SCIENCE AND PUBLIC PERCEPTION: THE MILLER EXPERIMENT

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Introduction

There is hardly a chemical experiment so well known both to scientists and to the general public as the Miller (or Urey-Miller) experiment that was performed in the fall of 1952 by a young American chemist named Stanley L. Miller (1930-2007), who made it as a part of his Ph.D. Thesis (1). By exposing the mixture of gases (CH_4, NH_3, H_2, H_2O), presumed by his mentor Harold C. Urey (1893-1981) to be the constituents of the first Earth atmosphere (2), to electrical sparking he obtained a mixture of organic compounds, and above all of amino acids, "the building blocks of proteins" (3, 4). From a purely chemical point of view, this could hardly be judged as being something new; he simply ran an uncontrolled (or poorly controlled) radical reaction in the gas phase—similar to Löb's experiments in the beginning of 20th century (5, 6). "Löb had been looking for the formation of amino acids, especially glycine, at least as early as 1909," wrote Hubert P. Yockey (7).

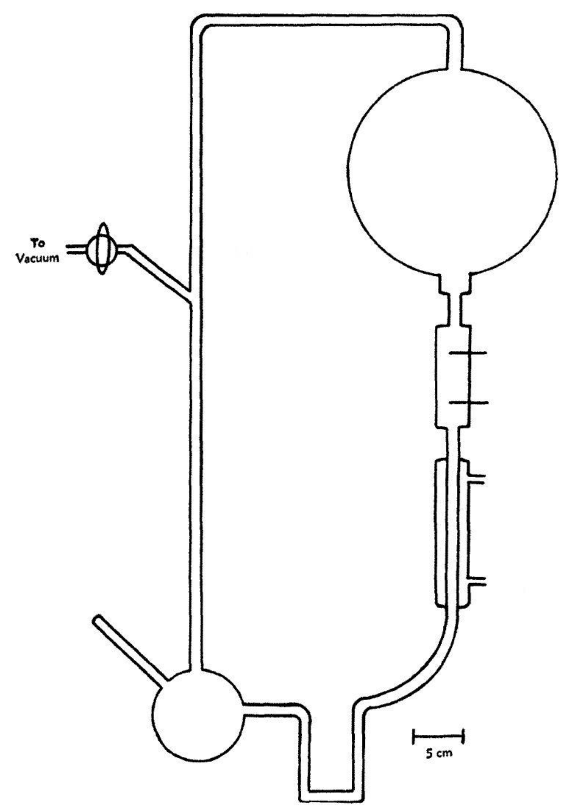

FIG. 1.

***Figure 1**. The original scheme of Miller's first apparatus. "The water in the flask was boiled, and the discharge was run continuously for a week." He obtained glycine, α- and β-alanine, α-aminobutyric acid and wrongly identified aspartic acid (3).*

Oskar Baudisch (1913) also showed that amino acids are generated by ultraviolet light only in reducing atmosphere. J. S. Haldane (1929) referred to the work of Edward Baly *et al.* (1922), who found glycine using ultraviolet light.

Even the idea of prebiotic synthesis is not Miller's invention. Aleksandr I. Oparin (8) wrote numerous schemes for possible prebiotic syntheses, including those of amino acids. He proposed that amino acids were formed by Trier's reaction of hydroxyl acids with ammonia (9) or by addition of ammonia to double bonds, e.g., conversion of fumaric into aspartic acid (10). "Thus, the primary formation of compounds of the protein type is in no way unusual, exceptional, or different than the formation of other complex organic substances," said Oparin (9). So, what is "unusual, exceptional, or different" in the Miller experiment (Figure 1)? I will try to answer this question in the proceeding paragraphs.

The Experiment's Scientific Merit

The leading idea of the experiment is to prove the validity of theory of his mentor, Nobel Prize laureate Harold Urey. This is evident from the very first sentence of his first paper (3):

> The idea that the organic compounds that serve as the basis of life were formed when the earth had an atmosphere of methane, ammonia, water, and hydrogen instead of carbon dioxide, nitrogen, oxygen and water was suggested by Oparin and has been given emphasis recently by Urey and Bernal.

Plainly speaking, Miller's idea was to produce amino acids by gas-phase reactions in not just *any* primordial atmosphere, but in a Jupiter-like one, as proposed by Urey (11). From this point of view his experiment should be judged as obsolete and erroneous, one of many "beautiful theories killed by an ugly fact," as Thomas Huxley (1825-1895) put it. In particular, there are recent geochemical findings (12) suggesting that the primitive Earth's atmosphere was more likely to resemble the one proposed by John B. S. Haldane (1892-1964), composed of CO_2 and NH_3 (13), rather than the atmosphere of the CH_4 and NH_3 type, as were assumed by Oparin and Urey. However, amino acids were obtained from gaseous mixtures of various compositions (14) and there are many ways how organics could originate before the dawn of life (15); there were many *primordial soups* and many *primordial cooks*, to use a metaphor by Max Bernstein (15b).

But there are many flaws in such an argument, aimed to disfavor Miller's priority. Oparin did not bother to test his theory of abiotic synthesis experimentally; after all, he was not a chemist (8a). The Russian scientist did not even believe at first in the report of Miller's experiment, as newspapers carried it (16). J. L. Bada and A. Lazcano vigorously opposed Yockey's opinion that Miller just updated Löb's work (17), stating Löb had not the slightest intention to contribute to theories on the origin of life, but to explain nitrogen assimilation (*Stickstoff-Assimilation*), which is evident from the very title of his second paper (6). "Neither Aleksander Oparin, J. B. S. Haldane nor Urey made any mention of Löb's work, which given Oparin's extensive review of early relevant literature suggests it was considered unimportant," stated Bada and Lazcano (17), but it seems that Miller himself found it important because he gave him a credit: "The only work that would have any bearing on the reducing atmosphere would be the experiments of Loeb who obtained glycine by the action of silent discharge on a mixture of carbon monoxide, ammonia and water" (4).

Public Perception

It is true that the Miller experiment "deserves recognition not only because of its intrinsic merits, but also because it opened new avenues of empirical research into the origin of life" (17), as any scientific discovery of real importance does, but it is also true that there is no such a thing as an independent discovery in science. Neither Newton nor Einstein by themselves founded a new physics, and besides Mendeleev and/or Lothar Mayer there were at least four more "co-discoverers" of the periodic system (18). So it was with the theories on the origin of life, or more specifically, with the problem of prebiotic synthesis. *Every* synthesis of organic matter from "inanimate substances," starting from Friedrich Wöhler's (1800-1882) famous 1828 experiment (19), contributed to the solution of the problem.

However, the reason for the exceptional popularity of the Miller experiment is not purely scientific (20):

> The finding caught the imagination of scientists everywhere by suggesting that it might soon be possible to reconstruct the emergence of the first living cells from the soup of chemicals generated by natural conditions on the early earth.

Moreover, it is a good story, for the "synthesis of live molecules" in chemical apparatus had a kind of mystical aura, resembling the making of an "artificial man," *homunculus* (21), in a retort, as had been proposed in the 8th century by Jabir ibn Hayyan (Geber) and was believed even by Paracelsus (1493-1541). The relation of a notable and respected scientist and his young and anonymous doctoral student is nearly as archetypical as the myth of Daedalus and Icarus: the old man made a miracle and the young one put it to its ultimate test, in Miller's case fortunately not also to the bitter end—and creationists possibly played the role of the Minotaur.

The next reason is that in the 1950s, after the end of World War II, public imagination overflowed with scientific and technical discoveries, starting from nuclear bombs and nuclear submarines, synthetic resins and plastics to the impending flight into space, not to mention discoveries in biochemistry, like the double helix of DNA (22). The Miller experiment showed that the problem of the life's origin if not solved, could be solved by scientific means (23):

> Published in the May 15, 1953 issue of *Science*, the results galvanized scientists and generated global head-lines. *The New York Times* credited Miller and Urey with inventing "a laboratory Earth." *Time* dubbed the experiment "semi-creation."

Max Bernstein wrote (15b):

> The results were breathtaking … Given that it was also the year that the structure of DNA was published, I am told that it seemed as if the secrets of life were being revealed and that very soon scientists would understand how life had come about.

From another side, all kinds of creationists and believers in intelligent design inevitably refer to the alleged fallacy and insignificance ("much ado about nothing") of his experiment (24), entirely neglecting numerous various and sophisticated similar experiments supporting evolution theory; it was proclaimed simply as an "evolutionistic fraud" (25). In their view, the *icon of evolution* "has little or nothing to do with the origin of life" (26) and, harshly, "The experiments were a ridiculous failure" (27). This is another, bad side of the overwhelming popularity of Miller's abiogenic synthesis.

Amino acids and proteins were, at least in the public imagination, nearly synonymous with life (28), and thus it is hardly surprising that the findings of the young American scientist had "breathtaking" response. Of course, the young chemist didn't obtain proteins in his apparatus, and the polymerization of amino acids in prebiotic conditions is only one of many controversies on the origin of life (29). Obviously, the value of Miller's experiment was exaggerated in general public, but it has to be acknowledged that he knew how to present his results in a popular and attractive way—a capability which was mostly missing in the middle 20th-century scientific community (30).

Conclusion

The story of the Miller experiment is a good example how the valuation of a scientific research depends not only on its intrinsic (scientific) value but also on its acceptance by the scientific community, as well as the general public. In spite of the development of rival theories, like the volcanic "iron-sulfur-world" (31), whose founder Günter Wächtershäuser "held that Dr. Miller's approach was a blind alley" (20), after 65 years the experiment of the young American scientist is still in the public focus. There are hundreds if not thousands of graphical representations of his apparatus on the web and elsewhere (Figure 2). Moreover, his scientific contribution was exaggerated in the public memory stating, wrongly, that he "was the first to demonstrate that the organic molecules necessary for life could be generated in a laboratory flask simulating the primitive Earth's atmosphere" (32), but against all odds "Miller's findings still provide invaluable insight into the formation of essential organic compounds" (33).

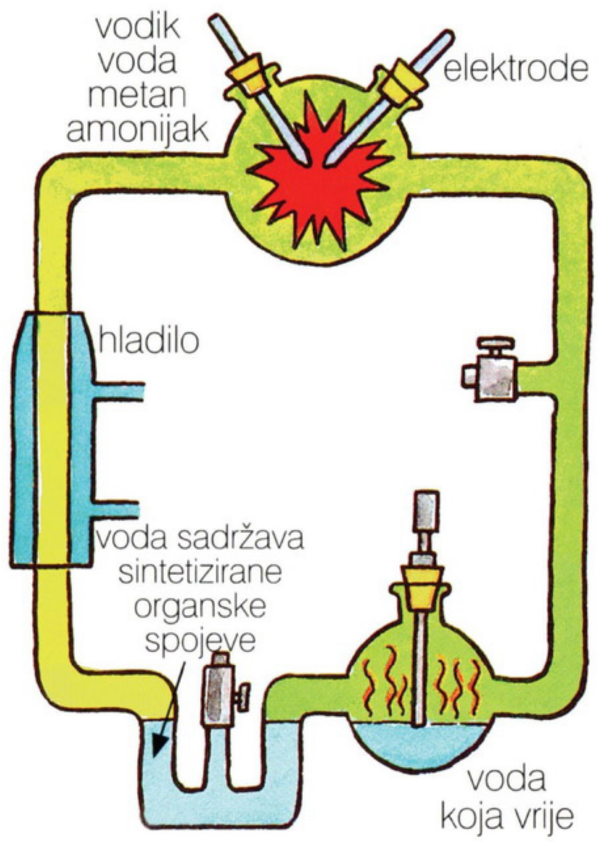

***Figure 2**. One of many graphical representations of Miller's apparatus—this one in the picture-book style for the fourth middle school grade (European eighth elementary school grade) textbook for an elementary course in organic chemistry. "It is not yet entirely clear how these small molecules organized themselves, created life and obtained the capacity for self-reproduction" (34).*

At the end, it has to be said that Miller experiment is undoubtedly a piece of scientific history and it has to be judged as such. It can be judged no more as "the most convincing of all experiments that have been done in this field," as Norman Horowitz (1915-2005) put it in 1963 (35). "The Miller-Urey experiment is now recognized as the single most significant step in convincing any scientists that life is likely to be abundant in the cosmos" (36), as said Carl Sagan (1934-1996), could be perceived as an exaggeration. The experiment may even be judged as "defunct and discredited" (37), but it cannot be denied that "the father of prebiotic chemistry" encouraged other scientists to do as he did, like abiogenic synthesis of nucleic bases in 1960 (38) or thermal polymerization of amino acids in 1956 (39) and clay-catalyzed polymerization of nucleotides in 1989 (40). The work of the young American chemist established a new paradigm (41), to say it in a philosophic way. This is the greatest legacy of the first synthesis of amino acids in the simulated primitive Earth's atmosphere.

References and Notes

1. It is a bit misleading to call the Miller experiment "Miller-Urey experiment" because the idea of its performing was originally Miller's, and Urey was not very enthusiastic about it. He did not believe much in its success and therefore in finishing Miller's Ph.D. Thesis. However, Miller acknowledged his mentor for "many helpful suggestions" (3) and "advice and encouragement during the course of this research" (4). a) J. L. Bada and A. Lazcano, "Prebiotic Soup—Revisiting the Miller Experiment," *Science*, **2003**, *300*, 745-746. b) J. L. Bada and A. Lazcano, "Stanley L. Miller, 1930-2007," *Biogr. Mem. Natl. Acad. Sci. USA* (online), **2012**, http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/miller-stanley.pdf (accessed Apr. 9, 2020).
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10. A. I. Oparin, Возникновение жизни на земле (*The Upspring of Life on Earth*), 4th Ed., 1941, p 103.
11. "In this apparatus an attempt was made to duplicate a primitive atmosphere of the earth, and not to obtain the optimum conditions for the formation of amino acids. Although in this case the total yield was small for the energy expended, it is possible that, with more efficient apparatus … this type of process would be a way of commercially producing amino acids" (3); X. Xie, D. Backman, A. T. Lebedev, V. B. Artaev, L. Jiang, L. L. Ilag and R. A. Zubarev, "Primordial Soup was Edible: Abiotically Produced Miller-Urey Mixture Supports Bacterial Growth," *Sci. Rep.*, **2015**, 14338.
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25. E.g. "This experiment is the only 'evidence' evolutionists have with which to allegedly prove the 'chemical evolution thesis'; they advance it as the first stage of the supposed evolutionary process leading to life. Although nearly half a century has passed, and great technological advances have been made, nobody has made any further progress. In spite of this, Miller's experiment is still taught in textbooks as the evolutionary explanation of the earliest generation of living things." (H. Yahya, *The Evolution Deceit: The Scientific Collapse of Darwinism and Its Ideological Background*, Ta-Ha Publishers, London, 1999, p 132; see also http://www.darwinismrefuted.com/molecular_biology_09.html, accessed Apr. 9, 2020.) "Miller set up a closed glass apparatus … evacuated it, and replaced air with methane, ammonia, hydrogen and water. (If he didn't clean the apparatus out of air, the next step would be his last.)" ("Evolucionističke prijevare o postanku života na Zemlji (Evolutionistic Frauds about the Origin of Life on Earth)," http://www.novi-svjetski-poredak.com/2013/06/01/evolucionisticke-prijevare-o-postanku-zivota-na-zemlji/, accessed Apr. 9, 2020). "When Stanley Miller had analyzed obtained products, he found a huge amount of the tar and traces of certain organic components, among them also amino acids… And that has been taken for certain that life was originated by abiotic way." ("Savremena hipoteza abiogeneze (Contemporary Hypothesis of Abiogenesis)," http://www.cps.org.rs/Cks1/cks14.html, accessed Apr. 9, 2020).
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1943) owes much of his popularity to his family name, which is not a typical Croatian (Slavic) cumbersome patronymic, e.g. Tomić, Modrić or Ivičević, but was derived from a nickname (*tesla* is Croatian for adze).

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