EVOLUTION

ORIGIN OF LIFE

Evolutionary Biology

It is the study of history of life forms i.e. the changes in flora and fauna that have occurred over millions of years on earth.

Theories for origin of life:

(1) Theory of special creation

- The greatest supporter of this theory was **Father Suarez**. This is a mythology based theory.
- This theory has three connotations-
  (a) All living organisms that we see today were created as such.
  (b) The diversity was always the same since creation and will be the same in future.
  (c) The earth is about 4000 years old.
- All these ideas were strongly challenged during the nineteenth century based on observations of **Charles Darwin, Wallace** etc. They believed that life forms varied over the periods of time.
- From fossils records and their dating, we can conclude that earth is very old, not thousands of years as was thought earlier but billions of years old.

(2) Cosmic panspermia theory-

- Some scientists believe that life came from outer space.
- Early Greek thinkers thought units of life called **spores** were transferred to different planets including earth.
- **'Panspermia'** is still a favourite idea for some astronomers.

(3) Theory of spontaneous generation (Abiogenesis/Autogenesis) -

- This hypothesis was supported by ancient Greek philosophers.
- According to this theory life came out of decaying and rotting matter like straw, mud, etc. spontaneously.
- They believed that the mud of **Nile** river could give rise to fishes, frogs, crocodiles etc when warmed by light rays.

(4) Theory of biogenesis - Proposed by **Harvey & Huxley**

- They stated "Omnis vivum ex ovo or vivo", which means "New life can be originated on earth only by pre existing life."
- Experiments of **Francesco Redi, Lazzaro Spallanzani, and Louis Pasteur** etc supported the theory of biogenesis and disproved the abiogenesis. Experiment of Louis Pasteur is most renowned among all of these.
- Hence spontaneous generation theory was dismissed once and for all. However, this did not answer how the first life form came on earth.

Experiment of Louis Pasteur:

- His experiment is also known as **'Swan neck flask experiment'.**
- He prepared sterilized syrup of sugar and killed yeast by boiling them in flasks.
- He took two flasks one of broken neck and another of curved neck (swan neck flask/ "S" shaped neck flask).
- He showed that in pre-sterilized swan neck flasks, life did not come from killed yeast because germ laden dust particles in the air were trapped by the curved neck which serves as filter while in another flask open to air (broken neck), new living organisms arose.

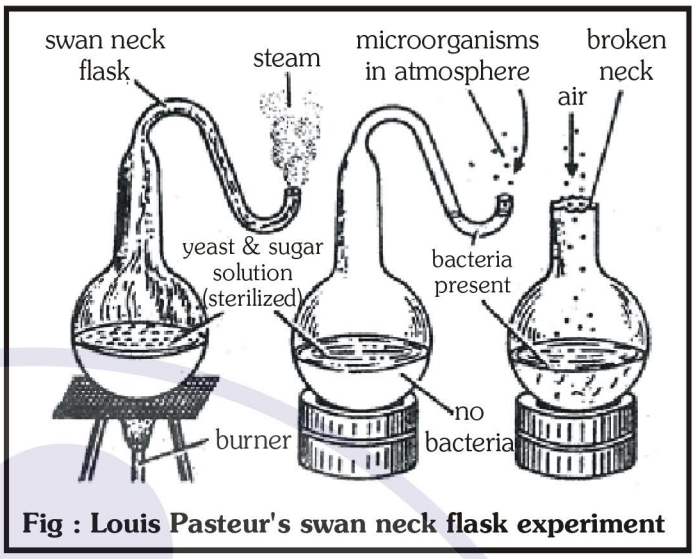


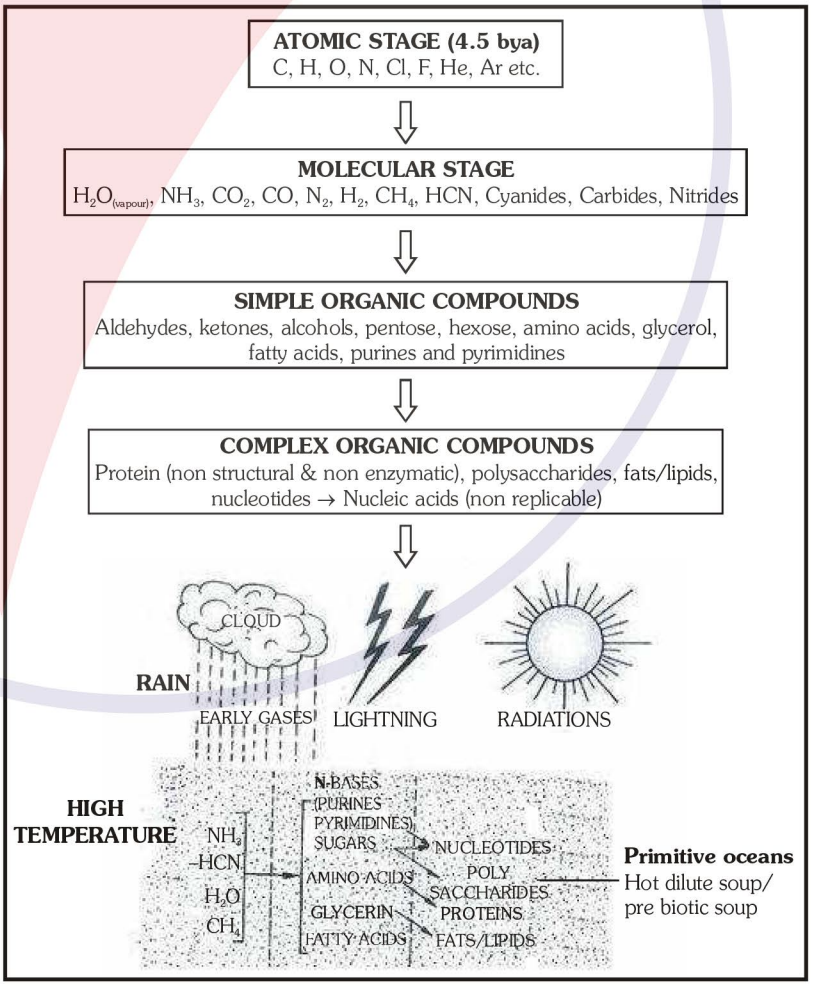
Fig : Louis Pasteur's swan neck flask experiment

(5) Oparin - Haldane theory (Modern theory)

- Oparin of Russia and Haldane of England proposed that 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.
- Oparin's theory was published in his book **'ORIGIN OF LIFE'**.
- First life originated in sea water, so water is essential for origin of life.

CHEMICAL EVOLUTION (Chemogeny)

- The primitive conditions on earth were **high temperature, volcanic storms, lightening and reducing atmosphere**.
- Early earth had free atoms of all those elements which are essential for formation of protoplasm (C, H, O, N etc.).
- Hydrogen was maximum among all of them.
- Due to high temperature hydrogen reacted with oxygen to form **water** and no free oxygen was left, which made the atmosphere reducing.
- Hydrogen also reacted with nitrogen and formed **ammonia**.
- Hence **Water and ammonia** were probably the first inorganic compounds formed on earth.
- **Methane (CH_4)** was the first organic compound.
- As the earth cooled down, the water vapour fell as rain, to fill all the depressions and form primitive oceans. During this, molecules continued to react with each other and formed various simple and complex organic compounds.



- Now, the water of oceans became a rich mixture of macromolecules/ complex organic compounds. Haldane called it **Hot dilute soup/ pre biotic soup.**
- Hence the possibilities of life were established in the water of primitive oceans because these macromolecules **(Proteins, polysaccharides, fats/lipids, nucleic acids)** form the main components of protoplasm.

However we have no clear idea about how the first self replicating metabolic capsule of life arose, but many attempts were made to solve the mystery of arise of life on earth. From these macromolecules how first life was originated, will be studied in **Biological evolution**.

BIOLOGICAL EVOLUTION (Biogeny)

(a) Origin of protobionts-

- Macromolecules which were synthesized abiotically in primitive oceans later came together and formed large colloidal drop like structures named as **protobionts**.
- It is believed that they were the clusters of proteins, polysaccharides, lipids, nucleic acids etc.
- These protobionts were unable to reproduce but they could grow by absorbing molecules from their surroundings and can exhibit simple metabolism.

Protobionts were also synthesized artificially by some scientists in laboratory.

For example, **Oparin** prepared some protobionts without a lipid membrane and he called them **coacervates**.

Similarly **Sydney Fox** synthesized some microscopic protenoid bodies with a lipid coat and called them **microspheres**.

(b) Origin of protocells (Eobionts)-

- Nucleic acid developed the ability of self duplication due to a sudden change called **mutation**.
- Nucleic acid and proteins combined to form **nucleoproteins**. Nucleoproteins were the first sign of life.
- Clusters of nucleoproteins surrounded by lipid coat called **protocell**, the **first form of life**.
- These **first non-cellular forms of life** could have originated **3 billion years ago.**
- They would have been giant molecules **(RNA, Protein, Polysaccharides, etc.)**. These capsules reproduced their molecules perhaps.
  - ☞ **Altman (1980)** discovered that some RNA molecules have enzymatic activity, called as **ribozymes**. It means at the time of origin of life, RNA molecule could carry out all the processes of life (replication, protein formation etc) without the help of either protein or DNA. Hence this concept called as **RNA World**.

(c) Origin of first cellular form (Prokaryotes) -

Origin of first cellular form (Prokaryotes)

Chemo - heterotrophic anaerobic

↓

Chemo auto trophs (Chemo synthesis) eg. Iron bacteria, Niteria, Nitrifying bacteria)

↓

Non-oxygenic Photosynthesis eg. Planktonic sulphar bacteria

↓

Oxygenic Photosynthesis bacteria eg. BGA cynobacteria

↓

Oxygen revolution → Oxidizing Atmosphere
→ Oxidation of CH_4 and NH_3
→ Formation of O_3 layer
→ Origin of aerobic respiration

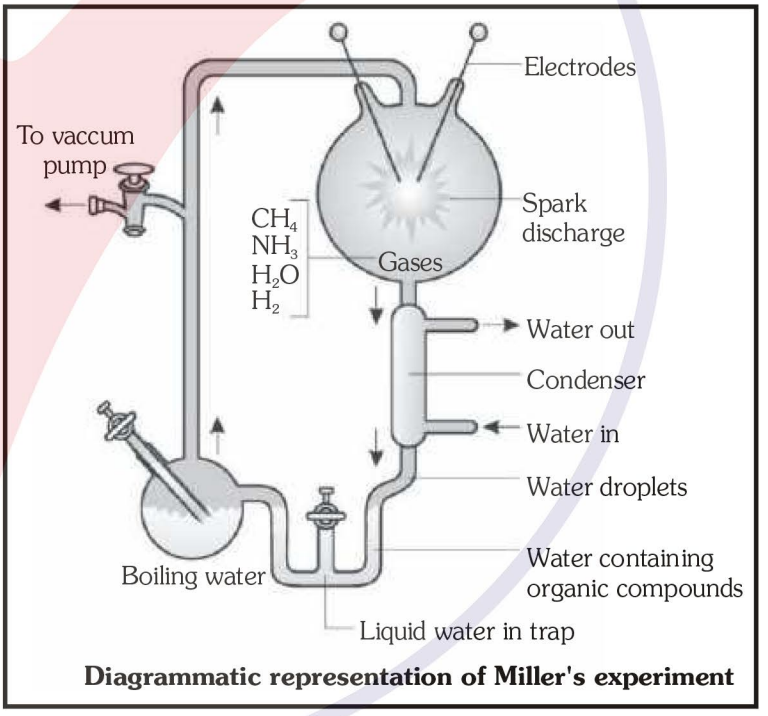
↓

Origin of Eukaryotic cells

EVIDENCES IN FAVOUR OF CHEMICAL EVOLUTION

Harold Urey & Stanley Miller Experiment

- In 1953, S.L. Miller, an American scientist created similar conditions at laboratory scale which were thought to be on primitive earth.
- He took **CH_4, NH_3, H_2 (in ratio 2:1:2)** and water vapour at **800° C** in a large flask.
- He created **electric discharge** by using two tungsten electrodes as source of energy.
- He observed the formation of simple amino acids like glycine, alanine, and aspartic acid.
- In similar experiments other scientists observed, formation of sugars, nitrogen bases, pigment and fats.



Diagrammatic representation of Miller's experiment

Evidences from meteorites

- Analysis of meteorite contents also revealed similar compounds indicating that similar processes are occurring elsewhere in space.

☞ With these limited evidences, the first part of the conjectured story, i.e., chemical evolution was more or less accepted.

☞ This version of abiogenesis, i.e., the first form of life arose slowly through evolutionary forces from non-living molecules is accepted by majority. However, once formed, how the first cellular forms of life could have evolved into the complex biodiversity of today is the fascinating story that will be discussed in **organic evolution**.

EVIDENCES OF ORGANIC EVOLUTION

Palaeontological evidences

- Study of **fossils** is called **palaeontology**.
- According to **Charles Lyell**, "Fossils are impression or remains of hard parts of life-forms found in rocks.
- Rocks form sediments and a cross-section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth. Such types of rocks are called as **sedimentary rocks**.
- Mostly fossils are found in sedimentary rocks.
- Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment.
- A study of fossils in different sedimentary layers indicates the geological period in which they existed.
- Some of them represent extinct organisms (e.g., Dinosaurs).
- The study shows that life-forms varied over time and certain life forms are restricted to certain geological time spans.
- New forms of life have arisen at different times in the history of earth. i.e. evolution has taken place.
- Generally, fossils found in older rocks are of simpler types and found in newer rocks are of complex type.
- By fossils we can study the evolutionary pedigree of animals like horse, elephants and man etc.
- **The geological history of earth closely correlates with the biological history of earth.**

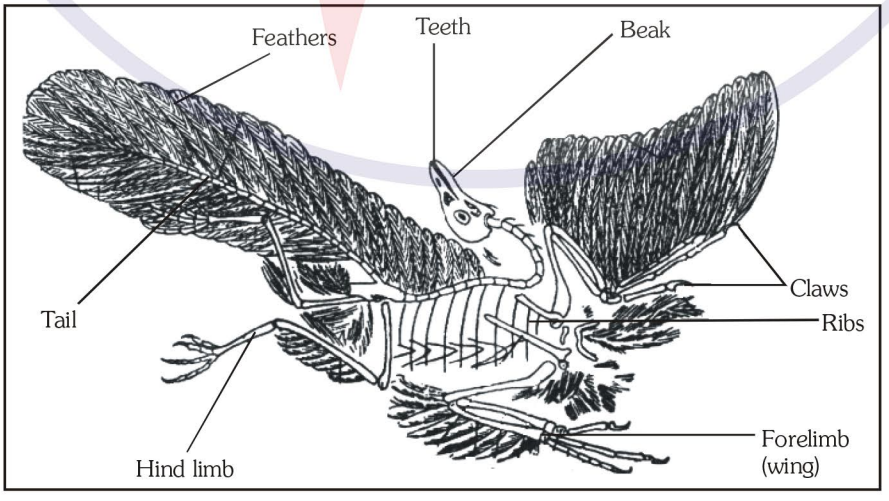
There are several methods used to determine the age of fossils-

(1) Uranium Lead method

(2) Radio carbon method

(3) Potassium argon method - this method is more commonly used to determine the age of older hominid fossils.

(4) Electron spin resonance (ESR) method - this is the modern and most accurate technique.

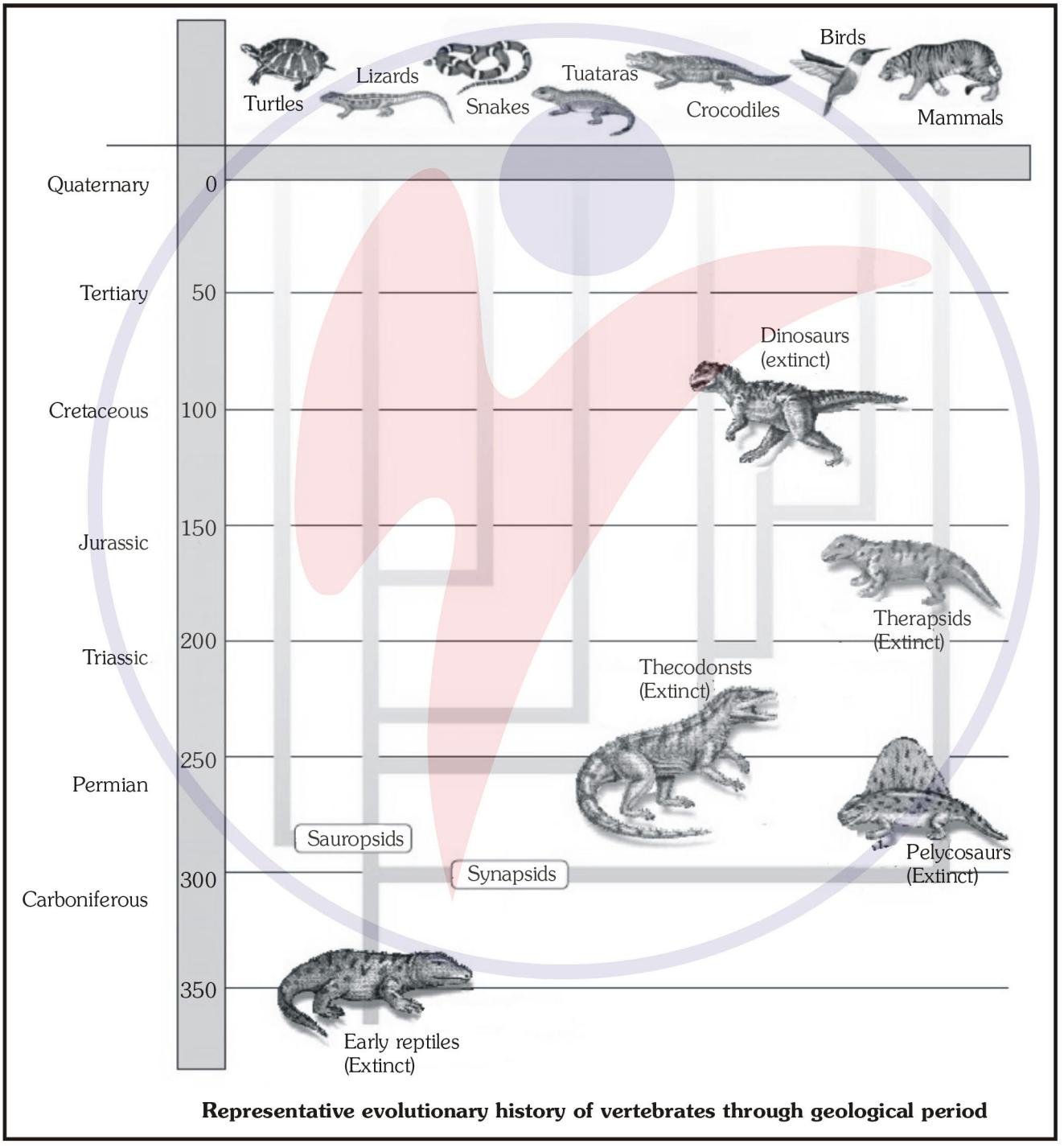


Archeoptaryx

GEOLOGICAL TIME SCALE			
Era	**Period**	**Epochs**	**Life forms**
COENOZOIC (Age of Birds, Mammals and Angiosperms)	**QUATERNARY**	Holocene (Age of Man)	Mental age, supremacy of man
		Pleistocene (ICE AGE)	Human appeared, social life of human started
	TERTIARY	Pliocene	Apelike ancestors of human appeared
		Miocene	
		Oligocene	Anthropoid apes evolved from monkeys
			Rise of monocots
		Eocene	Eohippus appeared
		Palaeocene	Origin of primates
ROCKY MOUNTAIN REVOLUTION			
MESOZOIC (Age of Reptiles)	**CRETACEOUS**		Extinction of Dinosaurs & archaeopteryx
			Origin of primitive placental mammals and
			Modern birds
			Angiosperms also appeared
	JURASSIC (Golden age of Dinosaurs)		Dominance of dinosaurs and origin of first toothed birds and marsupial mammals
			Gymnosperms and ferns also dominated
	TRIASSIC		Origin of dinosaurs and oviparous mammals
APPLACHIAN REVOLUTION			
PALAEOZOIC	**PERMIAN**		Origin of mammal like reptiles, first Gymnosperm appeared
	CARBONIFEROUS (Golden age of amphibians)		Amphibians were dominant and origin of reptiles (seymauria)
			First seed plant originated
	DEVONIAN (Golden age of fishes)		Fishes were dominant and origin of amphibians
	SILURIAN		Jawless fishes were dominant and Origin of true fishes
	ORDOVICIAN		Giant mollusks were dominant
			Origin of jawless fishes (1st vertebrates), origin of chordata
	CAMBRIAN		Trilobites (Extinct arthropods) were dominant
SECOND GREAT GEOLOGICAL REVOLUTION			
PROTEROZOIC			Origin of protozoa, sponges, coelenterate, annelida & mollusca
FIRST GREAT GEOLOGICAL REVOLUTION			
ARCHAEOZOIC			Prokaryotes originated and dominated
			(Era of invisible life)
			Eukaryotes also evolved
AZOIC			No life, Only **chemical evolution** took place

A brief account of evolution-

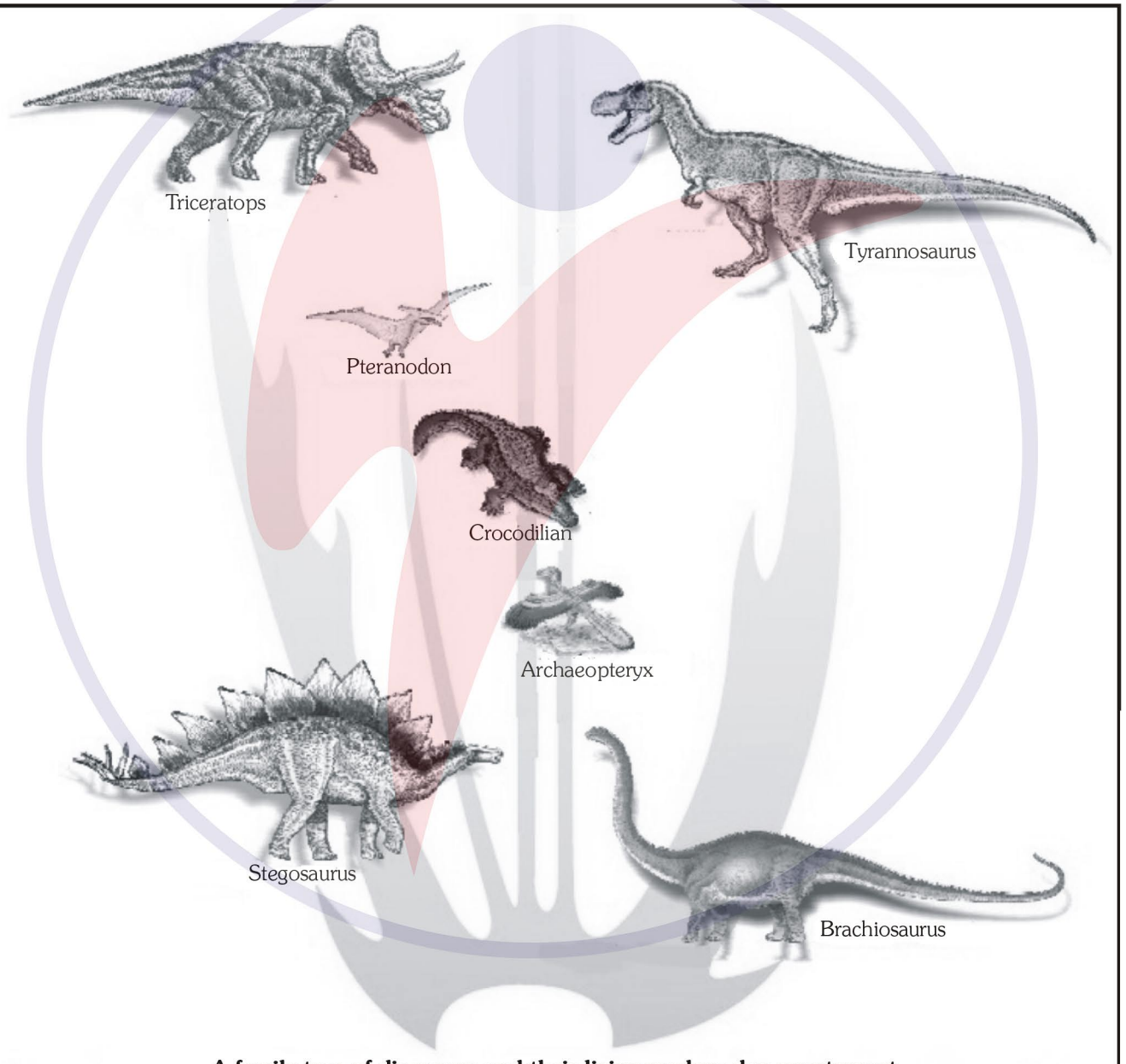
- About 2000 million years ago (mya) the first cellular forms of life appeared on earth.
- By the time of 500 mya, invertebrates were formed and became active.
- Jawless fishes probably evolved around 350 mya.
- Sea weeds and few plants existed probably around 320 mya.
- The first organisms that invaded land were plants. They were widespread on land when animals invaded land.



Representative evolutionary history of vertebrates through geological period

- 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.

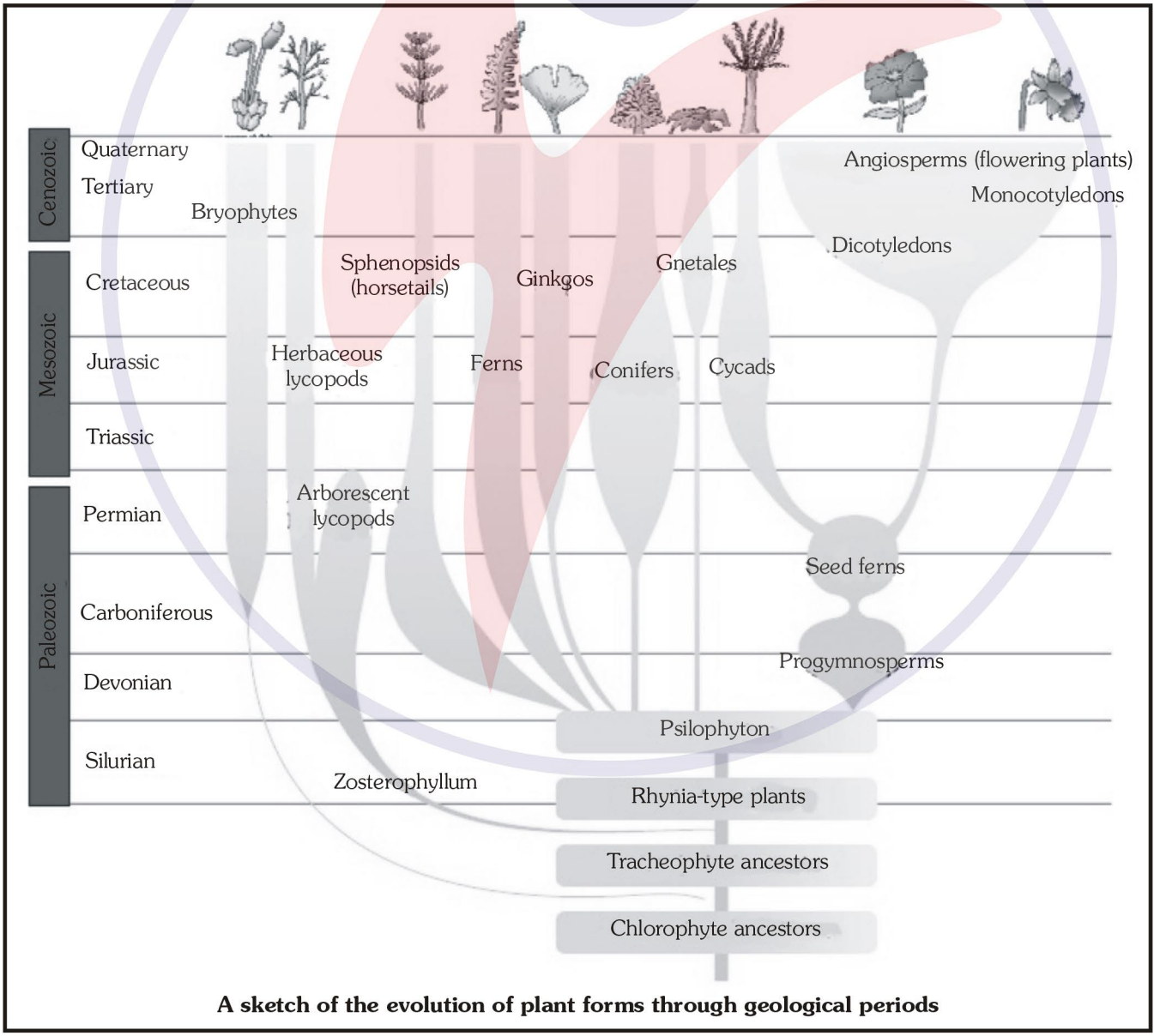
- These **Coelacanth** or **lobefins** evolved into the first amphibians that lived on both land and water. There are no specimens of these left with us. However, these were ancestors of modern day frogs and salamanders.
- The amphibians evolved into reptiles. They lay thick shelled eggs which do not dry up in sun unlike those of amphibians. Again we only see their modern day descendents, the turtles, tortoises and crocodiles.
- **Synapsids** were the mammal like early reptiles which gave rise to mammals.
- **Sauropsids** were the lizard like early reptiles which gave rise to different dinosaurs, modern reptiles and birds.



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

- In the next 200 million 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 the 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, was ***Tyrannosaurus rex*** 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. This may happened due to (i) Climatic changes killed them or (ii) Most of them evolved into birds or (iii) Meteorites collisions killed them. The truth is still unknown.
- 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.



A sketch of the evolution of plant forms through geological periods

Evidences from comparative morphology and anatomy

- Similarities and differences are found among organisms of today and those that existed years ago. Such similarities can be interpreted to understand whether common ancestors were shared or not.
- These similarities are of two types-

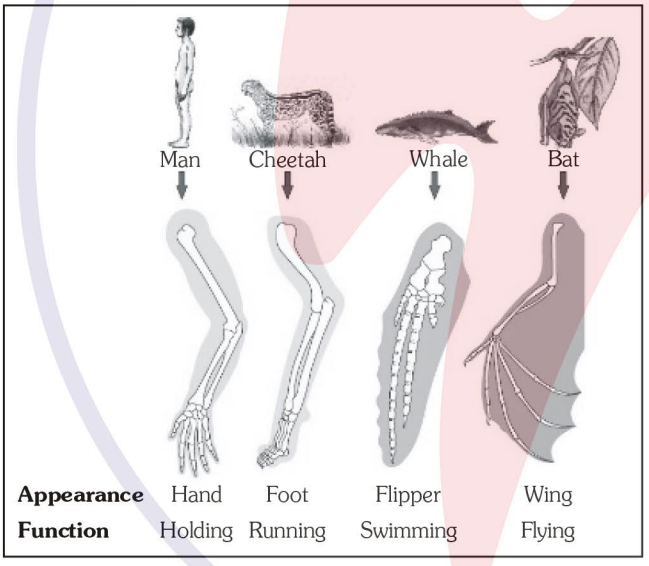
(A) Homology (B) Analogy

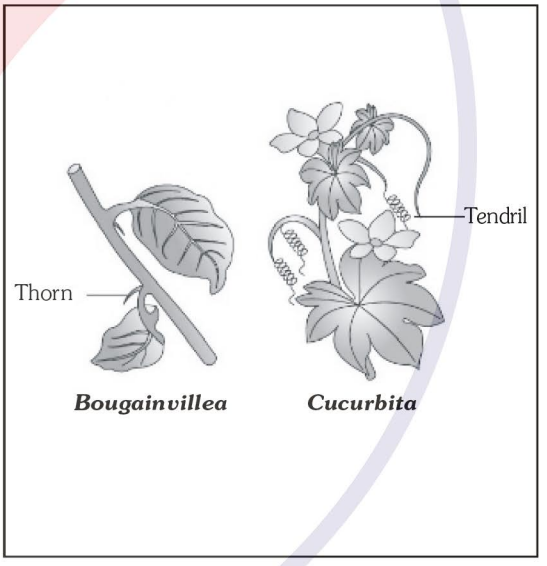
Homology

The organs which have common origin, embryonic development and same fundamental structure but perform similar or different functions are called as **Homologous organs** and this phenomenon is called Homology.

Examples of homologous organs:

(i) Forelimbs of mammals - 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, forelimbs have similar anatomical structure - all of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs.





(ii) Thorn of Bougainvillea and tendril of Cucurbita both are modification of axillary bud.

(iii) Vertebrate hearts or brains

(iv) Mouth parts of insects -

Cockroach	Honey bee	Mosquito
(Biting & chewing)	(Chewing & lapping)	(Piercing & Sucking)

In each of these insects mouth parts comprise labrum, mandible maxilla etc.

(v) Testes in male and ovaries in female

(vi) Potato and Ginger - both are modified shoot

(vii) Radish and Carrot - both are modified roots

(viii) Molecular homology - Homology found at molecular level. For example the plasma proteins found in the blood of man and apes are similar.

- When the same structures develop along different directions due to adaptations to different needs, this is called as **divergent evolution**.
- Homology indicates **common ancestry** and based on divergent evolution.

Analogy

The organs which have different origin and fundamental structures but perform similar functions are called **Analogous organs** and this phenomenon is called as analogy.

Examples of analogous organs:

(i) Wings of butterfly and birds - They are not anatomically similar structures though they perform similar functions i.e. used for flying.

(ii) Eye of the octopus and of mammals

(iii) Flippers of Penguins and Dolphins

(iv) Sweet potato (root modification) **and potato** (stem modification)

(v) Sting of bee and scorpion

(vi) Chloragogen cells of earthworm and liver of vertebrates

- When different structures evolve for the same function due to the similar habitat, this is called **convergent evolution**.
- Analogy doesn't indicate common ancestry and it is based on convergent evolution where different group of organisms have similar adaptive features due to similar habitat or towards the same function, hence analogous structures are a result of convergent evolution.

Evidences from vestigial organs

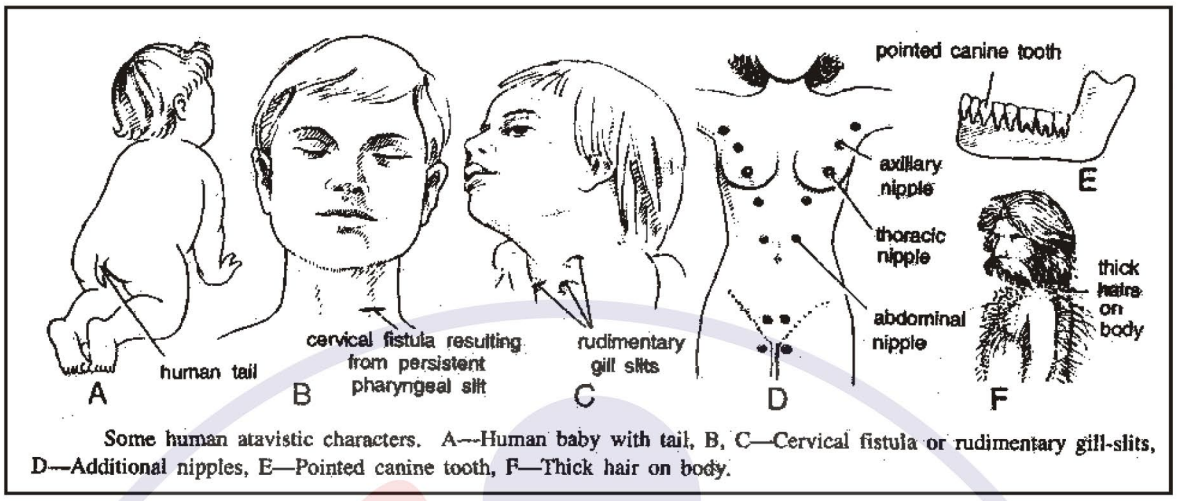
- The organs which are present in reduced form and do not perform any function in the body but are functional in related animals are called vestigial organs.
- They are remnants of organs which were complete and functional in their ancestors.

e.g. Nictitating membrane
Muscles of pinna (auricular muscles)
Vermiform appendix (Caecum)
Coccyx
Canine teeth
Third molars (wisdom teeth)
Body hair
Nipples in males
Segmented muscles of abdomen

Evidences from Atavism (Reversion)

- Sometimes in some individuals such characters suddenly appears which were supposed to be present in their ancestors but were lost during the course of evolution, this phenomenon is known as atavism or reversion.
- Atavism proves that animals developing atavistic structures have evolved from such ancestors in which these structures were fully developed.

e.g. Tail in new born baby
Extra long and pointed canine teeth
Functional auricular/pinna muscles
Long and thick body hair
Extra nipples in female
Cervical fistula (pharyngeal gills slits)



Some human atavistic characters. A—Human baby with tail, B, C—Cervical fistula or rudimentary gill-slits, D—Additional nipples, E—Pointed canine tooth, F—Thick hair on body.

Evidences from embryology

- **Baer's law:** This was proposed by Von Baer (father of embryology). He stated that "in embryonic stages general characters appear firstly and specialized characters appear later".
- Muller proposed **'Recapitulation theory'**, According to which **"Ontogeny recapitulates phylogeny"**.
- In 1866, **Ernst Haeckel** explained it in detail and called it **'Biogenetic law'**.
- It means an organism shows its ancestral adult stages during its embryonic development. In other words embryos of advanced species pass through stages represented by adult organisms of more primitive species.

  It shows that all organisms have common ancestry.
- Interestingly, **Von Baer** (1828) had disproven the 'Biogenetic law' before Haeckel invented it. He observed that embryos never pass through the adult stages of other animals, they resemble only the embryos of less complex animal means there are some stages, that related embryos do share.

Examples:

(1) The tadpole larva of amphibians resembles with fishes. This indicates origin of amphibians from fishes.

(2) During the development of heart in higher vertebrates like birds and mammals, it initially exhibits the 2 - chambered states same as fishes. Later on, it develops into 3- chambered as in amphibians and reptiles and finally in the last embryonic stages it becomes 4- chambered as such in the adults. This proves that all vertebrates have evolved from common fish like ancestors and also that both birds and mammals have evolved from reptiles.

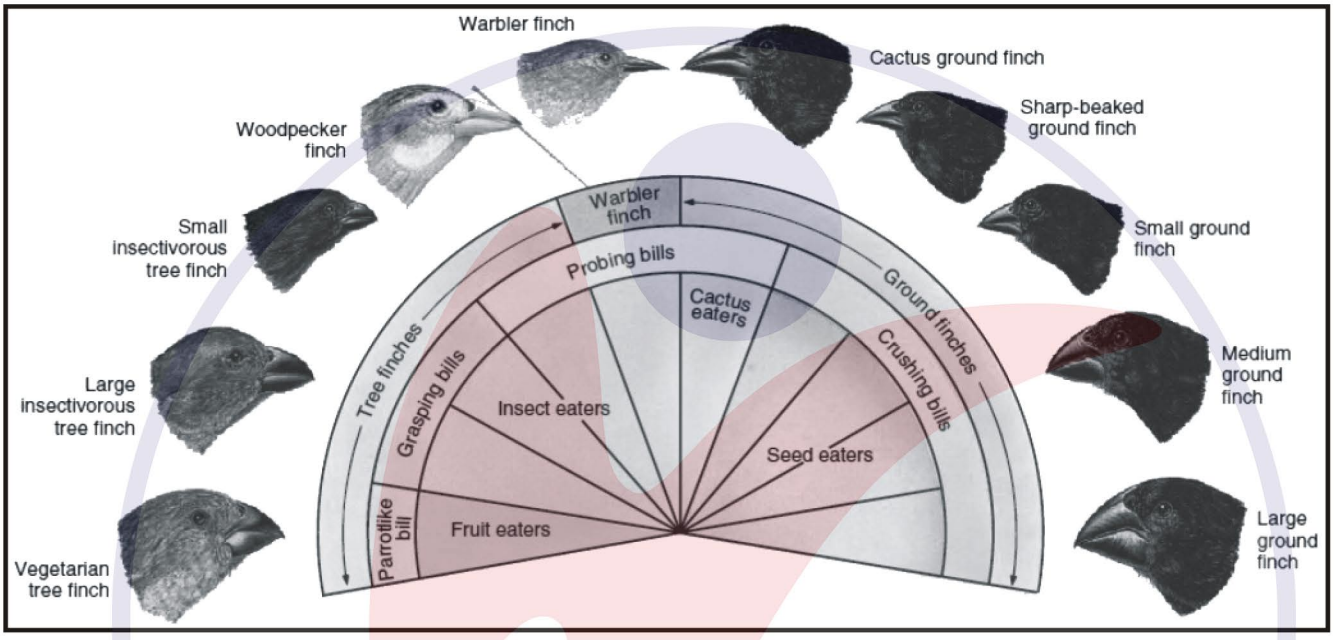
WHAT IS ADAPTIVE RADIATION/ADAPTIVE DIVERGENCE?

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**. Both the homology and adaptive radiation are based on **Divergent evolution**.

Examples:

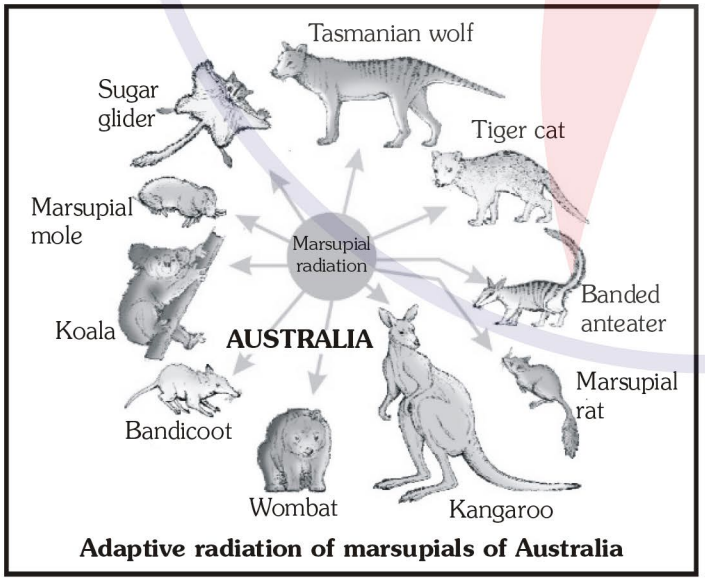
(1) **Darwin's finch -** During the journey of Galapagos Islands, Darwin observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him. Galapagos island is situated near south America which is a group of 22 smaller islands.

He realized that there were many varieties of finches at Galapagos 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.

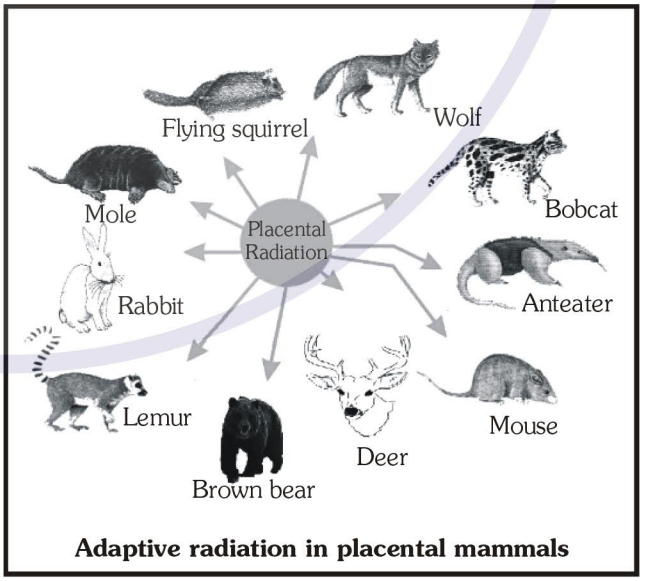


(2) **Australian Marsupials -** A number of marsupials, each different from the other evolved from an ancestral stock, but all within the Australian island continent.

(3) **Placental Mammals -** A number of placental mammals have evolved from a common ancestral type in other parts of world also. Placental mammals in Australia also exhibit adaptive radiation.



Adaptive radiation of marsupials of Australia

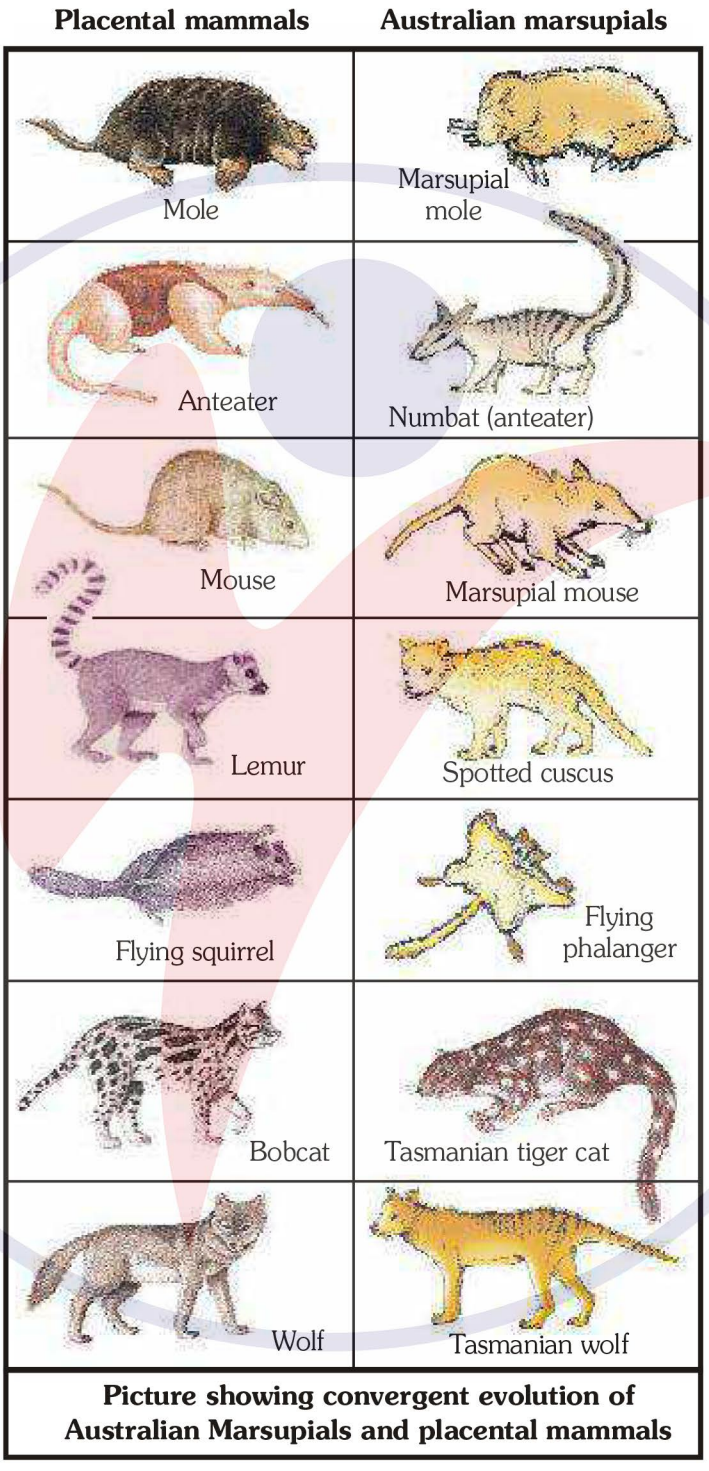


Adaptive radiation in placental mammals

Convergent evolution or Adaptive convergence - When more than one adaptive radiation appeared to have occurred in an isolated geographical area (representing different habitats), one can call this **convergent evolution**.

Placental mammals in Australia also exhibit adaptive radiation in evolving into varieties of such placental mammals each of which appears to be 'similar' to a corresponding marsupial.

e.g. Wolf (placental) and Tasmanian wolf (marsupial)



Picture showing convergent evolution of Australian Marsupials and placental mammals

Parallel evolution- When adaptive convergence is found in closely related species, it is called as **parallel evolution**. Parallel evolution occurs when two independent but similar species evolve in the same direction and thus independently acquire similar characteristics.

(1) LAMARCKISM/ Theory of inheritance of acquired characters

Criticism of Lamarckism

(1) Weismann's Theory of Continuity of Germplasm:

- Weismann cut off the tails of rats for as many as 22 generations and allowed them to breed, but tailless or reduced tailed rats were never born.
- On the basis of this experiment Weismann proposed the theory of continuity of germplasm.
- According to this theory -

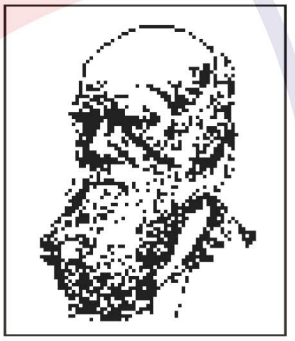
  Two types of protoplasms are present in an organism, **germplasm** and **somatoplasm**.

  There is a continuity of germplasm and the variations influencing the germ cells are only inherited but the somatoplasm is not transmitted to the next generation, hence it does not carry variations to next generation.

(2) Boring of ear pinna and nose in Indian women is never inherited to the next generations.

(3) Chinese women used to wear iron shoes in order to have small feet, but they still have normal feet.

DARWINISM/Theory of Natural selection



- Charles Robert Darwin was born on 12th Feb. 1809 in England.
- Darwin travelled by **H.M.S. Beagle** ship, which left on 27 Dec. 1831 and returned on 02 Oct. 1836 through S. America, S. Africa, Australia & Galapagos Islands.
- Darwin was influenced by two books-

  (i) **"Principles of population"** of **Malthus**

  (ii) **"Principles of geology"** of **Charles Lyell**
- **Alfred Wallace**, a naturalist who worked in **Malay Archipelago** had also come to similar conclusions around the same time and he sent his conclusions to Darwin in form of a chart.
- This theory was later on explained by Darwin in his book

  'On the origin of species by means of Natural selection' (1859).

Basic concepts of Darwinism

- **Branching Descent** and **Natural Selection** are the two key concepts of Darwinian Theory of evolution.
- Natural selection is based on certain observations which are factual.

(i) Over production:

– All organisms have the capability to produce enormous number of offspring or organisms (multiply in geometric ratio).

– Hence, theoretically population size will grow exponentially if everybody reproduced maximally (this fact can be seen in a growing bacterial population) but the fact is that population sizes in reality are limited.

(ii) Struggle for existence:

- Natural resources are limited and populations are stable in size (except for seasonal fluctuation) means that there had been competition for resources. Only some survived and grew at the cost of others that could not flourish. This is called **struggle for existence**.
- It is of three types -
  - **(a) Intra specific struggle:** It is competition among the individuals of same species for same needs like food, shelter and breeding. (Most acute type of struggle)
  - **(b) Inter specific struggle:** It is the struggle among the individuals of different species for food and shelter.
  - **(c) Environmental struggle:** This struggle is between the organisms and their environment. All organisms struggle with cold, heat, wind, rain, drought, flood etc.

(iii) Variations and heredity:

- Members of a population vary in characteristics (in fact no two individuals are alike) even though they look superficially similar i.e. population has built in variation in characteristics.
- Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors, etc.) are called **adaptive or useful variations** while others are called as **non - adaptive or harmful variations**.
- The novelty and brilliant insight of Darwin was, he asserted that variations, which are heritable and which make resource utilisation better for few (adapted to habitat better) will enable only those to reproduce and leave more progeny.

(iv) Natural selection/ Survival of the fittest:

- Individuals with more adaptive variations are "better fit" than the individuals with less adaptive variations. Hence, those who are better fit in an environment would be selected by nature and leave more progeny than others. Darwin called it **natural selection** and implied it as a mechanism of evolution.
- **Fitness is the end result of the ability to adapt and get selected by nature.**
- The fitness, according to Darwin, refers ultimately and only to **reproductive fitness**.
- It is observed that all adult individuals of a population don't have equal chances of mating; some males with better phenotype are preferred by females. This is called **Sexual selection**.

(v) Origin of New species:

- As a result of heritable variations and natural selection there would be a change in population characteristic and hence new forms appears to arise.

Criticism of Darwinism

1. The main drawback of this theory is that Darwin didn't have the knowledge of genetics and he had no satisfactory explanation for the cause, origin and **inheritance** of variations.
2. This theory only explained the survival of fittest but was unable to explain the **arrival of fittest**.

Mutation Theory

- This theory was proposed by **Hugo de Vries** based on his work on **evening primrose (*Oenothera lamarckiana*).**
- Large differences arising suddenly in a population are called mutations. Actually mutations are sudden changes of genetic material (DNA) and hence all are inheritable.
- In addition to recombination, mutation is another phenomenon that leads to variation in DNA.
- Mutation is a discontinuous source of variations and provides raw material for evolution.
- According to Hugo de Vries it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about.
- Mutations are **large, random** and **directionless** while Darwinian variations are **small** and **directional**.
- Evolution for Darwin was gradual while de Vries believed mutation caused speciation and hence called it **saltation** (single step large mutation).

Criticism-

(i) Natural mutations are not very common as Hugo de Vries thought.

(ii) Mutations are normally **recessive** & **harmful**, while the characters taking part in evolution are usually dominant.

NEODARWINISM/Modern synthetic theory of organic evolution-

- Neo-Darwinism is a modified form of Darwinism along with recent researches of **Weismann, De Vries, Stebbins, Dobzhansky, Sewall Wright, Mayr** etc.
- According to this theory following factors are responsible for formation of new species-

(i) Rapid multiplication

(ii) Limited food and space

(iii) Struggle for existence

(iv) Genetic variations

a) Gene recombination - New combinations of genes which are usually caused by the crossing over during gametogenesis. It is continuous and common source of variation in a sexually reproducing population.

b) Mutation - Discontinuous source of variations

c) Hybridization - It is crossing of organisms which are genetically different in one or more traits.

d) Gene migration & Gene flow - 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.

***e)* Genetic drift -** If the change in gene frequency occurs by chance, it is called genetic drift.

(v) Natural Selection: Natural selection is a process in which heritable variations enabling better survival are enabled to reproduce and leave greater number of progeny.

A critical analysis makes us believe that variation results in changed frequency of genes and alleles in future generation. Coupled to enhance reproductive success, natural selection makes it look like different population and lead to new species formation.

(vi) Isolation: Isolation is a segregation of populations by some barriers which prevent interbreeding. The reproductive isolation between the populations due to certain barriers leads to the formation of new species.

Genetic Drift (Sewall Wright effect) -

- Random change of gene/allelic frequencies in a population merely **by chance** is called genetic drift.
- It operates rapidly in **small population**.
- It is due to habitat fragmentation, isolation, natural calamities or any epidemics.
- Founder effect and bottleneck effect are two forms of genetic drift.

(a) Founder effect-

When a section of population get isolated or migrated or drifted from original population, than this section becomes genetically different from the original population due to change in allelic frequecy because gene pool of this section may contain some alleles in a very low frequency or may lack a few alleles.

Sometimes the change in allelic 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.

(b) Bottleneck effect-

Bottlenecks are the natural calamities like earthquakes, volcanic eruptions, floods, storms etc. A sudden change in the environment may drastically reduce the size of a population and now this population may be genetically different from the original population. Certain alleles may have more frequency among the survivors, others may be less, and some may be absent altogether.

If a population that has passed through a bottleneck ultimately recovers in size, it may have low levels of genetic variation for a long period of time and this may produce a new species.

HARDY- WEINBERG PRINCIPLE-

- In a given population one can find out the frequency of occurrence of alleles of a gene or a locus. This frequency is supposed to remain fixed and even remain the same through generations.
- This principle says that allele frequencies in a **randomly mating** 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.

  $p + q = 1$

  Where: p - Frequency of dominant allele (A)

  q - Frequency of recessive allele (a)
- The binomial expansion of this equation is:

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

  Where: p^2 – Frequency of individuals with genotype AA

  q^2 – Frequency of individuals with genotype aa

  2pq – Frequency of individuals with genotype Aa
- When frequency measured, differs from expected values, then the difference (direction) indicates the extent of evolutionary change. 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.
- Five factors are known to affect Hardy-Weinberg equilibrium. These are-
  1. Gene migration or gene flow
  2. Genetic drift
  3. Mutation
  4. Genetic recombination
  5. Natural selection

Examples of Natural Selection-

(1) Industrial Melanism - This phenomenon was studied by **Bernard Kettlewell** in England.

(a) (b)

Figure showing white - winged moth and dark - winged moth (melanised) on a tree trunk
(a) In unpolluted area (b) In polluted area

- In a collection of moths **(*Biston betularia*)** made in 1850s, i.e., before industrialization 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 industrialization, 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'**.
- Before industrialization 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.
- **Lichens can be used as industrial pollution indicators.** They will not grow in areas that are polluted.
- During post industrialization period, the tree trunks became dark due to industrial smoke and soot. Under this condition the white-winged moth did not survive due to predators while dark-winged or melanised moth survived.
- 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 industrialization 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. Remember that no variant is completely wiped out.

(2) 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/resistant population.

- ☞ 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 very less 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.

(3) Sickle cell anaemia and Malaria:

- Individuals, homozygous for sickle cell anaemia die at an early stage due to anaemia and the individuals in which heterozygous condition is present for this character, the RBC become sickle shaped.
- In this type of RBC, malarial parasite can't have a normal growth and individuals become resistant towards malaria.

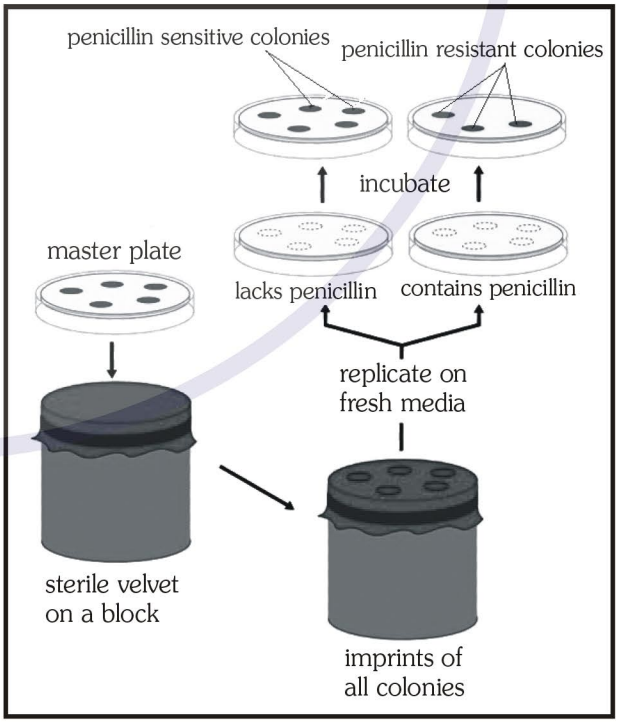
- The individuals with heterozygous condition have better chances of survival, hence are selected by nature.
- Thus the process of natural selection maintains the abnormal form of hemoglobin along with the normal form in a region where malaria is common. This type of selection is called **Balancing selection**. It means the preservation of genetic variability is maintained by the selection of heterozygote which is called **balanced polymorphism**. But this kind of balancing selection is found very rarely in nature.

GENETIC BASIS OF ADAPTATIONS/NATURAL SELECTION-

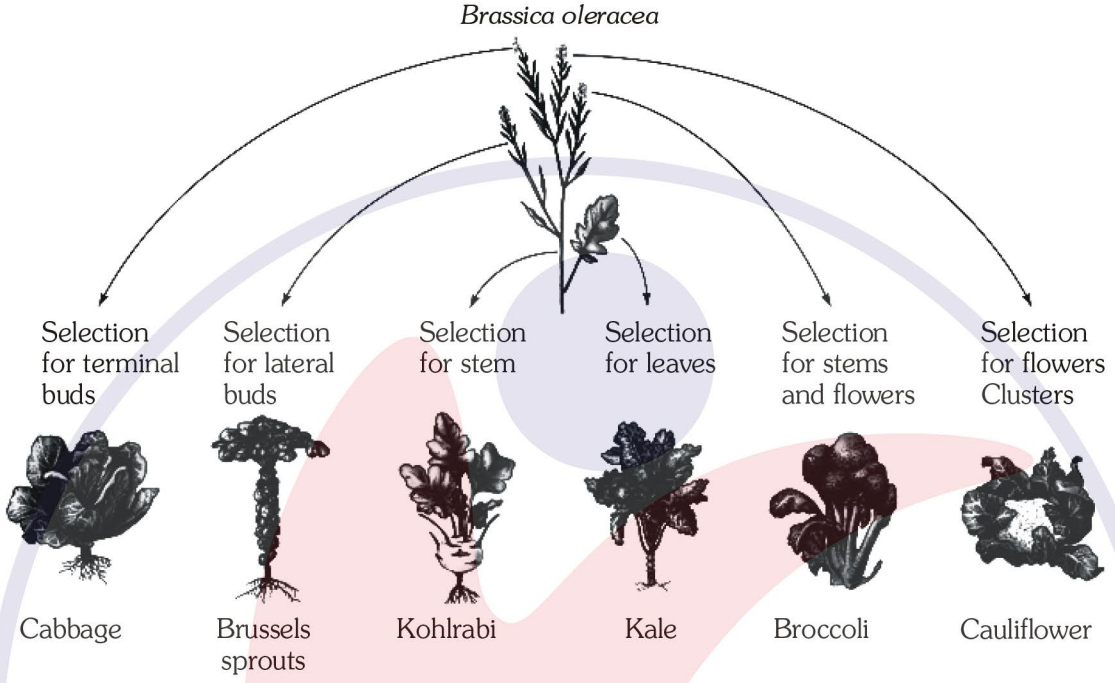
- The essence of Darwinian Theory about evolution is natural selection.
- The rate of appearance of new forms is linked to the life cycle or the life span.
- Microbes that divide fast have the ability to multiply and become millions of individuals within hours.
- A colony of bacteria (say A) growing on a given medium has built in variation in terms of ability to utilise a feed component. A change in the medium composition would bring out only that part of the population (say B) that can survive under the new conditions.
- In due course of time this variant population outgrows the others and appears as new species. This would happen within days.
- For the same thing to happen in a fish or fowl would take million of years as life spans of these animals are in years. Here we say that fitness of B is better than that of A under the new conditions.
- Fitness or adaptive ability is based on characteristics which are inherited. It has a genetic basis. Hence, **there must be a genetic basis for getting selected and to evolve**.
- Microbial experiments show that pre-existing advantageous mutations when selected will result in observation of new phenotypes. Over few generations, this would result in Speciation.

Lederberg's replica plate experiment:

- Performed by Joshua Lederberg & Esther Lederberg.
- They cultured the bacterial cells on agar plate and obtained many bacterial colonies. This multi colony agar plate is known as **master plate**.
- They prepared a **replica** of this master plate by gently pressing it on a velvet covered wooden block.
- Now they tried to prepare a replica on the agar plate which contains antibiotic penicillin. It was seen that some bacteria failed to grow on penicillin agar plate while some bacteria were able to grow and developed new colony.
- It was concluded that the bacteria which survived were penicillin resistant because they had penicillin resistant mutant gene which enabled them to survive in changed environment.
- It means mutations are pre adaptive and natural selection fixes them in a population over the generations.



Artificial Selection - Artificial selection is similar to natural selection except that the role of nature is taken over by man and the characters selected are of human use.



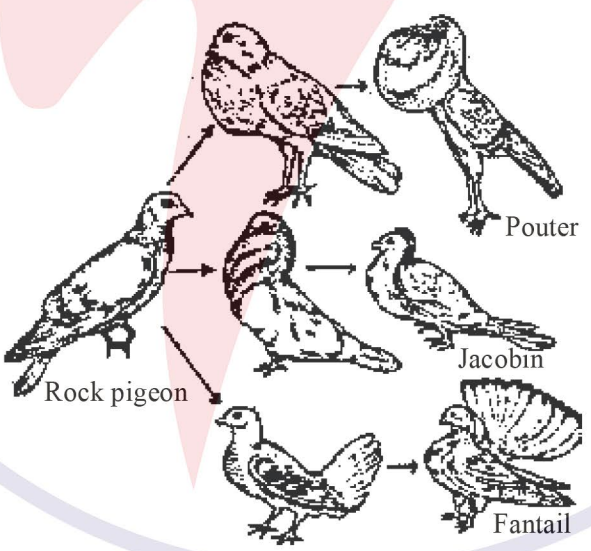


Fig.: Variations among breeds of domestic pigeons

Types of Natural Selection

(1) Stabilizing selection:

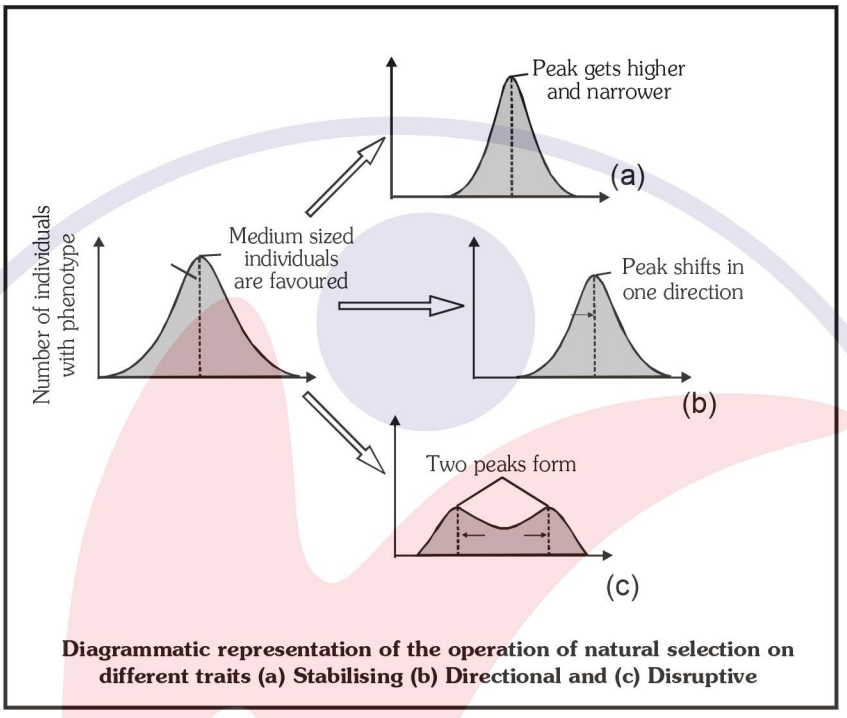
- It favours the average or normal phenotype and eliminates the extreme variants.
- After this natural selection mean value never change.
- Peak gets higher and narrower because more individuals acquire mean character value.
- Always operates in constant environment.

e. g. **Mortality in human babies:** The optimum birth weight favoured by stabilizing selection is 7.3 pounds. New born infants less than 5.5 pounds and more than 10 pounds have the highest mortality rate.

(2) Directional/ Progressive selection:

- It favours one extreme value and eliminates another extreme value and average value.
- After this natural selection mean value always changes.
- Peak shifts in one direction because more individuals acquire value other than the mean character value.
- Always operates in changing environment.

e. g. (i) Industrial melanism
(ii) DDT resistance in pests



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

(3) Disruptive selection:

- In this natural selection members of both extreme are selected simultaneously and average value get rejected.
- After this natural selection two peaks are formed because more individuals acquire peripheral character value at both ends of the distribution curve.

e. g. **Shell pattern in limpets:** Shell patterns of limpets (marine molluscs) present a continuous, ranging from pure white to dark tan. The white or light coloured limpets camouflaged with white barnacles and tanned ones are protected on the tanned coloured rocks. Limpets of intermediate shell patterns, being conspicuous are preyed by predatory shore birds, resulting in disruptive selection.

SPECIATION-

- Formation of one or more new species from an existing species is called speciation. Speciations are of two types-

(1) Divergent speciation (2) Transformation speciation

(1) Divergent speciation : When one or more new species are formed from an ancestor species.

(a) Allopatric speciation : When a species split into two or more geographically isolated populations and these populations finally form a new species, It is called allopatric speciation e. g. Darwin finches.

(b) Sympatric speciation : In this type of speciation a sub population becomes reproductively isolated from its parental population. It is the formation of species without geographical isolation. e. g. mainly present in plants due to polyploidy.

(2) Transformation speciation : When an ancestor species changes into a new species.

(a) Phyletic speciation : Ancestor species changes into new species by gradual changes in thousands of years. e.g. *Eohippus* → *Mesohippus* → *Merychippus* → *Pliohippus* → *Equus*

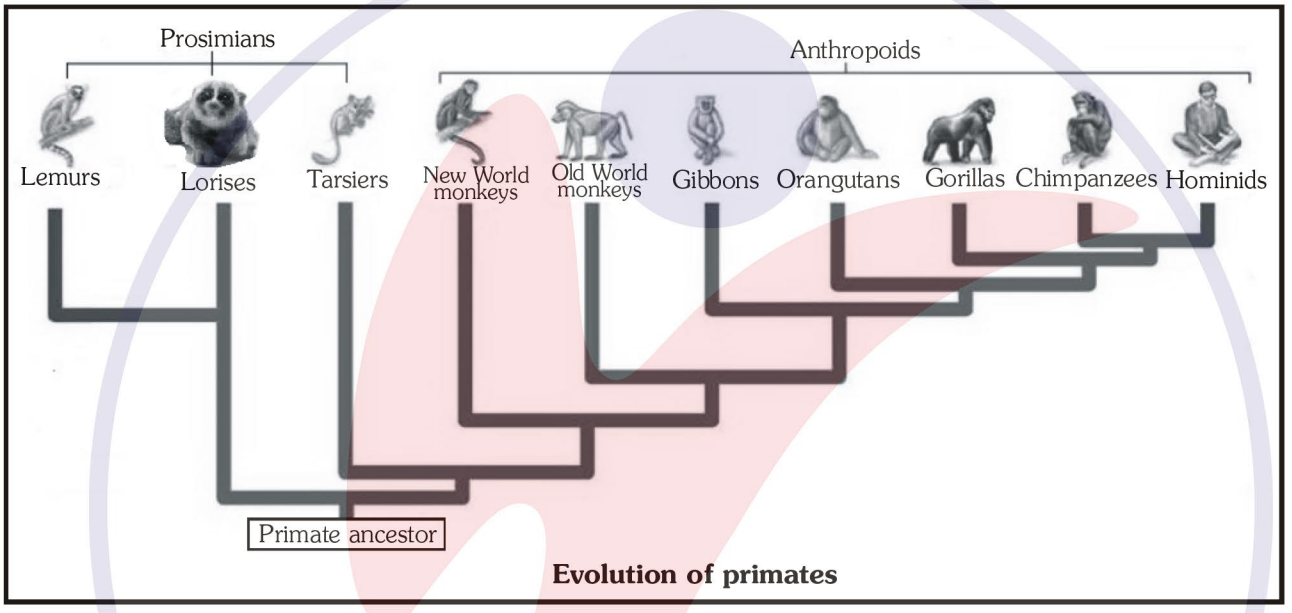
(b) Quantum speciation : In this process suddenly major changes appears in ancestor species and ancestor species immediately changed into new species. No connective links are present in this type of speciation. It is caused by major mutation.

Is evolution a process or the result of a process?

The world we see, inanimate and animate, is only the success stories of evolution. When we describe the story of this world we describe evolution as a process. On the other hand when we describe the story of life on earth, we treat evolution as a consequence of a process called natural selection. We are still not very clear whether to regard evolution and natural selection as processes or end result of unknown processes.

HUMAN EVOLUTION

- Human is a member of order Primata of class Mammalia.
- First real primate ancestors were **tree shrews**, originated in palaeocene epoch.



Evolution of primates

Evidences for Common Origin of Human & Apes:

(1) **Chromosomal similarities:-**

- Banding pattern of chromosome no. 3 & 6 of human and chimpanzee is 100% similar.
- Number of chromosomes are approx same in human (46) and apes (48).
- DNA content and DNA matching is same in both. This similarity is more than 99% with chimpanzee, 94% with Gibbon, 88% with Rhesus monkey.

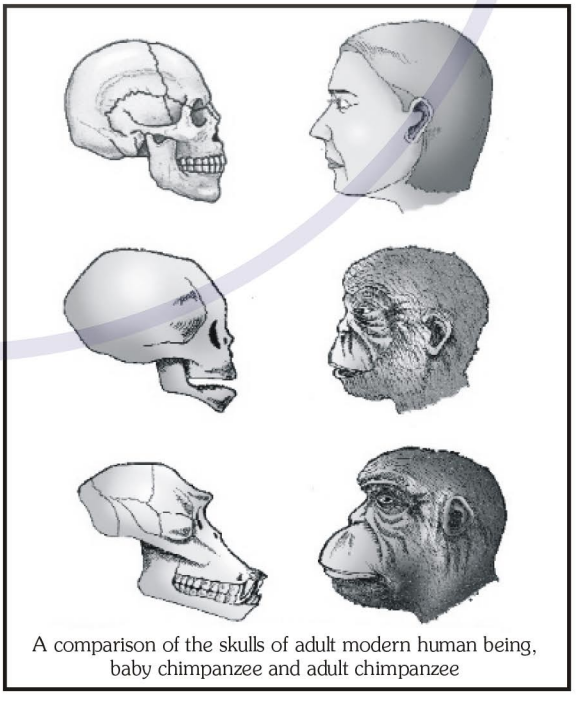
(2) The skull of baby chimpanzee is more like adult human skull than adult chimpanzee skull.

(3) Composition of Hb is same in both. Only one amino acid is different in human and gorilla.

(4) Blood group of AB series is present in both and plasma protein is also same.

(5) Menstruation cycle is present in females of both.

(6) Tail is absent in both and have grasping hands.



A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee

Human Evolution

(A) Ape Fossils - About 15 mya, primates called ***Dryopithecus*** and ***Ramapithecus*** were existing. They were hairy and walked like gorillas and chimpanzees.

(1) *Proconsul/ Dryopithecus*:

- It is considered as **common ancestor of man and apes**.
- *Dryopithecus* is considered as direct ancestors of modern day apes.
- They had **semi erect posture**, thick hair, U shaped jaws, larger and sharper teeth and were vegetarian.
- They walked on four legs and their forelimbs were longer than hind limbs.
- They were forest dwellers and spent most of the time on the trees.

(2) *Ramapithecus*
(3) *Shivapithecus*] Fossils discovered from Shivalik hills in India.

☞ ***Ramapithecus* was more man-like while *Dryopithecus* was more ape-like.**

(B) Ape man fossils - *Australopithecus*

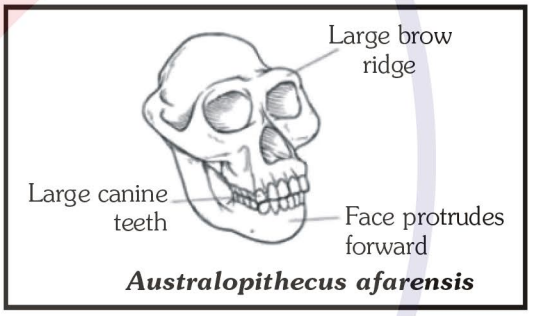
- **Prof. Raymond Dart** discovered a fossil of skull of 5-6 years old baby from the Pliocene rocks of **Tuang** region (S. Africa) and named it **Tuang baby**. Later he renamed it as ***A. africanus* (African apeman)**.
- 2 mya, ***Australopithecines*** probably lived in **East African grasslands**.
- Evidence shows they hunted with stone weapons but essentially **ate fruit**.
- It is also considered as connecting link between apes and man.

(i) Ape like characters:

- Less cranial capacity **(600 c.c.)**
- Thick growth of hair
- U shaped jaw (prognathous face)
- Larger and sharper teeth

(ii) Man like characters:

- Complete erect posture and Bipedal locomotion **(first man who stood erect)**
- Forelimbs shorter than hind limbs
- Vertebral column with distinct lumber curve



Australopithecus afarensis

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.

(C) Prehistoric Man

A number of other species of Homo appeared and became extinct from time to time on the evolutionary sense before the origin of Homo sapiens. These extinct species are called as prehistoric species of man.

(1) *Homo habilis*:

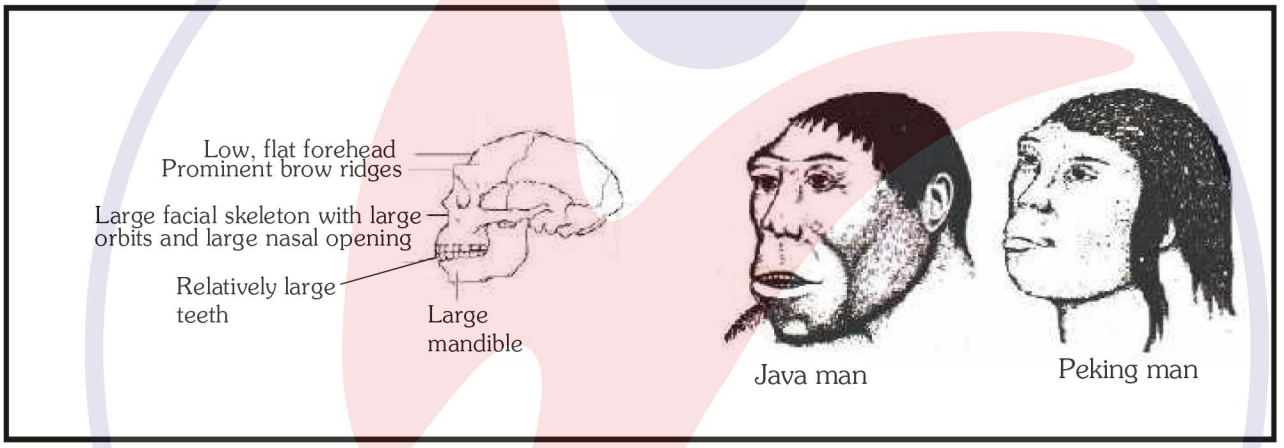
- First human like being
- First man who made tools of stones for hunting animals, hence called as **first tool maker man** or **Handy man**.
- They probably did not eat meat.
- The brain capacities were between **650-800cc**.
- Its fossils were discovered by Dr. Leakey from **2 million years old** rocks in Africa.
- They lived in caves.

(2) *Homo erectus*:

- They existed about 1.5 million years ago.
- They had large brain with a cranial capacity around **900cc.**
- They were cave dwellers and probably **ate meat**.
- Many subspecies are discovered of *Homo erectus* as given below

(a) Java man (*Homo erectus erectus/ Pithecanthropus erectus*):

- Its fossils discovered in **Java** in 1891.
- **First man who used fire** for hunting, protection and cooking.
- They used tools of bones and stones.
- Their cranial capacity was 800-1000cc **(avg. 900cc)**
- They were omnivorous and cannibalism have also found.



(b) Peking man (*Homo erectus pekinensis/ Sinanthropus erectus*):

- W.C. Pei discovered the fossils from China.
- They used fire for cooking meat and protection.
- They used sharp chisel shaped tools of stones/bones for cutting and killing animals.
- Their cranial capacity was 850-1300cc (**avg. 1050cc**)
- They were omnivorous and cannibalism have also found.

(c) Heidelberg man:

- Its fossil was recovered in form of lower jaw from Heidelberg in Germany.
- It is believed that this man was evolved as a branch from main line of evolution and got extinct after some time.

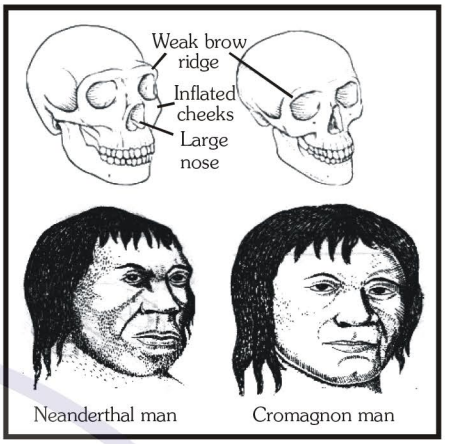
(3) *Homo sapiens*:

- Many subspecies are discovered of *Homo sapiens* as given below

(a) Neanderthal man (*Homo sapiens neanderthalensis*):

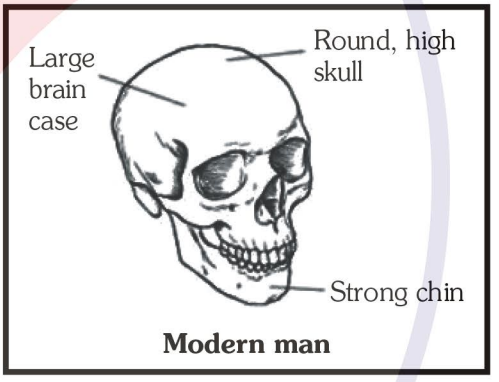
- They lived near east and central Asia between 1,00,000 - 40,000 years back, fossil was discovered by Fulhrott in **Neanderthal valley of Germany**.
- They had a brain size of **1400cc** (same as modern man).
- They used hides (skin of animals) to protect their body.
- They **buried their dead** and probably believed in **immortality of soul**.
- They lived in huts and omnivorous by nature.
- Development of speech and language centre started.

(b) Cromagnon man (*Homo sapiens fossilis*):



- Origin and evolution 50,000 to 10,000 years ago.
- Fossils discovered by Mac Gregor from **Cromagnon rocks of France.**
- They had a cranial capacity of **1650 c.c.(maximum)**
- They lived in caves and **Omnivorous by nature.**
- They had larger forehead and well developed chin.
- Semi circular jaw and **orthognathous face**.
- Speech and language centre were well developed in them.
- They wore clothes of animal skin.
- This man was hunter and used domesticated dogs in hunting, Hence **domestication was started** by this man.
- They also **painted beautiful paintings** on **cave walls**. Pre-historic cave art developed about **18,000 years ago.**

(c) Modern man (*Homo sapiens sapiens*):



Modern man

- During ice age between 75,000-10,000 years ago modern Homo sapiens arose.
- It arose in Africa and moved across continents and developed into distinct races (Caucasoid, Negroid, Mongoloid and Australoid).
- This is the **man of today** having a brain capacity of 1300 - 1600 c.c **(avg. 1450cc)**.
- This man has well developed chin, well developed speech centre, smaller forehead and reduced body hair.
- Semi circular jaw and **orthognathous face**.
- It is omnivorous by nature.
- **Agriculture** was also started by this man. Agriculture came around **10,000 years back** and human settlements started.