EVOLUTION

INTRODUCTION

- The branch of life science for the study of 'origin of life' and evolution of different forms of life on earth was called **bioevolution or evolutionary biology** by Mayer (1970).
- The word evolution means to unfold or unroll or to reveal hidden potentialities. Evolution simply means an orderly change from one condition to another.
- Evolution is a slow but continuous process which never stops.

ORIGIN OF LIFE

- Origin of life is the process by which living organisms developed from inanimate matter (which is generally thought to have occurred on Earth between 3800 - 4200 millions years ago).
- First life evolved about. 3800-4200 million years back.
- There are several theories about the origin of life, like big bang theory, theory of special creation, theory of eternity, cosmozoic theory etc.

BIG-BANG THEORY

- This theory was proposed by **Abbe Lemaitre**.
- According to this theory, the universe originated about 15 billion years ago due to a thermonuclear explosion of a dense entity. This thermonuclear explosion is called **Big-bang**. About 4.6 billion years ago, the origin of the solar system took place by the gaseous clouds formed due to this explosion.
- These gaseous clouds collapsed and converted into flat disc-like structure made up of atoms and small particles due to their own gravitational pull. This flat-disc like structure is called **Solar Nebula.** The very hot central part of this solar nebula became still hotter and converted into the sun. Now, due to condensation of atoms and dust particles moving around the sun, the formation of the other planets took place Like, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.
- The solid part of our planet earth was called **lithosphere** and the gaseous part was known as **atmosphere.**
- When the earth's surface cooled down and its temperature decreased to 100° C, water formed on it.

THEORY OF SPECIAL CREATION

- The greatest supporter of this theory was father Suarez.
- According to the Bible, life and everything was created by God in 6 days.
- According to Hindu mythology, the world was created by God Brahma. According to it, life has not changed ever since its origin.
- Special creation theory lacks scientific evidence so it is not accepted.

COSMOZOIC THEORY

- This theory is proposed by **Richter** and supported by **Arrhenius.**
- Protoplasm reached earth in the form of spores or other simple particles from some unknown part of the universe with cosmic dust and they gave rise to various forms of life.

COSMIC PANSPERMIA THEORY

- This theory was proposed by **Arrhenius.**
- According to this theory, organisms existed throughout the Universe and their spores could freely travel through space from one star to the other.

THEORY OF SPONTANEOUS GENERATION (ABIOGENESIS OR AUTOGENESIS)

- This hypothesis was supported by ancient Greek philosophers like Thales, Anaximander, Xenophanes, Plato, Empedocles, Aristotle.
- According to this theory, life was originated from non-living things spontaneously. They believed that the mud of the Nile river could give rise to frogs, snakes, crocodiles.

Abiogenesis was strongly supported by **Von Helmont**. He claimed formation of mice in 21 days, if a sweat soaked dirty shirt is kept in wheat barn.

- Theory of spontaneous generation was **disapproved by Francesco Redi** (1668), **Abbe Lazzaro Spallanzani** (1767) and **Louis Pasteur (1867)**

THEORY OF BIOGENESIS

- According to this theory, new organisms can originate on earth only from pre-existing life.
- This theory rejected the theory of spontaneous generation but cannot explain origin of life.
- To prove biogenesis and to disprove abiogenesis, experiments were performed by the following scientists–
  - **Francesco Redi's Experiment (Italian 1668) :** He took cooked meat in three jars. One was uncovered, the second was covered with parchment and the third was air tight.

He observed that maggots developed only in the uncovered jar while maggots could not develop in the meat in closed jars.
This proved that larvae were formed from eggs laid by the flies in open jars. Since the meat in closed jars could not be visited by flies so no larvae could develop. Therefore, life originated from pre-existing life.

  - **Lazzaro Spallanzani (Italian 1767) :** He boiled vegetables and meat to prepare a sterilized nutritive soup and he kept some of it in air sealed flasks and some in loosely corked flasks. He observed that the soup in sealed flask remained sterile while micro-organisms appeared in the soup in loosely corked flasks. Thus, even micro-organisms were formed from pre-existing ones in the air rather than spontaneously.
  - **Louis Pasteur (French 1862) :** Pasteur is popular for germ theory of diseases or Germ theory and he disproved abiogenesis. He prepared sterilized syrup of sugar and yeast by boiling them in flasks. He took two flasks, one of broken neck and another of curved neck (swan neck flask). No life appeared in swan neck flask because germ laden dust particles in the air were trapped by the curved neck which serves as filter while in the broken neck flask colonies of micro-organism were developed.

MODERN THEORY OF ORIGIN OF LIFE

- The modern hypothesis of origin of life was formulated by **Haeckel.**
- This theory was proposed by Russian Scientist **A.I. Oparin** and **J.B.S.Haldane** (England born Indian scientist). Oparin's theory was published in his book 'Origin of Life' in 1938.
- According to this theory, life originated by the composition of chemicals.
- Oparin's theory (also known as primary abiogenesis) is based on artificial synthesis. So, also called as **artificial synthetic theory.**
- 1st life originated in the water of oceans. So, water is essential for the origin of life. There is no life on the moon due to absence of water.
- At the time of origin of life, free O_2 was absent, so **first life was anaerobic.**
- In the primitive atmosphere, free oxygen was present but complete oxygen consumed in composition so primitive atmosphere of earth was reducing.

- Modern view regarding the origin of life includes **origin of earth and its primitive atmosphere; chemical evolution (chemogeny) and biological evolution (biogeny).**
- Four basic requirements for life to arise are–
  - primitive atmosphere (with little or no oxygen).
  - right chemicals (including water, various inorganic ions and organic molecules)
  - energy source
  - infinite time
- The energy needed for the chemical evolution on primitive earth mainly came from solar radiation and cosmic rays, electric discharges, volcanic eruptions, heat etc.
- The lightest atoms of nitrogen, hydrogen, oxygen etc. formed the primitive atmosphere.
- Primitive atmosphere was **reducing** because hydrogen atoms combined with all available oxygen atoms to form water and leaving no free oxygen.
- Evolution up to formation of coacervates termed is as **chemical evolution**, in which complex organic compounds were formed which were essential for formation of cellular structure.
- An experiment to prove that organic compounds were the basis of life was performed by **Miller.**
- Miller took a flask and filled it with methane, ammonia and hydrogen in the proportion of 2:1:2 respectively at 0°C. This proportion of gases probably existed in the environment at time of origin of life.

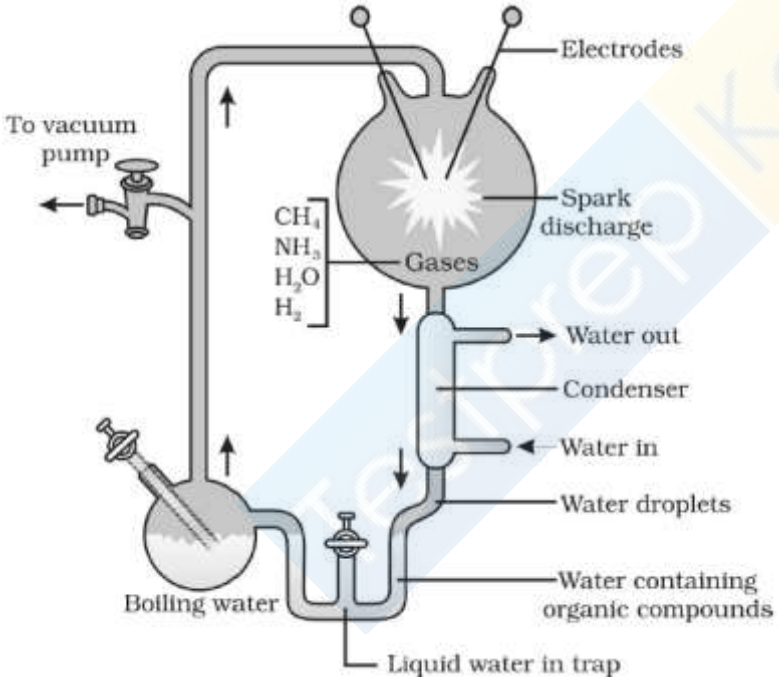


Fig. : Diagrammatic representation of Miller's experiment

This flask was connected with a smaller flask, that was filled with water, with the help of glass tubes. In the bigger flask, two electrodes of tungsten were fitted. Then a current of 60,000 volts was passed, through gases containing bigger flask for seven days. At the end of seven days, when the vapours condensed, a red substance was found in the
U-tube. When this red substance was analyzed, it was found that it contains amino acids, glycine and nitrogenous bases which are found in the nucleus of a cell.

- The apparatus used by Miller is called **spark discharge apparatus.**
- The energy used in the Miller Urey experiment was **electric spark.**

- Macromolecules which were synthesized abiotically in primitive ocean later came together and formed large colloidal drop like structures called **protobionts** (later called **coacervates** by **Oparin, Fox** called them **microsphere** and **Deamer** called them **vesicles)**.

Each protobiont was a cluster of macromolecules. These contained proteins, nucleic acids, lipids, polysaccharides etc. They grew by absorbing molecules from their environment. They could divide by budding like bacteria, many chemical reactions including the decomposition of glucose took place inside the protobionts. The sun provides energy for chemical reactions. According to Oparin, **coacervates were the first sole living molecules which gave rise to cell.**

- Evolution from coacervates to simple cell structure is known as **biological evolution.**
- The **first living form** named **protocell** originated in the primitive oceans.
- The protocell were clusters of nucleoproteins which is formed by composition of nucleic acids and enzymatic proteins. Nucleoproteins had the property of self duplication. Nucleoproteins were the first sign of life. The protocell **represented the beginning of life.**

From protocells or eobionts, few cores of nucleoproteins got separated free in oceans and became inactive but when they enter another eobiont they became active so virus like structures were formed.

EVIDENCE OF ORGANIC EVOLUTION

- There are many types of evidence which support the process of organic evolution
  - Palaeontological
  - Comparative anatomy and morphology
  - Physiological & biochemistry
  - Biogeographical distribution
  - Embryological
- The study of fossils is known as **palaeontology.**
- **Birbal Sahani** is famous for Indian palaeonotology.
- Two branches of palaeontology are
  - **Palaeobotany :** Study of plant fossils
  - **Palaeozoology :** Study of animal fossils
- "Impression of past organism found in rocks is called fossils."

PALAEONTOLOGICAL EVIDENCES

- **Charles Darwin** was the first to show that fossils provide direct evidence for organic evolution because it deals with the actual organisms which lived in the past.
- The different methods of fossilization are intact preservation, petrifaction, moulds and casts, impression, mummies, tracks and trails etc.
- Age of fossils is determined by dating the rocks in which fossil occurs.
- The method of determining the age of rocks or of the fossils are – carbon dating method.
- **By studying fossils, following facts about organic evolution are evident :**
  - Fossils found in older rocks are of simple type and those found in newer rocks are of complex types.
  - In the beginning, unicellular protozoans were formed from which multicellular animals evolved.
  - Some fossils represents connecting links between the two groups.
  - Angiosperms among plants and mammals among animals are highly developed and modern organisms.
  - By fossils, we can study the evolutionary pedigree of an animal like stages in the evolution of horse, elephant and man etc.

FOSSILS RECORD

- Though the fossils of horse, elephant, camel and others have been worked out, but the **fossil record of the horse is the best** and complete. The fossil record of humans is fragmentary. The evolution of horse has occurred almost in a straight line **(Orthogenesis).** All fossils have been traced from North America. The earliest is of Eohippus (Hyracotherium) which was about 30cm. in height with 4-toes (digits) , i.e. 2nd, 3rd, 4th and 5th.

Period/epoch	Name of fossil	Digits present
Pleistocene	*Equus*	1 digit (3rd) (with splint bones* representing 2nd and 4th toes)
Pliocene	*Pliohippus*	1 digit (3rd) (2nd and 4th digits very much reduced)
Miocene	*Merychippus*	3 digits (2nd,3rd, 4th) (2nd and 4th digits shorter)
Oligocene	*Miohippus*	3 digits (2nd,3rd, 4th)
Oligocene	*Mesohippus*	3 digits (2nd,3rd, 4th)
Eocene	*Eohippus*	4 digits (2nd,3rd, 4th, 5th)

In modern horse the radius and ulna are fused, and the metacarpal of 3rd digit is elongated to form Cannon-bone. Two splint bones, closely attached to rear end of Cannon, actually represent metacarpals of 2nd and 4th digits.

- The study of fossils indicates that the present day animals are different from past animals.
- The fossils of upper strata of sedimentary rocks are more advanced than the fossils of lower strata.
- The fossils of upper strata are closer to the present day animals.

Thus the study of fossils (palaeontology) provides **direct evidence** in favour of organic evolution.

Experimental Proof of Oparin's Theory – Stanley L. Miller (1953)

- Miller, under the guidance of his teacher, Harold C. Urey performed a classical, 'Simulation experiment' by using 'Spark discharge apparatus'. He created the conditions prevailing on proto-planet.
- He used a mixture of water vapour (H_2O), hydrogen (H_2), ammonia (NH_3) and methane (CH_4), the last three in the ratio of 2:1:2, at 800°C.

(To memorize the mixture see that first two components have hydrogen in the beginning and last two at the end. Oxygen, carbon-di-oxide and nitrogen were not used.)

- The tungsten electrodes were used to simulate lightening effect. The experiment was carried out in the dark for more than 15-days.
- This experiment also had a control (experiment) in which electric discharge was not provided.
- A red colour liquid was collected in the U-shaped tube. On analysis this liquid was found to contain Urea, lactic acid, sugars, acetic acid, and amino acids like Glycine, Glutamic acid, Alanine and Aspartic acid. All these complex organic compounds, including amino acids, were synthesized non-enzymatically.
- This proved that complex organic compounds could be synthesized in reducing atmosphere without the help of enzymes, and thus supported the theory of chemical evolution.

COMPARATIVE ANATOMY AND MORPHOLOGY

- Different animals and plants show dissimilarities in their structure but in some characters they show similarity. These similarities provide one of the most concluding evidence of organic evolution.

- Similarities are of two types : **homology** and **analogy**.

HOMOLOGY

- The similarity based on common origin, similar basic plan of organization and embryonic development is called **homology**.
- Similarity in appearance and function is not necessary.
- The organs which have common origin, embryonic development and the same basic structure but perform different functions are called homologous organs.
- Examples of Homologous organs are
  - **Forelimbs of mammals**

	Horse	Bat	Whale	Seal	Man
Appearence	Foot	Wings	Paddle	Flipper	Hand
Function	Running	Flying	Swim-ming	Swim-ming	Holding

In their fore limbs, similar bones are present like - humerus, radius, ulna, carpals, metacarpals and phalanges.

  - **Legs of invertebrates**

Cockroach	Honey bee
Walking	Collecting of pollens

In both cockroach and honey bee, segmented legs are present and segments are same like coxa, trochanter, femur, tibia and 1-5 jointed tarsus.

  - **Mouth parts of insects**

Cockroach	Honey Bee	Mosquito
Biting and chewing	Chewing and lapping	Piercing and sucking

In each of these insects, the mouth parts comprises labrum, mandibles and maxillae.

  - Homology is also seen in the skeleton, heart, blood vessels and excretory system of different vertebrates
  - Thorn of Bougainvillea and tendril of Cucurbita (modification of axillary bud)
  - Wings of sparrow and pectoral fins of fish
  - Hind limb of mammals
  - Potato & ginger
  - Radish & carrot
  - Homology is also seen amongst the molecules. This is called **molecular homology.** For e.g., the proteins found in the blood of man and apes are similar.

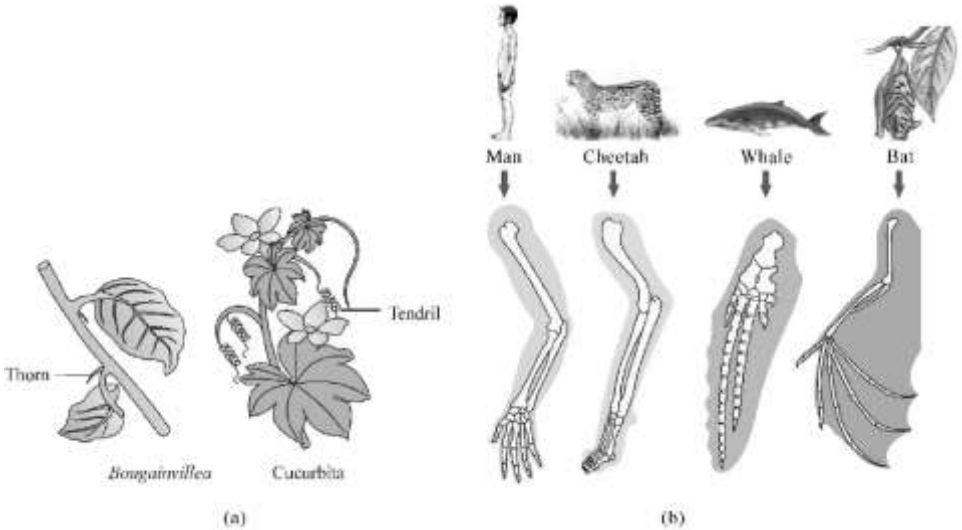


Fig. : Example of homologous organs in (a) Plants and (b) Animals

- Testes in male and ovaries in female develop from the same embryonic tissue.
- Pectoral fins of fish and flipper of Seal.
- Flipper of Penguin (bird) and Dolphin (mammal).

- Homology found in different animals indicate their evolution from common ancestors. The process in which species which have diverged after origin from common ancestor giving rise to new species adapted to new habitats and ways of life is called **adaptive radiation,** exhibit large number of homologous organs. Homology shows **divergent evolution.** For e.g., Adaptive radiation gave rise to a variety of marsupials in Australia.

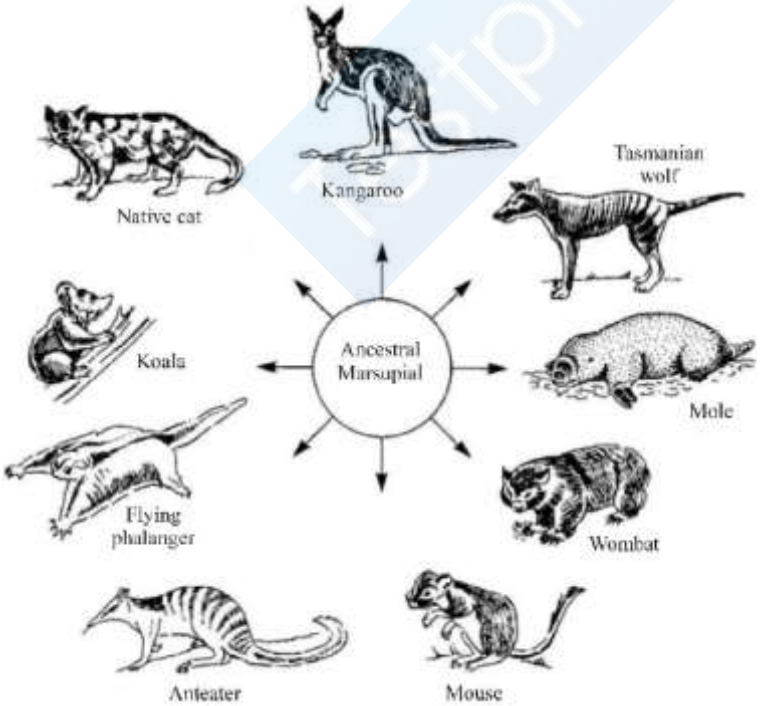


Fig. : Adaptive radiation of marsupials of Australia

ANALOGY

- It is similarity in organs based on similar function. Organs which have different origin and dissimilar fundamental structure but have similar functions are called **analogous organs.**
- **Examples of Analogous organs are**
  - Wings of bat & birds are analogous to wings of insects.
  - Pelvic fins of fish, flipper of seal.
  - Sting of bee and scorpion.
  - Phylloclade of Ruscus and leaf.
  - Chloragogen cell of Pheretima and liver of vertebrate.
  - Hands of man and trunk of elephants.
  - Potato and sweet potato.
  - Eyes of octopus and eyes of mammals (different in their retinal position).
  - Dog fish and whale.

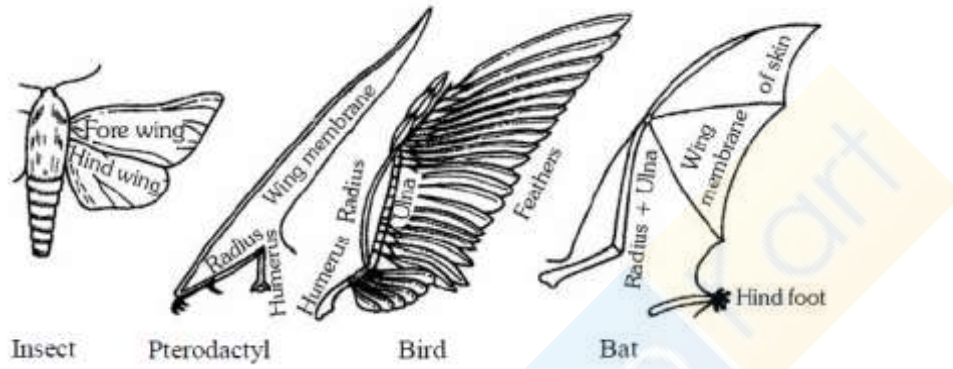


Fig. : Analogy in the wings

- Development of similar adaptive functional structures in unrelated groups of organisms is called **convergent evolution.** For e.g., Some of the marsupials of Australia resemble equivalent placental mammals that live in similar habitats of other continents. When adaptive convergence is found in closely related species, it is called parallel evolution.
- Analogous organs **do not show common ancestry** but they show evolution.

VESTIGIAL ORGANS

- The organs which are present in reduced form and do not perform any function in the body but correspond to the fully developed functional organs of related animals are called **vestigial organs.**
- These are remnants of organs which were complete and functional in their ancestors.
- Human body possess about **180 vestigial organs.**

Some of these are - nictitating membrane; muscles of pinna (auricular muscles); vermiform appendix; coccyx; canine teeth; third molars (wisdom teeth); segmental muscles of abdomen; caecum; body hairs; nipples in male and ear pinna.

CONNECTING LINKS

- Some animals and plants possess characters of two separate groups – one being primitive and the other is advanced group.

These species act as a bridge between two taxonomic groups. Such organisms are called **connecting links.**

- Connecting links provide good example of organic evolution and common ancestry. Examples–

1	Virus	Between living and non living.
2	*Euglena*	Between plants and animals.
3	*Proterospongia*	Between protozoa and porifera.
4	*Neopilina*	Between mollusca and annelida
5	*Peripatus*	Between annelida and arthropoda
6	*Archaeopteryx*	Between reptiles and birds
7	*Balanoglossus*	Between non chordates and chordates
8	*Chimera*	Between cartilaginous fish and bony fish
9	Lung fish *(Protopterus)*	Between fishes and amphibia
10	*Platypus*	Between reptiles and mammals
11	*Echidina*	Between reptiles and mammals.

ATAVISM (REVERSION)

- Sometimes in some individuals some characters suddenly appear which were supposed to be present in third ancestors but were lost during the course of development. This phenomenon is known as **atavism or reversion.**
- **Examples**
  - Human baby with tail
  - Cervical fistula - In some human babies, an aperture is present on the neck behind the ear called as cervical fistula. It represents pharyngeal gill slits which were present in aquatic vertebrate ancestors.
  - Long and pointed canine teeth represents carnivorous ancestors.
  - Large and thick body hair reflects our relationship with apes.
  - Extra nipples (more than two)

EVIDENCE FROM PHYSIOLOGY AND BIOCHEMISTRY

Different organism show similarities in physiology and biochemistry. Some examples are-

- **Protoplasm -** Structure and chemical composition of protoplasm is same from protozoa to mammalia.
- **Enzymes -** Enzymes perform same function in all animals like trypsin digests protein from Amoeba to man. Amylase digests starch from porifera to mammalia.
- **Blood -** Chordates show almost same composition of blood.
- **ATP -** This energy rich molecule is formed for biological oxidation in all animals.
- **Hormones** - Secreted in different vertebrates and performs same function.
- **Hereditary material -** Hereditary material is DNA in all organisms and its basic structure is same in all animals.
- **Cytochrome C** is a respiratory protein situated in the mitochondria of all organism. In this protein, (78-88) amino acids are identical in all organisms, which show common ancestory.

Physiology and biochemistry thus, prove that all animals have evolved from some common ancestor.

EVIDENCES FROM BIOGEOGRAPHY

- Biogeography is the study of the distribution of species and ecosystems in geographic space and through geological time. Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area.
- Biogeography is split into two areas: ecological biogeography, which is concerned with current distribution patterns and historical biogeography, which is concerned with long-term and large-scale distributions.

EVIDENCES FROM EMBRYOLOGY

- Evidences for embryology are based on the comparative study of the embryos of various animals.
- According to **Baer's law**, an organism show its ancestral stages in embryonic development. In embryo stage, general characters appear first then specialised characters appear.
- **Muller** firstly initially proposed '**Recapitulation theory'.** According to it, 'ontogeny recapitulates phylogeny'. It means any organism shows its ancestral adult stages during its embryonic development. It shows that all organisms evolved from a common ancestor.

Ernest Haeckel explained it in detail and gave it the name 'Biogenetic law'.

- **Examples**

○ The zygotes from which the development of all metazoan bodies start are single-celled and are quite comparable with the bodies of simple protozoans.

This indicates the origin of metazoans from protozoan ancestors.

○ The early stages of embryonic development, viz, morula, blastula and gastrula are basically similar in all metazoans, indicating a monophyletic origin of the latter.

○ The phylogenetically earliest metazoans i.e., sponges and cnidarians have retained early gastrula like double - layered (diploblastic) structure of body of metazoans.

○ In fishes, the young individuals, developing from gastrula, is almost-like an adult, but the tadpole larvae of amphibians bear more resemblance to the young ones of fishes than to their own adults. This indicates origin of amphibians from fish.

○ Even after gastrulation in vertebrates, the early post gastrula stages are quite similar in members of all the different classes, viz, fishes, amphibians, reptiles, birds and mammals.

The differentiation of class characters appear in the later stages, moreover, the embryo of phylogenetically higher vertebrates pass through the adult stages of lower vertebrates before attaining the characteristics of their own classes.

For e.g., in all birds and mammals including man, the embryo's pass through stages resembling the adult stage of fishes, amphibians and reptiles before finally attaining the characters of their respective classes.

This proves that all vertebrates have evolved from common fish like ancestors and also that both birds and mammals have evolved from reptiles.

○ When the heart first develops in the embryos of amphibians, reptiles, birds and mammals, it is
2-chambered, same as in embryos and adults of fishes. In later stages of embryonic development in amphibians, reptiles, birds and mammals, the heart becomes 3-chambered. This condition is retained in adults of amphibians and most reptiles. In birds and mammals, the heart becomes 4-chambered in the last embryonic stages to continue as such in the adults.

○ Modern Scientists have discovered "biochemical recapitulation" also, for example, fishes mainly excrete ammonia. Adult amphibians excrete urea, but their tadpoles excrete ammonia like fish. Birds excrete uric acid, but their embryos excrete first ammonia and then urea during earlier stages.

○ n embryonic stage, birds showed tooth buds for some time, which became extinct later. It showed that birds evolved from toothed reptile like ancestors.

NOTES

- The aquatic mammals (eg. dolphins, whales, seals, porpoises etc.) don't have gill slits-because their adaptation to aquatic life is secondary. .
- In Acacia tree, well developed compound leaves are found. But seedling has simple leaves like those found in all stages of development of its ancestors. This provides a good example of recapitulation.
- Modern day Oaks of southern United States of America retain their foliage throughout the year whereas the oaks of northern United States are deciduous and shed their leaves during winter. The southern species, on the basis of this character of leaves are considered to be more primitive than the northern oaks. However, the seedlings of northern species are generally seen to retain their leaves during winter. This provides a good example of recapitulation.
- **Evolutionary trend** : The continuous change of a character within an evolving lineage is termed as evolutionary trend.

THEORIES OF ORGANIC EVOLUTION

Four main theories to explain theories of evolution are-

- Lamarckism
- Darwinism
- Mutation theory
- Modern concept of evolution (synthetic theory)

LAMARCKISM

- **Theory of inheritance of acquired characters** is the first theory of organic evolution **proposed by Jean Baptiste de Lamarck (1744-1829).**
- Lamarck coined the terms: invertebrates, annelida.
- The term biology was given by Lamarck & Treviranus.

BASIC CONCEPTS OF LAMARCKISM (THEORY OF INHERITANCE OF ACQUIRED CHARACTERS)

- **Internal vital forces :** Some internal forces are present in all organisms. Due to the presence of these forces, organisms have the tendency to increase the size of their organs or entire body.
- **Effect of environment and new needs :** Environment influences all type of organisms. Changing environment gives rise to new needs. New needs or desires produce new structures and change the habits of the organisms.
- **Use and disuse of organs :** If an organ is constantly used, it would be better developed whereas disuse of an organ results in its degeneration.
- **Inheritance of acquired character :** During the lifetime of an organism, new characters develop due to internal vital forces, effect of environment, new needs and use and disuse of organs.

These acquired characters are inherited from one generation to another. By continuous inheritance through many generations, these acquired characters tend to make new generation quite different from its ancestors resulting in the formation of new species.

EXAMPLES IN SUPPORT OF LAMARCKISM

- Long neck and high forelimb of Giraffe.

- Aquatic birds stretched their toes and developed web.
- Snakes lost their legs
- Deers became good runners by the development of strong limbs and streamlined body.
- Retractile claws of carnivorous animals.

CRITICISM OF LAMARCKISM

- According to first concept, organisms tend to increase their size but it is not universally true. For example, among angiosperms, the trees seem to be primitive and shrubs, herbs and grasses have evolved from trees, where the size was reduced during evolution.
- Second concept is false. Can we sprout wings wishing to fly like birds?
- The third concept is somewhat true like the well developed bicep muscles of blacksmith and less developed wings in flightless birds. But this concept also have many objections like the eyes of a student/reader do not increase in size and power with increasing age, the constantly beating heart maintains a constant size through generations.
- Fourth concept is completely false because acquired characters are not inherited.
- Weismann and Payne criticized the theory of inheritance of acquired characters.
- **Weismann** cut off the tails of rats for about 22 generations but there was no reduction in the size of the tail. On the basis of this experiment, Weismann proposed the **theory of continuity of germplasm.**

According to Weismann,

- Two types of matters are present in organisms, somatoplasm and germplasm. Somatoplasm in somatic cells and germplasm in germinal cells.

Somatoplasm dies with the death of organism while germplasm transfers into the next generation.

- If any variation develops in germplasm, it is inherited, while if variation develop in somatoplasm, it is not transmitted.

- **Payne** kept Drosophila in dark up to 69 generations, but there was no reduction in the size or of eyesight.

NEO-LAMARCKISM (TERM BY PAKARD)

- Although Lamarckism remained controversial but some scientists gave the following evidence in favour of Lamarckism. They are known as **Neo-lamarckians.**
- According to Neo-lamarckism, environment affected the inheritance of acquired characters. According to it, changing environment gives rise to some physical and chemical changes in organisms, which effect their germplasm, and these acquired characters are definitely inherited. E.g.,

- **Sumner's Experiment :** Sumner kept a white rat in warm temperature resulting in elongation of the body, large pinna and long tail. These features were inherited by the offspring.
- **Kammerer's Experiment :** Kammerer kept Salamander in dark background. The black spots found on skin were widely spread. In lighter background, the skin became yellow with limited black spots. These characters were inherited by the offspring.
- **Mac Dugal's Experiment :** Mac Dugal trained white rats to cross a tank of water following definite route. These trained rats were mated and their offspring were again trained. It was observed that there was a decrease in the number of errors by offsprings of white rats.

Table : Differences between Lamarckism and Neo-Lamarckism

S. No.	Lamarckism	Neo–Lamarckism
1.	It is the original theory by Lamarck.	It is a modification of the original theory of Lamarck in order to make it more suitable to modern knowledge.
2.	The theory lays stress on internal force, appetency and use and disuse of organs.	Neo–Lamarckism does not give any importance to these factors.
3.	It believes that changes in environment brings about a conscious reaction in animals.	The theory stresses on the direct effect of changed environment on the organisms.
4.	According to Lamarckism, the acquired characters passs on to the next generation.	Normally only those modifications are transferred to next generation which influence the germ cells or where somatic cells give rise to germ cells.

DARWINISM

- "Darwinism" or "The theory of Natural Selection" was proposed jointly by **Charles Darwin** and **A.R. Wallace**. This theory was explained by Darwin in his book 'On the origin of Species by means of Natural Selection' (1859).
- Darwin was influenced by two books–
  - "Principles of Population" by Malthus.
  - "Principles of Geology" by Charls Lyell.
- **Alfred Russel Wallace** had travelled to South eastern Asia and South America. The idea of natural selection striked in his mind. Wallace wrote an essay and sent it to Darwin on the tendency of varieties to depart indefinitely from the original type. There was striking similarity between the views of Darwin and Wallace.

Wallace presented a chart to explain the main points of the theory of Darwin (given below).

S.No.	Facts	Consequences (Conclusions)
1.	(i) Enormous rate of reproduction among animals (ii) Constant number of animals of a species	→ **Struggle for existence**
2.	(i) Struggle for existence (ii) Heritable variations	→ **Survival of the fittest or natural selection**
3.	(i) Survival of the fittest (ii) Continuous environmental changes	→ **Continuous natural selection leading to evolution of new species.**

MAIN FEATURES OF THEORY OF NATURAL SELECTION

- **Overproduction**

○ All organisms have the capability to produce an enormous number of offspring, organisms multiply in geometric ratio.

○ E.g., (i) Plants produce thousands of seeds.
(ii) Insects lay hundreds of eggs.
(iii) One pair of elephant gives rise to about six offsprings and if all survived in 750 years a single pair would produce about 19 million elephants. Thus, some organisms produce more offsprings and other produce fewer offsprings. This is called differential reproduction.

- **Struggle for existence**

○ Every individual competes with others of the same and other species for basic necessities like space, shelter and food, it is called struggle for existence and it continues for the whole life from the zygote stage to its natural death.

○ The struggle for existence is of three types

▪ **Intraspecific struggle:** It is the competition between the individuals of the same species for same needs like food, shelter and breeding (most acute type of struggle).

▪ **Interspecific struggle:** It is the struggle between the individuals of different species for food and shelter.

▪ **Environmental struggle:** This struggle is between the organisms and their environment. All organisms struggle with cold, heat, wind, rain, drought and flood etc.

- **Variations and heredity**

○ Except the identical twins, no two individuals are similar and their requirements are also not same. It means there are differences among the individuals. These differences are called **variations**. Due to variations, some individuals would be better adjusted towards the surroundings than the others.

○ According to Darwin, the variations are continuous and those which are helpful in the adaptation of an organism towards its surroundings would be passed on to the next generation, while the others will disappear.

- **Survival of the fittest or natural selection**

○ The original idea of survival of the fittest was proposed by Herbert Spencer.

○ According to Darwin, most suitable and fit individuals are successful in the struggle for existence. The individuals with most favourable adaptations are able to lead most successful life and are able to win over their mating partners. Darwin called it sexual selection.

In the struggle for existence, only those members survive which possess useful variations (means nature selects fit individuals). This was called as natural selection. Fitness is the end result of the ability to adapt and get selected by nature.

- **Origin of new species**

Darwin explained that variations appearing due to environmental changes are transmitted to the next generation. So offsprings become different from ancestors. In next generation, process of natural selection repeats, so after many generations, a new species is formed.

CRITICISM OF DARWINISM

- Darwin does not explain the development of vestigial organs.
- This theory has no satisfactory explanation for the cause, origin and inheritance of variations.
- Darwin is unable to explain why in a population only a few individuals develop useful variation and others have harmful variations.
- Darwin was unable to differentiate between somatic and germinal variations.
- This theory was unable to explain over-specialization of some organs like tusk of elephants, antlers of deer.
- The main drawback of Darwinism was lack of the knowledge of heredity.

NEO-DARWINISM

- **Neo-darwinism** is a modified form of Darwinism along with recent researches of Weismann, Mendel, De Vries, Huxley, Gates, Stebbins etc. They performed many experiments to remove the objections against Darwin's theory.
- The **salient features of neo-darwinism** are as follows:-
  - It is the modification of Darwinism in the light of genetic research.
  - It incorporates causes of variation.
  - It considers only genetic inheritable variation (mutation) and raw material for evolution.
  - Unit of evolution is population.
  - Natural selection is referred as differential reproduction, leading to change in the gene frequency.
  - It considers reproductive isolation as an essential factor in speciation.
- According to Neo-darwinism, both mutation and natural selection are responsible for evolution.

Table : Difference between Darwinism and Neo-Darwinism

No.	Darwinism (Natural Selection)	Neo–Darwinism
1	It is the original theory given by Charles Darwin (1859) to explain the origin of new species.	Neo–Darwinism is a modification of the original theory of Darwin to remove its short–comings in light of genetic researches.
2	According to this theory, accumulation of continuous variations causes changes in individuals to form new species.	Instead of continuous variations, mutations and genetic variations are believed to help form new species.
3	It believes in the selection of individuals on the basis of accumulation of variation.	Variations accumulate in the gene pool and not in the individuals.
4	Darwinism does not believe in isolation.	Neo–Darwinism incorporates reproductive isolation as an essential component of evolution.
5	It can explain the origin of new characters.	The theory can explain the occurrence of unchanged forms over millions of years.
6	Darwinism cannot explain the persistence of certain forms in the unchanged condition.	Normally only those modifications are transferred to next generation which influence germ cells or where somatic cells give rise to germ cells.

MUTATION THEORY

- The mutation theory was put forward in 1901 by **Hugo de Vries**.
- The plant on which de Vries had experimented was Oenothera Lamarckiana.
- Role of mutations in evolution is genetic variations.
- Mutations are discontinuous variations called **sports** by **Darwin** and **saltatory variation** by **Bateson.**
- **Features of mutation theory are-**
  - It forms the raw material for mutation.

- It appears suddenly and produces effect immediately.
- Mutations are markedly different from the parents and there are no intermediate stages between the two.
- Mutations can appear in all directions.
- All mutations have a genetic basis and are therefore, inheritable.
- A single mutation may produce a new species.

SYNTHETIC THEORY

- **Dobzhansky (1937)** in his book 'Genetics and the Origin of Species' provided the initial basis of synthetic theory.
- 'Modern synthetic theory of evolution' was designated by **Huxley in 1942.**
- Some of the important workers who have contributed to the modern synthetic theory are : Th. Dobzhansky, R.A. Fisher, J.B.S. Haldane, Sewall Wright, Ernst Mayr and G.L. Stebbins.
- According to synthetic theory, there are **five basic factors involved in the process of organic evolution.** These are :
  - Gene mutations
  - Changes in the chromosome structure and number
  - Genetic recombinations
  - Natural selection
  - Reproductive isolation.
  - The first three factors (a, b, c) are responsible for providing genetic variability; the last two (d, e) are responsible for giving direction to the evolution process.
- The most accepted and recent theory of organic evolution is the synthetic theory.

GENETIC VARIATION

- Genetic variations are inheritable variations and form the raw material of evolution.
- **Causes of genetic variation** are environmental factors and genetic factors (migration, non-random mating, genetic drift, mutation, gene recombination and hybridization).
- The removal of alleles from one population or addition of alleles into another population is called **gene flow** or **gene migration.**
- **Non random mating** results in a deviation from the Hardy Weinberg distribution.
- **Hardy-Weinberg equilibrium** was proposed by G.H. Hardy, an English mathematician, and Wilhelm Weinberg, a German physician, in 1908. They established a simple mathematical relationship to the study of gene frequencies. Mutations introduce new genes into a species resulting in a change in gene frequencies.
- The conditions **necessary for gene frequencies** to remain constant are :
  - Mating must be completely random.
  - Mutations must not occur.
  - Migrations of individual organisms into and out of the population must not occur.
  - The population must be very large.
  - All genes must have an equal chance of being passed to the next generation.
  - According to Hardy-Weinberg concept, the gene frequencies will remain constant if all the above five conditions are met.
- The distribution of genotypes could be described by the relationship $A^2 + 2Aa + a^2 = 1$

where A^2 represents the frequency of the homozygous dominant genotype, 2Aa represents the frequency of the heterozygous genotype and a^2 represents the frequency of the homozygous recessive genotype.

- Changing gene frequencies would indicate that evolution is in progress.
- **Genetic drift :** The theory of genetic drift was developed by **Sewell Wright in 1930.** It is the elimination or addition of the genes of certain characters when some animals in a population migrate or die or immigrate. It changes the gene frequency of the remaining population. Genetic drift **operates only in a small population**. Changes in the frequency of genes in a gene pool is called **genetic drift.**
- Genetic drift in a new colony is called founder effect because only a few founders carrying a small fraction of genetic variability of the parent population begin the colony.
- **Bottleneck effect :** Death of several members of a population due to natural calamities (earthquake, storm, flood) also leads to genetic drift. The original size of population is then restored by mating among the survivors. The new population may lack the genes of certain traits. This may produce a new species after some time. The loss of a section of population by death and after sometime a new species is formed. This effect is known as **bottleneck effect.**
- **Gene recombination** is the process of bringing together new combinations of existing genes and alleles.
- **Hybridization** is a method of mixing the genes of two populations. It changes the gene frequencies and alters the phenotype of the offspring.
- **Natural Selection :** If differential reproduction (some individuals produce more, some only a few and still others none) is continuous for many generations, genes of the individuals which produce more offspring will become predominant in the gene pool of the population. Thus, natural selection occurs through differential reproduction in successive generations.
- Biologists recognize three major categories of natural selection based on its effect on the population over time
  - Stabilizing selection
  - Directional selection
  - Disruptive selection
- **Stabilising selection** favours individuals possessing an average value for a trait and are selected against individuals with extreme values.
- **Directional selection** tends to favour phenotypes at one extreme of the range of variation.
- **Disruptive selection** favours individuals at both extremes of variation. Selection is against the middle of curve.

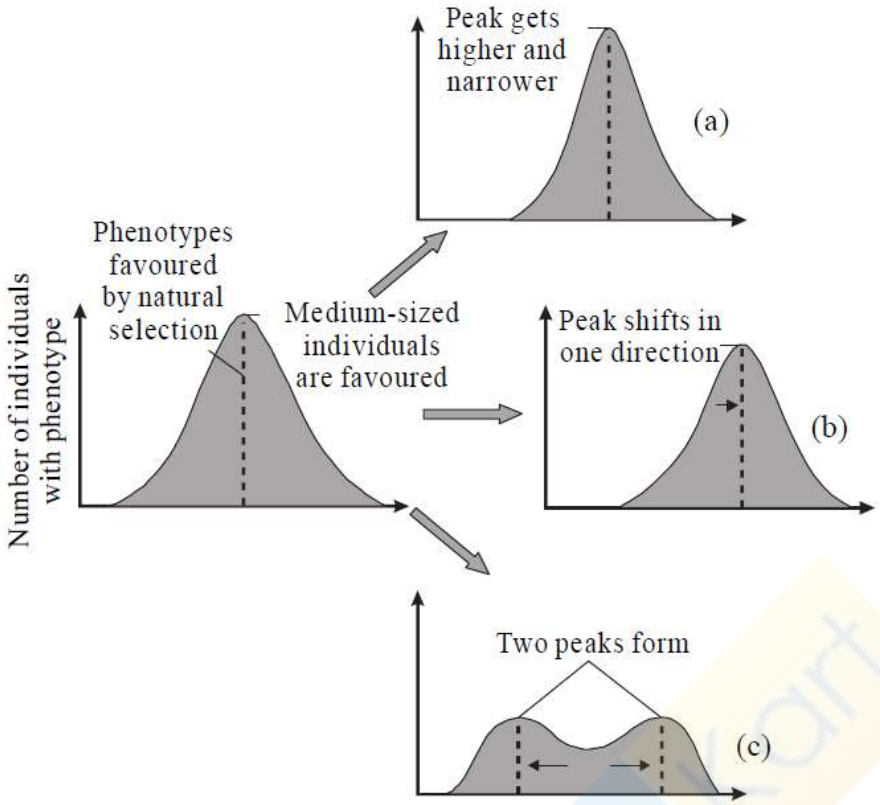


Fig. : Diagrammatic representation of the operation of natural selection on different traits : (a) Stabilising (b) Directional and (c) Disruptive

- **Examples of Natural Selection**

○ **Industrial Melanism:** This phenomenon was studied by Barnard Kettlewell.

Before the industrial revolution, the dull grey form of (peppered moth)-Biston betularia - was dominant; the Carbonaria form (Black) was rare because it was susceptible to predation by birds. The reason was that it was conspicuously visible while resting on tree trunks.

The industrial revolution resulted in large scale smoke which got deposited on tree trunks turning them black. Now grey varieties became susceptible-the black forms flourished. Replacement of coal by oil and electricity reduced production of black moth so the frequency of grey moths increased again.

○ **Drug resistance :** The drugs which eliminate pathogens become ineffective in the course of time because those individuals of pathogenic species which can tolerate them, survive and flourish to produce tolerant population.

○ **Sickle cell anaemia and malaria :** Individuals homozygous for sickle cell anaemia die at an early age. In heterozygous individuals, the cells containing abnormal haemoglobin become sickle shaped. In fact, when an RBC becomes sickle-shaped, it kills malarial parasite effectively so that these individuals are able to cope with malaria infection much better than normal persons. The process of natural selection thus maintains the abnormal form of haemoglobin along with the normal form in a region where malaria is common.

○ **Malaria and G-6-PD deficiency :** Glucose- 6-Phosphate dehydrogenase deficiency is a common abnormality in Negroids. Haemoglobin gets denatured and is deposited on cell membrane. The disease is called favism. In these RBCs, the malarial parasite cannot complete its life cycle. Such persons are protected from malaria.

- **Reproductive isolation** is the prevention of interbreeding between the populations of two different or closely related species. It maintains the characters of the species but can lead to the origin of new species.

- The mechanism of reproductive isolation is explained by **Stebbins** in his book 'Process of Organic Evolution'.
- **Two main sub-types of reproductive isolation are :-**
  - **Premating or prezygotic isolation :** It prevents mating or formation of zygote. It is of the following types-
    - **Ecological isolation :**Two species live in different habitats and do not meet. (One may be living in freshwater and the other in the sea).
    - **Temporal isolation:** Breeding seasons or flowering time may be different in the two species. It occurs only in plants.
    - **Behavioural isolation:** The males of one animal species are unable to recognise the females of another species as potential mates. Like, frog and toad are two related species but at the time of reproduction, sound produced will attract the same species.
    - **Mechanical isolation:** The structural differences in genitalia of individuals belonging to different animal species interfere with mating.
    - **Gametic isolation:** The sperms and ova of different species of animals are unable to fuse. In plants, the pollen coming from a different species may be rejected by the stigma.
  - **Postzygotic mechanisms:** A hybrid zygote is formed but it may not develop into a viable fertile adult. It is of following types-
    - **Hybrid inviability :** Hybrid zygotes fail to develop. In plants, embryos arising from interspecific crosses abort.
    - **Hybrid sterility :** Hybrid adults do not produce functional gametes. (Mules and hinny are common examples in mammals. Several hybrid ornamental plants are sterile.)

Exception

- African lioness + Asian tiger = Tigon

(Panthera leo) (Panthera tigris)

- Male lion + Female tiger = Liger
- Mallard duck + Pintail duck
- Polar bear + Alaskan brown bear
- Platy fish + Swordtail fish

Offsprings obtained from all these hybridizations are fertile but these species do not interbreed naturally.

- **Hybrid breakdown :** Sometimes interspecific mating produce a hybrid, which give rise to the next hybrid by back cross but they have reduced vigour or fertility or both.

GEOLOGICAL TIME SCALE

- In geological time scale the biggest and the smallest time units are ‘Eras’ and ‘Epochs’.
- The geological time scale has been divided into 5-eras, Archaeozoic (most ancient), Proterozoic, Palaeozoic, Mesozoic and Coenozoic.
- Archaeozoic and proterozoic eras, also known as ‘Pre-Cambrian era’, covered about 4 billion years. Palaeozoic era consisted of 300 million years. The Mesozoic and Coenozoic era covered 180 million years and 65 million years respectively.

EVENTS OF PRECAMBRIAN ERA

Event	Time (billion years ago)
1st Metazoan (Multi-cellular organism)	0.7
↑	
1st Eukaryote appeared	2.0
↑	
Appearance of Oxidizing atmosphere	2.75
↑	
Oldest fossil recorded (Blue-Green algae)	3.5
↑	
Origin of earth	4.5

ERA/Duration	PERIOD	EPOCH	ANIMAL LIFE	PLANT LIFE
PRE-CAMBRIAN (4 B.Yrs)			Prokaryotes and Eukaryotes evolved. Various groups of Marine invertebrates appeared.	Marine algae developed
2nd GREAT REVOLUTIO N				
P A L A	Cambrian		Giant arthropods (trilobites), giant molluscs (Brachiopods) & cephalopods abundant. 1st chordate (protochordate) appeared.	Marine algae
	Ordovician		1st vertebrate group (Ostracoderm s – jaw less fishes) appeared. All marine forms.	Marine algae
	Silurian		Fishes diversified and Jawed fishes developed. Migration of aquatic arthropods (centipedes, scorpions and spiders etc) on land.	Ist plant life on land. (Psillophytes) appeared. (They were ancestors of present day ferns)

E O Z O I C (300 M.Yrs)	Devonian		Fishes abundant (Golden age of **fishes**). Lung fishes appeared for the first time. First amphibian group (Stegocephalia) appeared	Ferns (Pteridophytes and Horse tails (Sphenopsids) appeared & evolved
	Carbonifer ous (Missisipian & Pennsylvanian)		Amphibians diversified. Stem reptiles / Cotylosaures (Seymourians) appeared. The present day tortoises and turtles also appeared Winged insects evolved.	Tree like ferns (Pteridophytes) abundant and their forests formed present day- coal mines, so named Carboniferous period. Seedferns appeared. Bryophytes appeared.
	Permian		Mammals like reptiles (Synapsids) appeared. Trilobites and ostracoderms disappeared.	Origin of conifers (first gymnosperms appeared) Cycads and Ginkgo also appeared. Seed ferns declined.

3rd GREAT REVOLUTION OR APPALACHIAN REVOLUTION				
M* E S O Z O I C (180 M.Yrs)	Triassic		First mammalian group (Prototheria) appeared. Giant reptiles (Dinosaurs) emerged from Thecodonts .	Gymnosperms (both cycads and conifers). Pteridophytes and Bryophytes continued Seed ferns extincted.
	Jurassic		Metatherians appeared. Dinosaurs diversified and abundant (Golden age of dinosaurs#) Birds (like Archaeopteryx) appeared from Thecodonts for the first time. Crocodiles and alligators present.	Gymnosperms abundant (Golden age of Gymnosperms). Angiosperms (Dicots) appeared
	Cr etaceou s		Mass extinction of Dinosaurs (after ~100 million years) Eutherian mammals appeared. Toothed birds (Archaeopteryx) disappeared.	Rise of dicots. Monocots appeared.

4th GREAT (ROCKY MOUNTAIN) REVOLUTION				
C* O E N O Z O I C (65 M.Yrs)	T E R T I A R Y (63.4 M.Yrs)	Palaeocene	Insectivorous mammals developed.	Angiosperms developed and diversified
		Eocene	Appearance of hoofed animals. Eohippus (ancestor of horse) appeared.	,, ,,
		Oligocene	Monkeys and Apes appeared.	,, ,,
		Miocene	Anthropoid apes or man like apes, Dryopithecus appeared. Merichippus horse evolved	,, ,,
		Pliocene	Pre-man developed. Horse ancestor- Pliohippus (1 - Toed) appeared.	,, ,,
	Q U A R T E R N A R	Pleistocene (~1.6 M.Yr)	Human appeared and evolved. Modern man appeared Giant mammals (mastodonts and wooly mammoths) extincted. Modern horse developed.	Grassland/fields appeared. Due to ice age, many species of plants extincted
		Holocene (Psychozoic era) (~0.01 M.Yrs.)	Modern man continued. Agriculture started	Age of herbs. (at the end of Ice Age)

Tyranosaurus - Biggest carnivorous dinosaur

Brontosaurus - Biggest herbivorous dinosaur

Ichthyosaurus - Aquatic dinosaur

Pterosaurus - Flying dinosaur

Coenozoic era is also known as **Golden age of insects, birds and mammals**.

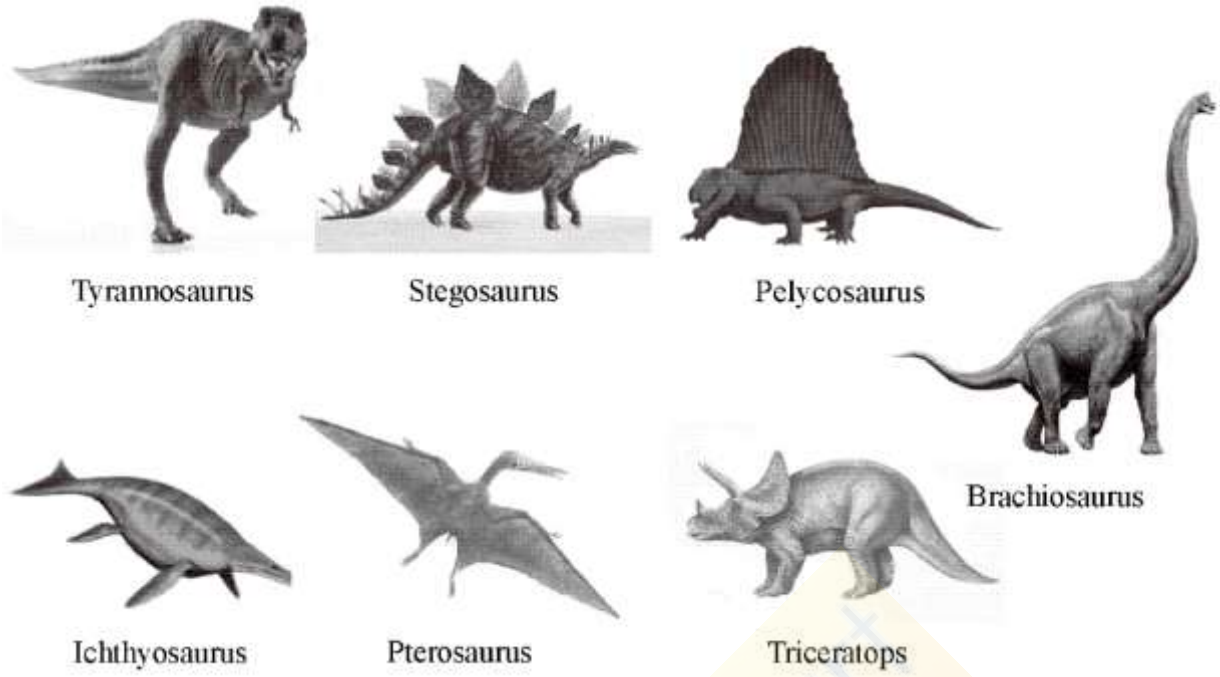
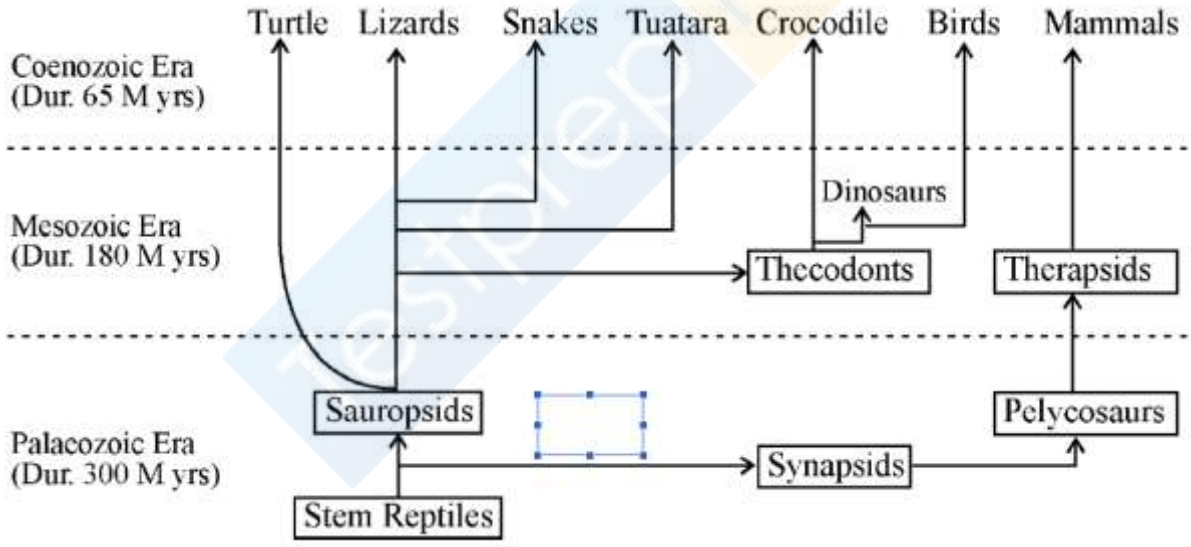


Fig. : Dinosaurs



Evolution of Reptiles, Birds & Mammals

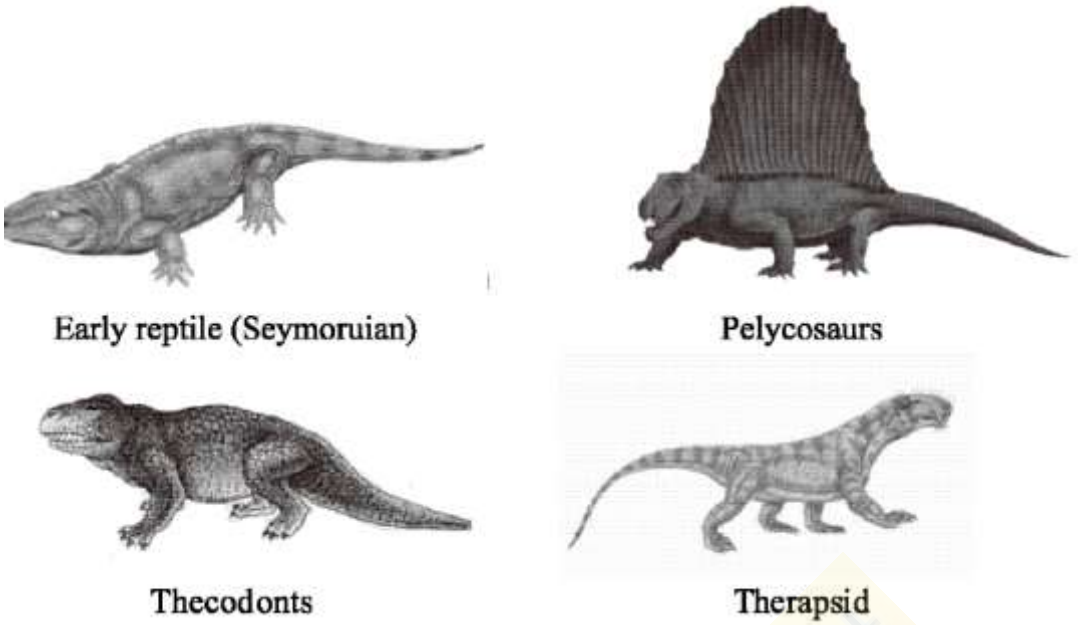


Fig. : Different types of reptiles

HUMAN EVOLUTION

- Evolution of man probably took place in **Central Africa.**
- Human evolution states that humans develop from primates or ape like ancestors.
- **Anthropology** is the study of human evolution and culture. It deals with the fossils of pre-historic and living man.
- The fossils of prehuman and ancestral human forms are obtained from widely diverse regions of Africa, Asia and Europe which indicates that humans' centre of origin was probably in Asia and Africa.
- Prehuman evolution includes origin of mammals and origin of primates.
- Mammals evolved in the Jurassic period about 195 millions ago from the cynodont reptiles which branched off from the stem reptiles called cotylosaurs.
- **Carolus linnaeus** gave the scientific name Homo sapiens to man.
- The primate (originated in the beginning of tertiary period) includes **Prosimians** (Lemurs, tarsiers and related forms) and **Anthropoids** (Monkeys, apes and Human). They are descended from small rodent like or insectivorous mammals that evolved about 80 million years ago.
- **Evolutionary characteristics of man :** The modern man possesses the following special features, which have been acquired during the course of evolution.
  - Bipedal locomotion.
  - Large brain and cranial cavity and intelligence
  - Grasping hands and feet.
  - Attainment of erect posture.
  - Stereoscopic (binocular) vision.
  - Sensitivity
  - Social organisation.
  - Expression by speech.
  - Flattening of face.
  - Shortening of body hair and reduction in their number.
  - Elevation and narrowing of nose.
  - Increase in height.

- Reduction of brow ridges.
- Rounding and enlargement of cranium.
- The bowl like form of pelvic girdle and broad ilia to support the viscera.
- Formation of chin.

- Origin and evolution of man were explained under the following headings.
  - Prior to apeman
  - Ape man including prehistoric man
  - True man including the living modern man.

PRIOR TO APE MAN

PROPLIOPITHECUS

- Origin & evolution in Oligocene epoch in Egypt, so called as Oligocene apes.

Evolution about 30-35 million years ago.

AGYPTOPITHECUS

- Origin and evolution in late Oligocene and Miocene epoch so called as Miocene apes.

DRYOPITHECUS

- Evolution ≈ 15-20 million years ago.
- Regarded as direct ancestor of modern day apes and man.
- They were forest dwellers, spending most of the time on the trees.
- Origin and evolution in Miocene epoch.
- Semi erect posture, quadrapedal locomotion, forelimbs longer than hind limbs.
- Thick growth of hair
- U shaped jaws, teeth larger and sharper
- By nature, vegetarian, fruit eater

PROCONSUL

- Its fossils were discovered by **Leakey** from East Africa near lake Victoria in Kenya from Miocene rocks.

It walked on its four legs (considered as **common ancestor of man and apes**).

SHIVAPITHECUS

- The fossil was discovered from middle and late pliocene rocks of shivalik hills of India, hence named shivapithecus.

RAMAPITHECUS

- It has been established that in Late Miocene epoch Dryopithecus gave rise to Ramapithecus which was on the direct line of human evolution.

- Ramapithecus survived from late miocene to pliocene. Thus, he appeared about 14-15 million years ago.
- Fossils of Ramapithecus was discovered by **Edward Lewis** from pliocene rocks of shivalik hills of India.

APE MAN INCLUDING PREHISTORIC MAN

AUSTRALOPITHECUS (THE FIRST APE MAN)

- **Prof. Raymond Dart** discovered a fossil of skull of (5 - 6) year old baby from the old pliocene rocks of Tuang region (S. Africa). He named it **Tuang baby,** later on he renamed it or A. africanus.
- About 3-2 million years ago, it lived in East African grasslands.
- Evidences show that they hunted with stone. His **cranial capacity** was **350-480** cc.
- It was an ape man because it had many characters of man and apes, so it is also considered as the **connecting link** between apes and man.

HOMO HABILIS

- Homo habilis lived in early pleistocene about 2–1.75 mya.
- His cranial capacity was about 735 cc.
- He was the **first fossil man** who used tools of chipped stones extensively.

HOMO ERECTUS (THE FORERUNNER OF MODERN HUMANS)

- In the middle Pleistocene period, Australopithecines were succeeded by large brained form which were described under the name Pithecanthropus or Java man.
- Its first fossils were obtained by **Dubois (1891)**. These were named Pithecanthropus erectus (erect ape-man).

Similar fossils were found in a cave near Peking, China, and were named Sinanthropus pekinenis.

- **Homo erectus** includes three fossils - **Java ape man, peking man** and **heidelberg man**.

Fig. : Homo erectus skull

- **Java Man (Homo erectus erectus = Pithecanthropus erectus):**
  - Its fossils occurred in the Pleistocene deposits about 500,000 years ago.
  - Its **cranial capacity** was about **940 c.c;** (intermediate between that of Australopithecus (600-700 c.c.) and modern man (1300-1600 c.c.)
  - It was more than five feet tall with skeleton much like ours.

- Its forehead was low and slanting. The face was prognathous, and jaws were massive with huge teeth. The chin was absent and bony eyes are present. He might have learnt the use and construction of tools and knew how to lit fire.
- He was omnivorous, cannibal & had large protruding jaws.
- He was the first prehistoric man to make use of fire for hunting, defence & cooking.

Fig. : Java man skull

- **Peking man (Homo erectus pekinensis = Pithecanthropus pekinensis-Sinanthropus pekinensis) :**

These perhaps lived 500,000-2,00,000 years ago.

- It was very similar to Java man with heavy bony eyebrow ridges, low slanting forehead and chinless face.
- However, their **cranial capacity** was much larger as compared to Java man **ranging from 850-1200 ml. and averaging 1075 c.c.**

Fig. : Peking man skull

- **Heidelberg man :** The jaw is large and heavy and lacks a chin. **Its cranial capacity was 1300 cc.** Teeth are like those of modern man. Heidelberg is regarded as an ancestor to **Neanderthal man and contemporary** to **Homo erectus.**
- Homo erectus were succeeded by early Homo sapiens, which were described under different names Homo neanderthalensis, Homo heildelbergensis, etc. But they are grouped under Homo sapiens.

Fig. : Homo sapiens Skull

- The fossils of primitive man were found in Europe, Asia and Africa. These are Heildelberg man, Neanderthal man, Solo man and Rhodesian man.

TRUE MAN INCLUDING THE LIVING MODERN MAN

NEANDERTHAL MAN

- Their fossils were found in the Neanderthal valley in Germany. Previously, it was named as H. sapiens neanderthalensis. These arose some 1,50,000 years ago and flourished in Europe, Asia and North Africa.

The skull bones were thick, forehead was low and slanting and the eyebrow ridges were heavy. The jaw was deep with no chin.

- The **cranial capacity** was about **1450 c.c.** (almost equal to the modern man). But its lower and posterior portions were larger than the upper and anterior parts.

They were quite intelligent as they, to used and constructed tools. They buried their dead and could perform ceremonies as well as constructed hut-like dwelling structures.

CRO-MAGNON MAN

- Its fossils were first discovered in 1868 from Cro-magnon rocks of france by **Mac Gregor.**
- The **cranial capacity** was about **1650 cc.**
- Cro-magnon man **first started cave painting** as well as hunting with domesticated dogs.
- They were omnivorous and expressed themselves through painting and sculpture.

MODERN MAN (HOMO SAPIENS SAPIENS)

- First appeared about 10000 years ago in Asia near Caspian sea.
- They have cranial capacity of about 1300-1600 cc.
- They have developed sound into words.

Table : Cranial capacities of apes and man

	Primates	Cranial capacities
1	Chimpanzee & Gorilla	325-510 cc.
2	*Australopithecus*	350-450 cc.
3	*Homo habilis*	735 cc.
4	Java apeman	940 cc.
5	Peking man	850-1200 cc.
6	Heidelberg man	1300 cc.
7	Neanderthal man	1450 cc.
8	Cromagnon man	1650 cc.
9	Living modern man	1300-1600 cc.