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A NOTE ON THE ORIGIN OF LIFE

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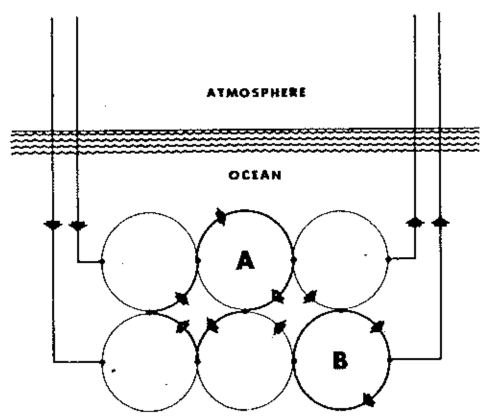
Oparin[1] made a significant contribution toward the solution of the problem of the origin of life by suggesting that the prebiological environment contained a great abundance of organic compounds, whose existence was possible because of the reducing nature of the atmosphere at that time. The gap between living organisms and simple inorganic compounds is thus considerably reduced. Since Oparin made his suggestion, Urey[2] has brought forward geochemical and astronomical arguments in favor of the thesis that the original atmosphere of the earth was of a reducing nature. Recently it has been shown experimentally[3] that passage of electrical discharges through such an atmosphere produces organic compounds in great variety and abundance. The original speculations of Oparin thus appear to have been well founded.

There is, nevertheless, a large gap between the simplest living organism and an aqueous solution of organic compounds. I propose here that this gap can be further narrowed.

A biochemical system can be regarded as a system of catalysts regulating the transformation of other compounds so as to make available to the system energy and matter for its further increase and maintenance. Since the catalysts cannot be produced without metabolism, and metabolism cannot proceed without the catalysts, the origin of such a system has naturally been difficult to comprehend.

If one accepts the arguments mentioned above as to the prebiological environment of the earth, it will be noted that the transformation of matter would have formed an "ecological cycle." Under the influence of the energy of light or electrical discharges, simple compounds (methane, ammonia, etc.) of the original atmosphere form a great variety of organic compounds in solution in the ocean. These compounds are metastable and tend, at rates determined by the activation energies of the processes involved, to disintegrate into the compounds from which they originally arose. While in solution in the ocean, the organic compounds will interact, forming numerous molecular species. On a two-dimensional figure the molecular transformations can be represented as a reticulum, within which cycles can be arbitrarily delineated (heavy lines in Fig. 1).

As has been shown, particularly by the long researches of von Langenbeck,[4] primary valence-bond catalysis is a common phenomenon in organic chemistry. Hence it is to be expected that many of the compounds in solution will catalyse some reaction represented by the reticulum. Now consider the following case: a product of cycle A catalyzes a rate-limiting reaction in cycle B, and conversely a product of cycle B catalyzes a rate-limiting reaction in cycle A. In such a case the quantity of matter passing through these two cycles will increase at the expense of other reaction cycles. A kind of "natural selection" based on reaction rates will result. Eventually (and automatically), a system of interlocking cycles will be selected which operates at the maximal rate.



Such a system of self-generating catalysts meets the minimal definition of life. In this initial stage, however, there are no discrete organisms, and there exists only one living thing, the metabolizing ocean. The further evolution of this system presumably led to the production of catalysts of a high molecular weight and peptide nature. These may have agglomerated, and eventually the system would have become delineated into small discrete masses, the individual organisms. A better understanding of the biosynthesis of proteins and the nature of enzymatic catalysis may eventually make it possible to speculate in more detail on the nature of the above process.

This proposal has the advantage that it is not necessary to invoke a series of highly improbable events to account for the origin of life. Furthermore, since the metabolism of such a primitive system is primarily determined by the catalytic properties of compounds rather than by their initial concentrations, metabolic systems of a similar kind might arise in any large solution of organic compounds, relatively independently of the exact initial composition of the system, given a suitably coupled energy source. If bodies similar to the earth occur elsewhere in the universe, the occurrence of life with very similar properties may therefore be cosmologically a common event.

[1] A. I. Oparin, *The Origin of Life* (New York: Dover Publications, 1953).
[2] H. C. Urey, these PROCEEDINGS, **38**, 351, 1952.
[3] S. L. Miller, *J. Am. Chem. Soc.*, **77**, 2351, 1955.
[4] W. von Langenbeck, *Advances in Enzymol.*, **14**, 163, 1953.