CHAPTER- 7: EVOLUTION

Evolutionary Biology: the study of history of life forms on earth.
Evolution: the process by which different kinds of living organisms are believed to have developed from earlier forms during the history of the earth.

ORIGIN OF UNIVERSE:

- The universe is around 20 billion years old and comprise of huge clusters of galaxies.
- Galaxies contain stars and clouds of gas and dust.
- **The Big Bang theory:** According to it, a huge explosion occurred, the universe expanded hence the temperature came down and Hydrogen and Helium were formed sometime later. The galaxies of the present day universe were then formed due to condensation of the gases under gravitation.

ORIGIN OF EARTH:

- The earth was supposed to have been formed about 4.5 billion years back in the solar system of the Milky Way galaxy.
- Initially, there was no atmosphere and the surface of the earth was covered with water vapour, Methane (CH_4), Carbon dioxide (CO_2) and ammonia (NH_3) released from molten mass.
- The UV rays from the sun broke up water into Hydrogen and oxygen.
- The lighter H_2 escaped and O_2 combined with NH_3 and CH_4 to form water, CO_2 and others and the ozone layer was also formed.
- As it cooled, the water vapour fell as rain to fill all the depression and form oceans.

THEORIES OF ORIGIN OF LIFE: Life appeared 500 million years after the formation of earth i.e almost 4billion years back.

- Different theories were given to explain the origin of life.
  I. **Theory of special creation:** God created life by his divine act of creation.
  II. **Theory of panspermia/cosmozoic theory:** According to early Greek thinkers, units of life called spores or panspermia were transferred to different planets including earth.
  III. **Theory of spontaneous generation:** It was believed that life came out of decaying and rotting matter like straw, mud etc.

- However, Louis Pasteur demonstrated that life comes only from pre-existing life and the spontaneous generation theory was dismissed.
- He showed that in pre-sterilised flasks, life did not come from killed yeast while in another flask open to air, new living organisms arose from 'killed yeast'.

IV). Theory of chemical evolution/ Oparin- Haldane Theory:

- Oparin (Russia) and Haldane (England) proposed that life could have originated from pre- existing non- living organic molecules (eg: 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 earth favouring chemical evolution were high temperature, volcanic storms, reducing atmosphere containing CH_4, NH+3 etc.

Experimental Evidence of Chemical Evolution/Miller's experiment

- In 1953, S.L. Miller (America) created similar conditions in laboratory scale.
- To simulate conditions of primitive earth, he created electric discharge in a closed flask containing CH_4, H_2, NH_3 and water vapour at 800^0c.
- He observed formation of amino acids.
- Similarly other Scientists observed formation of sugars, nitrogen bases, pigments and fats.
- Meteorite content analysis also supports chemical evolution indicating similar process occurring elsewhere in space.
- It thus provides experimental evidence for the theory of chemical origin.

Formation of first cell

- The first non- cellular forms of life could have originated 3 billion years back.
- They would have been giant molecules (RNA, Protein, Polysaccharides etc.) which might have reproduced their molecules themselves.
- First cellular form of life originated about 2000 million years ago.
- These were probably single cells all formed in water environment only.
- This version of abiogenesis i.e the first form of life arose slowly through evolutionary forces from non-living molecules is accepted by majority.

EVOLUTION OF LIFE FORMS:

Theory of origin of species by Natural selection:

- During the 19th century, based on observation made during a sea voyage in a sail ship called H.M.S. Beagle round the world, Charles Darwin 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.
- There has been gradual evolution of life forms.
- All population of organisms have variations in characteristics.
- Individuals with characteristics that allow better adaptability survive better in natural conditions (Climate, food, physical factors etc.) and would therefore outbreed others with less favourable characteristics (**Survival of the fittest**).
- It leads to the survival and propagation of the fittest organisms in the population and therefore only the fittest survive and produce more progeny then others.
- The fitness according to Darwin refers ultimately to the ability to survive a change and hence is selected by nature. He called it **natural selection** and implied it as a mechanism of evolution.
- Alfred Wallace (Naturalist, Working in Malay Archipelago) also came to similar conclusions.
- All the existing life forms share similarities and share common ancestors.
- The geological history of earth closely correlated with the biological history of earth.

WHAT ARE THE EVIDENCES FOR EVOLUTION:

Paleontological evidences: Paleontolgly is the study of fossils. Fossils are remains of hard parts of life-forms found in rocks.

- Different aged rock sediments contain fossils of different life- forms that probably died during the formation of the particular sediment.
- They represent the extinct organisms (eg. Dinosaurs).
- A study of fossils in different sedimentary layers indicates the geological period in which they existed.
- The study showed that life forms varied our time and certain life forms are restricted to certain geological period and new forms of life have arisen at different times in the history of earth.

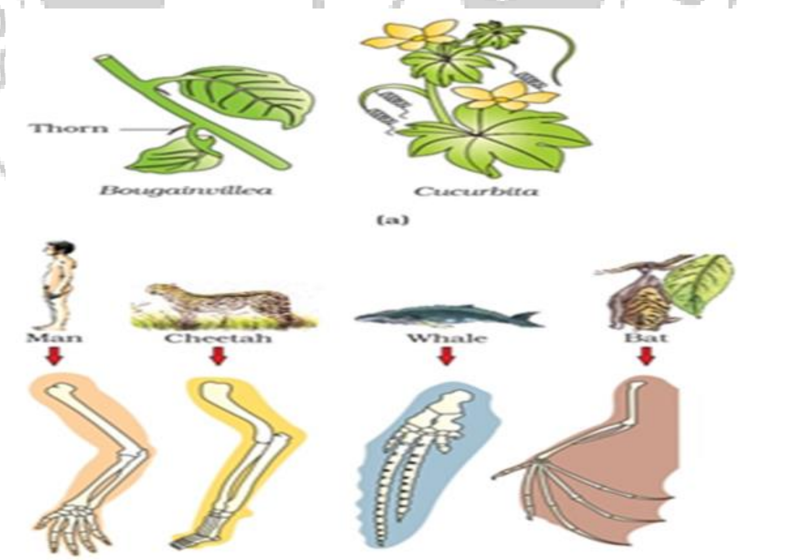
  * [Ages of fossils are calculated by **Radioactive-dating**, which is a method used to date rocks and other objects based on the known decay rate of radioactive isotopes].

Embryological Evidences:

- It was put forward by Ernst Heckel by observing certain features during embryonic stage common to all vertebrates that are absent in adult.
- All vertebrate embryos including human embryos develop a row of vestigial gill slits just behind the head and it is functional organ only in fishes but is absent in other adult vertebrates.
- Karl Ernst Von Baer discarded this proposal and noted that the similarities in embryos never pass through the adult stages of other animals.

Morphological and comparative anatomical evidences:

- The phylogenetic history can be revealed by comparative study of external (morphological) and internal (anatomical) structures.
- **Divergent Evolution:**
  The organs with similar anatomical structures and organ but performing different functions are called **homologous organs.**
- Examples: Forelimbs of whales, bats, cheetah and all mammals have similar anatomical structures i.e. humerus, radius, ulna, carpals, metacarpals and phalanges.
- Hence, in these animals, the same structure developed along different directions due to adaptations to different needs. This is called divergent evolution.
- Homology thus indicates common ancestry.
- Other examples are vertebrates heart or brain in animals, Thorns and tendrils of Bougainvillea and cucurbita in plants (fig 1).



(b)

FIG 1: Examples of homologous organs in (a) plants and (b) animals

CONVERGENT EVOLUTION :

- The organs which are anatomically different but perform similar functions are called **analogous organs.**
- Wings of butterfly and birds,
- Eyes of octopus and mammals,
- Flippers of Penguins and Dolphins,
- Sweet potato (root modification) and potato (stem modification).
- Different structures evolving for the same function and hence having similarity refers to convergent evolution.

Biochemical Evidences :

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

EVOLUTION BY NATURAL SELECTION: Example

Industrial Melanism:

- An observation in a collection of moths in 1850's were made in England before industrialization set in.
- More white-winged moths were observed than dark-winged or melanised moths on trees covered with thick growth of almost white-coloured lichen.
- However, after industrialization, i.e., in 1920, more dark-coloured moths were observed in the same area and the tree trunks became dark due to industrial smoke and soot.

Explanation : Predators will spot a moth against a contrasting background.

- Under this condition, white-winged moths did not survive due to predators.
- Lichens are used as industrial pollution indicators as they will not grow in polluted areas.
- Hence, moths that were able to camouflage themselves survived.
- This showed that in a mixed population, those that can better adapt, survive and increase in population size although no variant is completely wiped out.

EVOLUTION BY ANTHROPOGENIC ACTION :

- Excessive use of herbicides, pesticides etc. resulting in selection of resistant varieties in a much lesser time scale.
- Similarly, employment of antibiotics or drugs in eukaryotic organisms/cells results in drug resistance in microbes.
- Thus, evolution is a stochastic process based on chance events in nature and chance mutation in the organisms.

ADAPTIVE RADIATION :

- 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. Examples;

(i) Darwin's Finches :

- Darwin's theory was based on observation of many varieties of finches (a group of about 26 species of small black birds) in the Galapagos Islands (Fig 2).
- All the varieties 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.

Fig 2: Variety of beaks of finches that Darwin found in Galapagos Island

(ii) Australian Marsupials :

- Within Australian island continent, many different marsupials or pouched animals evolved from an ancestral stock.

(iii) Placental mammals in Australia :

- They seem to be evolved from a marsupial into varieties of such placental mammals each of which showed similarities to the ancestral marsupial. Eg: placental wolf and Tasmanian wolf-marsupial.

BIOLOGICAL EVOLUTION: Theories of evolution

(i) Lamarckism/Theory of inheritance of acquired characters :

- According to Lamarck (French naturalist), evolution of life forms occurred due to use and disuse of organs.
- Eg: long necks of giraffes. This character was acquired in an attempt to forage leaves on tall trees and this acquired character was passed to succeeding generations.
- This theory is no longer accepted.

(ii) Darwin's theory of evolution :

- The essence of Darwinian theory about evolution is Natural Selection.

- (a) Theoretically, population size will grow exponentially if all individuals reproduce maximally.
  (b) But in reality, population sizes are limited indicating that there had been competition for resources.
  (c) Organisms with favourable variations are better adapted to survive in natural environment.
  (d) Those populations which are better fit (reproductively) in the environment will be selected by nature (**natural selection**) and will survive more enabling only those variations to reproduce and leave more progeny (**survival of the fittest).**
  (e) Over many generations there would be a change in population characteristic and hence new forms appear to arise.

  ***Two key concepts of** Darwinian Theory of Evolution are **Branching descent (Adaptive radiation)** and **natural selection**.

Natural selection is based on certain <u>factual observations</u>.

- Limited natural resources.
- Stable population size except for seasonal fluctuations.
- Varying characteristics of members of a population.
- Most of the variations are inherited.

<u>Mutation theory of Hugo de Vries</u>

- This theory was brought forth by Hugo de Vries based on his work on evening primrose.
- According to him, evolution is caused by mutation which is the large difference arising suddenly in a population and not the minor variations (heritable) that Darwin talked about.
- Mutations are random and directionless while Darwinian variations are small and directional.
- Evolution was gradual for Darwin while de Vries believed mutation caused speciation and called it **Saltation** or single step large mutation.

HARDY-WEINBERG PRINCIPLE:

- It is a mathematical equation that can be used to calculate the genetic variation of a population at equilibrium.
- The equation is an expression of the principle known as Hardy – Weinberg equilibrium, which states that the amount of genetic variation in a population will remain constant from one generation to the next in the absence of disturbing factors.

- To explore the Hardy – Weinberg equation, we can examine a simple genetic locus at which there are two alleles, "A" (Dominant) and "a" (Recessive)
- The Hardy – Weinberg equation is expressed as :

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

Where, p= frequency of "A" allele and

q = frequency of "a" allele in the population

- In the equation,

p^2= frequency of the homozygous genotype AA,

q^2= frequency of the homozygous genotype aa, and

2pq= frequency of the heterozygous genotype Aa.

- In other words,the probability that an allele 'A' with a frequency of p to appear on the chromosomes of a diploid individual is defined as the product of the probabilities i.e. p x p = p^2.
- Similarly of allele 'a' is q^2 and of 'Aa' is 2pq.
- Hence $p^2+2pq+q^2=1$ which is a binominal expression of $(p+q)^2$.
- In addition, the sum of the allele frequencies of all the alleles at the locus must be 1, so,

p+q=!

- The Hardy – Weinberg equation can be used to measure whether the observed genotype frequencies in a population differ from the frequencies predicted by the equation.
- In other words, it is a mathematical method of telling if a population is changing i.e. evolving or
- If population frequencies are stable, population is not changing i.e. not evolving.
- This is to say that, a population that is not evolving shows allele and genotypic frequencies that are in Hardy Weinberg Equilibrium.
- If the population is not in Hardy- Weinberg equilibrium, it can be concluded that population that population is evolving.

Five factors are known to affect Hardy- Weinberg equilibrium.

1. **Gene migration/gene flow**
   - When migration of a section of population to another place occurs, gene frequencies for both the population changes with new genes/alleles added to new population and lost from the old.
   - **Gene flow**- When gene migration happens multiple times gene flow occurs.

2. **Genetic drift:** If the change in gene frequencies occur by chance, it is called genetic drift.

- **<u>Founder effect</u>:** Sometimes the change in allele frequency is so different in the new sample of population that they become a different species.
- This effect is called <u>founder effect</u> and the original drifted population a different is called <u>Founder</u>.

3. **<u>Mutation</u>:** Advantageous mutations lead to new phenotypes and over few generations result in speciation or formation of species.
4. **<u>Genetic recombination</u>:** During gametogenesis, variations due to recombination result in new phenotypes.
5. **<u>Natural Selection</u>:** It is a process in which heritable variation enabling better survival are enabled to reproduce and leave greater number of progeny.

Natural selection operates and can have the following effects on different traits (Fig 4).

!) <u>Stabilisation</u> – More individual acquire mean character value, so peak of graph gets higher and narrower.

2) <u>Directional change</u> – More individuals acquire value other than the mean character value. So peak shifts in one Direction.

3) <u>Disruption</u> – More individuals acquire peripheral character value at both ends of the distribution curve and two peaks are formed.

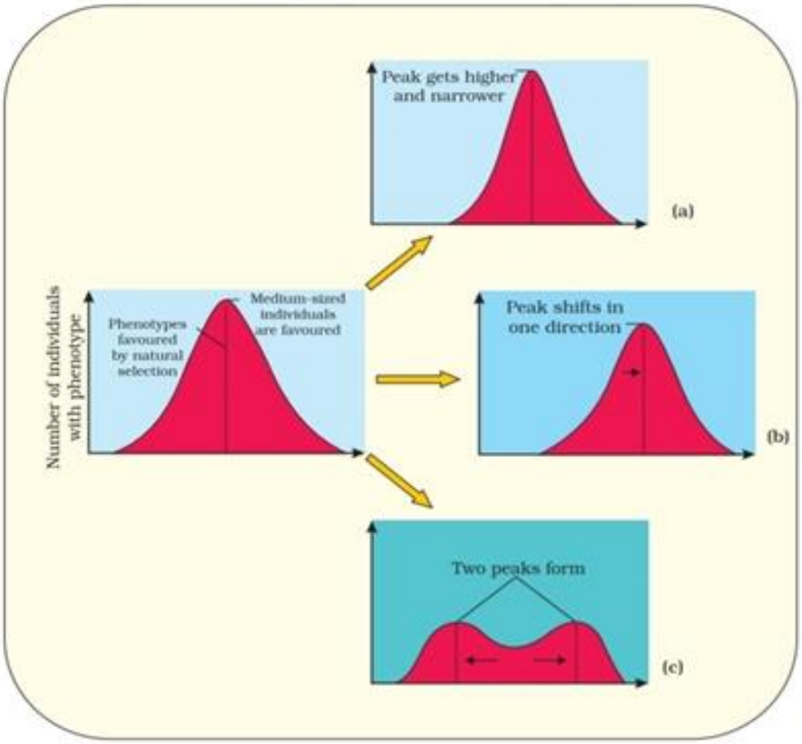
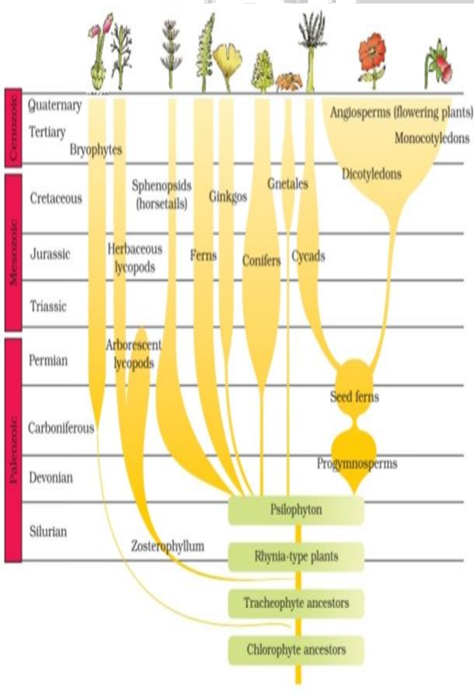


Fig4: Diagrammatic representation of the operation of natural selection on different traits: (a) Stabilising (b) Directional (c) Disruptive

A BRIEF ACCOUNT OF EVOLUTION:(Fig 5 and Fig 6)

- Approximately about 2000million years ago (mya), the first cellular forms of life appeared on earth.
- Some of these cells had the ability to release O_2 and the reaction could have been similar to the light reaction in photosynthesis.
- Slowly single – celled organisms become multi – cellular life forms.
- Around 500 mya, invertebrates were found and active.
- Around 350 mya, jawless fish probably evolved.
- Around 320 mya, seaweeds and few plants existed.
- Plants invaded land earlier than animals.
- About 350 mya, fish with stout and strong fins could move on land and go back to water.
- Coelacanth/lobefins, a fish caught in S. Africa in 1938 and thought to be extinct evolved into the first amphibian that were ancestors of modern day frogs and salamanders.
- Amphibians evolved into reptiles that lay thick- shelled eggs which do not dry up in sun unlike those of amphibians.

- Their modern day descendants are turtles, tortoises and crocodiles.
- Around 200mya, reptiles dominated the earth.
- Giant ferns (pteridophytes) were present but they all fell to form coal deposits slowly.
- Some reptiles went back to water to evolve into fish like reptiles probably 200mya (eg: Ichthyosaurs).
- The land reptiles were dinosaurs, of which Tyrannosaurus rex was biggest.
- About 65 mya, dinosaurs suddenly disappeared from the earth.
- The first mammals were small and shrew- like.
- Mammals evolved to become viviparous i.e. they protect their unborn young ones inside the mother's body.
- Pouched mammals of Australia survived because of lack of competition from any other mammals.
- This lack of competition was a result of continental Drift.


Cenozoic
Mesozoic
Paleozoic
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Bryophytes
Sphenopsids (horsetails)
Ginkgos
Gnetales
Angiosperms (flowering plants)
Monocotyledons
Dicotyledons
Herbaceous lycopods
Ferns
Conifers
Cycads
Arborescent lycopods
Seed ferns
Progymnosperms
Psilophyton
Zosterophyllum
Rhynia-type plants
Tracheophyte ancestors
Chlorophyte ancestors

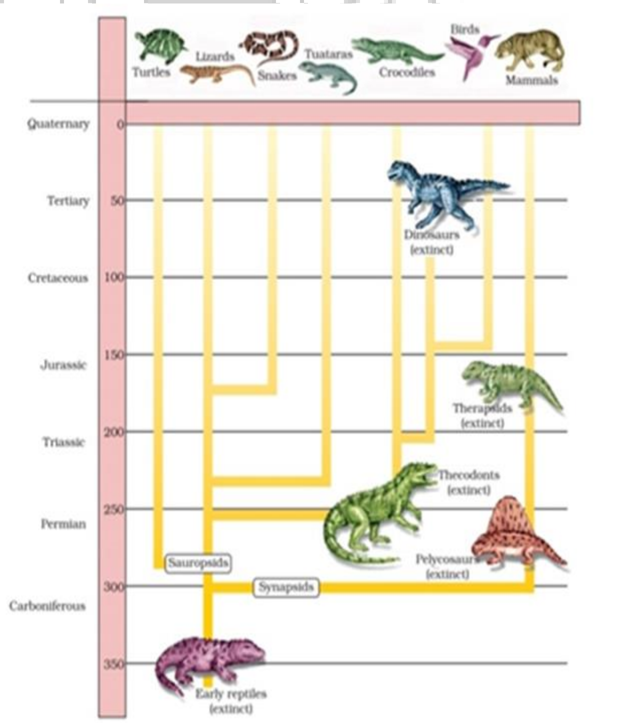

Turtles
Lizards
Snakes
Tuataras
Crocodiles
Birds
Mammals
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
0
50
100
150
200
250
300
350
Dinosaurs (extinct)
Therapsids (extinct)
Thecodonts (extinct)
Pelycosaurs (extinct)
Sauropsids
Synapsids
Early reptiles (extinct)

Fig5: A sketch of the evolution of plant forms through geological periods

Fig6: Representative evolutionary history of vertebrates through geological periods

ORIGIN AND EVOLUTION OF MAN

Human Ancestors	Time of origin	General features
Dryopithecus (more ape – like) Ramapithecus (more ape – like)	15 mya	They were hairy, walked like gorillas and chimpanzees.
Man-like primates	3-4 mya	Fossils found in Tanzania and Ethiopia revealed hominid features, 4ft. tall, walk upright.
Ausrtralopithecus	2mya	Lived in east African grasslands, hunted with stone weapons, essentially ate fruit.
Homo habilis	2mya	First human-like being –the hominid; Brain capacities between 650-800cc; did not eat meat.
Homo erectus (Java Man)	1.5mya	Fossils found in Java 1891, Large brain and 900cc, probably ate meat
Homo sapiens Neanderthal man	10,000-40,000 years back	Brain size of 1400cc; Found near east and central Asia; used hides to protect.
Homo sapiens sapiens (Modern Man)	75,000 – 10,000 years ago (ice age)	Arose in Africa, moved across continents and developed into distinct races, developed cave art about 18,000 years ago (Bhimbetka rock shelter in Raisen district of Madhya Pradesh; About 10,000 years back agriculture came and human civilization started).