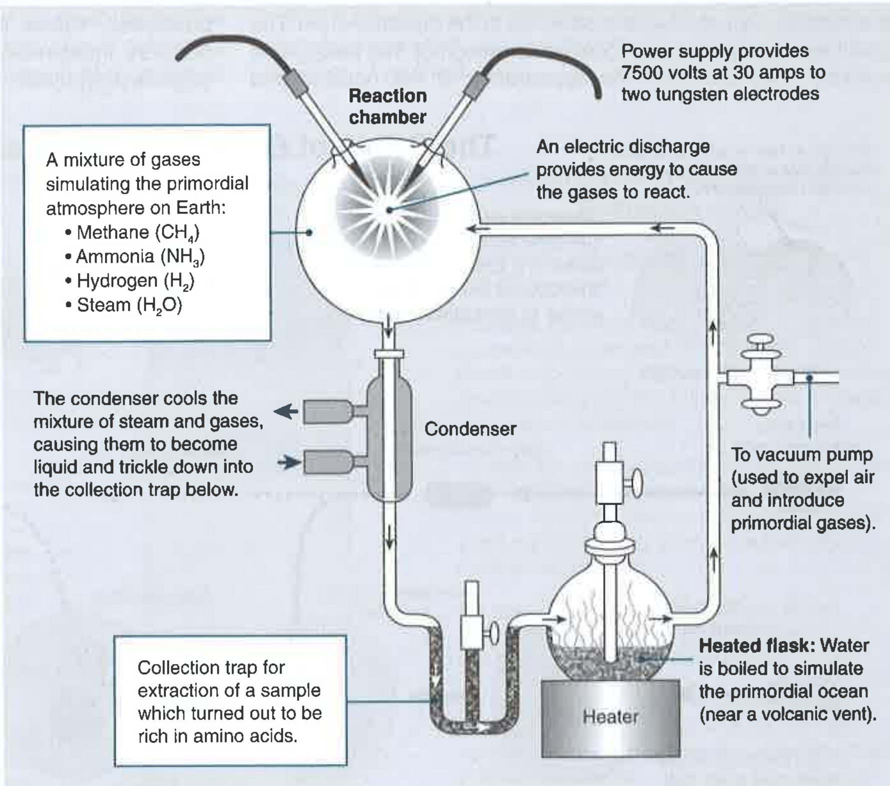
Prebiotic Experiments

In the 1950s, Stanley Miller and Harold Urey attempted to recreate the conditions of primitive Earth. They hoped to produce, in an experiment, to the biological molecules that preceded the development of the first living organisms. Researchers at the time believed that the Earth's early atmosphere was made up of methane, water vapor, ammonia, and hydrogen gas, so these were the components included in the experiments. Many variations on this experiment have produced similar results (below). It seems that the building blocks of life are relatively easy to create. Many types of organic molecules have even been detected in deep space.

The Miller-Urey Experiment

The experiment (right) was run for a week after which samples were taken from the collection trap for analysis. Up to 4% of the carbon (from the methane) had been converted to amino acids. In this and subsequent experiments, it has been possible to form all 20 amino acids commonly found in organisms, along with nucleic acids, several sugars, lipids, adenine, and even ATP (if phosphate is added to the flask). Researchers now believe that the early atmosphere may be similar to the vapors given off by modern volcanoes: carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen (N_2). Note the absence of free atmospheric oxygen.

Iron pyrite (fool's gold) (above) has been proposed as a possible stabilizing surface for the synthesis of organic compounds in the prebiotic world.



Some scientists envisage a global winter scenario for the formation of life. Organic compounds are more stable in colder temperatures and could combine in a lattice of ice. This frozen 'world' could be thawed later.

Lightning is a natural phenomenon associated with volcanic activity. It may have supplied a source of electrical energy for the formation of new compounds (e.g. oxides of nitrogen) which were incorporated into organic molecules.

The early Earth was subjected to volcanism everywhere. At volcanic sites such as deep sea hydrothermal vents and geysers (like the one above), gases delivered vital compounds to the surface, where reactions took place.

1. In the Miller-Urey experiment simulating the conditions on primeval Earth, identify parts of the apparatus equivalent to:

   (a) Primeval atmosphere: ______________________ (c) Lightning: ______________________

   (b) Primeval ocean: ______________________ (d) Volcanic heat: ______________________

2. What organic molecules were created by this experiment? ______________________

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3. (a) Why do you think the Miller-Urey experiment is not an accurate model of what happened on the primeval Earth?

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   (b) What changes to the experiment could help it to better fit our understanding of the Earth's primordial conditions?

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