THE ORIGIN OF LIFE

- **Origin of Life**

- **According to 'Big Bang theory' proposed by Abbe Lemaitre (1931), our solar system was created from gaseous cloud called solar nebula.**
- **The earth is about 4.6 billion years old, while oldest rocks on earth are 3.3 to 3.6 billion years old and sedimentary rocks are 2.7 to 3.2 billion years old.**
- **Sedimentary rocks are of particular evolutionary interest because their formation requires liquid water.**
- **Fossils are mainly found in sedimentary rocks.**
- **The first indications of primitive life occurred just over 3 x 10^9 years ago.**
- ***Eobacterium isolatum* is the oldest fossil (i.e., 3.2 billion years old), which belongs to cyanobacteria, its fossils were found in sedimentary rocks of South Africa.**

- Primitive atmosphere of earth was reducing, containing methane (CH_4), ammonia (NH_3), hydrogen (H_2) and water vapour (H_2O).
- There was no free oxygen, while temperature, rain fall and electric storms were high and ultra violet rays (UV rays) and cosmic rays could reach directly to earth surface because ozone layer in stratosphere was absent.
- In contrary to primitive atmosphere, present atmosphere of earth is oxidizing, containing nitrogen (N_2), oxygen (O_2) and carbon dioxide (CO_2) gases.
- There is no free hydrogen and UV rays can not reach directly to earth surface due to presence of ozone layer.
- Life was originated in water.
- According to recent and most popular hypothesis, life was originated in deep sea hydrothermal vents.

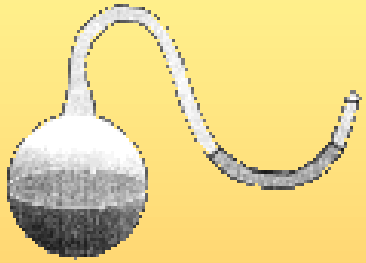
- This view is supported by genomics especially ribosomal RNA sequencing, which suggests that the ancestors of today's prokaryotes re Archaebacteria that live on the deep sea vents.
- Deep sea hydrothermal vents are sub-marine hot springs, in which sea water seeps through cracks in the bottom. The water is super heated containing hydrogen sulphide (H_2S), methane (CH_4), iron and sulphide ions.

Theories of Origin of Life

- Several theories have been put forward to explain the origin of life (i.e., biopoiesis), such as
  - Theory of special creation
  - Theory of spontaneous generation (abiogenesis)
  - Theory of biogenesis
  - Theory of cosmozoic origin or extra-terrestrial theory
  - Theory of panspermia/interplanatery theory
  - Theory of catastrophism
  - Oparin-Haldane theory of origin of life.

- Theory of special creation was given by Father Suarez and supported by Milton.
- As per this theory, life was created by some super natural power (God).
- According to the theory of spontaneous generation (abiogenesis or autobiogenesis), life was originated from non-living (life less) materials automatically.
- This theory was supported by Anaximander, Thales Aristotle, Xenophanes, Plato and von Helmont (1642), who claimed that mice formed in 21 days from a dirty, sweat soaked shirt put in a wheat barn in the dark.
- The theory of spontaneous generation was discarded by Francesco Reddi (1664), Lazzaro Spallanzani (1767) and Louis Pasteur through Swan necked flask experiment.

A flask is filled with broth and its neck is drawn out into an S shape. The broth is boiled to kill any pre-existing micro-organisms.



As broth cools ,a puddle of condensing water forms in the bottom of the S, effectively sealing the mouth of the flask. No micro-organisms grow in the broth.

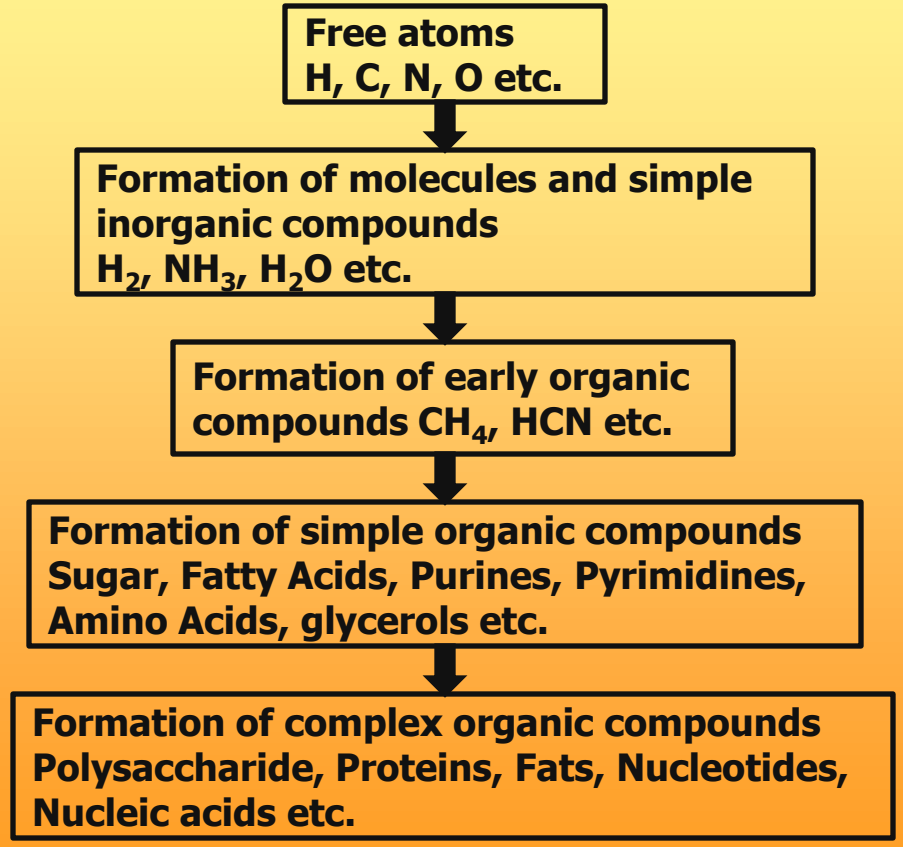
If the neck is later broken off the flask , outside air can enter carrying micro-organisms to the broth. Soon the broth swarms with micro-organisms

- **According to theory of Biogenesis, life originated from pre-existing life (*Omnis vivum ex ovo or vivo*).**
- **This theory was supported by Francesco Reddi, Lazzaro Spallanzani, Louis Pasteur, Harvey and Huxley.**
- **Francesco Reddi Was an Italian scientist, who set up experiment for refutation of the concept of spontaneous generation.**
- **He took meat from four different animals and boiled it gently.**
- **Then he placed well cooked meat in three jars.**
- **First jar was uncovered, second was covered by parchment paper and third was covered by muslin cloth.**
- **After some days, he observed that maggots developed only in uncovered , jar and there was no maggot in jar covered by parchment, while some eggs were on muslin cloth.**
- **F Reddi concluded that white maggot on meat are larva of flies.**

- As flies visited the jar, laid eggs on uncovered meat and muslin cloth so some eggs fallen in the jar and maggot developed in first jar fully and in third jar a few, whereas second jar with parchment was not contaminated with egg so there was no maggot.
- Louis Pasteur, a French scientist who is known as father of Microbiology and is credited with the 'Germ theory of disease' disproved the theory of spontaneous generation by performing Swan-necked flask experiment.
- According to theory of cosmologic origin or extraterrestrial theory, both living and non-living objects were formed simultaneously and protoplasm reached to earth from other parts of universe in the form of spores, seeds, sperms etc. this theory was supported by Richter (1865).
- Theory of Panspermia or Interplanetary theory was proposed by Arrhenius (1908).

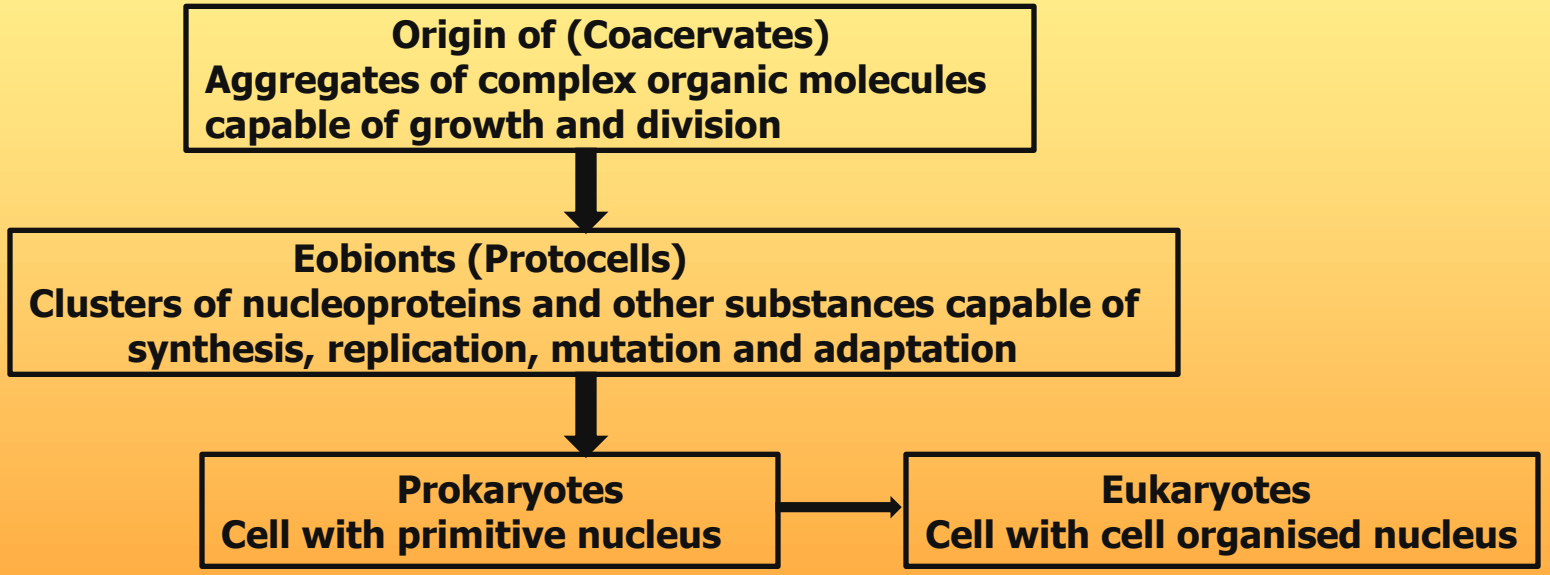
- Recently Francis Crick and Lesile Orgel proposed the theory of directed panspermia.
- The theory of catastrophist was supported by Cuvier, a French Paleontologist who believed that world has passed through many ages with catastrophe at the end of each age.
- Oparin-Haldane theory or Modern theory was proposed independently by A I Oparin (a Russian biochemist who wrote "The origin of life" in 1936) and J B S Haldane (a biologist who migrated to India in July 1957 and settled in Bhubaneswar, Orissa).
- As per this theory, origin of life is the result of a long series of physico-chemical changes, which brought about first by chemical evolution and then biological evolution.
- This theory is also known as primary abiogenesis.
- Abiogenic origin or chemical evolution of life can be tested experimentally.

- **Evolution up to formation of Coacervates is termed as chemical evolution. In which complex organic compounds were formed that are essential for formation of cellular structure.**



Chemical evolution

- **Evolution from Coacervates to simple cell structure is known as biological evolution.**



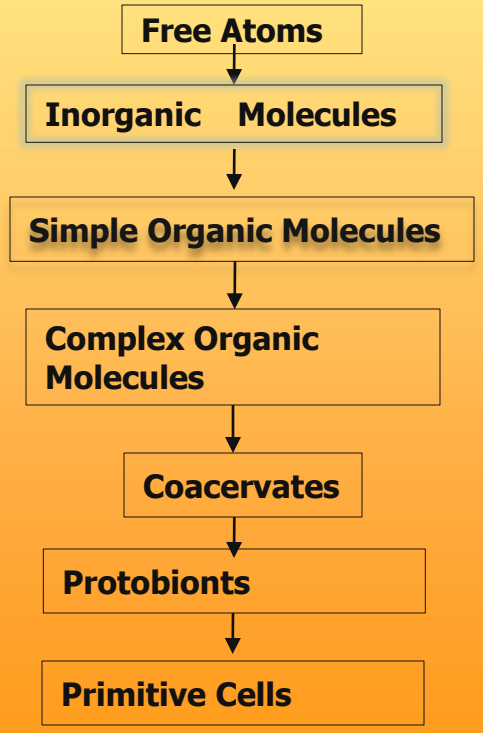
Biological evolution

- J B S Haldane (1920) used the term pre-biotic soup or hot dilute soup of organic substances for oceanic water containing mixture of simple organic compounds.
- Darwin used the term 'warm little pond' for early hot sea rich in biomolecules.
- The transformation from inorganic compounds to organic compounds is not possible in the present oxidizing atmosphere as in primitive atmosphere because oxygen or micro-organisms will decompose or destroy the living particle that may arise by ever chance.

- **Steps in the Origin of Life**

- When earth was formed, it was a hot revolving ball of gas consisting of atoms of various elements. Heavy elements such as iron, nickel were present in center, while comparatively lighter elements such as aluminium and silicon formed the middle layer and lightest elements like hydrogen, oxygen and carbon were present in the outermost layer.

- **As the earth started cooling gradually, the atoms started combining with one another to form molecules and then molecules to simple organic compounds to complex organic compounds to molecular aggregates and ultimately the first cells (protobionts) were formed.**
- **The main steps in the origin of life are as follows-**



Hydrogen (H), Oxygen(O), Carbon(C), Nitrogen (N)

Hydrogen(H_2), Water vapour(H_2O), Carbon dioxide (CO_2), Methane(CH_2) and Ammonia (NH_3)

$CH_4 + H_2O \longrightarrow$ Simple sugars, Fatty acids, Glycerol
$CH_4 + H_2O + NH_3 \longrightarrow$ Amino acids
$CH_4 + H_2O + NH_3$ HCN $\longrightarrow$ Purines and Pyrimidines
Sugars + Sugars $\longrightarrow$ Polysaccharides
Fatty acids + Glycerol $\longrightarrow$ Lipids
Amino acids + Amino acids $\longrightarrow$ Proteins
Purines + Sugars + Phosphates $\longrightarrow$ Nucleotides Adenosine
Pyrimidines $\longrightarrow$ Phosphates
Nucleotides + Nucleotides $\longrightarrow$ Nucleic acids

Aggregates of large organic molecules capable of growth and division

Nucleic acid-controlled Coacervates

Lipo-protein membrane bound structure with enzyme controlled metabolism and nucleic acid regulation

Summary of Steps Involved In Origin of Life

- **Formation of Inorganic Molecules and Compounds**

- **With a considerable decrease in the earth's temperature over thousands of years, the atoms of different elements came together at random and formed inorganic molecules.**
- **Since the lighter elements (hydrogen, oxygen, carbon and nitrogen) were the most abundant in the outermost layer, their atoms reacted with each other to form the first inorganic molecules.**
- **Thus, the earliest molecules formed were those of hydrogen (H_2), nitrogen (N_2), ammonia (NH_3), methane (CH_4), carbon dioxide (CO_2) and water vapour (H_2O).**
- **All the atoms of oxygen probably combined with those of hydrogen and carbon to form water vapour and carbon dioxide.**
- **Hence the lack of free molecular oxygen was responsible for the reducing type of atmosphere that existed on the primitive earth.**
- **The energy required for the configuration of these molecules must have come from the ultraviolet radiation in the sunlight.**

- **Formation of Simple Organic Compounds**

- As the earth cooled further, the primitive inorganic molecules interacted and combined with one another to form simple organic compounds.
- Simple sugars, fatty acids, glycerol, amino acids and nitrogen bases (purines and pyrimidines) were probably the simple organic compounds that resulted from the interactions of the inorganic molecules.
- Water vapour present in the primitive atmosphere formed the clouds, which then resulted in rainfall continuously for several centuries.
- This rain water filled the hollows and basins of the earth's crust to form the oceans.
- Water in these oceans contained ammonia and methane.
- These compounds reacted among themselves to form the primitive organic compounds, which had carbon-carbon linkages.
- Thus, ocean water provided the basis for formation of organic compounds.

- **Formation of Complex Organic Compounds**

- **The smaller and simpler organic compounds, gradually started combining among themselves to form complex organic compounds.**
- **Simple sugars like glucose combined among themselves to form complex polysaccharides such as starch and cellulose; fatty acids and glycerol molecules combined to form lipids and fats, whereas amino acids, to form polypeptides and proteins.**
- **Purines and pyrimidines combined with simple sugars and phosphates to form nucleotides which in turn combined to form nucleic acid.**
- **RNA is considered as first nucleic acid.**
- **Heat of the sun probably provided the energy required for the formation of complex organic compounds.**
- **Haldane suggested that due to the accumulation of complex organic molecules, the sea ultimately became a sort of 'hot dilute soup' where in, the molecules collided, reacted and aggregated to form more complex molecules.**

- **Formation of Molecular Aggregates**

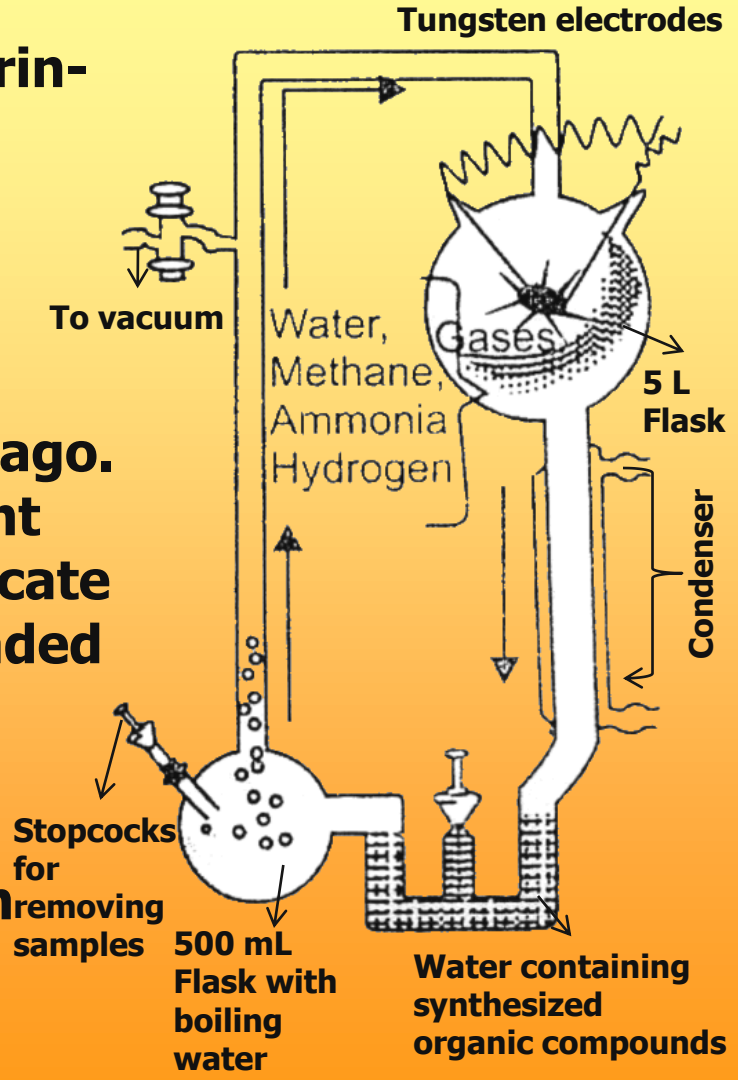
- It is suggested that the large organic molecules formed abiotically in the primitive earth came together spontaneously and due to intermolecular attraction, formed large colloidal aggregates called Coacervates.
- An envelope of water molecules formed around each such aggregate due to the hydrophilic nature of some of these compounds.
- A membrane of fatty acids protected and enclosed these molecules, increasing the chances of chemical reactions.
- Gradually, breakdown and building up reactions started for which the energy required was provided by the breakdown reaction.
- The coacervates selectively absorbed proteins and other materials from the ocean resulting in their active growth.
- The coacervates not only started growing rapidly but also started multiplying.

- **Formation of First Cell**

- The coacervates were in a state of dynamic equilibrium taking in new materials from the oceans and releasing degraded materials.
- Thus, they had all the basic properties of life such as metabolism, growth and reproduction.
- However, they lacked the complexity of molecular organization, catalytic proteins (enzymes) and precise control of nucleic acids.
- Later, the nucleic acids were said to have taken control of coacervate and the process of replication became precise in the due course of time.
- With the nucleic acids being established as the genetic material, the coacervates got transformed into the primitive living systems which have been called as protobionts or eobionts.
- Some of the proteins in protobionts are said to have developed the ability to catalyze chemical reactions, thereby functioning as the first enzymes.
- The formation of enzymes greatly enhanced the rate of synthesis of various molecules in the protobionts.

- In the course of time, the protobionts became enclosed by a protein lipid membrane, allowing the accumulation of some molecules and the exclusion of others.
- This property improved the ability of protobionts to survive and compete with others.
- With the processes of metabolism, growth and reproduction becoming regular, precise and regulated, the first cells or organisms were formed.
- The term progenote has been suggested by Carl Woese to describe the first cell, which served as the ancestor of all the forms of life existing today.
- The first forms of life developed among the organic molecules, in the oxygen free atmosphere. Hence, they presumably obtained energy by the fermentation of organic compounds.
- They were heterotrophs, requiring ready made organic compounds as food.

- **Miller and Urey's Experiment**
  - The first experimental support to Oparin-Haldane's theory of origin of life came from Urey and Miller's experiment in 1953.
  - In those days, Stanley Miller was a graduate student of Harold C Urey (1893-1981) at the university of Chicago. Urey (an astronomer) asked his student Stanley L Miller (a biochemist) to replicate the primordial atmosphere as propounded by Oparin and Haldane.
  - Miller (1953) made first experimental apparatus to access the validity of the claim for origin of organic molecules in primitive earth condition.



- In 1953. Miller built an apparatus of glass tubes and flasks in the laboratory. He created an atmosphere containing hydrogen (H_2), ammonia (NH_3), methane (CH_4) and water vapour (H_2O) in one large flask and allowed condensed liquids to accumulate in another small flask. The ratio of methane, ammonia and hydrogen in large flask was 2 : 1 : 2.
- Energy for apparatus was supplied by heating the liquid as well as by electric sparks from tungsten's electrodes in the gaseous flask (larger flask). The conditions of apparatus resemble those atmosphere present on early earth. The experiment run continuously for about one week and then analyzed the chemical composition of the liquid inside the apparatus.
- After continuous heating, cooling, circulation and electrical discharges in an air tight apparatus containing methane, ammonia, hydrogen and water vapour gases, Miller obtained a turbid red liquid. This turbid liquid was rich by simple organic compounds such as urea, hydrogen, cyanide, organic acids

(formic, acetic, lactic, succinic and propionic), sugars, pureness, pyrimidines and amino acids alanine, glycine and aspartic acid). The detail of some products formed under periodic conditions is as follows:

Carboxylic Acids	Nucleic Acid Bases	Amino Acids	Sugars
Formic acid	Adenine	Glycine	Straight and
Acetic acid	Guanine	Alanine	branched
Propionic acid	Xanthine	α-amino butyric acid	Pentoses and hexoses
Straight and branched fatty acids ($C_4 - C_{10}$)	Hypoxanthine	Valine	
Glycolic acid	Cytosine	Leucine	
Lactic acid	Uracil	Isoleucine, proline,	
Succinic acid		Aspartic acid, glutamic acid, serine, Threonine	

- Life originated in the era of Precambrian.
- First life on earth were chemoautotrophs.
- Primitive atmosphere was formed by the lightest atoms.
- The primitive atmosphere was reducing in nature.
- Oxygen was probably not present in large amounts in the atmosphere at the time of origin of life.
- Coacervates are believed to be the precursors of life.
- Coacervates are certain complex inorganic and organic compounds in the hot sea water aggregated in different combinations. Sydney Fox called them 'microsphere'.
- Coacervates containing nucleo-protein surrounded by several nutritive substances and covered by a surface membrane represent pre-cell.
- Proteins and nucleic acids have first evolved in the direction of origin of life on the earth.
- The concept of chemical evolution is based on chemicals under suitable environmental conditions.

- Protocells represented the beginning of life. They gave rise to prokaryotes.
- Carbon dioxide has replaced methane of the primitive atmosphere as the major carbon-containing compounds of the present-day earth's atmosphere.
- During the time of origin of life the water of primitive ocean has been called hot dilute soup of organic substances by Haldane.
- Von Helmont was the 17th century scientist to give a recipe for spontaneous generation of mice from dirty , sweat-soaked shirt put in wheat barn in the dark.
- Theory of spontaneous generation was given by Von Helmont.
- Abiogenesis means spontaneous generation.
- 3.5 billion years ago abiogenesis occurred.
- "Origin of life" as a result of chemical evolution has been properly explained by or the most logical biochemical theory of 'origin of life' has been given by A I Oparin.
- According to Oparin oxygen was not present in the primitive atmosphere of the earth.

- Louis Pasteur proved that life on present earth can originate only from pre-existing life.
- Pasteur's experiments and similar ones that followed convinced most people that spontaneous generation of life did not happen because Pasteur's swan-necked flasks ruled out the objection that spoiled air could have contaminated his experiments.
- In Stanley Miller's experiment H_2, CH_4, NH_3 and steam were subjected to electric discharge. Amino acids were obtained in
- Swan-necked flask experiment was done by Louis Pasteur.
- Synthesis of amino acids to prove that amino acids were formed in primitive ocean was experimentally proved by Stanley Miller.
- The primitive gases were placed in Stanley Miller's experimental system to show that organic molecules could have arisen from inorganic molecules on the primitive earth.

Thanks…