ORIGIN AND EVOLUTION

Our earth has two types of matters: living & non-living. All the matter, be it living or non-living changes from one form to other. Similarly all the biodiversity on earth also changed over time. Study of history of life forms on earth is called evolutionary biology.

In this chapter we will learn about origin of life, evolution of life forms, available evidences of evolution and in detail about mechanism driving evolution & human evolution.

Herbert Spencer coined the term organic evolution. Literally evolution means to unroll or to unfold. Branch of science dealing with evolution is called evolutionary biology & often Darwin is referred as father of evolutionary biology.

Thedosius Dobzhansky said "nothing in biology makes sense except in the light of evolution". Before going through the process of organic evolution, first question that arises in our mind is that how first forms of life, universe, earth, stars originated? So we will firstly study about origin of universe, our solar system & of course life!

ORIGIN OF LIFE (BIOPOIESIS)

"Life is capacity of an organism to maintain itself & reproduce to give rise to off springs. Before going through origin of life, we should acquaint our self with origin of universe & origin of earth.

Universe is very vast, probably infinite in volume consisting of billions of galaxies. One of these galaxies is ours i.e. The Milky Way (Aakash Ganga). Distance between stars, planets & galaxies is measured in light years & called stellar distances.

When an object is too far from us; in range of trillions (10^{14}) Kilometer away, light emitted from that will reach to our eyes after thousands of years. This is the reason, when we look at stars in a clear sky. It is said we are in a way, looking back in time or we can say that when we are looking at stars, we apparently are peeping into the past.

BIG BANG THEORY

Proposed by Abbe Lemaitre (1950). Universe is very old i.e. some 20 billion years old. (1 billion = 1000 million). This theory states about a single huge explosion, due to which universe expanded & hence temperature came down.

After some time of explosion, Hydrogen & Helium were formed. Which later on condensed under gravitational force to form higher elements & further galaxies were formed.

NEBULAR THEORY

Proposed by Kant & Laplace for origin of our solar system but now a days stands rejected. Somehow our solar system & earth were formed due to condensation of primitive material of universe & it occurred some 4.5 billion years ago.

CLASSICAL THEORIES FOR ORIGIN OF LIFE

1. Theory of special creation

Spanish Priest, father Suarez was greatest supporter of this theory. He said that

i. Earth is 4000 years old.

ii. All living organisms that we see today were created as such.

iii. Diversity was always the same since creation & will remain the same in near future also.
According to Bible, life was created by God in 6 days.
This theory is based on mythological belief purely & has no scientific evidence, so was rejected.

2. Theory of spontaneous creation (Abiogenesis)

This theory states that life is created spontaneously from nonliving matter. Aristotle & Pluto were great supporters of this theory.

Von Helmont believed that if a dirty shirt & wheat grains are kept together for 21 days in dark room, it will give rise to mice.

This theory was rejected after careful experiments of Louis Pasteur, Fransisco Redi & Lazzaro Spallanzani.

3. Cosmozoic theory/Theory of Panspermia

This theory was put forward **by Richter (1865) and supported by Arrhenius.** As per this concept, life is distributed all over **cosmos** in the form of resistant spores (of living organisms) called **cosmozoa**, which together with the cosmic dust, might have reached the earth accidentally, from other planets of the universe.

Due to vacuum, fluctuating temperature of space, no life form can survive there, so it was rejected. Still it is favourite idea of astronomers.

4. Theory of Biogenesis

This theory explains that the existing living organisms originated from pre-existing living beings and not from non-living entities.

To prove biogenesis and to disapprove abiogenesis the following experiments were performed.

F. Redi (1668) conducted an experiment in which he cooked some meat so that no micro-organism was left alive and placed it in three jars; one jar left uncovered, one jar was covered with muslin cloth and the third jar covered with parchment paper. He concluded that flies arise from the pre-existing flies.

Lazzaro Spallanzani (1767) prepared a nutritive broth of vegetables and flesh and he boiled the broth and placed it in flasks and sealed the necks of the flasks just to check the entry of air and left these flasks undisturbed for many days.

He observed that no living organisms appeared in the broth. So, he concluded that microorganisms are formed from preexisting microorganisms.

Louis Pasteur (1860) refuted the concept of spontaneous generation on the basis of an experiment. He designed the 'swan necked flask'. He prepared a sterilized syrup of sugar and yeast by boiling them in flasks.

He took two flasks; one having a broken neck and another having a curved neck (swan neck flask). No life appeared in the swan neck flask because germ laden dust particles in the air were trapped by the curved neck which serves as a filter while in the broken neck flask, colonies of microorganisms developed. By this experiment and result, Pasteur conclusively disproved the idea of spontaneous generation.

- ❖ Theory failed to explain origin of first cell.

5. Theory of catastrophism

This theory was supported by Cuvier. According to him, catastrophe causes complete devastation of life on earth. After each catastrophe, life originates from inorganic matter. Due to lack of evidences the theory was rejected.

THEORY OF CHEMICAL ORIGIN OF LIFE / OPARIN-HALDANE THEORY / MODERN THEORY / ARTIFICIAL SYNTHESIS THEORY

A. I. Oparin was Russian Biochemist, he wrote a book "The origin of life", in which he presented his point regarding origin of life.

J.B.S Haldane was born in England, Later on moved to India, he was geneticist & evolutionary biologist. He died in 1964 in Bhubaneswar.

Both of them proposed their theories separately, but now studied collectively. This theory is also called "primary abiogenesis" or "Naturalistic theory". Their theory has two parts namely chemical evolution & biological evolution.

I. Chemical evolution

A. Atomic Stage. Earth originated 4.5 billion years ago, process of origin of life started 4.0 billion years ago.
First element present on earth was Hydrogen, which reacted further to from all elements.

$$H + H \longrightarrow He$$

Though all elements were present viz C, H, O, and N but most abundant of them was Hydrogen.

B. Formation of simple inorganic compounds.
Free atoms reacted to from simple inorganic compounds.

$$2\,H_2 + O_2 \longrightarrow 2\,H_2O$$
$$3\,H_2 + N_2 \longrightarrow 2\,NH_3$$

First compound to be formed were water & ammonia, in reaction for formation of water, O_2 was limiting factor, so the reaction continued till O_2 was present & so early atmosphere was anaerobic/reducing.
Later on CO_2, CO were formed & some amount of N_2 & H_2 were left.

C. Formation of early organic compounds

$$N_2 + \text{Metal ion} \longrightarrow \text{Nitrites}$$
$$CO_2 + \text{Metal ion} \longrightarrow \text{Carbides}$$
$$\text{Carbides} + H_2O\ (\text{water vapour}) \longrightarrow CH_4$$

Later on HCN was also formed. Heavy rain took place for millions of years so as to cool down the temperature of earth.
So CH_4 and HCN were first organic compounds to be formed on earth.

D. Formation of simple organic compounds
All the early organic compounds formed were collected in oceans formed due to heavy rain. Due to high amount of energy available, they reacted to form simple sugar, amino acids, glycerol, fatty acids, nitrogenous bases etc.

E. Formation of complex organic compounds
Simple compounds polymerized to form complex compounds as protein, polysaccharide, nucleic acid, fats etc.
First formed proteins were non enzymatic. Sea water containing these compounds was called hot dilute soup by Haldane.
Now we should know about source of energy for all these reactions, so the energy was supplied by
i. High temperature
ii. Volcanic eruptions
iii. UV radiations. (Ozone layer was absent)

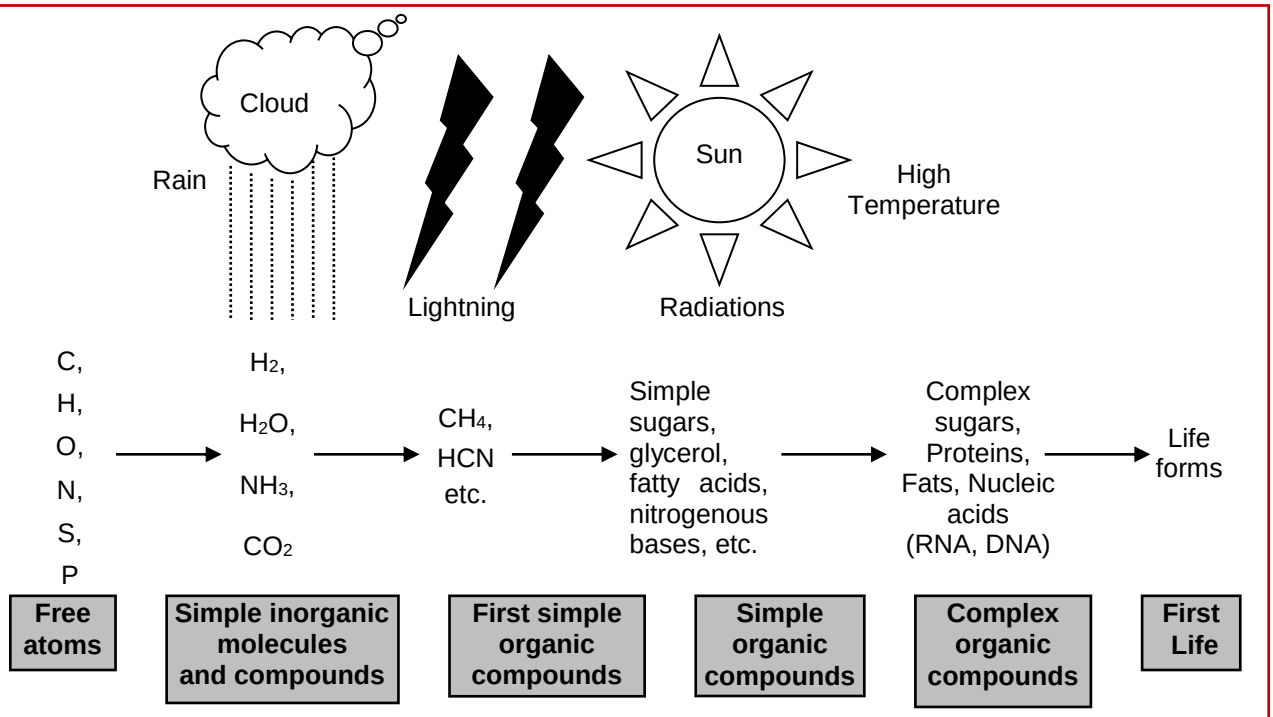


Fig. Process of chemical origin of life (as proposed by Oparin and Haldane)
The formation of diverse organic molecules from inorganic constituent was termed chemical evolution

EXPERIMENTAL VERIFICATION OF CHEMICAL ORIGIN OF LIFE

Stanley Miller and Harold Urey (1953) experimentally supported the chemical origin of life, which was explained by Haldane and Oparin. They tried to replicate the primordial atmosphere and successfully proved the chemical origin of life with their **simulation experiment.** Miller sealed a mixture of **water vapour, methane, ammonia and hydrogen (simulation of primeval atmosphere)**(ratio of methane, ammonia and hydrogen was 2 :1: 2) in the spark chamber, which was provided with electrodes for electric discharge **(simulation of lightning)**. The spark chamber was connected to another flask, with the provision for boiling (simulation of evaporation). The spark chamber was connected, on the other end, to a trap, by a tube that passed through condenser **(simulation of rain and condensation of Haldane's soup)**. The trap was also connected to the boiling flask for circulation. They noticed that after **7** days **Glycine, alanine**, **aspartic acid** were produced. Glycine was first amino acid to be formed. In similar experiments others observed formation of sugars, nitrogenous bases, pigments and fats. Around 15% of carbon available in experiment was incorporated in these amino acids.

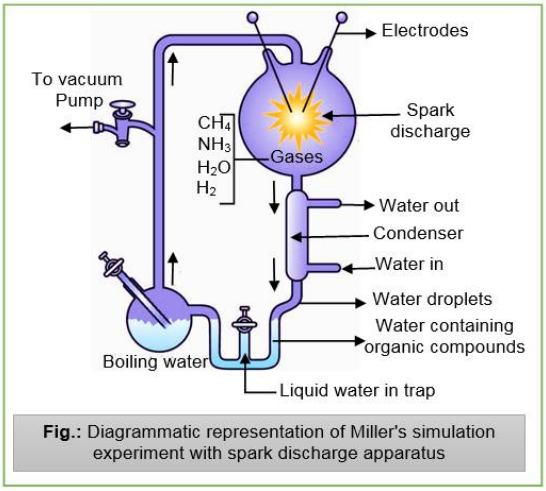


Fig.: Diagrammatic representation of Miller's simulation experiment with spark discharge apparatus

II. Biological evolution

Biological evolution includes formation of protobionts, origin of living organisms from the protobionts and the diversification of organisms all through the ages.

A. Formation of prebiotic structures or Protobionts

Polymers thus formed faster, predominated, as they were more stable. Stable polymers shifted the chemical equilibrium from **unstable monomers to stable polymers**. For the origin of life, three conditions were needed.

i. Self-reproducing molecules called **free genes or replicates**.

ii. Errors during the copying of replicates i.e. **mutations**.

iii. A continuous supply of **free energy and partial isolation** of the molecules from the environment

a. Coacervates

Oparin (1924), solution of carbohydrates & proteins made in water. Later on shaken to form coacervates. Could grow & exhibit metabolism, but lipid membrane & reproduction was absent.

Oparin made coacervates by mixing gum Arabic & histone proteins at a pH of 6.2.

b. Microsphere / Proteids

Sydney Fox (1964), heated mixture of amino acids (130-180°C) & later on poured in cold water with lipids. Lipid bilayer was present.

c. Vesicles

Deamer (1993), if coacervates & microsphere are mixed it will form protobiont, having all type of chemicals.

- ❖ Protobionts can't be regarded as precursor of life as they lack ability to reproduce.
- ❖ In our solar system, only Mars is supposed to have life as water is present there, but yet not proved.
- ❖ Moon could also have life as water is reported.

RNA FIRST MODEL

Proposed after first artificial RNA synthesis without DNA by Professor Hargovind Khorana. RNA has both genetic & catalytic abilities. First enzyme could have been RNA (ribozyme).

B. Formation of living organisms

The free genes, started absorbing the organic compounds from the prebiotic soup and evolved into **anaerobic heterotrophs, three to four billion years ago.** They obtained their energy by the fermentation of some of the organic molecules. The earliest living organisms had clumps of nucleoproteins containing one or two DNA molecules, which were similar to organisms of Monera. So chemoheterotrophs were the first organisms to be formed.

$$C_6H_{12}O_6 + 2ADP + 2Pi \xrightarrow{\text{Fermentation enzyme}} 2C_2H_5OH + 2CO_2 + 2ATP$$

During the course of evolution early prokaryotes acquired the "carbohydrate-synthesis" catalyzing enzymes. Thus, early **chemoautotrophic organisms (iron and sulphur bacteria)** evolved. These bacteria take carbon dioxide into their bodies and use the chemical energy to create nourishing carbohydrates and sugars. A unique characteristic of these chemoautotrophic bacteria, is that they thrive at high temperatures.

$$6CO_2 + 12H_2S \xrightarrow{\text{Chemical energy}} C_6H_{12}O_6 + 6H_2O + 12S$$

Meanwhile some bacteria synthesized **bacterial chlorophyll (purple and green sulphur bacteria)** from the **metalloporphyrin (magnesium porphyrin)** of ocean waters. This pigment trapped the solar energy and fixed the CO_2, The phosphorylation was anoxygenic. These were the **anoxygenic photoautrotrophic organisms**.

Later **oxygenic photoautotrophic organisms** like blue green algae (cyanobacteria) were evolved. The **bacterial chlorophyll** evolved into true chlorophyll (cyanobacteria and plants). Large quantity of oxygen was released into the atmosphere due to the evolution of true chlorophyll. O_2 released into the atmosphere brought about radical changes in the primitive atmosphere. These events transformed the reducing atmosphere into modern oxidizing atmosphere.

$$6CO_2 + 6H_2O \xrightarrow{\text{Solar energy}} C_6H_{12}O_6 + 6O_2$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$
$$6NH_4 + 6O_2 \longrightarrow 3N_2 + 12H_2O$$

The free oxygen began to accumulate in the atmosphere **about two billion years ago**. The modern atmosphere mostly contains nitrogen, oxygen, carbon dioxide and water vapour. With the availability of free oxygen finally aerobic mode of respiration was evolved. Carbon dioxide was released in this mode of respiration. Oxygen accumulated in atmosphere and was converted to ozone which stopped UV radiations and hence supply of high energy was interrupted.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

Eukaryotes were evolved by two processes. Endomembrane system of eukaryotes including nuclear membrane might have evolved by infolding of the plasma membrane of ancestral prokaryotes. Symbiotically prokaryotes lived in the ancestral eukaryotes and evolved into organelles like mitochondria and plastids.

PRESENT VIEW OF ORIGIN OF LIFE

- Complex organic molecules as RNA, Protein and Polysaccharide were first forms of life on earth: These giant molecules appeared some 3 billion years ago.
- First cell was chemo heterotroph & prokaryote, appeared 2 billion years ago.
- All life forms were formed in sea.
- Early forms of life were anaerobe, So O_2 was absent.
- Majority of scientists have accepted concept of first abiogenesis & then ever biogenesis.
- Chemoheterotrophs later on evolved to autotrophs& liberated oxygen.
- Oxygen made atmosphere aerobic, so no new origin of life is now possible.
- Oxygen converted to ozone, which formed ozone layer.
- Oceans are major source of oxygen.

WHAT ARE THE EVIDENCES FOR EVOLUTION?

Evidence that evolution of life forms has indeed taken place on earth has come from many quarters.

1. EVIDENCE FROM THE FOSSIL RECORD

- Fossils are remnant 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.
- Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment.
- Some of them appear similar to modern organisms. They represent extinct organisms (e.g., Dinosaurs). A study of fossils in different sedimentary layers indicates the geological period in which they existed.
- The study showed that life-forms varied over time and certain life forms are restricted to certain geological time-spans. Hence, new forms of life have arisen at different times in the history of earth. All this is called paleontological evidence.
- The father of Paleontology– **Leonardo da Vinci.**
- The founder or father of modern Paleontology-**George Cuvier.**
- **Birbal Sahni** is famous Indian paleontologist. Birbal Sahni Institute is in Lucknow.

TYPES OF FOSSILS

a. Unaltered Fossils : Fossils can be in the form of complete organisms, e.g. Wooly mammoths, Wooly rhino found in Siberian ice.
b. Petrified Fossils : They are formed by replacement of decomposed organic matter by minerals.
c. Mould : Statue like mineral bodies of the extinct organisms.
d. Cast : Sometimes minerals fill in the mould resulting in cast.
e. Coprolite: The fossils of faecal matter or rectal content are called '**Coprolites**'. They indicate the type of food consumed by the extinct organism.

DATING OF FOSSILS (ROCKS)

Fossils can be dated by two methods first by relative dating and second absolute dating, there are two main methods for absolute dating, the radioactive method (^{238}U, ^{40}K and ^{14}C) and Electron Spin Resonance (ESR) method, for dating of the rocks.

I. RADIOACTIVE METHODS

i. Radioactive Uranium method (^{238}U)

The half-life period of this uranium is 4.5 billion years. After which it finally changes to stable lead (^{236}Pb). It can be used for dating the fossil/rock of more than 50 million years old.

ii. Potassium argon method (^{40}K)

The half-life period of this radioactive isotope is 1.3 billion years, after which it is converted to ^{40}Ar.

iii. Radioactive Carbon method (^{14}C)

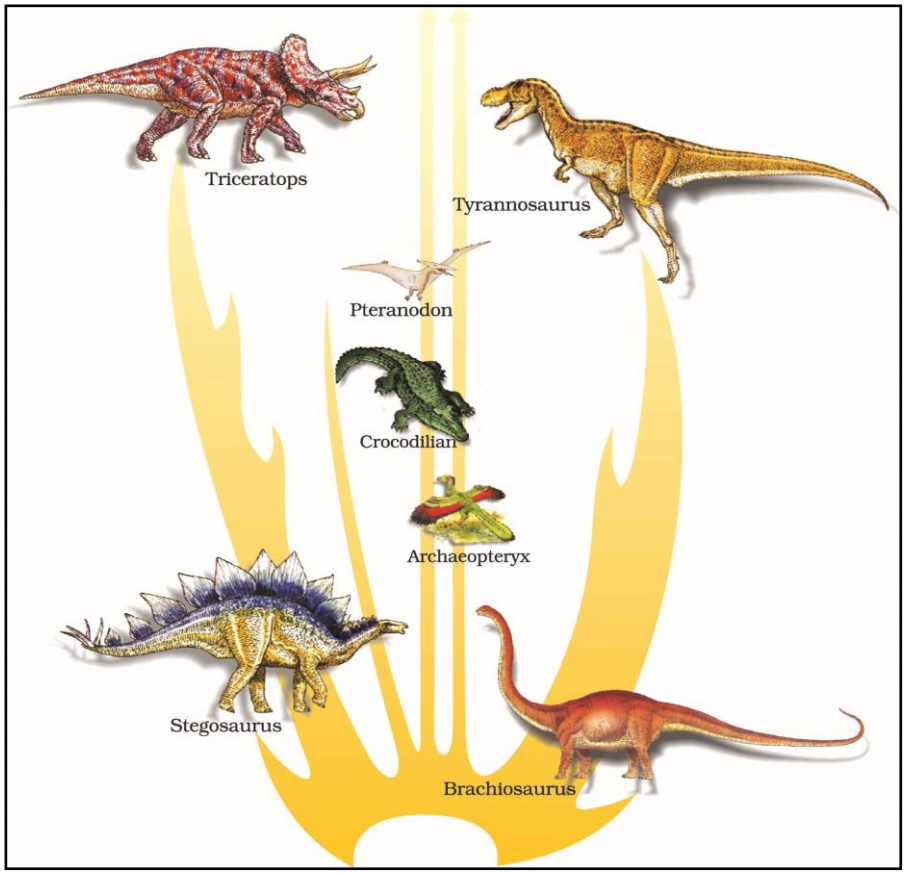
The half-life period of this carbon is 5750 years. After which it changes into ^{14}N. This method can be used for dating recent fossils.

II. ELECTRON SPIN RESONANCE (ESR) METHOD

It is also based on the accumulation of trapped electrons in minerals: more the trapped electron present, the older the sample is. It is used to find the age of coral reefs and tooth enamel.

- It is most accurate method for dating of fossils.

FAMILY TREE OF DINOSAURS



I. ***Tricerotops*****:** Herbivorous, 3 horned, present during cretaceous period, similar to modern Rhinoceros.

II. ***Tyrannosaurus*****:** Carnivorous ate *Tricerotops*, largest dinosaur, dagger like teeth, present during cretaceous period, biped locomotion.

III. ***Pteranodon*****:** Largest flying reptile, toothless, present in cretaceous period, technically was not a dinosaur.

IV. ***Stegosaurus*****:** Bony plates present on dorsal side and tail, herbivorous, present in late Jurassic period.

V. ***Brachiosaurus*****:** Giraffe like neck so tallest & longest, herbivorous, present in Jurassic period.

VI. ***Archaeopteryx*****:** Classified as Aves, is connecting link (missing link) between reptiles and Aves. Present in Jurassic period.

Reptilian characters of *Archaeopteryx*

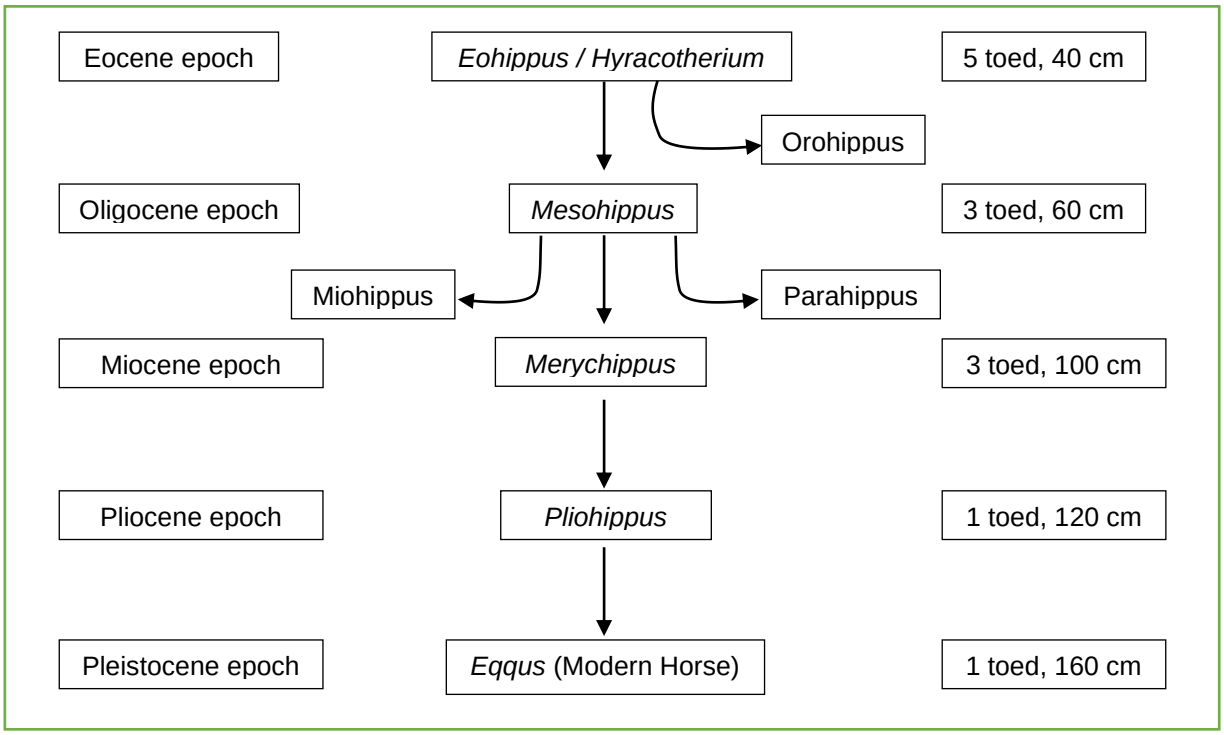
a. Body is more or less lizard like.
b. Bones are not pneumatic.
c. Similar teeth present.
d. Hand bears typical reptilian plan and each finger terminates in a claw.

Avian characters of Archaeopteryx

a. Presence of feathers on the body.
b. Jaws modified into a beak.
c. Hind limbs built on the typical avian plan.
d. Fusion of the skull bones as seen in the birds.

EVOLUTION OF HORSE

Described by C. Marsh: Most complete phylogeny is of Horse.



Trends in evolution of Horse

- Increased height & length of neck.
- Elongation of crown of teeth & development of enamel.
- Increase in cranial capacity.
- Decrease in number of toes.

THE GEOLOGICAL TIME SCALE

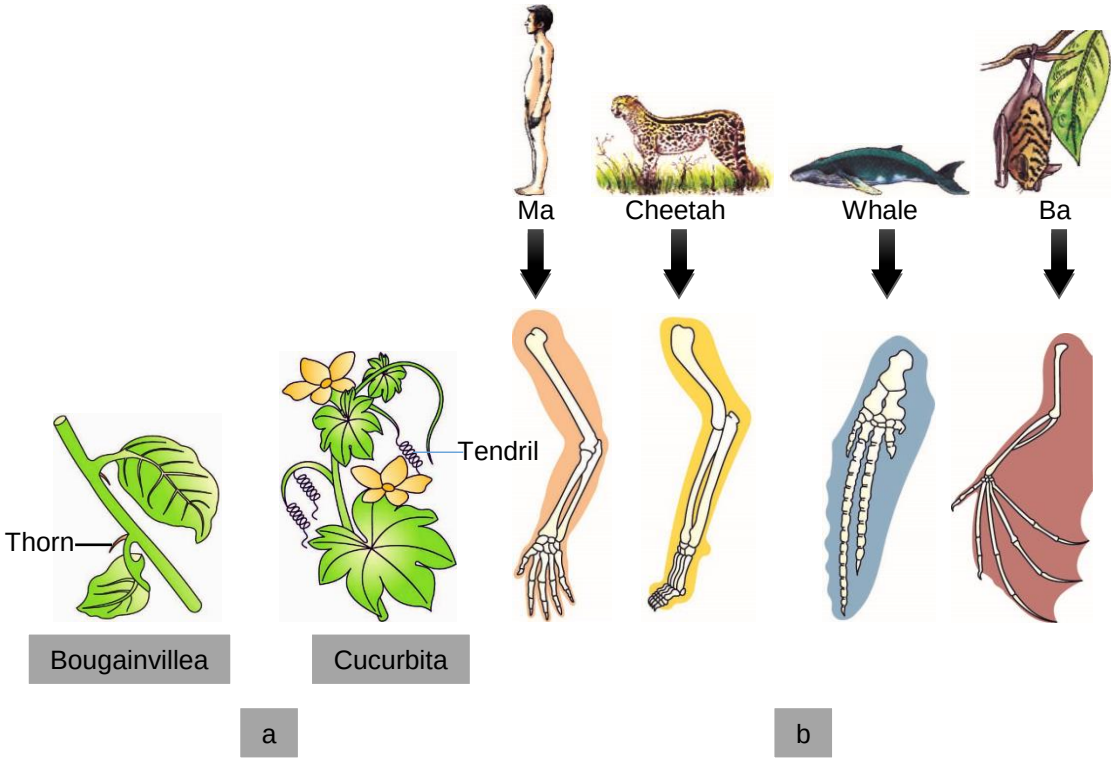
Era	Period	EPOCH	AGE (MILLIONS OF YEAR)	SOME IMPORTANT EVENTS IN THE HISTORY OF LIFE	Relative Time Span of Ears
Cenozoic	Quaternary	Recent	0.01	Historic time	Cenozoic
		Pleistocene	1.8	Ice age ; humans appear	Mesozoic
	Tertiary	Pliocene	5	Apelike ancestors of humans appear	
		Miocene	23	Continued radiation of mammals and angiosperms	Paleozoic
		Oligocene	34	Origin of most modern mammalian orders, including apes	
		Eocene	57	Angiosperm dominance increases; further increase in mammalian diversity, evolution of horse begun.	Precambrian
		Paleocene	65	Major radiation of mammals, birds, and pollinating insects	
Mesozoic	Cretaceous		144	Flowering plants (angiosperms) appear; dinosaurs and many groups of organisms become extinct.	
	Jurassic		208	Gymnosperms continue as dominant plants ; dinosaurs dominant; first birds	
	Triassic		245	Gymnosperms dominate landscape; first dinosaurs and mammals.	
Paleozoic	Permian		285	Radiation of reptiles, origin of mammal-like, reptiles and most modern orders of insects ; extinction of many marine invertebrates	
	Carboniferous		360	Extensive forest of vascular plants; first seed plants ; origin of reptiles; amphibians dominant– age of amphibians	
	Devonian		408	Diversification of bony fishes; first amphibians dominant. Age of fishes	
	Silurian		438	Diversity of jawless vertebrates ; colonization of land by plants and arthropods ; origin of vascular plants	
	Ordovician		505	First vertebrates (jawless fishes) ; marine algae abundant	
	Cambrian		544	Origin of most invertebrate phyla ; diverse algae	
Precambrian			700	Origin of first animals	
			1500	Oldest eukaryotic fossils	
			2500	Oxygen begins accumulating in atmosphere	
			3000	Oldest defined fossils known (prokaryotes)	
			4500	Approximate origin of Earth	

2. EVIDENCE FROM ANATOMY AND MORPHOLOGY

- Study of functional anatomy- Tectology.
- Different plants and animals show dis-similarities in their structure, but similarity in some characters.
- Organisms are classified, on the basis of common characters.

A. Homologous Organs

- Term coined by Richard Owen.
- They are those organs which have the same basic structure and developmental origin but perform different functions and often have different morphology too.
- Similarity is due to common ancestry.
- Homologous organs show divergent evolution or **Adaptive radiation**. It is the development of dissimilar functional structures in closely related group of organisms.



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

Examples

i. 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 yet they have similar anatomical structure – all of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs.

ii. Thorn of *Bougainvillea* & Tendril of *Cucurbita*. (Thorn for protection & tendril for climbing). Both are modification of Axillary bud.

iii. Heart & Brains of vertebrates.

iv. Mouth parts of insects.

v. Potato & Ginger (modification of stem).

vi. Radish & Carrot (root modification).

vii. Molecular Homology (similarity of biomolecules).

viii. Testes in male & ovary in female.

ix. Penis in male & Clitoris in female.

x. Limbs of cat, lizard for walking, fore limbs of whale & fore limbs of Bat.

B. Analogous Organs

- Different structures evolving for the same function and hence having similarity.
- Morphology may or may not be similar however anatomy is different.
- Indicate convergent evolution, i.e. different origin and ancestry.

Examples

i. Wings of Butterfly are analogous to wings of Bat & Birds.
ii. Eyes of Octopus & Mammal. (Different retinal position and lack of blind spot).
iii. Flipper of Penguin (bird) & Dolphin (mammal).
iv. Sweet potato (root modification) and Potato (stem modification).
v. Sting of Honeybee (Ovipositor) & Scorpion (abdominal segment).
vi. Hands of Human & trunk (modification of upper lip) of elephant.
vii. Chloragogen cell of *Pheretima* & liver of vertebrates.
viii. Gills of Prawn & Lungs of Human.

C. Vestigial Organ

- Organs present in reduced form & do not perform any function.
- These are remnant of organs that were functional in ancestors.
- Vestigial organs are considered as example of Lamarckism.

Examples in Human

- Robert Weidersheim published list of 86 vestigial organs in Human.
- Nictitating membrane
- Muscles of pinna
- Segmental muscles of abdomen
- Vermiform appendix
- Coccyx (tail bone)
- Mammary glands in male
- Canine teeth
- Caecum
- MSH in human

Examples in Other Animals

- Hind limb and pelvic girdle of python.
- Splint bone in limb of Horse.
- Wings of flightless birds.

Examples in plants

- Staminodes (vestigeal stamen), Pistillodes (vestigial Pistil) of Cucurbitaceae family.

D. Connecting Link: Organisms possessing characters of two different groups.

i. *Proterospongia (Choanoflagellates)*–Between Protozoa & Sponges.
ii. *Peripatus* – Between Annelida & Arthropoda.
iii. *Neopilina* – Between Annelida & Mollusca.
iv. Chimera – Between Chondrichthyes & Osteichthyes.
v. Lung fish (*Protopterus*) – Between Osteichthyes & Amphibia.
vi. *Archaeopteryx* – Between Reptile & Birds.
vi. Prototherians – Between Reptile & Mammals.

E. Living fossils: Living fossil are those animals, which underwent little changes during course of evolution.

i. *Limulus* (Arthropoda).
ii. *Neopilina* (Mollusca).
iii. *Latimeria* (Coelacanth fish).
iv. *Sphenodon* (Reptilia).

F. Atavism (Reversion): Sudden reappearance of some ancestral feature.

i. Human baby with tail.
ii. Large & pointed canine teeth.
iii. Extra nipples (more than two).
iv. Dense body hairs.

G. Embryological Evidences

- Proposed by Ernst Heckel, bases on observations of certain features during embryonic stage of vertebrates, that are absent in adult.
- The embryos of all vertebrates including human develop a row of vestigial gill slit just behind the head but is functional organ only in fish and not found in any other adult vertebrate.
- Ernst Heckel proposed Biogenetic law: Ontogeny recapitulates phylogeny.
- However this proposal was disapproved on careful study by Von Baer. He noted that embryos never pass through adult stages of other animals.
- Occurrence of ancestral traits in embryo-Paleogenesis.

3. EVIDENCES FROM BIO GEOGRAPHICAL DISTRIBUTION

- Biogeography is study of distribution of plants and animals on earth.
- Different animal species present in an area constitute fauna while that of plants is called flora.
- Around carboniferous period (345 mya) entire earth was in form of a single mass called Pangaea.
- P.L. Sclater (1858) divided world into 6 bio geographical realms for birds, which was later on adapted by A. R. Wallace (1876) for animals & plants.

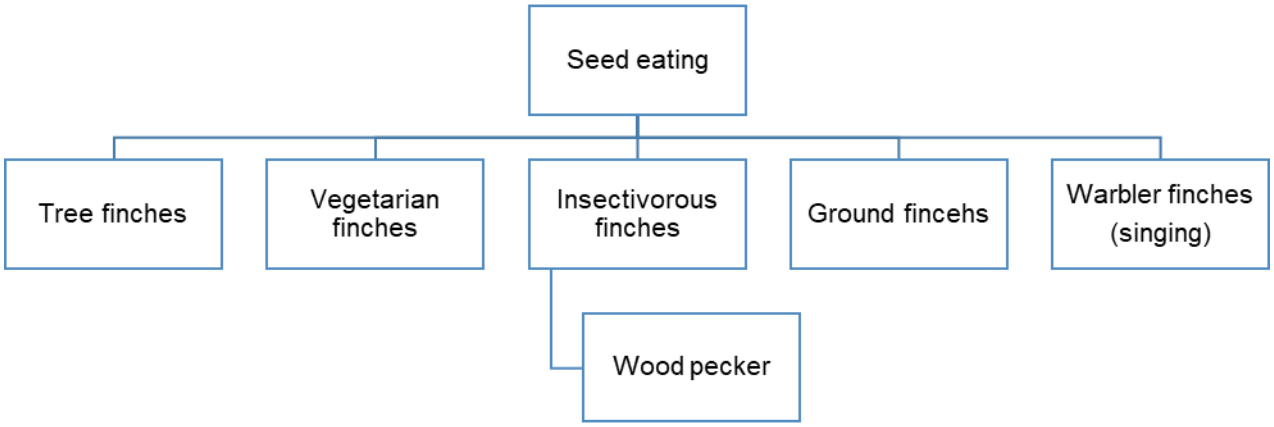
i. Nearctic, **ii.** Palaearctic, **iii.** Neotropical, **iv.** Oriental - India, **v.** Ethiopian, **vi.** Australian

- Palaearctic & oriental realms are separated by Himalaya.
- Bio geographical distribution provide following evidences.

a. Prototherians are found in Australia only as carnivore eutherians were absent there.

b. Marsupials are found only in Australia.

c. Darwin's finches (term coined by Dr. David Lack), present in Galapagos Island (on west coast of South America, 900 Km far from mainland), studied by Darwin.



- Group of 13 species of birds.
- Vegetarian finches are largest & warbler finches are smallest.
- Difference in beak is due to differential expression of BMP-4 gene (Beak morphogenetic protein).

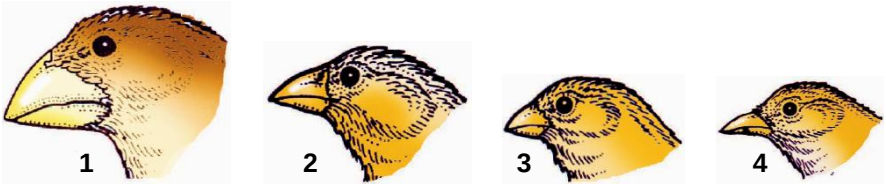
4. EVIDENCE FROM ADAPTIVE RADIATION

- The process of evolution of different species in a given geographical area starting from a point & literally radiating to other areas of geography is called adaptive radiation.
- Adaptive radiation lead to divergent evolution.
- It give rise to a variety of organisms.

Examples

a. Darwin's finches

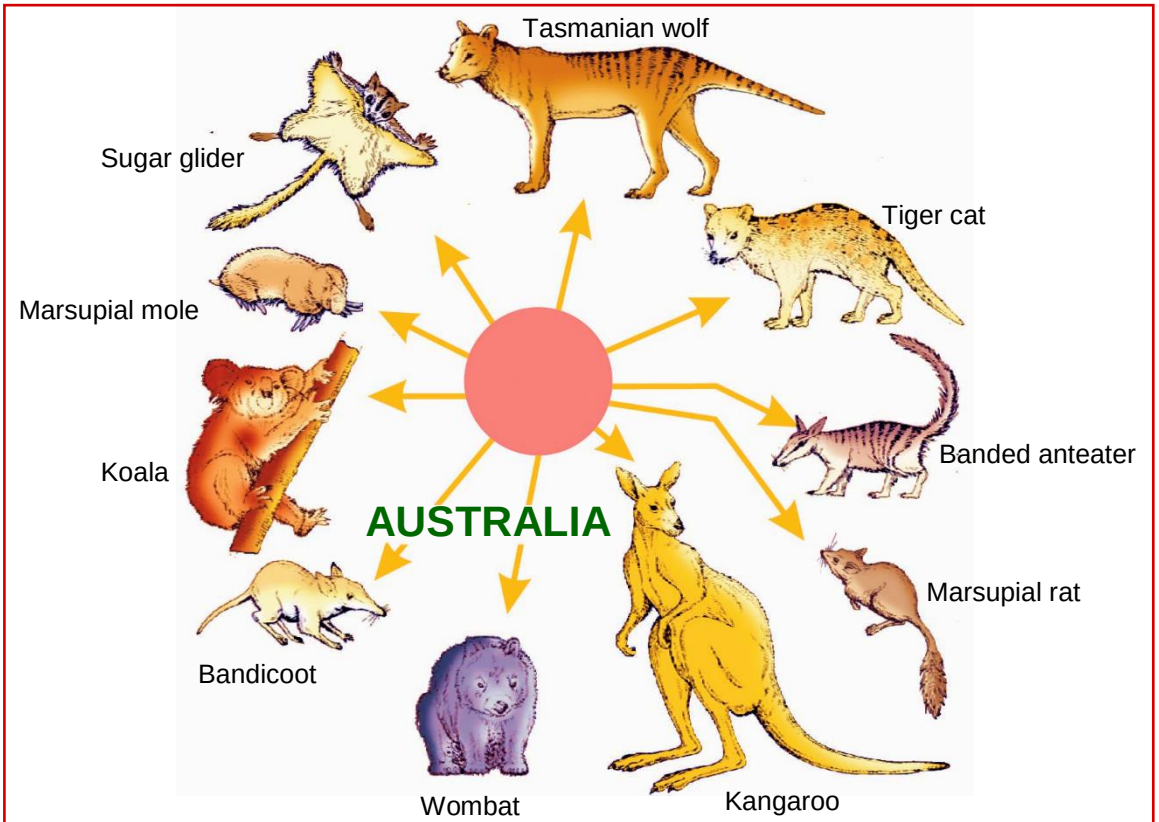
- During his journey Darwin went to Galapagos Islands (named after the giant turtles present there). There he observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him.
- He realized that there were many varieties of finches in the same island. All the varieties, he conjectured (conclusion based on incomplete information), 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.
- Darwin's finches represent one of the best examples of this phenomenon.



Variety of beaks of finches that Darwin found in Galapagos Island

b. Australian Marsupials

- Australian marsupial also support the phenomenon of adaptive radiation.
- Figure given here describes that a number of species arose from common marsupial stock.
- Difference in morphology & features of these animals is due to adaption in different environments.

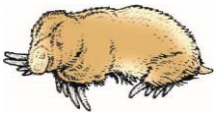
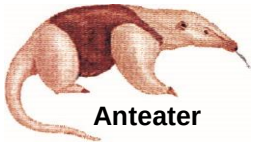
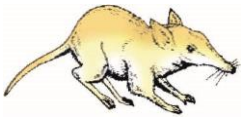
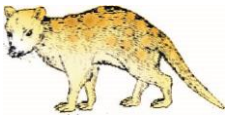
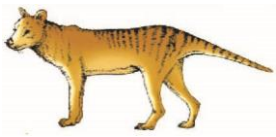


Adaptive radiation of marsupial of Australia

c. Placental Mammals

- Like as marsupials placental mammals also underwent adaptive radiation and developed different features and characters.

- When more than one adaptive radiation occur in an isolated geographical area (representing different habitats), It is called adaptive convergence. & it represent convergent evolution leading to origin of analogous organs. We can see the same in following diagram between marsupial mammals and placental mammals.

PLACENTAL MAMMALS	HABIT OR ADAPTATION	AUSTRALIAN MARSUPIALS
 Mole	BURROWING	 Marsupial mole
 Anteater	DIGGING ANT FEEDER	 Numbat (anteater)
 Mouse	SMALL RODENT LIKE	 Marsupial mouse
 Lemur	ARBOREAL	 Spotted cuscus
 Flying squirrel	ARBOREAL GLIDERS	 Flying Phalanger
 Bobcat	CAT-LIKE CARNIVORE	 Tasmanian Tiger cat
 Wolf	DOG-LIKE CARNIVORE	 Tasmanian wolf
PICTURE SHOWING CONVERGENT EVOLUTION OF AUSTRALIAN MARSUPIALS AND PLACENTAL MAMMALS		

THEORIES OF EVOLUTION

Evolutionary biology includes both the origin of life and the diversity of living organisms on the earth. Various concepts explain the process of evolution, but the important concepts or theories that explain the scientific basis of organic evolution are Lamarckism, Darwinism, mutation theory and modern synthetic theory.

1. LAMARCKISM OR INHERITANCE OF ACQUIRED CHARACTERS OR USE AND DISUSE OF ORGANS

Jean Baptiste de Lamarck (1774 - 1829), a French biologist is well known for his concept, inheritance of acquired characters in organisms for formation of new species, which he explained in his book *"Philosophie Zoologique" in* 1809*.*

❖ Term invertebrates & biology were coined by Lamarck.

I. Salient Features of Lamarckism

i. Living organisms and their parts tend to increase in size continuously due to internal forces of life.

ii. New organs (characters) are developed in order to meet the new requirements and are maintained (acquired characters).

iii. The development of organs and their use are proportional to the activities of these organs (use or disuse of the organs). Use and disuse of organs result in variations.

iv. Every new character that has been acquired in the life of an individual is preserved and transmitted to the next generation by them (inheritance of acquired characters).

Thus, Lamarck proposed that variations in organisms were the result of the influence of environment. When the environment of an organism changes, its needs also change. Changed needs lead to either special use of organs or disuse of organs. Organs that are used more, increase in their size and organs which are not used continuously, degenerate. Such acquired traits are inherited to next generation.

II. Examples of Lamarckism

- Lamarck cited the examples of giraffe and snakes to explain use and disuse of organs.
- An original deer like ancestor, living in Africa, found the supply of grass and herbs inadequate. It started feeding on the leaves of trees.
- In the process of reaching the leaves of higher branches, its neck got stretched and the forelegs were raised.
- As a result the neck became longer along with the forelimbs. Lamarck cited this example for the use of an organ.
- The ancestors of snakes were the four limbed animals. They adapted to burrowing habit in course of time.
- During this adaptation they lost their limbs gradually. Hence the snakes of the present day are without limbs. Lamarck cited it as an example of disuse of an organ.
- Eyes of fishes living in deep sea are present on dorsal side of body.

III. Germplasm Theory

Though Lamarckism appears to be simple and convincing, it was objected by later scientist on various grounds. **August Weismann** 1890 the German biologist, performed the decaudalisation experiments on mice and disproved Lamarckism and pangenesis theory of Darwin. He cut the tails of white mice for more than 20 generations and observed the effect on the length of tail in the coming generations. In all generations, the length of the tail was found to be normal. Hence, he believed that the acquired character was not inherited. August Weismann proposed the theory of germplasm, or germinal selection.

a. He differentiated the protoplasm into somatoplasm and germplasm. Somatoplasm is in the somatic cells (other than the sex cells). It does not play any role in heredity. Germplasm is the protoplasm in the sex cells. It plays an important role in heredity.

b. The changes that occur in the non-reproductive cells; or somatic cells are not transmitted; only the changes that occur in the reproductive cells, i.e in germplasm, are transmitted.

IV. Neo-Lamarckism

- Lamarckism is the first scientific assumption that recognized the "adaptation to the environment as a primary product of evolution".
- The followers of Lamarck (Neo-Lamarckians) like Cope, Osborn, Packard, Spencer etc. tried to modify Lamarckism to make it acceptable.
- These neo-Lamarckians considered that adaptations are universal. Organisms acquire the new structures due to their adaptations to changed environmental conditions.
- They argue that external conditions affect the somatic cells and stimulate these cells to produce specific secretions. These secretions reach the sex cells through the blood. So the variations caused in somatic cells are carried to the sex cell through secretions. Such variations can be inherited by offspring.

2. DARWINISM

Charles Robert Darwin (1809-1882) was an English naturalist born on 12th February, 1809 at Shrewsbury, England. He was appointed a Naturalist in 1831 upon a world survey-ship of British Government **H.M.S. Beagle**. He went on voyage for five years (1831 to 1836) and explored the fauna and flora of a number of continents and islands. The idea of **evolution of new species by natural selection** influenced his mind in the journey. After returning from Voyage he wrote a book: The voyage of Beagle 1838.

Darwin was much influenced by three publications namely the essay of T.R. Malthus,1798, titled *"**On the principles of populations*** "which states that populations increase geometrically and the food sources increase arithmetically, the book written by Sir Charles Lyell entitled ***"Principles of Geology"*** which explained the **gradualism** (earth has changed slowly and gradually through ages) and **uniformitarianism** (fundamental laws operate today on the earth in the same way as they did in the past) and the paper titled *"***On the tendency of varieties to depart from original types"** sent to him by Alfred Russel Wallace 1858.

Main points of essay of Thomas Malthus were

i. Every population has an inherent capacity to increase its number exponentially.
ii. Nature keeps a control over the size of population by posing several challenges like death, food shortage and disease.
iii. Natural resources are limited.
iv. The populations remain nearly stable in size except during some seasonal fluctuations.

Darwin presented the summary of his theory in a joint paper titled, *'Origin of species,* in1858 to the Linnaean society. Again in 24 November 1859, Darwin published his findings in detail in his book titled" **On the Origin of Species by Natural Selection".**

I. Darwinism (Theory of Natural Selection)

- Darwinism is the term coined for the explanation offered by Charles Darwin for the origin of species by natural selection.
- Darwinism does not exactly mean what evolution is, but it explains how evolution might have occurred in nature.
- Darwin's theory of natural selection is based on several facts, observations and inferences.
- Branching descent & natural selection are two key concepts of Darwin's theory.

i. Over Production, **or Enormous power of fertility**

- Every organism tends to increase in geometrical proportions in its population. e.g. *Paramecium* divides by binary fission three to four times in a day. At this rate, the mass of protoplasm equals to 10,000 times of the volume of the earth at the end of 9000th generation.
- A pair of elephants, the slowest breeder, in the absence of checks may have 19 million descendants at the end of 800th generation.

ii. Constancy in population

- However, an abnormal increase in the population of any species is not observed in nature. The population of each species remains more or less constant because the offspring die in large number before they become reproductively active.
- The food and other sources do not increase in the same rate as population increase. As a result there is a danger of population over running the food and other facilities. Consequently, more number of individuals are eliminated, because available resources support only a limited number of organisms.

iii. Struggle for existence

Over population results in severe competition. Darwin called it struggle for existence. The struggle is of three types.

a. Intraspecific struggle: It is the struggle found among the individuals of a species. This struggle is for food and mating. It is the most severe check of the rate of reproduction and most important too.

b. Interspecific struggle: It is found among animals of different species. Most of the species have same food habits. Hence competition exists among them for food and other needs.

c. Struggle with the environment or Inanimate nature: Living organisms struggle with the adverse environmental conditions like floods, cold waves, heat waves, earthquakes etc. The gigantic reptiles, dinosaurs, struggled very much in cretaceous period and perished.

iv. Universal occurrence of variations

- Variations exist in all organisms. These variations may be useful or harmful or neutral. Harmful variations make the organism unfit in the struggle for existence.
- The variations may be favoured or rejected by the nature.
- Beneficial variations are favoured by the nature. Useful variations are quite significant and make the organism fit in the struggle for existence.
- Such variations are inherited to the progeny, so that, the progeny has better chances of survival.
- Darwin was unaware about basis of variations but we know that these are due to mutation.

v. Natural Selection

- According to Darwin, during the struggle for existence, the organisms with beneficial variations alone will survive. Darwin hypothesized that these variations are sorted out by nature through competition. The organisms, which are selected by nature, are said to be the fittest. This idea of **survival of the fittest** was proposed by Herbert Spencer.
- Variations which are useful to the individual in a particular environment would increase that individual's ability to reproduce and leave fertile offspring. These are favoured by nature.
- Less favourable variations would be at disadvantage and organisms possessing them are reproductively less successful.
- Differential reproductive success exists among organisms. The concept of differential reproductive success of various forms is more accurate.
- Over period of time, the criterion for the success is the reproductive success. The organism that fails to reproduce cannot be represented in future generations, however fit it may be in the struggle for existence.

vi. Origin of species

- Darwin concluded that the struggle for existence leading to the survival of the fittest allows the successive generations to become better adapted to the environment.
- All the modifications caused by variations and selected by nature are accumulated from generation to generation till a generation is produced that is more adapted and has more chances of survival. He also believed that evolution is a gradual, rather than a sudden, biological event. Thus, as per natural selection, new species are evolved due to cumulative effect of fluctuating variations.

II. Objections to Darwinism

Darwinism is considered to be the best explanation for the biological event, organic evolution. Yet some objections are leveled against Darwin's Natural selection.

i. Natural selection stresses upon the small fluctuating variations, but these are mostly non-heritable. Thus Darwin did not distinguish between heritable and non-heritable variations. He also did not distinguish between somatic and germinal variations. To overcome this objection Darwin proposed theory of pangenesis which states that every organ of body produces minute hereditary particles called pangene or gemmules which are carried by blood into gametes.

- ❖ Theory of germplasm rejects theory of pangenesis but not Darwinism.

ii. Natural selection cannot explain the occurrence of vestigial organs, because they have no selection value.

iii. Darwinism explained the survival of the fittest, but did not explain the **arrival of the fittest** (origin of the fittest).

iv. Natural selection does not account for how an organ can be successful in its initial stages of formation. These stages of formation do not have the selection value, unless the organs are perfected in course of time like electric organs in electric rays. The effectiveness of these organs depends on the perfection'

v. It does not explain the over specialization of some organs like the antlers of extinct Irish deer. In some cases these organs led to the extinction of their possessors.

vi. Darwin did not consider the importance of macro variations in evolution. He called them as **sports of nature.**

vii. If the new species are formed due to the cumulative effect of fluctuating variations over generations, transitional forms must be available. However such forms were not found in most cases.

3. MUTATION THEORY OF EVOLUTION

Mutation is a **sudden, random, discontinuous and heritable change** independent of the environment in the genetic makeup of an individual. Darwin called such variations as sports, or saltations, Whereas Bateson called them discontinuous variations.

The **term mutation** was coined by **Hugo de Vries**, a Dutch botanist in 1901.Hugo de Vries observed this phenomenon in evening primrose *Oenothera lamarckiana.*

Hugo de Vries later proposed mutation theory of evolution in 1901 his book "Die Mutation Theory''. It states that new full-fledged species originate at once as a result of large, discontinuous variations, which appear suddenly.

I. Salient features of mutation theory

i. Mutations arise from time to time amongst the individuals of a naturally breeding population.

ii. Mutations are heritable and establish new forms or species.

iii. Mutations are large and sudden and are totally different from fluctuating variations of Darwin, which are small and directional.

iv. Mutations may occur in any direction.

II. Importance of mutations in evolution

Hugo de Vries stressed on the randomness of variation, whereas Darwin considered the adaptiveness of the variation in evolution, Hugo de Vries stated that new species arise by sudden jump, called mutation, whereas Darwin considered that new species arise by gradual fluctuating variations that accumulate in a series of generations. T.H. Morgan observed mutations in *Drosophila melanogaster* and confirmed the mutation theory.

III. Objections against Mutation Theory

i. Mutations are not so common (Their frequency is 1:1 million cell).
ii. Mutations are generally recessive.
iii. *Oenothera lamarckiana* is having abnormal chromosome number.
iv. The mutants of *O. lamarckiana* are now proposed as 7 different species.

4. HARDY-WEINBERG PRINCIPLE

- It was proposed by **G. H. Hardy** and **W. Weinberg (1908)**. In the year 1903 an American geneticist W. E. Castle also proposed the similar principle so sometimes it is also referred as **Hardy Weinberg Castle Law**.
- This principle states that a population is said to be in **genetic equilibrium** if it is not undergoing any kind of evolutionary change.
- Genetic equilibrium means that the frequency of occurrence of alleles of a gene is supposed to remain fixed and even remains the same through generations. Hardy-Weinberg principle stated it using algebraic equations. Main concepts of this principle are:

i. This principle says that allele frequencies in a population are stable and are constant from generations to generation.
ii. The gene pool (total genes and their alleles in a population) remains a constant. **This is called as genetic equilibrium.**
iii. Sum total of all the allelic frequencies is 1.

It can be explained as follows:

Allele mean any of the two forms of a gene, present on the same locus in the two homologous chromosomes and allelic frequency is the frequency with which a particular allele occurs in a population.

For example, in a population of diploid organisms, a gene has two alleles – A and a, suppose the frequency of occurrence of allele A is p and of a is q. Then the probability that allele A will appear on both the chromosomes of a diploid individual will be simply the product of its probabilities, i.e., $p \times p = p^2$. Hence, we can say that the frequency of AA individuals in this population is simply $\mathbf{p^2}$.

Similarly the frequency of aa individuals in this population is $\mathbf{q^2}$ and the frequency of Aa individuals (with allele A on one chromosome and allele a on other chromosome) in this population is **2pq** (or $2 \times p \times q$).

We can see that the probability of occurrence of hybrid condition (Aa) is twice ($2 \times pq$) than that of homozygous genotype (AA or aa) having p^2 and q^2 frequencies.

- ❖ Hardy-Weinberg principle states that the sum total of all the allelic frequencies of a gene is 1 and the possible frequencies of above mentioned genotypes. i. e., AA, aa and Aa are p^2, q^2 and 2pq, respectively.
- ❖ So mathematically this statement can be written as

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

We can see that this equation is a binomial expansion of $(p + q)^2$.

Interpretation: Hardy-Weinberg principle can be used to mathematically interpret whether evolution has occurred in a population or not. Disturbance in the genetic equilibrium or Hardy-Weinberg equilibrium, would be interpreted as evolution. When frequency measured, differences from expected values, the difference indicates the extent of evolutionary change.

Factors affecting Hardy-Weinberg principle

i. Gene migration or gene flow
ii. Genetic drift
iii. Mutation (Rare)
iv. Genetic recombination (Most common)
v. Natural selection

❖ Hardy-Weinberg principle is applicable for randomly mating populations only.

5. SYNTHETIC THEORY OF EVOLUTION OR NEO-DARWINISM

Darwin failed to explain the mechanism by which variations could appear. Weismann's theory of germplasm and Mendel's postulates of inheritance helped to a large extent in understanding the inheritance of variations. Hugo de Vries' mutational theory accounts for the origin of variations. Neo-Darwinists like Huxley, Weismann, Haeckel, G. G. Simpson supported the Natural Selection.

Later **R.A. Fisher, Sewall Wright and Mayr** explained Natural selection by **modern synthesis, or neoDarwinism.**

❖ Modern synthetic theory was designed by Huxley in 1942.
❖ Dobzhansky wrote a book "Genetics & Origin of Species".
❖ Stebbins wrote a book "Process of Organic Evolution".
❖ Unit of evolution is population, it is population that evolve role of single individual is to pass characters from one generation to other.
❖ Evolution at genetic level is called microevolution while at geological time scale level is macro evolution.

According to this theory following factors play role in evolution.

I. Mutation

It can be a two levels.

a. Gene Mutation

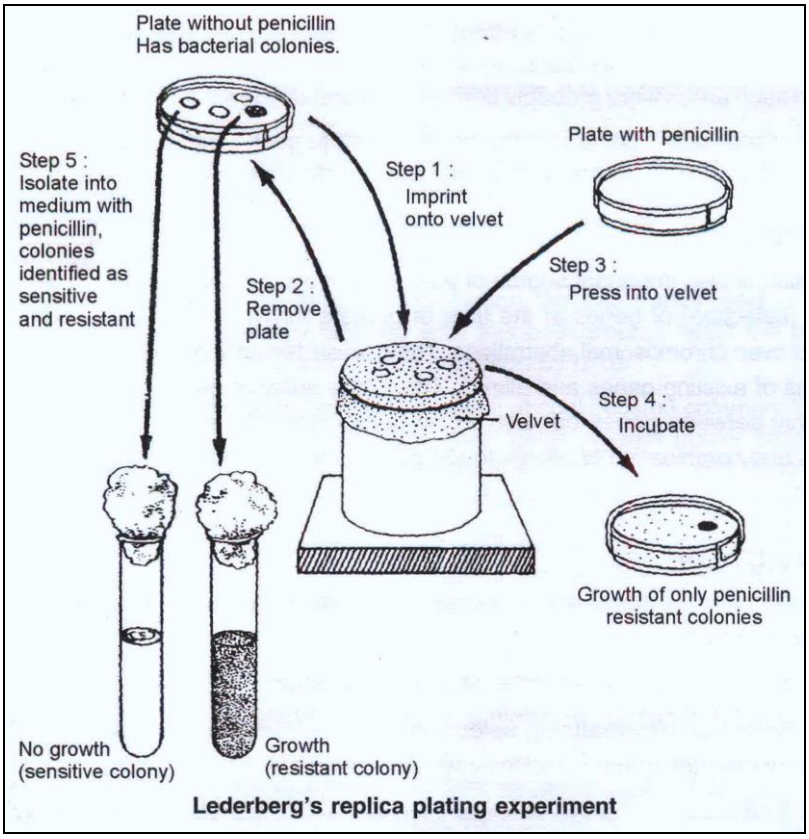
The heritable character of an individual depend on the genes which control them. These genes are portion of DNA molecules which have a complex polymer of nucleotides. Any structural change occurring in the chemistry of DNA molecule is called gene mutation. Changes in the genes alter the phenotypic characters of the individuals.

b. Chromosomal Mutation (Chromosomal Aberration)

Specific types of genes present in specific chromosome at specific location is the characteristics of a particular species. A change in the number of chromosomes (aneuploidy, polyploidy, etc.) or in the structure due to deletion, duplication, addition, inversion, or translocation brings about variations in the organism's phenotypes.

❖ **Lederberg's replica plating experiment**

- The Lederberg Replica Plating Experiment was demonstrated in bacteria by Joshua Lederberg and his wife Esther Lederberg.
- They grew *E. coli* bacteria on agar medium. After a period of growth colonies appear on agar plates.
- Then by using velvet discs bacteria were transferred to plates containing penicillin.
- Most colonies found on the master plate did not grow on antibiotic containing plates a few colonies grew.
- Obviously the colonies grown on antibiotic medium were resistant although parental colony was not.
- Now the question arises that what was the source of this adaption? According to Lamarckian view the bacteria would have changed itself after exposure of penicillin but in accordance to Darwinian Theory the bacterial population itself had variations and the useful variants were selected in changed environment.
- The new environment does not induce their formation, it only selects the pre-adaptive mutations that occurred earlier.



Lederberg's replica plating experiment

II. Genetic Recombination

- ❖ They are new combination of genes, which are usually caused by crossing over during gamete formation or independent assortment or by random fusion of gametes during fertilization.
- ❖ It is important source of variation.
- ❖ It add new allele & combination of alleles.
- ❖ Mutation and gene recombination provide genetic variability.

III. Natural Selection

- Organisms, which are physically, physiologically and behaviorally better adapted to the environment, are selected. They survive and reproduce. The organisms, which are not so well adapted, either fail to reproduce or die. Selection is therefore an operative process that occurs in a population whenever there is a difference in reproductive success of individuals.
- A measure of the reproductive success is the fitness, or adaptive value of a genotype. A genotype that produces more fertile offspring has higher fitness.
- Natural selection provide direction to evolutionary process.
- Natural Selections is of three types.

a. Stabilizing selection/centripetal selection/balancing selection

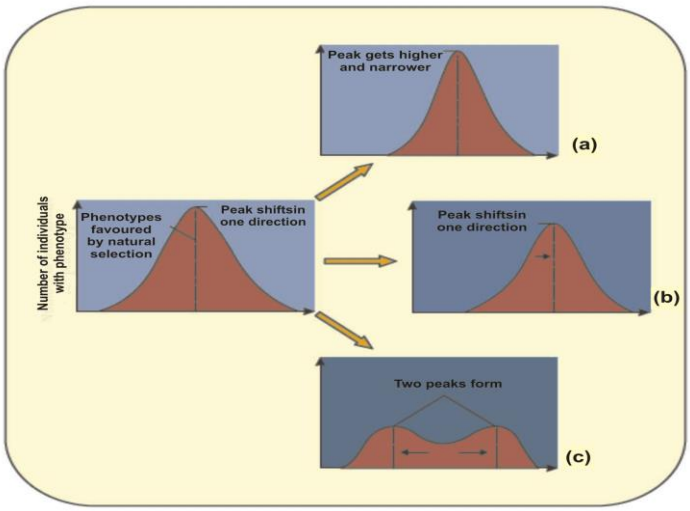
This selection operates in a stable environment. In this process extreme individuals from the two ends of the phenotypic distribution are eliminated. The organisms which are in the average of the phenotypic distribution are preserved. Stabilizing selection does not promote evolutionary change that leads to speciation, but tends to maintain phenotypic stability within the population over generations. Hence, over a time the same average value of the phenotypic distribution in the population is maintained. It removes deleterious genotypes from the population, for which reproductive success is zero. e.g.: In England, weights of babies in a large sample were taken. It was found that greater mortality in the babies was when the weight was greater or lesser than the average weight 3.62kg & sickle cell anaemia, wing span in birds of a particular weight.

b. Directional selection/progressive selection

This selection operates in response to gradual changes in environmental conditions. It works by constantly removing individuals from one end of the phenotypic distribution. Therefore, average value of fitness is constantly shifting towards the other end of the phenotypic distribution. e.g: In case of the long-necked giraffes the average value of neck shifted towards the long-neck. The development of resistance to DDT by mosquitoes is another example for directional selection. One more example can be taken from industrial melanism.

c. Disruptive selection: (centrifugal selection)

It is a rare form of selection, but, very important in bringing about evolutionary change. This process operates in the changing conditions within an environment (heterogeneous environment).Heterogeneous environment increases the competition in the population. The increased competition leads to selection pressure. This selection pressure removes the average of the phenotypic distribution in the population. Hence phenotypes move away from the average towards the ends of the population distribution. This can split the population in to two or more subpopulations, called sub-species populations. If the gene flow between the sub-species populations is prevented. Each population may give rise to a new species. It is also called **adaptive radiation**. e.g.: In California the sunflower population was divided into two subpopulations. One subpopulation was adapted to dry area and the other was adapted to wet area over a period of 12 years.



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

EXPERIMENTAL VERIFICATION OF NATURAL SELECTION

A. INDUSTRIAL MELANISM

A classic example of natural selection is the case of peppered grey moth *Biston betularia,* which was abundant before industrial revolution allover England. These moths showed colouration with two phenotypes, grey and black. The black forms were more and grey forms were less in the industrial period particularly in the industrial cities like Birmingham. Biologists proposed this change in the population of peppered moth was due to the pollution caused by the industrial revolution. Prior to industrial revolution the gray moths succeeded to camouflage the light trunks of the trees. With the industrial revolution more soot was released due to the burning of coal. Tree barks became black. Grey moths were easily identified and were more predated by the birds. Grey moths decreased in number and dark moths increased in the population. Therefore natural selection favoured the melanic moths to reproduce more successfully. Natural selection of darker forms in response to industrial pollution is known as industrial melanism.

Bernard Kettlewell, a British ecologist, tested the hypothesis experimentally. He reared the grey and dark forms of populations with equal numbers. He released the moths in two sets –one in Birmingham (polluted area) and the other in the Dorset (unpolluted area). Kettlewell recaptured more dark forms in the polluted area and more grey forms in the unpolluted area. This explains the differential survival of the moth. The release of smoke was reduced in the later periods. Consequently frequency of dark forms in the population declined and the light forms slowly increased. Reduction in the pollution is related to reverse evolution of gray moths.

- ❖ Lichen act as pollution indicator.
- ❖ Grey Moth: *Biston betularia.*
- ❖ Black moth: *Biston carbonaria*
- ❖ Different phenotypes of moth are due to mutation of a single gene.

a

b

B. Resistance of Mosquitoes to Pesticides

Mosquitoes have always been a major health hazard as they are vector of diseases like malaria and filaria. To check spread of these diseases pesticides were introduced to remove the vector, initially it was very successful as most mosquitoes were sensitive to DDT and were therefore killed. However DDT has now become ineffective against mosquitoes.

Initially number of DDT sensitive mosquitoes was more as compared to DDT resistant mosquitoes later on due to changed environment (introduction of DDT) number of DDT resistant mosquitoes increased and so now a days DDT is ineffective against mosquitoes.

C. Sickle Cell Anaemia

a. In few RBCs, 1–2% became sickle shaped.

b. The heterozygotes (Hb^A/Hb^S), who have one copy of sickle cell allele, coupled with one normal allele are better survivors in the areas where malaria is endemic.

c. The women who are heterozygous have higher fertility; that's why natural selection has not eliminated the allele.

d. The loss of deleterious recessive genes through deaths of homozygotes (Hb^S/Hb^S) is being balanced by the gain resulting from successful reproduction by heterozygotes. For this reason, the selection is called as balancing selection.

e. Heterozygotes enjoy some resistance to malaria, so they survive the malarial parasite more successfully than either normal or sickle cell homozygotes.

SEXUAL SELECTION

There are many evolutionary consequences related to the adaptation of sexual mode of reproduction. This includes the competition among the individuals for mates. So, animals developed the secondary sexual characters. Darwin considered the theory of sexual selection to explain the development of secondary sexual characters in the animals. These secondary characters cannot be explained by natural selection, because these are not useful in the struggle with the environment. These secondary sexual characters like brilliant colours, ornaments etc. appear mostly in males, because females choose the males with these characters for mating.

ARTIFICIAL SELECTION

- Artificial selection is a man-made selection. According to Darwin it is the commonest method of producing new races of animals by man.
- This process has been adopted for production of better races of domestic animals by man. An animal breeder selects the animals among the highly variable individuals with desirable characters. He breeds them until the desired character is perfected in the progeny. Artificial selection focuses on one trait rather than overall fitness of the animal.
- Man has bred selected plants and animals for agriculture, horticulture, sport or security. Man has domesticated many wild animals and crops. This intensive breeding programme has created breeds that differ from other breeds (e.g., dogs) but still are of the same group.
- It is argued that if within hundreds of years, man could create new breeds, could not nature have done the same over millions of years?
- Similarly, excess use of herbicides, pesticides, etc., has only resulted in selection of resistant varieties in a much lesser time scale. This is also true for microbes against which we employ antibiotics or drugs against eukaryotic organisms/cell. Hence, resistant organisms/cells are appearing in a time scale of months or years and not centuries. These are examples of evolution by anthropogenic action.
- This also tells us that evolution is not a direct process in the sense of determinism. It is a stochastic process based on chance events in nature and chance mutation in the organisms.
- Some examples are development of Poulter, Jacobin and Fantail from Rock Pigeon and development of cabbage, Kohlrabi and cauliflower from colewort (Wild cabbage).

IV. GENE FLOW / GENE MIGRATION

- Gene flow is the movement of alleles from one population to another because of the interbreeding between members of the two populations.
- The random introduction of alleles into the recipient population and their removal from donor population affects the allelic frequencies of both populations.

V. GENETIC DRIFT

- The variations that occur by **chance** in a small population cause deviations from Hardy-Weinberg Equilibrium. Any deviation due to chance variations is called random genetic drift, or Sewall Wright effect. Chance plays an important role in genetic drift.
- **Founder effect** is one form of genetic drift. It is the derivation of a new population from a small isolated group of individuals (founders) that is genetically different from the parent population. The allelic frequencies of the new population are similar to the founders rather than to the ancestral parent population. e. g. Human population founded on Pitcairn Island -is a good example of founder effect. Pitcairn Island population is resulted from the small numbers of founders of Caucasian and Polynesian individuals. The gene frequencies in the population of Pitcairn Island is neither similar to the Caucasian parent population nor the Polynesian parent population, but similar to the founders of Pitcairn islands.
- **Bottleneck effect** is another form of genetic drift. Bottlenecks are the natural calamities like earthquakes, volcanic eruptions, floods etc. After bottlenecks the parents of the next generation are reduced to a small number and may be genetically different from the original population. A genetically different population, from the parent population, may arise from these individuals that are left after bottlenecks.
- Genetic drift tends to *"reduce"* the amount of genetic variation within the population mainly by removing the alleles, which have low frequency.

VII. ISOLATION

Prevention of mating amongst inbreeding groups due to physical (e.g. geographical, ecological) and biotic (physiological, behavioral, mechanical and genetic) barriers. Any factor, which prevent inbreeding is known as isolating mechanism. It also provide direction to evolutionary process.

i. **Geographical isolation** can be defined as separation by geographical barrier like mountain, valley, desert, glaciers etc. Sea water isolate the Island from the mainland. India has 47% endemic plants. Effectiveness of isolation depends on duration. E.g. Darwin's finches.

ii. **Reproductive isolation** may be defined as the existence of intrinsic barrier to the interbreeding of natural populations. Each of these intrinsic barriers is called a reproductive isolating mechanism. According to Mayr (1942), reproductive isolating mechanisms are the *biological properties of individuals which prevent the interbreeding of naturally sympatric population.*

Reproductive isolating mechanisms may be classified as either **premating** or **post mating**. Premating isolating mechanisms act prior to mating. These may be ecological, behavioural and mechanical. Post mating isolation mechanisms act subsequent to mating, preventing the interbreeding populations by removing the hybrids from the gene pool. These mechanisms may be gametic mortality, zygotic mortality, embryonic or larval mortality, hybrid in viability, hybrid sterility and F_2 breakdown. Natural selection tends to favour the organisms that exhibit premating isolation over those that have only post zygotic isolation. Therefore the gene pools of different species are isolated from the other. On the contrary, members of the same species share a common gene pool. On this basis, a species can be defined as one or more populations sharing a common gene pool.

Reproductive isolation in the form of hybrid sterility is known since long. In the laboratory or in zoos, hybrids can be produced between species that do not interbreed in nature. Horse and donkeys are two different species; a hybrid, mule, is produced from the mating of a male donkey and a mare (female horse). Similarly, mating between stallion (male horse) and female donkey results in a hybrid called hinny. Both mule and hinny are sterile. Reproductive isolation has more role in process of evolution.

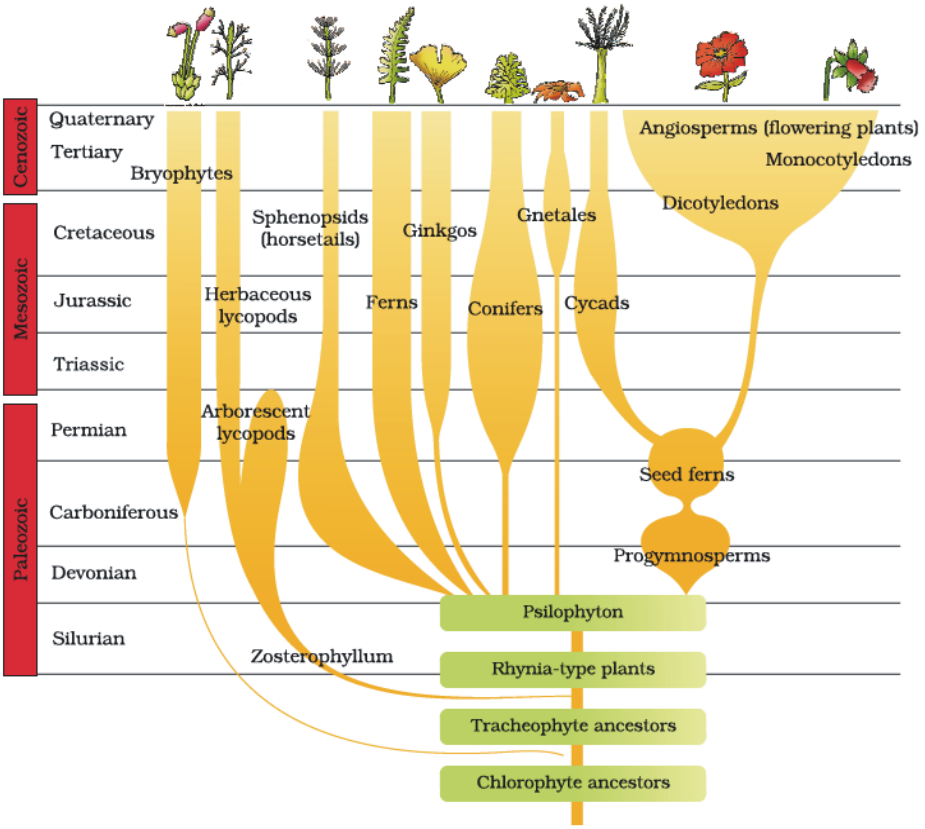
VIII. SPECIATION

Speciation is the formation of one or more new species from an existing species. The crucial episode in the origin of species occurs when the gene pool of a population is separated from other population of the parent species and gene flow no longer occurs. Speciation can take place in two modes on the geographical relationship of a new species to its ancestral species.

When a population, formerly continuous in range, splits into two or more geographically isolated population and form new species, the mode of speciation is called **allopatric speciation.** This can happen by subdivision of the original population, when a geographical barrier, such as a creeping glacier, a land bridge (e.g., Isthmus of Panama) or ocean or mountain, cuts across a species range. Alternatively, when a small number of individuals colonize a new habitat that is geographically separated from the original range. Recall the examples of Darwin's finches that formed separate species in the Galapagos Islands and the Australian marsupials that radiated to form new species.

In the second speciation mode, a subpopulation becomes reproductively isolated in the midst of its parent population; this is **sympatric speciation.** So, sympatric speciation is the formation of species within a single population without geographical isolation. The usually quoted example of sympatric speciation comes from **polyploidy,** which is the multiplication of the normal chromosome number. This can happen when chromosomes fail to segregate at meiosis or replicate without undergoing mitosis.

A BRIEF ACCOUNT OF EVOLUTION



A sketch of the evolution of plant forms through geological periods

- About 2000 million years ago (mya) the first cellular forms of life appeared on earth. The mechanism of how non-cellular aggregates of giant macromolecules could evolve into cells with membranous envelop is not known. Some of these cells had the ability to release O_2. The reaction could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelized by appropriate light harvesting pigments. Slowly single-celled organisms became multi-cellular life forms.
- By the time of 500 mya, invertebrates were formed and active. Jawless fish probably evolved around 350 mya.
- Sea weeds and few plants existed probably around 320 mya. We are told that the first organisms that invaded land were plants. They were widespread on land when animals invaded land.
- Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. In 1938, a fish caught in South Africa happened to be a Coelacanth which was thought to be extinct. These animals called lobefins evolved into the first amphibians that lived on both land and water. 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 descendants, the turtles, tortoises and crocodiles.
- In the next 200 million years or so, reptiles of different shapes and sizes dominated on earth. Some of these land reptiles went back into water to evolve into fish like reptiles probably 200 mya (e.g. *Ichthyosaurs*). The land reptiles were, of course, the dinosaurs. The biggest of them, i.e., *Tyrannosaurus rex* was about 20 feet in height and had huge fearsome dagger like teeth.
- Giant ferns (pteridophytes) were present but they all fell to form coal deposits slowly.
- About 65 mya, the dinosaurs suddenly disappeared from the earth. We do not know the true reason. Some say climatic changes killed them. Some say most of them evolved into birds. The truth may live in between. Small sized reptiles of that era still exist today.

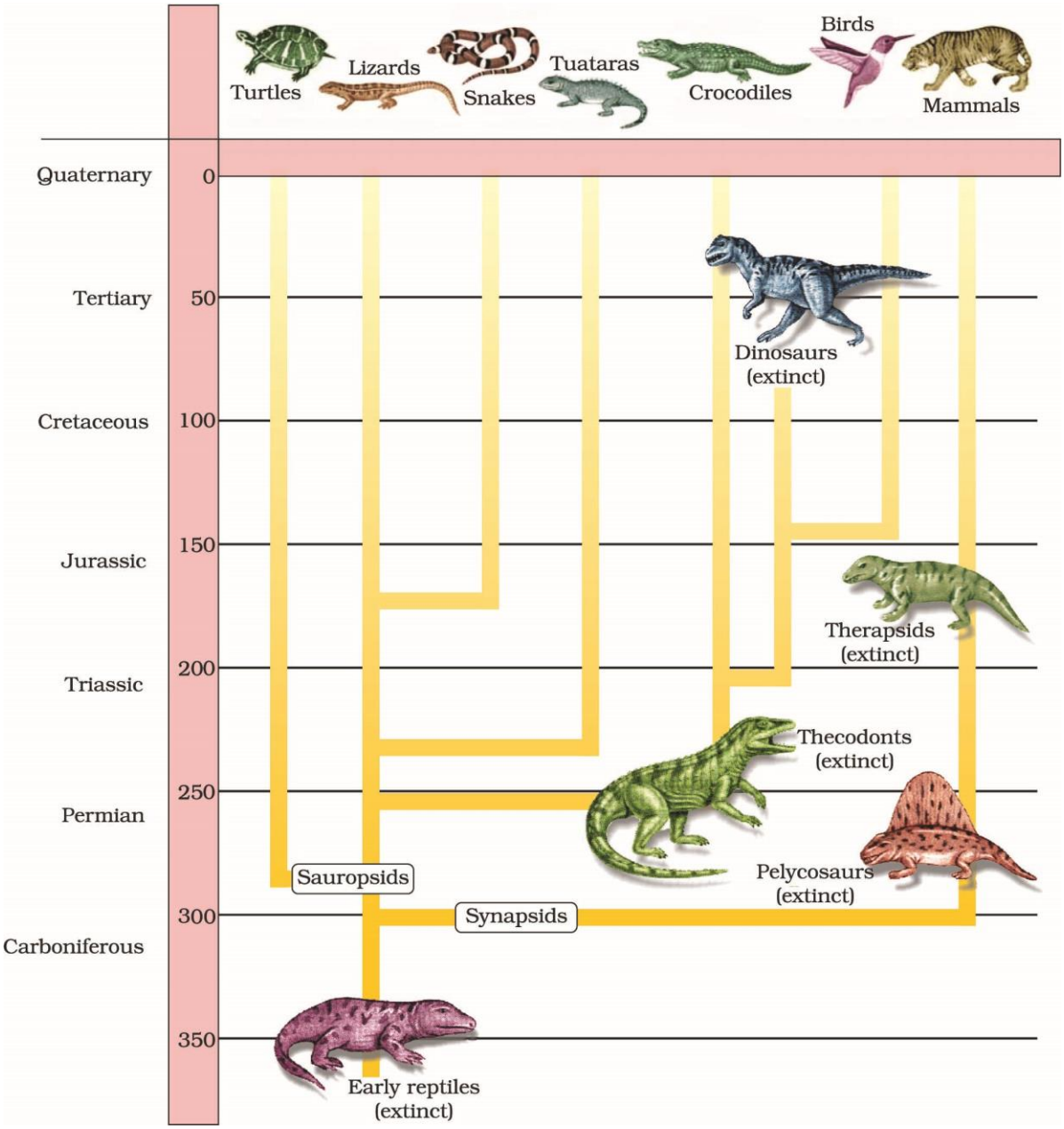


Fig. A rough sketch representing evolutionary history of vertebrates through geological periods

- The first mammals were like shrews. Their fossils are small sized. Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least.
- When reptiles came down mammals took over this earth. There were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna. Due to the same continental drift pouched mammals of Australia survived because of lack of competition from any other mammal.
- Lest we forget, some mammals live wholly in water. Whales, dolphins, seals and sea cows are some examples. Evolution of horse, elephant, dog, etc., are special stories of evolution. The most successful story is the evolution of man with language skills and self-consciousness.

ORIGIN & EVOLUTION OF HUMAN

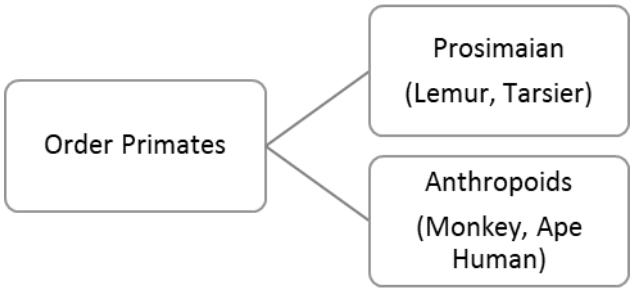
- Palaeoanthropology is study of human evolution & culture.

- Human evolution is studied with evolution of Apes.
- Evolution of man began in palaeocene epoch (65 mya), modern man originated in pleistocene epoch.

CLASSIFICATION OF HUMAN

Phylum	–	Chordata
Class	–	Mammalia
Order	–	Primates (Nail on digits)
Family	–	Homonidae (Erect posture, biped locomotion).
Genus	–	*Homo*
Species	–	*sapiens*

- Carolus Linnaeus called human as Homo sapiens Wiseman.
- Huxley explained origin of man in his book "The Man's place in nature by sexual relation"
- Darwin explained ancestor of man in his book "The descent of man"
- Primates originated in Palaeocoene epoch of coenozoic era some 65 mya.
- Primates evolved from shrew like insectivores.



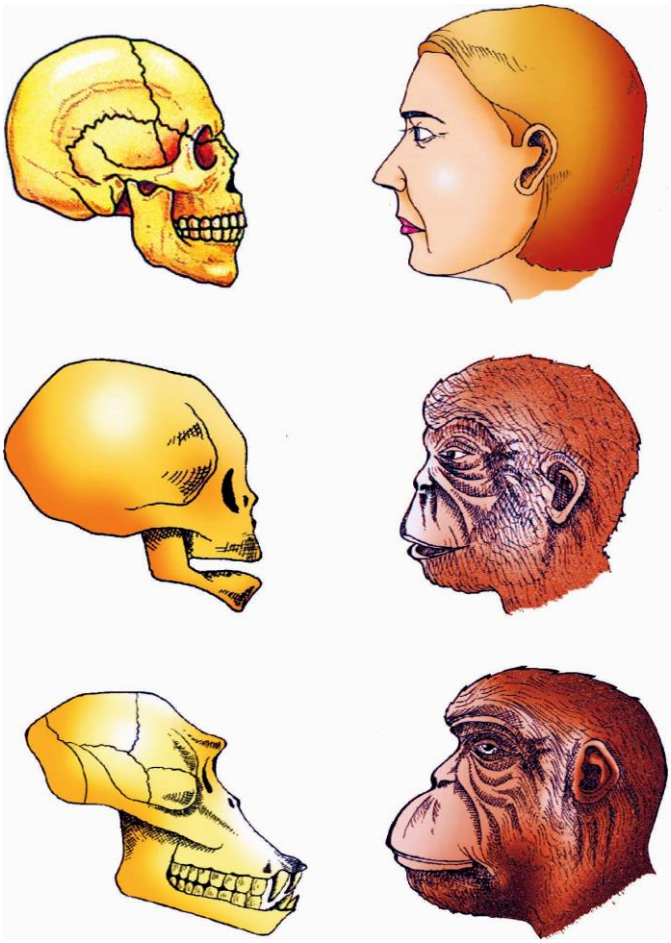
Members of Anthropoids

A. Monkey

	Old World Monkeys (Catarrhini)	New World Monkeys (Platyrrhini)
1.	Non-prehensile tail	Prehensile tail
2.	Narrow nose, downward directed nostrils.	Flat nose, forward directed nostrils
3.	Opposable thumb	Non-opposable thumb
4.	Dental formula $\frac{2123}{2123}$	Dental formula $\frac{2133}{2133}$
5.	Menstrual cycle in females e.g. *Rhesus* (Macaca), *Papio* (Baboon)	Estrous cycle in females e.g. *Ateles* (Spider monkey)

Old world monkeys are closer to human.

- **Apes:** Family- Hyalobatidae



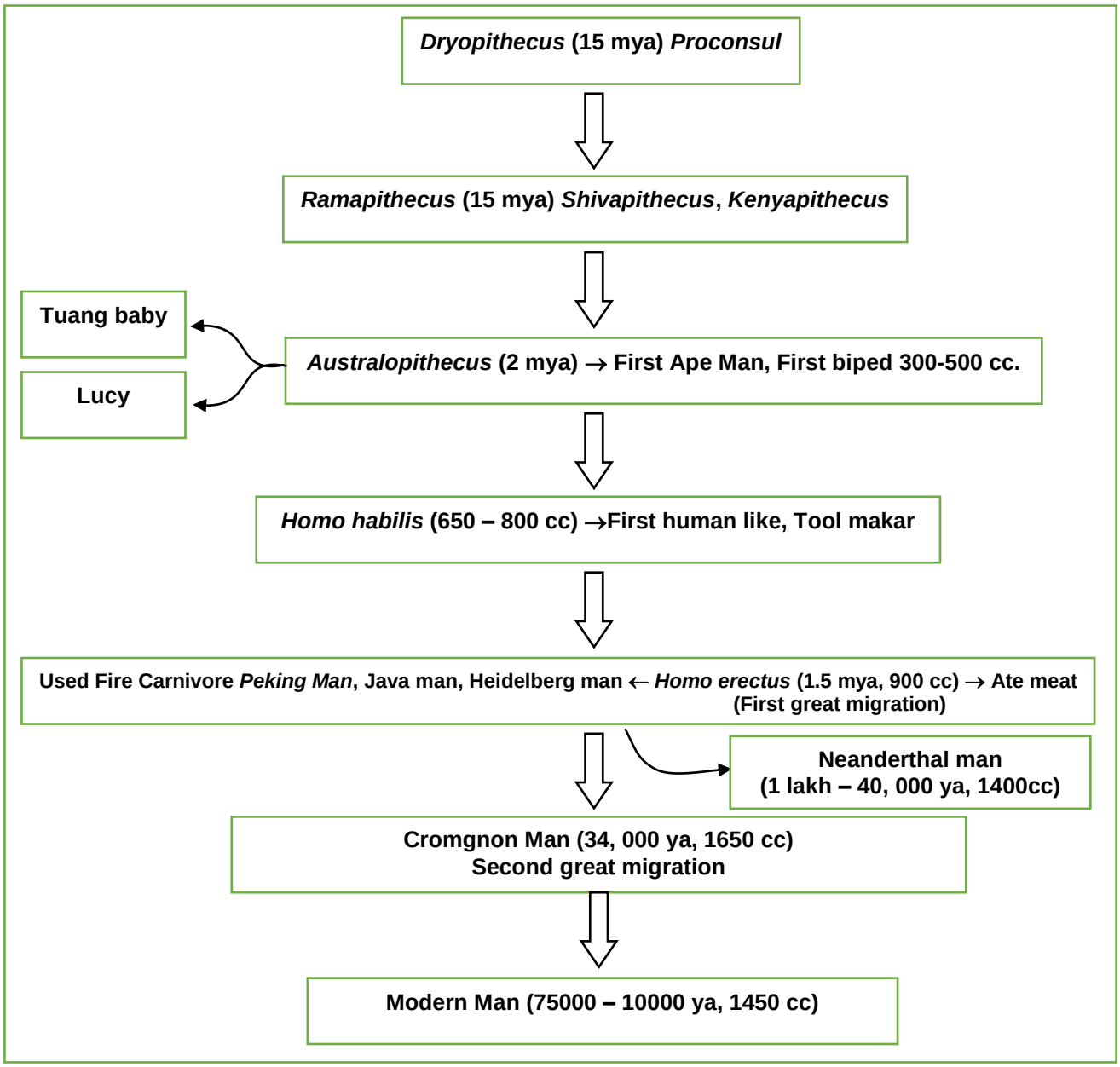
A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee. The skull of baby chimpanzee is more like adult human skull than adult chimpanzee skull

i. Chimpanzee- Most closely related to human.
ii. Gorilla- largest, most dangerous.
iii. Orangutan- Size equal to human, weight 50-100kg
iv. Gibbon– smallest only to be found in India-Assam forests.

Similarities between Man & Apes

- Human is more similar to baby chimpanzee than adult
- Tail absent
- Erect posture
- Grasping hand
- Facial muscles for expression
- Menstrual cycle in female
- ABO blood group
- Similar haemoglobin (1 amino acid different in Gorilla).
- Human has 46 chromosome. Apes have 48 chromosome, banding pattern of chromosome 3 & 6 are similar.

Differences between Man & Ape	
Apes	**Human**
Semi erect posture	Erect posture
Thick hairs on entire body	On some body parts
Less cranial capacity (450cc)	More (1450 cc)
U- shaped jaw	Semi-circular jaw
Chin absent	Chin present
Non-opposable thumb	Opposable thumb
Fore limbs longer	Fore limb shorter



PHYLOGENY OF HUMAN

A. *Dryopithecus*

- Lived 15mya
- Fossils discovered from Miocene rocks of Africa & Europe
- Common ancestor of man & apes
- Vegetarian, ate fruit
- Quadriped locomotion, hairy body.
- Also referred as proconsul.

B. *Ramapithecus*

- First man like primate.
- Hairy body, walked like apes.
- Present in East Africa (Ethiopia. Tanzania). 15 mya
- Height 4 feet
- Discovered by Lewis from Shivalik Hills.
- Shivapithecus & Kenyapithecus are of same group.

C. *Australopithecus*

- Lived in east African grasslands; some 2 mya. Also called southern ape
- Used to hunt with stone, ate fruit.
- First ape man. Cranial capacity 300-500cc.
- First biped
- Tuang baby by Raymond dart.
- Lucy by Donald Johanson. (Most complete and best preserved skeleton of prehuman hominid ever)

D. *Homo habilis* (Habilis = Mentally able)

- First human like being.
- Cranial capacity was 650 to 800 cc.
- Tool maker / skill man / Handy man.
- Discovered by leaky. Tobias and Napier from kenya

E. *Homo erectus*

- Fossils discovered by Eugene Dubois from central Java.
- Existed some 1.5 mya.
- Bigger head with cranial capacity 900 cc.
- Probably ate meat.
- First to use fire.
- Peking man (*Sinanthropus*) Java man (*Pithecanthropus*).Heiderberg man are of sometime.

F. Neanderthal Man

- *Homo sapienns neanderthalis*.
- Lived in central & East Asia. 1 lakh to 40, 000 ya.
- Used to wear tough skins of animals (Hides)
- Ceremonially burry their dead ones, had religious beliefs.
- Fossils recovered from Neanderthal valley in Germany.
- Cranial capacity 1400cc.

G. Cromagnon Man

- *Homo sapiens fossilis*.
- Fossils discovered from cromagnon rocks of France.
- Originated 34,000 ya.
- Most recent ancestors of modern man.
- Could walk & run faster lived in caves & with family.

- Made excellent tools & ornaments.
- Carnivorous.
- Cranial capacity 1650 cc (maximum).

H. Modern Man

- *Homo sapiens sapiens*.
- Final reduction of the jaws, the appearance of modern man's chin and of the rounded skull.
- Cranial capacity was about 1400 cc
- Arose in Africa (More variations in DNA in Africa than in Asia).
- Evolved around 75000 – 10,000 ya, during ice age.
- Pre-historic cave art developed 18,000 years ago.
- Agriculture & human settlement started 10,000 ya.
- Omnivorous diet.
- **Paleolithic period** (Stone Age): Age of tools of stones and bones, cave paintings.
- **Mesolithic period:** Age of domestication of animals and learning, reading and writing developed language.
- **Neolithic period:** age of agriculture, manufacture of pottery and clothes. This period is further sub-divided into following ages– Bronze age (Ancient age), Iron age (Modern age)
- Human evolution is example of adaptive radiations.
- Gestation period has not been changed in human.
- Most significant change is increasing cranial capacity.
- Loss of tail is useless change.

ADDITIONAL INFORMATION

Charles Robert Darwin (12 February 1809 – 19 April 1882), an English naturalist proposed theory of natural selection. This theory became widely accepted by the scientific community. Darwin's theory remains a cornerstone of biology, as it provides a unifying explanation for the diversity of life. His five-year voyage on the HMS Beagle established him as a geologist. The publication of his journal of the voyage made him a popular author. Darwin investigated, the transmutation of species and conceived his theory of Natural Selection in 1838. **Alfred Russel Wallace**, in 1858 sent him an essay describing a similar theory. Later, they published their joint publication. His book "On the Origin of Species" in 1859 established "evolution by common descent" as the dominant scientific explanation of diversification in nature. He examined human evolution in "The Descent of Man", and sexual selection in "Selection in Relation to Sex". His research on plants was published in a series of books, and in his final book, he examined earthworms and their effects on the soil. In recognition of Darwin's pre-eminence, he was buried in Westminster Abbey, close to John Herschel and Newton.

SPECIATION AND ISOLATION

There are examples of species, which can produce fertile hybrids in captivity. You might have heard about the famous 'tigons', a hybrid of African lioness (*Panthera leo*) and Asian tigers (*Panthera tigris*), which is fertile. No barrier to hybridization between these species has evolved during their long isolation from each other. Natural selection has not favoured a reduction in hybridization for the simple reason that no hybridization has been possible. Other example of species that breed in captivity and produce fertile hybrids are mallard (a duck) and the pintail duck, the polar bear and the Alaskan brown bear and the platy and swordtail fishes. But these species do not interbreed at all in natural condition.

CONCEPT OF SPECIES

i. Biological species concept

- ✓ Proposed by Mayr, 1942.
- ✓ Species is a population in which individual members can interbreed freely, with each other but not with other species.
- ✓ If two species are morphologically similar but do not interbreed normally are called sibling species.
- ✓ Example of sibling species are *Drosophila pseudoobscura* and *Drosophila persimillis*.
- ✓ A species having two or more subspecies is called polytypic species.
- ✓ Not applicable for asexually reproducing species, which are called pseudospecies / paraspecies.

ii. Morphological species concept

- ✓ Proposed by Devis & Heywood: 1963.
- ✓ Assemblage of individuals with common morphological features.
- ✓ Common characters are called Lumpers & different ones as splitters.

iii. Evolutionary species concept

- ✓ Proposed by Simpson: 1961.
- ✓ Species is a lineage which evolved separately from other species & have its own evolutionary role & tendencies.
- ✓ In this concept morphological, genetic, behavioural & ecological differences are included.

iv. Typological concept

- ✓ Proposed by Aristotle & Plato.
- ✓ Fix pattern of characters are present in the species of every living organisms and all the members of that species show maximum resemblance with this pattern.
- ✓ It is most acceptable concept.

TYPES OF SPECIATION

- ➢ Groups of populations with common gene pool is called deme.
- ➢ Species is collection of deme.

I. Allopatric Speciation

- ➢ Due to geographical isolation e.g. Darwin's finches.

II. Sympatric Speciation

- ➢ Due to reproductive isolation, mainly due to polyploidy in plants.

III. Parapatric Speciation

- ➢ Separates adjacent populations.
- ➢ Population enters a new niche or habitat at edge of the parent species range.
- ➢ Due to reproductive isolation.
- ➢ In flightless grasshopper. Snails & annual plants.

IV. Quantum Speciation

- ➢ Rapid and abrupt mode of species formation.
- ➢ Genetic drift play role.

TYPES OF MIMICRY

i. Protective Mimicry

It is useful for an organism to protect itself from the predator. It is of two types.

- **Concealing:** The organisms resembles the surrounding so it cannot be easily detected by predators.
- **Warning type:** The organism resembles a distasteful or poisonous organism.

ii. Aggressive Mimicry

It is generally of two types.

- **Concealing**

  In this type the predator cannot be noticed by the prey because it matches with the surroundings, involving colour or body shape of both.

- **Alluring type**

  The predator attracts the prey by resembling itself.

iii. Batesian Mimicry

Palatable and unprotected species of animals imitate the relatively unpalatable and well protected species.

iv. Mullerian Mimicry

Two or more unpalatable species resemble each other.

GENETIC LOAD

- The existence of deleterious genes within the populations is called genetic load. For example a single pair of alleles is involved in the highly fatal sickle cell disease. Those homozygous for sickle cell usually die early due to anaemia. Those heterozygous to these alleles live reasonably healthy. This heterozygous condition, sometimes, is found beneficial. The heterozygous individuals with sickle cell RBC exhibit resistance to malaria. So this disadvantageous gene is carried in heterozygous condition.

- Recessive mutations that are disadvantageous and carried in the population is referred to as genetic load.
  - ***Cope's Law:*** *it states that there is a tendency for animals to increase in size during the long course of evolution.*
  - ***Allen's Law:*** *It states, that in animals which live in very cold climates, their extremities such as ears, tails etc. become progressively smaller.*
  - ***Gause's Law:*** *Two species having the same ecological requirements cannot continue to occupy indefinitely the same habitat.*
  - ***Gloger's Rule:*** *Among warm blooded animals, those living in warm and moist climate develop more melanin pigment***.**