PALEOBIOCHEMISTRY

Fauna from a thin soup

An amazingly small number of chemical building blocks and mechanisms were needed to begin life on earth

by Ann Ewing

"... It is often said that all the conditions for the first production of a living organism are now present which could ever have been present. But if (and oh what a big if!) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., present, that a proteine compound was chemically formed, ready to undergo still more complex changes. . . ."

These words of Charles Darwin written nearly 100 years ago on events that may have preceded the origin of life hold, in essence, today's generally accepted ideas on the origin of life. This is that there once was a very dilute mixture, felicitously termed the primeval soup, that contained the basic ingredients necessary for the first living organism.

The essential ingredients, on which most scientists investigating life's origins agree, are water, ammonia, methane and hydrogen. These somehow combined to form an entity capable of reproducing itself, and that entity very gradually grew more complex, by mutation and natural selection.

Most scientists agree that there were no living forms, not even the simplest microorganisms, existing on earth 4.5 billion years ago. Within 2 billion years, however, at least the crust and oceans, as well as the low atmosphere, were teeming with life forms as complicated as the one-celled algae that reproduce themselves in today's laboratories.

Evidence continues to mount that these living organisms resulted from random interactions during hundreds of millions of years among the essential ingredients of the primeval soup, not from an event that occurred only once here on the planet earth and could never occur elsewhere in the universe.

The starting point for evidence supporting this viewpoint is the presumed chemical makeup and interaction of earth's environment some 4.5 billion years ago. If the atmosphere believed to have surrounded the planet then—water, ammonia, methane and hydrogen—were still here now, there would be no life on earth.

The transformation of the atmosphere is believed to have occurred very gradually and to reflect changes in the chemical cauldron, as organic compounds evolved from lifeless combinations of carbon and other elements into ancestral forms of life capable of reproducing themselves.

That organic compounds can be formed in the agreed-on primitive atmosphere was first demonstrated by Dr. Stanley L. Miller, now at the University of California at San Diego in La Jolla, while he was at the University of Chicago in 1953, working under the direction of Nobelist Dr. Harold Urey, who is now a professor-at-large at the University of California.

Dr. Miller exposed mixtures of methane, ammonia and water to various forms of electrical energy, some for as long as 10 days. The result was a mixture of such varied organic compounds as amino acids, sugars and vegetable acids. Similar experiments with differing mixtures and other forms of radiation were soon tried in laboratories all over the world and are still underway today, especially in the United States, the Soviet Union and Japan.

The great variety of starting points that have been used in these experimental syntheses is a strong argument for the contention that early pre-life forms could have been created under many conditions.

The original experiment by Dr. Miller and subsequent ones by a host of chemists and biochemists demonstrate not only that Darwin had the right idea but that the theories expressed independently in the 1920's by a Russian and a British scientist were correct approaches to the origin of life.

Aleksandr I. Oparin, a Russian biochemist, in 1924 first explained life's beginnings in terms of the necessary biochemistry under presumed primitive conditions, with special emphasis on the oceans and changes in earth's primitive atmosphere. Five years later, J. B. S. Haldane put forward essentially the same ideas independently.

There is growing evidence that the intermediate organic molecules characteristic of life, mostly carbon and nitrogen compounds of moderate complexity such as adenine and the amino acids, can occur in other places than on earth —notably the asteroids from which some meteorites are derived.

According to Dr. J. D. Bernal of the University of London, an expert on crystal structure and author of the book, "The Origin of Life," the next experimental step is the polymerization of the intermediate organic molecules. This decisive event ends in the formation of complicated biochemical compounds, "ordered polymers, the nucleic acids, the proteins and at least some of the complex and varied processes by which the latter are produced from the information contained in the former."

Explaining how these true precursors of life were formed is exceedingly difficult, since there are as yet no experiments to guide researchers.

The third stage, Dr. Bernard says, is from polymer to organism—"the passage from a mere living area of metabolizing material without specific limitations into a closed organism which separates one part of the continuum from another, the living from the non-living."

That stage is also shrouded in mystery, although some light on it is coming from fossil records that regularly push back the oldest known date for the existence of living forms. The earliest record for what may have been living things was found in a piece of South African rock by Dr. Elso S. Barghoorn and J. William Schopf of Harvard University, who found that biochemically complex organisms were in existence over 3.1 billion years ago.

Their latest studies of pre-Cambrian sediments, reported in the February PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, indicate that amino acids they found in fossils from 1 billion to 3 billion years old have the same composition as living systems today and, therefore, that the basic constituents of life have not changed significantly since very early in biological history.

The essential event from which most others in the origin of life can be dated was the advent of photosynthesis, on a scale large enough to influence the atmosphere and both fill it with oxygen, and top it off with a protective shield of ozone that blocks the sun's lethal ultraviolet radiation. The time of this change-over correlates with the appear-

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ance of cells, and suggests the existence of sophisticated biochemical reactions.

A major contributor to today's understanding of the photosynthetic process is Nobelist Dr. Melvin Calvin of the University of California at Berkeley. Using radioactive carbon, Dr. Calvin and his co-workers have traced the essentially complete path of the absorbed carbon dioxide through the very complex series of intermediate compounds to the final product—carbohydrates, fats and proteins. This elucidation of the key process of photosynthesis includes some understanding of how and how much energy is used in each step.

One result of the photosynthetic process is the formation of hydrocarbons, which many regard as the truest markers in early organic chemistry. Oils of biological origin contain parts of the chlorophyll molecule, particularly phytane and pristane. Both of these are isoprene derivatives and are found in rocks some 3 billion years old, as ancient as any known fossils.

Dr. Calvin and Dr. Philip Abelson, director of Carnegie Institution's Geophysical Laboratory in Washington, are investigating the chemical make-up of ancient hydrocarbons, a field known as paleobiochemistry.

Dr. Abelson suggests that the generally accepted model of the earth's early atmosphere is not consistent with geological and geochemical evidences. He proposes, in lieu of a methane-ammonia environment, that the poisonous chemical hydrogen cyanide was the principal ingredient of a very thin soup (SN: 12/24/66 p. 527).

Under certain conditions, Dr. Abelson notes, "the chemical step from primitive materials to an enzyme like ferridoxin may be very short," since it is an unusually simple protein containing only 55 amino acids. The functions of ferridoxin are basic to cell chemistry, and the compound occurs in both photosynthetic and nonphotosynthetic organisms.

Dr. Sidney Fox and his colleagues at the Institute for Molecular Evolution at the University of Miami are convinced that the heat from volcanoes or hot streams was sufficient to cause formation of amino acids. They have substantiated this theory by producing 14 of the 18 amino acids most commonly found in proteins, after passing atmospheric elements through a variety of solid materials including sand, volcanic lava and alumina, at temperatures of 950 to 1,050 degrees C.

Whatever theory may prove correct eventually, scientists are becoming increasingly impressed with how few mechanisms and building blocks appear to be involved in the origin of life.