Evolution

Chapter – 7

- **Evolutionary Biology**: study of history of life on earth.
    - Origin of life on earth
    - Origin of different forms of life on earth

ORIGIN OF LIFE:

The Big Bang theory: Origin of universe

- Proposed by **Abbe Lemaitre** 1931.
- Universe around 20 billion years old.
- A singular huge thermonuclear explosion of unimaginable scale at the initial stage form the galaxies.
- In the solar system of the Milky Way galaxy, earth was supposed to have been formed about 4.5 billion years back.

Condition of early earth

- No atmosphere when earth was form.
- Later, water vapour, CH_4, CO_2 and NH_3 released from molten mass covered the surface.
- The UV rays from the sun broke up H_2O into H_2 and O_2 and the lighter H_2 escaped.
- Oxygen combined with ammonia and methane to form H_2O, CO_2 and others.
- As earth cooled further, water vapor fell as rain, to form oceans and lakes.

- First life appeared **500 million** years after the formation of earth, i.e., almost four billion years back.

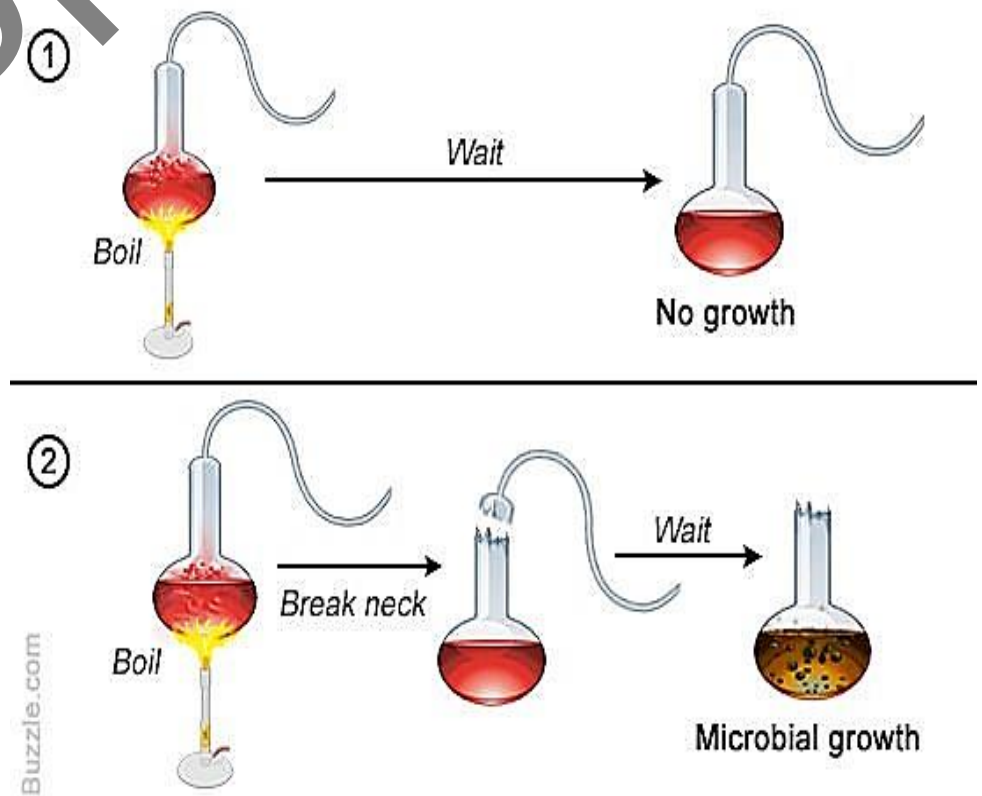
Origin of life: Ancient Theories of origin of life

1. Cosmozoic/Panspermia theory

- Propounded by Early **Greek philosophers.**
- Life exist in other planets of the galaxy
- Units of life called spores were transferred to different planets including earth along with cosmic dust.
- First life on earth was established by such spores.

2. Theory of spontaneous generation

- According to this theory, life came out of decaying and rotting matter like straw, mud etc. spontaneously.
- Disapproved by **Louis Pasteur.**
- His **Swan Neck flask experiment** demonstrated that life comes only from pre-existing life ("**Biogenesis Theory**").
  - In a pre-sterilised flasks, life did not come from killed yeast
  - while in another flask open to air, new living organisms arose from 'killed yeast'.



3. Oparin and Haldane's Theory

- Primitive life forms might have generated spontaneously from non-living organic molecules and that formation of life was preceded by formation of diverse organic molecules from inorganic constituents.

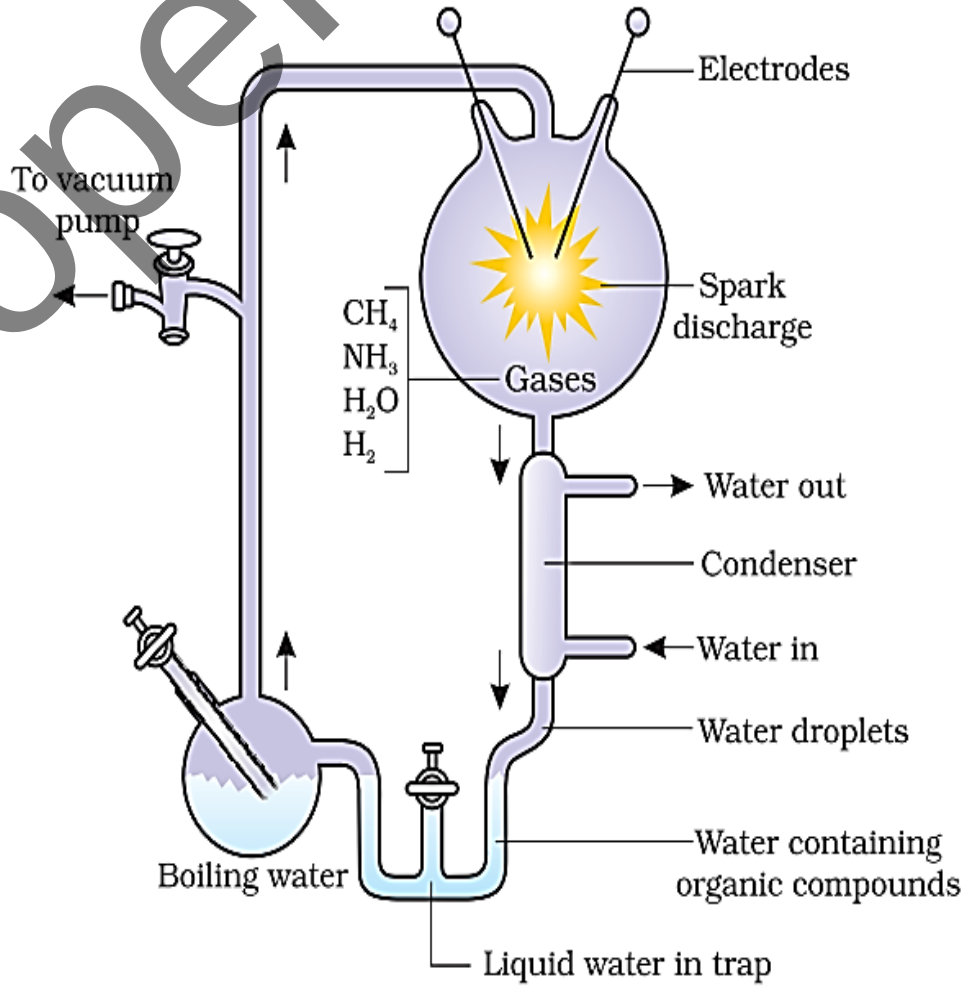
- origin of life – two steps
    - Chemical evolution
    - biogenesis

A. Chemical evolution.

- They proposed that in early earth conditions, smaller inorganic molecules react with one another to form larger organic molecules.
- The conditions on earth were –
    - high temperature, volcanic storms,
    - atmosphere were reducing i.e. no free oxygen
    - Contains CH_4, NH_3, etc.
- Energy from ultraviolet light, lightning and volcanic heat caused chemical reactions to occur in the atmosphere.
- These reactions created small organic molecules from inorganic constituents.

Evidence of chemical evolution - Urey and Miller experiment:

- In 1953, S.L. Miller created a closed apparatus similar to early earth conditions.
  - Electric discharge was passed in a closed flask containing CH_4, NH_3, H_2 and water vapour at 800ºC.
  - The circulation of water vapour is continued for several days.
    - Electric discharge - Lightning.
    - Condenser - rain
    - Water collecting flask - Primitive Ocean.
    - Heating of water chamber - evaporation.
  - Observation - formation of amino acids from simple inorganic molecules.



Other evidences

- In similar experiments others observed, formation of sugars, nitrogen bases, pigment and fats.
- Analysis of meteorite content also revealed similar compounds indicating that similar processes are occurring elsewhere in space

B. Biogenesis – origin of first life form

Two steps

i. Formation of non-cellular forms of life – Proto-bionts

- non-cellular membrane bound aggregates of complex organic compounds which exhibit living cell like characters. For example ability to reproduce their own molecules and growth.
- The first non-cellular forms of life could have originated 3 billion years back.

Two evidences of proto-biont formation

a. **Cocervates** – an aggregate of colloidal particles in liquid phase that persist for a period of time as suspended membranous droplets.

- they posses life like characters ability to increase in size.
- they are created artificially in the laboratory by **Oparin**.

b. Microsphere – they are microscopic membrane bound spheres having cell like properties.

- they are created artificially in the laboratory from protenoids – protein like structures produced by heating a mixture of amino acids.
- it was demonstrated by **Sydney Fox.**

ii. Formation of first cellular forms of life.

- The first cellular form of life evolve about 2000 million years ago.
- ***Once protobionts become capable of reproduction***, ***presumably through evolution of genetic material, they become first living cell***
- These were probably single-cells like the **archeabacteria**.
- All life forms were in water environment only.

A BRIEF ACCOUNT OF EVOLUTION:

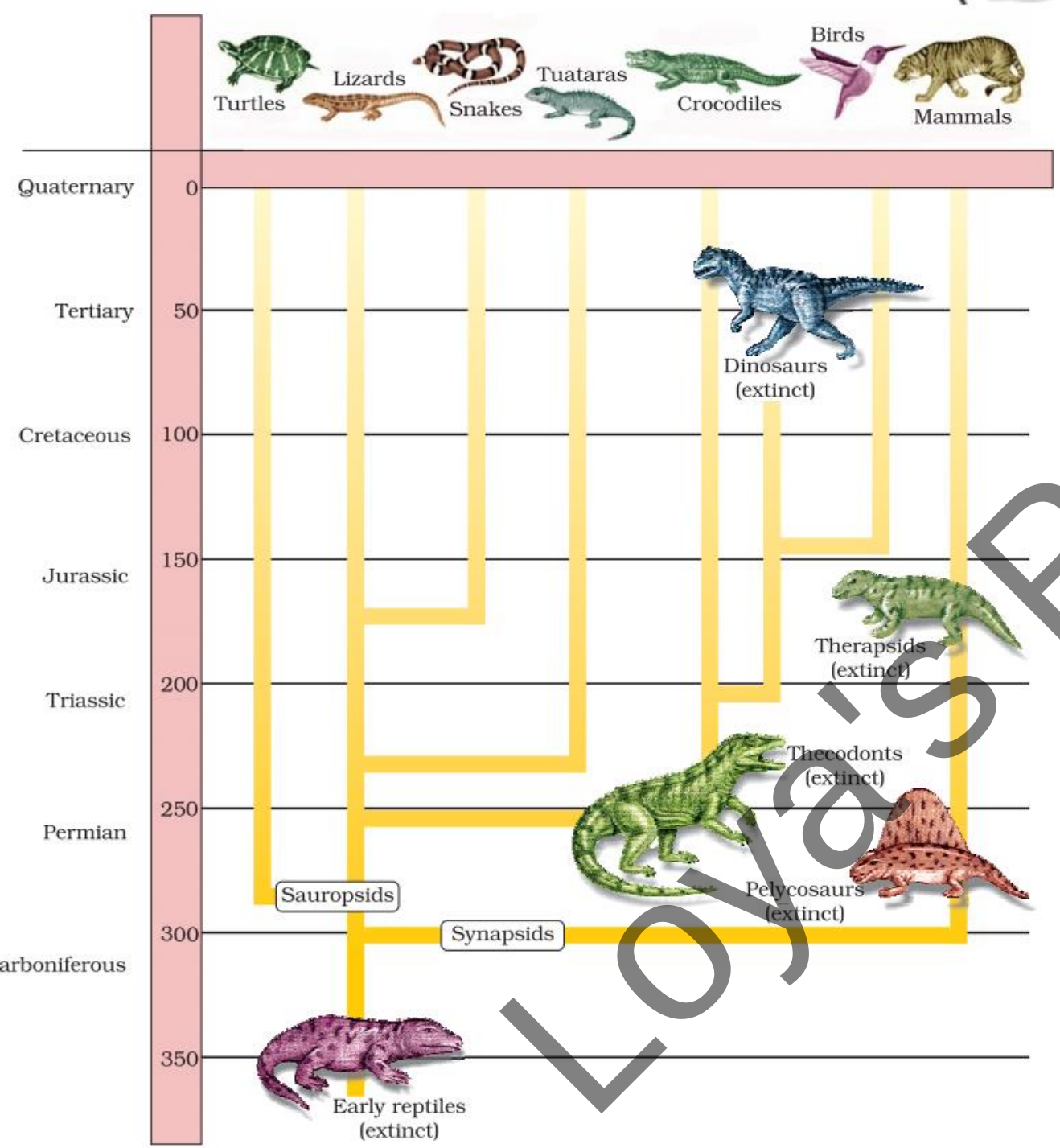
- About 2000 million years ago (mya) the first cellular forms of life appeared on earth.
- By the time of 500 mya, multicellular organisms like invertebrates were formed and active.
- Jawless fish probably evolved around 350 mya.
- All early life forms were originated in water.

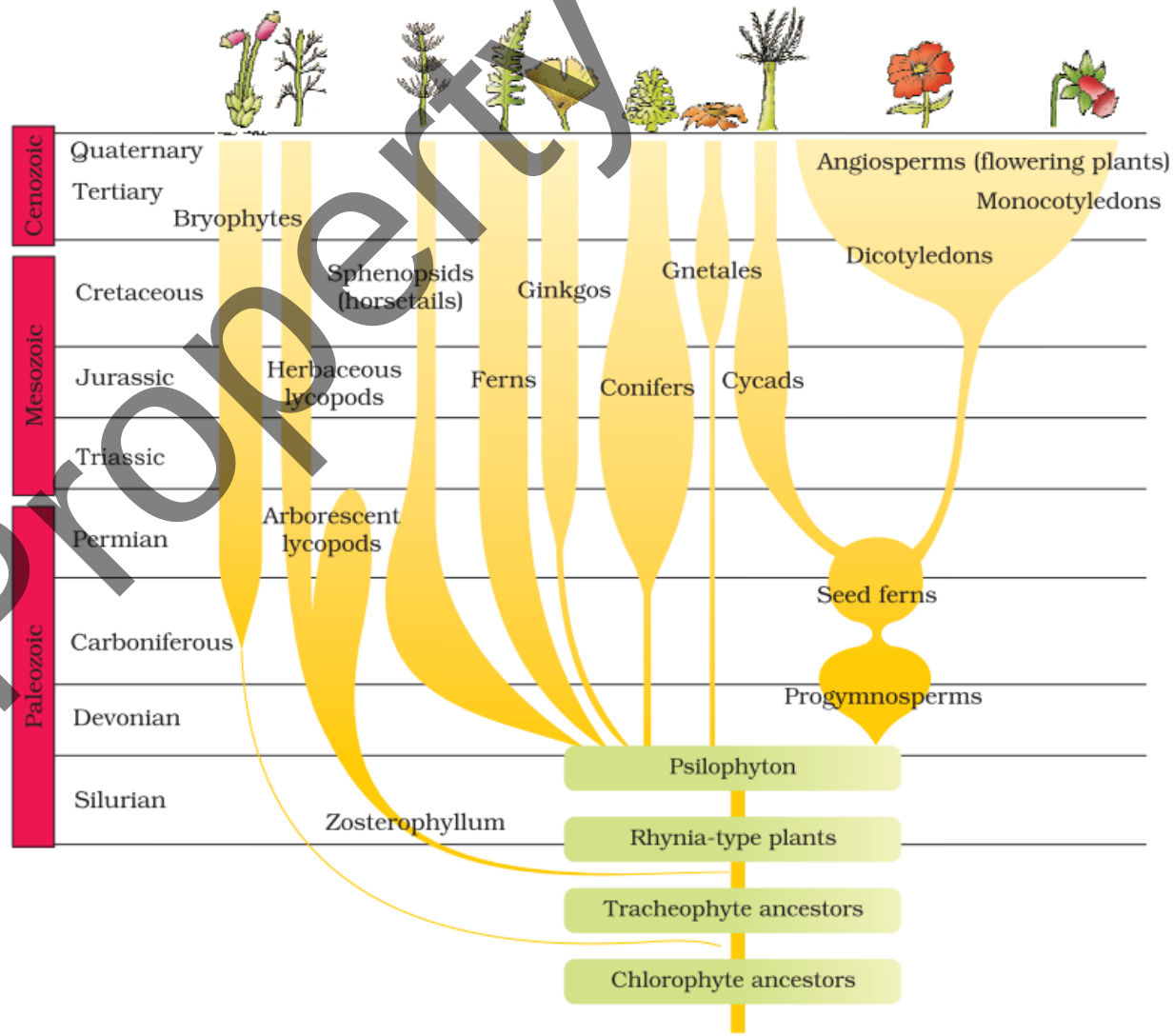
- Sea weeds and few plants existed probably around 320 mya.
- The first organisms that invaded land were plants. They were widespread on land when animals invaded land.

- At around 350 mya, Fish with stout and strong fins which could move on land and go back to water were evolved.
- 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.
- However, 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
- Probably around 200 mya, some of these land reptiles went back into water to evolve into fish like reptiles (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.
- However Small sized reptiles of that era still exist today.

- When reptiles came down mammals took over this earth.
- The first mammals were like shrews
- Due to the 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





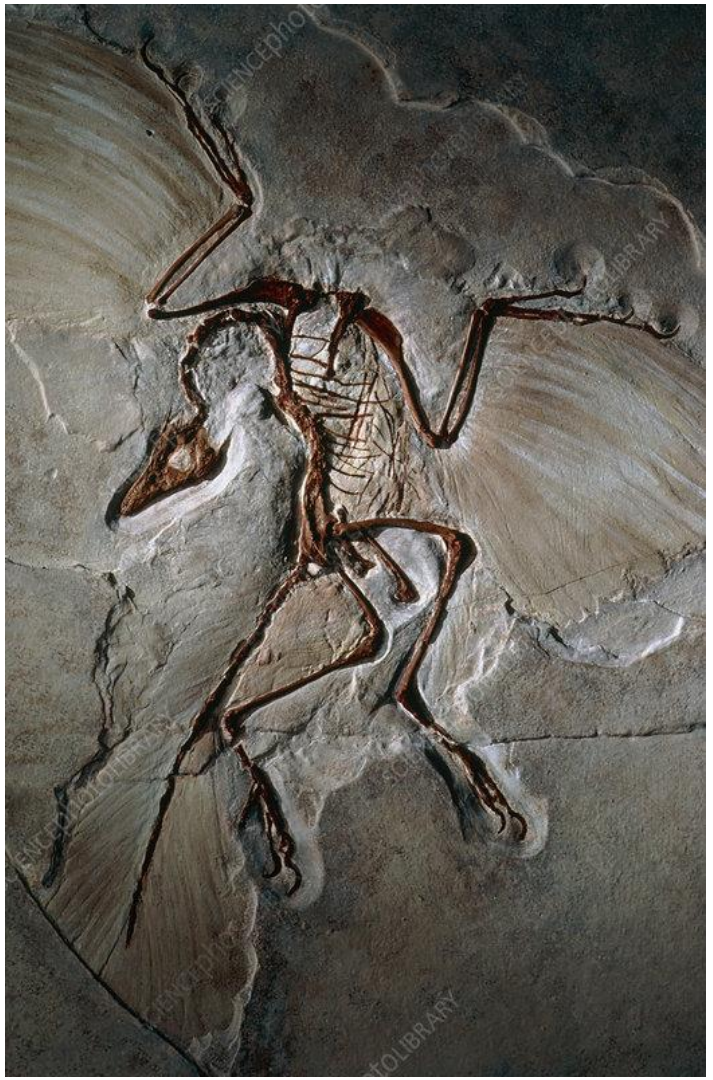
EVIDENCES FOR EVOLUTION

A. Paleontological evidence:

- **Fossils** - are remains of hard parts of life-forms found in rocks.
- Different-aged rock - contain fossils of different life-forms existed at different geological time period.
- Certain life forms are restricted to certain geological timespans.
- Rocks of early era contains less number of fossils with simple body structure while rocks of later era contains fossils of more complex organisms.
- It shows that ***complex forms have evolve from simple forms*** in gradual manner at different times in the history of earth.

- Fossil also provide evidence for gradual evolution in the form of **missing links** – fossils records showing transitional link forms i.e. characters of two different groups of organisms.

E.g. ***Archaeopteryx*** – transitional fossil between birds and reptiles



a. <u>Reptilian characters</u>

- A long tail is present
- Bones not pneumatic
- Jaws are provided with similar teeth
- Presence of free caudal vertebrae
- Forelimb typical reptilian plan, each digit terminate into a claw

ii. Avian characters

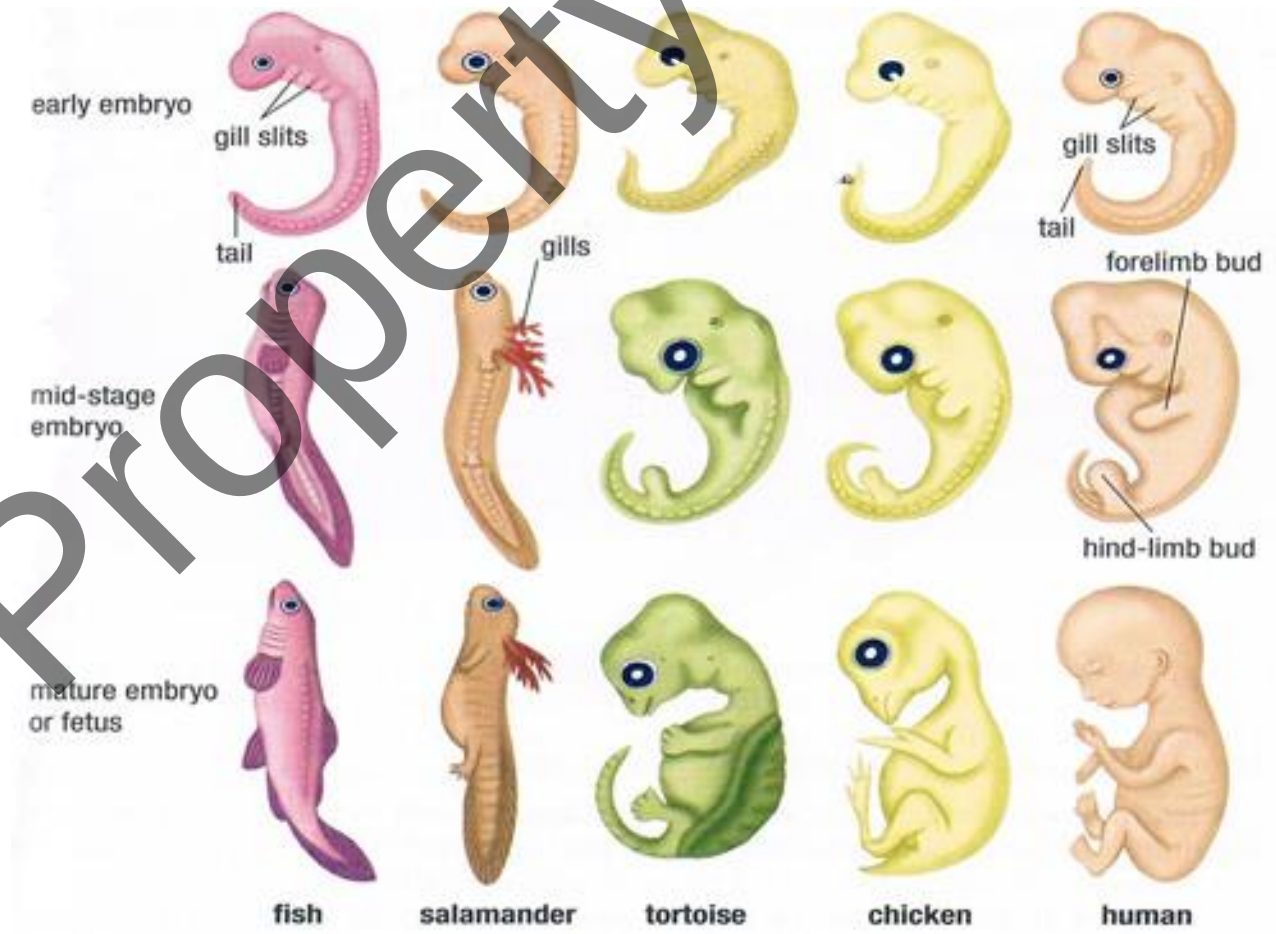
- Presence of feathers on the body
- Two jaws modified into a beak
- Forelimbs modified into wings
- Hind limb typical avian plan –
- Intimate fusion of skull bones

- This evidence suggest that one form of organism evolved from another organism through gradual modifications.
- "Birds are glorified reptiles"

B. Embryological evidence

i. Resemblance among vertebrate embryos

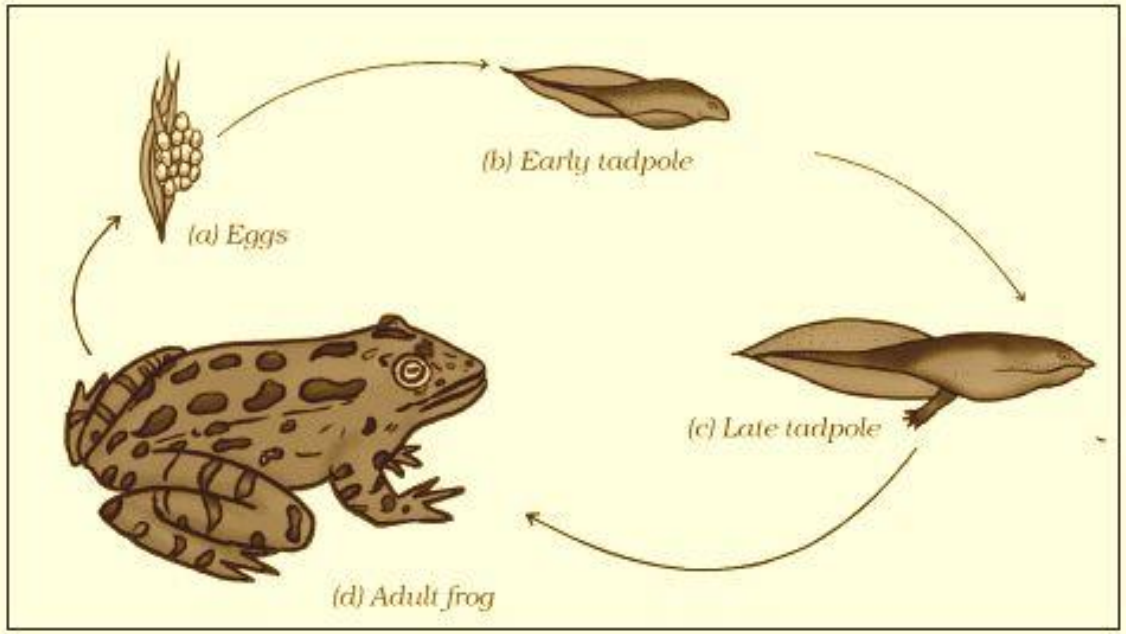
- Proposed by **Ernst Heckel**
- Certain features during embryonic stage common to all vertebrates that are absent in adult.
- The embryos of all vertebrates - develop a row of vestigial gill slits just behind the head.



ii. Recapitulation theory or Biogenetic law –

- First proposed by **Von Baer** as **Baer's Law**
- Later called Biogenetic Law by **Ernst Haeckel**
- It states that "***Ontogeny recapitulates phylogeny***"
- It means that the development of the embryo of an animal, from fertilization to gestation or hatching (ontogeny), goes through stages resembling or representing adult stages in the evolution of the animal's ancestors (phylogeny).

- E.g. in the development of frog, a fish like tailed larva is formed, which swims with the tail and respire by gills like fish. This suggest frog evolve from fish like ancestor.

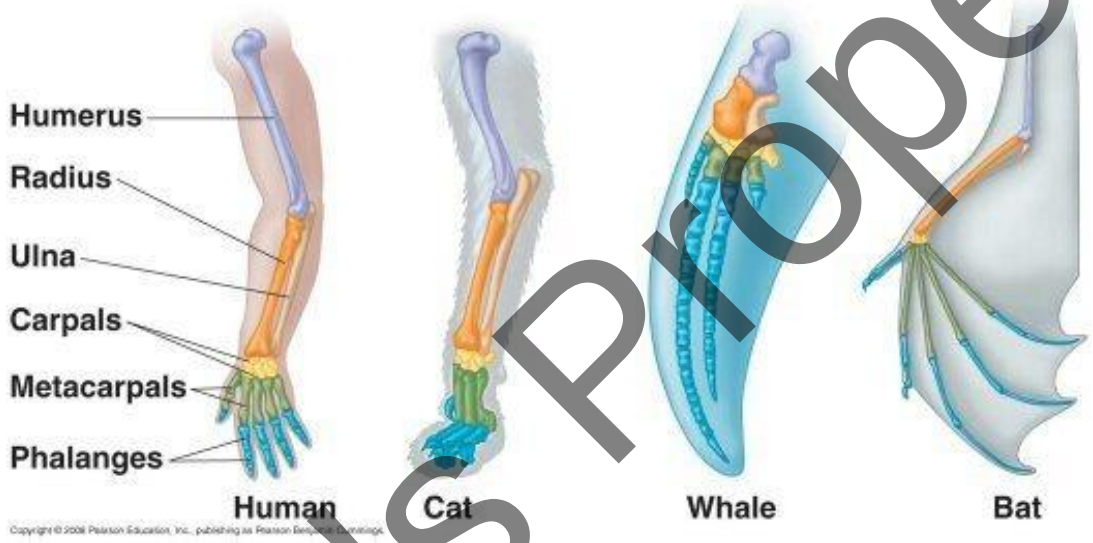


C. Comparative anatomy and morphological evidence:

- Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago.
- The similarities can be interpreted as - Homologous organs, Analogous organs, Connecting links, Vestigial organs, Atavism

i. Homologous organs

- Organs having different functions but same fundamental structure and origin.
- E.g. **pattern of bones of forelimbs of whale, bats, cheetah and human**

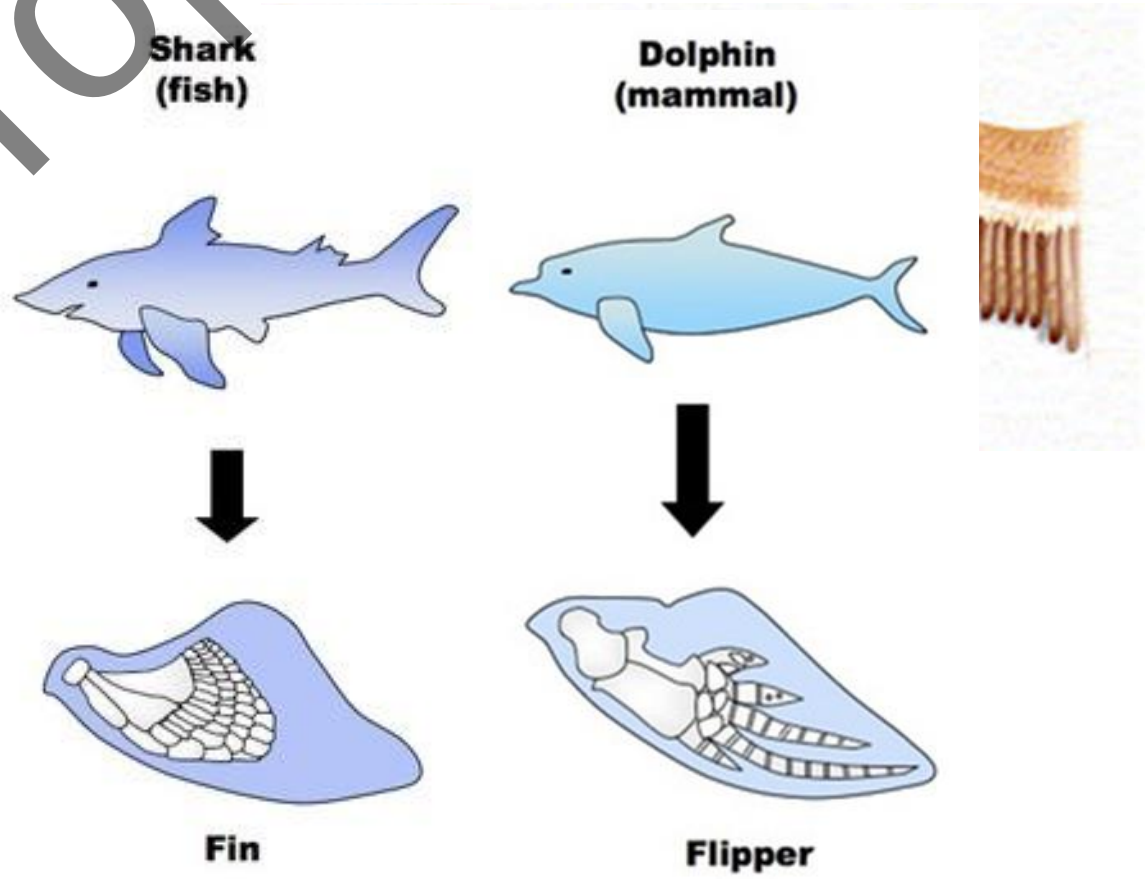


- These forelimbs perform different functions in these animals
- But they have similar anatomical structure – all of them have *humerus, radius, ulna, carpals, metacarpals and phalanges*.
- Such organs are result of **divergent** evolution – same structures modified into different forms due to adaptation to different needs or habitat.

- Examples in plants
  - **Thorn of *Bougainvillea*** and **tendrils of *Cucurbita***
  - The axillary buds in the two plants are developed into different structures to perform different functions

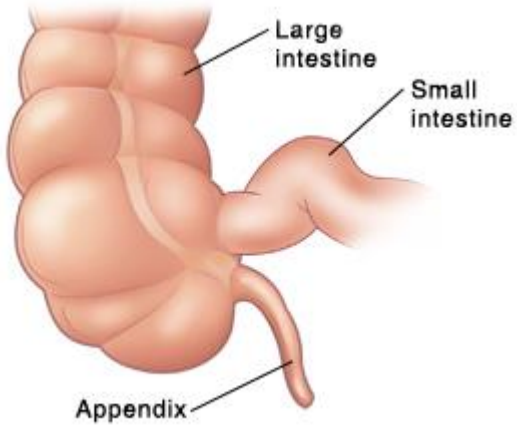
ii. Analogous organs

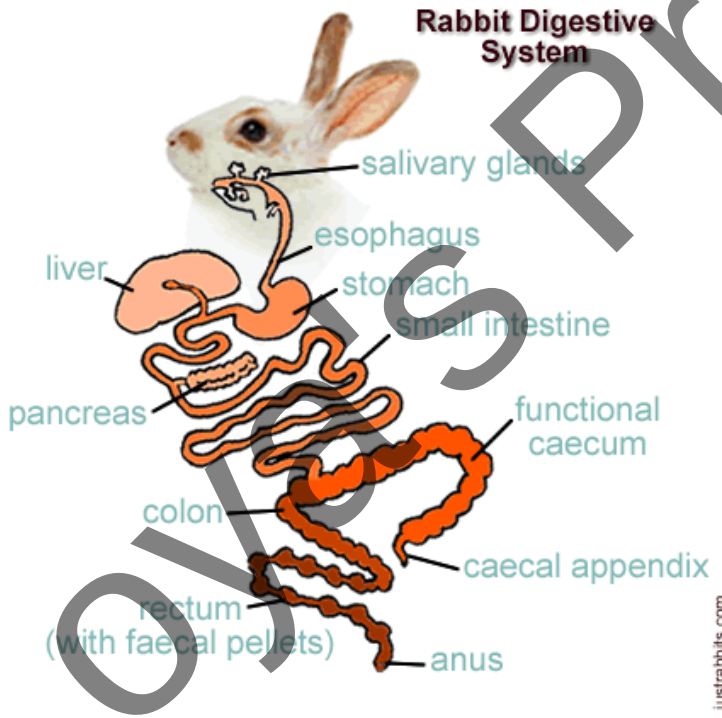
- Organs which have similar functions but different anatomical structures and origin.
- Analogous organs are result of **convergent evolution** - the similar habitat has resulted in selection of similar adaptive features in different groups of organisms but toward the same function.
- Examples
  a. Wings of butterfly and of birds.
  b. Eye of octopus and eye of mammals.
  c. Pectoral fins of shark and flippers of whale/dolphin
  d. Flippers of Penguin and Dolphin
  e. Sting of honey bee and scorpion.
  f. Sweat potato (root modification) and potato (stem modification).



iii. Vestigial organs

- The degenerated, rudimentary organs which are non-functional in the possessor but corresponds to functional in their ancestor and in related animals
- E.g. *Vermiform appendix, auricular muscles of pinna, coccyx, third molar (wisdom teeth), nictitating membrane, goosebumps etc.*



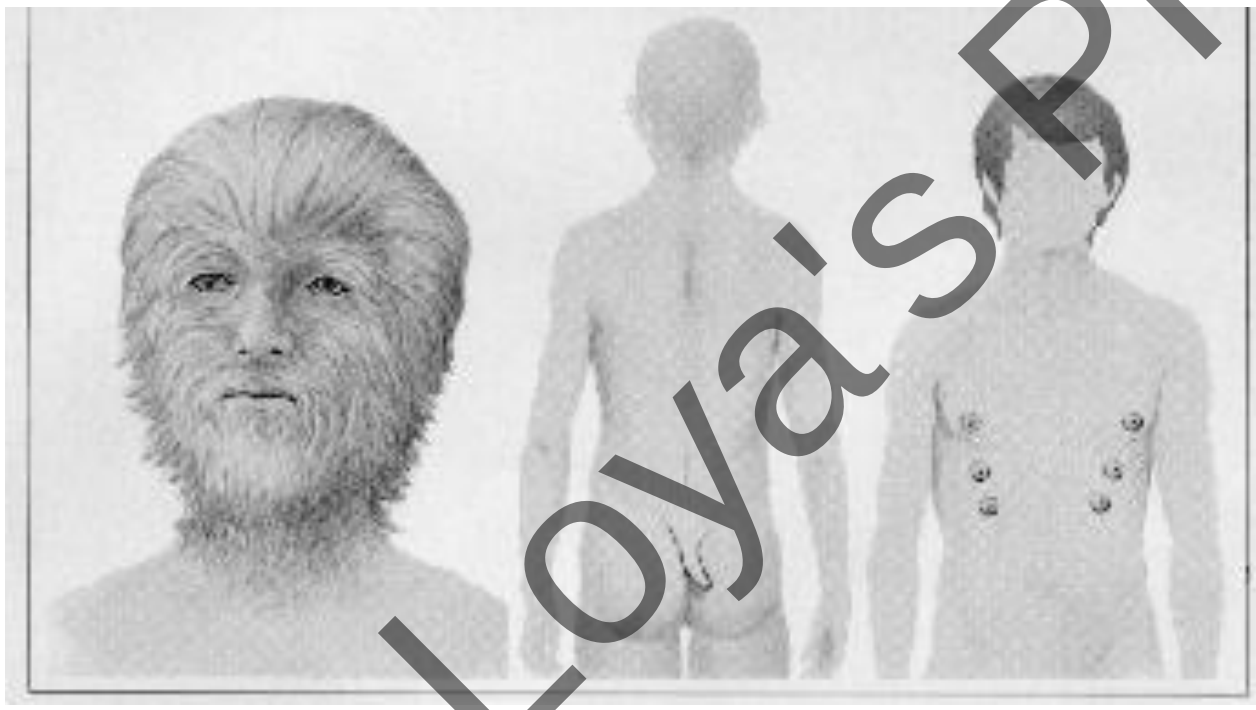


Tail bone in human being

Nictitating membrane in the eyes of man (Left) and ape (Right)

iv. Atavism

- Sudden reappearance of some ancestral organs, which have either completely disappeared or are present as vestigial organs.
- E.g. *Long and dense facial hair, power of moving pinna, baby with a tail etc.*



D. Evidences from connecting links

- Organisms having the characteristics of more than one group of organisms. Such organisms establish continuity in the series by providing that one group has evolve from the other.
- E.g.
  - *Euglena* – plants and animals.
  - *Balanoglossus* – non-chordate and chordata
  - *Latimeria* – Fish and amphbians
  - Lung fishes – fish and Amphibians.
  - *Ornithorhynchus* – reptiles and mammals

E. Biochemical evidences:

- Similarities in proteins and genes performing a given function among diverse organisms give clues to common ancestry.
- Hemoglobin chains of humans, gorillas and chimpanzees,
  - Between humans and gorillas – one amino acid in both alpha and beta chains
  - Humans and chimpanzees no difference.
  - The differences between gorillas and humans and the similarities between humans and chimpanzees also show that a closer genetic link exists between humans and chimpanzees.

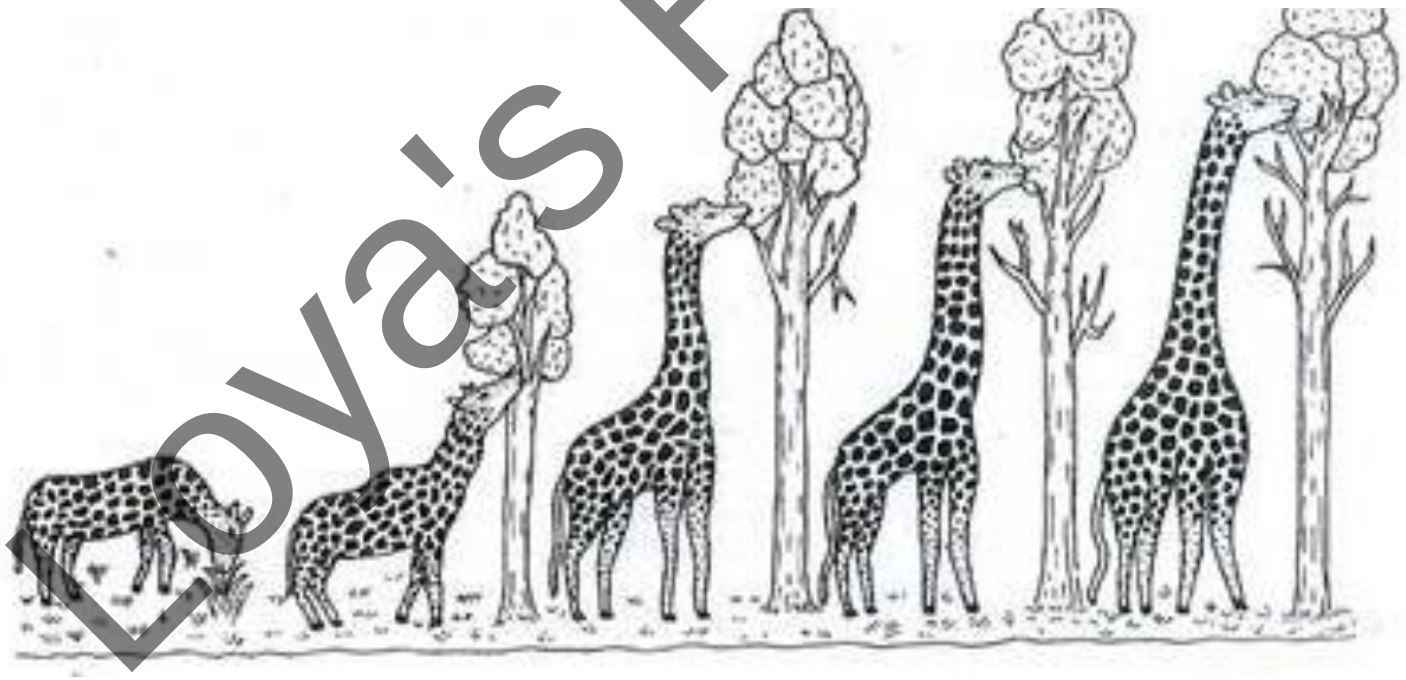
BIOLOGICAL EVOLUTION - Theories of evolution

A. Theory of special creation

- Conventional religious literature beliefs.
- All living organisms was created by God with his divine powers.
- three connotations of the theory:-
    i. All the living organisms (species types) that we see today were created as such.
    ii. The diversity was always the same since creation and will be same in future.
    iii. Earth is about 4000 years old.

Lamarck theory of evolution: (theory of inheritance of acquired characters)

- Evolution of life forms had occurred, driven by use and disuse of organs.
- Constantly used organs become stronger and get inherited, unused organs degenerate (Inheritance of acquired characters).



E.g. Evolution of Giraffe:

- Ancestors of Giraffes had short neck.
- Sudden disappearance of grass leaves the giraffe to feed on tree leaves.
- Continuous stretching of neck in an attempt to forage leaves on tall trees result in elongation of necks.
- They passed on this acquired character of elongated neck to succeeding generations.
- Giraffes, slowly over the years, came to acquire long necks.

Darwin’s theory of natural selection

- **Darwin’s Observation**
  - There has been gradual evolution of life forms on earth.
  - New forms arising at different periods in history.
  - At the same time there have been extinctions of different life forms too in the past.
  - Existing life forms share similarities to varying degrees not only among themselves but also with life forms that millions of years ago.

Theory of Natural Selection

- **Variability in a population**
  - Individuals in a population has built in variations in characteristics.
- **Survival of fittest** (**Natural Selection**)
  - The process where individuals having characteristics which enable to survive better in natural conditions would outbreed others and left a large number of offspring while individuals which are lesser fit failed to reproduce and survive.
  - Individuals who are better adapted will survive more in subsequent generations and hence are said to be selected by nature i.e. natural selection.
- This is the mechanism of evolution of different life forms.

Theory of Alfred Wallace,

- a naturalist who worked in Malay Archipelago had also come to similar conclusions around the same time

Conclusion

- All the existing life forms share similarities and evolve from a common ancestors.
- However, these ancestors were present at different periods in the history of earth
- earth is very old, not thousands of years as was thought earlier but billions of years old

Example of evolution by natural selection

Industrial melanism:

- Based on observation of moth population in England made in 1850.
- Before industrialization set in, it was observed that there were more white-winged moths on trees than dark-winged or melanised moths.
- After industrialization i.e. 1920 there were more dark-winged moths in the same area i.e. the proportion was reversed.

Explanation:

Pre industrialization period

- thick growth of white-coloured lichen covered the trees
- in that background the white winged moth survived but the dark-coloured moth were picked out by predators

Post industrialisation 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.

- This showed that in a mixed population, those that can better-adapt, survive and increase in population size. The most adapted ones are then said to be selected by nature.

Evolution by anthropogenic action:

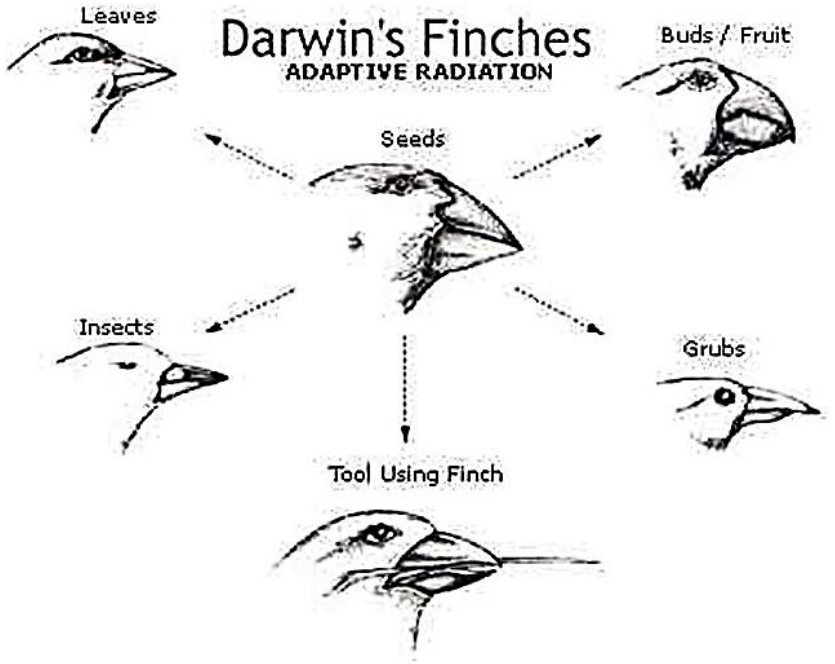
- Excess use of herbicides, pesticides etc., resulted in selection of resistant varieties in a much lesser time scale.
- Evolution of microbes resistant against antibiotics or drugs.
- Hence, resistant organisms/cells are appearing in a time scale of months or years and not centuries

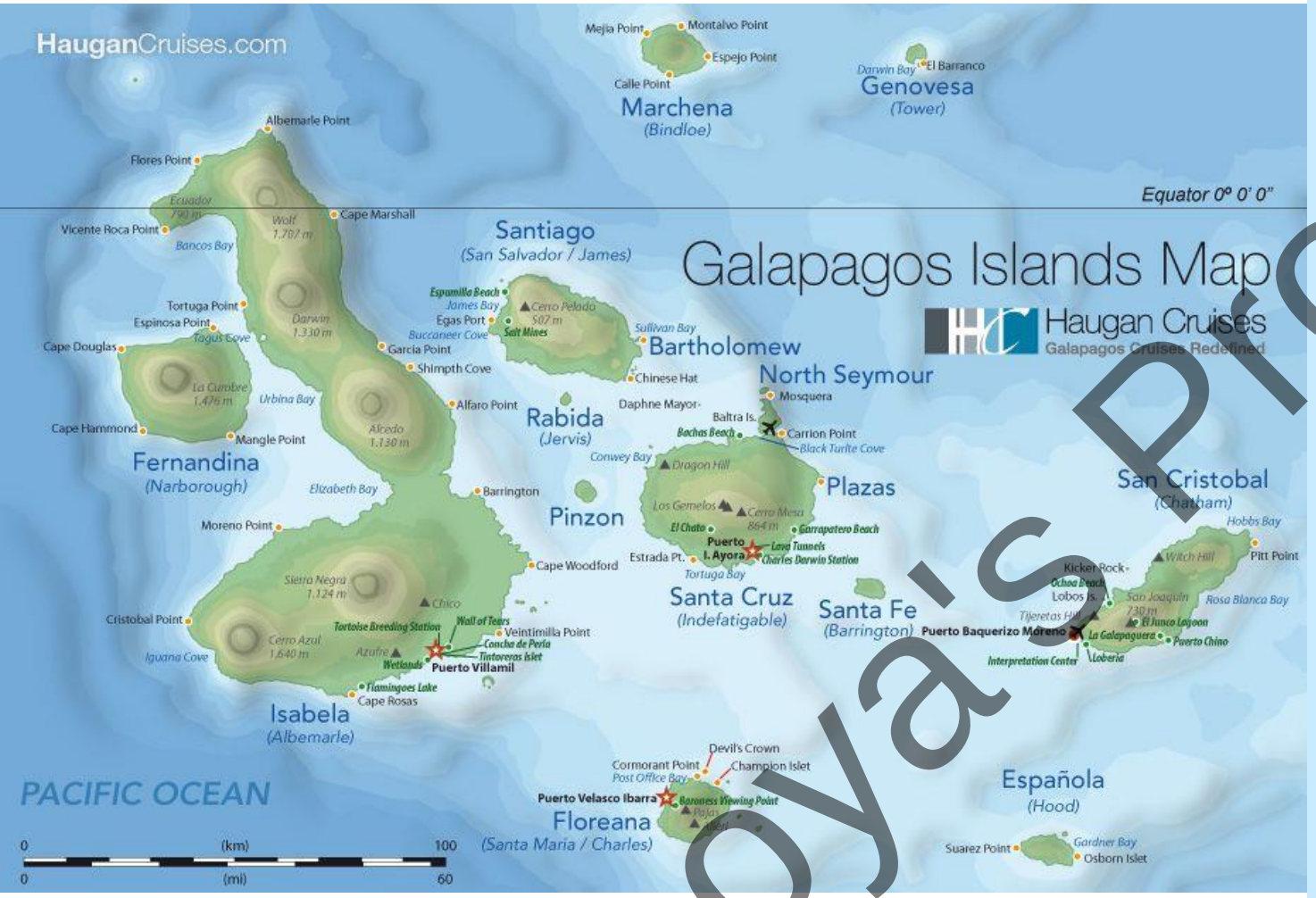
Adaptive Radiation (Divergent evolution)

- Development of different species with diverse forms from a common ancestral species adapted to different habitats in an isolated geographical location is called **adaptive radiation**.

Darwin's Finches:

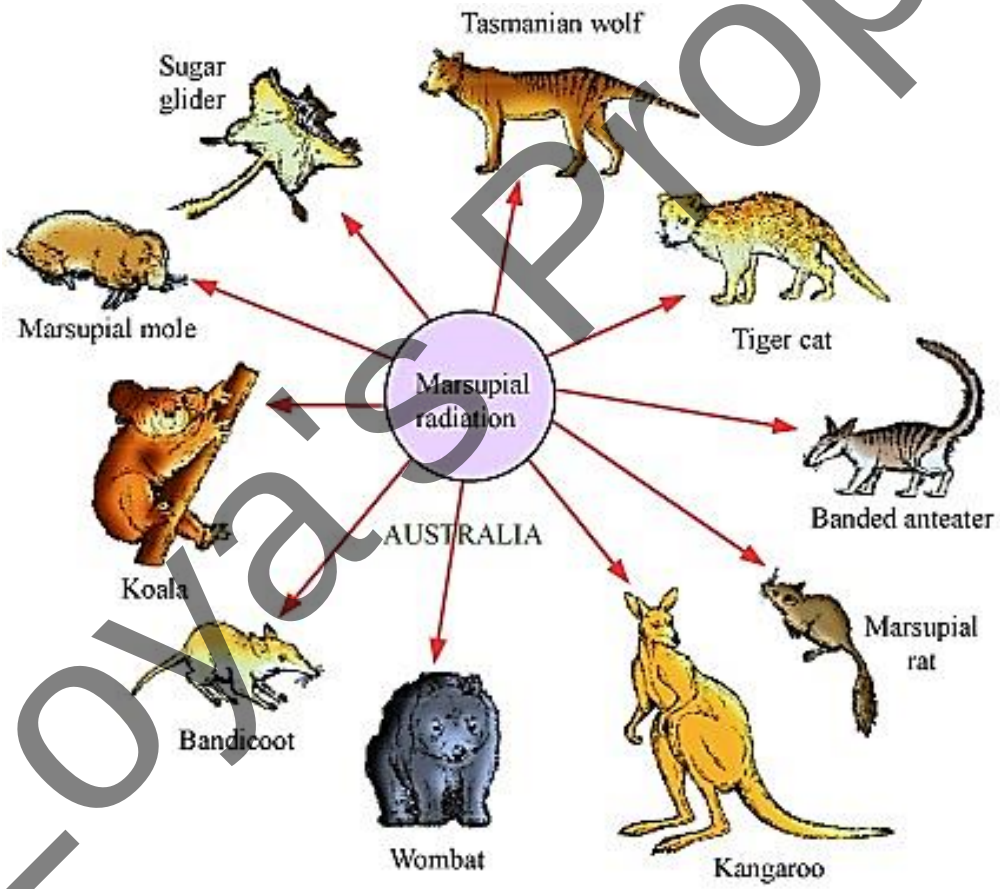
- Examples
- Small black Birds observed by Darwin in Galapagos Islands.
- Observe many varieties of finches each differs in beak size.
- He conjectured that all varieties evolved on the island itself from original - seed-eating features, to other forms with altered beaks, each adapted to different foods available on different islands.





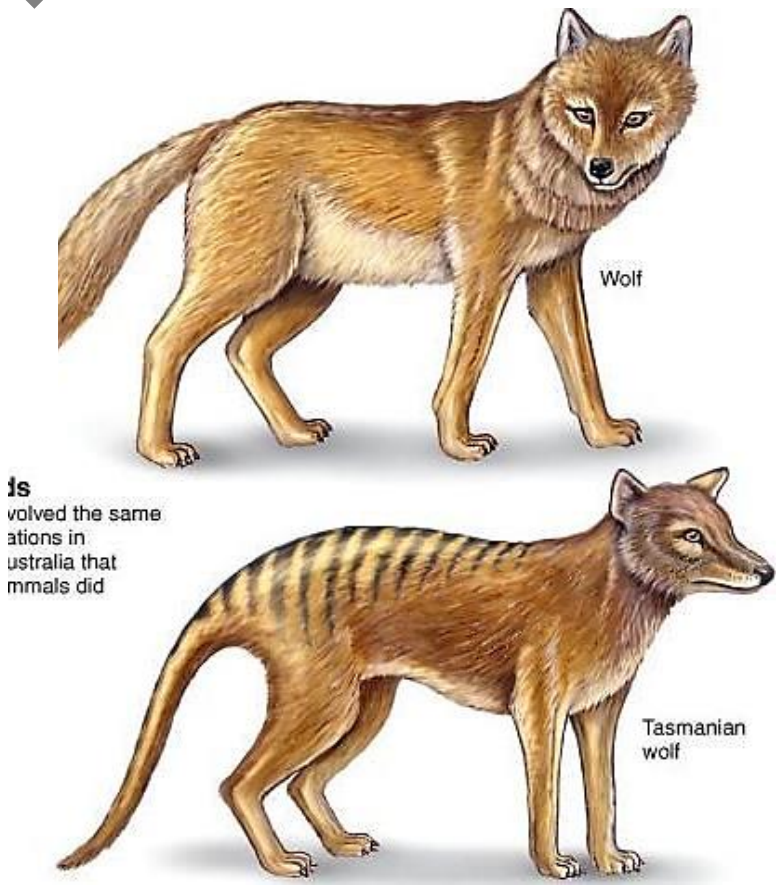
Australian marsupial:

- A number of marsupials each different from the other evolved from an ancestral stock, all within the Australian continent.



Convergent evolution

- more than one adaptive radiation occurred in an isolated geographical area (representing different habitats) resulting into similar organisms.
- **E.g.** adaptive radiation **of Placental and Marsupial mammals** in Australia into different varieties, each of which appears to be ‘similar’ to a corresponding **marsupial** (e.g. placental wolf and Tasmanian wolf-marsupial).



MUTATION THEORY OF HUGO DEVRIES

- Mutation is the large difference arising suddenly in a population.
- According to this theory evolution of one form of organism from another takes place through a single step large mutation called **saltation**.

Differences Darwin's theory of natural selection and mutation theory

- Mutation is the force of evolution and not through minor variations that Darwin think.
- Mutations are random and directionless while Darwinian variations are small and directional.
- Evolution for Darwin was gradual while de Vries believed that single step large mutation caused speciation.

MODERN SYNTHETIC THEORY

- T. Dobzhansky, J.B.S. Haldane, R.A. Fisher, Sewall Wright, G.L. Stebbins, Ernst Mayr in the years 1930 and 1940 describe this theory.
- Term was coined by Huxley and are often called neo-darwinism.
- This theory is the merging of the Darwinian evolution with the Mendelian genetics.
- This theory states that – ***Evolution occurs due to accumulation of genetic variations (change in allele frequencies) in population over long periods of time***.
- **Alternatively** - ***genetic changes occurring in the populations leads to the formation of new species.***

- Formation of new species involves the following basic functions.

I. Genetic variability in a population

- Difference in allele composition (hence morphological difference) among individuals of a population.

II. Natural selection –

- Individuals which are better fit, survive and leaves more umber of progeny than lesser fit individuals.
- This results in difference in allele frequency of genes from one generation to another in a population.

III. Reproductive isolation and Speciation –

- Separation by geographical and physiological barriers between two populations results in preventing the interbreeding of related organisms (reproductive isolation).
- These populations become different from each other morphologically and genetically and finally become different species.

HARDY – WEINBERG PRINCIPLE:

- The principle states that allele frequencies in a population are stable and is constant from generation to generation provided population is not acted upon by evolutionary forces.
- The gene pool (total genes and their alleles in a population) remains a constant generation after generation. This is called **genetic equilibrium**:

- Hardy-Weinberg principle stated it using algebraic equations.

i) **p+q=1** Sum total of the allelic frequencies of a gene occupying a locus is 1.

ii) $\mathbf{p^2 + 2pq + q^2 = 1}$ Sum total of genotype frequencies of a gene in a population is 1

p = frequency of dominant allele

q = frequency of recessive allele

p2 = frequency of individuals with homozygous dominant genotype

q2 = frequency of individuals with homozygous recessive genotype

2pq = frequency of individuals with heterozygous genotype

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

- Factors that affect Hardy-Weinberg equilibrium. These event must be absent on order to maintain H.W.E.
    i. **Mutation.**
    ii. **Gene migration or gene flow.**
    iii. **Genetic drift.**
    iv. **Genetic recombination.**
    v. **Non-random mating.**
    vi. **Natural selection.**

- **Mutation:**
  - Sudden heritable change in genetic material of an organism.
  - Major source of variation in a population.

- **Gene migration or gene flow**
  - Migrations of a section of population to another place occur leading to change in gene frequencies in the original as well as in the new population is termed as gene flow.
  - New genes /alleles are added to the new population and these are lost from the old population.

- **Genetic drift (Sewall wright effect)**:
  - Random change in allele frequencies of a small population occur by chance is called genetic drift.
  - Has two effects
    - **Founder effect:** Sometimes one or few individuals of a population migrate from their original population to a new habitat, and established into a population; the allelic frequency in the new population become different from original population. The original drifted population becomes **founder species** and the effect is called **founder effect.**
    - **Bottle neck effect:** random change in allele frequency when a population is affected by natural disaster such that the population is represented by very few surviving individuals. The resultant alterations and loss of genetic variability has been termed as bottleneck effect.

- **Genetic recombination:**
  - Non-parental arrangement of alleles in a progeny due to independent assortment and crossing over during gamete formation. It results in new allele combination as well as create new genes.

- **Non-random mating:**
  - Mating between individuals with certain genotypes more commonly than random basis. It results in increase of homozygocity of alleles within a population.

- **Natural selection:**
  - Selection of individuals better adapted (fit) to the environment leading to their survival and continuous reproduction leads to increase in frequency of those alleles in the population.
  - If the selection is done by environmental factors –**natural selection**

Types of natural selection

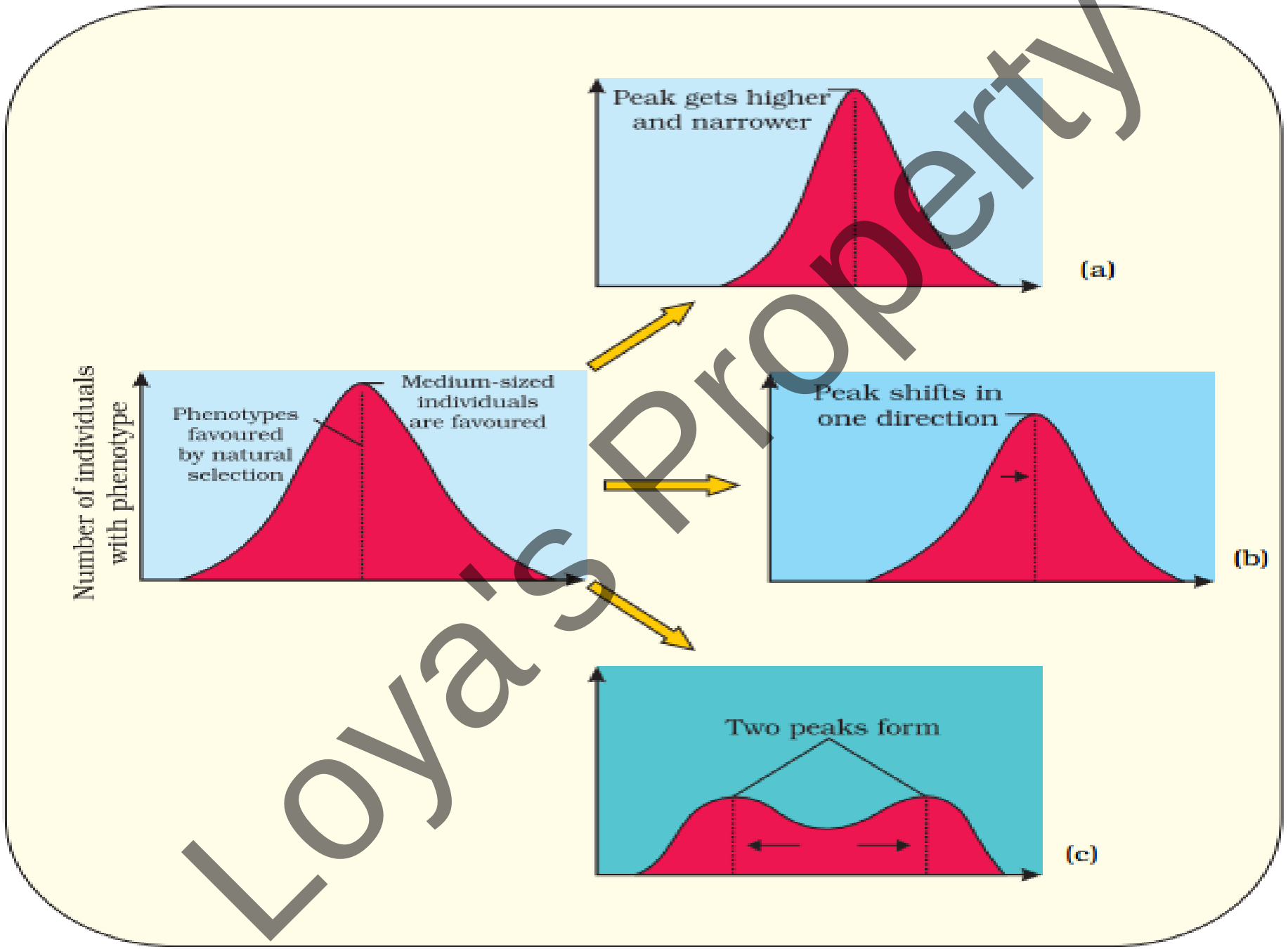
- **Natural Selection** - It is the process by which those organisms which are better adapted to the environment survive and leaves a larger number of offsprings while organisms not so well adapted fail to reproduce and die. The former organisms pass on their characters to next generation whereas the latter do not.

- Types – a population usually has

  i) **Stabilizing selection** – selection that favours average sized individuals while eliminates small size individuals.

  ii) **Directional selection** – the population changes towards one particular direction

  iii) **Disruptive selection** – this selection favours both small sized and large sized individuals while medium size individuals are eliminated leading to two different populations.



In a random mating population of 1000 individuals, 640 individual belongs to RR genotype, 320 belongs to Rr genotype while the remaining 40 belongs to rr genotype what will be frequency of recessive allele :-

(1) 0.2

(2) 0.8

(3) 0.6

(4) 0.4

If the frequency of an autosomal dominant allele is 0.6. Calculate the frequency of recessive phenotype in a population of 6000 :

(1) 1200

(2) 4000

(3) 960

(4) 1000

In a random mating population frequency of dominant allele is 0.7. What will be the frequency of recessive phenotype:-

(1) 0.49

(2) 0.09

(3) 0.3

(4) 0.21