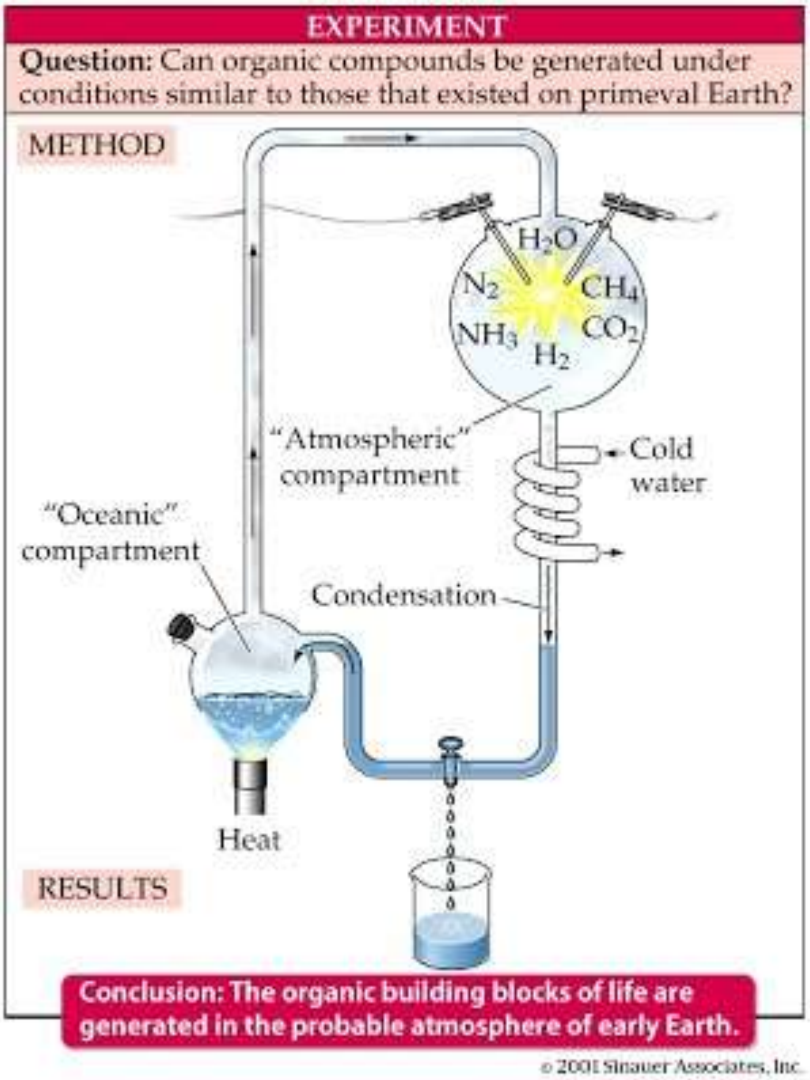
Miller–Urey Experiment



The Miller-Urey experiment was the first attempt to scientifically explore ideas about the origin of life. The purpose was to test the idea that the complex molecules of life (in this case, amino acids) could have arisen on our young planet through simple, natural chemical reactions.

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Miller–Urey Experiment

The building blocks of life have been discovered and characterized since the early 19th century. Regarding the synthesis of molecules of prime interest to the origin of life, two major achievements shall be given. In 1850, Adolf Strecker succeeded in the first laboratory synthesis of an amino acid: alanine from a mixture of acetaldehyde (CH_3CHO), ammonia (NH_3), and hydrogen cyanide (HCN).

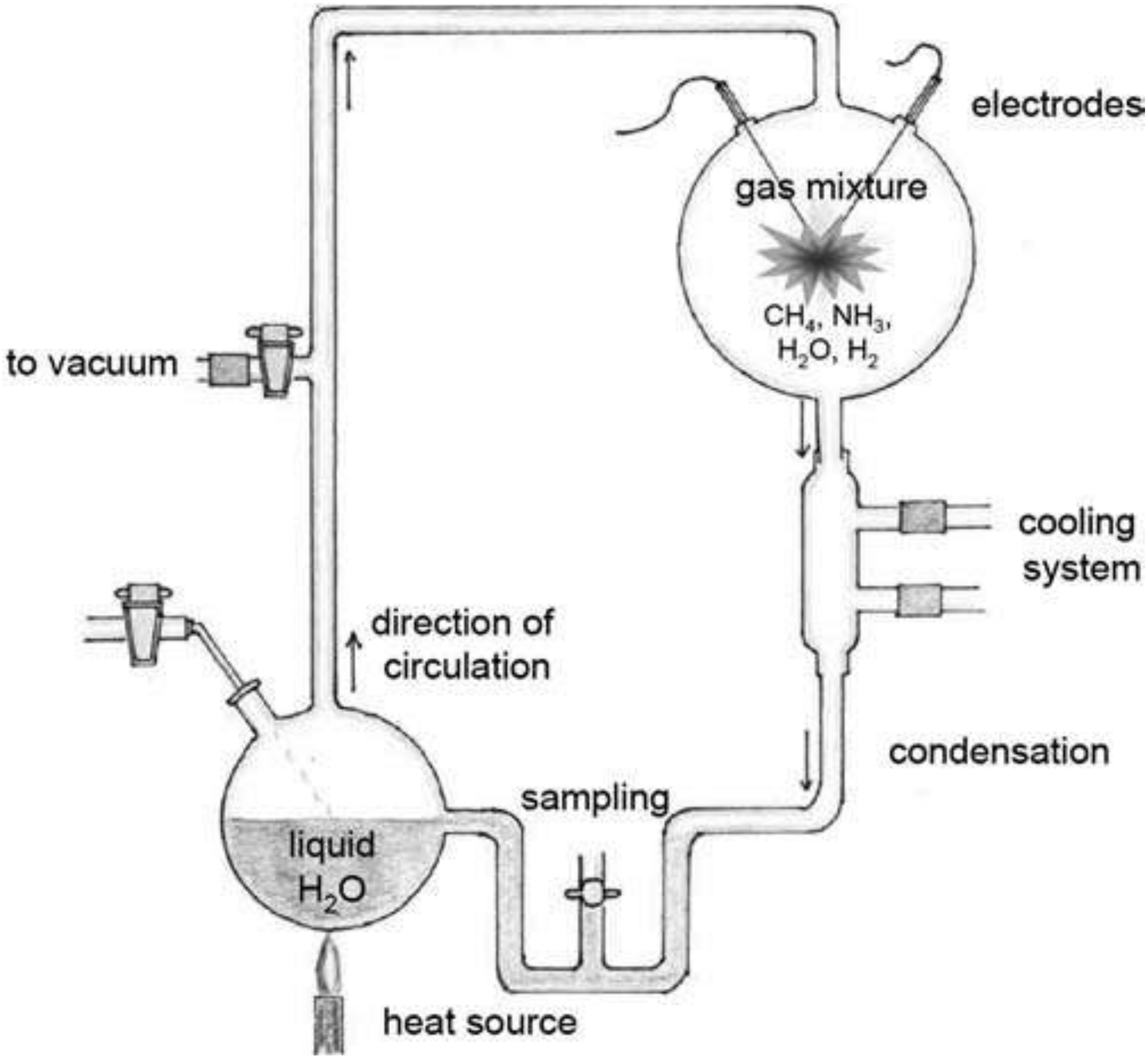
A few years later, in 1861, Alexandr Butlerov performed the first laboratory synthesis of sugar mixtures (also known as the formose reaction) from formaldehyde (HCHO) using a strong alkaline catalyst (NaOH). Although these discoveries were very interesting, they were not linked to the origin-of-life problem. Hence, little progress was made in finding a scientific description of the origin of life was introduced by Aleksandr Ivanovich Oparin.

Oparin introduced the concept of chemical evolution, which could be seen as the roots of the Darwin theory of evolution. In this concept, life was the result of successive spontaneous chemical reactions that produce increasingly complex chemical structures. He suggested that such chemical evolution would take place within an oxidizing atmosphere of the primitive Earth.

After sometime he made some modifications in his early concepts and changed the early atmosphere to a highly reducing environment. Similar ideas were simultaneously given by the English biologist John Haldane, who was the first to mention the concept of a **"prebiotic soup"** where chemical evolution took place. Oparin and Haldane's ideas were expressed at a theoretical level only. The experimental confirmation of the theory of chemical evolution was provided in 1953 by Stanley Miller and Harold Clayton Urey. They conceived and built an experiment to simulate a putative primitive Earth environment.

In this experiment a gaseous mixture of hydrogen (H_2), methane (CH_4), ammonia (NH_3), and water (H_2O) was exposed to an electric discharge that simulated that of storm lightning. The mixture was connected to a bulb filled with liquid water that could be heated. It was found that within a week 15% of carbon originally present as methane had converted into other simple carbon compounds. Among these compounds were formaldehyde (HCHO), hydrogen cyanide (HCN). These compounds then combined to form simple molecules, such as formic acid (HCOOH) and urea (NH_2CONH_2) and more complex molecules containing carbon-carbon bonds including the amino acids glycine and alanine.

The resulted production of a large amount of organic molecules, including several amino acids was the experimental proof of the theory of chemical evolution. This experiment showed that the chemistry between simple molecules, which were abundant in the atmosphere of the primitive Earth, led to the synthesis of key compounds that in turn might have led to the forms of life on Earth.



Miller–Urey experiment set-up, which simulates in the laboratory the coupled chemistry between the primitive Earth atmosphere (upper right bulb) and warm oceans (lower left bulb). In the first version, an atmosphere made of CH_4, NH_3, H_2O, and H_2 was considered. A spark discharge simulated storm lightning

The mixture of CH_4, NH_3, H_2 and H_2O creates a reducing atmosphere and considered due to following reasons:

- CH_4, NH_3, H_2O, and H_2 had been detected in the atmosphere of giant planets since the 1930 s.
- All the primitive atmospheres of planets were identical, captured from the Solar Nebula.

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- Giant planets, cold and distant from the Sun, have kept their original composition.

Therefore, Urey and Miller concluded that the current composition of the atmosphere
of giant planets of the Solar System was a good proxy for the composition of the atmosphere of the primitive Earth.

Miller–Urey experiment is not as conclusive:

This experiment was a great achievement because it showed that that important prebiotic compound scan be abiotically synthesized in environments simulating "natural" conditions.

But there are several findings which prove the conclusion of this experiment wrong!

1. It is now quite well established that telluric planets do not have sufficient mass to capture the Solar Nebula gas like the giant planets did. To do this, a minimum mass of 10 to 15 Earth masses is required. Only then can a forming planet efficiently trap the volatile elements of the nebula to form its atmosphere. In addition, recent observations have supported the conception that at a distance of one astronomical unit (AU) from the Sun – that is where the Earth accreted – the gaseous component of the Solar Nebula was probably dominated by CO2 and N_2.

2. Earth, like Venus and Mars, has a secondary atmosphere built from volatile compounds that outgassed from the mantle on one hand or were imported via meteorites and comets on the other hand.

3. Third, the composition of the primitive Earth atmosphere was most probably dominated by CO2 and N2, in which organic syntheses are not as efficient as in a reducing atmosphere.