Chapter-7

EVOLUTION

(NV)

Evolutionary biology : It is the study of history of life forms on earth.

- Stellar distances are measured in light years
- The origin of life is considered a unique event in the history of universe.

Universe

The universe is very old **– almost 20 billion years old**. Huge clusters of galaxies comprise the universe. Galaxies contain stars and clouds of gas and dust. Considering the size of universe, earth is indeed a speck. The **Big Bang** theory attempts to explain to us the origin of universe. It talks of a **singular huge explosion** unimaginable in physical terms.

The **universe expanded** and hence, the temperature came down. **Hydrogen and Helium formed sometime later**. The gases condensed **under gravitation** and formed the galaxies of the present day universe.

Earth

In the **solar system** of the **milky way galaxy**, earth was supposed to have been formed about **4.5 billion years back**. There was no atmosphere on early earth. **Water vapour, methane, carbondioxide and ammonia** released from molten mass covered the surface.

The UV rays from the sun brokeup water into Hydrogen and Oxygen and the lighter H_2 escaped. **Oxygen combined with ammonia and methane to form water, CO2 and others**. The ozone layer was formed. As it cooled, the water vapor fell as rain, to fill all the depressions and **form oceans**.

Origin of life

The origin of life is considered a unique event in the history of universe Life appeared **500 million years** after the formation of earth, i.e., almost **four billion years back**. There are several theories to explain the origin of life. Some of the theory are given below

HSSLIVE.IN

1.Theory of panspermia/ cosmozoic theory

Early Greek thinkers thought units of life called **spores (Cosmozoa)** were transferred to different planets including earth.

2. Spontaneous generation of life/ /theory of abiogenesis

For a long time it was also believed that life **came out of decaying and rotting matter like straw, mud, etc**. This was the theory of spontaneous generation.

Louis Pasteur by careful experimentation demonstrated that life comes only from pre-existing life. He showed that in pre-sterilised flasks (Swann necked flask), life did not come from killed yeast while in another flask open to air, new living organisms arose from 'killed yeast'. Spontaneous generation theory was dismissed once and for all. However, this did not answer how the first life form came on earth.

3. Theory of biogenesis

According to theory living organisms are formed from pre existing life.

4. Theroy of special creation

Religious literature tells us about the theory of special creation. This theory has three connotations.

i) All living organisms(species or types) that we see today were created as such.
ii) The diversity was always the same since creation and will be the same in future
iii) The earth is about **4000 years old**

5. Chemical evolution/Organic evolution

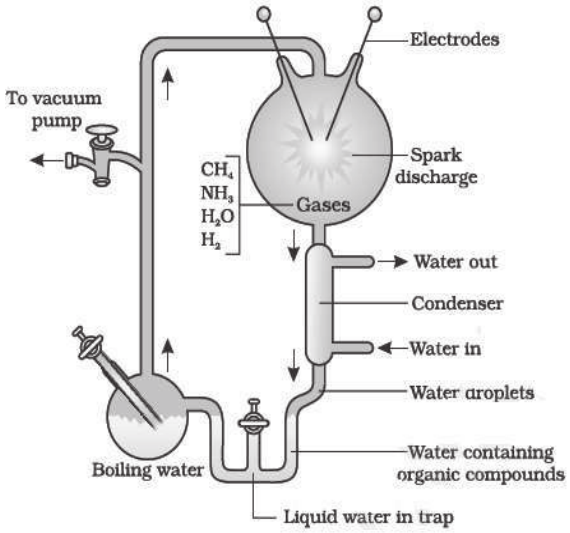
Oparin of Russia and Haldane of England proposed Chemical evolution. According to this theory the first form of life could have come from **pre-existing non-living organic molecules (e.g. RNA, protein, etc.)** and that formation of life was **preceded by chemical evolution**, i.e., formation of **diverse organic molecules from inorganic constituents**. **The conditions on primitive earth were – high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, etc.**

Experimental proof of chemical evolution

In 1953, S.L. Miller, an American scientist created similar conditions in a laboratory scale similar to that of primitive earth. **He created electric discharge in a closed flask (Sparkle discharge apparatus) containing CH_4, H_2, NH_3 (2:2:1) and water**

vapour at 800^{0}C. He observed formation of **amino acids**. In similar experiments others observed, formation of **sugars, nitrogen bases, pigment and fats**.

- Amino acids, sugar, glycerol, and fatty acids gave rise to polymers., which may have assembled into spherical structures called **Protobiont.**Protobiont made of polypeptide are called **microsphere** (term coined by Sideny Fox), those of lipids are called **Liposomes**.Those of combination of polypeptide, nucleic acids, polysaccharide are called coacervative (Term coined by Oparin)
- The coacervative started to absorb organic substance of ocean and became **anerobes**
- **Analysis of meteorite content also revealed similar compounds indicating that similar processes are occurring elsewhere in space.** With this limited evidence, chemical evolution was more or less accepted.
- The **first non-cellular forms** of life could have originated **3 billion years** back. It would have been giant molecules (RNA, Protein, Polysaccharides, etc.). These capsules reproduced their molecules perhaps.
- The first cellular form of life did not possibly originate till about **2000 million years ago**. These were probably single-cells. All life forms were in water environment only. This version of a biogenesis, i.e., the first form of life arose slowly through evolutionary forces from non-living molecules is accepted by majority.



Diagrammatic representation of Miller's experiment

Evidences of evolution.

1. paleontological evidence

Study of fossils is called **paleontology**. Fossils are the petrified remains of organism that lived in the past. organisms . They represent extinct organisms (e.g., Dinosaurs).

Significance of fossil study

i. It help to study the form and structure of extinct animal
ii. It help to study the habit and behavious of extinct organisms
iii. A study of fossils in different sedimentary layers indicates the geological period in which they existed
iv. It help to study the evolutionary history (Phylogeny) of certain animals like horse, elephant,man etc
Eg:Eohippus->Mesohippus-> Merychippus-> Equus
v. The presence of intermediate forms in fossil records indicate the connecting link between two group of organisms. Eg; Archaeopterix shows the feature of both reptiles and birds. Hence it is called as Reptile bird. Archaeopterix had a beak like the birds but the beak had teeth like reptiles
   - Its forelimbs is modified into wings like birds. But the wings possess 3 free digits bearing claws like reptiles

navas9895@gmail.com

HSSLIVE.IN

- Wings are made of feathers like birds, But scales are also present like reptile
- It has feathery tail like the birds and had tail vertebra

❖ ***The age of the fossils are calculated by radioactive dating***

2. Comparative anatomy and morphology

Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago. Such similarities can be interpreted to understand **whether common ancestors were shared or not.**

a)Homologous organs

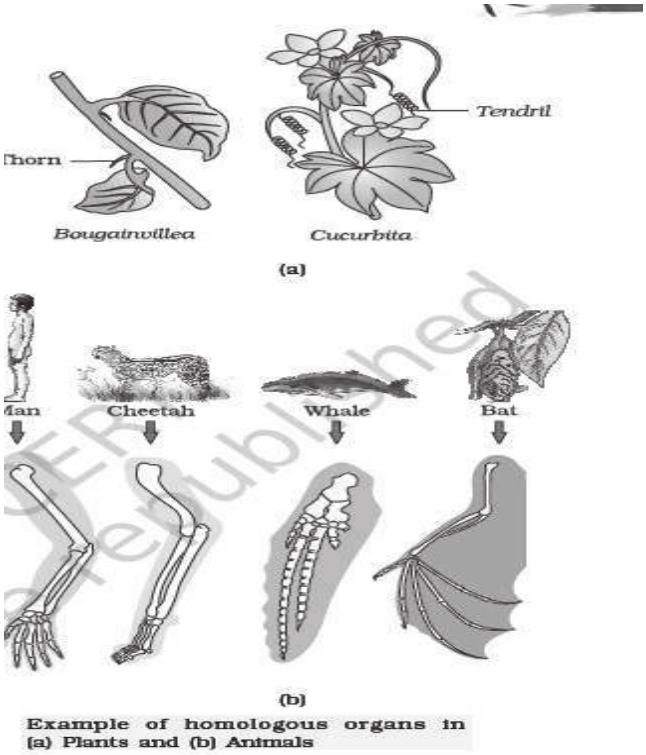
Homologus organs are organs having **same structure** and origin **but different functions**. This phenomenon is called **homology**. such organs are developed due to **divergent evolution**.

Eg:1) whales, bats, Cheetah and human (all mammals) share similarities in the pattern of bones of forelimbs

Though these forelimbs perform different functions in these animals, they have similar anatomical structure – all of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs. Hence, in these animals, the same structure developed along different directions **due to adaptations to different needs**. This is **divergent evolution** and these structures are **homologous**

Eg;2) the thorn and tendrils of *Bougainvillea* and *Cucurbita* represent homology

Eg;3) vertebrate hearts or brains



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

b) Analogous organ

Organs having **same function** but different structure and origin. This phenomenon is called Analogy. Such organs are developed due to **Convergent evolution**.

Eg;1) Wings of butterfly and of birds look alike. They are not anatomically similar structures though they perform similar functions. – here different structures evolving for the same function and hence having similarity

Eg;2) the eye of the octopus and of mammals

Eg;3) the flippers of Penguins and Dolphins.

Eg;4) Sweet potato (root modification) and potato (stem modification)

- So one can say that it is **the similar habitat** that has resulted in selection of similar adaptive features in **different groups** of organisms but toward the same function. It results in the formation of Convergent evolution

3. Biochemical evidence

Similarities in proteins and genes performing a given function among diverse organisms give clues to common ancestry.

4. Molecular evidence

Similarity of organism at the molecular level indicate phylogenetic (Evolutionary history) relationship. Human DNA differs in only 1.8% of its bp from chimpanzee DNA and

HSSLIVE.IN

there is no difference between two in the amino acid sequence for protein cytochrome C. Similarly molecular structure of **actin and tubulin** protein in all animal point their common ancestory.

A common **genetic code** is overhelming evidence that all organisms are related

5.Embryological evidence

It is proposed by **Earnst Heckel**. According to his observation certain features are common to all vertebrates during their embryological stage. It is absent in their adult (Ontogeny repeats phylogeny/ re capitulation theory)

Eg: appearance of **vestigial gill slit** behind the head during embryological development in all vertebrates. But it is functional only in fishes

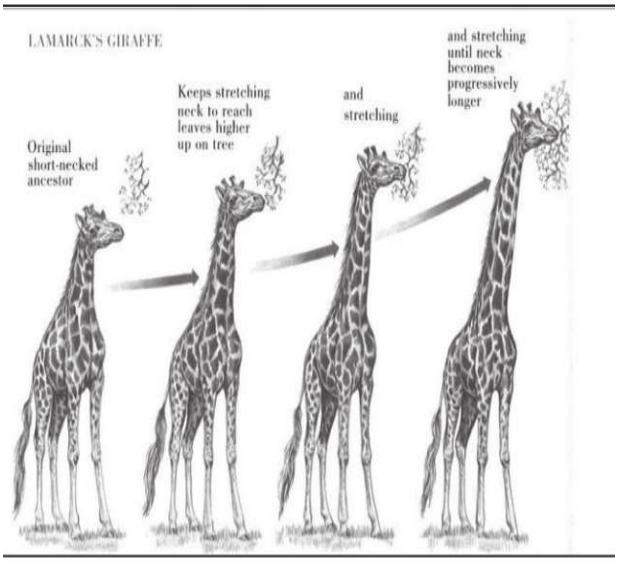
This observation was disproved by Von Baer. He noted that embryos never pass through the adult stage of other animal.

Horticulutre :The art or practice of garden cultivation and management

Jean Baptiste de Lamarck

He was a **French Naturalist**. **Even before Darwin,** he proposed that evolution of life forms had occurred but driven **by use and disuse of organs.**

He gave the examples of **Giraffes** who in an attempt to **forage leaves** on tall trees had to adapt by elongation of their necks. As they passed on this acquired character of elongated neck to succeeding generations, Giraffes, slowly, over the years, came to acquire long necks. This theory was disproved by **August Weisman**



- ✓ **Lamarck's theory is called Theory of inheritance of acquired characters .He published this theory in his famous book Philosophie zoologique.**

Charles Darwin

Theory of **special creation** were strongly challenged during the **nineteenth century.** Based on observations made during a sea voyage in a sail ship called **H.M.S. Beagle round the world**, concluded that existing living forms share similarities to varying degrees not only among themselves but also with life forms that existed millions of years ago. Many such life forms do not exist any more. There had been extinctions of different life forms in the years gone by just as new forms of life arose at different periods of history of earth. There has been gradual evolution of life forms. Any population has built in variation in characteristics. Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors, etc.) would outbreed others that are less-endowed to survive under such natural conditions. Another word used is **fitness of the individual or population**. The fitness, according to Darwin, refers ultimately and only to reproductive fitness. Hence, those who are better fit in an environment, leave more progeny than others. These, therefore, will survive more and hence are selected by nature. He called it **natural selection** and implied it as a mechanism of evolution.

navas9895@gmail.com

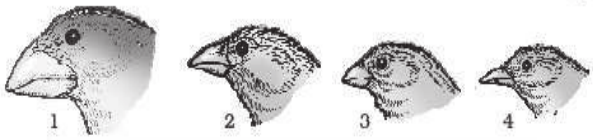
HSSLIVE.IN

- The work of **Thomas Malthus (His book name : Principles of populations)** on populations influenced Darwin
- **Alfred Wallace**, a naturalist who worked in Malay Archipelago had also come to similar conclusions around the same time

Adaptive radiation/ Divergent evolution

The process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography (habitats) is called **adaptive radiation**.

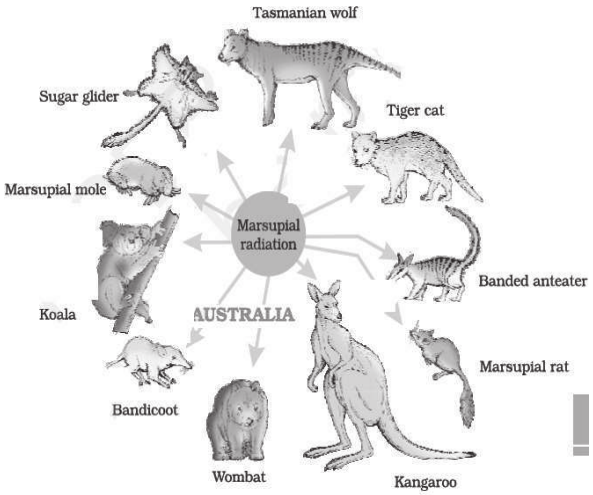
Eg:1) : Galapogos finches :during his journey Darwin went to Galapagos Islands. There he observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him. He realised that there were many varieties of finches in the same island. All the varieties, he conjectured, evolved on the island itself. From the **original seed-eating** features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches.



Variety of beaks of finches that Darwin found in Galapagos Island

Eg:2) Australian marsupials. A number of marsupials, each different from the other evolved from an ancestral stock, but all within the Australian island continent.

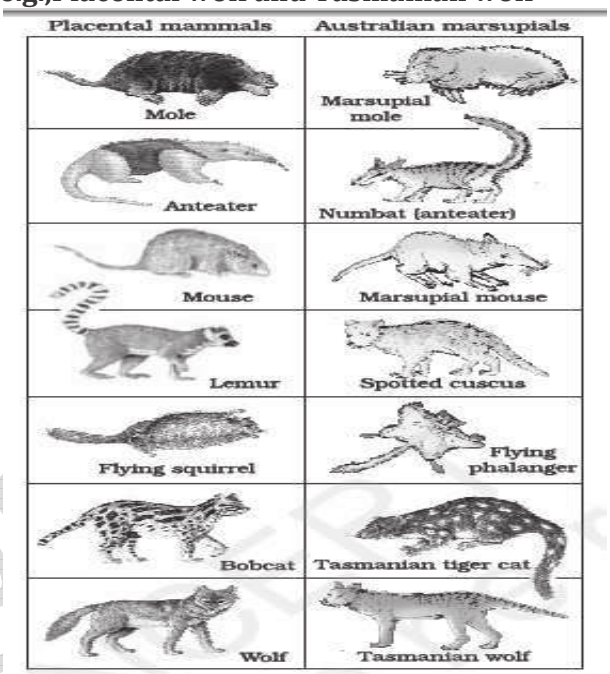
Eg:3) Placental mammals in Australia



Convergent evolution

When more than one adaptive radiation appeared to have occurred in an isolated geographical area (representing different habitats), one can call this convergent evolution

Eg: Placental mammals in Australia appears to be 'similar' to a corresponding marsupial **e.g.,Placental wolf and Tasmanian wolf**



Picture showing convergent evolution of Australian Marsupials and placental mammals

HSSLIVE.IN

Industrial Melanism

Interesting observation supporting evolution by natural selection comes from **England**. In a collection of **moths** made in **1850**s, i.e., before industrialisation set in, it was observed that there were **more white-winged moths on trees than dark-winged** or melanised moths. However, in the collection carried out from the same area, but after industrialisation, i.e., in **1920**, there were more dark-winged moths in the same area, i.e., the proportion was reversed.

The explanation put forth for this observation was that 'predators will spot a moth against a contrasting background'. During post industrialization period, the **tree trunks became dark due to industrial smoke and soots.** Under this condition the white-winged moth did not survive due to predators, dark-winged or melanised moth survived**. Before**

industrialisation set in, thick growth of almost white-coloured lichen covered the trees - in that background the white winged moth survived but the dark-coloured moth were picked out by predators. **the lichens can be used as industrial pollution indicators** They will not grow in areas that are polluted. Hence, moths that were able to camouflage themselves, i.e., hide in the background, survived. This understanding is supported by the fact that in areas where industrialisation did not occur e.g., in rural areas, the count of melanic moths was low. **This showed that in a mixed population, those that can better-adapt, survive and increase in population size**

Evolution by anthropogenic action

The excess use of herbicides, pesticides, etc., has only resulted in selection of resistant varieties in a much lesser time scale. This is also true for microbes against which we employ antibiotics or drugs against eukaryotic organisms/cell.

Hence, resistant organisms/cells are appearing in a time scale of months or years and not centuries. These are examples of evolution by anthropogenic action. This also tells us that evolution is not a directed process in the sense of determinism. It is a stochastic process based **on chance** events in nature and chance mutation in the organisms

- **Branching descent and natural selection are the two key concepts of Darwinian Theory of Evolution**

Types of Natural selection

a)Stabilsing selection/Normalizing selection

Here more individuals acquire mean character value. This occurs when the environment doesnot change. Fossil evidence shows that , many species remain unchanged for long period of geological time. One of the most stable environment on earth is the deep sea.

Eg: Birth weight of human. The heaviest and lightest babies have the highest mortality

b)Directional selection

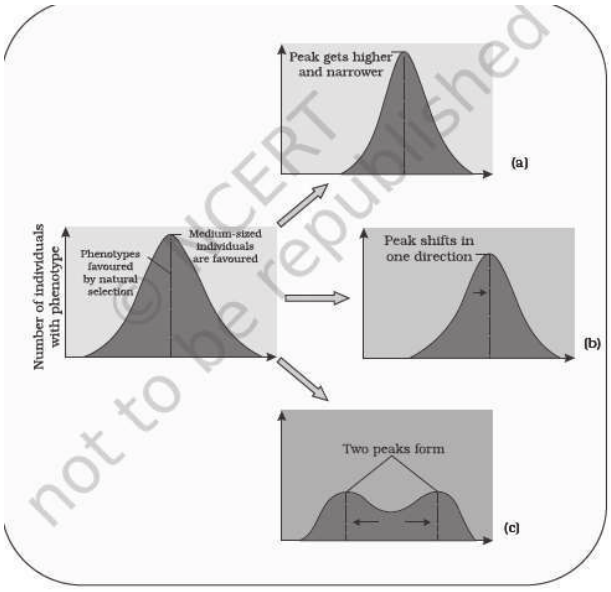
Here more individuals acquire value other than the mean character

Eg:Industrial melansim

c)Disruptive selection

Here more individuals acquire peripheral character value at both ends of the distribution curve

Eg: adaptive radiation



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

Hugo deVries

Darwin **either ignored or kept silence** about the factors Mendel talked about. In the first decade of twentieth century, **Hugo deVries** based on his work on **evening primrose** brought forth the idea of mutations – large difference arising **suddenly** in a population.

He believed that it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about. Mutations are random and directionless while Darwinian variations are small and directional. Evolution for Darwin was gradual while deVries believed mutation caused speciation and hence called it **saltation (single step large mutation**). Studies in population genetics, later, brought out some clarity on this.

HARDY-WEINBERG PRINCIPLE

Proposed by G.H Hardy and Wilhelm Weinerg. This principle says that allele frequencies in a population are stable and is constant from generation to generation. **The gene pool (total genes and their alleles in a population) remains a constant**. This is called genetic equilibrium.

Sum total of all the allelic frequencies is 1.

© NCERT not to be republished

navas9895@gmail.com

HSSLIVE.IN

Disturbance in genetic equilibrium, or Hardy-Weinberg equilibrium, i.e., change of frequency of alleles in a population would then be interpreted as resulting in evolution

$(p + q)^2 = p^2 + 2pq + q^2 = 1$

Where:

p = the frequency of allele A
q = the frequency of allele a
p^2 = the frequency of individual AA
q^2 = the frequency of individual aa
2pq = the frequency of individual Aa

Five factors are known to affect Hardy Weinberg equilibrium. These are

i) Gene migration or gene flow,
ii) Genetic drift,
iii) Mutation,
iv) Genetic recombination and
v) Natural selection.

- ✓ When migration of a section of population to another place and population occurs, gene frequencies change in the original as well as in the new population. New genes/alleles are added to the new population and these are lost from the old population. There would be a gene flow if this gene migration, happens multiple times.
- ✓ Change in gene frequency occurs by **chance**, it is called genetic drift.

(c) Sixteen percent of the population of Europe is Rhesus negative. Use the Hardy-Weinberg equation to calculate the percentage of this population that you would expect to be heterozygous for the Rhesus gene. Show your working. (2)

$$q^2 = \frac{16}{100}$$

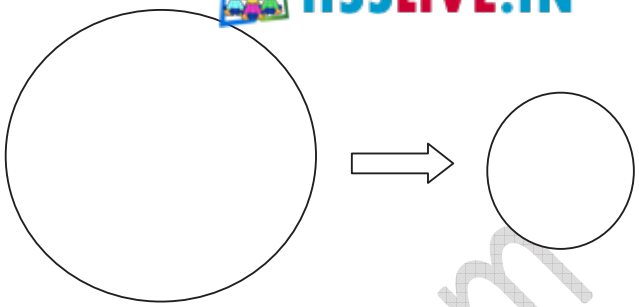
$$q = \sqrt{0.16} = 0.4$$

$$p = 1 - 0.4 = 0.6$$

$$2pq = \text{heterozygotes} = 2 \times 0.6 \times 0.4 = 48\ \%$$

- ✓ The **founder effect** is change in allele frequency that occurs when a new population is established by a very small number of individuals from a larger population. Here the change in allele frequency is so different in the new sample of population that they become a different species. The original drifted population becomes founders and the effect is called **founder effect**.

HSSLIVE.IN



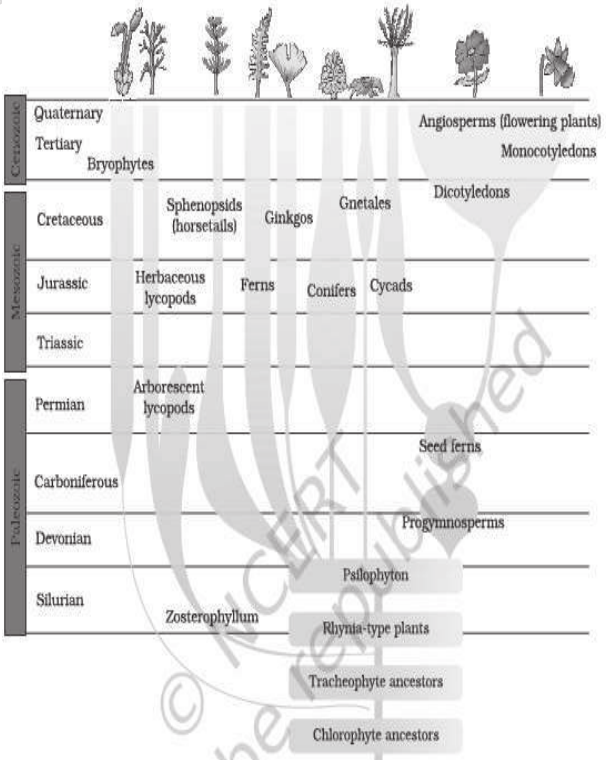
A brief account of evolution

- ✓ About **2000 million years ago** (mya) the first cellular forms of life appeared on earth
- ✓ Some of these cells had the ability to release O2.
- ✓ The reaction periods could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelised by appropriate light harvesting pigments.
- ✓ Slowly single-celled organisms became multi-cellular life forms.
- ✓ By the time of **500 mya**, **invertebrates** were formed and active.
- ✓ **Jawless fish** probably evolved around **350 mya.**
- ✓ **Sea weeds and few plants** existed probably around **320 mya**.
- ✓ the first organisms that invaded land were plants. They were widespread on land when animals invaded land.
- ✓ Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. In 1938, a fish caught in South Africa happened to be a **Coelacanth** which was thought to be extinct. These animals called **lobefins** evolved into the first amphibians that lived on both land and water. These were ancestors of modern day frogs and salamanders.
- ✓ The amphibians evolved into reptiles. **They lay thickshelled eggs which do not dry up in sun unlike those of amphibians.**
- ✓ In the next **200 millions** years or so, reptiles of different shapes and sizes dominated on earth. **Giant ferns (pteridophytes)** were present but they all fell to form **coal deposits slowly.**

- ✓ Some of these land reptiles went back into water to evolve into **fish like reptiles** probably **200 mya** (**e.g. *Ichthyosaurs***).
- ✓ The land reptiles were, of course, the dinosaurs. **The biggest of them, i.e., *Tyrannosaurus rex* was about 20 feet in height and had huge fearsome dagger like teeth**.
- ✓ About **65 mya**, the dinosaurs suddenly disappeared from the earth. We do not know the true reason. **Some say climatic changes killed them. Some say most of them evolved into birds**. Small sized reptiles of that era still exist today.
- ✓ The first mammals were like **shrews**. Their fossils are small sized. Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least.
- ✓ **When reptiles came down mammals took over this earth**.
- ✓ There were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna. Due to the same continental drift pouched mammals of Australia survived because of lack of competition from any other mammal.
- ✓ some mammals live wholly in water. **Whales, dolphins, seals and sea cows** are some examples.
- ✓ The most successful story is the evolution of man with language skills and self-consciousness.

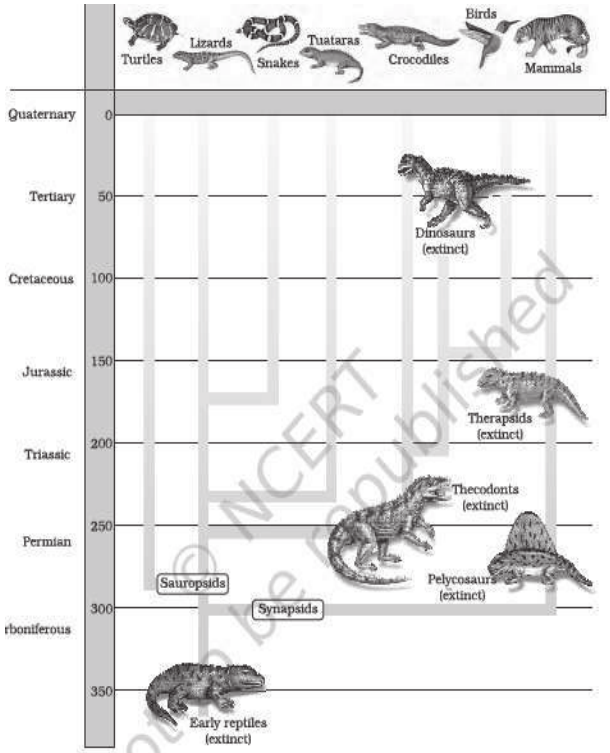
ORIGIN AND EVOLUTION OF MAN

- ✓ About **15 mya**, primates called ***Dryopithecus and Ramapithecus*** were existing. They were hairy and walked like gorillas and chimpanzees. *Ramapithecus* was more man-like while *Dryopithecus* was more ape-like.
- ✓ Few fossils of man-like bones have *been* discovered in **Ethiopia and Tanzania** . These revealed hominid features leading to the belief that about 3-4 mya, man-like primates walked in eastern Africa. They were probably not taller than 4 feet but walked up right.
- ✓ **Two mya, *Australopithecines*** probably lived in East African grasslands. Evidence shows they **hunted with stone weapons but essentially ate fruit**. Some of the bones among the bones discovered were different. This creature was called the first human-like being the hominid and was called ***Homo habilis*.** The brain capacities were between **650-800cc**. They probably **did not eat meat.**
- ✓ Fossils discovered in **Java in 1891** revealed the next stage, i.e., *Homo erectus* about **1.5 mya.** *Homo erectus* had a large brain around **900cc.** *Homo erectus* probably **ate meat**.
- ✓ The **Neanderthal man** with a brain size of **1400cc lived** in near east and central Asia between 1,00,000- 40,000 years back. **They used hides to protect their body and buried their dead**.
- ✓ ***Homo sapiens* arose in Africa** and moved across continents and developed into distinct races.
- ✓ **During ice age between 75,000-10,000 years ago modern *Homo sapiens* arose.**
- ✓ Pre-historic cave art developed about 18,000 years ago. Agriculture came around 10,000 years back and human settlements started.

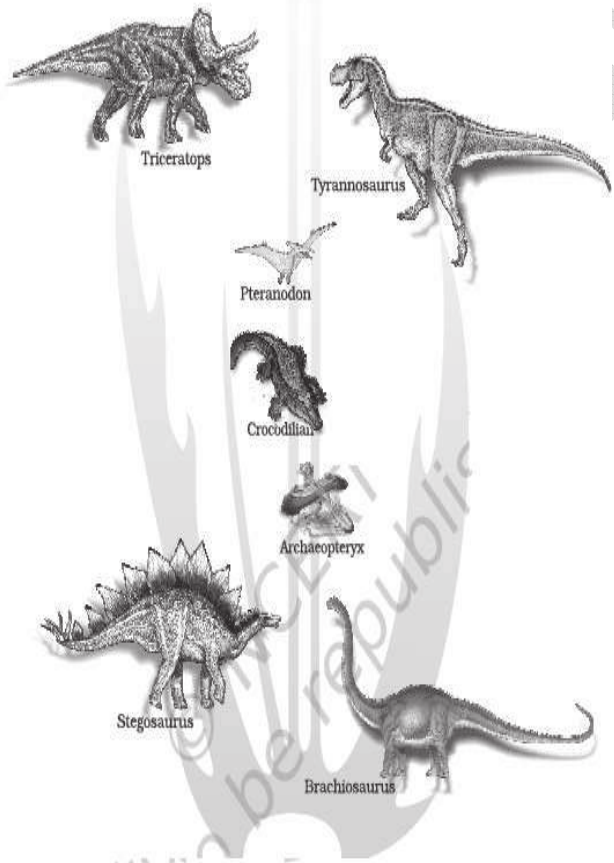


A sketch of the evolution of plant forms through geological periods

navas9895@gmail.com © NCERT not to be republished



Representative evolutionary history of vertebrates through geological periods



A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds

HSSLIVE.IN