ARULMIGU PALANIANDAVAR ARTS COLLEGE FOR WOMEN

PALANI

PG DEPARTMENT OF ZOOLOGY

LEARNING RESOURCES

EVOLUTION

DEFINITION OF BIOLOGICAL EVOLUTION

Biological evolution of organic evolution is defined as 'the process of contend of life with constant modification.' It means living organisms modify and a according to the ever changing environmental needs. These modifications keep accumulating in the organism generations, after generations, resulting in more complex better adapted new species. Therefore, organic evolution is the evolution of pre complex and highly organized living beings from simpler and less organism living beings of the past by gradual modifications accumulated through successive generations over millions of years.

BASIC CONCEPT OF ORGANIC EVOLUTION:

The basic concept of organic evolution envisages 'continuity of life with constitute modification'. It suggests that:

Environmental conditions in nature are ever changing.

Organisms have an interest tendency to change in response to the changing environmental conditions. This is called adaptability or adaptation.

Such adaptive changes in organisms are inherited by the offspring and lead the 'Origin of new species' (Evolution).

Since changes in the organisms are due to adaptations, new species are always better adapted and more organized than their ancestors.

Different members of a species, on being adapted to different environmental diversity and evolve along several divergent lines and form new species.

All the present day species had a common ancestor at some or other time their evolution (Monophyletic genealogy).

Individuals migrate from their place of origin to varied geographical areas gradually adapt to different environmental conditions. This results in the formation of several new species from one ancestral species (Divergent evolution).

Organisms from varied regions also migrate to a common habitat and most to adapt to that habitat. As a result organism from distantly related grows develop common features (Convergent evolution).

Evolution is a very complex and extremely slow process. It is not possess to see one type of animals changing to other, but presence of integrated organisms supports the concept of evolution.

Evolutionary changes are continuous. They occurred in past, are continuously present and will continue in future.

DEVELOPMENT OF THE IDEA OF EVOLUTION:

Charles Darwin's name is closely associated with the concept of evolution and for many people Darwinism is evolution, but the concept of evolution, for the first time reared in the writings of ancient Greeks. Their explanation of the origin of living brings as given by Empedocles and Anaximander supported the notion of dynamic old and replaced the mythological explanation.

GREEK THEORIES:

Thales (624-548 BC) propounded the theory of aquatic or marine origin of life.

Anaximander (611-547 BC) was called 'the earliest evolutionist' by Osborn. He proposed that all living beings have arisen from a primordial fluid or due to which they ultimately return. The plants and animals were formed as this dried. It was presumed that man himself was first shaped like a fish and lived water. Later, when he became capable of terrestrial life, he cast off his fish-like capsule like a butterfly comes out of its chrysalis and assumed human form. The dry is crude yet the implication is clear. He also proposed that simple forms needed more complex forms.

Xenophanes (576-480 BC) contemporary to Anaximander, recognized that soils are the remains of organisms living in past. According to him, the existence fossils of marine animals on dry land indicated that the dry land was once under sea and that life originated in the sea.

Empedocles (504-433 BC) has been hailed as 'Father of evolutionary idea', Osborn. He believed in spontaneous generation and proposed that evolution of mammals was a series of attempts by nature to produce more perfect forms. The main its of his proposition are:

His theory was shaped as follows:

All the matter was formed of four elements namely, air earth, fire and water. These were acted upon by two great forces, the love and hate, which caused their seen or separation. As a result, parts of animals were formed separately as undistinguished organs. They joined together in haphazard manner under the influence of the over hate. The conglomerations produced this way were mostly monsters or harmonious and incapable of living, but a few could function as successful living organisms. Such successful combinations populated the earth. This theory provides first glimmerings of the idea of survival of the fittest, which formed the basis Darwin's theory of natural selection twenty three centuries later.

Aristotle (384-322 BC) called 'the greatest investigator of antiquity' by Locy (1923), was vitalist and hid ideas dominated biological thoughts well over a thousand years. He proposed that living things were animated by a vital force or guiding intelligence, which operates constantly and improves and perfects the living world. Aristotle suggested that the various organisms constitute a series, the so called ladder of life in which organisms can be arranged in a sequence of increasing complexity from non-living matter through plants to plant-like animals (like sponges and sea anemones) or lower animals and then to higher animals. He placed man on the top of this ladder.

Aristotle also introduced the concept of Teleology. According to this concept the natural processes such as development or evolution are guided by their final stage or final goal (*telos*) or for some particular purpose. The external teleology indicates guidance of a process towards some specified end decided by an external mystical source. The internal teleology indicates the end point of a process that has an understandable materialistic basis that develops from the process itself. For example, plants are engaged in photosynthesis and animals seek food for survival and the ultimate purpose of survival is reproductive success.

Epicurus (341-271 BC) and Soretium (99-55 BC) gave an evolutionary explanation of origin of plants and animals. Plants appeared before animals and humans appeared last of all.

PRE-DARWINIAN THEORIES:

Evolutionists of medieval age were:

Francis Bacon (1561-1680), who received Aristotelian idea and presumed that new species could arise from the old species by degenerative process caused due to mutability in the species. He, therefore, emphasized on variations as being the cause for the origin of new species from the old one. He suggested that flying fishes are intermediate between fishes and birds, and bats between birds and quadrupeds. His work influenced the thinking of the successors.

Jan Swammerdam (1637-1680), the Dutch scientist, proposed the 'Pre formation Theory'. According to this theory ova contain miniature of the adult in preformed state. The act of fertilization (i.e., union with the sperm) provides initiation for growth and the miniature grows into adult. All parts of the embryo lie folded together in the egg. During development these parts grow in size, and stretch themselves.

When spermatozoa were discovered, they were called the animalcules and were described to possess the miniature of the embryo. The eggs were presumed to supply nourishment for the developing embryo.

The pre formation theory was discarded by the valuable observations made by Casper Friedrich Wolf (1759), who studied chick embryo and concluded that the preformed embryo is not found either in egg or sperm. The development includes the division of one cell and the modifications in the cells produced by its division to form various organ systems.

Demaillet (1656-1738) contributed mainly on the nature and formation of fossils. He also pointed out the similarities between aquatic and terrestrial forms and proposed that the terrestrial forms have evolved from the marine forms which were trapped in marshes. Many of such species failed to make the transition and had an ill-fate. He cried the examples of origin of birds from flying fish, and men and women from mermen and mermaid.

Maupertius (1698-1759) was the first to propose a general theory of evolution. He proposed that hereditary material was particulate matter. It was transmitted through both maternal and paternal sides of the family. He thought that hereditary particles could be changed by environment (acquired characters). He also appreciated the role of natural selection in evolution and of isolation in speciation.

Bonnet (1706-1793) proposed ‘Emboitement Theory or Encasement Theory’. It advocated that the initial member of a species encapsulates within it the preformed germs of all future generations. These existed inside the germ cells of mother. The theory was discredited by Prevost (1824).

Wolf Theory of Epigenesis was proposed by Casper Friedrich Wolf to replace pre formation theory. According to this theory, an embryo develops by the gradual differentiation of undifferentiated simple tissues into organs.

Linneaus (1707-1778) is known as the ‘Father of Taxonomy’. He believed in special creation. He presumed that species are created by god and are immutable and fixed entities.

Buffon (1707-1778) believed in the inheritance of acquired characteristics and the direct effect of environment on the structural modifications of organisms. Through, he never gave a consistent theory of evolution but he did state parts of the theory of organic evolution.

James Hutton (1726-1797) postulated that activities bring magma up from earth’s molten interior which on solidification forms new igneous rocks. He also noted that forces like wind, water (rain, surf), heat, cold, ice (glaciers) and activities of plants and animals erode rocks and the eroded particles are transported by water, and are deposited in layers. These layers get compressed into sedimentary rocks. His idea of gradual geological changes brought about by natural process is known as uniformitarianism. This was greatly championed by the great geologist Charles Lyell and has greatly influenced Darwin.

Erasmus Darwin (1731-1802), the grandfather of Charles Robert Darwin, gave the first clear statement of the inheritance of acquired characters, according to which the effects produced by the environment on the organisms are transmitted to the offspring. The theory was elaborated by Lamarck in the year 1809.

he contributions made by Lamarck, Darwin, Cuvier, Weismann, Huxley, etc., are of great importance, since they provoked real scientific thinking of evolutionary process and their theories are still helpful, but in a somewhat modified form. The various modern theories have been discussed in detail separately hence a brief survey will serve the purpose here.

Lamarck’s Theory of Inheritance of Acquired Characters (1744-1829): Lamarck’s theory emphasizes the influence of environment on the living beings. The changes introduced by the

environment are acquired by the living beings and are inherited by the next generation. Modern supporter of Lamarckism was Lysenko (1930), a Russian botanist.

Theory of Catastrophism: The theory was formulated to explain differences in the past and present forms of life and sharp discontinuous in the fossils records present in the stratified rocks. It states that there had been several creations, each proceeded by a catastrophe due to some supernatural forces and not the geological disturbances, like volcanic eruptions, upheaveling of earth, torrential rains, unprecedented increase in sea level, etc. Each catastrophe completely destroyed the life. The new create resulted in life quite different from the previous one.

George Cuvier (1769-1832) and Orbigne (1802-1832) were the chief advocate of the Theory of Catastrophism.

Cuvier (1769-1832) is considered to be the 'Father of Palaeontology Comparative Anatomy'. Cuvier believed in the fixity of species. The occurring of fossils in different rock strata was accounted on the basis of catastrophism succession of catastrophes have periodicallydestroyed all living things, follows each time by the successive creations of new and higher forms.

Theory of Eternity of Life: According to this theory, life has ever be exixtance in the form asit exists today and will continue to be so far ever. It not had beginning nor an end and has not changed or evolved.

However, with present knowledge, the theory cannot be accepted. The evidences clearly indicate the gradual complexity in the organization of living beings.

Theory of Uniformitarianism: James Hutton (1785) and Charles Lyell established theconcept of uniformitarianism which holds that slowly acting general social forces (erosion, sedimentation, disruption and uplift) result in the formation of fossil-bearing rock strata. The same forces are acting even today.

EVOLUTIONARY THEORIES SINCE DARWIN:

Darwin's Theory of Natural Selection (1809-1822): Darwin formulated theory of 'Origin ofSpecies by Natural Selection in 1859'.

To explain some of the phenomenon, which were not suitably explained by natural selection, Darwin proposed some more theories. These are:

Theory of Pangenesis: To explain how the characteristics are transmitted parents to the offspring, Darwin proposed Pangenesis theory. According to this theory each and every cell of the body produces minute primordial called gemmules of the pangene. These gemmules from all the parts of the body are carried by the blood of the gonads where these accumulate in the germ cells. Each gamete represents minute replica of parent's body.

Theory of Sexual Selection: Darwin presumed that there is always a contest among males for the possession of females. For this season they have developed various methods to attract the female. Some are beautifully coloured, in other species they are provided. With horns or they exhibit different attractive behaviours or produce sound. This results in sexual dimorphism, which is very common in animals.

Artificial Selection: Darwin recognized artificial selection exercised by human beings as the commonest method for improving the races of domestic animals and cultivated plants and producing new varieties. He presumed that if new races could be developed by artificial selection, the same is possible in nature.

Weismann's Theory of Continuity of Germplasm: Considering the futility Darwin's theoryof pangenesis, Auguest Weismann (1892), a staunch supporter Darwin, proposed that the cytoplasm of animal body is differentiated into cytoplasm and germplasm. The germplasm produces gametes which transmit characteristics of parents into the offspring. The remaining body of the organism formed of somatoplasm. Weismann also emphasized that only those changes in occur in the germplasm are heritable, changes occurring in the body (some somatoplasm) due to environmental effect are not inherited.

The essential features of the theory can be summarized as under:

Germplasm and Somatoplasm: Weismann proposed that the organisms comprise of two types of protoplasm-the germplasm present in the germ cells only and which is passed on to the offspring, and the somatoplasm, the protoplasm forming remainder of the body that plays no role in heredity. The germ cells of the two parents unite during reproduction and form the zygote or fertilized egg. During development zygote divides into two daughter cells, each of which receives an equal share of germplasm. Through germ cells a continuity of germplasm is maintained generation after generation.

Presence of Determinants: Situated in the germplasm are minute complex structures. These are known as determinants. The determinants can be compared with the present day chromosomes. The characteristics of the organisms are represented in the determinants in the form of minute physiological units, the determiners (equivalent to genes).

Immortality of Germplasm: The germplasm is immortal because it perpetuates from one generation to the next through meiotic division. The germplasm is maintained generation after generation. The somatoplasm is mortal and dies with the death of the organism.

Only those variations which appear or which are introduced in the germplasm (germplasm or heritable variations) can be inherited and not those which appear in the somatoplasm.

The germplasm is composed of 'ids' i.e., equivalent portions of germplasm contain all kinds of determinants present in the parent body or which are responsible for the development of characteristics in the offspring.

In a fertilized eggs 'ids' from both the parents are contributed in equal amounts.

De Vries Theory of Mutation: Darwin in his Theory of Natural Selection described the occurrence of variations but he did not explain the method of their origin. Moreover, he emphasized on small and cumulative variations. Hugo de Vries (1848-1935) suggested that variations which are important for evolution are sudden and large, which he called mutations or saltations. He proposed 'Mutation Theory' in 1886 for the origin of species.

Karl Naegeli and Wanger Gulik emphasized the presence of some inner directive which guides the course of evolution independent of the environment.

Recapitulation Theory of Haeckel: Ernst Haeckel (1811) proposed that 'Ontogeny recapitulates phylogeny', i.e., the development of the individual repeats the evolutionary history of the race, condensing some stages and eliminating the others.

Theory of Orthogenesis: According to the theory of Orthogenesis the variations (or in other words the evolutionary changes) occur along certain definite lines, guided by some undefined or inherent mystical force. The term 'orthogenesis' was proposed by Haeckel in 1893. There were two views regarding orthogenesis. Karl Von Naegeli believed in the presence of some mystical principle of progressive development in the living organisms which brings about the particular specialization. The theory is merely mythical and has no scientific basis. Theodor

Eimar was of the opinion that lines of evolution are determined by laws of organic growth, aided by inheritance of acquired characters, and proceed in specific direction.

In certain cases directional evolution has resulted to an enormous increase of size of horns which has ultimately proved to be harmful to the organisms and has led to their destruction.

Isolation Theory: The role of isolation in evolution was first emphasized by M. Wanger. He stated that any factor or mechanism which separates the individuals of a species into groups, so that these are unable to intermingle and interbreed, constitutes the isolating mechanism and is helpful in the progress of evolution. It was supported by Jordan Cellogg, Gulick and Crompron.

MODERN EVOLUTIONARY THEORY:

Modern evolutionary theory has its foundation in the Evolutionary Synthesis or Modern Synthesis that is formulated on the basis of contributions from Genetics, Systematics and Palaeontology. It was named Neo-Darwinian Theory.

The modern synthetic theory of evolution has evolved during the last century through accumulation of facts and theoretical conclusions from a number of scientists. Theodosius Dobzhansky (1900-1975) in his book 'Genetics and the Origin of Species' emphasized the role of genetic changes in natural populations od Drosophila in the process of evolution. Julian Huxley (1924) and Ernst Mayr (1942-43) have explained the mechanism of origin of variations in higher animals and Stebbins in higher plants. Clevland, Blackeslee, Renner and others have shown that a combination of gross chromosomal aberrations, rare combinations in balanced lethal systems and obligate self-fertilization are important factors for variation and evolution. Rensch (1960) has suggested that the forces operating for the origin of species also operate for the evolution of genera, families and other higher categories.

At present the synthetic theory of evolution recognizes five basic processes, namely, gene mutations, changes in chromosome number, genetic recombination, natural selection and reproductive isolation. The three accessory processes also contribute to the evolutionary phenomenon. These are migration, hybridization and chance in small populations.

Othniel C.Marsh (1831-1989), Cope (1840-1897), Mathew, Gregry, Romer and Simpson in America, Woodward (1864-1944) and Wa son in England and Broom (1866-1951) in South Africa contributed immensely to vertebrate palaeontology. J.B.S Haldane (1892-

1964), Fisher (1890-1962), and Sewall Wright (1889-1988) and S.S Chetverikov (1920s) have provided mathematical theory for gene frequency change under natural selection that leads to the evolution of new populations. Species on genus Crepis by E.B.Babcock provided support to Neo-Darwinian theory.

At the same time, when evolutionists were busy to seek plausible explain for evolution, some scientists were trying to accumulate facts about evolutionary process. The evidences are from morphology, physiology, taxonomy and embryology of living forms and the palaeontology (the fossils of previously existing form). The recent techniques have been helpful in demonstrating the evolution the place in the laboratory within short periods of only a few years. If organ with very short life cycles, such as fruit fly or bacteria are reared for some generations in laboratory, new kinds of individuals are observed in the process. Initially, these individuals differ slightly from their parents, but as they increase in number, differences keep on accumulating and a stage is reached when become so markedly different from their parents that they fail to interbreed their parents and thus form a new species.

THEORY OF SPECIAL CREATION

Hypothesis of special creation is the oldest hypothesis and is based on the mythological belief that divine.

God created life.

Its essential features are:

- All living plants and animals existing now were created by some supernatural power, the god or creator.
- These forms were designed according to the surroundings.
- They have existed unchanged from the time they were formed.

According to Christianity, the chapter of 'Genesis' in Bible states that the world was created by the creator in six days from material prima. The heaven and earth were created on the first day, sky and sea on the second day, dry land and plants on third day, sun, moon and stars on fourth day, fish and fowl on fifth day and animals including man and beats on sixth day. First man, the Adam, formed from clay while the first women, Eve, was created from his 12^{th} rib. According to Hindu mythology, God of creation, Lord Brahma, created different forms of life from various parts of his body.

THEORY OF SPONTANOUS GENERATION OR ABIOGENESIS OR AUTOGENESIS

Until seventeenth century people believed in abiogenesis (gr, a, not, bias, life, genesis, origin) or spontaneous generation of living organisms from non-living inanimate matter.

Empedocles, Anaximander, and Aristotle were the main propounders of this theory.

- According to Epicures (342-271 B.C,) worms and numerous other animals were generated from the soil or manure by the action of moisture and warmth of the sum and air.
- According to Aristotle (384-322 B.C,) , the common worms, bee larvae, wasps, ticks, glow worms and various other insects are born from dew, rotten slime, manure, dry wood, sweat and meat, etc. Eels develop from sea mud, frogs and salamanders from coagulated slime and butterflies from cheese.
- Two thousand years later, Van Helmont (1577-1644) described that mice arisefrom wheat barn and sweaty shirt kept in a pot for 21 days in dark room.
- Similarly, a variety of bird, the 'barnacle goose' was presumed to be derived from some worm barnacle living in sea, or from goose tree.

Theory of abiogenesis was discredited by Francisco Redi (1626-1698), Spallanzani (1729-1799) and Pasteur (1822-1895).

THEORY OF BIOGENESIS(LIFE FROM LIFE)

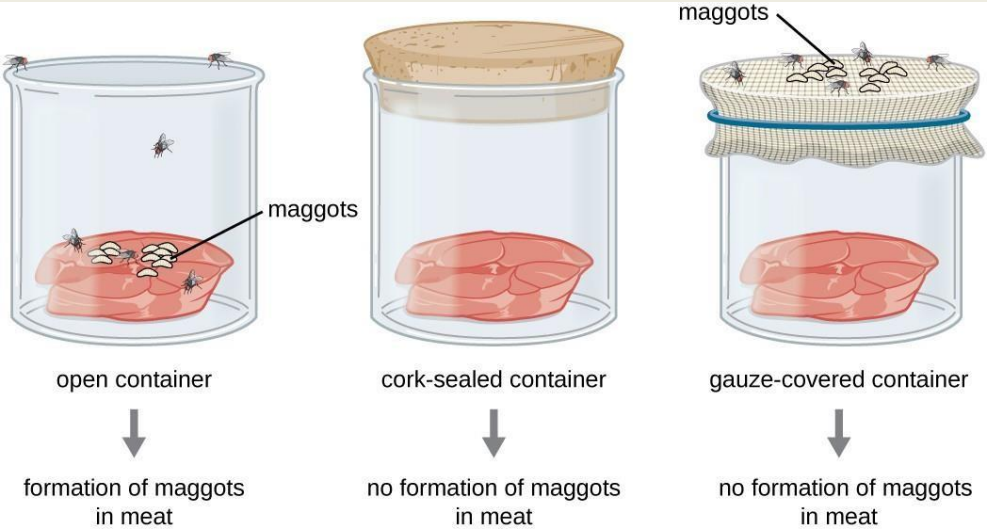
According to biogenesis, 'Life can arise from pre-existing life' and non from the non living matter by abiogenesis.

This theory is supported by the following evidences.

1. REDI'S EXPERIMENT:

Italian physician, Francisco Redi (1621-1697), demonstrated that maggots could not be created from meat but the smell of meat attracted flies which laid eggs on

the flesh. The maggots appeared when eggs hatched. Redi placed lumps of boiled meat in three jars A, B and C.Jar A was left uncovered. Jar B was decayed in all the jars but maggots appeared only in the uncovered jar A where flies could lay their eggs on meat. Plenty of flies were seen sitting and laying eggs on muslin cloth and parchment paper, but no maggots appeared on the meat in jar B and C.



2. SPALLANZANI'S EXPERIMENT:

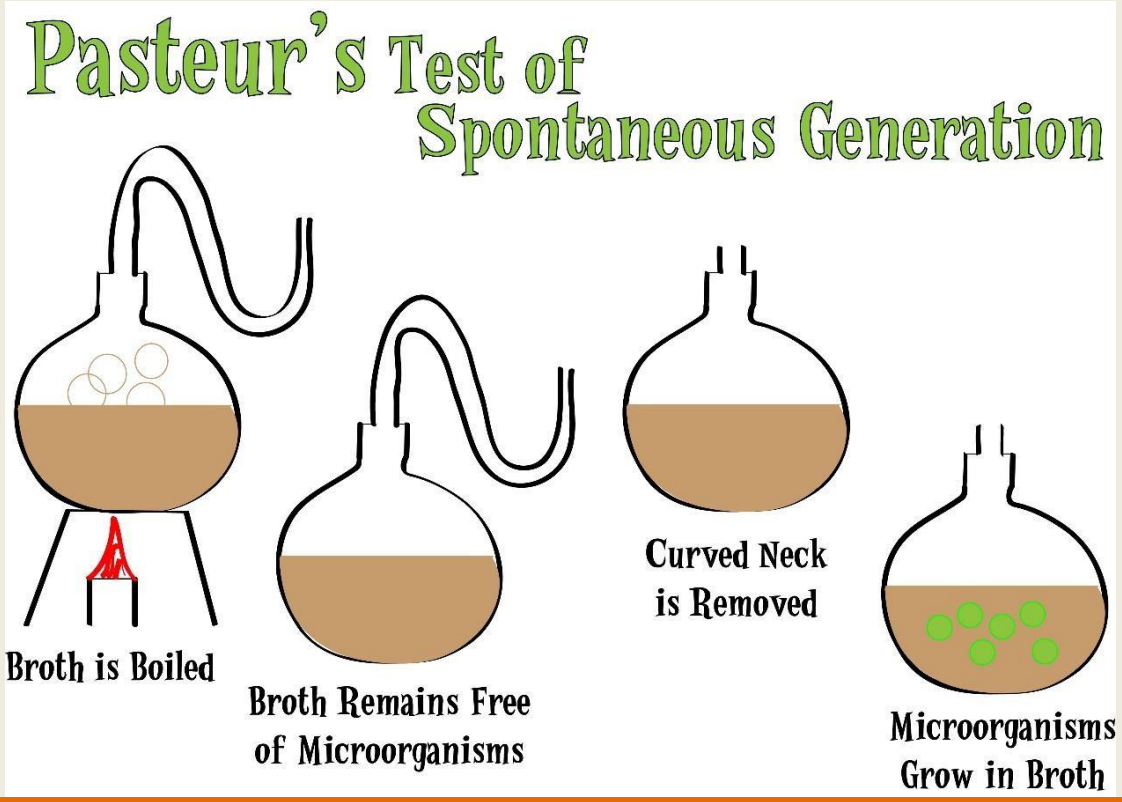
Italian scientist, Lazzro Spallanzani (1729-1799) poured hay infusion in eight bottles and boiled all of them. Four of them were just corked and other four were made airtight. After a few days, he found that there was thick growth of microorganism in all the corked bottles but no organisms in the airtight bottles. He argued that air contains microorganisms and was the source of contamination.

3. PASTEUR'S EXPERIMENT:

The remaining doubts were cleared by Louis Pasteur (1822-1895). He kept a mixture of sugar and yeast powder in a flask and filled about half of it with water. He, then, softened the neck of the flask and drew it out in the shape of 'S'. The contents of the flask were boiled till strong current of steam rushed out from the curved neck, boiling killed the microbes in the flask and made the contents sterile. The flask was cooked and left undisturbed. It was noted that the contents of the flask remained unchanged even after 18 months. But, when neck of the flask was broken the solution of the flask came in contact with air and microbial growth started.

It means air contains microorganism, which could not reach the solution in swan- necked flask and settled in curved neck.

Pasteur's experiment revealed that even the minute organism arise from pre-existing organisms of their kind. This supports the concept that life cannot arise spontaneously under conditions that exist on earth today. Conditions on the primaeval earth billions of years ago were assuredly different from present conditions. The first form of life appeared as simple self-duplication particles that might have arisenspontaneously from non-living chemical substances.



4. FORMATION OF FATTY ACIDS AND GLYCEROL:

Condensation and polymerization of the aldehydes and ketones and their oxidation resulted in the formation of fatty acids. Such compounds had lesser percentage of oxygen than long straight chains of carbon. In primitive oceans, glyceroland fatty acids combined resulting in the formation of fats.

5. FORMATION OF AMINO ACIDS:

Combination of hydrocarbons, ammonia and water under the influence of freelyavailable energy reacted to form amino compounds, commonly known as amino acids.

BIOCHEMICAL (OR) CHEMOSYNTHETIC ORIGIN OF LIFE

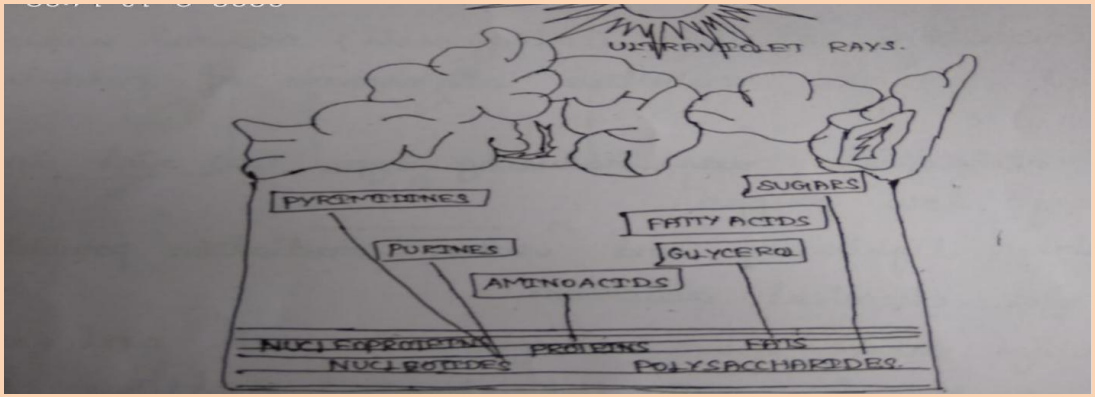
A.I oparin (1923) and Haldane (1988) started that life originated about 2.5 billion years ago from some non living organic compounds in the oceans of primitive earth through a series of biochemical reactions. Spontaneous generation of life (abiogenesis) occurred under the conditions prevailed in the primitive atmosphere of primitive earth. Earth's initial atmosphere was reducing type (i.e) rich in hydrogen and very low oxygen. High temperature, lightening and solar radiation provided energy required for chemical reactions. First living beings arise from simple inorganic and organic compounds as a result of series of chemical reactions by polymerization. This process extended over a billion years. Lederberg considered three stages in the origin of life namely chemogeny, biogeny and cognogeny.

CHEMOGENY (OR) CHEMICAL ORIGIN OF LIFE:

About 4 billion years ago, earth's atmosphere had ammonia methane and water vapours. There was no free oxygen. Formation of various simple and complex organic molecule from these gases is called prebiotic evolution it involves following steps.

1. FORMATION OF SIMPLE ORGANIC COMPOUNDS:

The primitive inorganic molecules interacted and combines to form simple organic compounds like alcohols, aldehydes, glycerol, aminoacids, sugars and nitrogenous bases.

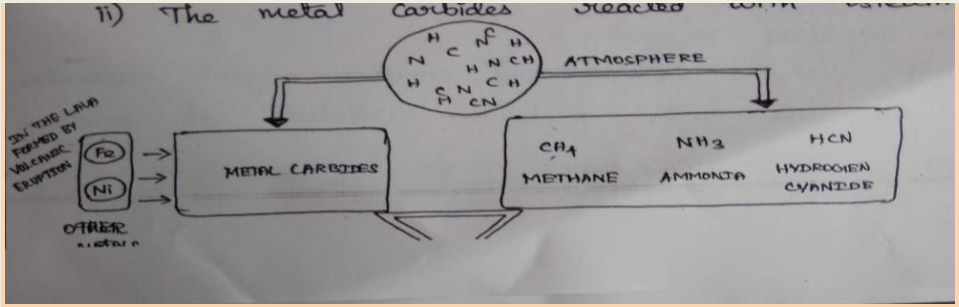


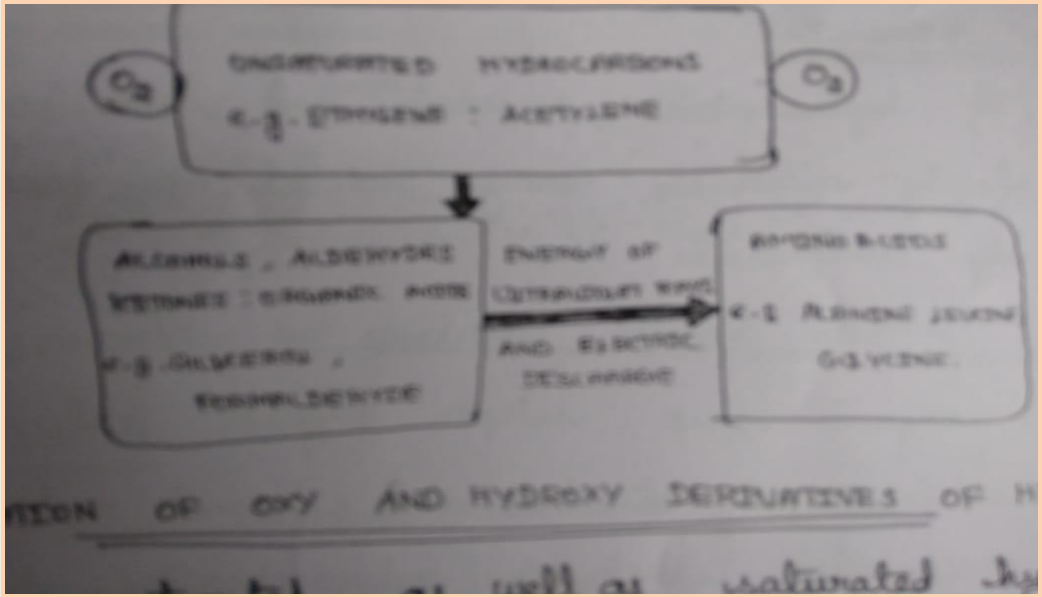
A) FORMATION OF HYDROCARBONS: (MICROMOLECULES)

When the temperature of earth surface cooled down to 1000˚c or even lower, a variety of simple saturated and unsaturated hydrocarbons were formed.

i) The combination of highly reactive free radicals CH and CH_3.

ii) The metal carbides reacted with steam.





B) FORMATION OF OXY AND HYDROXY DERIVATIVES OF HYDROCARBONS:

Both unsaturated as well as saturated hydrocarbons reacted with superheated steam and formed oxy and hydroxyl derivatives such as aldehydes, ketones and acids.

C) FORMATION OF CARBOHYDRATES:

Small chain compounds of C_3H and O were also formed from hydroxy derivatives. These first formed compounds must have been glucose and fructose. Their condensation resulted in the formation of disaccharides and polusaccharides (sugar, starch).

D) FORMATION OF FATTYACIDS AND GLYCEROL:

Condensation and polymerization of the aldehydes and ketones and their oxidation resulted in the formation of fatty acids. Such compounds held lesser percentage of oxygen then long straight chains of carbon. In primitive oceans, glycerol and fatty acids combined resulting in the formation of fats.

E) FORMATION OF AMINOACIDS:

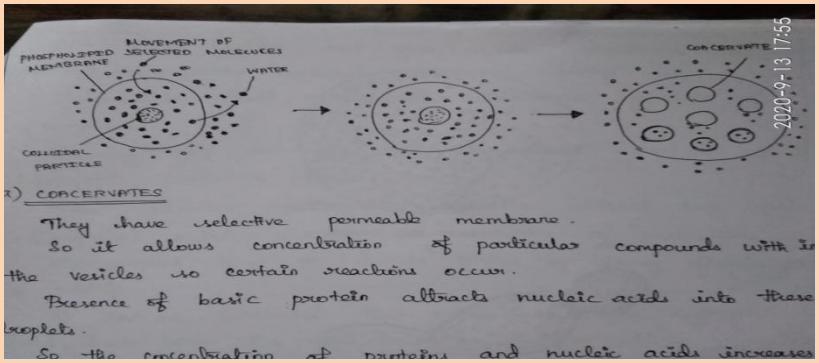
Combination of hydrocarbons, ammonia and water under the influence of freely available energy reacted to form amino compounds namely aminoacids.

II. FORMATION OF COMPLEX ORGANIC COMPOUNDS (OR) MACROMOLECULES:

In the hot organic soup, simple organic molecules underwent condensation, polymerization and formed more and more complex organic molecules such as polysaccharides, fats, proteins, nitrogenous bases, nucleosides and nucleotides. Sugar molecules combined to form starch, cellulose and glycogen. Fats were formed by the condensation of fatty acids and glycerol. Amino acid molecules formed long polypeptide chains. Nature could synthesize all the compounds known to exist in the present day living beings but at a very low place.

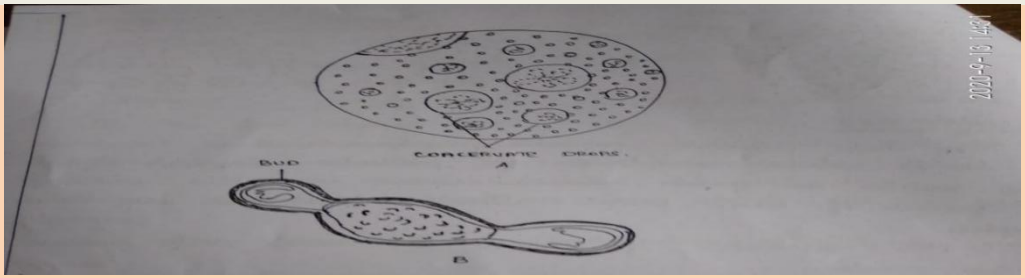
III. FORMATION OF MOLECULAR AGGREGATES (OR) PREBIOTIC MOLECULES:

Complex organic molecules are synthesized abiotically in the ocean on primitive earth. These molecules are formed of intermolecular attraction. These colloidal aggregates of macromolecules were called coacervates, proteinoid microspheres, protocells, micells or liposomes. Lipoid bubbles are called coacervates and proteinoid aggregates as proteinoid microsphere.



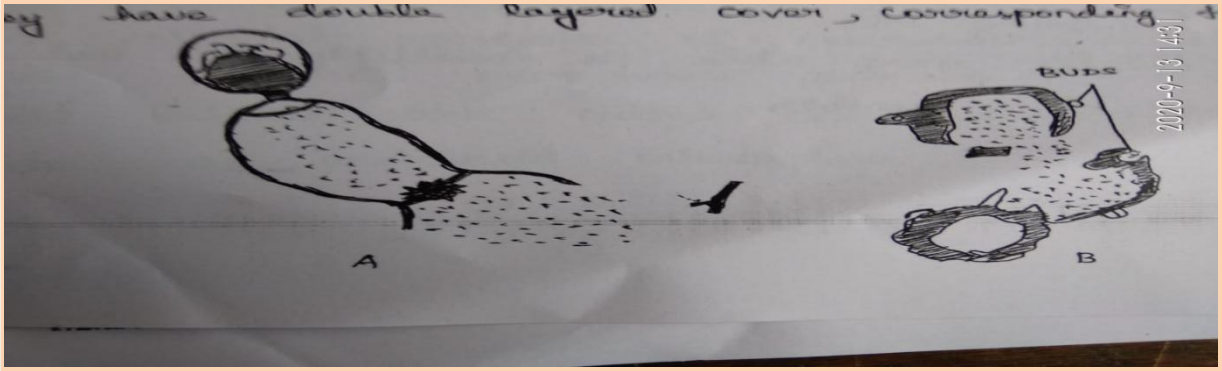
a) COACERVATES:

They have selective permeable membrane. So it allows concentration of particular compounds within the vesicles so certain reactions occur. Presence of basic protein attracts nucleic acids into these droplets. So the concentration of protein and nucleic acids increases within vesicles. Small size of vesicles allow chain reactions to occur so building up and breakdown reactions occur. So coacervates of could carry out such functions as synthesis and hydrolysis of starch and breakdown of glucose to release energy. They were able to preserve their organization and use energy and matter entering them. These coacervates were able to multiply by buding and increase in number.



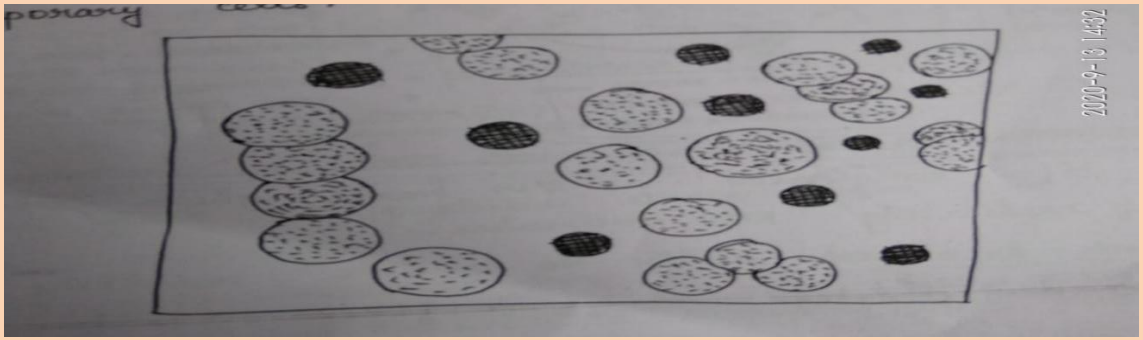
PROTEINOID MICROSPHERES :

Oparin called the colloidal bubbles as proteinoid microspheres or probionts. Microspheres are easily formed when water is added to thermal proteinoids. They exhibit great uniformly in size and shape. These resemble coccoid bacteria and are stable. They have double layered cover, corresponding to cell membrane.



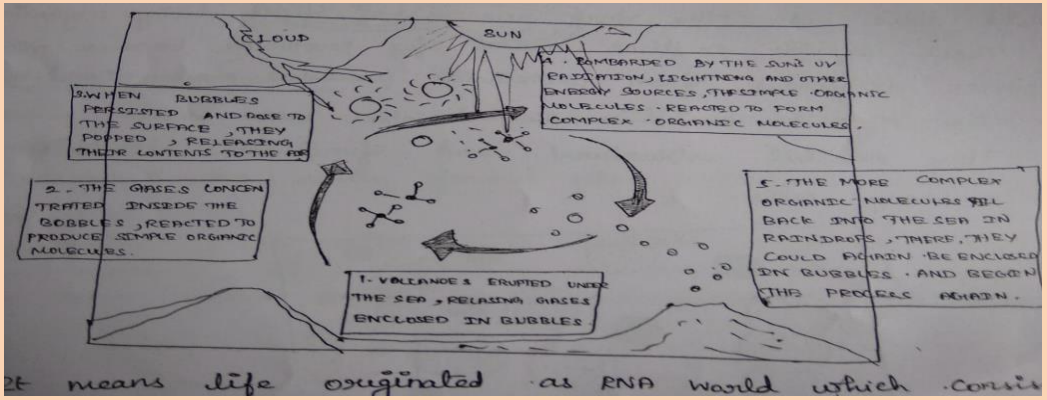
Both gram positive and gram negative microspheres have been produced microspheres exhibit non random motility. Information could communicate within an aggregate of microsphere. In hypotonic solution, the microspheres swell up and in hypertonic solution, these shrink. This behavior stimulates osmosis without any lipid microspheres retain enzyme like activities of proteinoids. Microspheres tend to divide either by binary fission or by budding. It can be concluded that microsphere like aggregates could have been the fore

runners of first living organisms. These provide excellent model for protoceps because microspheres originated from proteinoids produced under conditions exixting on the primitive earth. They exhibit structural and functional attributes of contemporary cells.



IV. FORMATION OF NUCLEIC ACIDS: (THE NAKED GENES)

By the polymerization of nucleic acids lead to the forms of nucleotides. These self replicate poly nucleotides (nucleic acids) got established in the primordial earth about 3.5 billion years ago. Because of errors during replication different varieties of nucleic acids were formed. RNA poly nucleotides molecules developed the quality of directing synthesis of polypeptides they are now called as ribosomes.



It means life originated as RNA world which consisted solely of self replicating RNA molecules. Later on, DNA developed ability to mutate, resulting in the diversification of living cells. The nucleic acids were like naked genes. Their formation was the first step to enter the vaguely defined frontiers between life and non life.

V. FORMATION OF NUCLEOPROTEINS (OR) PROTOBIONS:

Due to aggregation, giant molecules of nucleoproteins were formed by the union of nucleic acid and basic protein molecules.

PROTORIBOSOMES:

These nucleoproteinoid particles had fibrous or globular appearance. The globular nucleoproteinoid micro particles might have been a model for early ribosomes and are named protoribosomes.

PROTOVIRUSES:

Some giant nucleoproteinoid molecules had certain characteristics of a free living gene. These could be compared to prevent day viruses having nucleic acid core and protein covering. They were called protoviruses (or) probionts by oparin.

BIOGENY OR BIOLOGICAL EVOLUTION

VI. FORMATION OF FIRST CELLS (EOBIONTS OR PROTOBIONTS)

The first cell probably arose from the probionts and were anaerobic prokaryotes. They gave rise to two groups of cells membranes and protistiants, which acted as ancestor to present day prokaryotes and eukaryotes.

MONERANS:

The cell without defined nucleus are called monerans. They evolved into prokaryotes like bacteria. These lacked the nuclear membrane. Therefore, their nuclear material (DNA) was not isolated from the surrounding cell cytoplasm.

PROTISTANTS:

They are the cells with distinct nucleus and have a nuclear membrane around their genetic material. This membrane isolated genetic material from cell cytoplasm from protistans arose eukaryotes which evolved into protozoa, metazoa and metaphyla.

VII. EVOLUTION OF MODES OF NUTRIENTS:

CHEMOHETEROTROPHS:

The first living organisms or cells were chemoheterotrophs. They multiplied rapidly and obtained energy by the fermentation of prebiotic substances. Due to increase in number of chemoheterotrophs nutrients in sea under exhausted and lend to evolution of several mode of nutrition.

a. PARASITISM:

These are animals that started living on the bodies of living organisms.

Ex: Monerane, Virus.

b. SAPROPHYTISM:

Some organisms started drawing their nourishment from the bodies of dead and decayed cells.

c. PREDATION (OR) ANIMALISM:

This was animal like way of eating in which are organism eats another in whole or in part and obtains its food in this manner.

d. CHEMOSYNTHESISERS (OR) CHEMOAUTOTROPHS:

Protocells with enzymes of metabolic pathways could use less complex nutrients and synthesized more complex molecules. The chemoautotrophs obtained energy by a relatively simple and inefficient process of fermentation. These early fermentation or anaerobic chemoautotrophs were similar to our present day anaerobic bacteria and yeast. They released large amount of CO_2 which was initiated for synthesizing organic compounds by trapping solar energy.

B) ANAEROBIC PHOTOTROPHS:

Evolution of chlorophyll molecule enabled certain protocells to utilize light energy and synthesize carbohydrates. They were the photosynthetic cells. The first photosynthetic cells were anaerobic. This was the beginning of autotrophism.

Ex: Sulphur bacteria, green bacteria.

C) ANAEROBIC PHOTOAUTOTROPHS:

It is presumed that accumulation of CO_2 in atmosphere and formation of chlorophyll molecules resulted in the evolution of autotrophic forms. They released free oxygen in the atmosphere and also called oxygen producing photosynthesis. They appeared about 3300 to 3800 million years ago.

EFFECT OF PHOTOSYNTHESIS:

Photosynthesis lead to the regular inflow of energy, charged atmosphere from reducing to oxidizing method of utilizing carbon dioxide and converting it to sugar.

EFFECT OF OXYGEN:

With the increase in the number of photosynthesing organisms, oxygen was liberated. The oxidizing atmosphere lead to the formation of ozone layer (ozonosphere) and present day atmosphere. Free ozone is atmosphere finally led to the evolution of aerobic mode of respiration.

COGNOGENY

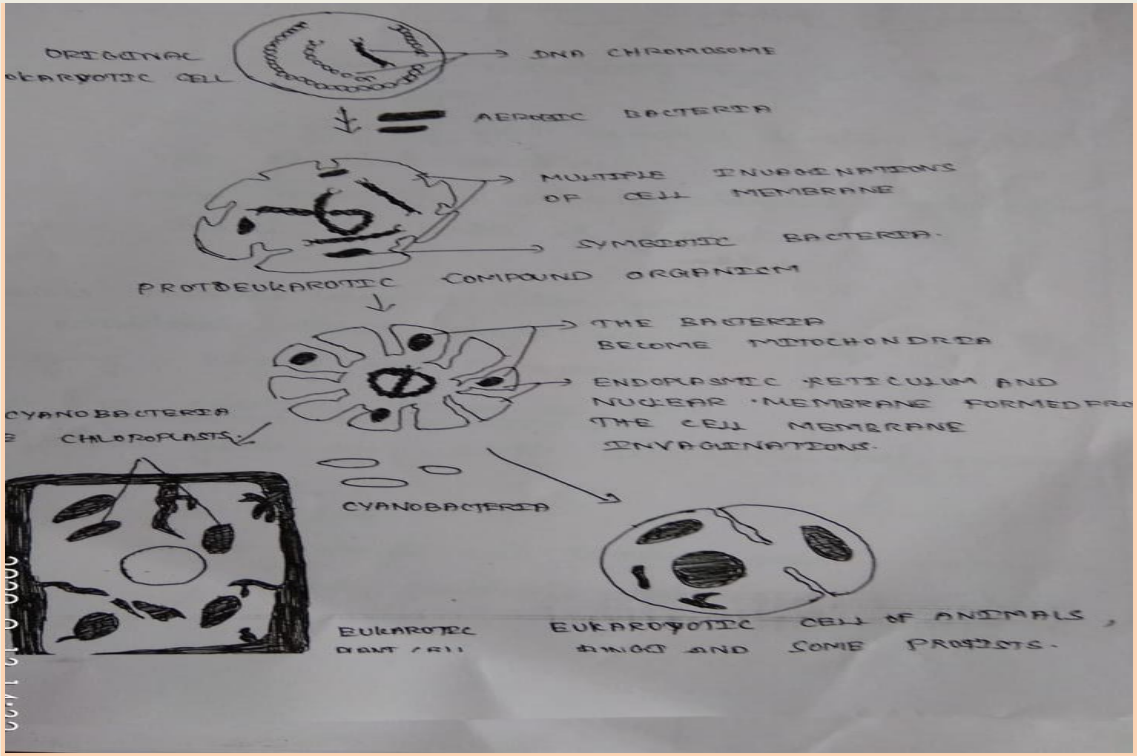
EVOLUTION OF MECHANISM OF PERCEPTION, EXPRESSION AND COMMUNICATION

VIII. EVOLUTION OF EUKARYOTES:

The protocells were prokaryotic and archaebacteria like and the eukaryotic cells evolved from the archaic prokaryotic cells. These are two views regarding their mode of origin of eukaryotic cells.

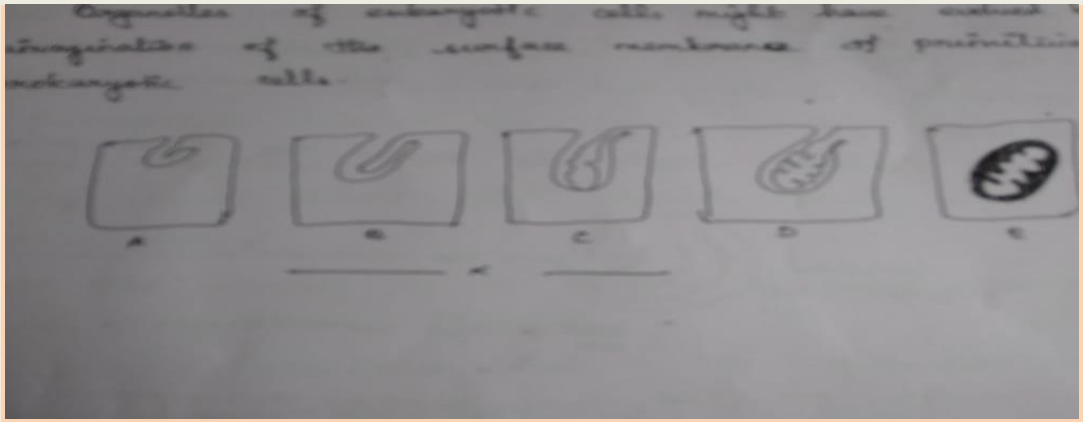
ENDOLYMBIOTIC ORIGIN:

Anaerobic predator host cells engulfed primitive aerobic bacteria but did not digest them. The origin respiring bacteria established themselves permanently inside host cells and developed mutual association. Such predator host cells become the first eukaryotic cells.



ORIGIN OF INVAGINATION:

Organelles of eukaryotic cells might have evolved by invagination of the surface membrane of primitive prokaryotic cells.



FOSSILS AND THEIR TYPES

Fossils are the remains or traces of ancient life that have been preserved by natural processes. Examples of fossil include shells, bones, stone imprints of animals or microbes, exoskeletons, objects preserved in amber, petrified wood, coal, hair, oil, and DNA remnants. There are five types of fossils:

1. Body Fossils
2. Molecular Fossils
3. Trace Fossils
4. Carbon Fossils
5. Pseudofossils

1. Body Fossils – Soft Parts

The first type, body fossils, are the fossilized remains of an animal or plant, like bones, shells, and leaves. These can be mould and cast fossils, like most of the fossilized dinosaur skeletons and big bones we see, replacement fossils, like petrified wood, or whole-body fossils – mammoths caught in the ice, or insects trapped in amber.

A mold is an imprint left by the shell on the rock that surrounded it. There are two types of molds. They are:

External Mold:

It is a mold of the outside of the shell. Each time we break a shell or bone out of the rock, an external mold is left behind.

Internal Molds:

Molds of the underside of the shell may be left on the surface of rock that formed when sand or mud filled the inside of the shell.

2. Molecular Fossils

Molecular fossils are often referred to as biomarkers or biosignatures and represent products of cellular biosynthesis that are incorporated into sediments and eventually into a rock. Many of these chemicals become altered in known ways and can be stable for billions of years.

3. Trace Fossils

Trace fossils are marks left by an animal or plant that has made an impression. These fossils include nests, burrows, footprints or any other markings of the animal's time on the earth. The structure of the animal or plant remains as a mineral form. The colours of the minerals that replace the form can be dazzling. Sometimes they are made into art and jewellery.

4. Carbon Fossils

All living things contain an element i.e. carbon. When an organism dies and is buried in sediment, the materials that make the organism break down and eventually only the carbon remains. The thin layer of carbon left behind can show an organism's delicate parts like leaves or plant e.g. fern fossil 300 million years old.

5. Pseudofossils

Sometimes watery solutions of various minerals speed through the sediments and it takes the shape of some plant part or animal. Their study shows that they are neither plants nor animals. Such fossils are called pseudofossils.

Importance of fossils

1. They provide crucial information regarding the organism.
2. It helps develop connecting links between different groups of organisms and study evolutionary relationships.
3. *Tiktaalik roseae* is an extinct animal that was discovered in 2004. Its discovery helped predict when the first fish would have ventured onto land.
4. Fossils are key evidence that helps study evolution and the adaptation of different organisms to the environment.
5. It provides the record of how organisms evolved and is represented as the tree of life.
6. Fossils present at the bottom of the rock are simple while the ones which are present at the top are the most recent fossils.
7. This succession revolves around evolution.
8. The fossil record of certain mammals can be studied in a series of evolution by looking into their geological time scale.

Geological time scale

The vast expanse of geological time has been separated into eras, periods, and epochs. The numbers included below refer to the beginnings of the division in which the title appears. The numbers are in millions of years. The named divisions of time are for the most part based on fossil evidence and principles for relative dating over the past two hundred years. Only with the application of radiometric dating have numbers been obtained for the divisions observed from field observations.

Era	Period	Epoch	Plant and Animal Development
Cenozoic	Quaternary	Holocene (.01)	Humans develop
		Pleistocene (1.8)	
	Tertiary	Pliocene (5.3)	"Age of mammals"
		Miocene (23.8)	
		Oligocene (33.7)	
		Eocene (54.8)	
		Paleocene (65.0)	Extinction of dinosaurs and many other species.
Mesozoic	Cretaceous (144)	"Age of Reptiles"	First flowering plants
	Jurassic (206)		
	Triassic (248)		First birds Dinosaurs dominant.
Paleozoic	Permian (290)	"Age of	Extinction of trilobites and many

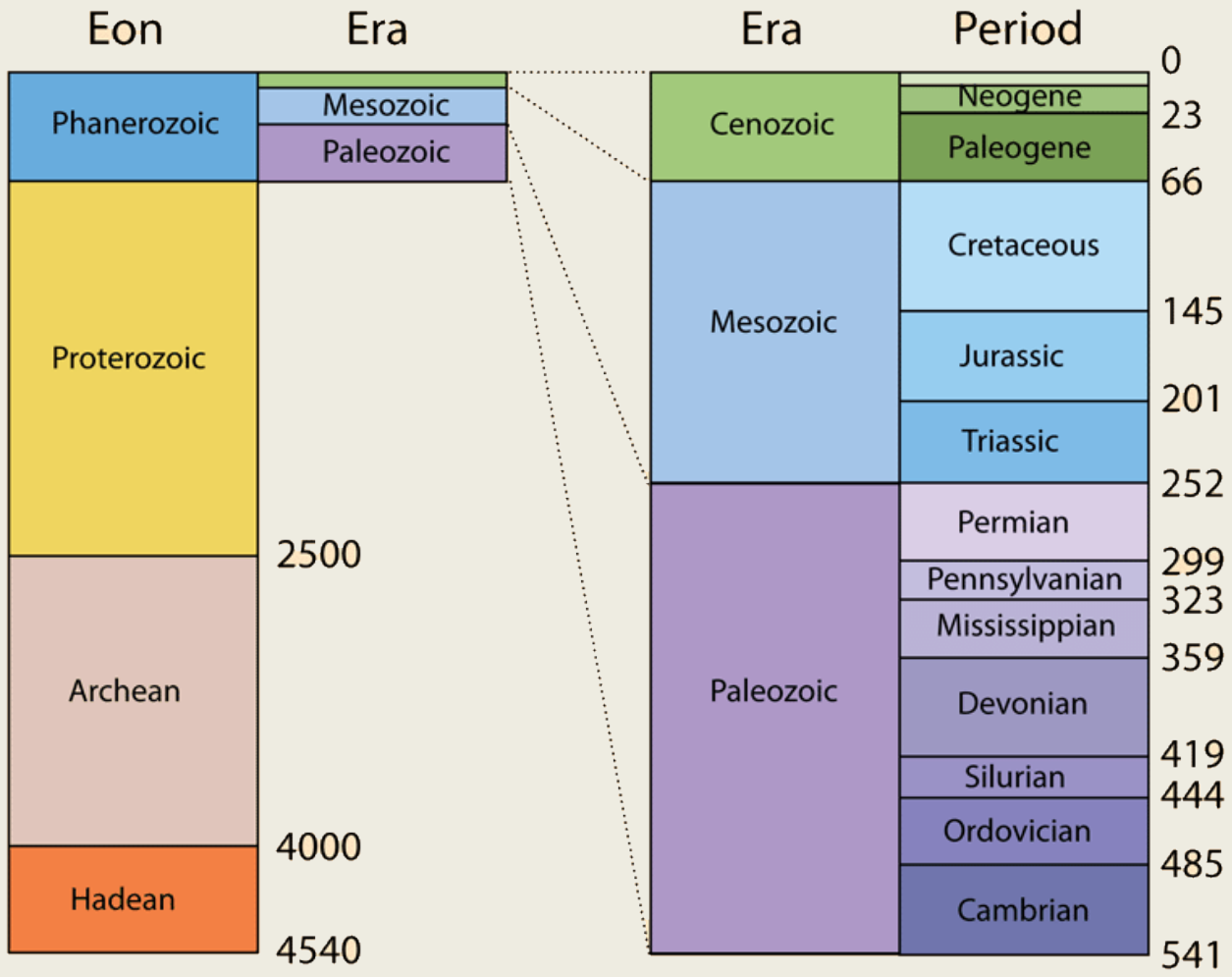
	Carboniferous: Pennyslvanian (323)	Amphibians"	other marine animals First reptiles
	Carboniferous: Mississippian (354)		Large coal swamps Large Amphibians abundant.
	Devonian (417)	"Age of Fishes"	First insect fossils
	Silurian (443)		Fishes dominant First land plants
	Ordovician (490)	"Age of Invertibrates"	First fishes
	Cambrian (540)		Trilobites dominant First organisms with shells

Precambrian - comprises about 88% of geologic time (4500)	First multicelled organisms First one-celled organisms Origin of Earth

Adapted from Lutgens and Tarbuck. They cite the Geological Society of America as the source of the data.

There is another kind of time division used - the "eon". The entire interval of the existence of visible life is called the Phanerozoic eon. The great Precambrian expanse of time is divided into the Proterozoic, Archean, and Hadean eons in order of increasing age.

The names of the eras in the Phanerozoic eon (the eon of visible life) are the Cenozoic ("recent life"), Mesozoic ("middle life") and Paleozoic ("ancient life"). The further subdivision of the eras into 12 "periods" is based on identifiable but less profound changes in life-forms. In the most recent era, the Cenozoic, there is a further subdivision of time into epochs.



Geologic time and the geologic column

Quaternary

Quaternary Period, Cenozoic Era, Phanerozoic Eon [1.8 Myr - 0]

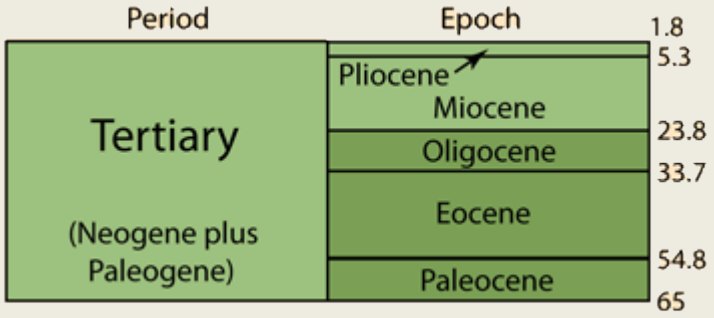
In the time scale of Lutgens & Tarbuck, the Quaternary Period is further divided into the Pleistocene Epoch from 1.8 to 0.01 Myr and the most recent Holocene Epoch from 0.01 Myr to the present.

By the beginning of the Quaternary Period, most of the major plate tectonic movements which formed the North American continent had taken place, and the main modifications past that were those produced by glacial action and erosion processess. Human beings emerged during this Period.

Neogene

Neogene Period, Cenozoic Era, Phanerozoic Eon [23 Myr - 1.8 Myr]

In the time scale of Lutgens & Tarbuck, the Neogene Period and the Paleogene Period below are combined and called the Tertiary Period. Calling this span from roughly 66 Myr to 1.8 Myr the Tertiary Period is fairly common in geologic literature. It is sometimes referred to as the "age of mammals".



Lutgens & Tarbuck further subdivide this Neogene Period into the Miocene Epoch from 23.8 to 5.3 Myr and the Pliocene Epoch from 5.3 to 1.8 Myr.

Paleogene

Paleogene Period, Cenozoic Era, Phanerozoic Eon [66 Myr - 23 Myr]

The Paleogene Period (or the early part of the Tertiary Period) represents the time period after the major extinction that wiped out the dinosaurs and about half of the known species worldwide. Lutgens & Tarbuck further subdivide this time

period into the Paleocene Epoch (65-54.8Myr), the Eocene Epoch (54.8-33.7Myr), and the Oligocene Epoch (33.7-23.8 Myr).

Cretaceous Period, Mesozoic Era, Phanerozoic Eon [145 Myr - 66 Myr]

The Cretaceous Period is perhaps most familiar because of the major extinction event which marks the Cretaceous-Tertiary boundary. It is typically called the K-T extinction, using the first letter of the German spelling of Cretaceous, and it marked the end of the dinosaurs. There is large body of evidence associating this extinction with the large impact crater at Chicxulub, Yucatan Peninsula, Mexico.

The Cretaceous, Jurassic and Triassic Periods are collectively referred to as the "age of reptiles".

The first flowering plants appeared near the beginning of the Cretaceous Period.

Evidence suggests that a vast shallow sea invaded much of western North America, and the Atlantic and Gulf coastal regions during the Cretaceous Period. This created great swamps and resulted in Cretaceous coal deposits in the western United States and Canada.

Jurassic Period, Mesozoic Era, Phanerozoic Eon [201 Myr - 145 Myr]

The distinctive fossil progression characteristic of this period was first found in the Jura Mountains of Russia.

Dinosaurs and other reptiles were the dominant species. The Jurassic Period saw the first appearance of birds.

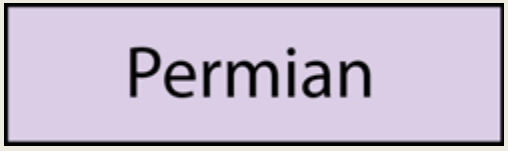
It appears that a shallow sea again invaded North America at the beginning of the Jurassic Period. But next to that sea vast continental sediments were deposited on the Colorado plateau. This includes the Navajo Sandstone, a white quartz sandstone that appears to be windblown and reaches a thickness near 300 meters.

The early Jurassic Period at about 200 Myr saw the beginning of the breakup of Pangaea and a rift developed between what is now the United States and western Africa, giving birth to the Atlantic Ocean. The westward moving Atlantic plate began to override the Pacific plate. The continuing subduction of the Pacific plate contributed to the western mountains and to the igneous activity that resulted in the Rocky Mountains.

Triassic Period, Mesozoic Era, Phanerozoic Eon [252 Myr - 201 Myr]

Dinosaurs became the dominant species in the Triassic Period.

In North America there is not much marine sedimentary rock of this period. Exposed Triassic strata are mostly red sandstone and mudstones which lack fossils and suggest a land environment.



Permian Period, Paleozoic Era, Phanerozoic Eon [299 Myr - 252 Myr]

The Permian Period is named after the Perm region of Russia, where the types of fossils characteristic of that period were first discovered by geologist Roderick Murchison in 1841. The Permian, Pennsylvanian and Mississippian Periods are collectively referred to as the "age of amphibians". By the end of the Permian Period the once dominant trilobites are extinct along with many other marine animals. Lutgens & Tarbuck label this extinction "The Great Paleozoic Extinction" and comment that it was the greatest of at least five major extinctions over the past 600 million years.

The modeling of plate tectonics suggests that at the end of the Permian Period the continents were all together in the form called pangaea, and that the separations that have created today's alignment of continents have all occurred since that time.

There is much discussion about the causes of the dramatic biological decline of that time. One suggestion is that having just one vast continent may have made seasons much more severe than today.

Pennsylvanian Period, Paleozoic Era, Phanerozoic Eon [323 Myr - 299 Myr]

The Pennsylvanian Period saw the emergence of the first reptiles. This period saw the development of large tropical swamps across North America, Europe and Siberia which are the source of great coal deposits. Named after the area of fine coal deposits in Pennsylvania.

Mississippian Period, Paleozoic Era, Phanerozoic Eon [359 Myr - 323 Myr]

Amphibians became abundant in this period, and toward the end of it there is evidence of large coal swamps.

Devonian Period, Paleozoic Era, Phanerozoic Eon [419 Myr - 359 Myr]

The Devonian and Silurian Periods are referred to as the "age of fishes". In the Davonian Period fishes were dominant. Primitive sharks developed. Toward the end of the Davonian there is evidence of insects with the first insect fossils. From finger-sized earlier coastal plants, land plants developed and moved away from the coasts. By the end of the Davonian, fossil evidence suggests forests with trees tens of meters high. The Devonian period is named after Devon in the west of England.

By late Devonian, two groups of bony fishes, the lung fish and the lobe-finned fish had adapted to land environments, and true air-breathing amphibians developed. The amphibians continued to diversify with abundant food and minimal

competition and became more like modern reptiles.

Silurian Period, Paleozoic Era, Phanerozoic Eon [444 Myr - 419 Myr]

The Silurian Period marked the emergence of the first land plants.

Ordovician Period, Paleozoic Era, Phanerozoic Eon [485 Myr - 444 Myr]

The Ordovician and Cambrian Periods are referred to as the "age of invertebrates", with trilobites abundant. In this period, brachiopods became more abundant that the trilobites, but all but one species of them are extinct today. In the Ordovician, large cephalopods developed as predators of size up to 10 meters. They are considered to be the first large organisms. The later part of the Ordovician saw the appearance of the first fishes.

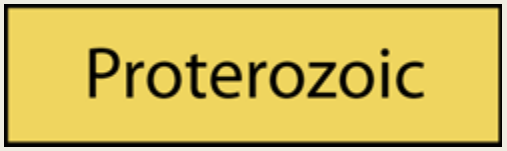
Data suggest that much of North America was under shallow seas during the Ordovician Period. There are large bodies of evaporite rock salt and gypsum which attest to shallow seas.

Cambrian Period, Paleozoic Era, Phanerozoic Eon [541 Myr - 485 Myr]

The beginning of the Cambrian is the time of the first organisms with shells. Trilobites were dominant toward the end of the Cambrian Period, with over 600 genera of these mud-burrowing scavengers.

The Cambrian Period marks the time of emergence of a vast number of fossils of multicellular animals, and this proliferation of the evidence for complex life is often called the "Cambrian Explosion".

Models of plate tectonic movement suggest a very different world at the beginning of the Cambrian, with that plate which became North America largely devoid of life as a barren lowland. Shallow seas encroached and then receded.



Proterozoic Eon [2500 Myr - 541 Myr]

Near the end of the Precambrian, there is fossil evidence of diverse and complex multicelled organisms. Most of the evidence is in the form of trace fossils, such as trails and worm holes. It is judged that most of Precambrian life forms lacked shells, making the detection of fossils more difficult. Plant fossils were found somewhat earlier than animal fossils.

There is no coal, oil or natural gas in Precambrian rock.

Rocks from the middle Precambrian, 1200 - 2500 Myr hold most of the Earth's iron ore, mainly as hematite (Fe_2O_3). This can be taken as evidence that the oxygen content of the atmosphere was increasing during that period, and that it was abundant enough to react with the iron dissolved in shallow lakes and seas. The process of oxidizing all that iron may have delayed the buildup of atmospheric oxygen from photosynthetic life. There is an observable end to this formation of iron ore, so the increase in atmospheric oxygen would have been expected to accelerate at that time.

Fossilized evidence for life is much less dramatic in the pre-Cambrian time frame, with amounts about 88% of Earth's history. The most common Precambrian fossils are stromatolites, which become common about 2000 Myr in the past. Stromatolites are mounds of material deposited by algae. Bacteria and blue-green algae fossils have been found in Gunflint Chert rocks at Lake Superior, dating to 1700 Myr. These are prokaryotic life. Eukaryotic life has been found at about 1000 Myr at Bitter Springs, Australia in the form of green algae.

Archean Eon [4000 Myr - 2500 Myr]

Evidence for prokaryotic life such as bacteria and blue-green algae has been found in southern Africa, dated to 3100 Myr.

Banded iron formations have been dated to 3700 Myr, and presuming that this requires oxygen and that the only source of molecular oxygen in this era was photosynthesis, this makes a case for life in this time period. There are also stromatolites dated to 3500 Myr.

Hadean Eon [4500 Myr - 4000 Myr]

The age of the Earth is projected to be about 4500 Myr from radiometric dating of the oldest rocks and meteorites. There is evidence of a time of intense bombardment of the Earth in the time period from about 4100 to 3800 Myr in what is called the "late heavy bombardment". There is ongoing discussion about what may have caused this time of intense impacts. There is no evidence for life in this Eon whose name translates to "hellish".

EVOLUTION

Evolution involves gradual changes from simple to more complex forms. Humans are believed to have developed from simpler forms. Evolution is hypothesized to have begun in the oceans billions of years ago. Darwin gave the theory of evolution. In his book -The Origin of Species, Darwin has stated that evolution has come through a series of natural selection. The theory emphasized the following points:

- Natural Selection
- Variation
- Struggle To Exist
- Survival of the Fittest

Evolution is the outcome of the interaction amongst the following five processes:

- Mutation
- Genetic Recombination
- Chromosomal Abnormalities
- Reproductive isolation
- Natural Selection

EVOLUTION OF MAN

- *Homo sapiens*, the most prominent species on earth is the result of over 7 million years of evolution. The traces of human evolution have been obtained through fossil records, and morphological, physiological and embryological studies.
- Man belongs to the family Hominidae of the order Primates. Humanlike apes belong to the same order. With the passage of time, their ancestors evolved and became more and more different.
- The first-ever ancestors of humans are believed to have originated in Africa, eventually migrating to Europe, Asia and the rest of the world

Earliest Ancestor

Ardipithecus were one of the earliest ancestors to have been discovered, with fossils dating back more than 4.4 million years old. The details of human evolution are still debated as fossil evidence of many ancestors is quite vague. In fact, instead of the human evolution tree, a more accurate analogy could be drawn to an evolutionary bush.

Charles Darwin never implied the fact that humans evolved from apes, although, many of his fellow contemporaries insisted that he had. Furthermore, the concept of a “missing link” between apes and humans was considered preposterous by scientists because we have evolved alongside the great apes. However, we do have a common ancestor that lived roughly 7 million years ago. Furthermore, evolution points to the presence of “nodal fossils”, meaning that humans evolved gradually, as opposed to a sudden change.

Process of Human Evolution

The evolution process involves a series of changes that cause the species to either adapt to the environment or become extinct. Evolution is the result of changes in the genetic material of humans. It does not change a single organism, but the entire group of organisms belonging to the same species.

Man originated through several stages:

Dryopethicus

It is the earliest known ancestor of man. They were found in some parts of Africa, Asia and Europe. The evolution of man began with him. Dryopethicus was followed by Australopithecus.

Australopithecus

These were 1.2 metres tall and could walk upright. They inhabited the African mainland. They had large jaws and human-like teeth.

Homo habilis

They were five feet tall and could make use of tools. They are believed to have been able to speak.

Homo erectus

They were more evolved beings. They were also upright and had a larger brain size. They had a prominent speech. They invented fire and were carnivorous.

Homo sapiens

These are modern men. They developed the power of thinking, used tools, were omnivorous and produced art. Their brain size was reduced to 1300 cc.

Neanderthals

Homo sapiens is the only extant species of hominin around today, but a few thousand years ago, there were a few other species that existed alongside anatomically modern humans – the Neanderthals, Denisovans and the *Homo floresiensis*. Today, scientists consider Neanderthals to be more of a subspecies of humans rather than a completely separate species.

Stages in Human Evolution

The following are the stages of human evolution:

1. Dryopithecus

These are deemed to be the ancestors of both man and apes. They lived in China, Africa, Europe and India. The genus Dryopithecus refers to the oak wood apes. When Dryopithecus was alive, the tropical lowlands which it inhabited were densely forested, so the members could have predominantly been herbivores.

2. Ramapithecus

Their first remains were discovered from the Shivalik range in Punjab and later in Africa and Saudi Arabia. They lived in open grasslands. Two pieces of evidence confirm their Hominid status:

1. Thickened tooth enamel, robust jaws and shorter canines.
2. Usage of hands for food and defence and extrapolations of upright posture.

3. Australopithecus

The fossil of this genus was first discovered in 1924 in South Africa. They lived on the ground, used stones as weapons and walked erect. They were 4 feet tall and weighed 60-80 pounds.

4. Homo Erectus

The first fossil of Homo Erectus was found in Java in 1891. These were named as Pithecanthropus Erectus. These were considered as the missing link between the man and apes. Another discovery made in China was the Peking man. This specimen had large cranial capacities and is believed to have lived in communities. Homo erectus used tools comprising quartz. Tools made of bones and wood were also discovered. There is evidence of collective huntings. There is also evidence of the use of fire. The Homo Erectus is believed to dwell in caves.

5. Homo Sapiens Neanderthalensis

The Homo Erectus evolved into Homo Sapiens. During evolution, two sub-species of Homo Sapiens were identified- Homo sapien Neanderthal and Homo sapiens sapiens. The cranial capacity of Neanderthal grew from 1200 to 1600 cc. Some small hand axes had also been discovered. This species of hominids could hunt big names such as mammoths.

6. Homo Sapiens Sapiens

The remains of Homo Sapiens were first discovered in Europe and were named Cro-Magnon. In these, the jaws are quite reduced, the modern man’s chin appeared, and the skull was rounded. Their cranial capacity was about 1350 cc. They gathered food through hunting. Art first appeared during this time.