



UNDERSTANDING THE LIVING MATTER

-THE PHYSICAL BASIS OF LIFE

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Abstract

Everybody understands matter in its various forms and names such as in solid, liquid or gas stages or as in organic or inorganic forms. But living matter is somewhat different and unique in the sense that it is an active form of matter capable of executing various life processes within itself. Biologists claim that the physical basic of living matter is protoplasm. But we would like here to unfold the fundamental physical principles in the form of a cosmic plan or a blue print that has been followed sequentially by nature all over the billions of years of its cosmic evolution in physical, chemical and biological level ultimately to arrive at this unique phase of matter, the living matter.

Key Words- *Living matter, Chemical and Biological level in living matter, Cosmic Evolution.*

Introduction

"At first concealed in darkness, all in discriminated chaos. All that existed then was void and formless; By the great power of warmth was born that unit. There were begetters; there were mighty forces; free action here and energy up yonder" - Thus said the scriptures in Rig Veda regarding the origin of matter, energy and forces starting from an initial formless void. Modern Science also believes in the creation of this Universe in similar way with a so called 'Big Bang', nearly 14 billion years ago. Space, time, matter and forces have gradually appeared in due course through several epochs of cosmic evolution. As it appears today; billions of years of the cosmic evolution has culminated in the creation of living matter; a unique phase of matter where-in merrily dwells life with consciousness and varying degrees of instincts and intellects. The living matter, that we see in our terrestrial models of various organisms or life- forms is a very intricately designed complex system with well-coordinated interacting internal parts. Its biological aspects are well studied in Bio-sciences. But looking into the physical aspects of living matters one can realize that it has evolved spontaneously on a cosmic scale from the non- living matter, through



natural selection processes at every stage, intimately based on certain physical principles. Then rising above the mundane terrestrial level; one can realize the universal character in its structure. occurrence and sustenance through a basic common plan. The purpose of this article is to address and elaborate on these points.

General Characteristics

First of all; let us understand precisely what is meant by living matter and what are its significant characteristics as it appears to be from the terrestrial samples. Then we can analyse them in general terms to search for an underlying basic plan in its formation.

- I. Living matter as we know; can be broadly defined as a form of the complex bio-matter intricately organised in various appropriate configurations surcharged with life and consciousness as well as instinct and intelligence in varying degrees.
- II. It has well-coordinated interacting internal parts with self-regulatory internal control mechanism. It can establish contact with its environment through the exchange of matter/energy and quite well respond as well as adapt to the changing conditions of the environment.
- III. It requires steady in-take of appropriate energy for its sustenance. Living matter does not have a very stable configuration, since it can decay and disintegrate to non-living bio-matter when it becomes un-sustainable.
- IV. Living matter once formed is capable of replicating itself through self-reproduction. Thus, it is capable of multiplying itself by transmitting its characters to the replica editions.

On the basis of these general characteristics let us ask ourselves the questions (a) how exactly living matter is formed out of non-living bio-matter? and (b) can it be possible to transform ordinary matter to its living phase in the laboratory? The signature of the earliest living matter left behind in the so far oldest fossil organism-'Stromatolite carbonates'. dates back to about 3.5 billion years. If we consider it as one of the foremost appearances of living matter; then taking into account the age of our earth and the Universe respectively as 4.5 billion and 14 billion years; we may observe that living matter must have taken billions of years for its formation from non-living matter. Thus, the transition from non-living to the living phase of matter must have taken several evolutionary epochs. This cosmic time scale involved in its formation makes it impossible to be prepared in the laboratory. However, bio-matter like amino- acids which form one of the basic ingredients of terrestrial living matter can be spontaneously produced in the laboratory by passing an electric discharge in a gas mixture of ammonia, methane, carbon-dioxide and water vapour. This was the famous experiment by Stanley Miller demonstrating the spontaneous formation of glycine, the amino acid



that forms an integral part of the living matter. Therefore, one may presume that all the various components of complex bio-matter which constitute the living matter must have been formed similarly at certain stages of the prebiotic evolution. In the long run living matter could have been spontaneously evolved in a cosmic scale from the bio-matter in a similar manner deriving appropriate free energy from local cosmic events.

Be that as it may; it is certainly a fact that the formation of living matter from non-living ones has taken place in a cosmic time scale. This implies that the probability of such a transition from non-living matter to its living phase is infinitesimally small. In physics; we have many examples of processes with very low transition probability, which results basically due to the local violation of some basic physical principle. Then what could be this basic physical principle which living matter could possibly violate locally during its formation? We know that the living matter requires a steady intake of appropriate energy from its environment for its sustenance, which otherwise would decay and disintegrate to non-living matter. But decay and disintegration are in fact synonyms of chaos and disorder. In that case we can say that the unsustainable living matter naturally decays and disintegrates to a more chaotic or disordered phase of matter in its non-living form. Then living matter has to be in a phase of very high degree of order.

We know that transition from order to disorder or vice versa is associated with increase or decrease of a physical quantity called entropy in thermodynamics. Consider an example of a gas whose molecules move about randomly in a chaotic manner filling the entire available space. When its temperature is reduced appropriately the gas condenses and the molecules get into some ordered state. As a result, the entropy decreases during liquification of a gas. Further cooling results in solidification realizing more order in the crystalline arrangement with further decrease in entropy. It follows that with larger entropy there is more disorder and vice versa. According to statistical physics a more ordered state is less probable. In other words, less ordered states have greater probability to exist for which nature favours mostly the irreversible processes where the entropy tends to increase to a maximum value. This universal principle is well known as the second law of thermodynamics. So, we can say that those processes which locally violate this thermodynamic principle are statistically less probable.

Now if we believe that living matter is a state of matter with very high degree of order; then in its formation from non-living matter entropy must decrease locally violating the second law of thermodynamics. This should therefore render its probability of formation almost infinitesimal. Decrease of entropy in the living matter makes it capable of transforming free energy to more useful stored energy. Erwin Schrodinger of Quantum mechanics fame had rightly remarked that "life feeds on entropy." This is therefore the reason for which living matter requires steady flux of free energy to combat otherwise



continuous increase of disorder. It requires continuous efforts to sustain it, failing which it decays and disintegrates.

The Driving Force

Now let us ask the question about force that should be responsible in producing a very high degree of order with very less entropy in the living phase of matter. The same force should also drive all the life processes. In fact, unlike the inert non-living matter; the living matter is internally as well as externally very active being capable of transforming free energy to the stored energy. Therefore, inside the living matter physical, chemical and biological processes go on incessantly for which some fundamental interaction as the driving force is necessary. In fact, all the processes occurring in nature are governed by any of the four fundamental interactions; namely 'the strong, weak; electromagnetic and gravitational. Which particular force out of these available ones might have been selected by nature as suitable driving force for the living matter? 'With purely attractive type force like strong, weak or gravitational, the most probable shape of matter in its organized form would naturally be spherical. But a spherical arrangement of matter having perfect rotational symmetry does not correspond to a state with very high degree of order. Therefore, the driving force for living matter must have to be both attractive and repulsive in nature in order to realize very high configurational order. Then nature's-choice is obviously restricted to the electromagnetic force; which is the only fundamental force of this kind.

The Fundamental Building Blocks

If the living matter in the universe has to be the way we analysed and understood it so far; what kind of fundamental building blocks would be necessarily preferable? When electromagnetic force was made available and effective towards the later part of the cold era in cosmic evolution; the Universe was roughly a million years old and the cosmic matter at that time existed in a plasma state with leptons (electron e^- and neutrino), photons (particle of light) and light nuclei of hydrogen (H) helium (He) built out of neutron (n) and proton (p). But if nature had an ultimate aim in creating living matter; it would have certainly selected at this stage the fundamental particles like neutron (n), proton (p), photon (γ) and electron (e) as the basic constituents leaving aside the weakly interacting neutral neutrinos for other purposes. Photon being the mediator of electromagnetic interaction and proton, electron, neutron being electrically/magnetically charged; they all participate in electromagnetic interaction. These particles give rise to various nuclei and atoms which are stable to the cosmic time scale. During cold and very cold era of the cosmic evolution lighter elements like hydrogen (H) and helium (He) were copiously produced in the cosmic matter. Heavier elements like oxygen(O), Carbon (C), Nitrogen (N) and others which were subsequently cooked in the stellar



furnace through the fusion processes were available with lesser degree of their abundances.

Out of all these varieties of chemical elements, only those which are chemically more active and are of high cosmic abundance can be selected as suitable constituents of living matter. They are as follows. Hydrogen (H) is the most abundant cosmic element (96 atoms per 100) which is chemically very active exhibiting the weak chemical bond. Oxygen (O) comes second. Then comes the third most abundant element, Carbon (C) which is a constituent of many molecules due to its high valency and small radius. Carbon containing molecules are also highly organised and form macro-molecules. Nitrogen (N); the fourth most abundant element can be involved with H, O and C in numerous compounds and can form a large number of macro-molecules. Besides (H, O, C, N), some other trace elements (S, P, Na, K, Fe and Mg...) are also necessary for some specific functions. Phosphorus of this category is probably a component of those macro-molecules which are carriers of genetic information in the first phase of chemical evolution. Molecular synthesis would have taken place on the basis of the largest difference in the electro-negativity of the participating atoms determining the mutual chemical bonding and their cosmic abundance determining their likelihood of mutual collisions. Local cosmic events might have supplied the necessary free energy. Out of the compounds most likely to have been formed at this stage; chemically very active ones are water (H₂O), methane (CH₄), ammonia (NH₃); hydrogen sulphide (HS) and CO₂. Monomers like Carbohydrates and analogues (H₁₂OCs), amino-acids (HOC₂N) and nucleotides (HO, CNP) are some examples of larger molecules which could have been spontaneously synthesized during the pre-biotic evolution from the basic reactive compounds like H₂O, CH₄, NH₃, and CO₂ etc. Macro-molecules like Proteins, RNA and DNA etc. would have been realized in the complex spontaneous process of polymer synthesis. Thus, nature would have prepared matter in various forms, shapes and sizes through sequential steps during the long 'period of chemical and pre-biotic evolution by way of collecting all the necessary ingredients to build the very complex and highly organized living matter. Since we are not concerned here with the biological aspects; the details of macro-molecular- ingredients are not relevant to our discussion.

A medium of transport

We know that living matter, for its sustenance, needs to exchange matter and energy with its environment. It also needs internal transportation of energy and matter and co-ordination with various internal parts. Therefore, a basic ingredient of the living matter has to be some suitable medium which can provide a moderate to high speed of transport. Being an integral part of the living system; it should preferably be crystalline or semi-crystalline structure to hold and sustain the ordered structure.



So, nature would have selected a suitable medium to meet this requirement from out of all the molecular forms of matter. Such a medium could only be water, which is the most abundant cosmic compound. Water is chemically active and carries an internal order being semi-crystalline in nature. It is an excellent solvent and is stable over a wide range of temperature variation. In fact, the chemical composition of terrestrial life forms (which is very similar to the chemical composition of the universe) shows that 66% of the living biomass is water. Thus, water plays the role of chief actor on the cosmic chemical stage producing and supporting living matter.

Steady source of free energy

Living matter requires a steady flux of free energy to combat natural increase of disorder. Having very low entropy content living matter is capable of transforming free energy to more useful stored energy. This acquired energy is transported to all internal parts to drive the chemical processes. Therefore, a suitable source of free energy is very essential for the formation and sustenance of living matter.

Since more than 60% of the living matter consists of water; the source of free energy should be in commensurate with the limitations of energy storage in H₂O molecule which is 237 KJ/molecule. Such an amount of energy would correspond to photon of wave length 600 nm emitted from a black body at a surface temperature T-103 K. Such a steady source in the cosmic scale with surface temperature of several thousand Kelvin could be a star. But any star may not be suitable. The star must be a long lived one to a time scale of several billion years appropriate for chemical and biotic evolution of matter. A living organism requires a steady flux of energy with intensity several watts/m². The star should provide the energy flux with such appropriate intensity. A middle-mass main-sequence star like our Sun is in fact an appropriate life-giving source of energy. Although Sun is not the only one of its kind in this vast universe; it is not known exactly why should the planet earth be unique in providing a happy harbour to living matter.

Early Living structure

Before we end our discussion, let us have a cursory look at the very early living structures. Of course, from polymer synthesis to spontaneous formation of life, it is no doubt a very long and complex path. Nevertheless, life did originate.

It is believed that proto-bionts; the first living structures formed spontaneously in the primordial soup, consumed high energy content molecules called ATP. ATP depletion



in the primordial soup must have led to the first starvation. But the adaptability character of these living structures would have generated spontaneous changes in the carriers of genetic information, enabling some proto-bionts to synthesize ATP by fermentation process. These Proto- bionts would have evolved to the next stage; the 'eobionts'; which consumed the carbon containing molecules of the primordial soup. Depletion of the carbon-containing molecules might have forced eobionts consuming other eobionts thus generating a line of typical hetero-tropic organisms. Further depletion of the primordial soup might have resulted in the second large starvation. At this stage of crisis; the living matter must have discovered and mastered the very sophisticated bio-physical mechanism 'photo-synthesis'. After this stage, evolution of living matter would have proceeded smoothly over a period of say billion years ultimately evolving into a highly thinking intelligent being-the human being.

Conclusion

Thus, we find that formation of living matter is based on the chemical interaction of light elements in the neighbourhood of middle-mass main-sequence stars. Had there been no galaxies in the Universe; there would not have been any stars. planets and hence no living matter. But it is believed that galaxy formation is possible only in an isotropic, homogeneous Universe with appropriate expansion velocity. Whatever may be the cause and mechanism for galaxy formation; they do exist in our Universe. Therefore, we can conclude that life is only possible in our type Universe. Could we then say that this Universe was created from the very beginning with an aim to produce ultimately life and intelligence? This reminds us the prophetic words of Isaac Newton; where he said:

"It seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable, movable particles of such sizes and figures and with such other properties and in such proportion to space; as most conducive to the end for which he formed them".

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