**THE ORIGIN OF LIFE - DID IT BEGIN IN A FROZEN OCEAN?**
**By**
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Many large questions remain to be answered in biology. Perhaps the most fascinating question of all is - how did life first arise on earth? A dramatic experimental breakthrough was made 47 years ago. The basic insight provided by that famous experiment remains valid, but developments in the meantime have led some to believe that life first began in a very cold ocean under a thick layer of ice, rather than in a completely liquid ocean as originally surmised.

In 1952 Stanley Miller, a young graduate student at the University of Chicago, working under the supervision of the Nobel laureate chemist Harold Urey, carried out an experiment in which he attempted to reproduce the conditions that first produced life on earth. He connected two flasks with tubing. Into one he put water (the ocean), and into the other a mixture of gases, principally hydrogen, ammonia and methane (the original atmosphere). He passed an electric arc (lightning) through the gases for one week. By this time the water had turned brown and chemical analysis showed that it contained many organic compounds found in biological organisms, including several amino acids. Amino acids are the building blocks of proteins, one of the main components of the living cell.

Since then many experiments have been carried out using various mixtures of gases thought to approximate to the chemically reducing atmosphere of the early earth, and using other sources of energy, such as ultraviolet light, known to be available on the young planet. In most cases a rich mixture of organic compounds was formed containing many of the basic building blocks of life - ‘prebiotic soup’.

And so, the following consensus emerged amongst scientists. The building blocks of life were formed as demonstrated in Miller’s experiment. The various chemicals in this prebiotic soup interacted and reacted in a form of chemical evolution lasting for millions of years. Eventually information-rich self-replicating molecules arose, and, later still, the first living cell.

The insight provided by Miller’s 1952 experiment promised that an explanation would quickly emerge as to how events evolved from simple building blocks to the first living cell. However, while progress has been made in this area, it must be admitted that science remains at a very long distance from the answer to this question.

Life began on earth about 3.8 billion years ago, having arisen from pre-biotic soup, if we accept the proposal of Urey and Miller. On the face of it, to go from simple building-block chemicals to a living cell is an enormously improbable step. Several prominent scientists (e.g. Francis Crick and Fred Hoyle) have concluded that there wasn’t enough time available on the early earth to allow this development to evolve.

Both Crick and Hoyle have proposed that life began elsewhere in the universe and was subsequently seeded on earth - panspermia. It is now well known that organic compounds and basic building-block chemicals found in living organisms are formed on a widespread basis throughout the universe. The Murchison meteorite, which landed in Australia in 1969, contains about 80 amino acids, including at least 8 of the 20 amino acids that are present in proteins in earth organisms.

The panspermia hypothesis is not widely accepted by scientists. The general consensus remains that life began on earth by evolving from the primeval prebiotic soup. However, certain difficulties have emerged with the details of this model as it was originally proposed. One problem concerns the composition of the primeval atmosphere.

Urey and Miller originally assumed that the early earth had a reducing atmosphere, i.e. it favoured chemical reactions that would produce organic compounds. It was thought that the early atmosphere was devoid of oxygen, was rich in methane and ammonia, and also contained hydrogen. It is known that the early earth was violent, riven by electrical storms, suffused with strong ultraviolet light, rocked by volcanic eruptions, and bombarded with comets and asteroids. Under such conditions, as Miller's experiment shows, the basic building blocks of life are easily formed.

However, evidence has emerged since the 1950s that the composition of the early atmosphere may have been chemically very different to that previously proposed. Many meteorologists have pointed out that gases such as methane and ammonia are unstable in ultraviolet light and would not persist in the atmosphere. Many atmospheric scientists now favour an atmosphere largely composed of nitrogen and carbon dioxide almost from the very beginning. This atmosphere contained no oxygen, and it had much more carbon dioxide than our present atmosphere. The problem with this revised early atmosphere is that, if you repeat Miller's experiment using these gases, nothing happens.

So, if the revised notion of the early atmosphere is right, how could the building blocks of life have been formed? A new proposal to answer this question has come forward from Miller, J. Bada (Scripps Institution, University of California), Stanley Miller and co-workers, in which the necessary reducing environment is present in the waters of the ocean, rather than in the gases of the atmosphere. In this scenario it is necessary to have the reaction vessel in the liquid ocean partitioned off temporarily from the atmosphere above. This would happen if the oceans were frozen, but not all the way to the bottom.

The earth is presently maintained well above freexing temperatures on average because sufficient heat from the sun is retained close to the earth by the gases in the atmosphere, keeping the climate temperate - the greenhouse effect. Carbon dioxide is an important greenhouse gas. The sun that shone on our early earth 4 billion years ago was 20 to 30 per cent cooler than at present. The greenhouse effect of the gas mixture in the very early atmosphere may not have been strong enough to compensate for the weak sun and, consequently, the earth could have frozen.

The ocean would not have frozen all the way to the bottom. Radioactive decay in the earth produces heat that flows out into the ocean. Four billion years ago this heat flow was 3 times greater than now. This heat would have kept the ocean liquid, below a surface ice-sheath about 300 metres thick. Methane and ammonia could enter the water by bubbling up through vents in the ocean floor. Reaction would then take place in the water to form the basic building block chemicals. The cold temperature of minus 2 degrees Celsius would prolong the life span of the organic molecules and would provide a particularly favourable environment for chemical evolution to occur over millions of years, producing a rich pre-biotic soup from which a living cell would eventually emerge.

How did the earth subsequently unfreeze itself? The sun at the time was too weak, but cosmic collisions could have provided enough energy. The early earth was subject to frequent collisions with meteorites, comets, asteroids and miscellaneous debris left over from the formation of the solar system. When such objects hit the earth, 75 per cent of their energy is dissipated at the site of impact and 25 per cent heats the atmosphere. An object 100 kilometres across could have melted all the ice on earth. Once the ice was melted, the high concentration of carbon dioxide in the early atmosphere, although insufficient to trap enough heat to melt the ice, would have prevented it from freezing again once it was melted by an asteroid collision.

This revised scheme is basically very similar to the original scheme proposed by Miller and Urey. It differs in details to accommodate revised ideas of the composition of the early atmosphere. Urey's half-joking remark made in 1953 still applies - 'If God didn't do it this way, he missed a good bet'.

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