

# THE ORIGIN OF LIFE:

## Where Did Organic Molecules Come From?

by

Annie Prud'homme-Généreux, Nicole F. Magill, and Tatiana N. Bliss  
Life Sciences

Quest University Canada

### Part I – A Flash of Insight

*I know how to test this!*

It was the fall of 1951. Twenty-one-year-old Stanley had recently traveled from his native California to the University of Chicago to pursue a graduate degree in chemistry. At a departmental seminar, his imagination was captured by the presentation from a professor in his department, the Nobel Laureate Harold C. Urey.

"In the course of an extended study on the origin of the planets I have come to certain definite conclusions relative to the early chemical conditions on the Earth and their bearing on the origin of life," said Urey."

Stan listened intently while Urey continued to explain how the early Earth atmosphere was not as it is today.

"One sees that hydrogen ( $H_2$ ) was a prominent constituent of the primitive atmosphere and hence that methane ( $CH_4$ ) was as well. Nitrogen was present as nitrogen gas ( $N_2$ ) at high temperatures but may have been present as ammonia ( $NH_3$ ) or ammonium salt at low temperatures."

Stan was riveted. Urey went on to suggest, as had the Russian biochemist Oparin before him, that organic molecules (compounds containing carbon atoms) might have formed on the early Earth from inorganic gases. This was provocative because it suggested that the molecules of life (which are organic) could be created by simple chemistry, and it could explain how the building blocks of life were first created on our primitive lifeless planet.

"It seems to me that experimentation on the production of organic compounds from water ( $H_2O$ ) and methane in the presence of ultra violet light of approximately the spectral distribution estimated for sunlight would be most profitable. The investigation of possible effects of electric discharges on the reactions should also be tried since electric storms in the [Earth's early] atmosphere can be postulated reasonably."

*I know how to test this!* thought Stan again. Circumstances didn't allow him to approach Urey immediately, but a few months later, he asked Urey for the opportunity to test the idea that the conditions and atmosphere of early Earth were sufficient to create organic molecules, the building blocks of life. Urey thought the project was "too risky" for a graduate student since it was unlikely to yield interesting results in the time allowed to complete a PhD (after all, the process might have occurred over millions of years on Earth). At Stan's insistence, Urey gave him a year to experiment.

#### Question

1. What experiment did Stan have in mind? Propose an experimental design to test the hypothesis that organic molecules formed from inorganic ones under the conditions prevalent on the early Earth. Provide as many details as possible.

\* The events described in this case are inspired by the biography of Stanley Miller (Bada & Lazcano, 2003: 2012).

\*\* This "presentation" is constructed from a paper published by Urey a year later (Urey, 1952).

## Part II – Earth in a Bottle

Stan designed the glassware apparatus shown in Figure 1. He first sterilized all of his equipment to make sure there were no living things inside of it. He then created a vacuum inside the tubes to remove our atmosphere and inserted a mixture of the following gases: hydrogen ( $H_2$ ), methane ( $CH_4$ ), and ammonia ( $NH_3$ ). He filled the bottom flask with water ( $H_2O$ ) and placed it over a flame to heat it. In the top flask, he carefully inserted two electrodes and passed an electric current which created sparks. Between the top and bottom flasks, one of the connecting tubes (left connecting tube in Figure 1) was fitted with a condenser to cool any gas present at that location in the tube. Stan also placed a few valves to permit sampling of the chemicals inside his apparatus. After a few days, he noticed that the water inside the flask rapidly turned from clear, to yellow, to a darker shade of brown. These color changes indicated the creation of novel chemicals inside his apparatus.

### Questions

- This apparatus was meant to simulate the conditions of early Earth. Describe how each element mimics a component of the early Earth environment. Be sure to address the following:
  - The bottom flask that is heated
  - The top flask
  - The electric discharge
  - The condenser
- What might constitute an appropriate control in this experimental design?
- What data should Stanley measure and record in this experiment? What does he have to do to collect this data?
- What are possible pitfalls of this experimental design?
- Electric discharges simulate lightning, a source of energy to drive chemical reactions. What other sources of energy (identify at least two) might have been present on the early Earth? How might they be simulated in this experiment?
- If some of life's organic molecules are created in Stan's experiment, what are the implications for the origins of life? (Will this tell us how life arose on Earth?)

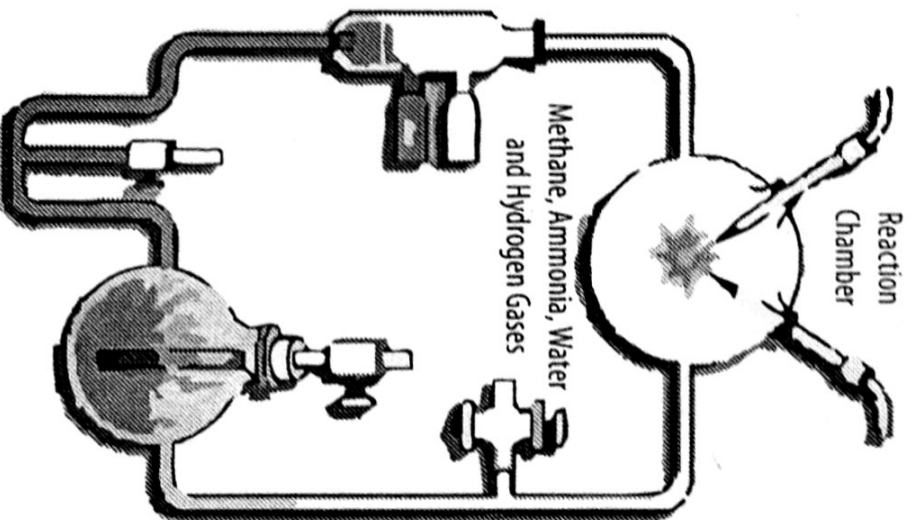


Figure 1. Stanley Miller's experimental set-up.