Lecture 3: Origin of Life (Part-I)

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.

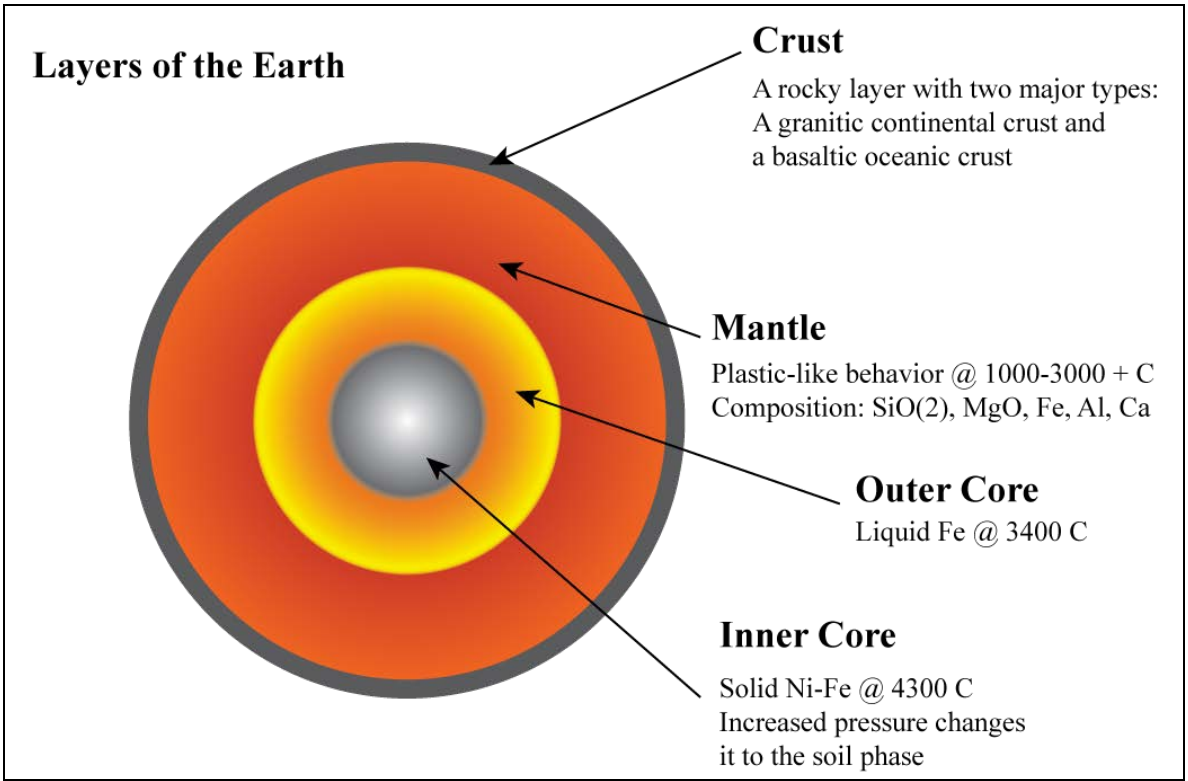


Figure 3.1 : Cross section of Earth

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_4) and ammonia (NH_3). Due to gravitional 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 tooks almost 1 billion years from the formation of earth to appearance of life. Such a lon 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 believes 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 hadful 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, Francisco redi and Louis Pasteur. These great scientists performed well designed scientific experiments to disprove the theory of spontaneous generations.

1. Redi's experiment: Francisco 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 layed eggs which eventually gave birth new larvae. Whereas in Jar No. 2, flies couldn't be able to enter and no larve 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 immigately. 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.

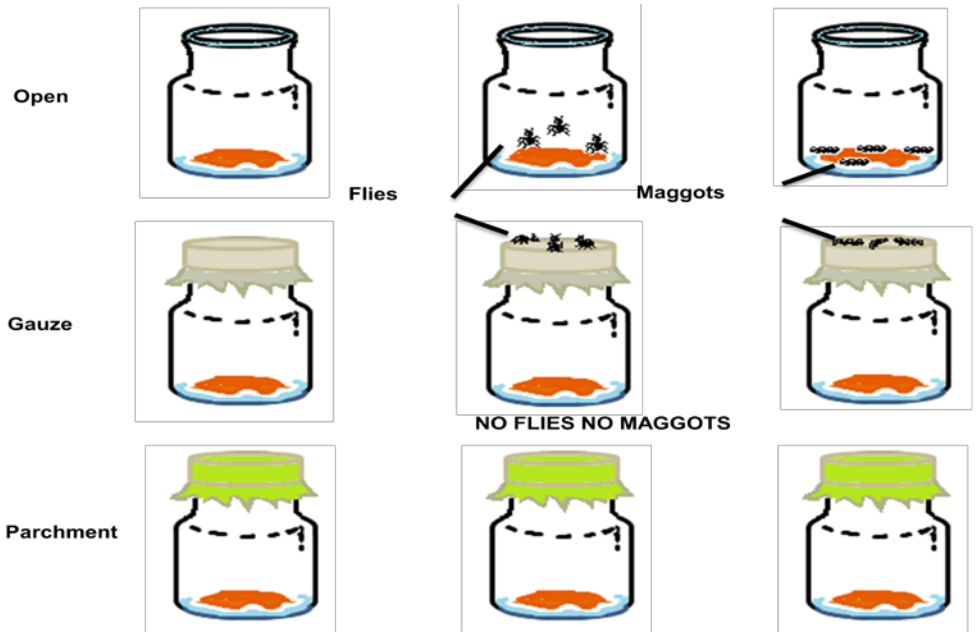


Figure 3.2 : Redi's Experiment to disprove the theory of abiogenesis.

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 evolvment of different types of organisms on earth. The critism of the current theory is same as previous one, No scientific experiment to support the hypothesis and mostly be based on imaginery concepts.

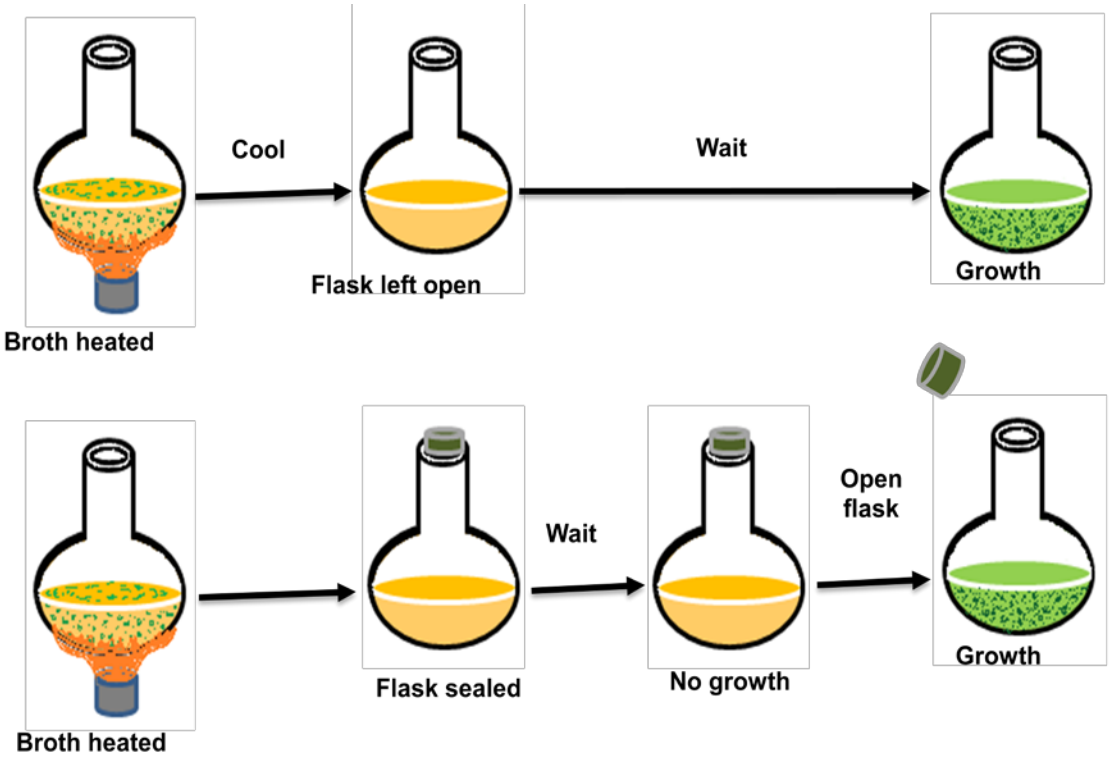


Figure 3.3 : Spallanzani's Experiment to disprove the theory of abiogenesis.

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.

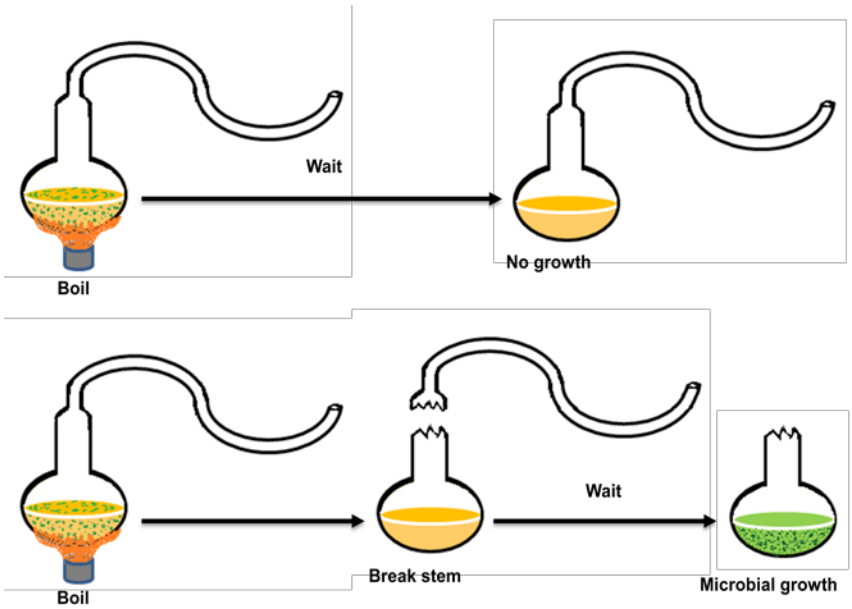


Figure 3.4 : Pasteur's Experiment to disprove the theory of abiogenesis.

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?

Lecture 4: Origin of Life (Part-II)

Summary of Previous Lecture: The previous lecture deals with the introduction to life and formation of earth from a hot planet to life supporting earth with low temperature. Next, we discussed different theories to explain the origin of life. There are six different theories were proposed and in the last lecture I discussed 5 hypothesis. Now in the current lecture, we will discuss the modern theory of origin of life.

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 donot permit abiogenesis. The idea of chemical theory was put forward by two scientist, 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 experiment in mimicking primitive earth environment. The experimental design used for the experiment is given in the 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 (CH_4), ammonia (NH_3), and hydrogen (H_2) in the ratio of 2:2:1 and water (H_2O) vapor at 800^0C. 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 mimicks lighting in the primitive earth atmosphere. While passing the mixture, gases were passes 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

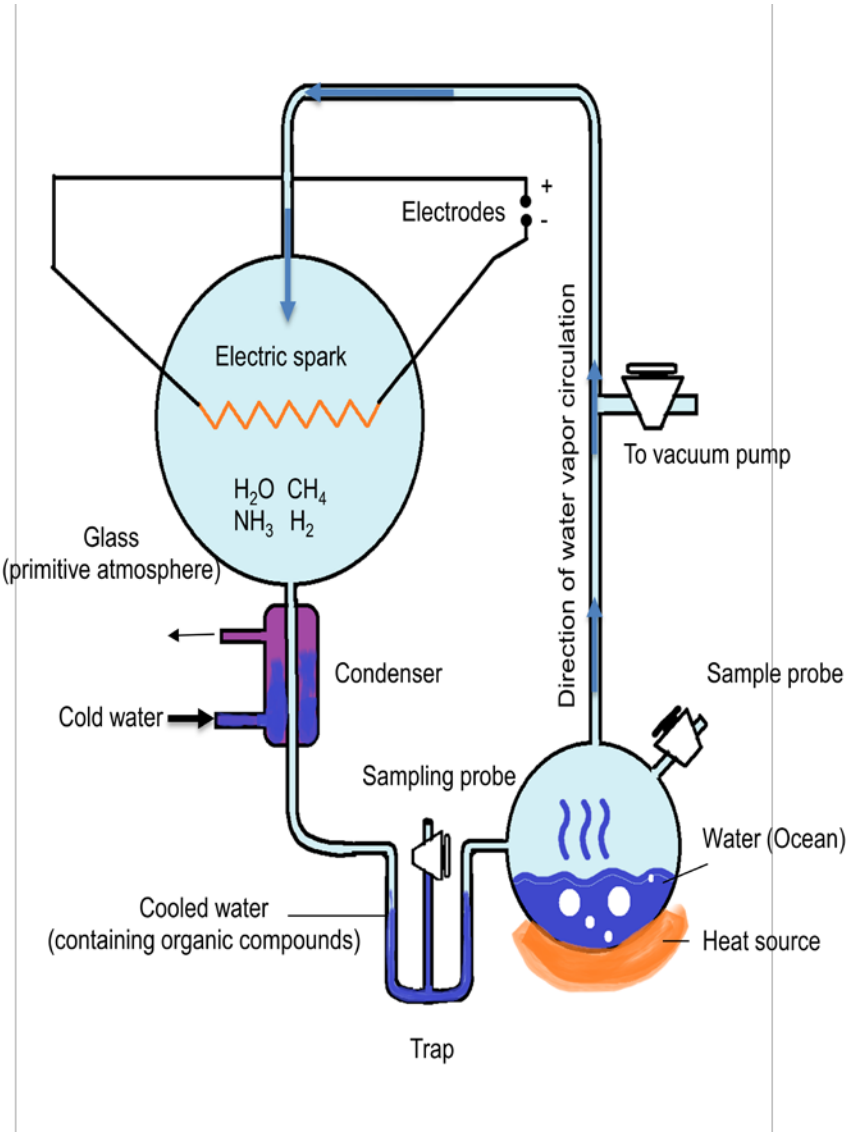


Figure 4.1 : Miller Experiment to show the synthesis of organic compounds.

simple sugar ribose. In addition, he found hydrogen cynide (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:

$CO_2 \rightarrow CO + [O]$ (atomic oxygen)----------[Eq 4.1]

$CH_4 + 2[O] \rightarrow CH_2O + H_2O$ ----------[Eq 4.2]

$CO + NH_3 \rightarrow HCN + H_2O$ ----------[Eq 4.3]

$CH_4 + NH_3 \rightarrow HCN + 3H_2$ ----------[Eq 4.4]

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

$CH_2O + HCN + NH_3 \rightarrow NH_2\text{-}CH_2\text{-}CN + H_2O$ ----------[Eq 4.5]

$NH_2\text{-}CH_2\text{-}CN + 2H_2O \rightarrow NH_3 + NH_2\text{-}CH_2\text{-}COOH$ ----------[Eq 4.6]

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, lighting or volcanic eruptions.

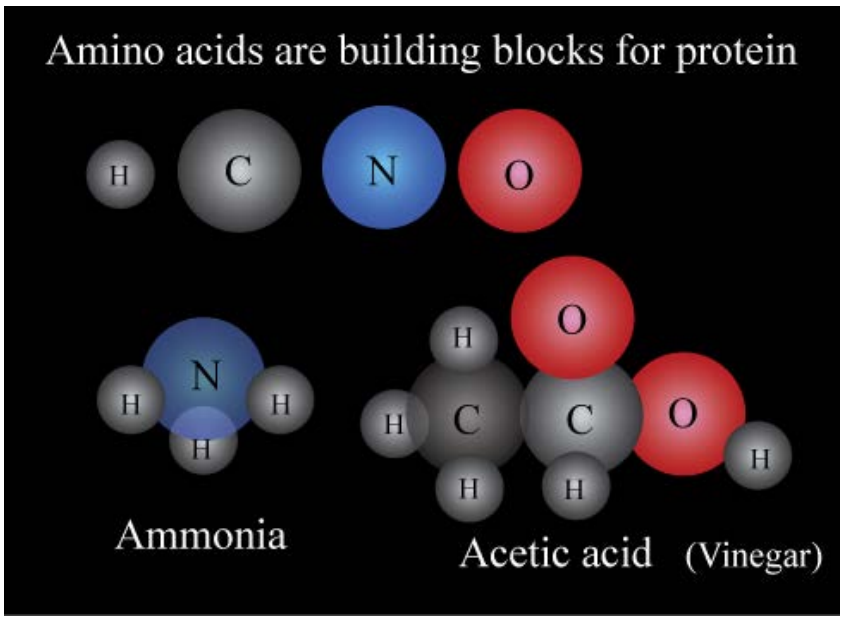


Figure 4.2 : Different molecules prevalent on primitive earth.

(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.

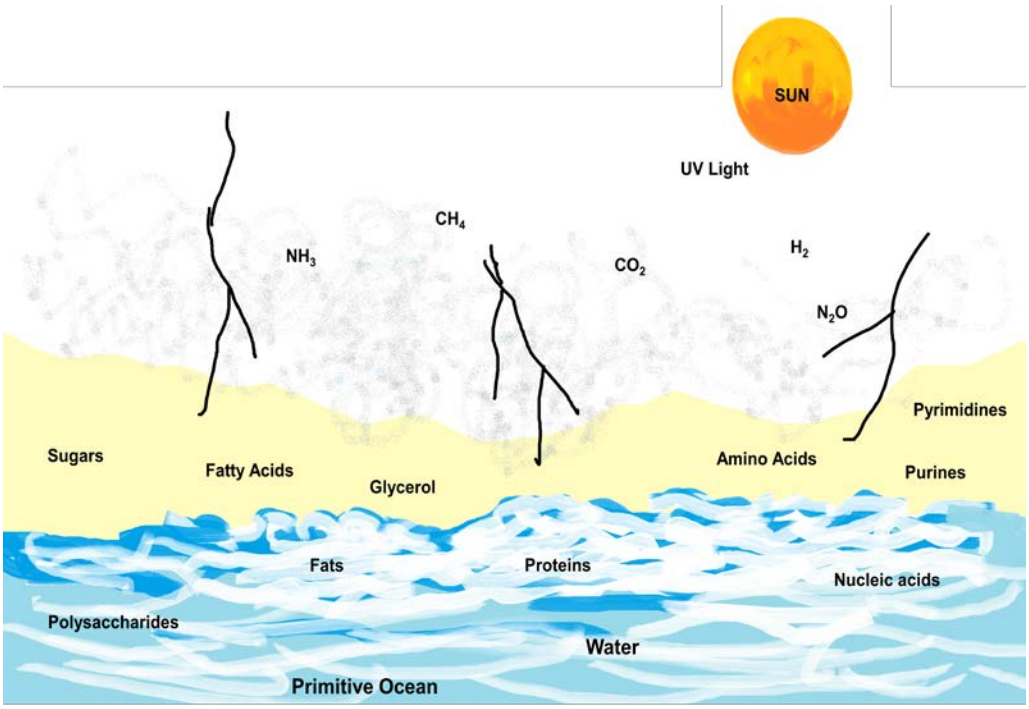


Figure 4.3 : Different simple organic molecules prevalent on primitive earth.

(3) Spontaneous formation of complex organic compounds: The small, simpler organic compounds react to form complex organic compounds. The simple amino acids reacts 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.

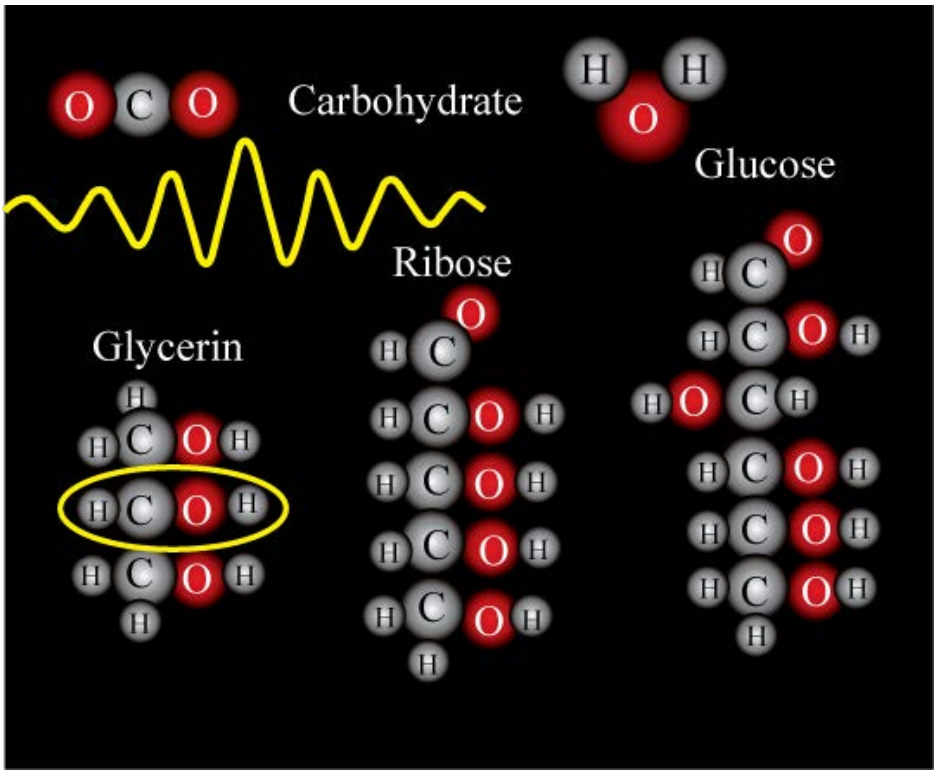


Figure 4.4 : Different complex organic molecules prevalent on primitive earth. [REDRAW REQUIRED]

(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 comlexicity (Figure 4.5). As coacervate divides into multiple small ones.

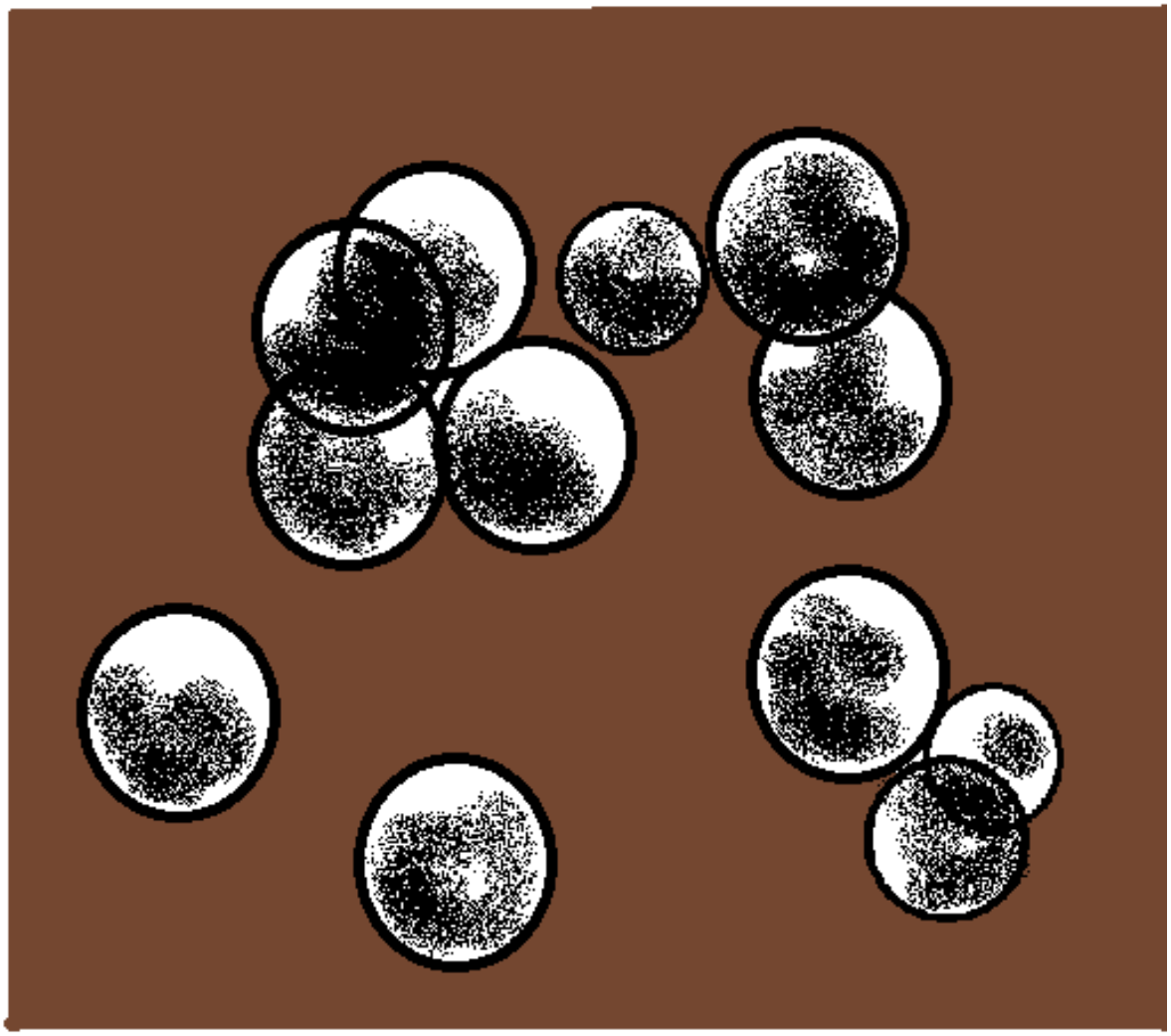
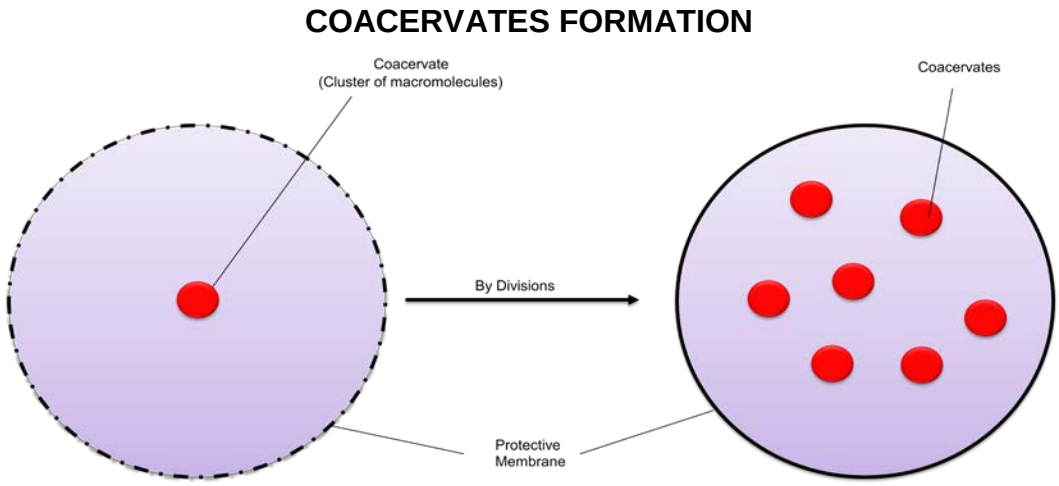


Figure 4.5 : Formation of aggregates.

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 enahced 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



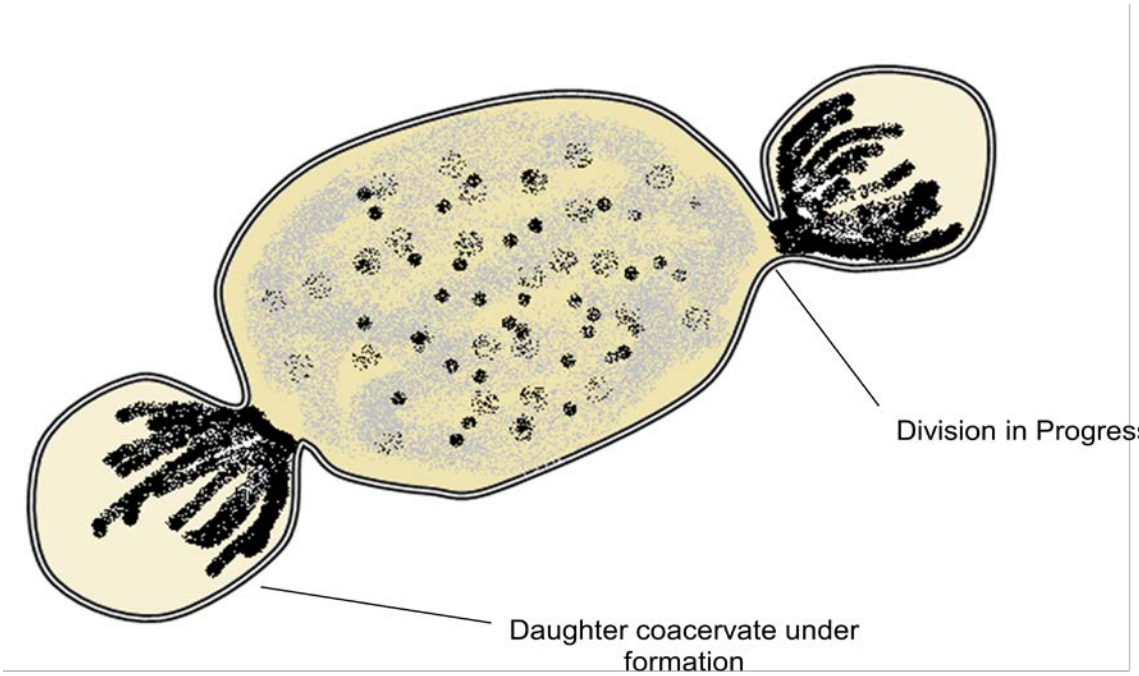


Figure 4.6 : Coacervate formation and division to form protocell.

primitive cell for intake or exlusion 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.

UV RADIATION OR ELECTRIC DISCHARGE IS SYNTHESIZING NEW ORGANIC MOLECULES BUT THESE PRESENCE OF OXYEGN IS EITHER DISTROYING THESE MOLECULES AND NOT ALLOWING CONDENSATION REACTIONS. HENCE, ORGANIC EVOLUTION IS NOT POSSIBLE IN THE CURRENT EARTH ATMOSPHERE.

Lecture 5: Evolution (Part-I)

Introduction: In the previous lecture, we discussed the chemical theory to explain the origin of life. Life is originated as primitive cell with ability to replicate, absorb nutrition and repair the damage. These single cells are the starting material to form multicellular system and eventually the development of organisms with tissue and organ system. In addition, individual organisms also acquire features over time to adopt better towards changed environment. The progressive advancement of organism is by the process known as evolution. Aristotle has considered evolution as “Ladder of chain” or “Scala naturae” involving hierarchical linking of series of forms.

Chemical Evolution: The term evolution refers to change from one form to another. Change in living organism with time is known as organic or biological evolution. The process of evolution can be understood from the fact that unicellular organism appear first, simple multicellular and later development of complex multicellular organisms such as seed plants and vertebrate animals. The fishes were the initial early vertebrate and it gradually change to form amphibians. These amphibians has produced reptiles and that has evolved further to give birds and mammals. These hierarchical linking of different species is considered by ladder of chain by Aristotle as given in Figure 5.1. In the same series, mammals have evolved to human involving ape-like primates by acquiring changes over the course of time **(These changes and different intermediate forms are discussed in a later lecture)**.

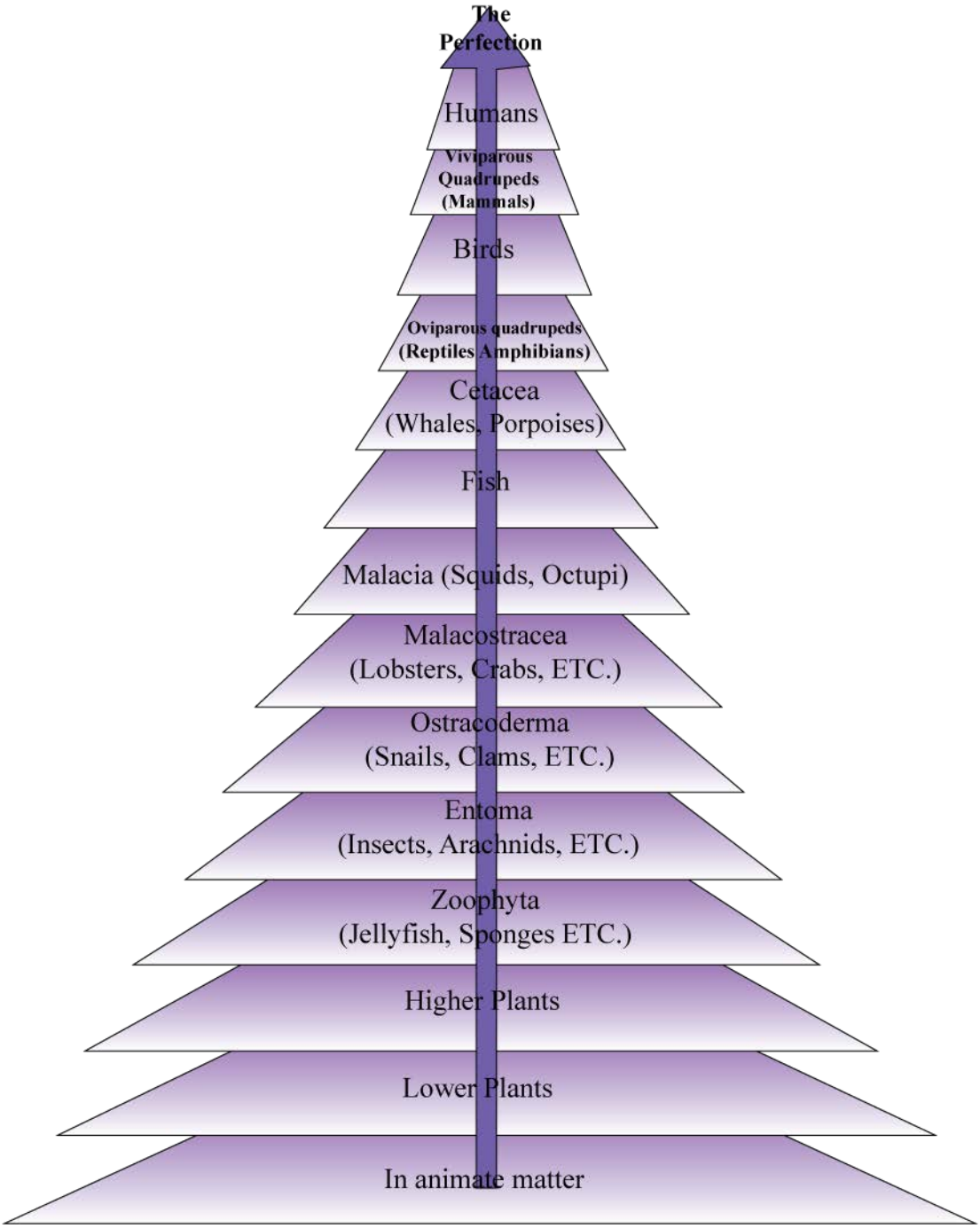


Figure 5.1 : Aristotle's ladder of Nature.

Now the question is what are the scientific evidences that organisms are evolved from the previously existing organisms?

Study of physiology, anatomy, development of different organisms give clues about the several similarities between related organism with selected differences. The correlation of the difference within related organism has allowed to identify properties use to study the evolutionary stages of an organism. These evolutionary evidences are as follows:

1. Morphological and structural evidences: Comparative study of the morphology and anatomy of organisms indicate that few of the features are similar. These are as follows:

A. Body organization: The body organization of different organism is evolving over time with different level of organization. The unicdellular organism with single cells are the most primitive bdy organization followed by cells to arrange to give rise tissues, the tissues gather to form organs, and organ co-operate to form organ-system. For examples, Amoeba is unicellular, sponge is multicellular but these cells are not organized into the tissue to exhibit **cellular level of organization**. In coelenterates, cells are organized to form tissue but latter do not form organs. This is a **tissue level organization**. In platyhelminthes and higher animals, different types of tissues give rise to **organ-system level of body organization**.

B. Homologous organs: The orans of different species of common descent which look different and perform different functions but has similar structure, similar topographic origin and similar embryonic origin are called as homologous organs. Homology is based on divergent evolution. Few Examples of homologous organs are as follows:

Example 1: Forelimb in vertrbrate animals: The forelimb in man, cheetah, whale and bat are different shapes and perform different functions (Figure 5.2). These are used for grasping object in man, running in cheetah, swimming in whale and flying in bat. In each case, the structure of the form arm has similar plan: upper arm having humerus, followed by radius and ulna, and hand with carpals in the wrist. All vertebrates have basic similarity in the structure of their forelimbs due to their origin from a common ancestral with five digits.

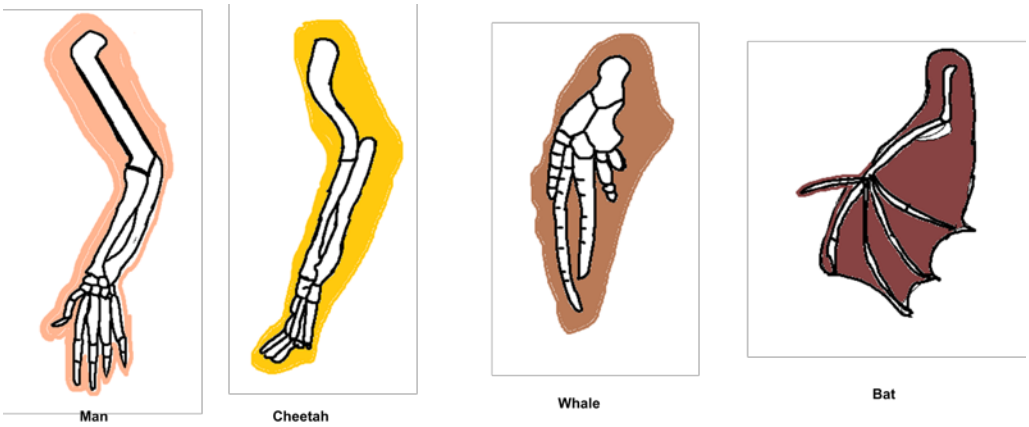


Figure 5.2 : Forelimb of mammals showing homology.

Example 2: Thorn and tendrils in plants: The thorn in bougainvillea and tendril in passion flower are the homologous organ in the plants. They looks different and help the plant in climbing but both arises from the axillary position and are modified branches (Figure 5.3).

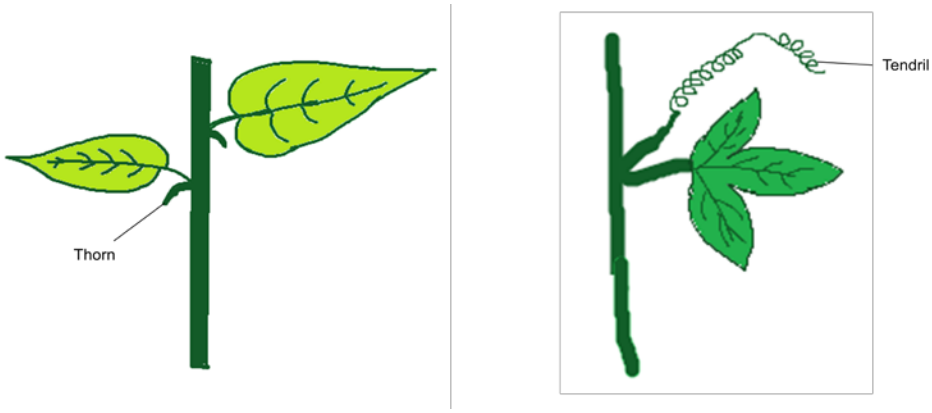


Figure 5.3 : Thorn/tendrils in plant.

C. Analogous Organs: The organs which perform same function and looks similar but are quite different in their structure. These organs are called as analogous organs. Analogy is based on the convergent evolution. Few Examples of analogous organs are as follows:

Example 1: Insect and bord wings: The wings of bord and insect are the analogous organ (Figure 5.4). In both organism, these organs are used to fly in air but they are different in structure. Insect wings is an extension of the integument whereas bird wing is formed of limb bones covered with flesh, skin and feathers.

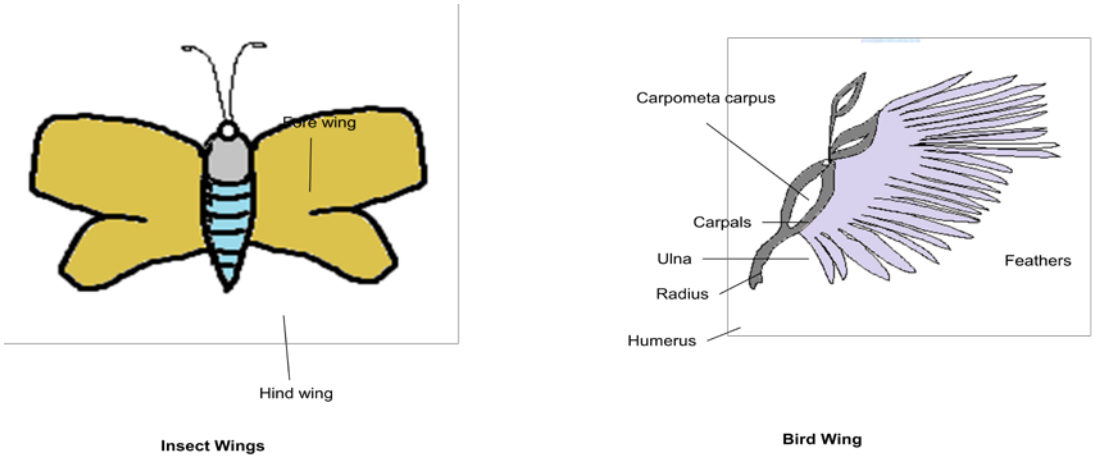


Figure 5.4 : Bird wings and insect wing.

Example 2: Fin and flippers: The pectoral fins of fishes and flippers of dolphins are flattened organs used for swimming but both have different structure (Figure 5.5). The flippers are the modified pentadactyl forelimbs whereas fins are pentadactyl.

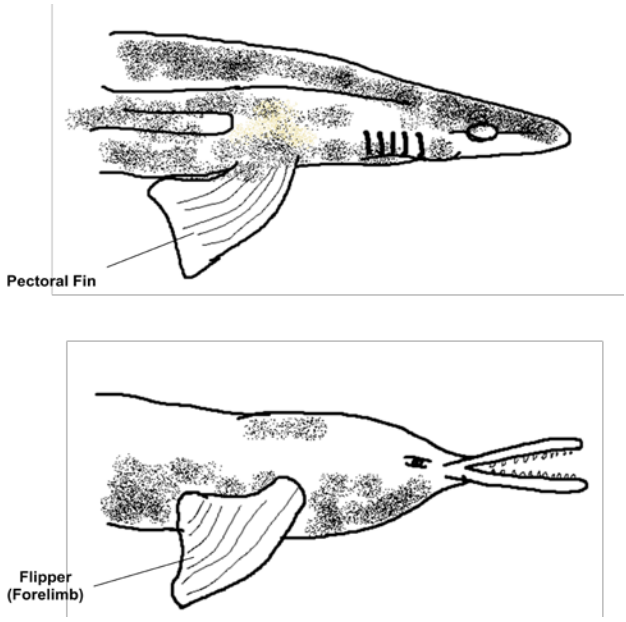


Figure 5.5 : Pectoral Fin of shark and dolphin flippers.

D. Gradual Modifications: In several cases, organs or tissue exhibits gradual modifications during the corse of organic evolution. For example, Heart is two chambered (one auricle and ventricle) in the fishes, 3 chambered (two auricle and ventricle) in amphibians, pseudo four chambered (two auricle and partly divided ventricle) in reptiles (snake) and 4 chambered in higher reptiles (crocodile), birds and mammals (Figure 5.6).

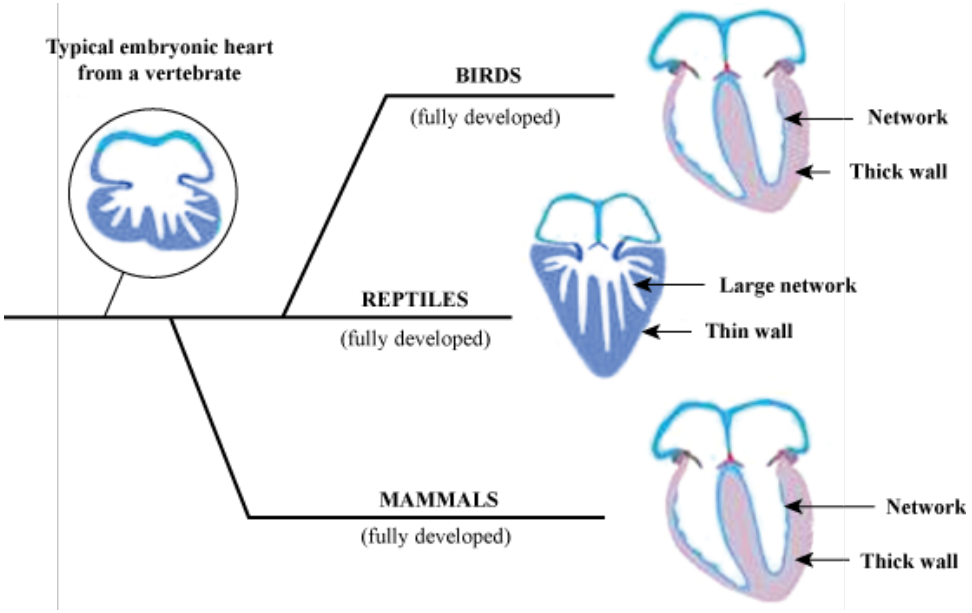


Figure 5.6 : Heart from different organism

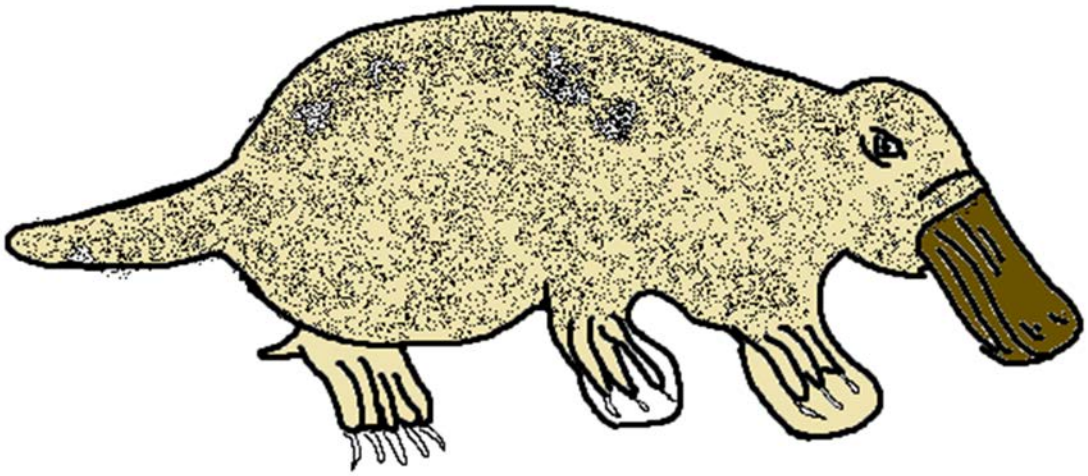
E. Connecting Links: The living organisms exhibiting character of two different group of organisms are known as connecting links. There are few selected examples of connecting links and few selected examples are as follows:

Example 1: Euglena: Euglena has dual character of plant and animals. It can perform photosynthesis through specialized chloroplast and it can perform contractile vacuole, mouth and binary fission just like animal.

Example 2: Peripatus: it is an examples of connecting link between arthropods and annelids. It hs worm like body, unjoined legs similar to annelids whereas claws, jaws, tracheae and dorsal tubular hearts as arthropods.

Example 3: Egg laying mammals: Egg laying mammals are the connecting link between reptiles and mammals. For example, duck-billed platypus. They have few mammalian

characters such as hair, mammary glands, diapharm whereas it lays eggs with yolk and egg shell similar to reptiles (Figure 5.7).



Ornithorhynchus- the duck- billed platypus

Figure 5.7 : Duck-billed platypus.

Few other examples of connecting lins are as follows:

Neopalina: it is a connecting link between annelids and the mollusks.

Balanoglossus: it is a connecting link between non-chordates and chordates.

Chimaera: it is a connecting link between cartilaginous and bony fishes.

Coelocanth: it is a connecting link between bony fishes and amphibians.

Sphenodon: it is a connecting link between amphibians and reptiles.

Connecting link clearly highlight the fact that different organisms are evolved together from a common ancester.

2. Embryological evidences: Comparative study of the embryology of different organisms shows stricking similarities between them. To explain this phenomenon, biogenetic law was proposed by Ernst Haeckel. This theory states that an organism in its individual development follow different developmental stages through which its ancesters have passed in the course of their evolution. In another words, **"ontogeny repeats phylogeny"**. The embryological stages of selected organism is given in the Figure 5.8. Lets take the example of development of frog from it. In its development

stages, it forms fish like tadpole larva with tail, fin, gills for breathing in water. It indicaes that frog is evolved from fish like ancestor.

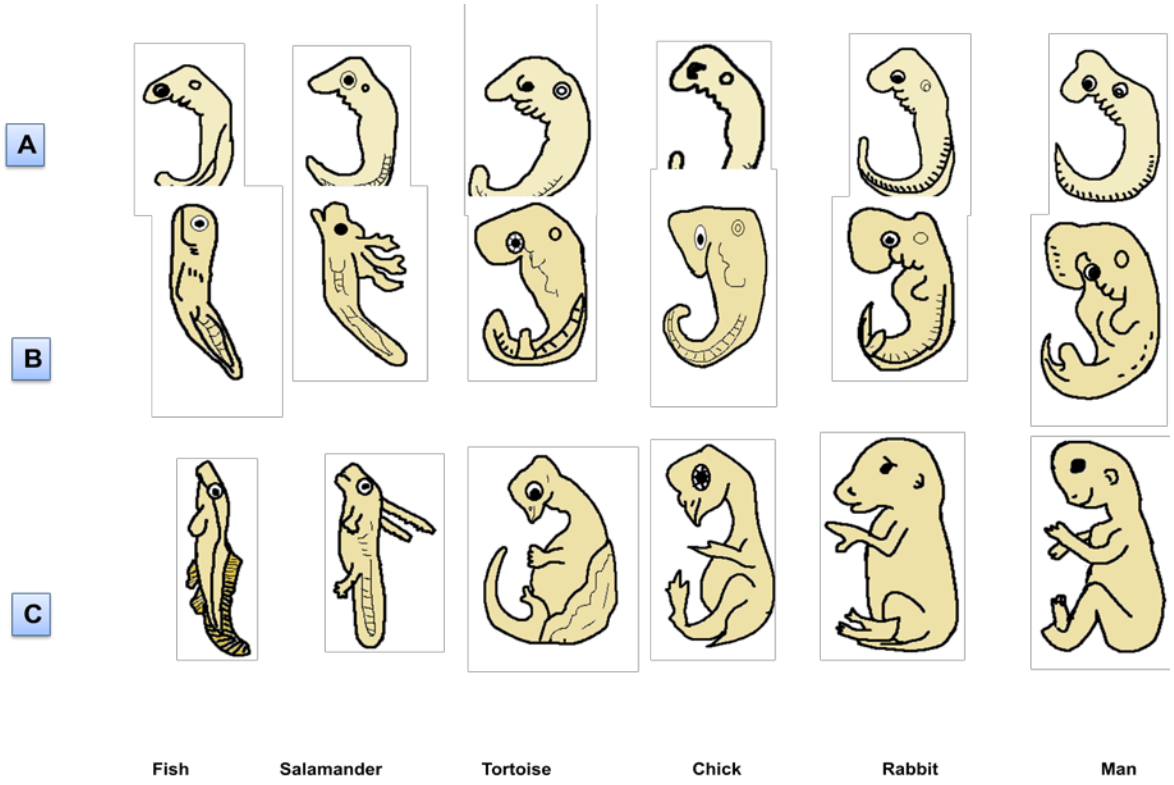


Figure 5.8 : Vertebrate embyos in three successive stages.

3. Palaeontological evidences: Availability of different fossil forms also gives evidences for the evolution (Figure 5.9).

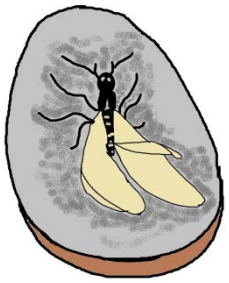


Figure 5.9 : A fossil of termite preserved in amber.

Lecture 6: Evolution (Part-II)

Summary of Previous Lecture: In the previous lecture, we discussed the chemical theory to explain the origin of life. In addition, we discussed the different types of evidences to support the evolution of primary cells to different organisms. The evidences we discussed in the previous lectures are as follows:

1. Morphological and structural evidences.

2. Embryological evidences:

3. Palaeontological evidences: Palaeontology is the study of past life based on the fossil record. The palaeontology study the number and nature fossils in the early rocks, distribution of fossils in the successive strata. Now the question is, **What are fossils and how it is formed and provide information about evolution?** The fossils are the remains or impression of the ancient organism preserved by natural means in some medium (Figure 6.1). The medium found with fossils are sedimentary rocks, amber, asphalt, volcanic ash, ice, peat bogs, sand and mud.

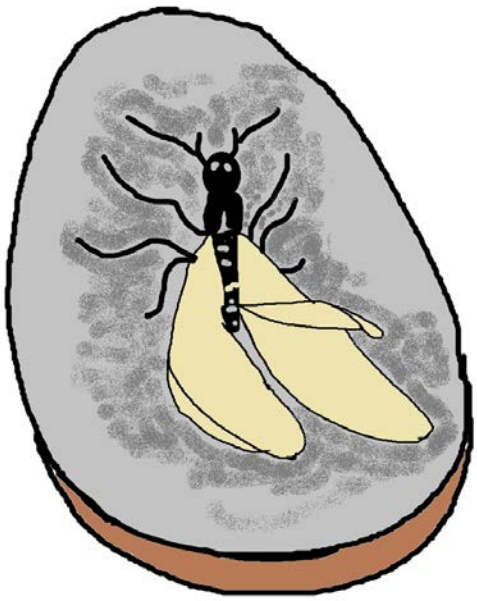


Figure 6.1: A fossil of termite in amber.

What is the mechanism of fossil formation?

During the formation of sedimentary rocks, the dead animals of the sea or large lakes and the land carried to the sea or large lakes by river, sink down and get buried in the rocks. Supply of oxygen is limited in this condition and prevent the decay or reduces the decay rate to minimal. As a result, animal remains preserved in the rock and have formed the fossil. The hard remains of dead animals got preserved layer by layer in the sedimentary rocks. The fossils present in depper layer are earlier and upper layer had more recent fossils. There are seven different kinds of fossils. These fossils are distributed in amber, asphalt, ice, volcanic ash, peat bogs, storm dust and sand dunes. The different types of fossils, their mode of formation and suitable examples are given in the Table 6.1.

Table 6.1: Different kinds of fossils, their formation and examples.

Fossils	Mode of formation	Examples
Entrire Organism	Frozen in ice	Woolly mammoths in syberia.
	Encased in amber	Insects Exoskeleton
	Trapped in asphalt	Mummies of mammals and birds found in California.
	Buried in peat bogs	Giant elk of Ireland.
Skeltal Materials	Trapped in sedimentary rocks	Bones, teeth, shells, chitinious exoskeletons.
Moulds nad casts	Hard part trapped in sediments that harden to rock, skeleton dissolve leaving its impression as mould.	Gastropods from Portland.
Petrified Remains	Tissue replaced by water-carried mineral deposits.	Petrified forests of Arizona.
Impressions	Remains in fine-grained sediment on which organisms died.	Archaeopteryx feathers, leaf impressions.
Imprints	Footprints, trails, tracks and tunnels of organisms made in mud rapidly baked and covered by sediments.	Dinosaur footprints.
Coprolites	Faecal pellets buried in sediments.	Coenozoic mammals.

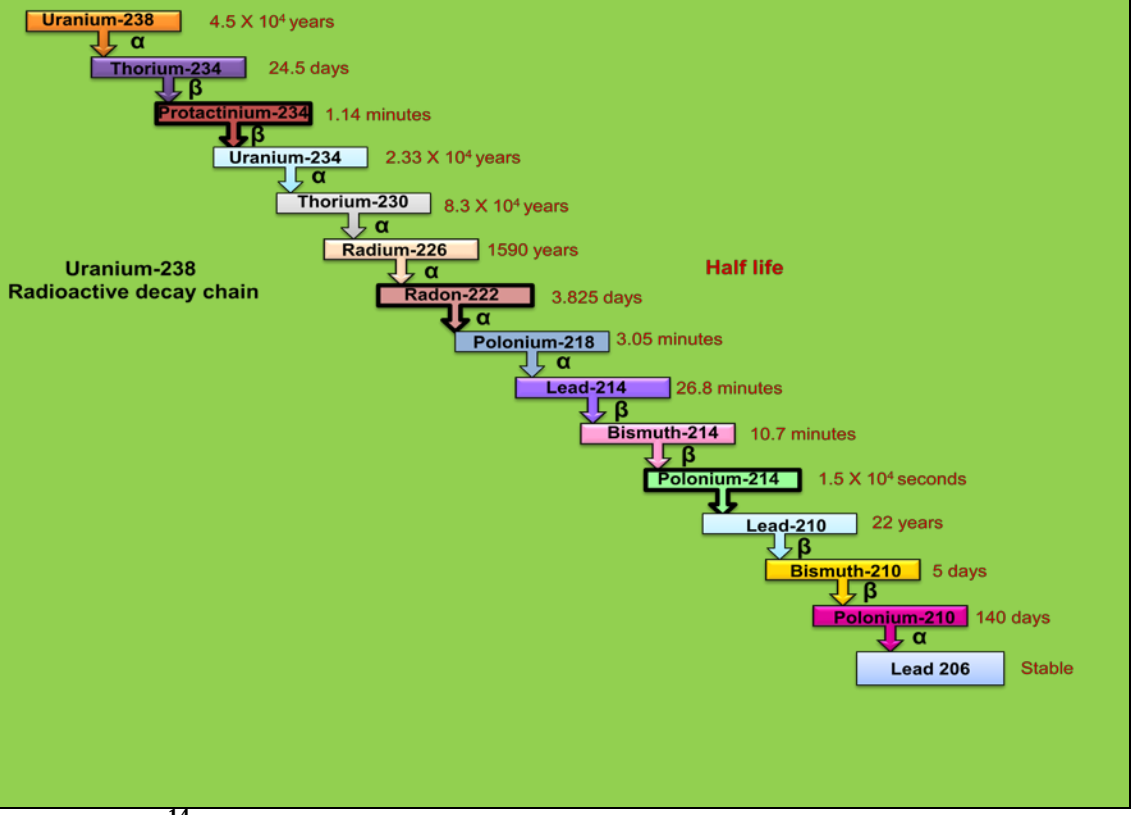
Determination of Age of Fossils: The age of fossils can be determined by following methods-

1. Relative Dating Methods: In early days, mechanism of absolute dating was not present and as a result relative dating technique were used to determine the age of rock and fossils. In this technique, the position and erosin rate of rock in particular environment. Older rocks are situated in deeper had ancient fossils and superficial rocks had fossils of recent fossils.

2. Absolute Dating Methods: These methods are using spontaneous decay of unstable radioactive nuclei into stable radioactive nuclei at a constant and known rate. Absolute dating technique uses radioactive nuclei in three different techniques:

(i) Uranium-Lead Technique: This technique was introduced by Baltwood in 1907. Rocks contains uranium (U^{238}) in the form of mineral zircon. Uranium decay spontaneously to Lead as per the given scheme (Scheme 6.1). It has a half life of 4.5 billion years which means it will take 4,500,000,000 years to decay 50% uranium. So determination of content of uranium and lead in a rock or fossil can be used to determine the age of rock or fossil.

Scheme 6.1: Scheme of Uranium degradation to lead.



(ii) Carbon (C^{14}) Dating Technique: This methods was introduced by W.F.Libby in 1950. Radioactive carbon (C14) in found naturally in rock. C14 has a half life of 5600 years and C^{14} decay gives nitrogen(N^{14}). Cabon dating technique can be used to measure fossil age upto 25,000 years old.

(iii) Potassium-Argon Technique: Radioactive Potassium (K40) is usually found in the rock of all kinds. Its life is $1.3x10^9$ years and disintegrate to form Argon.

Geological Time Scale: Use of the radioactive dating has allowed the determination of fossils found in different sedimentary rock samples. It has allowed to calculate the presence of different organisms preserved in the rock samples in the form of fossils. In addition, it helped scientist to predict that earth is almost 4-5 billion year old and life appeared on earth almost 4000 millions year ago. Since then the earth's history has been divided into 5 different time frame known as eras. Few of these eras are divided into the periods and which inturn split up into the epochs. The different Eras are as follows:

1. Archeozoic (4600-3500 millions year): it is thr first era and begins with the formation of earth and presence of solar system. There is no fossil form available from this era.

2. Proterozoic (3000-1000 millions year): it is the second era and begins with the origin of prokaryotes, primitive metazoans and eukaryotes. Reports are available about scanty fossils in this era.

3. Palaeozoic (570-280 millions year): it is the third era and known as era of ancient life. It saw the appearance of invertebrate, fishes, amphibian etc. Reports of spore bearing plants, tree ferns and origin of conifers is available. initial Reports are available about scanty fossils in this era.

4. Mesozoic (225-135 millions year): The appearance of tooth birds, therian mammals, reptiles and dominance of dinosaurs. In addition, placental mammals are also found. Reports of cycads and flowering plants is available.

5. Cenozoic (Modern era): This is the modern era and it witnessed the dominance of present age man, modern mammals, birds, fishes and insects.

Lecture 7: Theories of Evolution (Part-I)

Introduction: In continuation our discussion on evolution, so far we have discussed origin of life and the evidences to support the existence of evolution to give rise diversified organisms on earth. The mechanism of evolution is not known and several theories have been put forward to explain the process of evolution. These theories are as follows:

1. Theory of inheritance of acquired characters: This theory is proposed by French biologist Chevalier de lemarck in his famous book **"Philosphie zoologique"**. He proposed that organisms are not fixed and they evolve from the pre-exisiting organisms by modifications. The theory is proposed assuming three different assumptions:

- **New Needs:** Variation in environment, conditions and the over-all circumstance which affect the existence of organism, needs adaptation in organism to survive. As a result, organism has to put special efforts to fulfil its new needs for adaptation. In few cases, it just needs change in habit or behavior of the organism. New habit includes fresh or extensive use of certain organs or structure of the body or disuse of others.

- **Acquisition of Characters:** There are 3 ways to acquire the characters required to adopt into changed conditions:

  Innate Tendency: There is innate tendency in each organism to acquire greater complexicity and perfection to perform functions. In this process of achieving perfection, organism is better and better adapted to the changed environment.

  Use or disuse of organs: Use and disuse of organ affect their structure, shape and efficiency of functioning. More usage of a particular organ brings additional strength, size and more efficient. In contrast, disuse or underusage of organ gradually makes them weaker and smaller and finally they may disappear as well. Thus, differential usage of organ allowed the additional character in the body during the life span of an organism.

Environmental factors: Variation in environmental factors such as temperature, light, humidity, wind, ememies affects the living things and brings changes in life style and habits. The combined effect of use and disuse of organ and influence of environmental factors, results into the change in the body of organism and these characters are known as **"acquired characters"**.

- Inheritence of Acquired Characters: The characters acquired by one generation are transmitted to the new generation and subsequently newer characters are added in next generation to acquire perfection.

This, lemarcks proposed that evolution is a slow process where characters are acquired over the course of time in various generations.

Explanation of theory with observed evolution: Lemarck inhis book explained the evolution of various animals to elaborate the proposed hypothesis.

1. Giraffe: Lemarck uses his hypothesis to explain the appearance of Giraffe with long neck and forelimbs. The different evolutionary stages of present giraffe is explained as per lemarck theory in figure 7.1. As per the theory, the giraffe is evolved from the short height deer like ancestor. These ancesters are living in the barren place with leaves on the trees available to them for eating. In order to reach the leaves on tree, it streacted its neck and forelimbs. As a result, these organs get elongated. These acquired character in first generation passed on to the subsequent generation and continuous streatching accumules this character over the course of few generations to evolve giraffe with long neck and forearms.

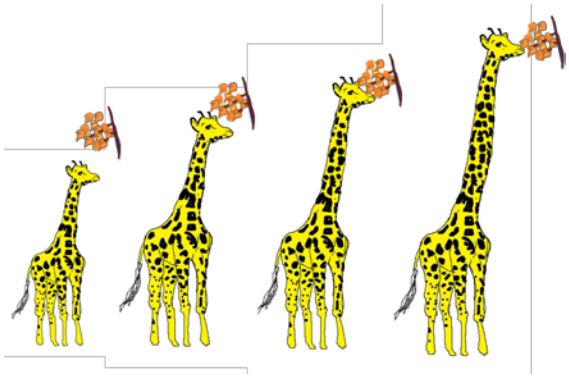


Figure 6.1: Event in the evolution of giraffe from deer link ancestor.

2. Other examples of use/disuse to support the Lamarck theory are black smith and rabbit. Blacksmith acquires large biceps muscle as they do rigrous hammering for wielding. Whereas, rabbit develop well developed pinna muscle to move the ear to receive sound waves from different direction to protect them selve from the enemy.

3. Aquatic Birds: Aquatic birds such as ducks needs to go into the water for food and protection. To achieve this, they spread their toes to float on water. As a result of continuos efforts, they have developed web between the web.

4. Snakes: it is considered that snake had lizard like ancestor with two pairs of fully developed legs. These ancestor needs to hide from the mammals and they prefer to stay in places with dense vegetation, holes and narrow spaces. In this process, they stretch their body to hide in a narrow space and did not use legs. Over the course of time, continuous stretching of the body made it cylindrical and they lost the legs.

5. Deer: It is believed that deer has acquired speed through continuous running in a process to protect himself from the enemies.

6. Cave animals: cave animals stay in low light environment and does not use eye and as a result they lost their vision over the course of time.

Criticism of the theory: Lamarck theory received initial attention but it could not be able to explain several observations. The initial two assumptions are correct; **(1)** New needs are created by a change in the environment and **(2)** these characters are acquired by use/disuse of organ and environmental factors. The inheritance of acquired chacarters to the subsequent generation is arguable. There are evidences against the inheritance of acquired characters.

1. The major critism is gathered by experiment performed by August Weismann. According to the Weismann's theory of continuity of germplasm, animal is made up of two types of cells; Somatic cells and germ cells. The nuclei present in germ cell is responsible for inheritance of characters whereas somatic cells contains nucei which respond to the environmental factors and use/disuse. Hence, acquired characters remains within the somatic cells. As a result this theory supports the idea that acquired characters

are not inherited. Weisman conducted a conclusive experiment on rat where he has cut their tails for 80 generations but it didn't produce rats tailless.

2. Boring of ear (pinna) is practiced in women for thousands years but this chacraters never been inherited.

3. European womens wear tight garments to maintain slender waist but their children have normal waist at birth.

4. Chinese women wear tight shoes to have small feet but their children have normal waist.

5. Child of athelete are not born with powerful muscle.

6. Children of noble laureate may not be as intelligent as the parent.

7. Pavlov has trained the mice to come for food on bell ring but he found that training is necessarily in each generations.

8. Eyes of a voracious reader do not grow in size nor they acquire improved eyesight with increasing age.

Neo-lamarckism: There are evidences to support the inheritance of acquired characters. For examples, effect of radiation and chamicals on germ cells and resulting change in the phenotype of the cell. The evidence for the inheritance of acquired character revived the Lamarck theory as neo-lamarckism. The modified neo-lamarckism has following postulates:

1. Germ cells are not always immune from the effect of environment.

2. Germ cells may be affected directly by environment without any effect on the somatic cells.

3. Germ cells may carried acquired character to the next generation.

Even considering these points, Lamarckism could not be able to provide satisfactory mechanism for evolution.

Lecture 8: Theories of Evolution (Part-II)

Darwin's Theory of Evolution: The theory of natural selection was proposed by Charles Darwin and Alfred Russel Wallace in their common publication. Both of them conducted scientific data collection from individual population survey. Charles Darwin travelled for 5yrs expedition around the world on the ship H.M.S Beagle. During this journey, he made observation of several animals and plants. He keenly observed the similarities among organisms and draw evolutionary relationship. In addition, economist Thomas Malthus's report on workers recognized that competition between species leads to the struggle for existence. Considering Wallace's view and Malthus observations of workers led Charles Darwin to propose the theory of natural selection in his book **"Origin of Species"**. The theory of natural selection is based on following points:

1. Rapid Multiplication: Every organism has enormous ability to reproduce to continuance of the species. All animals and plant tend to multiply in geometrical progression. For example, an organism will be double in Ist year, four times by 2^{nd} yr and 8 times in a third year and so on. Lets see few example of organism to understand the potential of organism to multiply. These examples are as follows:

(i) Paramecium: it has multiplication rate of 3 times in 48 hrs. if single paramecium will allow to grow and multiply in 5 yrs to give the mass equal to ten thousand times the size of earth.

(ii) Cod Fishes: Cod fish produces over 1 million eggs in a year. If all these eggs will rise to fishes, the whole atlantic ocean will be filled in next 5 yrs.

(iii) Oyester: An Oyester may lay 114,000,000 eggs at a single spawning. If all the oyster grow and survived upto adulthood for 5 generations, then number of oyster will be more than the number of electrons in the universe.

(iv) Elephant: Elephant has an average life span of 90 years and during the whole life span he can produce only six offsprings. If all the offsprings survived, single elephant pair would produce 19,000,000 elephants in 750 years.

(v) Plants: Plants produces thousands of seeds every year.

2. Limited natural resources: Inspite the enormous capacity of an organism to reproduce, the number of individual species remain constant. It is due to increase in population in animal or plant requires more space and food. Ultimately the food to plant or animal is provided by the CO_2 from air, water and mineral from soil. The amount of thes basic material is limited in universe. Hence, it does not allow the population of organism beyond the limit and an equilibrium is reached.

3. Struggle for existence: Due to shortage of food, water and space, there is severe competition among the off spring for existence. Every individual has few basic requirements, such as food, space, water, mate to reproduce and protection from enemies. In order to achieve basic needs, organisms compete with each other and it is known as struggle for existence. The struggle for an individual can be of 3 types:

(i) Intraspecific Struggle: The competition of the individuals of the same species. For example, fight between two dogs for a piece of meat. War is another example of intraspecific struggle among different human.

(ii) Interspecific Struggle: The competition of the individuals of the different species. For example, tiger attacks on deer for food.

(iii) Environmental Struggle: Every individual struggle against the change in environment such as temperature, humidity, level of water, rain, climate etc.

4. Variation: Each and every individual varies in several aspects to other individual. Even the offsprings produced by parents also differ in many aspects. The two individuals can be different from each other in their behavior, color, size, strength etc.

5. Natural Selection: Due to variation among different individual, they struggle towards their existence with different potentials. The variation in an individual may allow him to survive and complete its life cycle comfortable. Wheras, if the variations are unfavorable, the individual will struggle against every odds and as a result it may not be able to complete the life cycle. For example, fast running deer has better chance to escape from the tiger compared to the slow runner. Another factor is ability to adopt into the changed environment. Both Darwin and Wallace, recognized the environment as the principal

factor for natural selection. For example, plants with ability to hold more water and can be able to reduce loss of water will ultimately survive, despite the physical strength, height and other characters.

6. Inheritence of useful variations: The individual survived due to unique variation, mate and produces their off spring to complete their life-cycle. As a result, they transfer the useful variations to the next generations and allow the individual to multiply. Darwin believed that any variation which can help the individual to survive and help to favouable for struggle will be inherited. He considerd the variation which may be acquired or inheritable.

7. Formation of new Species: As a result of struggle and natural selection, only the individual fits to the environmental conditions will survive and complete its life-cycle. As a result, the number of these individual will increase over the course of time compared to the less favorable organism. In addition, the variation favoring will be inherieted to the next generation whereas unfavorable variation will be discarded. Due to continous selection, a new organism will appear which will be different from their ancesteral form.

Lets see the example of giraffe to understand the Darwin’t theory of natural selection. According to the the theory of natural selection, in the beginning there were two different types of giraffe present on earth; (1) Deer like short height and (2) Long neck and forearms (Figure 8.1). Until the grass was available on land, both of these species were surviving and be able to complete their life cycle. With change in climate and reduction of grass, there might be a struggle for food. The giraffe with long neck and forearms can still be able to eat leaves on the tress but the deer like giraffe could not be able to reach there and died due to starvation. In due course, several round of the natural selection led the giraffe with long neck and forearms dominated the region and be present as new species.

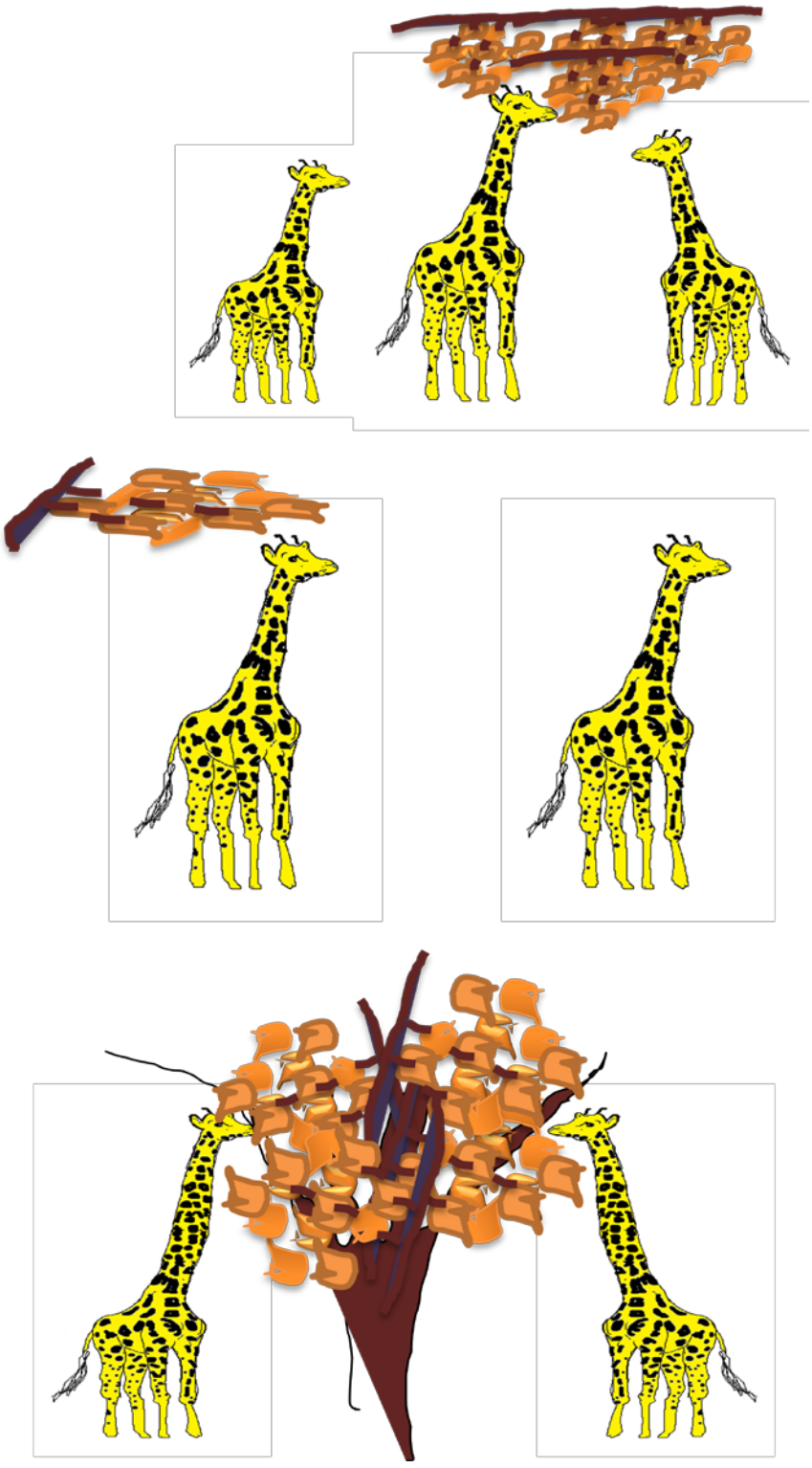


Figure 8.1: Event in the evolution of giraffe from deer link ancestor.

Evidences to support the theory of natural selection:

1. Artificial Selection: From ancient times, man is selecting good breed animals and plant for their use. In addition, they are performing cross breeding of these species to develop newer breed with derirable characters (Figure 8.2). The scientist supporting the Darwin's theory explained the evolution through natural selection to give rise to newer species, just like following similar mechanism as artificial selection by man. They further added that natural selection is a slow process but much more complex compared to the artificial selection procedure.

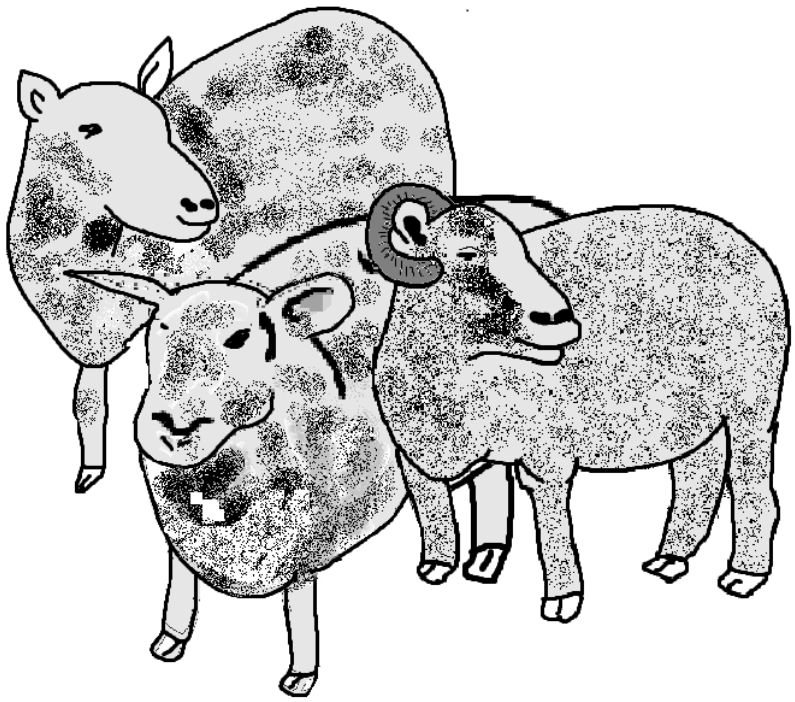


Figure 8.2: Development of small size sheep.

2. Mimicry and Protective colouration: The mimicry and protective colouration is very common in several organisms as the product of natural selection. Most of these organism acquire the pattern of coloration by gradually changing color at each stage.

3. Correlation of nectarines and proboscis: The position of nectarines and proboscis in insect correlates well and match well to facilitate pollination. This relation does not develop in single days but evolve gradually envisaged via the process of natural selection.

Evidences Againist the theory of natural selection:

1. Perpetuation of Vestigial Organs: Vestigial organs are selected despite the fact that they are not useful for animals but even then they are preserved generation over generation.

2. No explanation for variation: Darwin could not be able to explain the source and mechanism of generation of variation in organisms.

3. Distinction between continuous and discontinuous variations: According to theory, Darwin assumed that any variation essential for animal survival will be carried forward to next generation. We know that it is not true as per present knowledge of genetics.

4. Disapproval of Pangenesis theory of Darwin: Darwin put forward the theory of Pangenesis to explain the process of inheritance. It was disapproved by the experiments performed by August Weismann in 1892.

Lecture 9: Theories of Evolution (Part-III)

Hugo de Vries's theory: The theories of Lemarck or Darwin is based on the population study but both theories could not be able to explain the origin of variation and their mode of transmission from one generation ot next generation. To understand the gap, dutch botanist, Hugo de Vries has put forward mutation theory in 1901. According to the De Vries mutation theory state that new species arise from the pre-existing one in a single generation by sudden appearance of new features through a genetic variation known as mutations. Contrast to earlier theories (Lemarck or Darwin), De Vries proposed that evolution is a sudden, discontinuous and jerky process rather than continuous and gradual. He termed the process as Salation ie single step large mutation. In addition, natural selection works on mutation, preserve the mutations found useful and eliminates the mutants with harmful mutation. But he didn't support the struggle between the organism considered the co-existenance of them with the parent species (non-mutated species).

De Vries Experiment: To test the proposed mechanism of evolution, Huge De Vries conducted experiment on plant called as Evening Primrose (*Oenothera lamarckiana*). The outline of the experiment is given in Figure 91. He observed the subtle but significant difference between different wild type varients. He took normal plant and collected the seeds through self pollination. He found that majorty of seeds were normal like their parents except few one. These seeds were quite different from there parents. The plants with variants were true to give rise to plants with similar characterstics. In 2^{nd} generation, it breeds to give plants with majority of plants similar to their parents but few plants with different varients. Hence, he observed that in each generation, majority of the offsprings are similar to their parents but it gives few off springs with varients. In addition, he found that mutations appeared suddenly and were inherited by offsprings. De Vries found 4 different types of plants:

(i) Progressive, with newer traits.

(ii) Retrogressive, that had reduced or lost traits compared to their parents.

(iii) Degressive, plants with weak with low survival.

(iv) Inconstant, these plants are unstable and they resembles parents as well as at times produced variants.

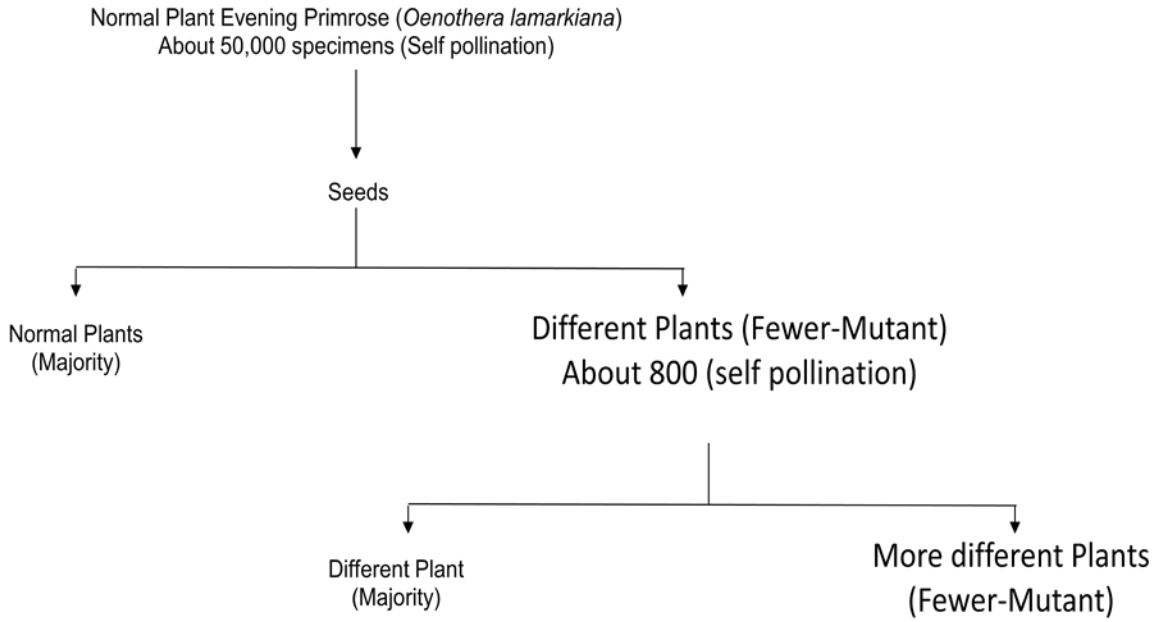


Figure 9.1: Huge De Vries Exeriment with Evening Primrose.

Important conclusions from Huge De Vries Mutation Theory are given in the Figure 9.2. These are as follows:

1. Mutations are the initiator factor for evolution.

2. Mutants are non-predictable, occur suddenly and produce their effect instantly.

3. No intermediate stage between appearance of mutant form and parent plants.

4. Mutations are commulative in nature and occurs on multiple occasion to increase the frequency of mutant in the population.

5. A single mutation may give rise to new species.

6. At last, environmental factors work as selective pressure to allow growth of benefitial mutants and eliminates lethal or not useful mutations.

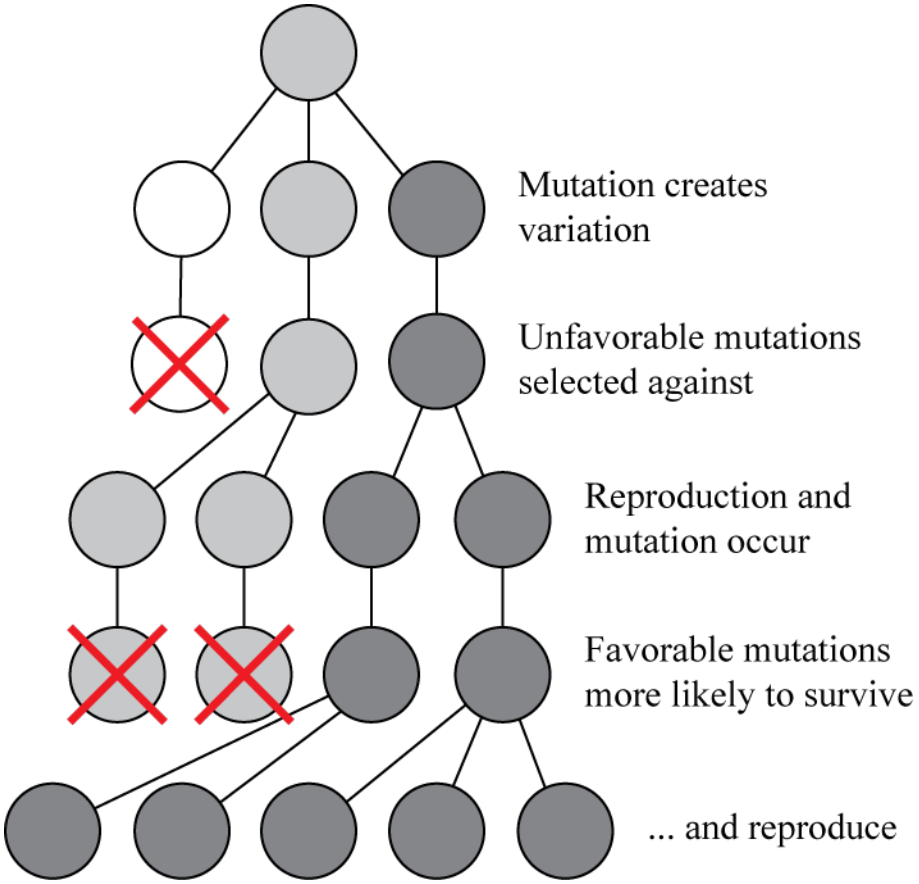


Figure 9.2: Huge De Vries Mutation Theory.

Evidence for the theory: There are experimental evidences to support the Huge De Vries mutation theory. These evidences are as follows:

1. The experiment performed by De Vries was reproduced by several other scientist and they came to similar conclusions.

2. Mutations found spontaneously in nature and these sudden appearance of mutant varities has strengthen the mutation theory. These evidences found in nature are as follows:

- The Ancon sheep was produced from an ordinary sheep in single step in 1891. The mutaed sheep was short height (Figure 9.3) and it was useful for farmers as they could not be able to jump from low stone fences.

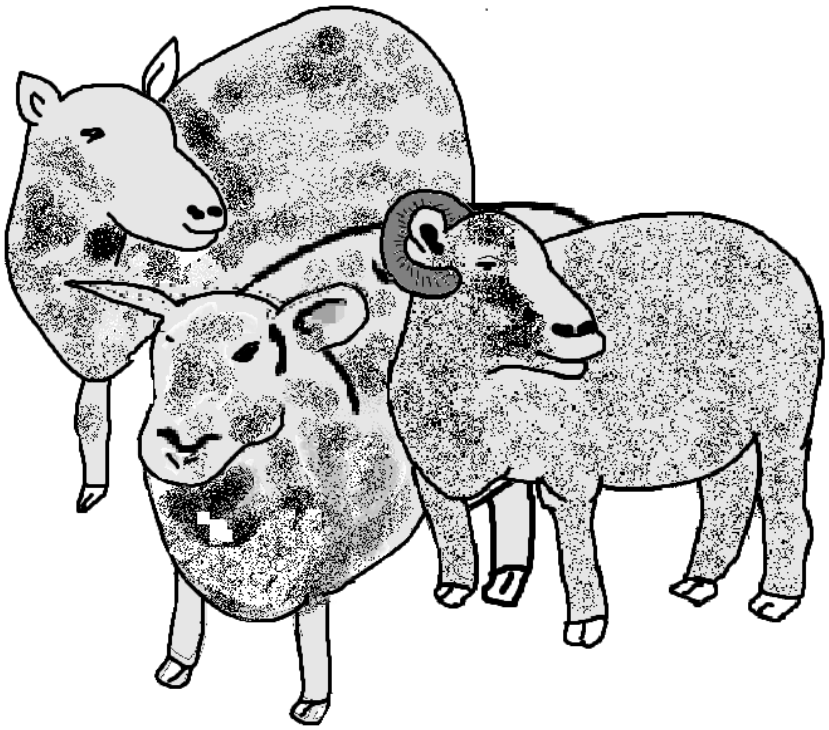


Figure 9.3: The ancon sheep and their noral parents.

- Hornless or polled Hereford cattle were produced in single step in 1889 from normal parents.
- The hairless cats, dog and mice were produced from normal parents in single step.

3. Oenothera lamarckiana has 14 chromosomes but the mutants were having 16,20,22,24,28 and 30 chromosomes.

4. Mutations are genetically linked and inheritable.

5. A single large mutation can produce new species in plant. For example, Delicious apple.

Evidence against the theory: There are evidences against the mutation theory proposed by Huge De Vries. These objections are as follows:

(i) The mutation are of rare occurrence. Hence it is difficult to assume that if all animal or plant species could appear solely by mutation.

(ii) The relationship between flower and the insect (such as length of proboscis in insect and position of nectariesd in flower) can not be explained by mutation theory.

(iii) Mutations are recessive where as it is generally the dominant mutations that brings about evolution.

Lecture 10: Human Evolution

Introduction: Human belongs to order primates. Other members of the same order were lemurs, lorises, tarsiers, monkey and apes. Human are closer to the ape, which in turn, are closer to the older world monkey. Together, human, monkey and ape belongs to suborder anthropoidea (Figure 10.1). In the current lecture, we will discuss evolutionary stages in the development of modern age man from the initial mammals.

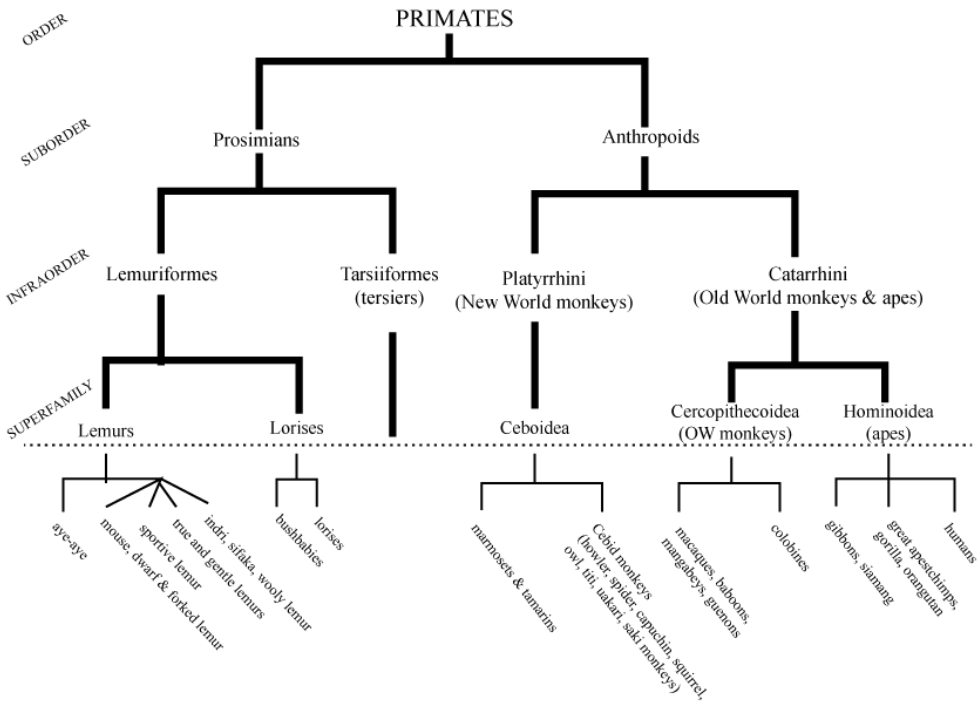


Figure 10.1 : Classification of humans among the primates.

Prehuman Evolution: Human evolution starts with the appearance of first mammals on earth. Mammals are further evolved into different classes including primates to which man belongs.

Origin of mammals: Mammals appeared on earth in the Jurassic period, approximately 195 millions years ago. Mammals, birds and snakes are considered to be originated from the common ancestor, cotylosaurs or stem reptiles (Figure 10.2). The initial mammals, tree shrew lived for several million years along with giant reptiles dinosaurs. The extraordinary ability of mammals to the changed environment, active life due to warm

body and sensitivity towards environment. Post extinction of dinosaurs, mammals evolved into a variety of forms to capture the available space (water, land and air) on earth.

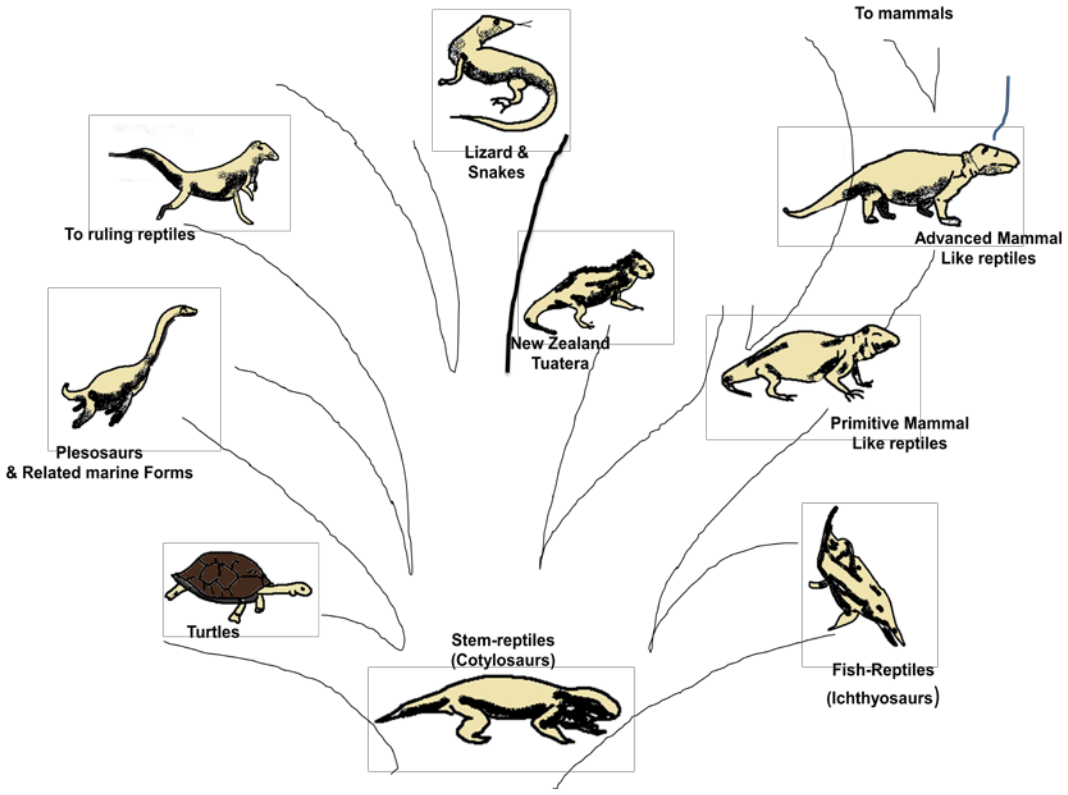


Figure 10.2 : Origin of mammals, birds and reptiles.

Origin of Primates: The primates appeared about 65 million years from the shrew link small insectivores. The shrew were long tailed squirrel-like creatures, similar to present day shrews. It give rise to primitive primates such as lemurs and tarsiers (Figure 10.3). These primates are collected termed as prosimians, the animals appeared before monkey and apes. These mammals have acquired 5 important features to maintain tree life. These are as follows:

1. Bipedal Locomoation:

2. Grasping Hand and Feet:

3. Streoscopic Vision:

4. Reduction in Snout:

5. Enlargement of Brain

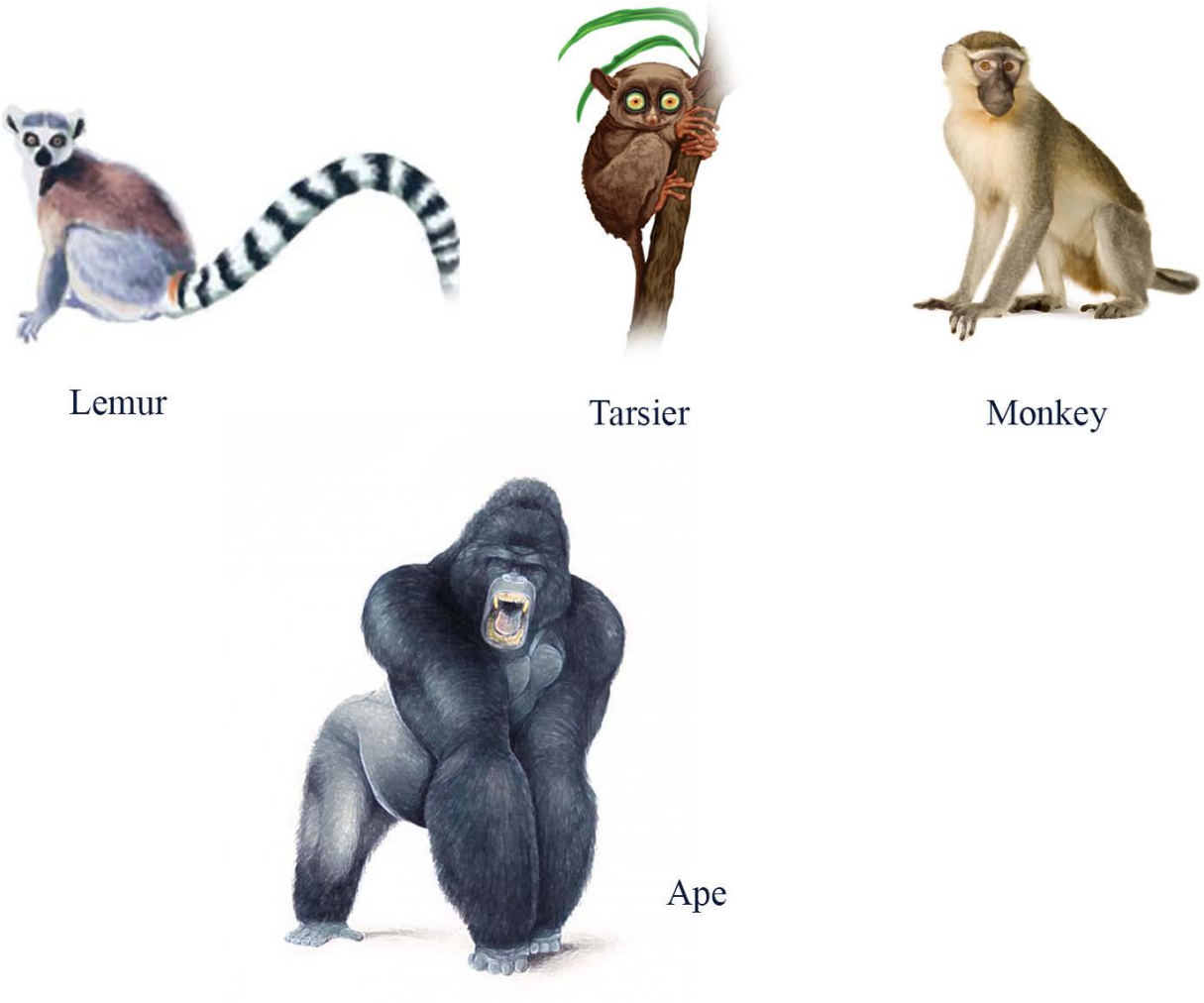


Figure 10.3 : Common Primates.

Human Evolution: it is belived to be that human evolution ocured in asia and Africa. The closet relative of human in primate is monkey and apes. As discussed before, tarsiers diverged into the anthropoids such as monkey, ape and humans. Monkey and tailess primates (Apes and man) evolve independtly 36 millioms year age from tarsoid stock (Figure 10.4).

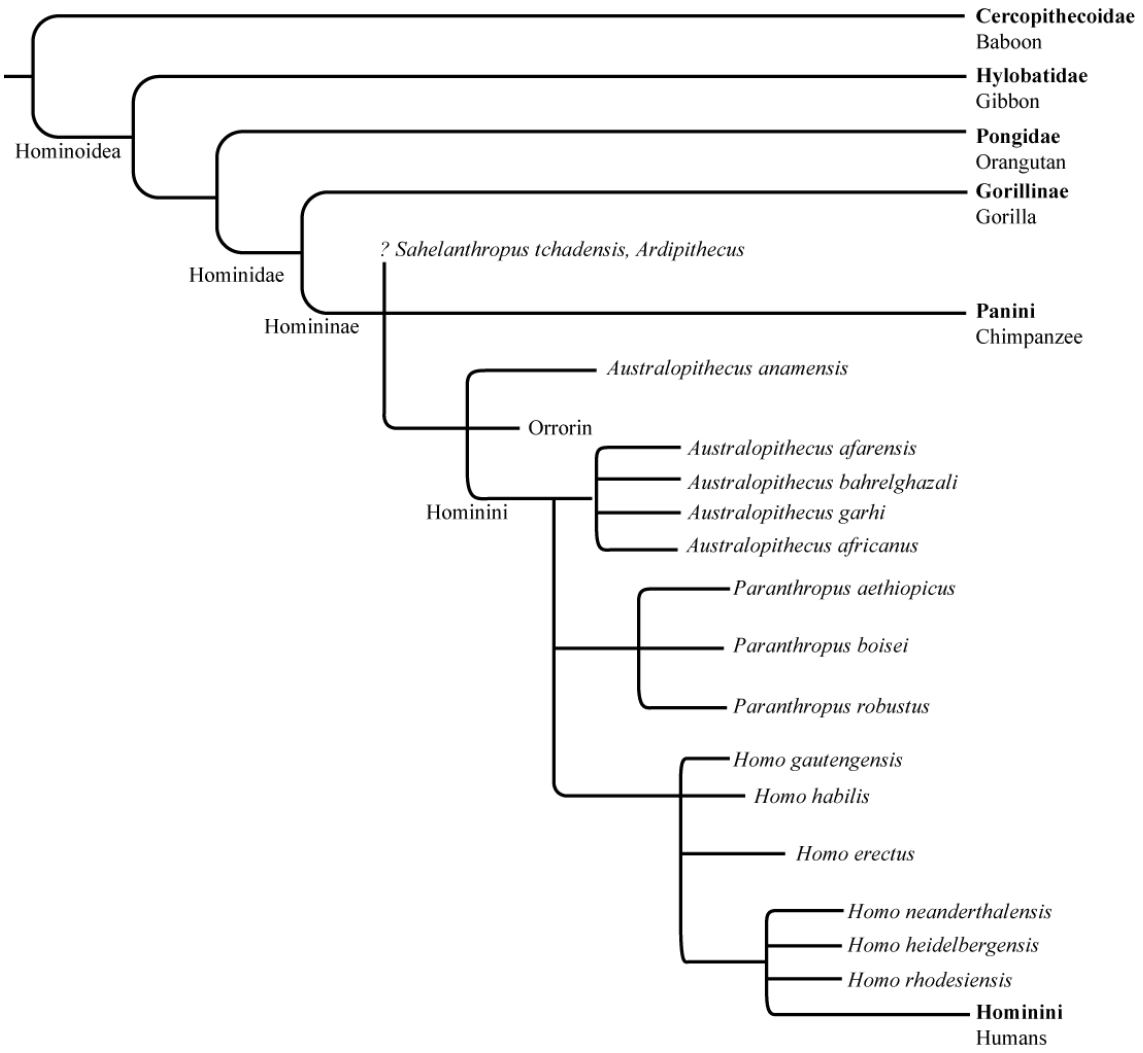


Figure 10.4 : Family Tree of Primates. [REDRAW REQUIRED]

Monkey: The monkey preferred to live arboreal life and adopted for this purpose. They evolved to jump from brach to brach and leaning on tree. The enlarged brain capacity has allowed monkeys to learn and for precise control of movement. The evolutionary lines of monkey and apes has several stages, starting from tarsiers. These are as follows:

(i) Parapithecus: These are earliest fossil form of monkey, ape and man is available to date. The fossils are found in lower Oligocene epoch in Egypt. The old world monkeys are diverged from the main trunk of primate evolution in the Oligocene.

(ii) Propilopithecus: Another evolutionary line, developed from main trunk in Miocence about 10 million years ago give rise to gibbons in two stages named propliopithecus and pliopithecus.

(iii) Dryopithecus: it is considered as fossil ape and a common ancestor of great ape (orangutan, chimpanzee and gorilla) and man. These ancestral forms were living in the early Miocene, some 25 millions years ago. It is similar to chimpanzee except that leg and hands of approximately same equal length.

(iv) Proconsul: Dryopithecines were evolved into fossil named proconsul africanus. It was discovered from the Miocene in south Africa. Proconsul diverged to give rise chimpanzee and gorilla in Pliocene about 4 millions years ago. Around 2.3 millions years ago, chimpanzee and gorilla diverged from each other in the Pleistocene Epoch.

Human ancestral forms: The charactersitcs of different human ancestral forms is given in the Figure 10.5.

(a) Ramapithecus: it was the primitive ape like primate, lived on tree and occasionally travelled and ate on ground. It survived life on nuts and food grains, as it lacks well developed cannines and molars. These ancestral forms extinct almost 7 million years ago.

(b) Australopithecus: These are considerd as first Ape-man. First report of these ancient forms on earth is 4-5 million years ago in South Africa. He was 1.05 meter high and was mainly living terrestrial creature with bipedal locomotion. There was no evidences that these ancestral forms can be able to made or used tools. The cranial capacity was 500

cm3 but had small canine and incisor teeth and short fingers. They can be able to walked in upright posture.

(c) Homo Habilis: Australopithecus give rise to homo hibalis around 2 million years ago in Pleistocene. He was 1.5-1.8 meter high and had small cannies and light jaw. The available fossil data indicate the first usage of tools by these ancestral forms. The cranial capacity was 650-800cm3. He is more closure to the man like features than ape. He was carnivorous and hunted large animals. He was maintaining a social life, started living in caves and cared for young one.

(e) Homo Erectus: Homo erectus evolved from homo habilis around 1.7 millions years ago in Pleistocene. He was 1.5-1.8 meter tall and had erect posture. He was capable of making fine quality stone and bone tools, hunted big games and knew use of fire. The cranial capacity was 800-1300 cm3. He was omnivorous and probably ate meat. By 150,000 year ago, homo erectus migrated to asia, and Europe. The fossile were found in java, peking in china and Heidelberg in germany, and these fossils were termed as Java-ape man (H.erectus erectus), Peking man (H.erectus pekinensis) and Heidelberg-Man (H. erectus heidelbergensis).

(f) Homo Neanderthalensis: These early men were inhabitated in sothern Europe and central asia during Pleistocene about 35000-100,000 years ago. He was 1.5-1.66 meter erect posture, strong shoulders and arms, powerful hands and large skull with thick bones (Figure 10.5). The cranial capacity was 1300-1600cm3, almost equal to the modern man. They have flat crainium, sloping forehead, thin large orbits, heavy brow ridges, protruding jaws, strongs mandibles and no chin. These were known to live in cave or probably known to build their own hut-like shelters. There are reports for them being able to made flint flake tools, skilled tools, used animal hides as clothing, knew the use of fire and perform rituals such as buried their dead. They were omnivorous and had not been doing agriculture or animal domestication. They were known to have migratory habits in response to climatatic changes and as a result they were spread o South Asia and Africa.

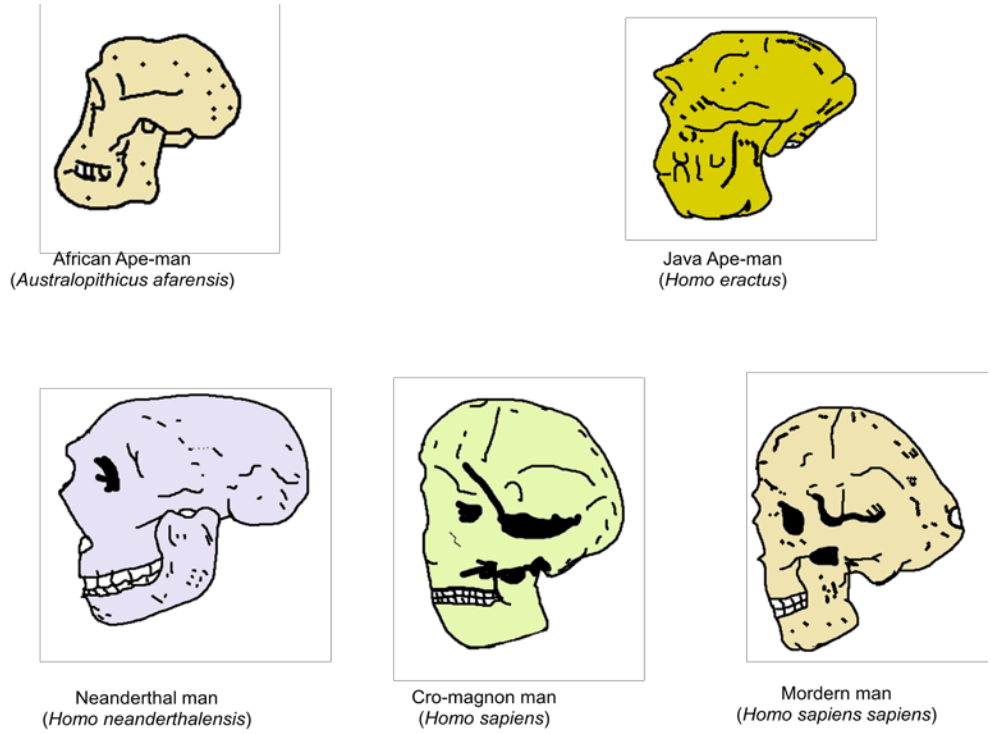


Figure 10.5 : Skulls of early and modern men.

(g) Cromagnon Man: The cromagnon Man was 1.8 meter tall with strudy, less hairly skin and has crainial capacity of 1650cm3. Crogman man lived in families in caves. There walking posture was erect and they can be ablke to make fine sophisticated tools, were fine hunters and knew the use of fire. They were using skin of animal as cloth. They were known to made ivory ornaments. They were still not practicing agriculture and animal domestication.

(h) Homo Sapiens or Modern Man: The modern man was supposed to appear around 25,000 years ago and started spreading all over the world around 10,000 years ago. He has modified slightly morphologicqal changes, such as thining of skull bones, lower crainial capacity (1300-1600cm3) and development of 4 curves in vertebral column. He lacks efficient mechanism of bitting, power of smell, feeble eightsight and hearing ability. But modern man compensated these things with the development of sophiscated tools and techniques. This has made him the most dominant animals on earth. He understand the importance to agriculture and domestic animals.

Important Features related to the Human Evolution: The important stricking features during the evolution of human from ape like animal is given in the Figure 10.6. These features are as follows:

1. Erect posture and bipedal movement on legs.

2. Increase in crainial capacity and intelligence.

3. Broadening of forehead with vertical elevation.

4. Stereoscopic Vision.

5. Reduction in size of pinnae.

6. Formation of chin.

7. Increase in mobility of neck to see round.

8. Reduction in body hair.

9. Development of curves in vertebral column for erect posture.

10. Increase in Height.

11. No specific breeding season and continuous gametogenesis in the gonads.

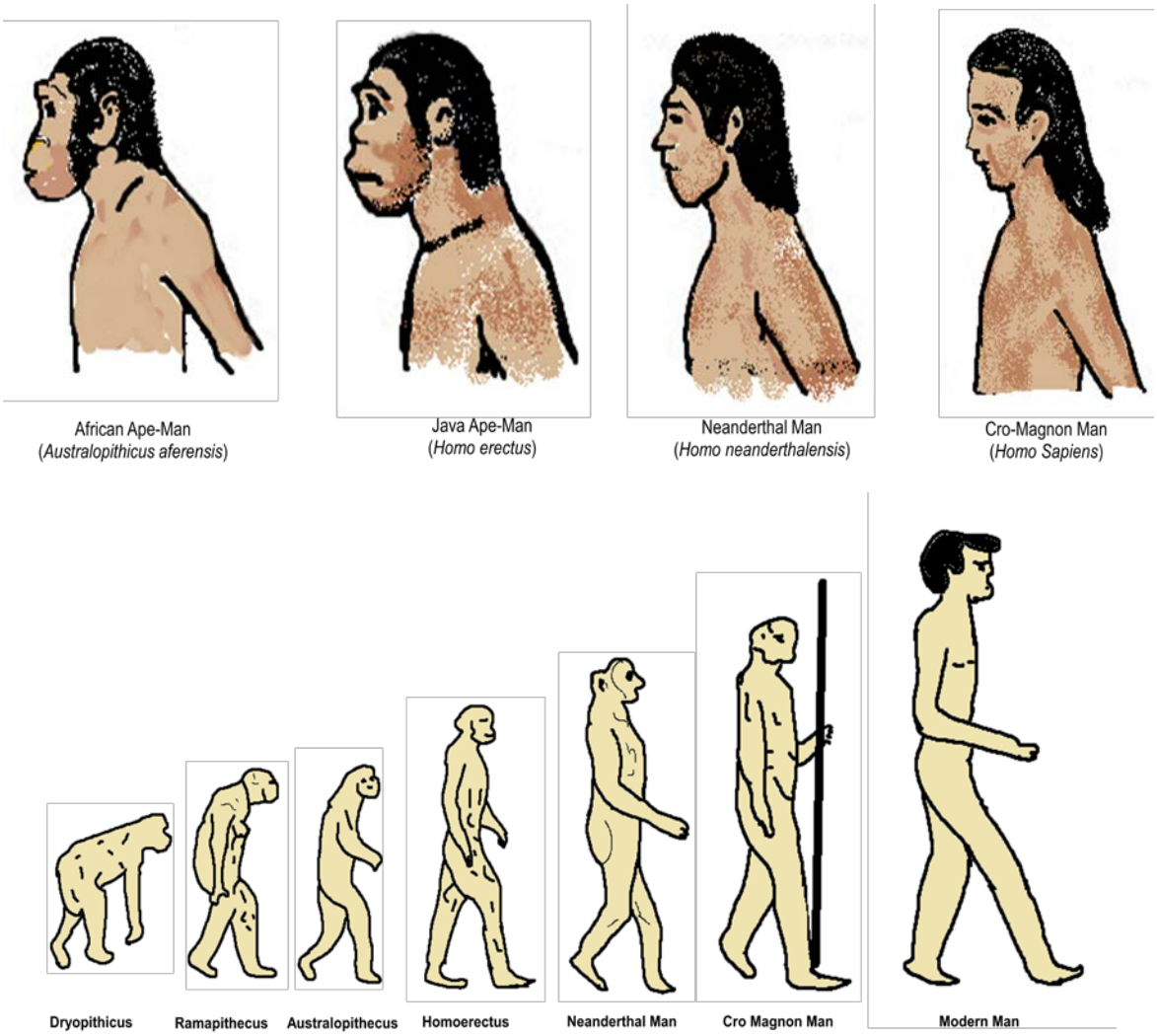


Figure 10.6 : Different evolutionary stages in human evolution.