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Review Article

The Origin of Life on Earth-Viruses and Microbes

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Abstract

Origin of life on the earth is a mystery. Nobody exactly knows how the first life appeared on the earth. However, it can be assumed that the basic constituents of life like Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorous and other inorganic substances combined in a proportion to create first life on earth. Probably the origin of life started from the production of purine, pyrimidine rings, amino acids, sugar alcohols, nucleic acid chains and the first life on earth is prokaryotic microbes which probably evolved from the virus like particles. Structure of viruses which are lacking the cytoplasm and definite cellular structure but containing nucleic acid core and protein covering are the proof that nucleic acid strands were first produced and later on, in presence of water they evolved to produce the desired products to form cytoplasm and biological membrane to create primitive cell. To explain the systematic assembling of all the basic structural elements leading to a structural unit with functional autonomy with bio-chemical synthesis, degradation (metabolism) , energy production, self-replication which can be called "nano-scale organization", a hypothesis has been proposed which is called Random Collision, the Association, Rejection with the Acquisition of Added characteristic Hypothesis which can explain the creation of first functional unit of life as a virus like particle and later on prokaryotic microbes and with the help of Darwin's theory of evolution it can be explained that this first functional unit of life later evolved into more complex multi-cellular living forms.

Keywords: Origins of Life; Random Collision; Acquisition of Added Characteristic; Functional Autonomy; Purine and Pyrimidine Ring; Systematic Assembling

Introduction

Origin of life on earth is the most mysterious & debatable thing in the field of scientific research. From several evidences of the fossilized microbes (cyanobacteria) in Stromatolytes it can be presumed that first life in earth probably originated in between 3.5 to 4.4 billion years ago [1,2]. But it is sure that the basic constituents of life like Carbon, Hydrogen, Nitrogen, Phosphorous, Oxygen and other inorganic substances combined in a proportionate way to create first life in earth, though there is a controversy between "Genetic-first" approach or "Metabolic-first" (Energy acquisition) approach or the "Compartmentalization first" approach for the emergence of life on earth. From several evidences it can be assumed that oxygen was not present in early earth's atmosphere and probably the primitive organism in earth was the heterotrophic bacteria. It is known that for any chemical reaction to occur an optimum temperature, pressure, catalyst, reagents are required. When present in suitable proportion and the required activation energy is reached, the reaction can occur and the desired product is formed. In the pathway of gradual transformation of Abiotic to Biotic earth, probably the origin of life started from the first production of amino acids, purine, pyrimidine rings, sugar alcohols, nucleic acid chains and other basic components of life. The first life on earth was prokaryotic microbes which probably evolved from the virus like particles. When a process progresses gradually step by step through a long period of time, the intermediary steps may persist as a proof that the process progressed through these steps. Following this logic, it can be said that the structure of viruses which are lacking the cytoplasm, definite cellular structure but containing nucleic acid core, protein covering are the proof that nucleic acid strands were first produced. Later on, in presence of water they created the desired products to form cytoplasm only after being enclosed by a biological membrane to create primitive cell or protocell. But before that chemical evolution took place leading to the embedment of structural information in chemical entities with

information storage, retrieval, transfer and processing of information through charge transfer in donor-accepter sequences which is a well-organized, highly efficient, directional and specific electron transfer process [3-5].

Moving backwards to the history of research in the field of origin of life, early philosophers and naturalists believed in spontaneous generation to explain the origin of life, but later on Lewis Pasture disproved the idea by showing that bacteria can grow only from bacteria or bacterial spores. After that, scientists adopted the idea that living organisms were the historical outcome of gradual transformation of lifeless matter. The heterotrophic origin of life was proposed by Russian biochemist Alexander Ivanovic Oparin [6] and British biologist B.S. Haldane [7]. They proposed the idea of a primordial protoplasm and hypothesized that life had been preceded by a lengthy period of abiotic syntheses and accumulation of organic compounds from the "hot primitive soup". At the initial stage earth's environment was anaerobic and the primitive organisms must have been heterotrophic bacteria. Later on, Miller-Urey experiment [8] strengthened the hypothesis that "generation of the first living organisms might have taken place if large quantities of organic compounds had been present in the oceans of the primitive earth." Electric discharge of thunder storm and UV radiation from our solar system might have played a significant role in the primitive atmosphere containing ammonia, methane, nitrogen, hydrogen, water etc. to produce amino acids and other complex components of the life in soupy sea [8,9].

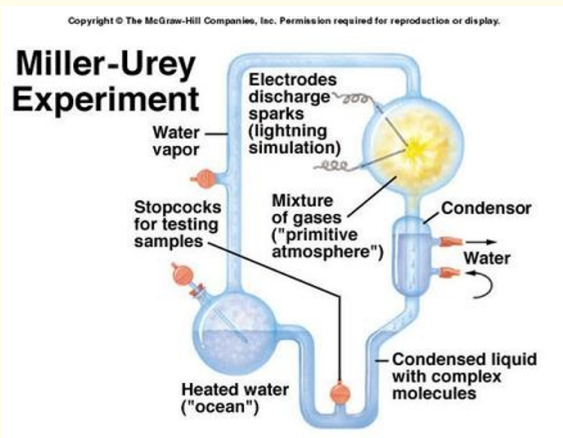

Figure 1: Miller- Urey Experiment (copyright @ McGraw-Hill Companies, Inc).

The Miller's paper (1953) was published only a few weeks after Watson and Crick's [10] classic article revealed their double helix model for the structure of DNA [10]. So, when Oparin & B.S. Haldane proposed the idea of "hot primitive soup" and Miller-Urey performed their experiment, that time knowledge of Genetics was limited. So, later on with the development of Biochemistry and Molecular Biology, scientific trends towards the understanding biological phenomena at the molecular level led authors like Troland [11], Muller [12] and others to propose that single molecules or viruses represented primordial living systems [11,12]. Muller proposed the "naked gene" theory for the origin of life. Later on "RNA hypothesis" of origin of life first proposed in 1968 by Leslie Orgel, supported by Crick and later on the term coined by Walter Gilbert in 1986 favors the assumption that RNA can simultaneously act as an enzyme (Ribozymes) and also as a storehouse of genetic informations [13]. However, from the 1960s onwards, scientists studying the origin of life split into camps. According to Sutherland the basic polarization was between the proponents of "metabolism-first" versus "genetics-first" theory. Meanwhile, a third group proposed the idea that "Compartmentalization must have come first, because there is no point doing metabolism unless it is compartmentalized." "Compartmentalization-first" – has its supporter in Pier Luigi Luisi of Roma Tre University in Rome, Italy. Luisi's reasoning was simple and hard to be argued as the evidence supporting the presence of lipid molecules in the prebiotic environment and their natural ability to self-organize into vesicular compartments cannot be denied [14]. Though till now the researches in these three directions have not shown any promising results towards unraveling the mysteries of first origin of life on earth, in this current paper a new theory has been proposed following the rules of nature, which may help in making the total process of creation logically more comprehensible and the theory is- Random Collision, the Association, Rejection with the Acquisition of Added characteristic Hypothesis.

Metabolism-first theory vs Genetic-first description of life

Metabolic-first approach for the origin of life requires the confirmation that metabolic (or protometabolic) routes can replicate and evolve. But so far there are no indications that this is the case and on the contrary the available experimental evidences strongly suggest that the prebiotic environment was already endowed with a wide range of monomers of biochemical significance, many organic and inorganic catalysts, purines and pyrimidines, i.e., the potential for template-directed polymerization reaction, and membrane-forming compounds, so the genetic first description of life

is more pragmatic. Indeed, the evidence supporting the presence of lipid molecules in the prebiotic environment and their natural ability to self-organize into vesicular compartments underlines the significance of theoretical models of simple cells involving an evolving ribozymic RNA polymerase [15].

Genetic-first description of life in the context of present hypothesis

In this paper to make the total process of creation logically more comprehensible, the origin of life has been divided into three steps- Step I – Formation of basic structural elements or building blocks of life like purine and pyrimidine rings, amino acids, glucose, phosphate energy bonds etc. Step II – Formation of more complex structural forms by chain elongation of basic structural molecules. Step III –Systematic assembling of all these structural elements leading to a structural unit with functional autonomy where all the biochemical reactions can occur automatically, repeatedly in an organized way, making it an autonomic functional unit (nano-scale organization) capable of recognition, sensing, signaling, bio-chemical synthesis, degradation (metabolism), energy production, self-duplication (reproduction), homeostasis and information dissipation. To explain this nano-scale organization more easily, a new hypothesis has been created which is called Random Collision, the Association, Rejection with the Acquisition of Added characteristic Hypothesis.

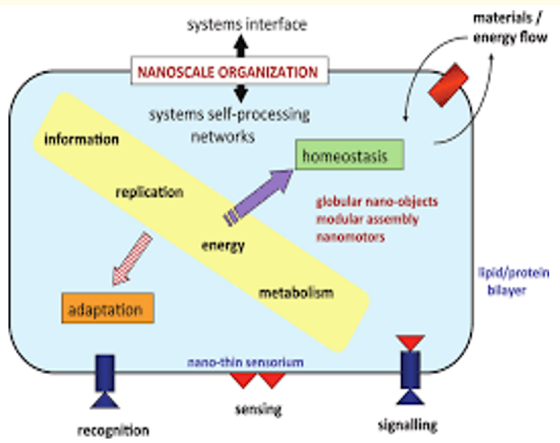

Figure 2: Cellular Organization (taken from- Stephen Mann, Systems of Creation: The Emergence of Life from Nonliving Matter, Accounts of Chemical Research, Nov 4, 2011).

In this context it is worth mentioning that the above mentioned Step I can be explained by the Miller-Urey Experiment where Stanley Miller in conjunction with fellow scientist Harold Urey, in 1953 first demonstrated the spontaneous synthesis of amino acids and organic compounds that are required as the basis of life on Earth, from the inorganic precursors and the simplest of organic molecules like ammonia, nitrogen, methane, hydrogen, water etc.

It can also be explained by the heterogeneous catalysis of the Fischer–Tropsch CO/H_2 reaction on silicon/metal oxides to form amino acids and nucleobases [16].

But the most difficult part is to explain the Step II and Step III. How the formation of more complex structural form by chain elongation & how the systematic assembly of these parts occurred to achieve functional autonomy, forming the first living form? To explain the formation of more complex structural form by chain elongation, it can be said that the purine, pyrimidine ring has some unusual property of organizing and assembling carbon, hydrogen, oxygen and nitrogen molecules in a systematic way. "RNA hypothesis" of origin of life favors the assumption that RNA can simultaneously act as an enzyme (Ribozymes) and also as a storehouse of genetic information's. It is also known that uridine ring, the phosphate bond (UMP, UDP and UTP) and adenine ring in Co-enzyme-A help in the polymerization of carbohydrate and fatty acid chains respectively. It is an important aspect that purine and pyrimidine ring creating the mRNA and tRNA helps in the polymerization of amino acids creating protein molecules which are the building blocks of life. The form in which the energy is stored in biological world (ATP) is made up of nucleotide and phosphate. So, it strengthens the idea that purine & pyrimidine rings, phosphate bonds are the key structures towards the creation of life. Though the chain elongation towards the formation of more complex form can be partly explained, the most difficult part is to explain how the systematic assembly of these parts occurred in such a complex, organized way to achieve the functional autonomy, forming the most incredible and mysterious form of thing in the universe which is life. It can be easily challenged that life as a single cell is several times more complex than a computer CPU!!

According to this newly created hypothesis- Random Collision, the Association, Rejection with the Acquisition of Added characteristic Hypothesis, it can be said that at the beginning of the creation, just like inorganic molecules randomly come in contact with

each other, in the similar way bio-molecules also came in contact with each other at random. As it is known that the bio-molecules have some affinity to each other if suitable condition prevails (just like a positively charged compound can be attached to a negatively charged compound), the combination occurred through charge transfer or electron sharing in donor-accepter sequences at random following the rules of permutation & combination in the primitive soup of Alexander Oparin [6] and B.S. Haldane [7]. For example---

"A" combining with "B" forming "AB", next "B" combining with "C" forming "BC" & so on

A + B = AB

B + C = BC

C + D = CD

D + A = AD

Now when "A" combines with "B" forming "AB" & if "AB" can acquire some extra property by which it can combine with another molecule "XY" to form "ABXY" with some added advantages then automatically it was selected by nature.

On the contrary, if "B" & "C" after combining to form "BC" do not acquire some extra property or added character to combine with "XY", then it was rejected. So this chain-wise selection & rejection processes can explain how it proceeds further to form more complex molecules. Whenever a new structural form was produced, if it acquired some extra functional capability or added advantages over other ones, it was automatically selected by nature. Whereas the combinations that did not acquire some extra functional capabilities, did not proceed further.

Example 1

AB+ XY ----------> ABXY +αβ ----------> ABXYαβ + γδ ----------> ABXYαβγδ

If A acquires extra characteristics by combining with B forming AB & similarly if AB acquires extra characteristics by combining with XY forming ABXY & similarly if ABXY acquires extra characteristic by combining with αβ forming ABXYαβ and if ABXYαβ with extra characteristic combine with γδ and proceeds further in a sequential way, then AB, ABXY, ABXYαβ, ABXYαβγδ and in this way more complex form will be produced.

Example 2

AB+ XY ----------> ABXY + γδ ----------->ABXYγδ ----------->Ÿ

Here AB acquires extra characteristics by combining with XY but ABXY does not acquire extra characteristic after combining with γδ. So, it proceeds to form AB, ABXY & ABXYγδ. But as it does not acquire extra functional characteristics after combining with γδ, so it does not proceed further from ABXYγδ. In each step, specific way of electron sharing or electron transfer, different type of bond formation (covalent bond, vander - waal bond, disulfide bond, hydrogen bond etc.) played a crucial role towards the formation of more complex form which needs a lot of further researches in this field.

So in this way, following the nature's rule it can be explained that bio-molecules by random collision, then combination and then acquisition of some functional capability, proceeded towards the more complex form with extra functional capability through the process of well organized, highly efficient, directional and specific electron transfer processes in donor-accepter sequences and ultimately led to the formation of living form with complete functional autonomy with information storage, retrieval, transfer and processing of information.

Step by step by random association, selection and rejection, it acquired the step by step functional capability. From the structures of viruses it can be depicted that before the origin of fully developed unicellular organisms only the RNA and then DNA core was developed with limited functional capability of producing few structural proteins, enzymes and in presence of water later the nucleic acid core evolved to form more complex form to produce all the necessary components of cytoplasm, cell membrane and other necessary enzymes to evolve into an independent existing cell. Here the Darwin's theory of evolution helps in explaining the development of higher living forms from the primitive cell or protocell.

Discussion

With the help of this theory- Random Collision, the Association, Selection, Rejection with the Acquisition of Added characteristic Hypothesis, Oparin's primitive soup, Miller-Urey's experiment, Muller's "naked gene" and Orgel and Walter Gilbert's "RNA world" can be connected.

However, it is worth mentioning here that the problem arose with the "RNA world" hypothesis in between 1980 to 2011 when

Jack Szostak, David Bartel, [15] Philipp Holliger, Gerald Joyce and Tracey Lincoln in separate experiments in their laboratory created RNA enzymes (R18, tC19Z) that replicates itself but can copy sequences up to 6 to 48% of its own length, but not necessary 100%. So, RNA has proved to be enormously difficult to make and the problem is the sugar and the base that make up each nucleotide. It is possible to make each of them individually, but the two stubbornly refuse to link together.

So, it was thought that there might be some other type of molecule on the early Earth: something simpler than RNA, which really could assemble itself out of the primordial soup and start self-replicating. This might have come first, and then led to RNA, DNA and the rest. In 1991, Peter Nielsen [17] of the University of Copenhagen in Denmark came up with a candidate for the primordial replicator. It was Polyamide nucleic acid, or PNA where the backbone of the molecule was made up of Polyamide instead of Ribose sugar. PNA can coil up into a double helix, just like DNA and Stanley Miller also thought that PNA was a more plausible candidate for the first genetic material. In 2000, Albert Eschenmoser [18] made another nucleic acid named Threose nucleic acid (TNA) which is basically like DNA, but with a different sugar in its backbone and can pair up to form a double helix, and information can be copied back and forth between RNA and TNA and in 2005 Eric Meggers [19] made glycol nucleic acid, which can form helical structures.Though each of these alternative nucleic acids has its supporters, but as there is no trace of them in nature, so it is very difficult to say whether the first life did use them or not at all.

However, it can be said that studies of more specific conditions, including the laboratory simulation of localized environments such as volcanic islands, tidal zones and micro-environments, including liposomes, clays and mineral surfaces, montmorillonite (James Ferris, 1986) and volcanic ponds, which could have been prevalent in the primitive environment, may yield promising results [20].

Now if come to the currently described theory which is based on nature's rule- Random Collision, the Selection, Rejection with the Acquisition of Added characteristic Hypothesis, it can be said that it can explain all the three theories like "Genetic first", "Metabolic first" or the "Compartmentalization first" theory. However, one thing that strikes the mind is what is meant by the acquisition of new functional capability. Bio-molecules in a living cell are interconnected in such a way that as an example it can be said if one interconnecting pathway is linked with the signal transduction, the effector molecule produced will result in a cleavage of another molecule and that cleaved product may be responsible for stimulating a particular gene to produce a final end product by transcription and translation. So, it can be said that all the bio-molecules are interconnected with one another in a finely tuned way or as a finely programmed way which is responsible for several functional outcomes. Here with the help of this selection, rejection with the acquisition of new functional capability hypothesis, it can be said that overall functional capability & structural organization was achieved step by step with the formation of new molecules. In each step the terminal product produced was one step ahead in functional capability from the preceding one, whether it was the formation of trans-membrane receptor or the formation of cAMP or cGMP molecules or the creation of signal transduction pathway or the creation of photosynthetic pigment like chlorophyll. Might be an unique way of electron sharing or electron transfer and different types of bond formation (covalent bond, vander-waal bond, disulfide bond, hydrogen bond etc.) played a crucial role towards the formation of more complex form with information storage, retrieval, transfer and processing of information.

Also, it can be said that as the primitive earth's environment was reduced and probably that time primitive microbes were heterotrophic in nature and only after the generation of photosynthetic pigments and the generation of autotrophic organisms, gaseous oxygen appeared in earth's atmosphere, so in the primitive unknown reduced atmosphere of earth, biochemical reactions might have occurred through different unknown pathways to perform the nano-scale organization.

Conclusion

Though Günter Wächtershäuser's [21] idea of the process of harnessing energy is utterly essential but the metabolic-first approaches requires the confirmation that metabolic (or protometabolic) routes can replicate and evolve and so far there are no indications that this is the case and on the contrary the form in which the energy is stored in biological world (ATP) is made up of nucleotide, so it can be said that the polymerization of nucleotide with the genetic first description of life is more pragmatic and initially the energy source was external from the surrounding environment and later on compartmentalization with the creation of enzyme on the membrane surface to harness energy from the proton gradient across the membrane in the form of ATP is more plausible to believe and one interesting thing is the theory that have proposed following the natures rule - Random Collision, the Selection, Rejection with the Acquisition of Added characteristic Hypothesis, can explain all the three theories like "Genetic first" , "Metabolic first" or the "Compartmentalization first" theory.

Lastly it can be said that though several researchers tried to explain the origin of life supported by the newly developed knowledge of cellular biology, for example Thomas Cech and his colleagues (1982) first discovery of RNA as an enzyme made the Leslie Orgel and Francis Crick's assumption of RNA hypothesis more plausible , and Günter Wächtershäuser's [21] metabolism first hypothesis also acquired reasonable support with the fact that energy is required for survival and Peter Mitchell's [22] clear delineation of proton gradient across a membrane and the stream of protons passing through give the enzyme residing on the membrane the energy it needed to make ATP, so until and unless more discoveries of cellular working pathways at the sub-cellular level come to our knowledge, it will be hard to delineate the exact pathway of nano-scale organization of the first protocell and the lack of exact knowledge of the environmental conditions of earth four billion years ago is another major problem to prove this nano-scale organization at the laboratory set-up [23- 37].

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