Origin of Life

In an International conference on the origin of life on earth in Moscow, the Russian Biochemist A.I. Oparin (1968) stated that life is a special form of matter in motion arising in an orderly manner at a certain stage in the evolution of matter. According to Korn and Korn (1971), a living system is a physicochemical system capable of elaborate polymeric synthesis directed in specific patterns by information contained in a polymeric form (nucleic acid) which is capable of changing to other controlled patterns at more efficient levels of environmental exploitation.

Origin of life is one of the most fascinating problems in biology.

Most of the biologists of today believe that life might have originated on the earth sometime in the remote past from non-living substances. But how did it so happen? Nobody could reply this question properly and none has succeeded in creating living organism from non-living matters.

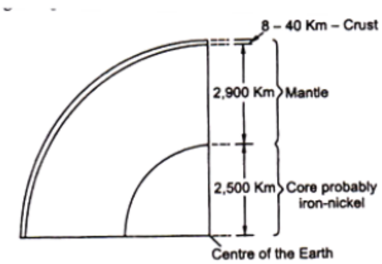
The explanations which some early biologists and philosophers have proposed in this regard are baseless and rather highly fantastic.

It is only in the twentieth century the biologists started thinking over the subject deeply and have analysed the problem scientifically and some of them have provided plausible conclusions. Modem biologists do not believe in discontinuous origin of life. They are of the view that life was eventual outcome of long process of chemical evolution which took place during the early stages of the earth's history.

The modern concept or the naturalistic theory suggests that there was no trace of life on this planet about two billion years ago. The earth originated sometime about 4.5 billion years ago either as a part shot out from the sun or in the form of interstellar gas cloud.

Urey (1952) postulated that the earth cloud originally contained chiefly hydrogen, methane, inert gases, a large number of iron compounds, ammonia, silicates etc.

Most authorities believe that the earth originally was a very hot and homogeneous gaseous ball. That in due course of time cooled down due to cosmic cooling effect and as a result of the cooling three zones viz.. Core (radius 2500 km. from the centre), mantle (about 2900 km. above the core surface) and solid crust (about 9 to 40 km. above the mantle) became differentiated.



<u>Formation of core, mantle of earth</u>

The crust is the superficial solid zone of earth sphere, the mantle is the middle zone which is still in molten condition and earth core is the central part that is most possibly in vaporized state.

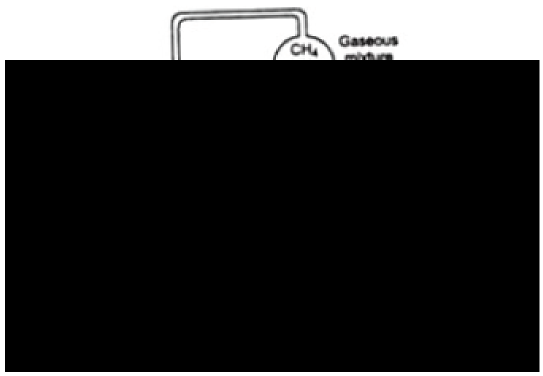
The conditions on the primitive earth were not suitable for life as free oxygen was not available in the earth's atmosphere. All the oxygen was in combined state, either in the form of water or as

oxides of other elements. It is perhaps about 2.5 billion years ago that conditions consistent with life developed.
In the cooling process several physical changes took place in the earth and as a result of these changes, oceans and mountains were formed. Side by side, innumerable continuous chemical reactions were going on. Water which was formed first was not in the liquid state but remained in vaporized state for very long time. The water vapour accumulated and became condensed to form dense cloud around the earth.
The water vapour on cooling precipitated in the form of rain drops. Rain drops on reaching the hot surface of earth became instantaneously vaporized and the vapour again accumulated to form clouds. Continuous and prolonged raining made the surface of earth more cold. Then the rain water accumulated in the low areas and formed oceans on the earth.
Countless volcanoes and fissures continuously gushed methane, steam, ammonia and perhaps carbon dioxide which accumulated around the earth and formed earth's first atmosphere. That air contained four main elements of life, carbon, hydrogen, oxygenand nitrogen which were in the form of gases deadly to present day life.
Moreover the atmosphere was flooded with short wave cosmic radiations or ultraviolet radiations and was stabbed by incessant lightning. This is the brief history of origin of earth and its atmosphere. Now the question arises as to how life originated on this earth in this elemental turmoil.

In the year 1924, A.I. Oparin, a Russian academician and biochemist, put-forth the concept that living matters might have originated from the non-living or inorganic matters. The same view was also expressed by J.B.S. Haldane and R. Bentner.
Oparin published a fascinating book. The Origin of life in 1936, in which he stated that in the first place carbon must have been present in the atmosphere primitive earth in the form of hydrocarbons and not in the form of CO .
Hydrocarbons might have united with other compounds to produce a variety of organic compounds, such as, alcohols, aldehydes, carboxylic acids and so on, and some of carboxylic acids could react with ammonia to form amino acids, the basic molecules of life.
Dr. Haldane, an English biochemist, wrote that the first formed substances must have been stored in the primitive oceans before life originated in them. He called such compound laden oceans "a hot dilute soup". He also suggested that on exposure to ultraviolet radiations the inorganic compounds should have been converted into organic compounds, such as, amino acids, polypeptides (proteins) and so on.
At one time, scientists believed that organic compounds could be produced only by living system, but since 1950 the scientists are striving to demonstrate experimentally that basic molecules of life could have emerged under primitive sets of conditions on earth.
Dr. Melvin Calvin of California University irradiated a mixture of CO and water vapour using cyclotron and obtained some organic compounds particularly formic acid, oxalic acid and succinic acid with one, two and three carbon atoms respectively. These are metabolic products of living organisms. Dr. Harold Urey, atomic scientist, in those days at the University of Chicago

reasoned that if hydrogen, ammonia and methane were probable constituents of primitive atmosphere of earth, what would happen if these gases were placed in a flask and intermittent electric discharge was passed into it.

In 1953, Stanley Miller, a student of Dr. Urey performed one such experiment in which he exposed a mixture of water vapour methane, ammonia and hydrogen gases to continuous electric sparking for a week and at the end of the experiment he found sugars, aldehydes, amino acids, such as glycine, alanine and a number of more complex organic compounds.



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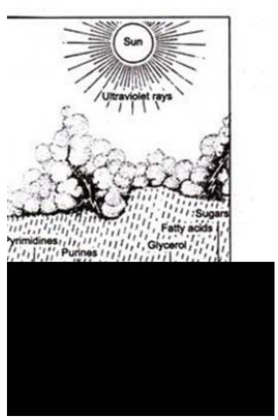
<u>Miller's Experiment</u>

These experiments provided clue that such complex organic compounds were formed in the atmosphere as a whole in the remote past during continuous rains and lightning. Cosmic radiations might have made the course of reactions more easy by supplying tremendous energy required in the processes.
These substances entered into solution. Life came into being as weak organic liquor. Now at this juncture after knowing the probable ways in which amino acids and other complex organic molecules were formed, one would question as to how proteins were formed from these amino acids and how the proteins would have given rise to first living cells?



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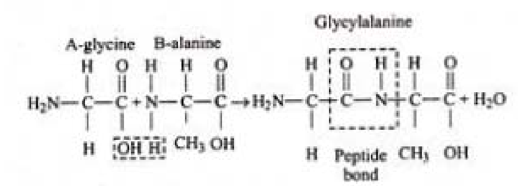
These two questions are puzzling the scientists all over the world and satisfactory explanation for them are yet to come out. Dr. Sidney Fox of the Institute of Molecular Evolution, Miami Florida, and Dr. George Wald of Harvard University have recently tried to supply some reasonable explanations for the above questions.

Blume (1957) and Dr. George Wald have pointed out that under pre-biological conditions, pools containing dissolved amino acids might have dried up because of high temperature of primitive earth and that primitive amino acids could have formed long polypeptides or primitive proteins under the influence of solar energy.

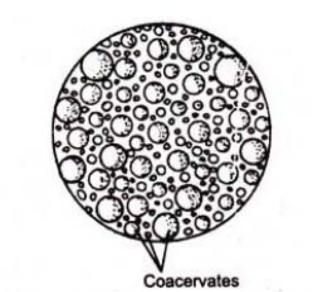
The following reaction illustrates the formation of polypeptides from amino acids:



Dr. Fox and Harada (1958) have demonstrated some such reactions in the laboratory by exposing a solution of amino acids at 170°C for evaporation. What they actually found in the experiment was that many amino acid molecules became linked up forming long thread-like sub-microscopic structures, the proteinoids. At least twenty different amino acids are known to take part as the synthesis of life proteins. These aminoacids unite in different ways to form various types of body proteins.

In 1963, one simple experiment was conducted to demonstrate formation of polypeptide chains. When oxygen was bubbled through artificial sea water containing dissolved amino acids, polypeptide chains with molecular weights as much as 3700 appeared. Peptide formation by this means possibly occurred in sea water but never in fresh water. The primitive proteins came long before living cells appeared on the earth. It is presumed that precisely ordered protein molecules of present day plants and animals would have taken many years in acquiring the definite sequence of amino acids. Phosphates present in natural bodies of water, fresh or salty, when combined with amino acid many things became possible. Nucleotides were formed leading to developments of energy transfer systems, such as ATP – ADP and to nucleotide chains.

Dr. Calvin has estimated that molecular life must have evolved about 2 billion years before the first living cell appeared. Fox, Harada and Kendrick (1959) have reported cat a large number of small uniform microscopic elastic ferules with firm outline were formed when hot saturated solution of proteinoides was cooled down.



These ferules behaved in many ways like bacteria and they clung together in chains as one celled blue green algae sometimes do. Although these spherules are not true cells, as they lack Deoxyribose nucleic acid (DNA) and genes and they are simpler than any other contemporary life, yet they do possess many cellular properties.

S.W. Fox (1956-57) has successfully synthesized uredo-succinic acid, one of the precursors of nucleic acid, by his thermal experiments. Life of proteins in water is very short. So one can expect that spherules of proteinoids could have persisted for a few weeks only.

Among the most effective substances which check the decomposition of proteins are nucleic acids. Perhaps, some nucleic acid precursors such as uredo-succinic acid might have prevented the decomposition of proteins in the primitive pools.

Dr. Fox (1957,1959) has put-forth an interesting hypothesis on the basis of results of his thermal experiments. In this, he suggested that in the pockets of compressed gases rising through the fissures of earth crust, simple compounds combined to form biological staples such as amino acids, vitamins.' Pyrimidines and carbohydrates and these staples likewise recombined to form biological macromolecules, such as, proteins, polysaccharides and nucleic acids involving loss of water and addition of energy. He further suggested that if the gases escaped through fissures in the hot oceans, the proteinoids would have formed the first cell like microsystems containing nucleic acid precursors and proteins.

In fact, life began with the coupling of nucleic acid polymerization with amino acid polymerisation. In this way primitive 'proteinnucleic acid system' bounded by a membrane or the cell wall would have been formed automatically and rapidly from the gases escaping out through the fissures in the earth crust.

Porphyrins which supplied molecular framework for such vital compounds as cytochromes, haemoglobin and chlorophyll must have been formed almost immediately after acetic acid and simple amino acid glycine first accumulated in the primeval ocean, a big step toward living system. Porphyrins are extremely stable at high temperatures and at the same time they form very stable complexes with all kinds of metals. The porphyrins might have been metabolically well active in the earliest and only partly living structures. They are coloured compound they are able to trap the energy of visible light and make it available for chemical conversions and photocatalytic reactions.

It seems reasonably certain that during an enormous period of time, one to two billion years, the conditions outside the first self reproducing units must have approached those found now only within the living protoplasm. During this long period of genesis of life no line could be drawn between the living and the non-living. The solar energy reaching the earth surface underwent highlysignificant qualitative changes. The atmosphere of primitive earth was possibly without free oxygen. The short wave ultraviolet rays (UV-rays) amounting to 5% of the total radiant energy, would have penetrated the atmosphere throughout and would have decomposed methane, ammonia, water and molecular hydrogen into reactive radicals. In these way traces of oxygen started accumulating in the atmosphere. The oxygen of primitive atmosphere absorbed the energy of radiations of I short wavelengths, like UV-rays, X-rays and gamma rays and consequently a part of oxygen, particularly at high atmospheric level became excited to form Ozone layer. Then the UV-rays of solar radiations were progressively absorbed by ozone layer. Thus, the very source of energy responsible for the initiation ozone became gradually cut off from the lower atmospheric levels by virtue of its own deeds. That marked the beginning of next phase of chemical and biological evolution.

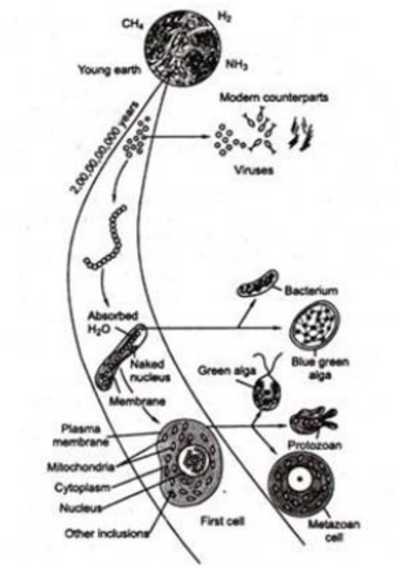
In the course of chemical evolution probably some proteins combined with nucleic acids and formed complex molecules which acquired the property of synthesising the molecules like themselves. Such hypothetical autocatalytic biological macromolecules would have had some of the properties of the viruses or free genes.

The genes arose in such an environment where all the materials required for their multiplication and chemical activities were present. When the protobionts or primitive cells were formed spontaneously, the DNA-RNA-Protein system became established and with this a variety of control mechanisms were also generated. Replication of DNA and division of primitive cells became integrated.

The primitive cells at some definite stage of growth automatically divided to form daughter cells. The newly formed cells resembled in all respects to their parents (reproduction property). The first living cells which originated in the oceans were heterotrophic in nature. The organic molecules present in the primitive oceans were source of energy and food for the growth and reproduction of those cells.

The primitive heterotrophs could survive only as long as the supply of organic molecules in the oceans existed. In the course of evolution new molecular machines and metabolic processes must have been added to first formed cells. The most important among them was the process of photosynthesis which changed some of the heterotrophs into autotrophs. The autotrophs started Synthesizing carbohydrates from free carbon dioxide and water liberating large quantity of oxygen. In this way, the photosynthetic machinery provided a new source of food for life and changed the atmosphere into an oxidising one.

The history of cellular forms of life could be traced back to the pre-cambrian period of geologic time, some 3000 million years ago. During the most part of that long period, the only inhabitants of the earth were simple microscopic prokaryotic organisms, many of which could be compared with modern bacteria.



Origin of first organism

The conditions under which those organisms lived were entirely different from those of today. Genetic variations made some individuals better adapted which survived and reproduced in a given environment. The emergence of new forms of life through this process of natural selection was influenced by the changes in the physical environment.

The development of oxygen generating photosynthetic process and accumulation of oxygen released as a by-product of photosynthesis in the atmosphere affected a new cycle of biological adaptation. In due course of time eukaryotes, a new type of cellular forms emerged in which genetic material was aggregated in a distinct nucleus having well defined nuclear membrane. Such nucleated cells were highly organised and were capable of sexual reproduction, the process whereby the genetic variations of the parents can be passed on to the offsprings. Gradually the large complex multicellular forms of life came into being.

The first evidence of the occurrence of fossil microscopic plants resembling the modern blue-green algae and bacteria was reported by A. Tylor (1954). In the recent years such micro fossils have been collected from a number of fossils ferous localities in the world and they throw sufficient light on the early history of origin of life. Much information has been obtained from the fossil remains of early microorganisms, and their size, shape, and degree of morphological complexity are among the most easily recognized features. Comparison of the metabolism and biochemistry of prokaryotes and eukaryotes provide strong evidence that the latter group arose only after the accumulation of oxygen in the atmosphere.

The microfossils present a variety of morphological complexities such as:

(i) Branched filaments made up of cells resembling modem fungi or green algae.

(ii) Fossils of unicellular algae containing intracellular membranes and small dense bodies.

(iii) A group of 4 spore-like cells in a tetrahedral fashion resembling some algae.

(iv) Spiny cells or algal cysts resembling some modem eukaryotic organisms.

(v) Highly branched filaments of large diameter similar to those of eukaryotic algae.

(vi) Spheroidal microfossils having two layered walls.
(vii) Tetrahedral group of 4 small cells resembling spores of some green algae.
Cyanobacteria are of particular interest as they might have been responsible for the development of an oxygen-rich atmosphere. Like higher plants, cyanobacteria carried out photosynthesis in which energy of sunlight was used to make carbohydrates from water and CO and molecular oxygen' released as a by-product. Although the biochemistry of the cyanobacteria differs from that of green eukaryotic plants, it suggests that the group originated during the time of fluctuating O concentration.
Early prokaryotes were capable of fixing nitrogen. The enzyme nitrogenase necessary for fixation of nitrogen was produced in the thick walled cells resembling heterocysts of some blue-green alga. It is likely that the capability for N -fixation in primitive prokaryotes developed early in the pre-cambrian and in anenvironment where fixed nitrogen was in short supply.
Some nitrogen-fixing organisms became adapted to an anaerobichabitat. By the time eukaryotes appeared, O and fixed nitrogen were enough in the atmosphere, so the eukaryotes never produced enzymes required N – fixation.
In all the bacteria photosynthesis is anaerobic product and O is not evolved as a by-product. Anaerobic photosynthesis evolved in primitive bacteria early in the Pre-cambrian when there was no O in the atmosphere.
In due course of time, such bacteria gave rise to the first organisms capable of aerobic photosynthesis, the precursors of modem cyanobacteria. The anaerobic bacteria became adapted to habitats where there was less light and lower concentration of oxygen. Many photosynthetic bacteria occupy such a habitat even today.
There are still such organisms living today as are closely related to the earliest forms of life. Thus, it appears that oxygen must have been freely present in the early atmosphere when first eukaryotic cells appeared probably 1400 to 1500 million years ago. Evidence comes from the study of minerals which contain oxygen. Modem biochemistry, geology and minerology have further supported the history of pre-cambrian life.
The most primitive forms of life where probably spheroidal prokaryotes comparable to modem bacteria of Clostridium group.
In the beginning those prokaryotes derived their energy from the minerals which were organic in nature, but of non-biological origin.
The appearance of aerobic photosynthesis resulting in the increase in the oxygen content introduced a change in the global environment during the mid pre-cambrian. This led to disappearance of many anaerobic organisms. With the development of citric acid cycle and release of energy from foodstuff, the dominance of aerobic organisms in the biological community confirmed.
The diversity of eukaryotic forms suggests that some forms of sexual reproduction might have evolved. Within the later 400 million years, the rapid diversification of eukaryotes had led to the emergence of multicellular forms of life and some of them were similar to modem plants and animals. Mutations must also have played good role in the evolution of primeval life from time

to time. The periodical mutations or changes in the cells provided it with new enzymatic compounds which controlled the inheritance of characters. Thus, the new individuals possessing these new physiological , characters wouldhave had better enzymatic reactions and better buffering or new sources of food.

In summary, the origin of life may be seen as taking place in six stages:

(i) Anaerobic phase rich in hydrogen and with energy entering the system as ultraviolet rays, ionising radiations, potential chemical energy and local heat which was responsible for the initiation and accumulation of organic substances of the sort now universally utilized by living cells in building up their own vital constituents.

(ii) Anaerobic phase poor in hydrogen when slow accumulation of molecular oxygen blocked the penetration of short-wave ultraviolet rays. Under the influence of short-wave ultraviolet rays some of the oxygen particularly at high atmospheric level assumed a state of excitation and became ozone which progressively absorbed short-wave ultra violet rays. Thus the very source of energy which initiated and promoted the most important reactions became cut off from the lower atmosphere by virtue of its own activity. Then the visible light reaching the earth atmosphere and organic chemicals were the main source of energy and the organic substances became more and more complex and diverse.

(iii) Simple anaerobic organisms distinguishable from their surroundings such as purple bacteria came into existence in a way difficult to imagine.

(iv) Depletion of accumulated organic substances from the environment by anaerobic micro organisms of the early period with anaerobic photosynthesis utilizing visible light as the energy source. Thus, intense competition was set in among the organisms, as a result of which one particular kind of microorganisms outgrew and out-multiplied all other kinds, setting the stage for further evolution.

(v) In the next stage, chance combination of porphyrins and manganese-protein complexes probably led to the formation of chlorophyll and then the photosynthesis of the kind typical of green plant cells became dominant with accompanying liberation and accumulation of free oxygen into the atmosphere and water caused gradual disappearance of anaerobic organisms except those that escaped into oxygen-free region in the soil and elsewhere.

(vi) In the sixth stage, oxygen itself became an evolutionary force which caused extinction of most anaerobic microbes and at the same time enabled achlorophyllous descendants of green cells as animal organisms to make use of the vast energy potential of the biological oxidation of organic substances. The spontaneous origin of life in present time seems impossible, yet all those events, which occurred in the past, are quite possible at present. Why spontaneous origin of life seems impossible in the present time?

There are two main reasons for this which is as follows:

1. The accumulation of organic molecules seems impossible in present set of conditions because bacteria, moulds and living things of other kinds will attack on these substances and will make them disappear soon.

2. The presence of free oxygen in the atmosphere will cause quick oxidation of organic molecules. The above two factors present in the modem biological environment were not available in the prebiotic times. If the modem theory of origin of life is correct then one can hope that conditions for the origin of life must exist on some other planets also and there the probability of existence of life can be expected.

Wherever life is possible it should appear and ramify into a wide range of varieties, some of them may be quite similar to those which are found on this earth but others may be quite dissimilar to the forms of life existing on this planet.