

## Origin of Life

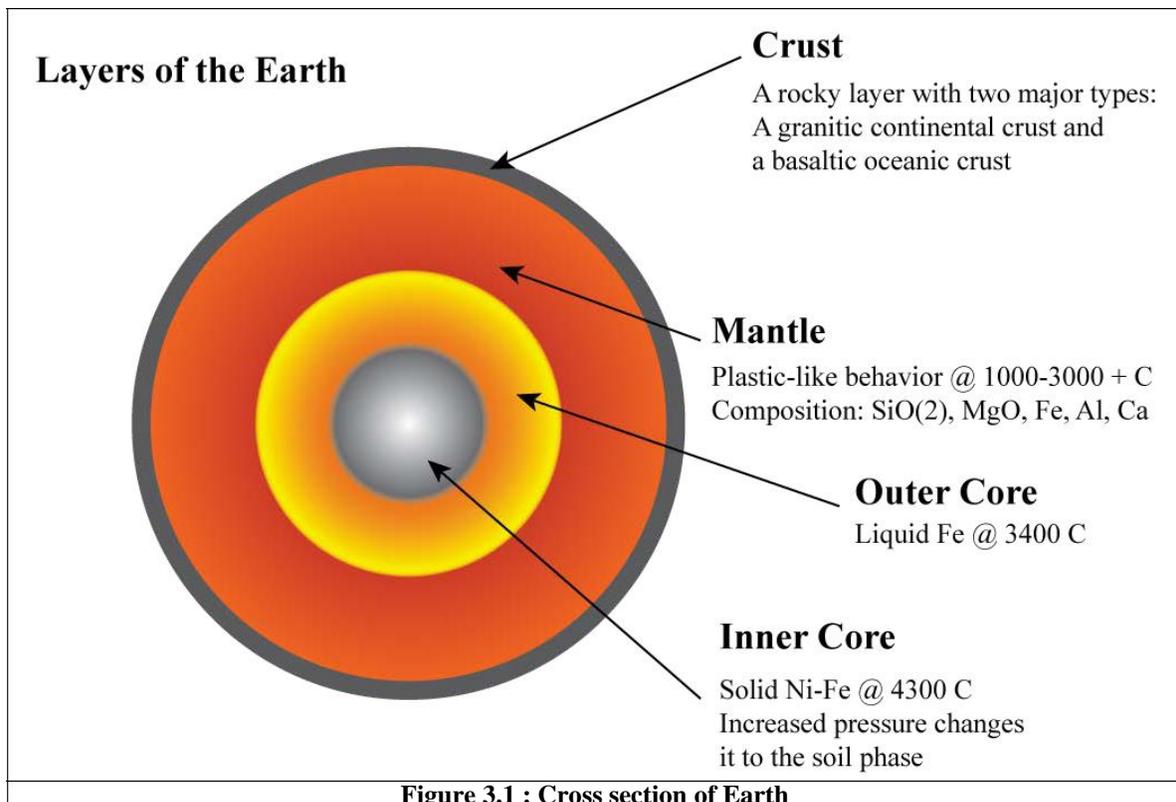
**Introduction:** Study of living organisms such as plants, animals and human etc is the active area of life science. Now question is how you will define “**LIFE**”. Life is defined as “the ability of an organism to reproduce, grow, produce energy through chemical reactions to utilize the outside materials”. But scientists and philosophers have tried to understand two important questions related to life

1. How life originated on earth?
2. How different kinds of organisms are formed in the world?

So first the question is how earth formed and how its internal structure support the life? evidences suggest that earth and other planets in solar system came to existence around 4.5-5 billion years ago. Earth originally had two components: solid mass **lithosphere** and the surrounding gaseous envelope **atmosphere**. Once the temperature of primitive earth cooled down below 1000C, liquid components known as **hydrosphere**.

The formed earth consists of three parts as given in Figure 3.1. These parts are as follows:

- 1. Baryosphere:** it is the central core of the earth. It is filled with molten magma with large quantity of iron and nickel. Baryosphere has two zones: inner core region (~800 miles radius) and outer core region (~1400miles radius).
- 2. Pyrosphere:** it is the middle part of the earth, also known as mantle. It is ~1800 miles in thickness and mainly consists of silica, magnese and magnesium.
- 3. Lithosphere:** it is the outermost region of the earth, also known as crust. It is 20-25 miles in thickness and mainly has silica and aluminium.



**Now the next question, what will be the pre-requisite of life on earth?** There are multiple conditions on earth to support the life on earth. These are as follows:

- Primitive earth with little or no oxygen. The earth original had a reducing environment due to presence of hydrogen and hydrogen compounds with water (such as CH<sub>4</sub>) and ammonia (NH<sub>3</sub>). Due to gravitational forces, these gases remains within the atmosphere of primitive earth. **The reducing environment of primitive earth will help to synthesize organic compounds from interaction of inorganic substances.**
- Inorganic raw material for origin of life: Inorganic material in the earth interact to form organic material required to to produce life.
- **Energy source.** The energy source on primitive earth came from the following sources:
  - Solar radiation
  - Electric discharge
  - Volcanic eruptions

Heat

Cosmic Rays

Radioactive Decays

- **Infinite time:** As per estimate it took almost 1 billion years from the formation of earth to appearance of life. Such a long time is needed for chemical reactions to occur without the help of enzyme.

## **NOW COMING TO OUR FIRST QUESTION? HOW LIFE ORIGINATED ON EARTH?**

Six major theories are proposed to explain the origin of life on earth. These theories are as follows:

**1. Theory of Special Creations:** The theory of special creation is proposed that life on earth is created by a supernatural power, the GOD. According to the Christian belief, god has created the universe, planet, animal, plant and human in six natural days. Similar beliefs are also been proposed by other religion as well. There are beliefs in the theory of special creation. These points are as follows:

A. All living organisms were created same day [**NO DIFFERENCE IN THEIR APPEARANCE**].

B. They were created in the present form [**NO EVOLUTION**].

C. Their bodies and organs are fully developed to meet the requirement to run the life [**NO ADAPTATION**]

### **OBJECTIONS TO THE THEORY OF SPECIAL CREATION:**

- It was purely based on religious belief.
- There was no experimental evidences to support the assumptions.
- The age of different fossils proves that living organism appear on earth in different time frame.

**2. Theory of spontaneous generations:** The theory of spontaneous generation or abiogenesis assumes that non-living material in a spontaneous manner give rise to life. There are several observations supporting this theory, which are as follows:

- Hair of horse tail dipped in the water gives rise to horsehair worm, *gordius*.
- Fly larvae develops on rotten meat.
- In ancient Egypt, it was believe that frog, snake, crocodiles in the mud of Nile river warmed with sun.
- Van Helmont claimed that he can produce mice from the dirty shirt and handful of wheat grains kept in dark cupboard in 3 weeks.

**EVIDENCES AGAINST THE THEORY OF SPONTANEOUS GENERATION:**

Theory of spontaneous generation was criticized by Lazzaro Spallanzani, Francesco Redi and Louis Pasteur. These great scientists performed well designed scientific experiments to disprove the theory of spontaneous generations.

**1. Redi's experiment:** Francesco Redi did conclusive and well designed experiment to disapprove the theory of spontaneous generation. He placed meat and fishes in 3 separate jars. Jar No. 1 was left open, No. 2 was covered with gauze and the third one was covered with paper. The meat/fishes decayed in all three jars and attracted flies. In Jar No. 1, flies entered and laid eggs which eventually gave birth new larvae. Whereas in Jar No. 2, flies couldn't be able to enter and no larvae was found inside the jar. But flies laid eggs on gauze that produced larvae. This has conclusively proves that organisms arise from the pre-existed organism rather than non-living matter.

**2. Spallanzani's Experiment:** The experimental setup is given in the Figure 3.3. In the designed experiment to test the validity of theory of spontaneous generation. In this experiment, Spallanzani has prepared animal or vegetable broth and boiled them for several hours and then either remained open or sealed airtightly. These broth remained free from microorganism growth. He concluded that high temperature boiling had killed all microorganisms and in the absence of microorganism life could not appear. The broth left open or exposing of sealed broth shows growth of microorganisms.

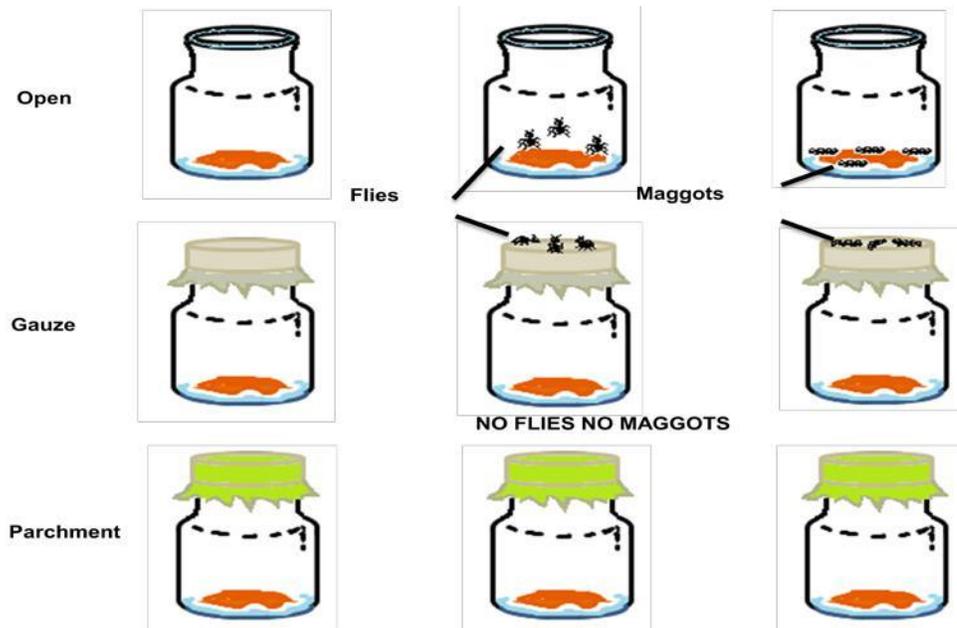


Figure 3.2 : Redi's Experiment to disprove the theory of abiogenesis.

**3. Louis Pasteur Experiment:** In another conclusive experiment, Pasteur had designed experiment in a flask with "S" shaped curve tube (Figure 3.4). He took hay infusion in the flask and boiled for several minutes. After cooling, the steam condensed into the lower part of tube and act as barrier to stop the entry of microorganisms. No life appeared in the flask for several months. Analysis of condensed water indicates appearance of microorganism in the neck of the tube. Breaking of "S" tube allowed the growth of microorganisms in the flask.

**3. THEORY OF CATASTROPHISM:** This is the extension of the theory of special creation. This theory assumes that life is originated by the creation and it is followed by catastrophe due to geographical disturbances. Each catastrophe destroyed the life completely whereas each creation forms life different from the previous one. Hence, each round of catastrophe/creation is responsible for evolution of different types of organisms on earth. The criticism of the current theory is same as previous one, No scientific experiment to support the hypothesis and mostly be based on imaginary concepts.

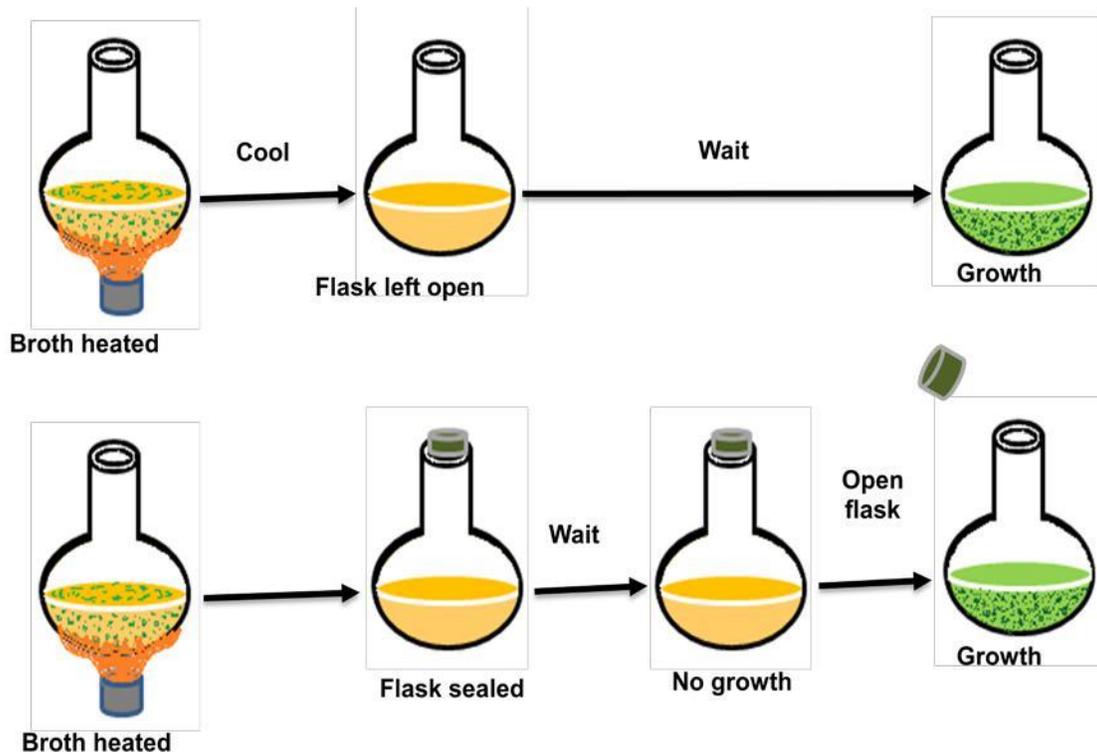


Figure 3.3 : Spallanzani's Experiment to disprove the theory of abiogenesis.

**4. THEORY OF COSMOZOIC:** This theory was put forward by Richter and strongly supported by Arrhenius. The theory assumes that life was present in the form of resistant spores and appeared on earth from other planet. Since the condition of earth was supporting the life, these spores grew and evolved into different organisms. This theory was also known as “**theory of panspermia or spore theory**”. The theory initially got the support from the fact that fossils of microorganism were found in meteorites in 1961. But no mechanism is known about the transfer of spores from other planet or whether these spores could survive the journey in space. The absence of life forms on any planet except earth and no details about the spores, its origin and mechanism of crossing interplanetary space and reaching earth. In addition, this theory doesn't add much into the fundamental details about origin of life. No scientific experiment were given to support the theory. As a result, the hypothesis didn't receive much attention.

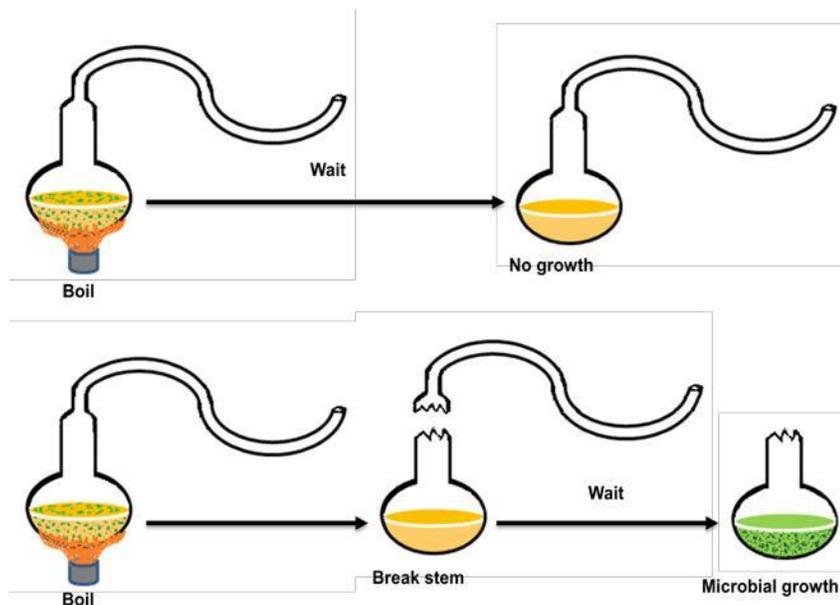


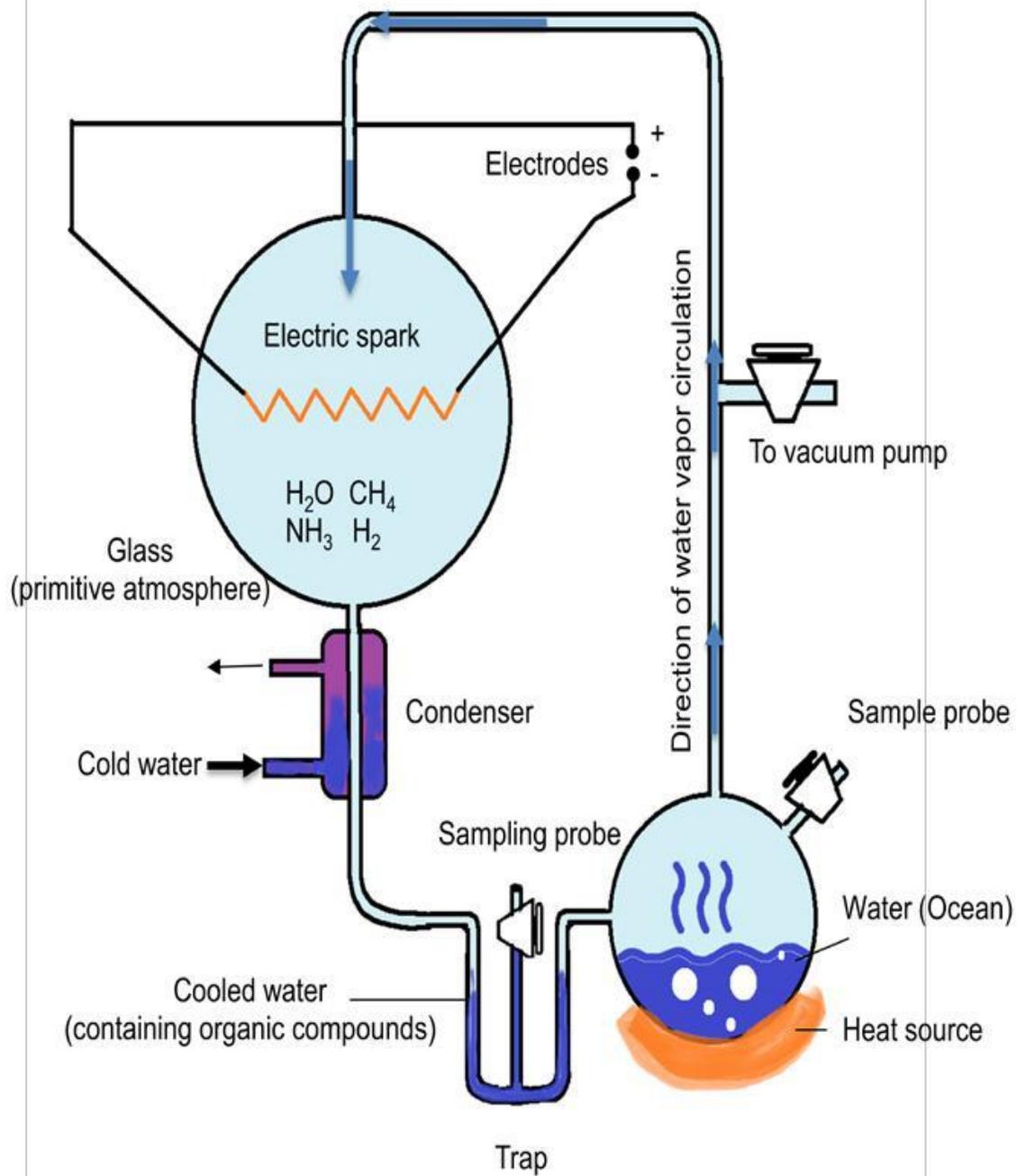
Figure 3.4 : Pasteur's Experiment to disprove the theory of abiogenesis.

**5. THEORY OF ETERNITY OF LIFE:** This theory assumes that life had no beginning or end. It believes that life has ever been in existence and it will continue to be so ever. It further believe that there is no question of origin of life as it has no beginning or end. The theory is also known as **steady state theory**. The main objection against the proposed theory that it could not be able to explain; evidences support that initially earth forms and then life appeared on it. Where life exist before the formation of earth?

**6. MODERN THEORY:** The modern theory is also known as “chemical theory” or theory of primary abiogenesis. In the modern theory, the hypothesis of abiogenesis was proposed with a condition that the non-living materials can give rise to life in the condition of primitive earth. The condition of the primitive earth is different from the present conditions which do not permit abiogenesis. The idea of chemical theory was put forward by two scientists, A.I. Oparin and J.B.S Haldane. It has made following assumptions:

1. Spontaneous generation of life under the present environment is not possible.
2. Earth’s atmosphere ~1 billion years is very different from the current conditions.
3. Primitive earth’s atmosphere was reducing in nature.
4. Under these conditions, the chemical molecules (inorganic molecules) react with each other through a series of reactions to form organic substances and other complex biomolecules.
5. The solar energy and UV radiation provided the energy for the chemical reactions.

**Experimental Evidences supporting chemical theory:** The hypothesis proposed by Haldane didn’t find much support without scientific experimentation. To conclusively support the chemical theory, Miller and Urey conducted an experiment in mimicking primitive earth environment. The experimental design used for the experiment is given in Figure 4.1. The experimental setup consists of a glass flask, a condenser, and a liquid flask interconnected with tubes and a source of electric spark to provide energy (Figure 4.1). He introduced a mixture of methane ( $\text{CH}_4$ ), ammonia ( $\text{NH}_3$ ), and hydrogen ( $\text{H}_2$ ) in the ratio of 2:2:1 and water ( $\text{H}_2\text{O}$ ) vapor at  $800^\circ\text{C}$ . He allowed to circulate the mixture into this closed glass apparatus for 18 days continuously. He provided energy in the form of spark by supplying electricity of 75000 volts through two electrodes. The electric sparks mimic lightning in the primitive earth atmosphere. While passing the mixture, gases were passed through a liquid flask to simulate the volcano. The mixture was collected from the stop cock and analyzed using chromatographic and calorimetric techniques. The analysis of mixture indicates the presence of amino acids such as glycine, alanine, aspartic acid, nitrogen base adenine and simple sugar ribose.

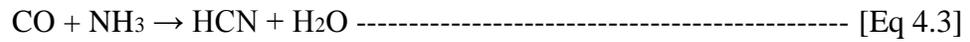
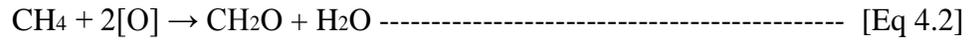
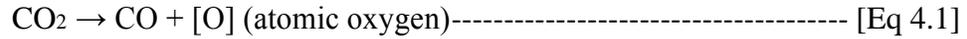


**Figure 4.1 : Miller Experiment to show the synthesis of organic compounds.**

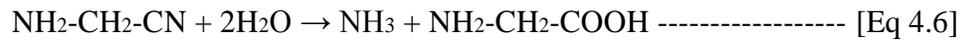
In addition, he found hydrogen cyanide (HCN), formaldehyde (HCHO) and other active intermediate compounds such as acetylene and cyanoacetylene.

The chemical reactions which might explain the formation of these compounds are as follows:

**1. Formation of HCN, HCHO etc:**

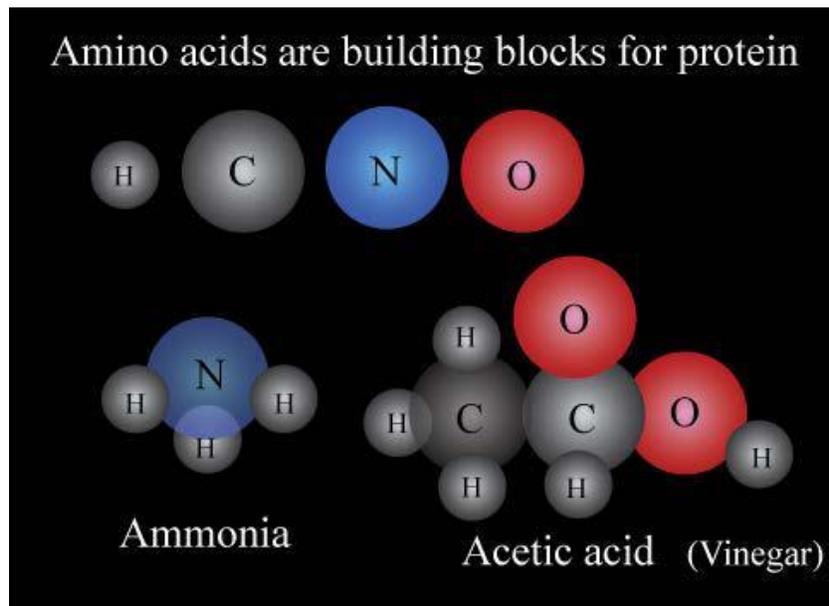


**2. Formation of Glycine:** The formaldehyde, ammonia, and HCN then react to form glycine.



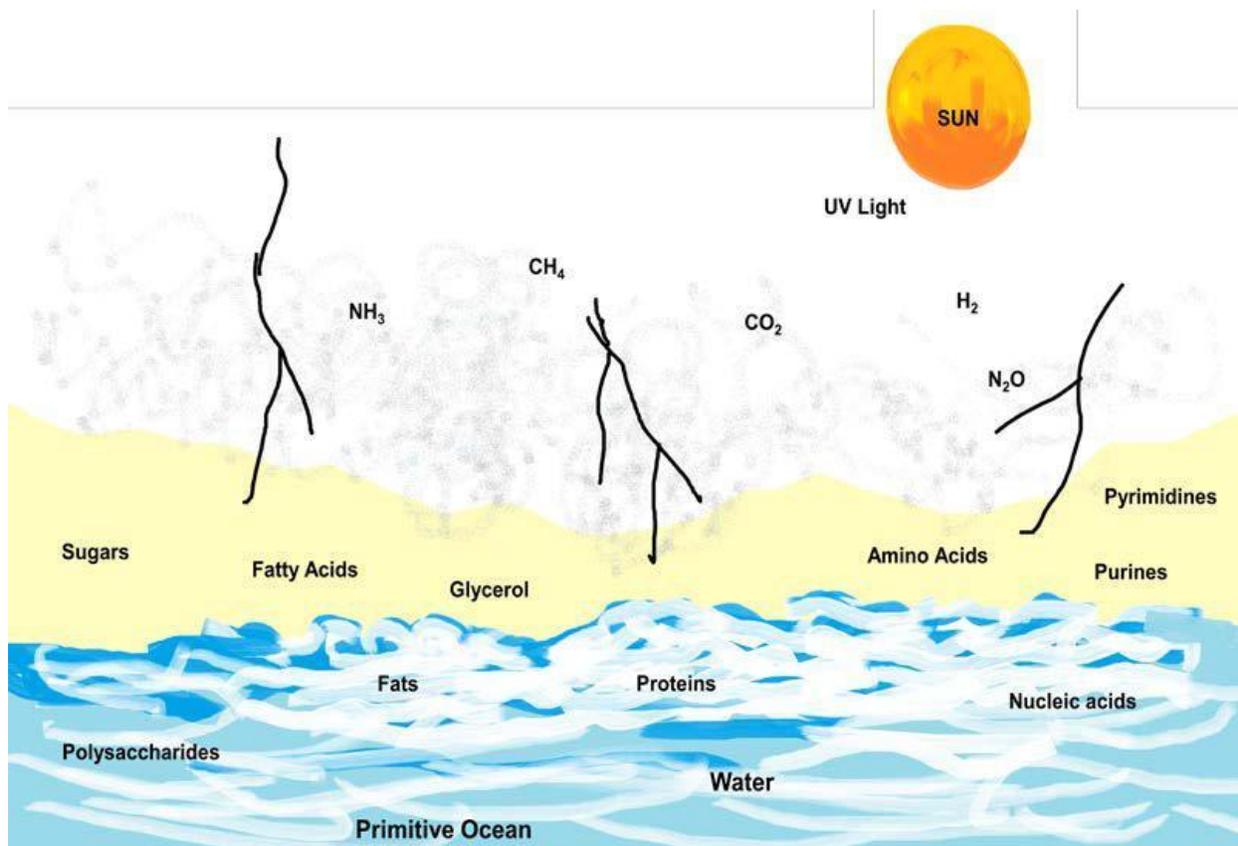
**STEPS PROPOSED IN THE ORIGIN OF LIFE:** According to the chemical theory of origin of life, a series of chemical synthesis give rise to life. As per the hypothesis, origin of life have four major steps:

**(1) Formation of Inorganic molecules:** The high temperature of primitive earth didn't allow the condensation of atoms to form inorganic molecules. As temperature of earth goes down, condensation of different atoms give rise to simpler molecules. The elements most abundant on the primitive earth are hydrogen, oxygen, nitrogen and carbon. The reaction of these molecules give rise to the different gases such as hydrogen, nitrogen, ammonia, methane, carbon dioxide and water vapor. The molecules present on initial earth is given in the Figure 4.2. The energy for these reactions was provided by sunlight, lightning or volcanic eruptions.



**Figure 4.2 : Different molecules prevalent on primitive earth.**

**(2) Spontaneous formation of monomeric organic compounds:** The simple molecules interact with each to form simple monomeric organic compounds. These molecules were sugar, fatty acids, glycerol, amino acids and organic bases (purine/pyrimidine). The reactions between the inorganic to give simple organic molecules occurs in reducing environment inside ocean. The inorganic molecules were condensed in the form of rain as temperature of earth lower down. Hence, both inorganic compounds and simple organic compounds were present in the primordial ocean.



**Figure 4.3 : Different simple organic molecules prevalent on primitive earth.**

**(3) Spontaneous formation of complex organic compounds:** The small, simpler organic compounds react to form complex organic compounds. The simple amino acids react to form polypeptides, sugar reacts to form large sugar molecules, fatty acid and glycerol combined together to give fat (Figure 4.4). Heat of the sun is utilized for providing energy for these reactions.

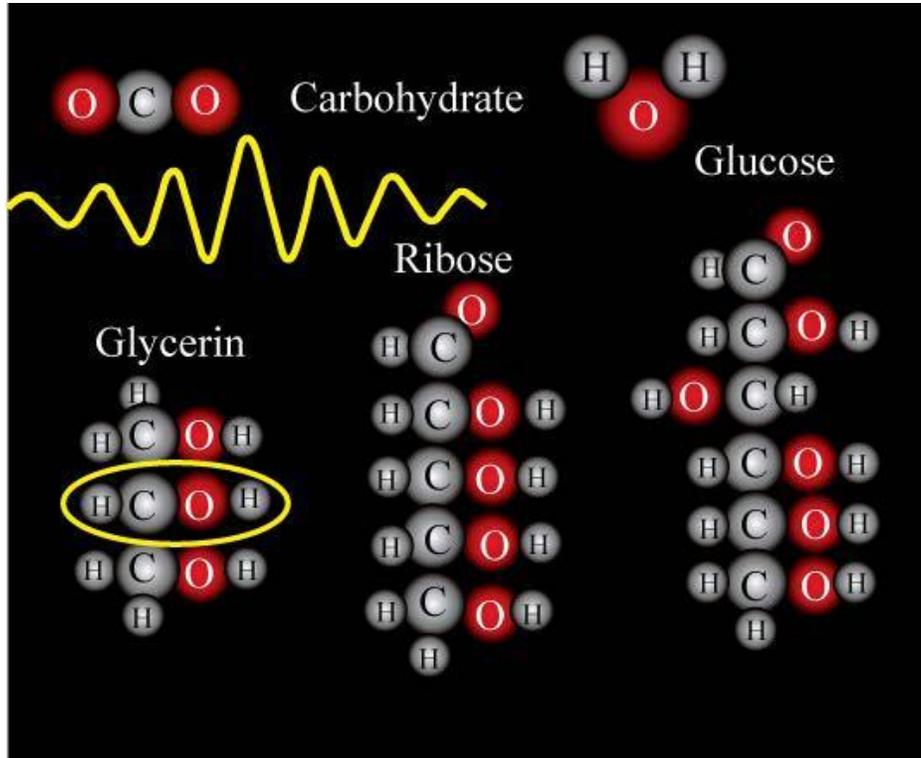
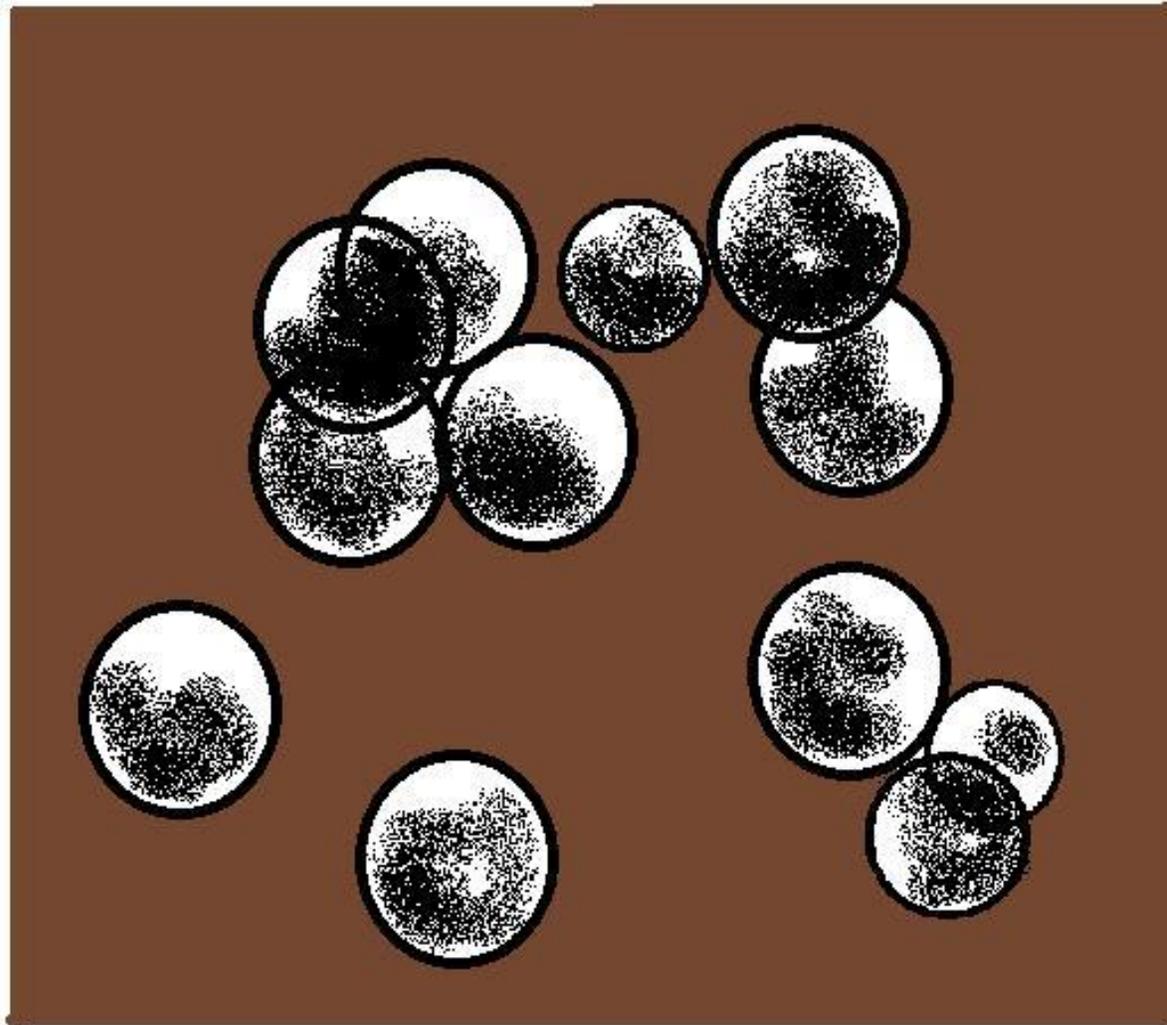


Figure 4.4 : Different complex organic molecules prevalent on primitive earth.

**(4) Spontaneous formation of molecular aggregates:** large organic molecules came together to form large colloidal aggregates called as coacervates. A layer of water molecules forms around the protein molecules present in coacervates. The membrane present around the molecules protect the molecule and bring high local concentration to enhance the chemical reactions. The colloidal aggregates absorb protein and other molecules from the ocean. This results in growth in coacervate as well as internal complexity (Figure 4.5). As coacervate divides into multiple small ones.

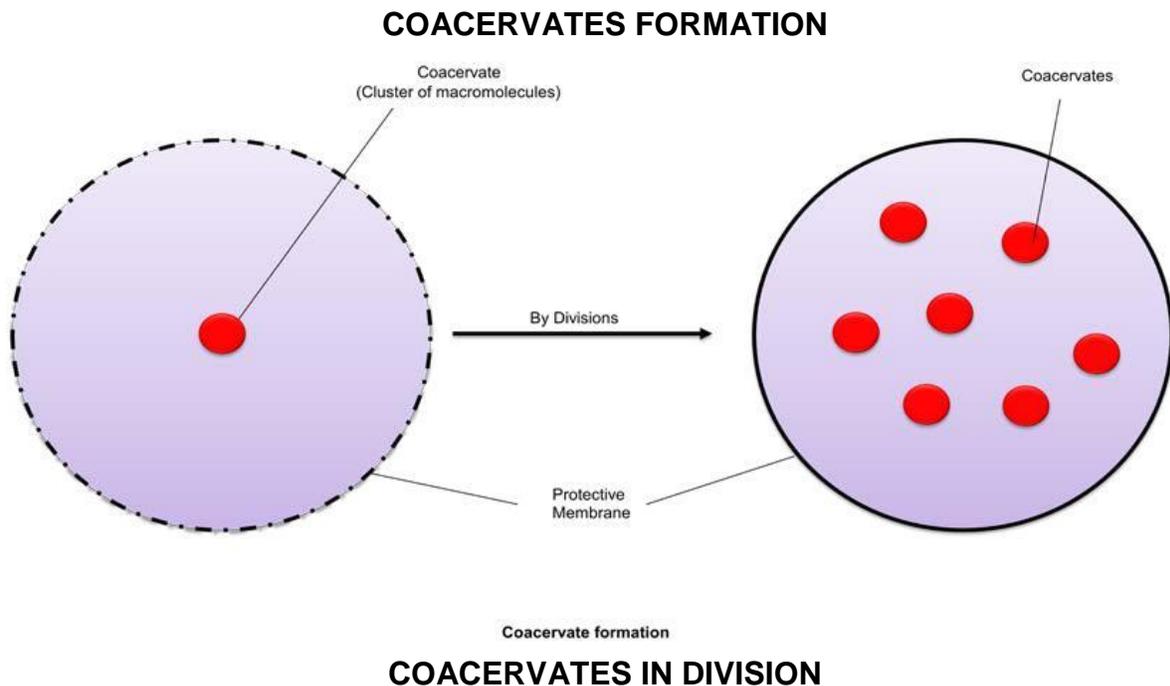


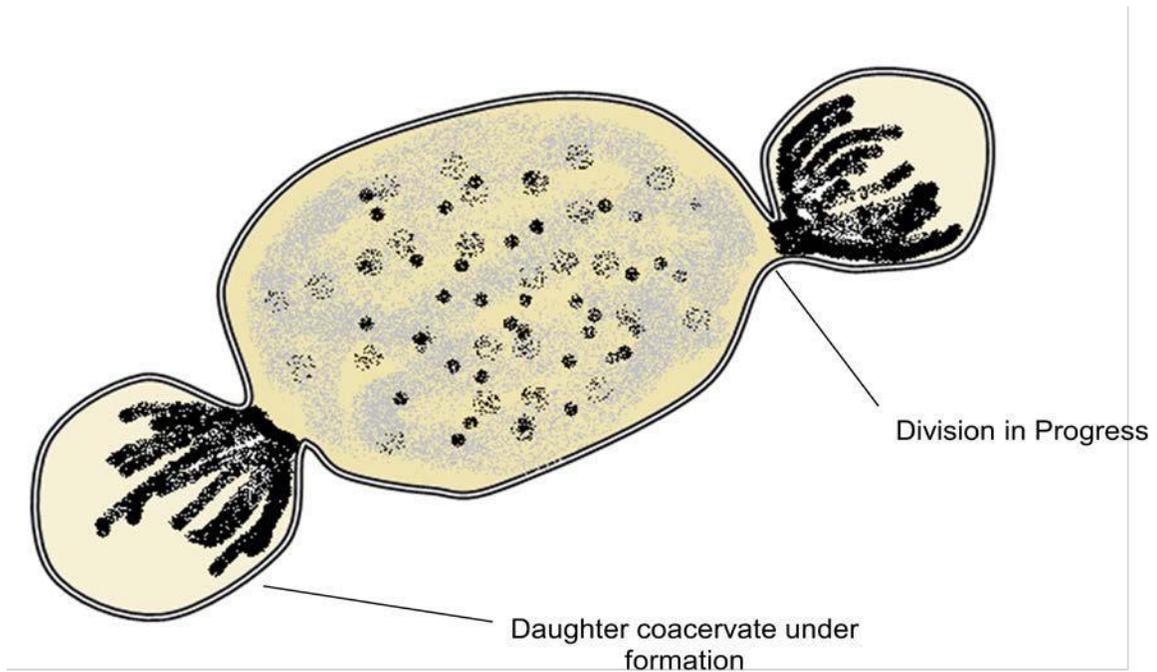
**Figure 4.5 : Formation of aggregates.**

These coacervates are the initial species present in the ocean to start the formation of primary cells. This process is accomplished in two steps:

**Formation of eobionts or protocells:** The coacervates has the ability to take up new molecules to replace the degraded molecules and maintain the size. Thus, coacervates has the basic property of living system but it doesn't have complex molecules such as enzyme etc (Figure 4.6). The process of acquiring new molecules was not regulated. Later, nucleic acid is entrapped within the coacervates and process of division became precise and controlled. This form of coacervates with nucleic acid is known as eobionts or protocells.

**Formation of first cells:** Protein molecules and appearance of enzymes has enhanced the synthesis of several of biomolecules in eobionts. RNA and DNA developed and these molecules has taken over the protein synthesis. Interaction of lipid and protein allowed the formation of biomembrane which has provided selectivity in the





**Figure 4.6 : Coacervate formation and division to form protocell.**

primitive cell for intake or exclusion of material. It allowed the appearance of membrane bound protocell and that has eventually given first cell on earth. The mutation in DNA and selection of fast growing cell give rise to the appearance of first primordial cell. The first cellular form on earth appeared ~2000 million years ago.

**Source:** NPTEL – Basic Courses – Basic Biology (Joint initiative of IITs and IISc – Funded by MHRD);'0p\