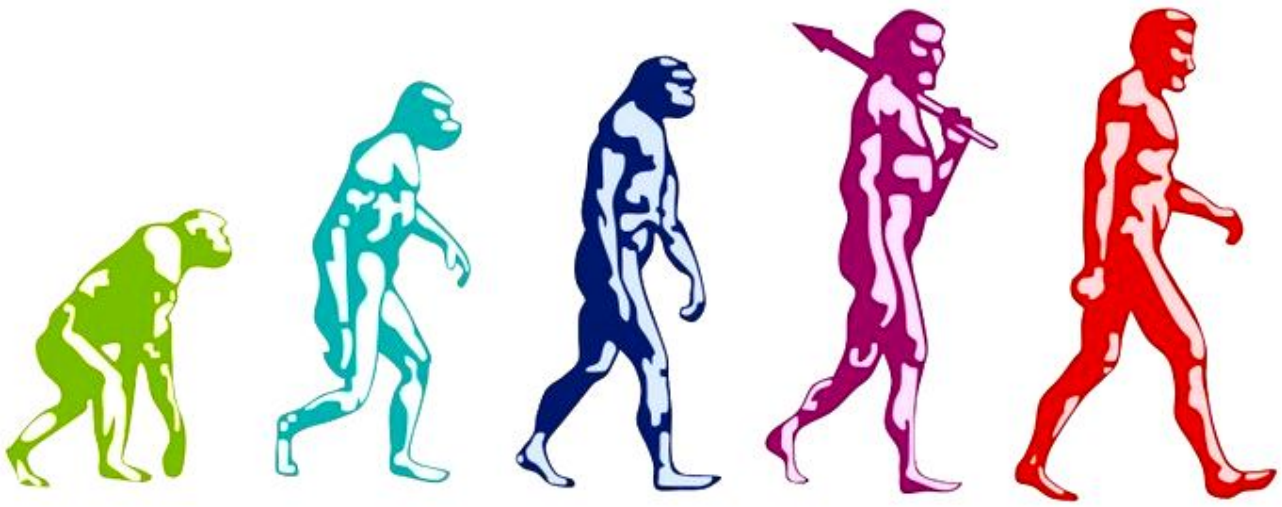
BIOLOGY

for NEET & BOARD



EVOLUTION

Key Features

1. All-In One Study Material (For Boards/Medical/Olympiads).
2. Concise, Conceptual & Trick – Based Theory.
3. NTA Based Solved Multiple Choice Questions With Answers.

Evolution

Chapter – 7

India's First Trick Based Study Material

1 INTRODUCTION

- The theory of evolution maintains that the different kinds of organisms that we see today have evolved from common ancestors over millions of years.
- This theory is one of the most important concepts in biology.
- The distinguished scientist **Theodosius Dobzhansky** has said : **"Nothing in biology makes sense except in the light of evolution".**
- For more than a century, the theory of evolution has exerted a very strong influence on our thinking about biology, also on developments in other disciplines such as sociology, politics, economics and religion.
- Life originated on the earth between 3000 and 4000 million years ago, in the form of unicellular organisms.
- How did these simple cells lead to (or evolve into) organisms as large as a whale or a *Sequoia* (redwood) tree, and structures as complex and delicate as the eye and the brain?
- The "Theory of Evolution by Natural Selection", was put forward by **Charles Darwin** and
  Alfred Russel Wallace towards the middle of the nineteenth century.
- It has provided us with a scientific framework for understanding the evolutionary changes that have occurred, and continue to take place in the biological world.

2 FROM ORIGIN OF EARTH TO ORIGIN OF LIFE

1. Evolution is a slow, continuous and irreversible process of change.
2. **Origin of Earth:** The **Big Bang Theory** proposes that the universe had an explosive beginning. The universe originated about **20 billion** years ago by a big bang **(thermonuclear explosion)** of a dense entity. About 4.6 billion years ago, our solar system was probably created when the gaseous cloud called Solar Nebula started to collapse under the force of its own gravity, until it became a flattened spinning disc of atoms and particles. Its central region heated up and became a star
3. Earth is about 4.6 billion years old, and the oldest rocks that have persisted in recognizable form are about 3.8 billion years old. For many years, scientists believed that such ancient rocks did not contain any fossils, but they knew that fossils were simply too small to be seen clearly without an electron microscope.

4. The oldest microfossils discovered so far are that of cyanobacteria that appeared 3.3 to 3.5 billion years ago.
5. Massive limestone deposits called **Stromatolites** became frequent in the fossil record about 2.8 billion years ago. Produced by cyanobacteria, stromatolites were abundant in virtually all freshwater and marine communities until about 1.6 billion years ago.
6. The fossil records indicate that unicellular protists -**the first eukaryotes** -appeared about 1.5 billion years ago.
7. Basic unit of evolution is population.

According to recent literature, the first non-cellular forms of life could have originated 3 billion years back. They would have been giant molecules (RNA, protein, polysaccharides etc.) These capsules reproduced their molecules perhaps. The first cellular form of life did not possibly originate till about 2000 million years ago.

3 THEORIES ON THE ORIGIN OF LIFE

(a) Ancient Theories for origin of life :

1. Theory of special creation –

- ✓ The greatest supporter of this theory was **father Suarez** According to Bible life and everything was created by god in 6 days.
- ✓ **on first day : Earth and heaven**
- ✓ **on second day : Sky and water**
- ✓ **on third day : Land and plants**
- ✓ **on forth day : Sun, moon and stars**
- ✓ **on fifth day : Fishes and birds**
- ✓ **on sixth day : Land animals and first man Adam and from his 12th Rib first woman Eve.**
- ✓ According to **hindu mythology** the world was created by **God Brahma.** (The first man was **Manu** and the first woman was **Shraddha**)
- ✓ According to it life has not changed ever since its origin.
- ✓ Special creation theory lacks scientific evidences so is not accepted.

2. Theory of Spontaneous Generation (Abiogenesis or Autogenesis) –

- ✓ This hypothesis was supported by ancient Greek philosophers like Thales, Anaximander, Xenophanes, Plato. Empedocles, Aristotle.
- ✓ According to this theory life was originated from nonliving things spontaneously.
- ✓ They believed that the mud of the **Nile** river could give rise to frogs, snakes, crocodiles.
- ✓ Abiogenesis was strongly supported by **Von Helmont.** He claimed formation of mice in 21 days. If a sweat soaked dirty shirt is kept in wheat barn.

3. Cosmozoic Theory –

- ✓ Proposed by **Richter.**
- ✓ Protoplasm reached on earth in the form of **spores** or other simple particles from some unknown part of the universe with cosmic dust and they gave rise to various forms of life.

4. **Cosmic panspermia theory –**

- ✓ Proposed by **Arrhenius.**
- ✓ According to this theory organisms existed throughout the universe and their spores could freely travel through space from one star to the other

5. **Theory of Eternity of Life –**

- ✓ **Helmholz** believed that life is **immortal.**

6. **Theory of Biogenesis –**

Harvey (1651) and

Huxley (1870)

{Omnis vivum ex ovo or vivo.}

- ✓ New organisms can be originated on earth only by pre-existing life.
- ✓ This theory rejected the theory of Spontaneous generation but cannot explain origin of life.
- ✓ To prove Biogenesis and to disprove abiogenesis experiments were performed by –

Francesco Redi (Italian 1668) –

- ✓ He took cooked meat in three jars, one was uncovered, the second was covered with parchment and the third was air tight.
- ✓ He observed that maggots developed only in the uncovered jar while maggots could not develop in the meat in closed jars.
- ✓ This proved that larvae were formed from eggs laid by the flies in open jars. Since the meat in closed jars could not be visited by flies so no larvae could develop. Therefore life originated from pre existing life.

Lazzaro Spallanzani (Italian 1767) –

- ✓ He boiled vegetables and meat to prepare a sterilized nutritive soup and he kept some of it in air sealed flasks and some in loosely corked flasks.
- ✓ He observed that the soup in sealed flask remained sterile while micro organisms appeared in the soup in loosely corked flasks.
- ✓ Thus even micro organisms were formed from pre existing ones in the air rather then spontaneously.

Louis Pasteur (French 1862) –

- ✓ Pasteur is popular for **Germ Theory of Diseases or Germ theory** and he disproved abiogenesis.
- ✓ He prepared sterlized **syrup** of sugar and yeast by boiling them in flasks.
- ✓ He took two flasks one of broken neck and another of curved neck (swan neck flask). No life appeared in swan neck flask because germ laden dust particles in the air were trapped by the curved neck which serves as filter while in broken neck flask colonies of microorganism were developed.

7. **Theory of catastrophism** was given by **Cuvier,** according to which after a gap of certain period (called age), the world undergoes a catastrophe (sudden calamity) which kills almost all the living organisms and then God creates a new generation or new life from inorganic matter.

Abiogenic or Chemical Origin of Life

- ✍ Majority of the scientists are ofthe opinion that life originated from inanimate matter. Since the theory of **abiogenic origin or chemical evolution** of life is the only one that provides an explanation, which can be tested, most scientists have tentatively accepted it.

Oparin-Haldane Hypothesis

1. Alexander I. Oparin (1894-1980), a Russian biochemist, and J.B.S. Haldane (1892-1964), a British scientist, put forward the concept that the first living organism evolved from non-living material. They also suggested that the sequence of events that might have occured. In 1923, Oparin postulated that life originated on Earth at some point of time in the remote past, and under the conditions no longer observed. In his book, *The Origin of Life* (1938), Oparin submitted" *abiogenesis first, butbiogenesis eversince".* Oparin's theory is known as primary abiogenesis.
2. According to Oparin and Haldane (1929), spontaneous generation of early molecules might have taken place ifthe earth once had more reducing atmosphere compared to the present oxidising atmosphere. Oparin and Haldane agreed that the primeval Earth contained little, if at all, oxygen. Perhaps, in the primitive atmosphere oxygen in the free gaseous state was virtually absent. Therefore, no degradation of any organic compound arising in the primeval Earth could have taken place.
3. As there was no ozone layer in the atmosphere, any absorption of UV radiations, that is lethal to our present lives, was not possible in the primeval Earth.
4. The early gas cloud was rich in hydrogen, being present in the combined form in methane (CH_4), ammonia (NH_3) and water vapour (H_2O).
5. Moreover, the atmospheric water vapour along with early gas cloud condensed into drops of water and fell as rain that rolled down the rock surfaces and accumulated to form liquid pools and oceans. In the process, erosion of rocks and washing of minerals *(e.g.,* chlorides and phosphates) into the oceans were inevitable. Thus, Haldane's hot dilute soup was produced and the stage was set for combination of various chemical elements.
6. Atmospheric chemicals and those in water produced small precursor molecules, like amino acids, sugars, nitrogenous bases etc. These precursor molecules then combined resulting in the appearance of proteins, polysaccharides and nucleic acids.
7. The energy sources for such reactions of organic synthesis were the UV radiations (solar radiation), cosmic rays, electrical discharges (lightning), intense dry heat (volcanic eruption) and radioactive decay of various elements on the Earth's surface. Once formed, the organic. molecules accumulated in water because their degradation was extremely slow in the absence of any life or enzyme catalysts. Such transformation is not possible in the present oxidising atmosphere because oxygen or micro organisms will decompose or destroy the living particle that may arise by mere chance.

Experimental Evidence for Abiogenic Molecular Evolution of Life

- ✍ Harold C.Urey (1893 -1981), an astronomer, accorded the first adequate recognition of Oparin-Haldane's view on the origin of life in 1952.
- ✍ Urey asked his student Stanely L. Miller, a biochemist, to replicate the primordial atmosphere as propounded by Oparin and Haldane.
- ✍ **Miller** (1953) made the first successful simulated experiment to assess the validity of the claim for origin of organic molecules in the primeval Earth's conditions.

Abiotic synthesis of biomolecules is studied under following headings:

1. **Chemogeny:** Synthesis of organic molecules by chemical reactions.
2. **Biogeny:** Formation of self replicating biomolecules in broth (primordial hot soup or warm little pond).
3. **Cognogeny:** Evolution of various forms of life or diversification of existing groups.

Enclosing the Prebiotic Systems

- ✍ The experiments of Miller and other scientists demonstrate that prebiotic molecules could have been formed under the conditions which most likely existed on early Earth.
- ✍ Still, the formation of prebiotic soup of small molecules does not necessarily lead to the origin of life.
- ✍ For origin of life, atleast three conditions needed to have been fulfilled:
  1. There must have been a supply of self-replicators *i.e.,* self-producing molecules
  2. Copying of these replicators must have been subject to error via mutation.
  3. The system of replicators must have required a perpetual supply of free energy and partial isolation from the general environment.
- ✍ The high temperature prevailing in early Earth would have easily fulfilled the second condition, that is, the requirement of mutation. The thermal motion would have continually altered the prebiotic molecules.

4 MODERN THEORY OF ORIGIN OF LIFE

- ✓ **(Oparin-Haldane theory of origin of life)**
- ✓ **Naturalistic theory Or Theory of Chemical Evolution –**
- ✓ This theory was proposed by Russian Scientist **A.I. Oparin** and **J.B.S Haldane** (England born Indian scientist)
- ✓ Oparin's theory was published in his book 'ORIGIN OF LIFE'.

Memories

- ✍ According to this theory life originated by the composition of chemicals. (Chemical evolution).
- ✍ Oparin's theory is based on Artificial Synthesis. So also called as **artificial synthetic theory.**
- ✍ Ist life originated in the water of oceans. So water is essential for origin of life. **There is no life on moon due to absence of water.**
- ✍ At the time of origin of life free O_2 was absent, so first life was **anaerobic.**
- ✍ In the primitive atmosphere free oxygen was present but complete oxygen consumed in composition so primitive atmosphere of earth was **reducing.**
- ✍ Oxygen was reproduced by photosynthesis and atmosphere converted in oxydising.

(A) CHEMICAL EVOLUTION :

1. **The atomic stage –**

   - ✓ The earth was originated about 4.5 billion years ago. Early earth had free atoms of all elements which are essential for the formation of protoplasm. The lightest atoms like **carbon, hydrogen, nitrogen and oxygen** formed the primitive atmosphere.

2. **Molecular stage (Origin of molecules and simple Inorganic compounds) –**

   - ✓ Free atoms combined to form molecules and simple inorganic compounds.
   - ✓ Due to presence of high temperature, active hydrogen atoms combined with all oxygen atoms to form water and leaving no free oxygen.
   - ✓ Thus the primitive atmosphere was **reducing** (without free oxygen) unlike present **oxidising** atmosphere (with free oxygen).
   - ✓ Hydrogen atoms also combined with nitrogen to from NH_3.
   - ✓ **(The first molecular compounds formed were probably water and Ammonia).**
   - ✓ These Lighter elements also formed CO_2 , CO, N_2 , H_2 etc.

3. **Origin of early organic compounds –**

   - ✓ The nitrogen and carbon of the atmosphere combined with metallic atoms forming nitrides and carbides.
   - ✓ Water vapour and metallic carbides reacted to form to **first organic compound Methane (CH_4).** Later on **hydrogen cyanide (HCN)** was formed .
   - ✓ Water which formed on earth due to high temperature evaporated so **clouds** were formed.
   - ✓ Water vapour changed into rain drops and by the collection of water on earth primitive oceans were formed.

4. **Origin of simple organic compounds –**

   - ✓ Water of primitive oceans contained large amount methane, ammonia, hydrogen, cyanides, carbides, nitrides.
   - ✓ These early compounds interacted and formed simple organic compounds like, aldehyde, Ketones. Alcohols . Pentose and hexose sugar, Amino Acids, Glycerol, Fatty Acids, Purines, Pyrimidines etc.
   - ✓ **Energy was obtained from U.V. Rays of sunlight, cosmic rays and heat of volcanic ` eruptions.**

5. **Origin of complex organic compounds –**

   The small simple organic molecules combined to form large complex organic molecules, e.g –

   - – Amino acids Joined to form polypeptides and proteins, which were non-enzymatic.
   - – Simple sugar units combined to form polysaccharides.
   - – Fatty acids and glycerols united to form fats and lipids.
   - – Sugar, nitrogenous bases, phosphates combined into nucleotides which polymerized into nucleic acid, which unable to replicate.
   - • These macromolecules forms main component of protoplasm hence the possibility of origin of life in primitive oceans could be established. After long time the water of primitive oceans became rich mixture of organic compounds as a result of chemical evolution.

- **Haldane called this saturated water of oceans as pre-biotic soup or hot dilute soup.**
- The major requirement for promoting polymerization is the availability of continuous source of energy and removal of water from the surface of reactants so that they can concentrate and prevent depolymerisation.

Experimental Evidence For Formation Of Simple Organic Compounds –

- ✓ **By Stanley Miller** who was a student of **Harold Urey.**
- ✓ In this experiment Miller took the mixture of **methane, ammonia and hydrogen (ratio 2 : 1 : 2)** in a large flask and passed steam over it by boiling water and connecting it with a glass tube.
- ✓ Electric spark discharged in the mixture by using two tungsten electrodes as **source of energy.**
- ✓ After **18 days** this fluid was collected and analysed. This dark red fluid was found to contain.
- – Simple amino acids – **glycine**, **alanine**, **aspartic** acid.
- – Simple organic acids – formic, acetic, oxalic, lactic, succinic acids.
- – Pentose, hexose, aldehyde, ketone etc.

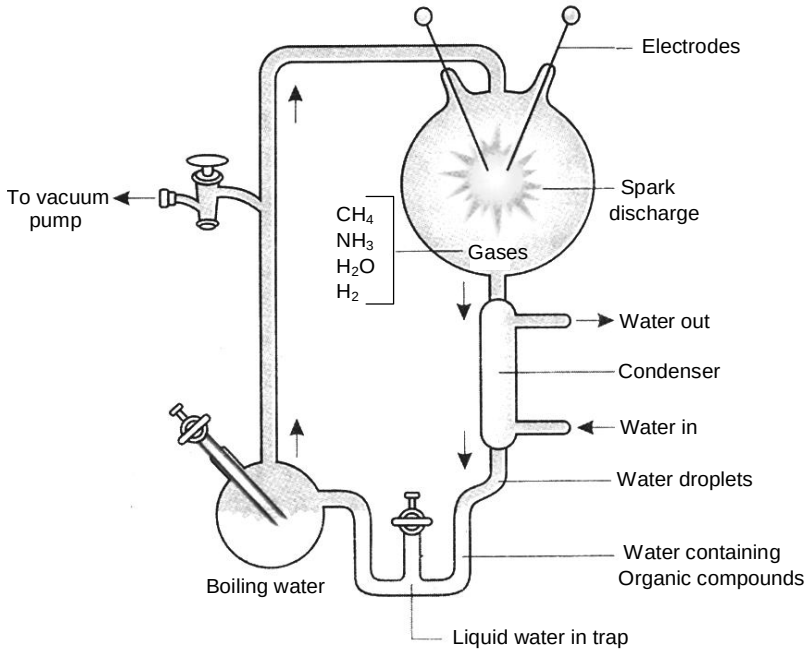


Fig: Diagrammatic representation of Miller's experiment

(B) BIOLOGICAL EVOLUTION :

(i) Origin of Protobionts and Nucleoprotein (Coacervates)

- ➢ Macromolecules which were synthesized abiotically in primitive ocean later came together and formed large colloidal drop like structures named as Protobionts **(Later called coacervates by oparin, Fox and called them Microsphere and Deamer called them vesicles).**
- ➢ Each protobiont was **cluster** of macromolecule.
- ➢ They contain proteins, nucleic acids, lipids, polysaccharides etc.
- ➢ They grew by absorbing molecules from their environment.
- ➢ They could divide by budding like bacteria, many chemical reactions including the decomposition of glucose took place inside the protobionts.
- ➢ The sun provide energy for chemical reaction.

- According to oparin **coacervates were the first sole living molecules** which gave rise to cell.

Different types of Protobionts obtained by scientist

- **Oparin** (1924) took a solution of carbohydrate and large protein. The solution was shaken. It caused separation of coacervates.
- In coacervates higher concentration of protein, carbohydrate were present with small amount of water.
- Oparin's coacervates could grow and exhibit simple form of metabolism. However a lipid membrane and reproduction was absent.
- **Fox (1957)** obtain **microspheres** with a primitive membrane. He heated a dry mixture of Amino acids at 130° – 180° C. It formed **PROTEIDS/PROTENOIDS** (Polymer of amino acid).
- When these proteids poured in Cool water along with lipids, microsphere get separated. (size 1-2 nm)
- **Deamer** (1993) Microsphere and coacervates could fused to form protobionts having various type of chemicals like proteins, Nucleic acids, Carbohydrates etc. enclosed inside a lipid membrane. Deamer called them **vesicles.**

(ii) Origin of protocells (Eobiont) :

- The first living form named **protocell** originated in the primitive oceans.
- The protocell were clusters of nucleo-proteins which formed by composition of nucleic acids and enzymetic proteins.
- Nucleoproteins had the property of self duplication.
- **Nucleoproteins were first sign of life.**
- **The protocell represented the beginning of life.**
- From protocells or eobionts few core of nucleoproteins gets separated free in oceans and became inactive but when they enter in another eobionts they became active so virus like structures were formed.
- Origin of virus like structure is an example **retrogressive evolution** (complex to simple).

Memories

✍ ***Khorana (1970) artificially synthesized 77 nucleotide RNA molecule out side a living cell which suggests that probably RNA was the primordial genetic material rather than DNA.***

- ***Zaug, Thomas cech and Altman described that some RNA molecules have enzymatic activity hence probably the RNA enzymes called ribozymes were able to replicate the primordial RNA.***
- ***The discovery of RNA molecule working as enzyme has also changed our thinking about origin of life.***
- ***It is now believed that about 4 billion years ago earth was an 'RNA world' in which RNA molecule carried out all the process of life without the help of either protein or DNA,***
- ***By this discovery evolution is named as RNA world.***

✍ ***It is estimated that life originated about 3.0 billion years ago as protocell (eobionts) in precrambian era which was anaerobic heterotrophic.***

(iii) Origin of Prokaryotes –

As a result of mutation the protocells became more complex and efficient and used the materials available in the surrounding medium and condensed themselves into prokaryotic cells.

Thus the first living being were prokaryotic, like bacteria they were single celled and consisted of naked DNA. Nutritionally they were **chemoheterotrophs** (saprotrophs), respiration was **anaerobic.**

(iv) Origin of Autotrophism –

It includes the origin of **chemosynthesis** and **photosynthesis.**

(a) Origin of chemosynthesis :

- Due to continue withdrawal of organic molecules by chemoheterotrophs organic
- material decreased in oceans.
- Before the organic material disappeared in sea, new modes of Nutrition developed, one of them was **chemosynthesis**.
- The organism which perform chemosynthesis are called as **chemoautotrophs.** They were anaerobic and synthesise organic molecules from inorganic material. The energy was obtained by oxidizing inorganic materials present in the sea.
- **Such mode of nutrition is found in Bacteria e.g. sulphur bacteria, nitrifying**
- **bacteria.**

(b) Origin of Photosynthesis :

After some time bacteriochlrophyll developed in some autotrophic bacteria like organism. They could absorb solar energy and convert it into chemical form these organism called **photoautotrophs.**

They were anaerobic and utilized hydrogen from sources other than water like H_2S. Therefore, no oxygen was evolved and atmosphere remained reducing .

This stage of photosynthetic autotrophism is represented by planktonic sulphur bacteria of today.

$$6CO_2 + 12H_2S \xrightarrow{\text{Solar enery}} C_6H_{12}O_6 + 6H_2O + 12S$$

The Bacteria chlorophyll by molecular changes formed true chlorophyll.

Such organism which were bearing true chlorophyll are similar to today's **Cyanobacteria (B.G. Algae).**

They utilized water as hydrogen donor and evolved oxygen.

$$6CO_2 + 12H_2O \xrightarrow{\text{Solar enery}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Oxygen revolution –

Liberation of free O_2 by blue green algae like prokaryotes due to photosynthesis was a revolutionary change in the history of earth. It is called **oxygen revolution.**

It includes important changes like –

(1) Atmosphere of earth changed from **reducing to oxidising**, hence possibilities of further chemical evolution and abiogenesis got over, because chemical evolution always take place in reducing environment.

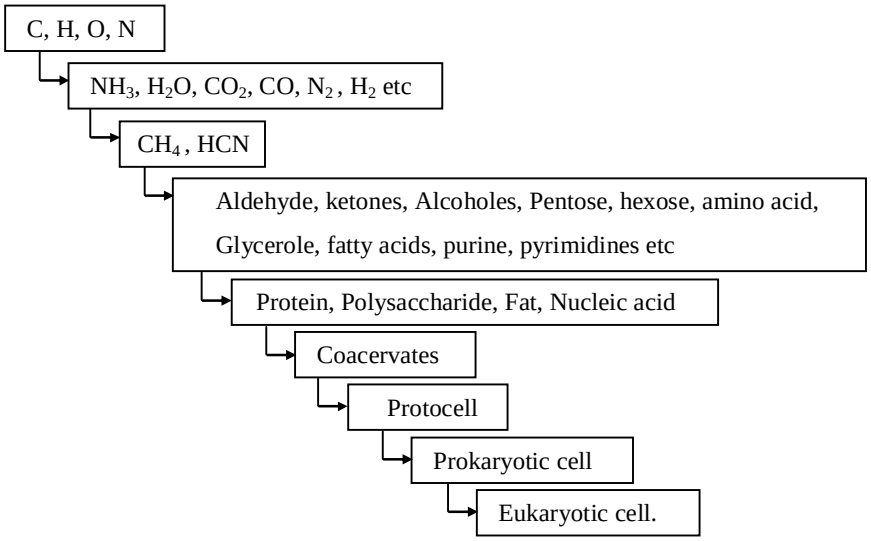
(2) Free O_2 oxidized CH_4 and NH_3 to form gases like CO_2 , N_2 and H_2O.

(3) Accumulation of free O_2 formed a layer of **O_3 (ozone)** above the atmosphere of earth, which started absorbing most of the U.V. rays of sunlight.

(c) Origin of Eukaryotic cell –

About 2.7 billion years ago conditions become suitable for aerobic respiration with the release of free O_2 . Aerobic respiration yields about **20 times more energy** then anaerobic respiration hence the prokaryotes adapted themselves for aerobic mode of respiration.

Nucleus, mitochondria and other cell organelles developed in the cell and free living eukaryotic cell like organism originated about 2.0 billion years ago in the primitive ocean.



EVIDENCES OF EVOLUTION

(C) EVIDENCES OF ORGANIC EVOLUTION

1. **EVIDENCES FROM ANATOMY:** Different animals and plants show dissimilarities in their structure but in some characters they show similarities. These similarities are of two types.
   a. Homology b. Analogy

Examples of Homologous organs

a. Homology –

- The similarity based on common origin, similar basic plan of organization and embryonic development is called **homology.**
- **Similarity in appearance and function is not necessary.**
- The organs which have common origin, embryonic development and same basic structure but perform different functions are called **Homolgous organ. Homologous term given by Richard Owen.**

- These organs have the similar basic structure and developmental origin.
- The organisms which possess such organs are said to have originated from common ancestor.
- Homologous organs show divergent evolution which means that the similar structures developed along different directions due to adaptions to different needs or **Adaptive Radiation** which is the development of dissimilar functional structures in closely related group of organisms.

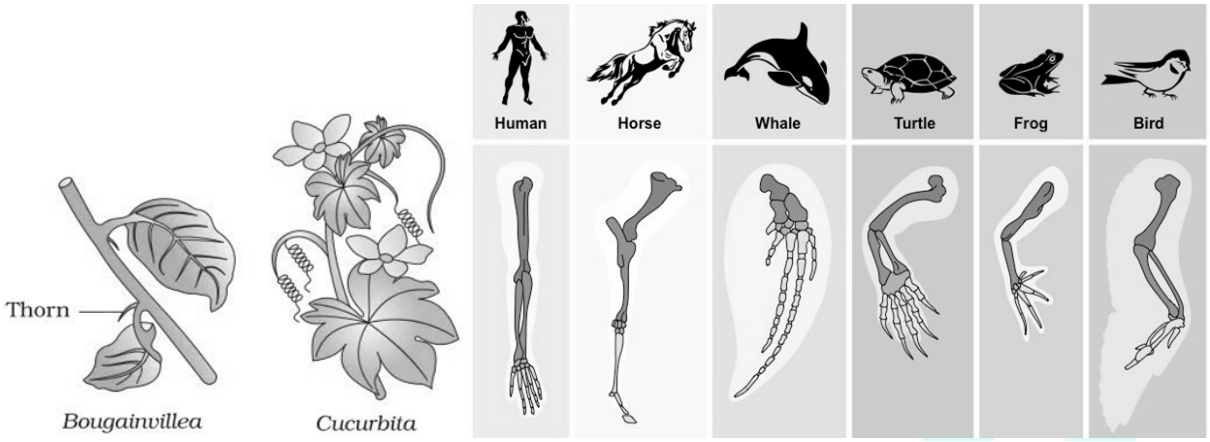


Fig: The Pentadactyl Limb

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

EXAMPLES:

- Despite possessing similar bone arrangements, animal limbs may be highly dissimilar according to the mode of locomotion:
- Human hands are adapted for tool manipulation (power vs precision grip)
- Bird and bat wings are adapted for flying
- Horse hooves are adapted for galloping
- Whale and dolphin fins are adapted for swimming

(i) Forelimbs of mammals –

	Horse	**Bat**	**Whale**	**Seal**	**Man**
Appearence	Foot	wings	Paddle	Flipper	Hard
Function	Running	Flying	Swimming	Swimming	Holding

In their fore limbs similar bones are present like – **humerus, radius, ulna, carplas, metacarpals and phalanges.**

(ii) Legs of invertebrates –

Cockroach	**Honey bee**
Walking	Collecting of pollens

But in both segmented legs are present are segments are same like **coxa, Trochanter, Femur, tibia, 1-5 jointed tarsus.**

(iii) Mouth parts of insects

Cockroach	**Honey Bee**	**Mosquito**
Biting and chewing	Chewing and lapping	Piercing and sucking

In each of these insects the mouth parts comprise **labrum, mandibles and maxillae.**

(iv) Homology is also seen in the skeleton, heart, blood vessels and excretory system of different vertebrates.

(v) Thorn of Bougainvillea and tendril of cucurbita (Modification of axillary bud).

(vi) Wings of sparrow and pectoral fins of fish.

(vii) Hind limb of mammals.

(viii) Potato & ginger.

(ix) Radish & Carrot

(x) Homology is also seen amongst the molecule. This is called **molecular homology.** For example the proteins found in the blood of man and apes are similar.

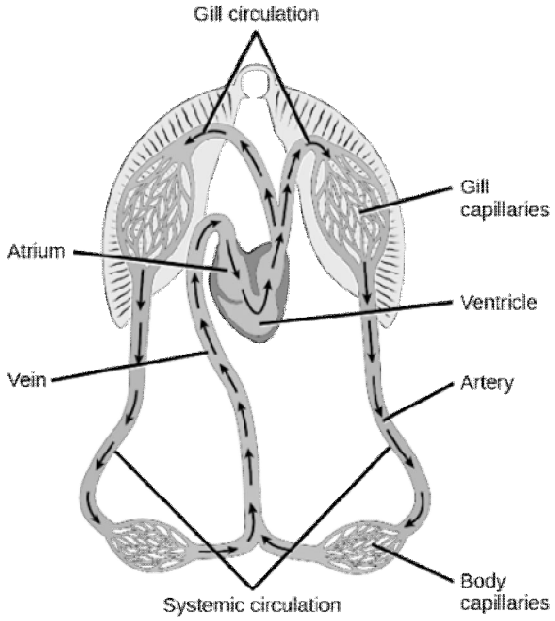
(xi) Testes in male and Ovaries in female develop from same embryonic tissue.

(xii) Pectoral fin of fish and flipper of seal.

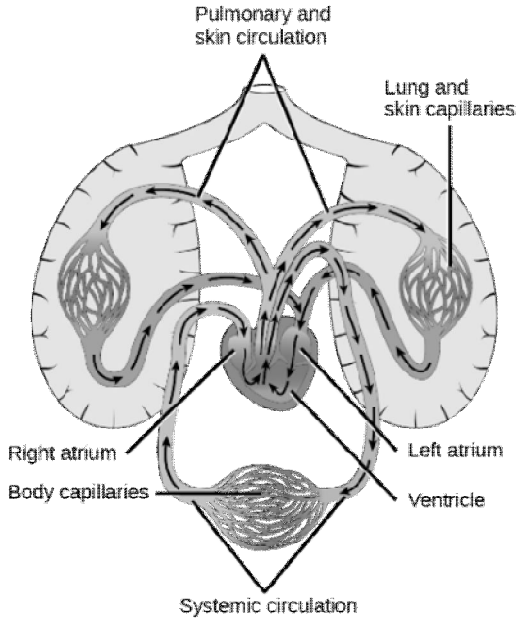
(xiii) Flipper of penguin (bird) and dolphin (mammal)

Divergent evolution (adaptive divergence/adaption radiation)

- Homology found in different animals indicate their evolution from common ancestors.
- Species which have diverged after origin from common ancestor giving rise to new species adapted to new habitats and ways of life is called **adaptive radiation,** exhibit large number of homologous organs.
- Homology shows **Divergent evolution.**
- (Homology indicates common ancestry. Other examples are comparison of heart and brain of vertebrates)
- For Example Adaptive radiation gave rise to a variety of marsupials in Australia



(a) Fish



(b) Amphibians

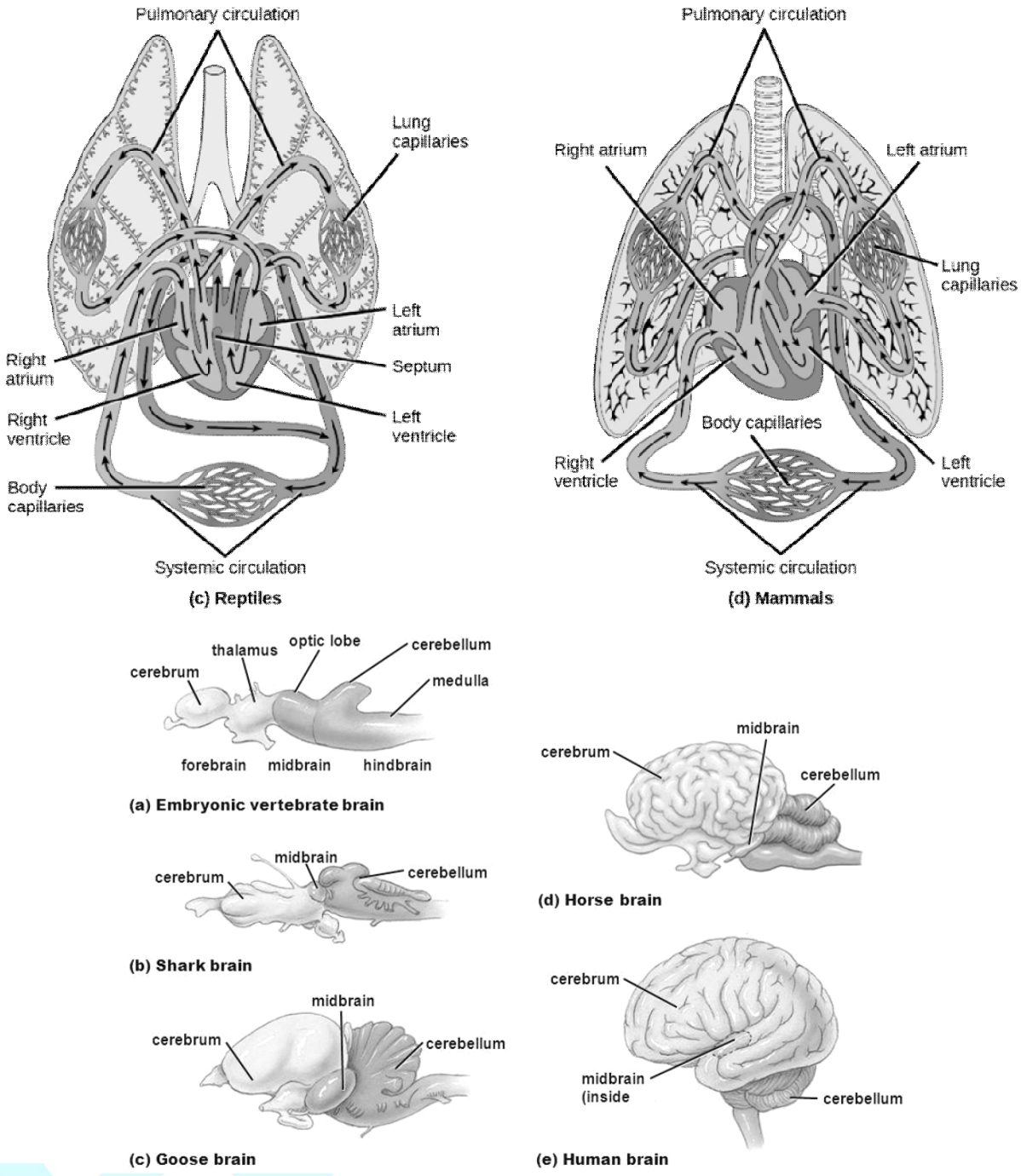


Fig: A comparison of vertebrate hearts and brains

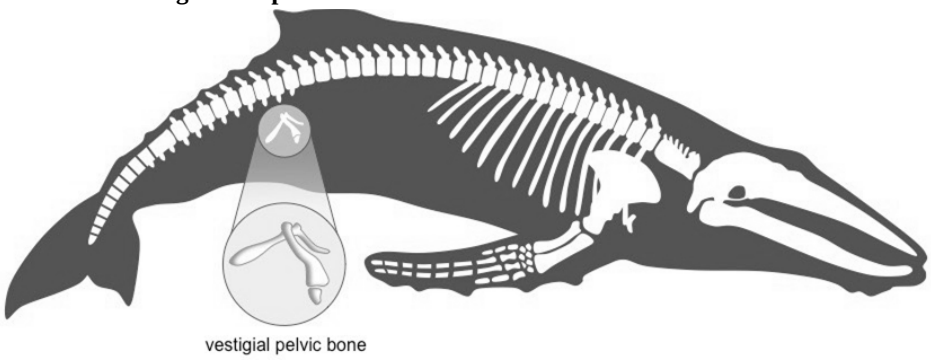


Fig: Example of a Vestigial Structure

(b) Analogous organs :

- These organs which are **not anatomically similar** though they perform **similar functions.**
- For example, the wings of birds and of butterfly look alike, they perform the similar function of flying but they are not anatomically or structurally similar.
- Even the wings of birds and bats are also analogous structures which have different origins.
- Other examples are flippers of penguin and dolphin (the former is a bird and the later is a mammal); eye of an octopus and the eye of a mammal, both differ in retinal position, still the function is same.
- In plants, sweet potato (root modification) and potato (stem modification) is another example of analogy.
- Both are **meant** for storage of food but modifications of different parts of plant.
- Now, what is the reason of development of analogous structures?
- The possible explanation may be that it is the **similar habitat** that has resulted in selection of similar adaptive features in different (distantly related) groups of organisms put toward the same function.
- This phenomenon is termed **adaptive convergence or convergent evolution** which is the opposite of adaptive radiation as seen in the homologous structures trifoliate leaf.

(i) *Vestigial organs:*

- They are believed to be **remnants** of organs which were complete and functional in their ancestors.
- The study of vestigial organs offer an evolutionary explanation of such rudimentary vestiges by stating that adaptations to new environment of the organism have made these structures redundant.
- Such structures are called **vestigial organs**.
- The rudiment of the reptilian jaw apparatus, the rudiment of the hind limbs of python and Greenland whales are some of the examples of vestigial organs.
- In humans, many vestigial structures indicate a relationship to other mammals, including the primates.
- For instance, muscles of the external ear and scalp are rudimentary and often non-functional.
- But these are common to many mammals where they are functional.
- The reduced tailbones and nictitating membrane of the eye, the appendix of the caecum, rudimentary body hair and wisdom teeth -all are examples of vestigial organs.
- The appendix of man is thought to be a remnant of the large caecum -the storage organ for cellulose digestion in herbivorous mammals.
- Similarly, the non-functional vestiges of the pelvic girdle in python and porpoise show, for instance, that the snake and the porpoise originally evolved from four footed ancestors.

Vestigial organs in plants –

- Scale leaves of Ruscus and various underground steams.

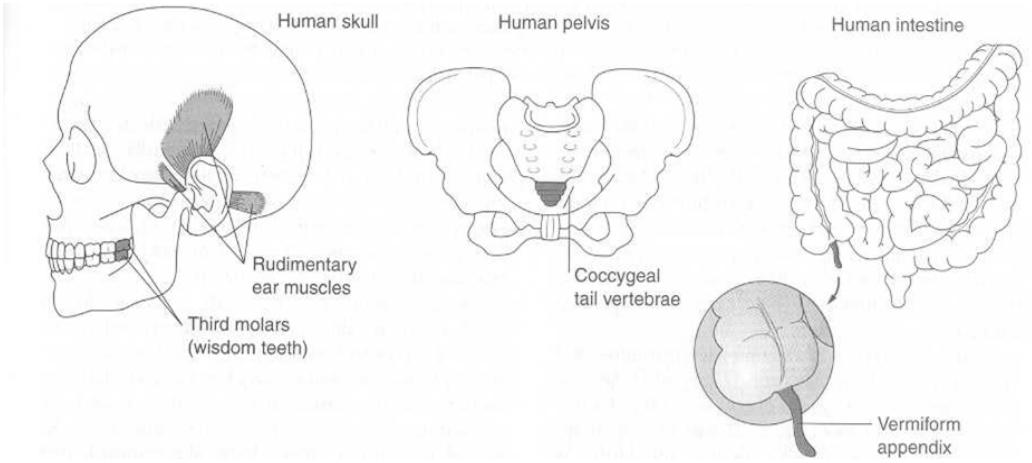


Fig: Some vestigial structures found in humans. (after Romanes, modified.)

2. EVIDENCES FROM ATAVISM (REVERSION) –

Sometimes in some individuals such characters suddenly appears which were supposed to be present in their ancestors but were lost during the course of development.

This phenomenon is known as **atavism or reversion.** Atavism proves that animals developing atavistic structure have evolved from such ancestors in which these structures were fully developed.

Examples :

1. ***Human baby with tail***
2. ***Cervical fistula*** *– in some human babies an aperture is present on neck behind the ear called as cervical fistula. It represents pharyngeal gill slits which were present in aquatic vertebrate ancestors.*
3. ***Long and pointed canine teeth represented carnivorous ancestors.***
4. ***Large and thick body hair reflect our relationship with apes.***
5. ***Extra nipples (more than two)***
6. **Evidence from physiology and biochemistry –**

Different organism show similarities in physiology and biochemistry. Some clear examples are –

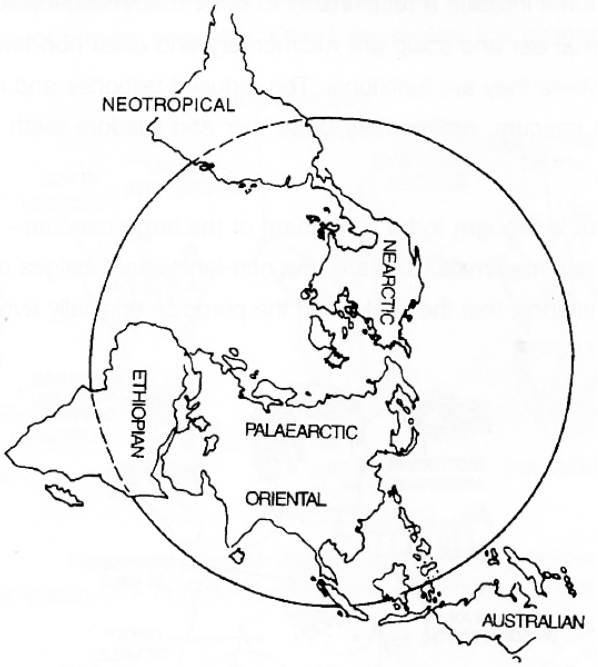
1. **Protoplasm :** Structure and chemical composition of protoplasm is same from protozoa to mammalia.
2. **Enzymes :** Enzymes perform same function in all animals like **Trypsin** digest protein from amoeba to man. **Amylase** digest starch from porifera to mammalia.
3. **Blood :** Chordates show almost same composition of blood.
4. **ATP :** This energy rich molecule is formed for biological oxidation in all animals.
5. **Hormones :** Secreted in different vertebrates performs same function.

6. **Hereditary material :** Hereditary material is DNA is all organism and its basic structure is same in all animals.

7. ***Cytochrome C** is a respiration protein situated in the mitochondria of all organism. In this protein from 78-88 A.A. are identical in all organism, which show common ancestory*

3. BIOGEOGRAPHICAL EVIDENCES

- The study of patterns of distribution of animals and plants in different parts of the earth is called **Biogeography**.



The biogeographical realms

✍ **Alfred Russel Wallace** (1823 -1913) divided the whole world into six major biogeographical regions or realms.

1. **Palaearctic :** Europe and Asia north of the tropics, north-western corner of Africa, including the Atlas Mountains.
2. **Nearctic :** North America exclusive of the tropics, Alaska, Canada, United States and
3. Mexico.
4. **Neotropical :** Central America including low lands of Mexico, islands of the Caribbean and all of South America.
5. **Ethiopian** Africa (with exception of the Atlas Mountains), Madagascar and adjacent islands.
6. **Australian :** Austrialia, Tasmania, New Guinea, New Zealand and Oceanic islands of the pacific. It is believed that millions of years ago all the continents were present in the form of a single land mass called **Pangaea.**

✍ Biogeography describes the distribution of life-forms over geographical areas, both in past and present times.

- Related species are usually found in close physical proximity (supporting the concept of speciation via gradual divergence)
- Fossils found in a particular region tend to closely resemble the modern organisms of the region

- ✍ Biogeography provides evidence for evolution because it suggests that closely distributed species share a common lineage
  - If speciation was random, the distribution of structurally similar species would be expected to be scattered
- ✍ Examples of bio-geographical distribution indicating shared ancestry can be observed by the fact that:
  - Most modern marsupials are found almost exclusively in Australia (~70% of extant species)
  - Australia has few placental mammals compared to South America, even though environmental conditions are similar
- ✍ Exceptions to this correlation between biogeographical distribution and common ancestry can be explained by *continental drift*
  - Over 250 million years ago, there was a single continental landmass (Pangaea) which split into the 6 current land regions
  - Closely related species that were separated by the breaking landmass are localised to regions that were once connected
  - For example, ratites (flightless birds) are distributed globally according to regions that were once part of Gondwanaland

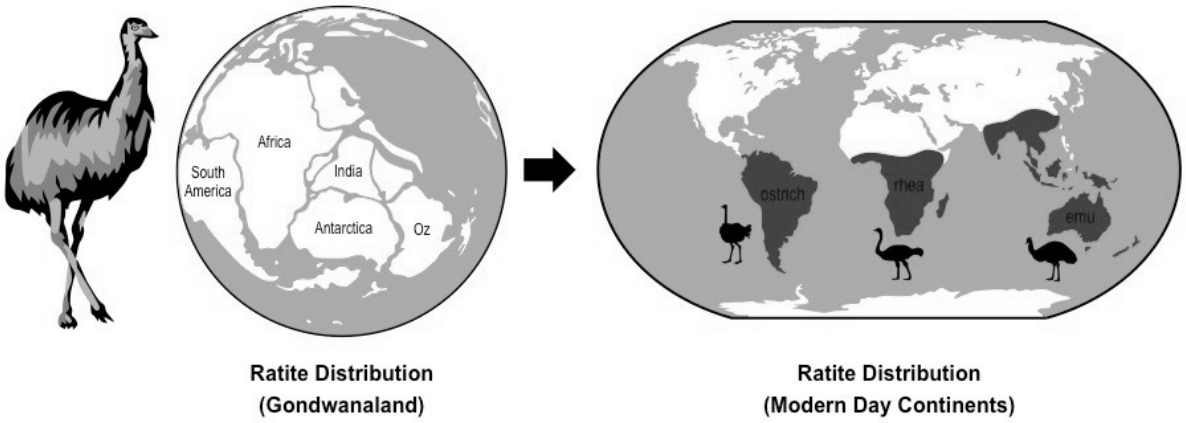


Fig: Biogeographical Distribution of Ratites as Explained by Continental Drift

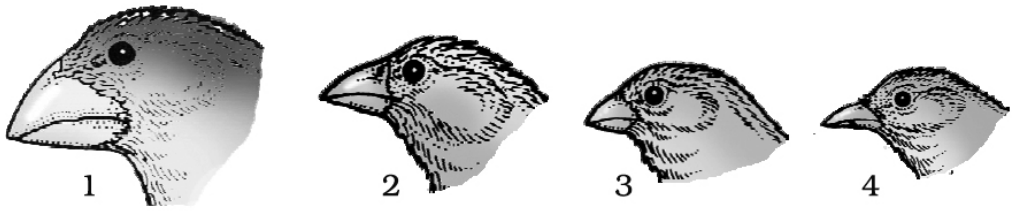
As these continents moved away, they got separated from each other by the seas. As these continents had different environmental conditions so plants and animals evolved there were of different varieties. **(New species).**

1. **Prototheria –**
   - ➢ This is sub class of mammalian, which includes egg laying mammals like **Platypus** and
   - ➢ **Echidna** found in Australia.
   - ➢ After the evolution of prototherians from reptiles Australia got separated from mainland of Asia.
   - ➢ Later on Eutherian mammals evolved in Asia, Due to their carnivorous nature they destroyed prototherians and metatherians from Asia.
   - ➢ So these groups became extinct on the mainland but they survived in Australia due to absence of Eutherians.
   - ➢ Today eutherians are also found in Australia **(they were later transported by man).**
2. **Marsupialia –** The subclass of class mammalian includes kangaroos and Opossum which are found only in Australia.

3. Darwin's finches –

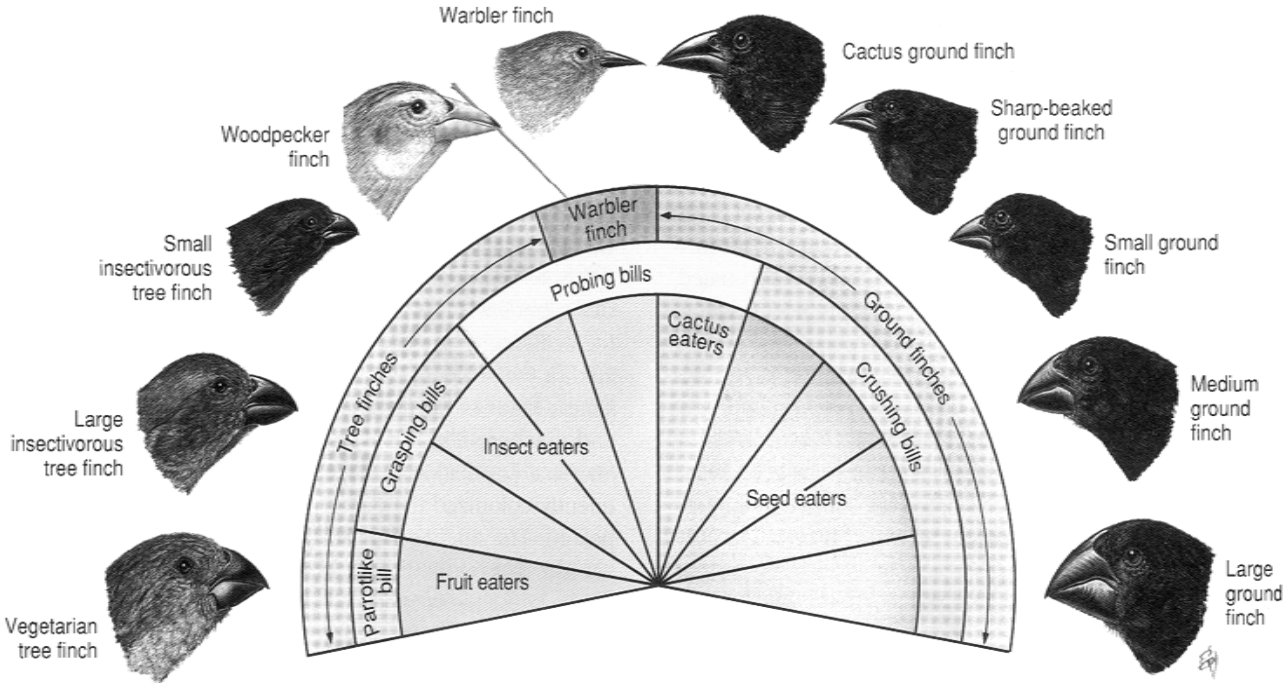
ADAPTIVE RADIATION

- Galapagos Islands are chain of 22 islands, present on the west coast of South America.
- During his journey, Darwin went to Galapagos Islands.
- There he observed an amazing diversity among creatures.
- Of particular interest, small black birds, later called **Darwin's finches**, amazed him.
- He realised that there were many varieties of finches in the same island
- All the varieties, he conjectured, evolved on the island itself.
- From the original seed eating features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches.
- These birds in Galapagos island show different in bills and feeding habits, but still resemble with the birds present on original mainland.
- Hence, we have seen different species have evolved from single common ancestor

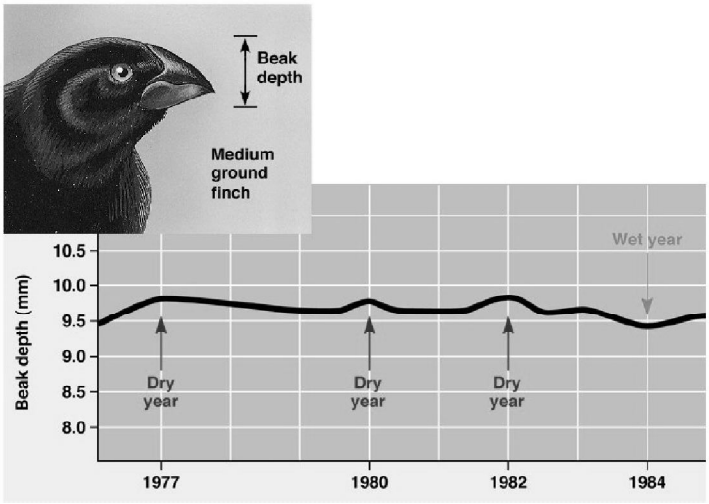


Variety of beaks of finches that Darwin found in Galapagos Island

Large ground finch (seeds) | Cactus ground finch (cactus fruits and flowers) | Vegetarian finch (buds) | Woodpecker finch (insects)



✍ And this process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography (habitats) is called **adaptive radiation** of which the Darwin's finches represent one of the best example.



Fig; Adaptation in Darwin's Finches

✍ The clusters of species that have been formed on the Galapagos Islands are thus a Tasmanian wolf clear example of species formation arising by microevolutionary divergence from an ancestral form occupying different habitats of microevolution leading to macroevolution

✍ Another example is Australian marsupials.

✍ A number of marsupials, each different from the others, evolved from an ancestral stock, but all within the Australian continent.

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

4. Elephants and lions are mainly found in Africa and India.

5. Giraffe, Zebra and hippopotamus are found only in Africa.

6. Main land of human evolution in Africa

- **Placental mammals in Australia** also exhibit adaptive radiation in evolving into varieties of such placental mammals each of which appears to be 'similar' to a corresponding marsupial *(e.g.,* Placental wolf and Tasmanian wolf marsupial)

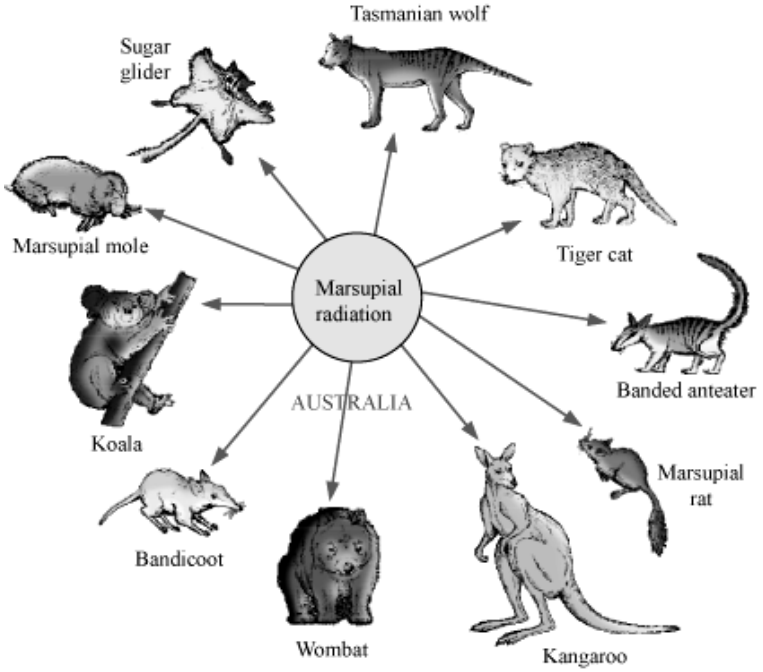
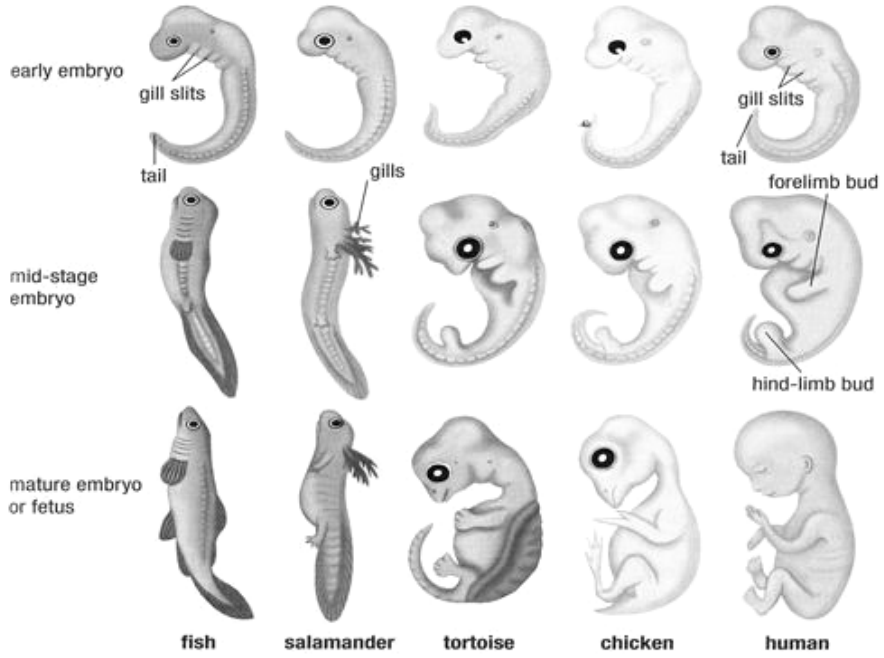


Fig: Adaptive radiation of marsupials of Australia

- **Placental mammals** in Australia also exhibit adaptive radiation in evolving into varieties of such placental mammals each of which appears to be 'similar' to a corresponding marsupial (e.g., Placental wolf and Tasmanian wolf marsupial).

4. EMBRYOLOGICAL EVIDENCES

- The sequence of embryonic development in different vertebrates show striking similarities.
- Gill clefts and notochord appear in the embryonic development of all vertebrates from fishes to mammals.
- The notochord is replaced by the vertebral column in all adult vertebrates.
- Similarly, gills are replaced by lungs in adult amphibians, reptiles and mammals.
- Such similarities in embryonic development once again reinforce the idea of evolution from common ancestors.
- Occasionally, embryonic features such as the tail and gill slits persist in adults
- According to Ernst Haeckel, ontogeny (development of embryo) is recapitulation of phylogeny (the ancestral sequence).



Comparing the embryonic development of a range of diverse animal species, it can be seen that:

- All terrestrial animals have non-functioning gill slits (pharyngeal slits) as early embryos (suggesting an aquatic origin)
- Many vertebrates (including humans) demonstrate a primitive tail at an early stage of embryonic development.

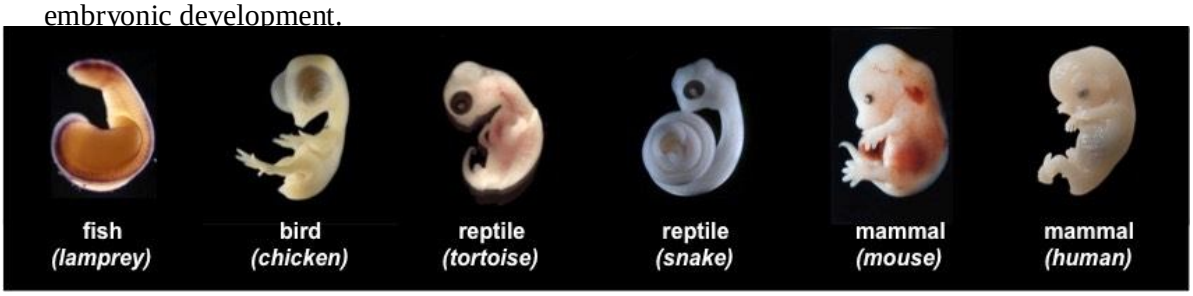


Fig: Comparative Embryology

- ✍ This view was summarised by his Biogenetic Law : Ontogeny Recapitulates Phylogeny.
- ✍ Developmental evidence for evolution is also available from plants.
- ✍ It is generally believed that mosses and ferns are more evolved than algae.
- ✍ Protonema of mosses resembles certain green algae.
- ✍ This provides a clue to their evolutionary relationship.
- ✍ Both bryophytes and pteridophytes have ciliated sperms and require water for fertilisation.
- ✍ Gymnosperms do not need water for fertilisation.
- ✍ But *Cycads* and *Gingko*, the primitive gymnosperms, have ciliated sperms like the pteridophytes.
- ✍ This suggests that gymnosperms have descended from pteridophyte-like ancestors.
- ✍ The occurrence of ancestral traits in embryo is called **Palaeogenesis.**

5. PALAEONTOLOGICAL EVIDENCES

- ✍ Fossils are the remains and/or impressions of organisms that lived in the past last few centuries and palaeontologists have painstakingly built up extensive collections of fossils from all over the world. The fossil record has helped in building the broad historical sequence of biological evolution. Phylogeny, the evolutionary history of the organism, can sometimes be reconstructed with the help of fossils.
- ✍ Horse, elephant and man are good examples of relatively complete reconstructions of phylogeny.
- ✍ Besides form and structure, the habits and behaviour of extinct species can be inferred from the well-preserved fossils.
- ✍ It is also possible to reconstruct the entire habitat of an organism from fossils.
- ✍ Fossils also indicate the connecting links between two groups of organisms.
- ✍ *Archaeopteryx* shows features of both reptiles and birds.

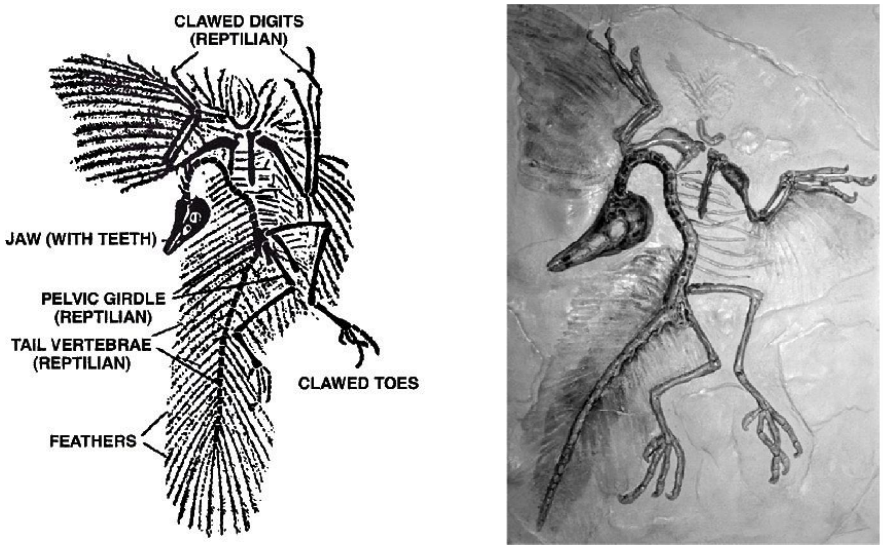


Fig: Transitional Fossil – Archaeopteryx

Reptilian characters of *Archaeopteryx*.

(a) The body axis is more or less lizard-like
(b) A long tail is present.
(c) The bones are not pneumatic.
(d) The jaws are provided with similar teeth.
(e) Presence of a weak sternum.
(f) Presence of free caudal vertebrae as found in lizards.
(g) The hand bears typical reptilian plan and each finger terminates in a claw

Avian characters of *Archaeopteryx*.

(a) Presence of feathers on the body.
(b) The two jaws are modified into a beak.
(c) The fore limbs are modified into wings.
(d) The hind-limbs are built on the typical avian plan.
(e) An intimate fusion of the skull bones as seen in the birds.

- ✍ By careful analysis of the distribution of fossils in different strata of rocks, the time in history when different species were formed or became extinct can be inferred

Special points : -

1. The aquatic mammals [eg. **Dolphins, Whales, Seals, Porpoises** etc.] don't have gill slits-

❹ EVOLUTIONARY TREND :

- The continuous change of a character within an evolving lineage is termed as **evolutionary trend.**

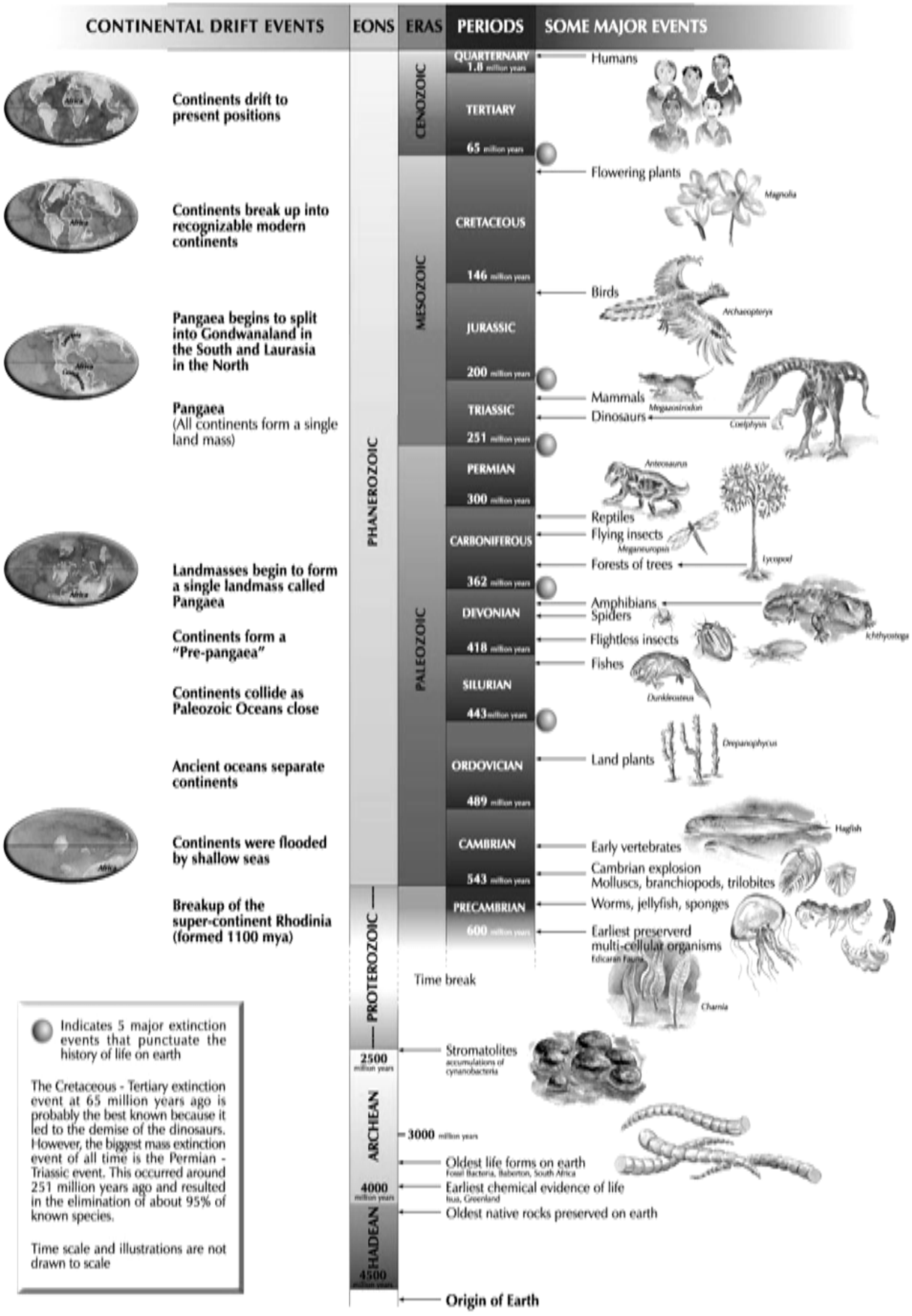
(I) Time Line of Evolution

- ✍ When scientists first began to study and date fossils, they had to find some way to organise the different time periods from which the fossils came.
- ✍ They divided the earth's past into large blocks of time called **eras**.
- ✍ Eras are further sub-divided into smaller blocks of time called **periods**, and some periods, in turn, are sub-divided into epochs.
- ✍ The major geological eras, with their approximate dates in millions of years as given in the table.
- ✍ "The geological time scale."

Table-I: THE GEOLOGICAL TIME SCALE

ERA	PERIOD	EPOCH	AGE (MILLION OF YEARS)	SOME IMPORTANT EVENTS IN THE HISTORY OF LIFE
	Quaternary	Recent	0.01	Historic time
		holocene	1.8	Ice ages; humans appear
		Pleistocene		
Cenozoic (Age of mammals)	**Tertiary**	Pliocene	5	Apelikeancestors of humans appear
		Miocene	23	Continued radiation of mammals
		(Golden age of		and angiosperms
		mammals)		
		Oligocene	34	Origin of most modern mammalian
				orders, including apes
		Eocene	57	Angiosperm dominance increases;
				further increase in mammalian
				diversity
		Palaeocene	65	Major radiation of mammals, birds,
				and pollinating insects
Mesozoic (Age of reptiles)	**Cretaceous**		144	Flowering plants (angiosperms) appear; dinosaurs and many groups of organisms become extinct. First modern birds appeared.

	Jurassic **Triassic**		208 245	Gymnosperms continue as dominant plants; dinosaurs dominant; first birds 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
	Carboniferous **Devonian**		360 408	invertebrates Extensive forests of vascular plants; first seed plants; origin of reptiles; amphibians dominant. Age of amphibians
				Diversification of bony fishes; first
	Silurian		438	amphibians dominant. Age of
				fishes.
				Diversity of jawless vertebrates;
	Ordovician		505	colonization of land by plants and
				arthropods; origin of vascular
				plants
	Cambrian		544	First vertebrates (Jawless fishes);
				marine algae abundant. Age of
				invertebrates
				Origin of most invertebrate phyla;
				diverse algae
Precambrian			700	Origin of first animals
or			1500	Oldest eukaryotic fossils
Proterozoic			2500	Oxygen begins accumulating in
				atmosphere
			3500	Oldest definite fossils known
				(prokaryotes)
			4600	Approximate origin of Earth



✍ The Earth formed ~4.6 billion years ago and the earliest forms of life are thought to have

Memories

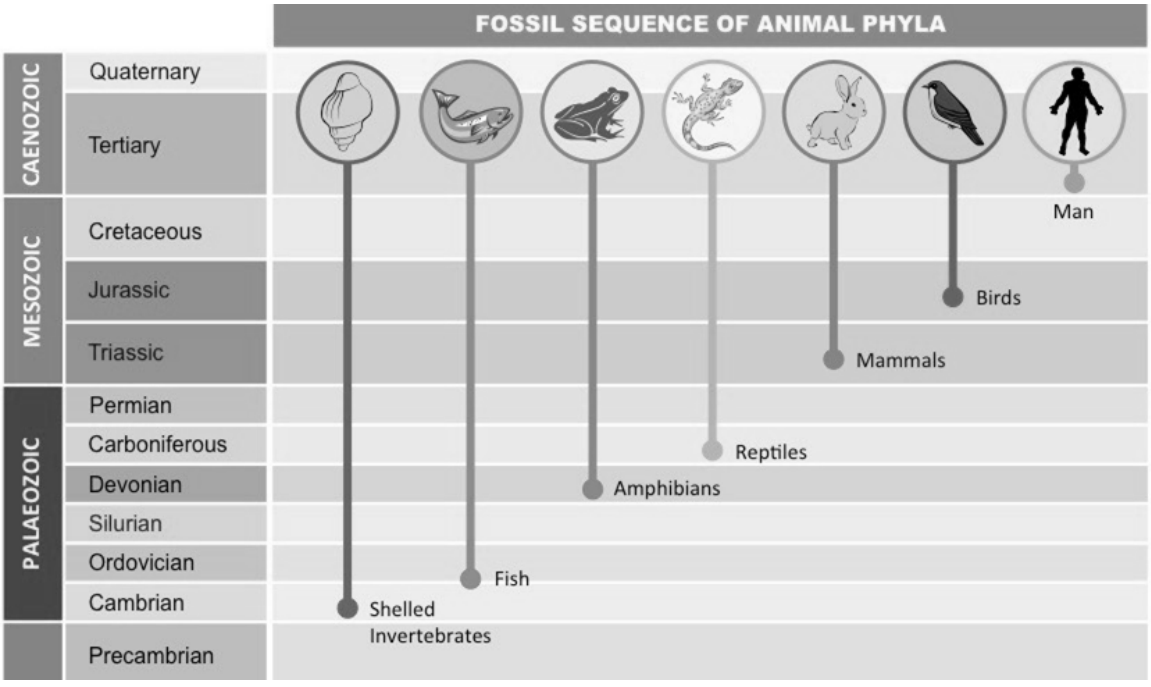


Fig: The Law of Fossil Succession

(II) Types of Rocks –

(a) Sedimentary Rocks –

These are formed at the bottom of ancient oceans by deposition of sediments of

sand, lime, coal and minerals which slowly change into hard layers.

Sedimentry rocks are also called as stratified rocks. Eg. Lime Stone, Sand Stone.Fossils are mostly found in sedimentary rocks.

(b) Igneous rocks –

Such rocks are formed by ancient volcanic deposits which slowly cooled down and hardened as rocks. Fossiles are absent in it. *e.g.*, Granite rocks.

(c) Metamorphic rocks –

These are formed by change in chemical composition of sedimentary rock and igneous rocks or metamorphosis. Such metamorphosis may be caused by pressure heat and physical movements. *e.g*. Marble Slate rocks. Fossils are also absent in it – due to chemical changes in the fossils are destroyed.

(III) Types of Fossils

(a) Unaltered Fossils :

In this type whole bodies of extinct organisms are found frozen in ice at the polar regions eg. Wooly mammoths (25000 yrs before extinct fossils were found from Siberian region)

(b) Petrified fossils – Most common type of fossil.

Replacement of organic part by mineral deposits is called **petrification**.

These fossils consists of only the hard parts e.g. bones, teeth, shells, wood etc. of extinct organisms.

In human body first fossilization occurs of teeth.

(c) Mould fossils –

Here no part of the original organism is present, only an impression of the external structure of body is preserved in wet soil.

(d) Cast fossils –

Sometimes minerals fills in the mould, resulting in cast fossils.

(e) Print Fossils –

Foot print or prints of wings, skin, leaves, stems etc made in soft mud which subsequently become fossilized are a common type of fossils.

(f) Coprolites –

These fossils include the fossil preservation of contents of the intestine or excreta of many ancient animals including particularly the reptiles or fishes

The stages of fossilisation generally occur as follows:

1. ***Death and decay*** **–** Soft body parts are decomposed or scavenged, leaving only the hard body remains.
2. ***Deposition*** **–** The hard remains are rapidly covered with silt and sand, and over time more layers continue to build

(IV) By studying fossils following facts about organic evolution are evident –

1. Fossils found in older rocks are of simple type and those found in newer rocks are of complex types.
2. In the beginning unicellular protozoans were formed from which multicellular animals evolved.
3. Some fossils represents connecting links between two groups
4. Angiosperms among plants and mammals among animals are highly developed and modern organism
5. By fossils, we can study the evolutionary pedigree of an animal like stages in evolution of horse, elephant and manetc.

(V) Fossil Parks

- ✍ Our country has rich deposits of fossil plants spanning a gap of 3500 million years.
- ✍ Twenty million years old fossil forests have been discovered and studied by the **Birbal Sahni Institute of Palaeobotany, Lucknow.** These forests need to be systematically studied and conserved for scientific understanding and enlightenment. Some of the excellent localities that can be raised to the status of national fossil parks are:

1. Fifty million years old fossil forests preserved in the sediments between the streaming lava flow that poured out into the Deccan country at Mandla district, Madhya Pradesh.
2. One hundred million years old fossil forest located in Rajmahal Hills, Bihar.
3. Two hundred and sixty million years old coal-forming forests in Orissa.

(VI) Microfossils and Fossil Fuel Exploration

- ✍ Palaeobiological study helps in understanding and locating coal and hydrocarbon sources.
- ✍ **Palyno-fossils** -tiny microscopic spores, pollen and other vegetal remains of the past - assist us in interpreting ancient environmental conditions favourable for organic matter accumulation and its conversion to fossil fuels by transformation and subsequent thermal alteration.
- ✍ By quantitative analysis of microfossils, it is possible to determine the approximate location and configuration of near shore marine deposits, which are in turn responsible for formation and accumulation of hydrocarbons.
- ✍ The main source of hydrocarbons are phytoplankton, marine and terrestrial algae as

well as lipid-rich plant remains.

✍ Thus, the study of fossil plants offers an effective tool in stratigraphical geology and can be exploited in tapping organic fuel resources

(VII) Dating Fossils

- Naturally occurring radioactive isotopes of certain elements are employed in this process.
- Such isotopes are unstable and decay over the course of time at a steady rate, producing other isotopes.
- One of the most widely employed methods of dating -the carbon -14 (^{14}C) method uses estimates of the different isotopes present in samples of carbon.
- Most carbon atoms have an atomic weight of 12.
- But a fixed proportion of the atoms in a given sample of carbon consists of carbon with an atomic weight of 14 (^{14}C).
- ^{14}C is produced from ^{12}C as a result of bombardment by particles from space.
- But after an organism dies and is no longer incorporating carbon, its ^{14}C gradually decays over time, by the loss of neutrons.
- The common radioactive elements which lose their radioactivity and change into their non radioactive isotopes at a fixed rate are :
  1. Potassium^{40} ; Argon^{40}
  2. Carbon^{14} ; Nitrogen^{14}
  3. Uranium^{238} ; Lead^{207}
  4. Rubidium^{87} ; Strontium^{87}
  6. Thorium^{232} ; Lead^{207}

➔ The half life of C-14 is 5730 ± 40 years which means in every 5730 ± 40 years, half of C^{14} will decay back to N^{14}.

➔ Radioactive carbon can be used to determine the age of fossils upto 70,000 years old. Half life of potassium^{40} is 1.3×10^9 years.

➔ Potassium -Argon method is useful because potassium is a common element found in all sorts of rocks.

➔ Potassium decays into Argon extremely slowly.

➔ Electron spin resonance method is relatively most accurate method for dating of fossils

➔ There are three types of radioactive decay that can occur (depending on the radioisotope involved):

- *Alpha decay* – Atom releases two protons and two neutrons (alpha particle) to form a new, more stable element
- *Beta decay* – A neutron decays to produce a proton, electron and anti-neutrino (electron is released and a new element forms)
- *Gamma decay* – Involves the release of electromagnetic radiation (gamma rays), but does not change the mass of the atom

➔ Alpha radiation can be stopped by paper, beta radiation can be stopped by wood, while gamma radiation is stopped by lead

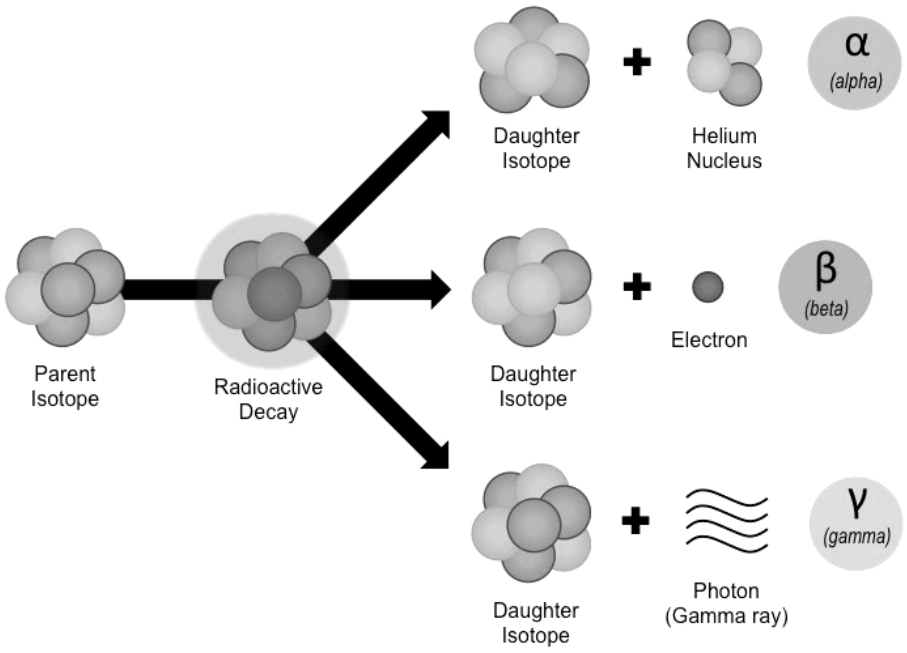


Fig: Types of Radioactive Decay

Other Dating Techniques

While radioisotope dating is the most commonly used method for dating fossils, other techniques do exist

- These other techniques include relative dating via index fossils and electron spin resonance (ESR)

Index Fossils

- The earth is arranged into sedimentary layers (stratification) with older stratum at the bottom and newer layers on top
- Different regions will not always have the same sedimentary layers due to environmental conditions (erosion, flooding, etc.)
- Index fossils represent short-lived species and thus can only be found in a restricted depth of rock strata
- Index fossils can be used to synchronise the ages of rock layers when other dating techniques are not available

Electron Spin Resonance

- Electron spin resonance (ESR) is a useful dating tool for organic samples that are aged between 50,000 – 500,000 years old
- ESR depends on the fact that when objects are buried they are bombarded by natural radiation from the soil
- This causes the electrons in minerals to move to (and remain in) a higher energy state
- The number of high energy electrons in a sample can be used to determine when the sample was buried

(VIII) Evolution of Modern Horse Eohippus (=HYRACOTHERIUM)

- ✍ The evolution of modern horse began in the **Eocene epoch**.
- ✍ The first fossil named *Eohippus*, 'dawn horse', was in North America.
- ✍ This horse was about the size of a fox or terrier dog (a type of small dog for unearthing foxes), only 40 cm high at the shoulders.
- ✍ It had short head and neck.
- ✍ The fore limbs were with four complete fingers (2, 3, 4 and 5) and one splint of first finger and the hind limbs with three functional toes (2, 3 and 4) and one splint of fifth toe.

- ✍ Splints are non-functional reduced fingers and toes of horse.
- ✍ Teeth were with incomplete cement.
- ✍ Molar teeth had no serrations.
- ✍ Low-crowned molar teeth were adapted to browse soft lush vegetation.

MESOHIPPUS.

- ✍ *Mesohippus,* the intermediate horse, evolved from *Hyracotherium* about three crore years ago during **Oligocene epoch**.
- ✍ It was of the size of modern sheep, about 60 cm high at the shoulders.
- ✍ Fore feet had three fingers and one splint of fifth finger and hind feet possessed three toes, but the middle one was longer than others and supported most of the body weight.
- ✍ Molar teeth had some serrations.

MERYCHIPPUS

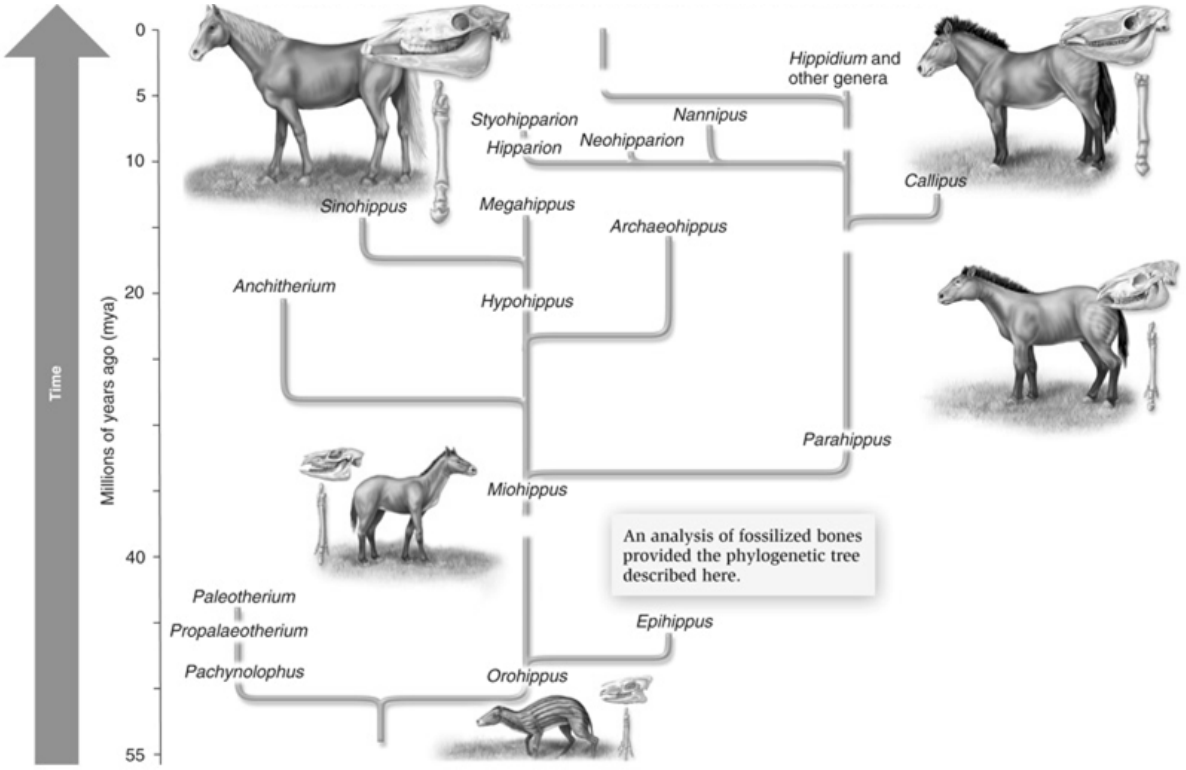
- ✍ *Merychippus,* the ruminating horse, arose from *Mesohippus* in Miocene epoch about two crore years ago.
- ✍ It was of the size of small pony, about 100 cm high at the shoulders.
- ✍ It had a longer neck.
- ✍ Its fore and hind limbs had three fingers and three toes, the middle finger and toe being longer than others and supported entire body weight.
- ✍ There was no splint.
- ✍ Teeth were longer with cement.
- ✍ Molar teeth had well developed serrations

PLIOHIPPUS

- ✍ *Pliohippus,* the Pliocene horse, evolved from *Merychippus* in Pliocene epoch about one crore years ago.
- ✍ It was the size of modern pony, about 120 cm high at the shoulders.
- ✍ Its each fore and hind limbs had one complete finger and one complete toe and two splints hidden beneath the skin.
- ✍ *Pliohippus is, therefore, referred to be the first one toed horse.*
- ✍ The, molar teeth were long with well developed cement and serrations.
- ✍ Teeth were adapted for eating grass.

EQUUS

- ✍ This is the modern horse which arose from *Pliohippus* in Pleistocene epoch about nine to ten lakh years ago in North America and later spread throughout the world except Australia.
- ✍ It is about 150 cm high at the shoulders.
- ✍ It has a long head and a long neck.
- ✍ Each fore and hind limb of the modern horse has one finger and one toe and two splints.
- ✍ The crowns of molar teeth are elongated with enameled ridges and are highly suitable for grinding.



During evolution of horse, there was:

(i) General increase (with occasional decrease) in size,

(ii) Progressive loss of toes,

(iii) Lengthening of toes that was retained,

(iv) Lengthening of limbs in general,

(v) Enlargement of brain, especially cerebral hemispheres,

(vi) Increase in height,

(vii) Increase in the complexity of molar teeth and an enlargement of the last three premolars until they came to resemble molars

Connecting Links :

The organisms which possess the characters of two different groups. Examples

1. ***Proterospongia* :** A link between Protozoa and Porifera.
2. ***Neopilina* :** A connecting link between Annelida and Mollusca.
3. ***Peripatus* :** A connecting link between Annelida and Arthropoda.
4. Lungs fishes, *e.g., Protopterus, Lepidosiren, Neoceratodus* are considered the connecting links between the fishes and amphibians.
5. Egg laying mammals; example duck billed *Platypus (Ornithorhynchus)* and spiny ant eater *(Echidna)* are considered connecting links between reptiles and mammals

(VIII) Evolution Of Vertebrates And Major Groups Of Plants

- ✍ The patterns of evolution of vertebrates and major groups of plants are conspicously different.
- ✍ The major groups of vascular plants have left relatively small number of fossils which even show gaps (fossilless dark periods).

- ✍ There are relatively few major lineages, and all the lineages are very distinct from one another.
- ✍ Instead of showing gradual and continuous change through time, the major lineages appear suddenly in the fossil record.
- ✍ After that, they persisted with little fundamental change for hundreds of millions of years.
- ✍ The existence of many of the major subdivisions of the vascular plants living today can be recognised about 345 million years ago on the basis of their distinctive reproductive structure.
- ✍ All primitive land plants reproduce via tiny spores contained in the sporangia. The major taxonomic groups are distinguished by the position of sporangia on the plant.

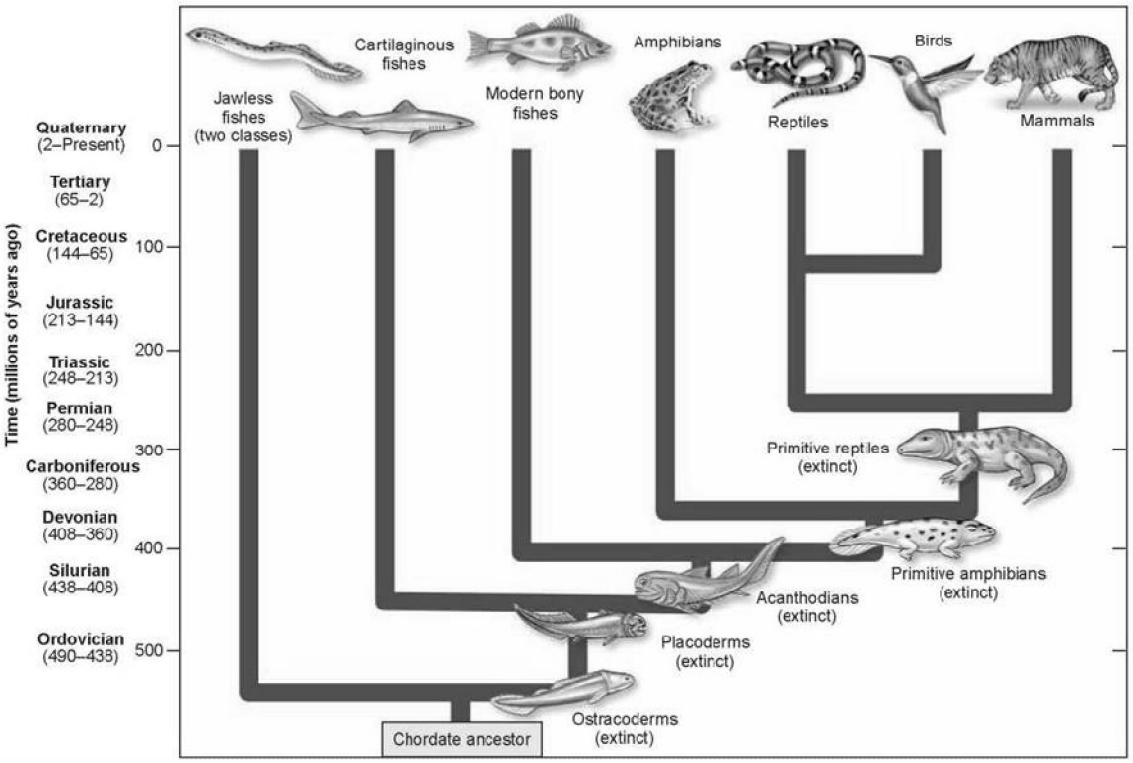


Fig: Evolution of vertebrates (Hypothetical)

- ✍ The sporangia are terminal, located at the tip of the plant in the most primitive Psilopsida.
- ✍ These are placed at the base of the leaves in the Lycopsida (represented in the modern flora by *Lycopodium* and *Selaginella).*
- ✍ The sporangia are arranged in whorls at the top of the plant in Sphenopsida (horsetails).
- ✍ Fossil evidences document that these basic patterns have been maintained for more than 350 million years.
- ✍ Few, if any, intermediates are known between these patterns.

Fig. Convergent evolution: many paths to one goal.

- ✍ The origin of seeds in the land plants was achieved about 345 million years ago in lineages recognised as ancestral to all more advanced vascular plants.
- ✍ The last major evolutionary advancement among the vascular plants was the emergence of flowering plants (the angiosperms) about 140 million years ago.
- ✍ But the fossils left no clue as to their ancestors
- ✍ The fossil records also indicate that nearly all the living orders of angiosperms and most of the characters of their modern-day representatives evolved from them.
- ✍ The continuous change of a character within an evolving lineage is termed as **evolutionary trend.**
- ✍ A lineage is an evolutionary sequence, arranged in linear order from an ancestral

group to a descendant group.

- ✍ The number of trends in any lineage is, therefore, same as the number of characters evolving.
- ✍ A trend may be progressive (a general increase in size of organs) or retrogressive (a general degeneration and loss of organs).

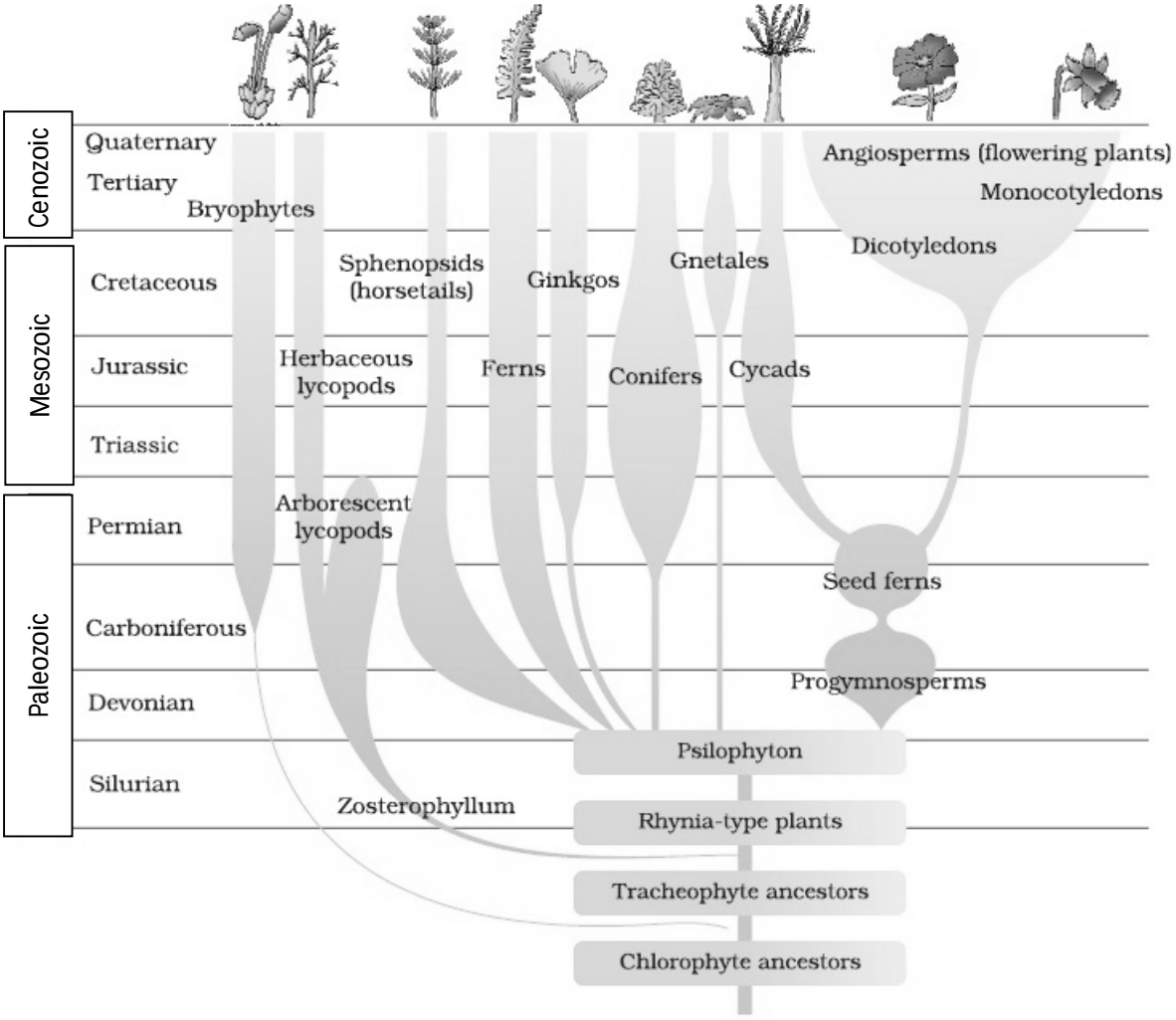


Fig: A sketch of the Evolution of plants forms through geological periods (Hypothetical)

BRIEF ACCOUNT OF EVOLUTION

- 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 channelised by appropriate light harvesting pigments.
- Slowly, single-celled organisms became multi-cellular life forms.
- *By the time of 500 mya, invertebrates were formed and active.*
- Jawless fishes 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.
- 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 thickshelled eggs which do not dry up in sun unlike those of amphibians.*
- Again we only see their modern day descendents, the turtles, tortoises and crocodiles.

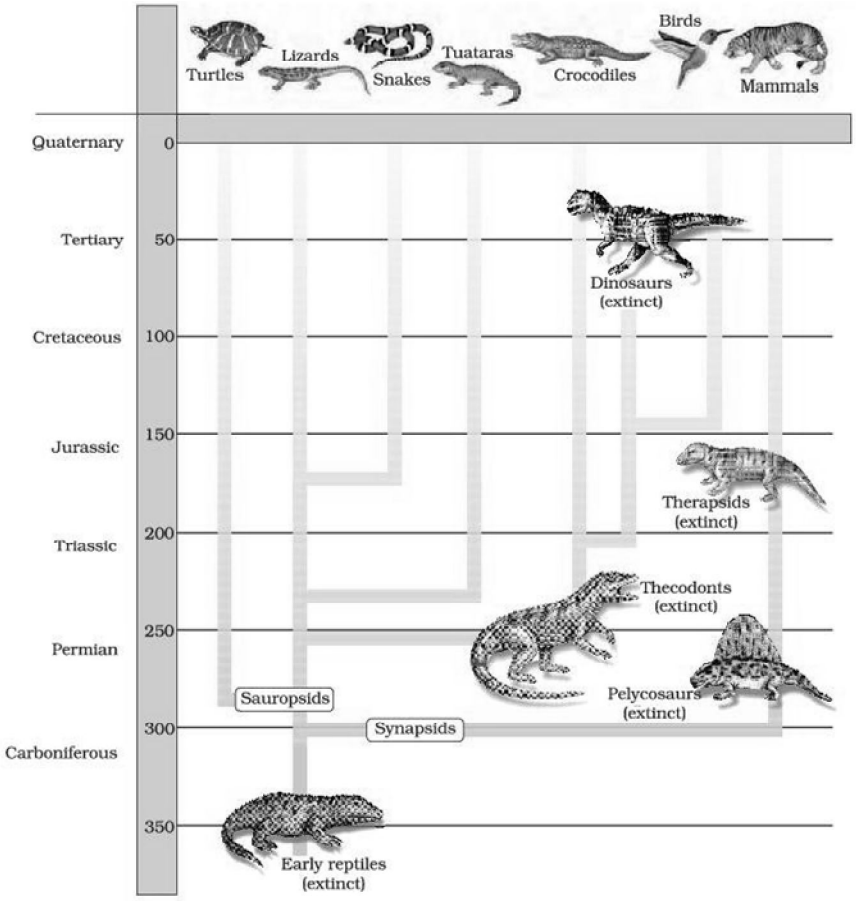


Fig: Representative evolutionary history of vertebrates through geological periods

- This was about 350 mya.

- In 1938, a fish caught in South Africa happened to be a Coelacanth which was earlier thought to be extinct.
- These animals called **lobefins** evolved into the first amphibians that lived on both land and water.
- In the next 200 millions years or so, reptiles of different shapes and sizes dominated on earth.
- Giant ferns (pteridophytes) were present but they all fell to form coal deposits slowly.
- Some of these land reptiles went back into water to evolve into fish like reptiles probably 200 my a *(e.g. Ichthyosaurs).*
- The land reptiles were, of course, the dinosaurs.
- The biggest of them, *i.e., Tyrannosaurus rex* was about 20 feet in height and had huge fearsome dagger like teeth.
- **About 65** mya, the dinosaurs **suddenly disappeared** from the earth.
- *We, do not know the true reason. Some say climatic changes killed them.*
- **Some say most of them evolved into birds.**

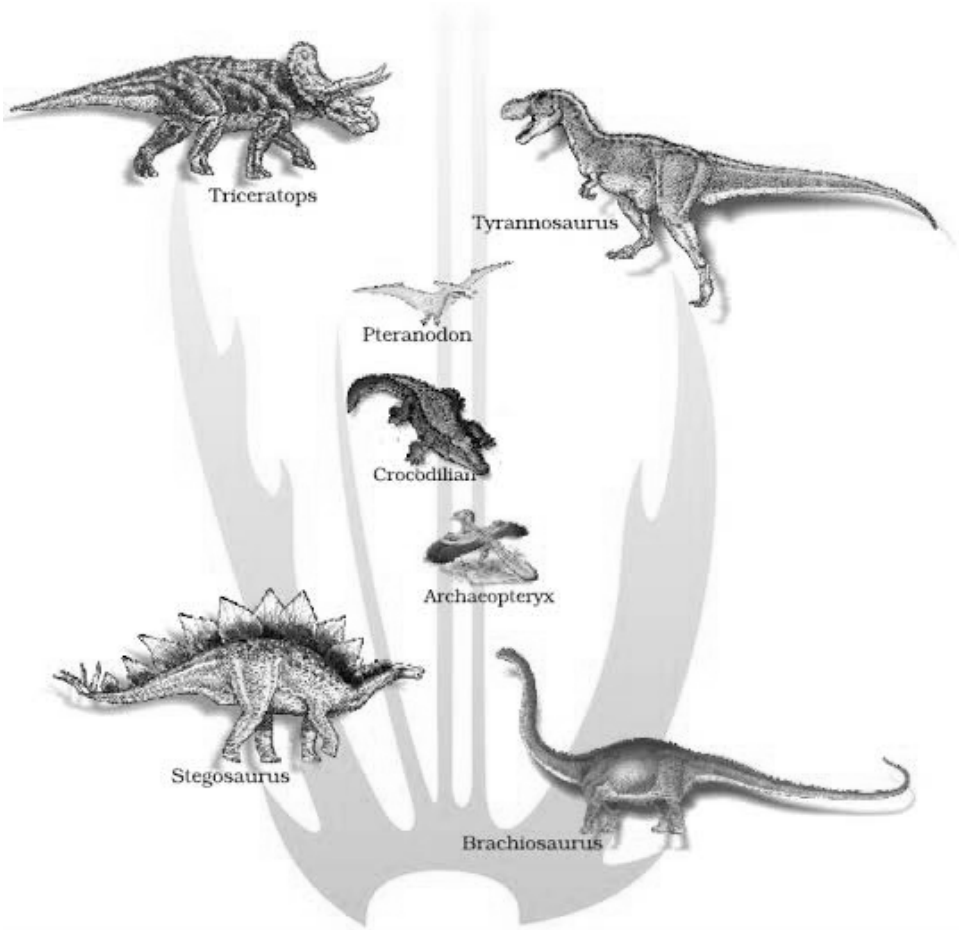
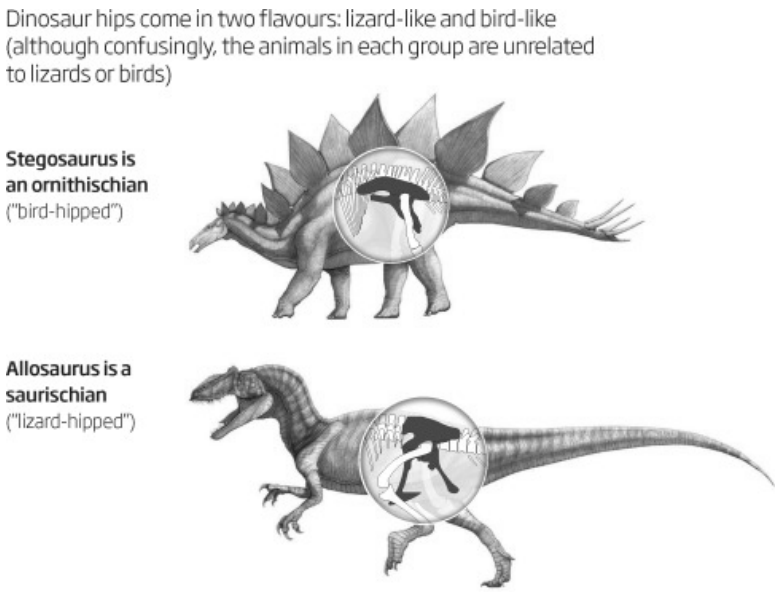


***Fig:** A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds*



- ✍ **The truth may live in between.**
- ✍ **Small sized reptiles of that era still exist today.**
- ✍ The first mammals were like shrews.
- ✍ Their fossils are small sized.
- ✍ Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least.
- ✍ When reptiles came down mammals took over this earth.
- ✍ There were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc.
- ✍ Due to continental drift, when South America joined North America, these animals were over ridden 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.
- ✍ You will learn about these in higher classes. The most successful story is the evolution of man with language skills and self-consciousness.

❺ THEORIES OF ORGANIC EVOLUTION

(I) LAMARCKISM :

- First teory of evolution was proposed by
- **Jean Bapttiste de Lamarck (17-44 - 1829)**
- Book : **Philosophie Zoologique (1809)**
- Lamarck coined the terms – **Invertebrates, Annelida**.
- The term **Biology** was given by **Lamarck & Treviranus**.

Theory of Inheritance of Acquired Character–

Basic Concept of Lamarckism–

(i) Internal Vital Forces :

Some internal forces are present in all organisms. By the presence of these forces organism have the tendency to increase the size of their organs or entire body.

(ii) Effect of environment and new needs:

Environment influences all type of organisms. Changing environment gives rise to new needs. New needs or desires produce new structures and change habit of the organism.

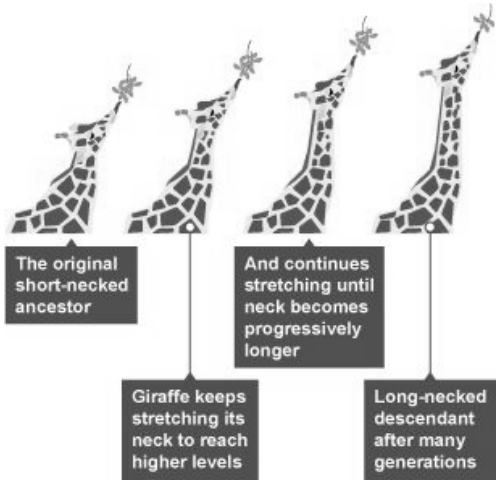
(iii)Use and disuse of organs:

If an organ is constantly used, it would be better developed whereas disuse of organ result in its degeneration.

(iv)Inheritance of acquired character:

During the life of an organism new character develop due to internal vital forces, effect of environment, new needs and use and disuse of organs.

These acquired character are inherited from one generation to another. By continuous inheritance through many generation these acquired characters tend to make new generation quite different from its Ancestors resulting in the formation of new species.



Example in support of Lamarckism :

1. Long neck and high fore limb of Giraffe
2. Aquatic birds stretched their toes and developed web.
3. Snakes lost their legs.
4. Deers became good runners by the development of strong limbs and streamlined body.
5. Retractile claws of carnivorous animals

Criticism of Lamarckism -

1. According to first concept organism tends to increase their size but it is not universally true.

For Example among angiosperm the trees seem to be primitive and the shrubs, herbs and grasses have evolved from trees but the size was reduced during evolution.

2. Second concept is false. Can we sprout wings wishing to fly like birds.

3. The third concept is some what true like the well developed biceps muscles of blacksmith and less developed wings in flight less birds.

   But this concept also have many objections like the eyes of a student/reader do not increase in size and power with increasing age, the constantly beating heart maintains a constant size through generation.

4. Fourth concept is completely false because acquired characters are not inherited.

Weismann –

Weismann cut off the tails of rats for about 22 genrations but there was no reduction in the size of tail on the basis of this experiment Weismann proposed **the theory of continuity of germplasm.**

According to Weismann.

(i) Two types of matters are present in organism, **somatoplasm and germplasm.**

(ii) Sometoplasm in somatic cells and germplasm in **Germinal cell.**

(iii) Somatoplasm dies with the death of organism while germaplasm transfers into the next generation.

(iv) If any **variation** develops in germplasm, it is inherited , while if variation develop in somatoplasm it is not transmitted.

Pyane :

Pyane kept drosophila in dark up to **69 generation,** but there was no reduction in the size or sight of eyes

- Boring of ear and nose in Indians.
- Iron shoes of Chinese.

Neolamarckism-Term by Packard

Although Lamarckism remained controversial but some scientists gave the following evidences in favour of Lamarckism. The are known as **neo-lamarckians.**

According to neolamarckism environment effected the inheritance of acquired charater. According to it changing environment give rise some physical and chemical changes in organism, which effect their germplasm, and these acquired characters are definitely inherited.

1. Sumner's Experiment–

Sumner kept white rat in warn temperature resulting in elongation of body, large pinna and long tail. These features were inherited by the offspring.

2. Kammerer's Experiment–

Kammerer kept salamander in dark background. The black spots found on skin were widely spread. In lighter, background the skin became yellow with limited black spots. These character were inherited by the offspring.

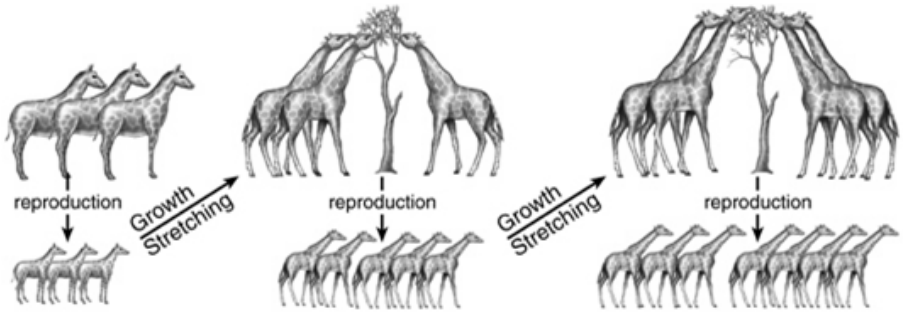
3. Mc Dugal's Experiment-

Mc Dugal trained white rats to cross a tank of water following a definite route. These trained rats were mated and their offspring were again trained. It was observed that there was decrease in the number of errors by offsprings of white rats.

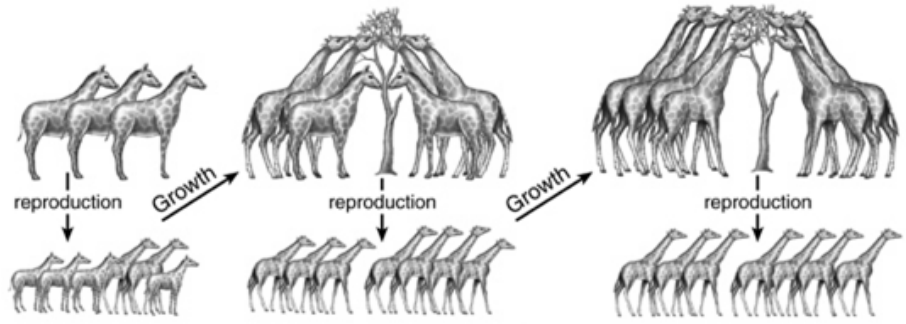
(II) DARWINISM

- Charles Robert Drawin was born on 12th feb. 1809 in England. Darwin traveled by **H.M.S. Beagle.**
- The ship left on Dec. 27, 1831 and returned on Oct. 2, 1836. He travelled South America, **South Africa, Australia and Galapagos Islands.** Darwin was influenced by two books.
- **"Principles of population" of Malthus.**

"Principles of Geology" of Charls Lyell.



(a) **Lamarck's theory: variation is acquired.**



(b) **Darwin's theory: variation is inherited.**

Alfred Russel Wallace :

- He travelled South eastern Asia and South America. The idea of natural selection striked in his mind. Wallace wrote an essay and sent it to Darwin. **"On the tendency of varieties to indefinitely from original type"**.
- There was striking similarity between the view of Darwin and **Wallace.**
- Wallance's chart : Wallace presented a chart to explain main points of theory of Darwin:
- "Darwinism" or "The theory of Natural Selection" was proposed by both Charles Darwin and A.R. Wallace.
- This theory was later on explained by Darwin in his book **'On the origin of species by the means of Natural Selection' (1859).**

S. No.	Facts	Consequences (Conclusions)
1	(i) Enormous rate of reproduction among animals (ii) Constant number of animals of a species	Struggle for existence
2	(i) Struggle for existence (ii) Heritable variations	Suvival of the fittest or natural selection
3	(i) Survival of the fittest (ii) Continuous environmental changes	Continuous natural selection leading to evolution of new species

The main features of theory of Natural Selection are as follows –

(1) Over production : (High rate of Reproduction)

All organisms have capability to produce enormous number of offspring, organisms multiply in geometric ratio.

e.g. – Plants produce thousands of seeds.

– Insects lay hundreds of egg

– One pair elephant gives rise to about six offspring and if all survived in 750 year a single pair would produce about 19 million elephant. Thus some organisms produce more offspring and other produce fewer offspring This is called **differential reproduction.**

(2) Struggle for existence :

Every individual competes with other of the same and other species for basic necessities like. Space, shelther and food. It is called struggle for existence and it continues for the whole life from zygote stage to its natural death.

(3) Variations and heredity :

- ➔ Except identical twins no two individuals are similar and their requirements are also not same.
- ➔ It mean there are differences among the individuals. These differences are called **variations.**
- ➔ Due to variations some individuals would be better adjusted towards the surroundings than the others.

- ➔ According to Darwin the variations are continuous and those which are helpful in the adaptation of an organism towards its surroundings would be passed on to the next generation, while the others will disappear.
- ➔ VARIATION:
  - Within a population of any given species there will be genetic variation (i.e. variation which is inheritable)
  - Typically this variation will be *continuous* and follow a normal distribution curve as the rate of change is gradual and cumulative.
  - If two populations of a species become geographically separated then they will likely experience different ecological conditions
  - Over time, the two populations will adapt to the different environmental conditions and gradually diverge from one another
  - The degree of divergence will depend on the extent of geographical separation and the amount of time since separation occurred
  - Populations located in close proximity that separated recently will show less variation (less divergence)
  - Distant populations that separated a longer period of time ago will show more variation (more divergence)

Fig: Variation Within a Population

(4) Survival of the fittest or natural selection :

- ➔ **The original idea of survival of fittest was proposed by Herbert Spencer.**
- ➔ According to Darwin most suitable and fit individuals are successful in struggle for existence.
- ➔ The individuals with most favourable adaptations are able to lead most successful life and are able to win over their mating partners.
- ➔ Darwin called it Sexual Selection.
- ➔ In the struggle for existence only those members survive which posses useful variations means nature selects fit individuals.
- ➔ This was called Natural Selection.
- ➔ Fitness is the end result of the ability to adapt and get selected by nature.

(5) Origin of New Species :

- ➔ Darwin explained that variations appearing due to environmental changes are transmitted to the next generation.
- ➔ So offspring become different from ancestors. In nest generation process of Natural selection repeats so after many generation a new species is formed.

Criticism of Darwinism –

1. Darwin does not explain the development of vestigial organs.
2. No satisfactory explanation for the cause, origin and inheritance of variation.
3. Darwin is unable to explain why in a population only a few individuals develop useful variation and others have harmful variations.

4. Criticism of Darwinism was based on sexual selection. Why only female selects the male for mating why not vice versa.

5. Darwin was unable to differentiate between somatic and germinal variations.

6. This theory was unable to explain over-specialization of some organs like tusk of elephants,

   antelers of deer.

7. This theory only explain the survival of fittest but unable to explain **arrival of fittest**.

8. The main drawback of Darwinism was lack of the knowledge of **heredity**

THEORY OF PANGENESIS

➔According to this theory all organs of an individual produce Pangenes, which are minute particles carrying information about the organs.

➔The pangenes travelling through the blood stream will ultimately reach the gametes, so that each gamete will have pangenes for each of the different organs.

➔After zygote formation, the pangenes tend to form the same organs from which these pangenes were produced.

(III) NEODARWINISM :

Mendel, DeVries, Huxley, Gates, Stabbins ets. They performed many experiments to remove the objections against Darwin's theory.

The salient features of neodarwinism are as follows–

1. ***Rapid multiplication :*** All organism multiply in geometrical ratio.

2. ***Limited food and space :*** Food and space are limited.

3. ***Struggle for existence :*** It is of three types. Intraspecific, Interspecific and environmental.

   The struggle for existence is of three types –

   (i) Intra-specific struggle : It is competition between the individuals of same species for same needs like food, shelter and breeding **(most acqute type of struggle).**

   (ii) Inter-specific struggle : It is the struggle between the individuals of different species for food and shelter.

   (iii) Environmental struggle : This struggle is between the organism and their environment.

   All organism struggle with cold, heat, wind, rain drought and flood etc.

4. Genetic Variations : They are inheritable variation which can occur due to the following reasons.

(a) Mutation : They are **discontinuous variations** which develop due to permanent changes in genotype. Mutations are of three types –

– **Genomatic mutations :** Change in number of chromosome.

– **Chromosomal Aberrations :** Changes in number of chromosome.

– **Gene Mutation :** Change in nucleotide.

(b) Gene recombination : They are new combination of genes which are usually caused by **crossing over.**

(c) Hybridisation and gene migration : It is crossing of organisms which are genetically different in one or more traits.

(d) Random Genetic drift : It is the elimination or addition of the genes of certain chartain characters when some animals in population migrate or dies or immigrate. It changes the gene frequency of remain population. Genetic drift operates only in **small population.**

(Changes in frequency of genes in a gene pool is called drift)

Founder Effect : Gene pool is the sum total of all the genes found in a population.

Change in the frequency of gene in a gene pool is called genetic drift.

Genetic drift always operates in small population.

By genetic drift often the phenotype of this small population quickly become different from the parental population and some time form a new sp. Such an effect is called Founder Effect.

Bottleneck Effect : Death of several members of population due to natural calamities (Earthquake , Storm, Flood) also leads to genetic drift.

The original size of population is then restored by mating among the survivor.

The new population may lack the genes of certain.

This may produce a new species after some time.

The loss of a section of population by death an after sometime a new species is formed that effect is known as Bottleneck effect.

5. Natural Selection :

If differential reproduction (some individuals produce more, some only few and still others none) continue for many generations, genes of the individuals which produce more offspring will become predominant in the gene pool of the population.

Thus natural selection occurs through differential reproduction in successive generations.

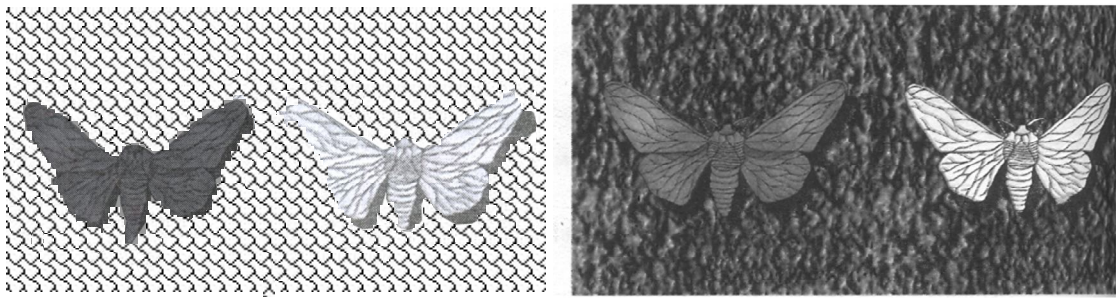
6. Isolation :

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

Example of Natural Selection –

(1) Industrial Melanism :

- This phenomenon was studied by **Barnard kettlewell.**



(a) (b)

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

- Before industrial revolution, the dull grey forms of prepared moth-**Biston betularia** – were dominant; the **Carbonaria** form (Black) was rare because it was susceptible to predation by birds.
- The industrial revolution, resulted in large scale smoke which got deposited on tree trunks tuning them Black. Now grey varieties became susceptible – the black forms flourished.
- Replacement of coal by oil and Electricity reduced production of black moth so the frequency of grey moths increased again.

(2) Drug resistance :

The drugs which eliminate pathogens become ineffective in the course of time because those individuals of pathogenic species which can tolerate them, survive, flourish to produce tolerant population

(3) Sickle cell Anaemia and Malaria :

Individuals homozygous for sickle cell Anaemia die at an early age.

In heterozygous individuals, the cells containing abnormal haemoglobin **Sickle** shaped.

In fact, When an RBC becomes sickle-shaped, it kills Malarial parasite effectively so that these individual area able to cope with malaria infection much better than normal persons.

The processs of natural selection thus maintains the abnormal form of haemoglobin along with the normal form in a region where Malaria is common.

(4) Malaria and G-6-PD deficiency :

Glucose 6- Phosphate dehydrogenase deficiency is a common abnormality in Negroids. Haemoglobin gets denatured and is deposited on cell membrane.

The disease is called favism. In these RBC, the malarial parasite cannot complete It's cycle.

Such persons get protection from Malaria.

7. Artificial Selection –

- Man has been taking the advantage of genetic variations for improving the qualities of **domesticated plants and animals.**
- He selects the individuals with desired characters and separates them from those which do not have such characters. The selected individuals are interbred.
- This process is termed as **Artificial Selection**. This process is man made.
- If it is represented for many generations it produces a new breed with desired characters.
- By artificial selection animal breeders are able to produce improved varieties of domestic animals like **dogs, horse, pigeons,, poultry, cow, goats, sheep** and **pigs** from their wild ancestors. Similarly, the plan breeders have obtained improved varieties of useful plants like wheat, rice, sugarcane, cotton, pulses vegetables fruits etc.
- Artificial Selection is similar to natural selection except that the role of nature is taken over by man and the character selected are of human use.
- The breeders have successfully produced the toy-like Shetland pony, the Dane dog, the sleek Arabian race horse by selection.
- Many crop plants like broccoli, kale cabbage, Cauliflower, Brussels sprouts and kohirabi have been produced through selective breeding.
- The various breeds of fowl ranging from the ceremonial cocks **(the Japanese onago-dori)** to the **broiler. leghorns** are all derived from a single jungle fowl **Gallus gallus.**

8. Reproductive Isolation –

- Reproductive isolation is the prevention of inter breeding between the population of two different or closely related species.
- It maintains the characters of the species but can lead to the origin of new species.
- The mechanism the characters of the species but can lead to the origin of new species.
- The mechanism of reproductive isolation is explained by **Stebbins** in his book **'Process of Organic Evolution'.**

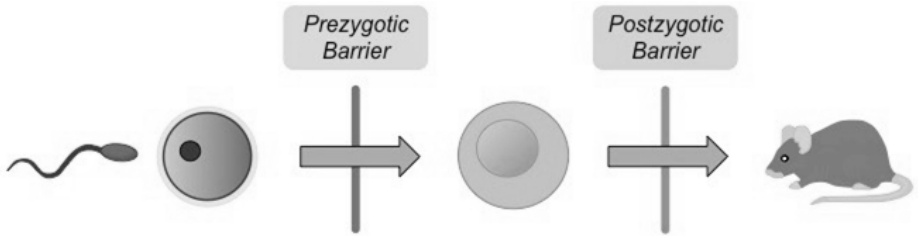


Fig: Reproductive Isolation Mechanisms

Two main subtypes of reproductive isolation are–

1. Premating or prezytotic isolation :

Prevent matting or formation of zygote.

(1) Ecological isolation : Two species live in different habitats and do not meet. (One may be living in fresh water and the other in the sea).

(2) Temporal isolation : Breeding seasons or flowering time may be different in the two species.

(3) Behavioural isolation : The males of one animal species are unable to recognize the females of another species as potential mates.

(4) Machanical isolation : The structural differences in genitalia of individuals belongings to different animal species interfere with mating.

(5) Gametic isolation : The sperms and ova of different species of animals are unable to fuse. In plants, the pollen coming from a different species may be rejected by the stigma.

2. **Postzygotic Isolation :** A hybrid zygote is formed but it may not develop into a viable fertile adult.

(1) Hybrid inviability : Hybrid zygotes fail to develop. In plants, embryos arising from interspecific crosses abort.

(2) Hybrid sterlity : Hybrid adults do not produce functional gametes. (Mules and henny are common example) in mammals. Several hybrid ornamental plants are sterile.

Exceptions ::

– Africal lioness + Asian tiger = tigon ; – Male lion + Female tiger = Liger (panthera leo) (Panthera tigris) ; – Mallard duck + pintail duck

– Polar bear + Alaskan brown bear ; – Platy fish + Swordtail fish

Offspring which obtained from all these hybridizations are fertile but these species do not interbreed naturally.

3. **Hybrid breakdown :** Sometime inter specific mating produce a hybrid, which give rise to next hybrid by back cross but they have reduced vigour or fertility or both.

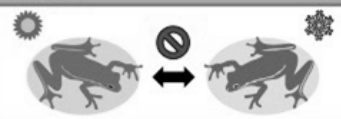
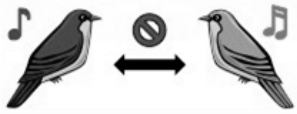
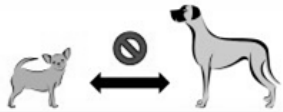
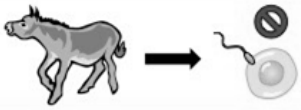
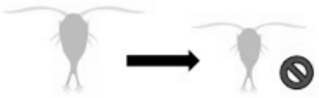
Pre-zygotic Isolating Mechanisms		Example	
Temporal	Occurs when two species mate at different times of year	Frogs live in same pond but breed during different seasons (summer vs spring)	
Ecological	Occurs when two species occupy different habitats	Lions and tigers can potentially interbreed, but usually occupy different habitats	
Behavioural	Occurs when two species have different courtship behaviours	Certain groups of birds will only respond to species-specific mating calls	
Mechanical	Occurs when physical differences prevent copulation / pollination	Certain breeds of dog are morphologically incapable of mating due to size	
Post-zygotic Isolating Mechanisms		**Examples**	
Hybrid Inviability	Hybrids are produced but fail to develop to reproductive maturity	Certain types of frogs form hybrid tadpoles that die before they can become a frog	
Hybrid Infertility	Hybrids fail to produce functional gametes (sterility)	Mules are sterile hybrids resulting from mating between a horse and a donkey	
Hybrid Breakdown	F_1 hybrids are fertile, but F_2 generation fails to develop properly	The offspring of hybrid copepods have less potential for survival or reproduction	

Fig: Types of Reproductive Isolation

(IV) GENETIC BASIS OF ADAPTATIONS :

Joshua Lederberg & Esther Lederberg shown genetic basis of adaptations by experimenting on bacteria. This experiment is known as Ledeberg's Replica plate experiment.

1. Lederberg cultured the bacterial cells on agar plate.

   Many bacterial colonies or groups grew on this agar plate.

   In this every colony is formed by the division of bacterial cells.

   Therefore its all cells were of same genetic structure.

   This type of group of cells is known as **clone.**

   This multi colony agar plate is known as **master plate.**

2. On this master plate one sterile velvet plate was pressed slightly so that some bacteria got stuck on velvet plate. In this way this becomes **replica of master plate.**

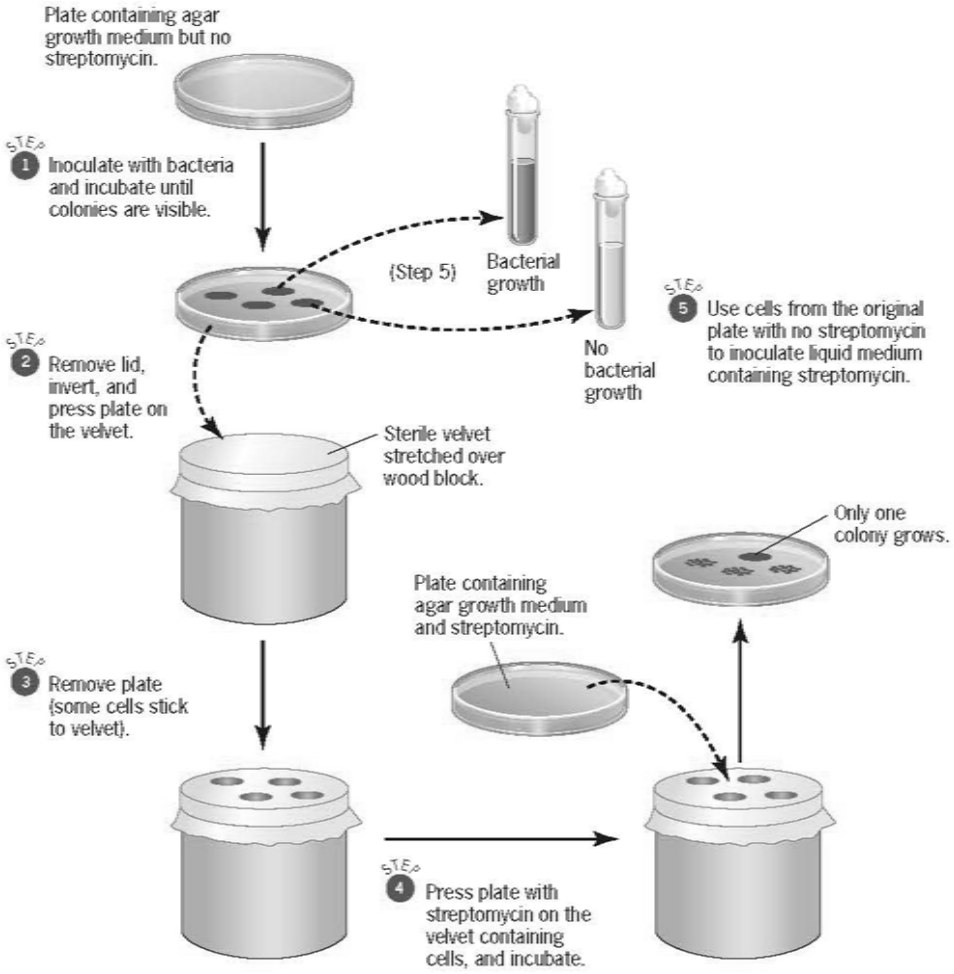


Fig: Joshua Lederberg & Esther Lederberg's use of replica plating to demonstrate the random or nondirected nature of mutation. For simplicity, only four colours are shown on each plate, and only two are tested for streptomycin resistance in Step 5. Actually, each palte would contain about 200 colonies, and many paltes would be used to find an adequate number of mutant colonies.

3. Now efforts of preparing replica had been made on those agar plates whose agar contains an antibiotic penicillin. It was seen that some bacteria failed to grow on penicillin agar plate while some bacteria were able to grow and developed new colony.

   It was concluded that these bacterial colonies were penicillin resistant.

   These bacteria have penicillin resistant mutant gene.

   Lamarckian view : Penicillin induced a change in some bacterial cells enabling them to grow in medium containing penicillin (wrong concept).

   According to Darwin some bacterias were penicillin resistant in bacterial suspension. In penicillin medium normal bacteria did not survive while mutant bacterias survived, as they are adapted, and form colony.

(V) MODERN SYNTHETIC THEORY OF ORGANIC EVOLUTION :

- This theory is the result of the work of a number of scientist namely **Dobzhansky, Fisher, Haldane, Swall wright, Mayr, Stebbins.**
- Stebbins discussed this theory in his book **''Process of Organic Evolution''** and Dobzhansky explained it is his book **''Genetics and the origin of species''**.
- According to this theory new species can not evolved by the presence of variable genotype in a population. Two factors are also required-natural selection and reproductive isolation.
- Natural selection guides different population in to different adaption direction and reproductive isolation between them due to geographical barriers leads these direction to the evolution of new species.
- In this theory following factors are included –

  (i) Gene mutation

  (ii) Change in chromosome number and structure

  (iii) Genetic recombination

  (iv) Natural selection

  (v) Reproductive isolation.

Besides these factors there are two more processes which cause evolutionary changes. These are –

(i) Migration of individuals from one population to another.

(ii) Hybridisation among species and also related genera which causes genetic variation in the population undergoing process of evolution.

(VI) HARDY -WEINBERG PRINCIPLE

- Five basic processes affect the **Hardy Weinberg equilibrium** and cause variations at **genetic level.** These are:
  (i) Mutation
  (ii) Gene migration
  (iii) Genetic drift
  (iv) Recombination
  (iv) Natural selection
- **Mechanisms of Change**

Changes to allele frequency within a gene pool (evolution) can result from five key processes:

- ✓ **Mutation:** A random change in the genetic composition of an organism due to changes in the DNA base sequence
- ✓ **Gene flow:** The movement of alleles into, or out of, a population as a result of immigration or emigration
- ✓ **Sexual reproduction:** Sex can introduce new gene combinations and alter allele frequencies if mating is assortative
- ✓ **Genetic drift:** The change in the composition of a gene pool as a result of a chance or random event
- ✓ **Natural selection:** The change in the composition of a gene pool as a result of differentially selective environmental pressures

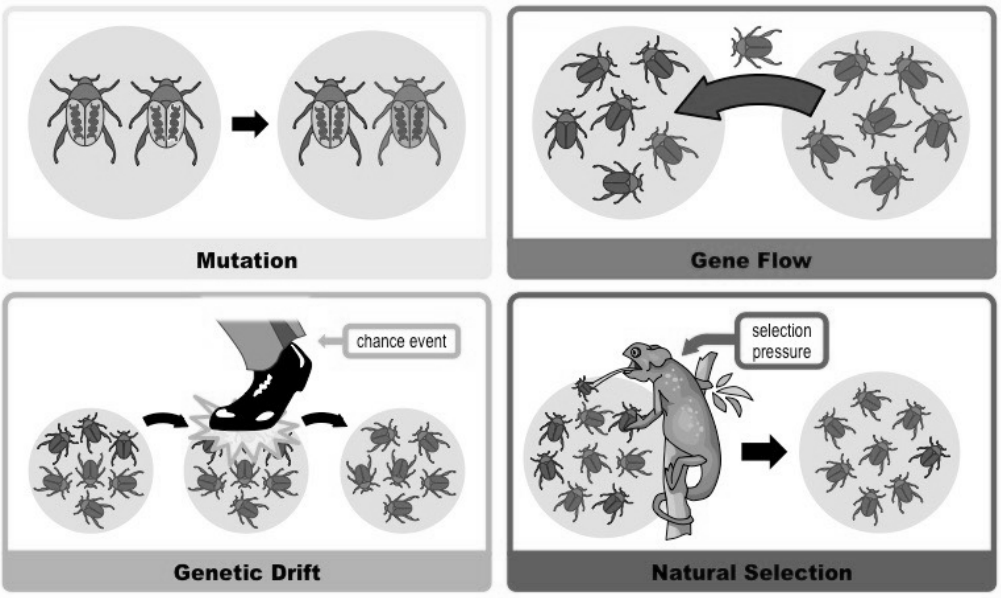


Fig: Mechanisms for Changing Allele Frequency within a Gene Pool

- The Hardy-Weinberg principle states that the proportions of different alleles will stay the same in a large population if mating occurs at random and the above mentioned forces are absent.
- In algebraic terms, the Hardy-Weinberg principle is written as an equation.
- Its form is what is known as a **binomial expansion**.

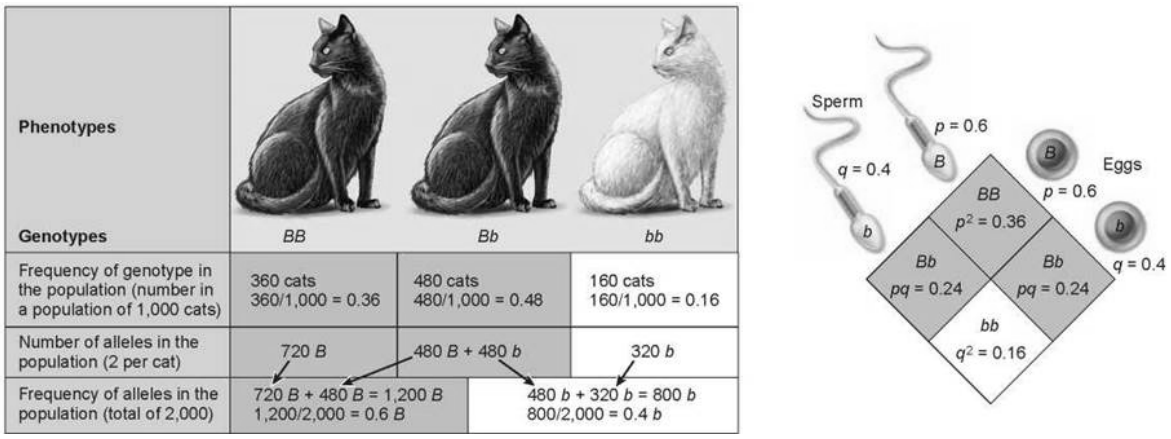


Fig. Calculating allele frequencies at Hardy-Weinberg equilibrium.

$$\underset{\text{Individuals homozygous for allele } B}{p^2} + \underset{\text{Individuals heterozygous for alleles } B \text{ and } b}{2pq} + \underset{\text{Individuals homozygous for allele } b}{q^2} = 1$$

- For a gene with two alternative alleles, called **A** and **a**, the frequency of allele A can be expressed as p and that of alternative allele a as q, because these are only two alleles, **p + q must always be equal to one.** The equation looks like this

$$(p + q)^2 = \underset{\text{Individuals}}{p^2} + \underset{\text{Individuals}}{2pq} + \underset{\text{Individuals}}{q^2}$$

homozygous for allele A	heterozygous for alleles A and a	homozygous for allele a

- For example, if q is the frequency of the allele a, then the Hardy-Weinberg equation states that q^2 = percentage individuals homozygous for allele a say 16%.

  $q^2 = 0.16$, $q = 0.4$

Factors of Evolutionary Change

(i) Mutation (ii) Migration (iii) Genetic Drift

(iv) Recombination (v) Natural Selection

(M) Mutation Theory Y (A) IN HARDY

Proposed by Hugo-de-vries on the basis of his experiments on a plant Oenothera lamarckiana.

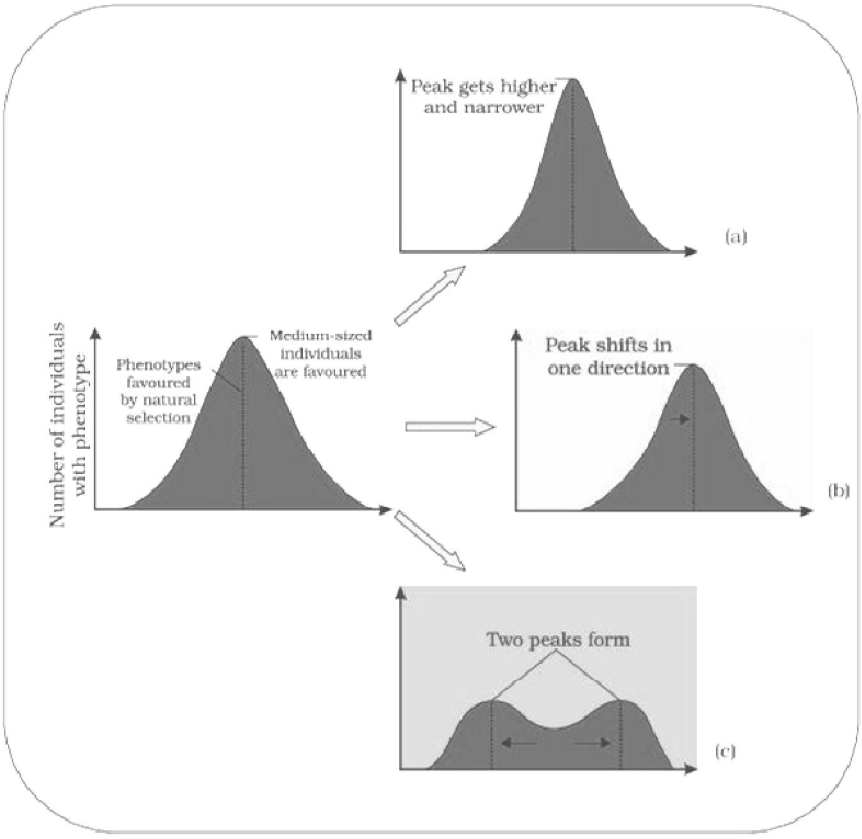


Fig: Diagrammatic representation of the operation of natural selection on different traits: (a) Stabilising (b) Directional and (c) Disruptive

ALFRED – Allele Frequency Database

Allele frequencies represent the prevalence of a particular allele in a population, as a proportion of all the alleles for that gene

- Consequently, allele frequencies are either represented as a percentage or as a value from 0 to 1.0

Changes in allele frequency can reflect either random processes (genetic drift) or differential processes (natural selection)

- Population bottlenecks and the founder effect will exacerbate genetic differences between geographically isolated populations
  Allele frequencies between populations can be compared using the **Al**lele **Fre**quency **D**atabase (ALFRED)
  How to Compare Allele Frequencies:
  1. Go to the Allele Frequency Database (ALFRED)
  2. Type a gene name into the search parameter
  3. Choose a specific gene loci
  4. Select a polymorphism
  5. Choose a frequency display format
  Examples:
- **SCL45A2** – involved in human melanin production (allele frequency differs in Northern Europe)
- **ABO** – blood groups show regional variation (e.g. O blood more common in Africa)
- **LCT** – lactase is required for lactose tolerance (more common in Northern Europe / Africa)

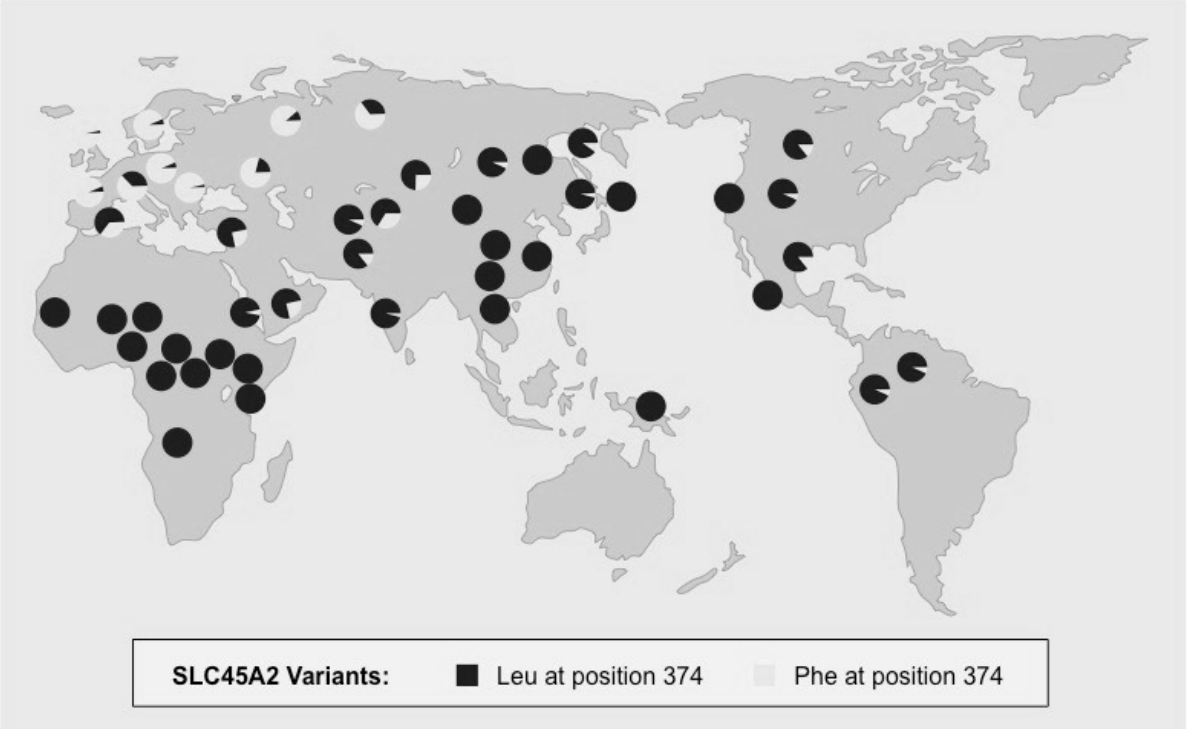


Fig: Comparison of Frequency of Leu → Phe Mutation in the SCL45A2 Gene

Please Note: SCL45 is one of a number of genes contributing to melanin production and the pigmentation of human skin. A particular allele responsible for lighter pigmentation is more frequent in Northern Europe.

Main Point of mutation theory :

1. Mutation or discontinuous variation are the raw material of evolution.
2. Mutation appears suddenly and produced their effect immediately.
3. Mutants are different from the parents and there are no intermediate stages between the two.
4. The same type of mutation can appear in several individuals of a species.
5. Mutation can appear in all direction and all mutations are inheritable.

6. useful mutations are selected by nature and lethal mutations are eliminated.

7. Mutation are recurring so that the same mutant can appear again & again so change of selection by nature are increased and new species is formed.

8. De-vries termed single step large mutation as **saltation.**

9. Mutations are large, random and directionless while Darwinism variations are small and directional.

Points in favour of mutation theory :

1. Mutations are actually the source of all variations and fountainhead of evolution.

2. Mutation theory can explain both progressive & retrogressive evolution.

Significance :

De-vries mutation theory generally accepted because the mutation were found to be inheritable. It was later through that evolution cannot occur by mutation alone, natural selection and isolation of mutants are also necessary for evolution.

(I) MIGRATION

- Migration, defined in genetic terms as the movement of individuals from one population into another, can be a powerful force in upsetting the genetic stability of natural populations.
- If the characteristics of the newly arrived animal differ from those already there, the genetic composition of the receiving population may be altered, if the newly arrived individual or individuals can adapt to survive in the new area and mate successfully.
- **Gene pool** : A total collection of all genes and its allele in a population is called **gene pool.** Thus, gene pool will have all genotypes *i.e.,* genes of the organisms.
- **Gene flow:** If genes are exchanged between two different populations of a species, it is **gene flow.**

(II) GENETIC DRIFT I SEWALL WRIGHT EFFECT I NON-DIRECTIONAL FACTOR

- Natural selection is not the only force responsible to bring about changes in gene frequencies. There is the role of chance or **Genetic Drift** also.
- **Genetic Drift** causes the change in gene frequency by **chance in a small population.**
- In a small population, the one individual alleles of a gene are represented by a few individuals in a population.
- These alleles will be lost if these the individuals fail to reproduce.
- Allele frequencies appear to change randomly, as if the frequencies were drifting, Janes thus, a random loss of alleles in small population is Genetic Drift.
- A series of small populations that are isolated from one another may come to differ strongly as a result of Genetic Drift.
- **Genetic Drift** has two ramifications are described below.

1. Bottle neck effect:

➔ It is the decrease in genetic variability in a population, *e.g.,* cheetah population

in Africa decreased due to hunting.

➔ Theirdecreased numbers have limited cheetahs genetic variability, with serious
➔ consequences.

➔ The present cheetah population is susceptible to a number of fatal diseases.

➔ If any of these diseases attacks the cheetah population, the path of extinction of cheetah cannot be reversed.

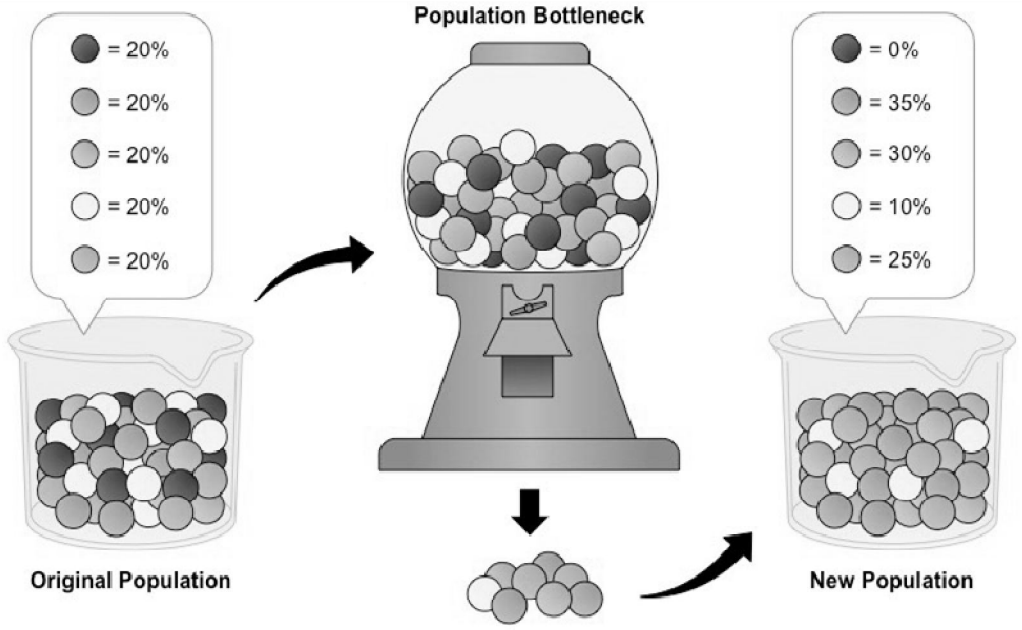


Fig. Genetic drift: a bottleneck effect

2. Founder's effect:

➔ When one or a few individuals are dispersed and become the founders of a new, isolated population at some distance from their place of origin, the alleles that they carry are of special significance.

➔ Even if these alleles are rare in the source population, they will be a significant fraction of the new population's genetic endowment.

➔ This effect by which rare alleles and combinations of alleles may be enhanced in new populations -is called the founder's effect.

➔ The founders effect is particularly important in the evolution of organisms on islands, such as **Galapagos** Islands which Darwin visited.

➔ Most of the kinds of organisms that occur in such areas were probably derived from one or a few initial founders.

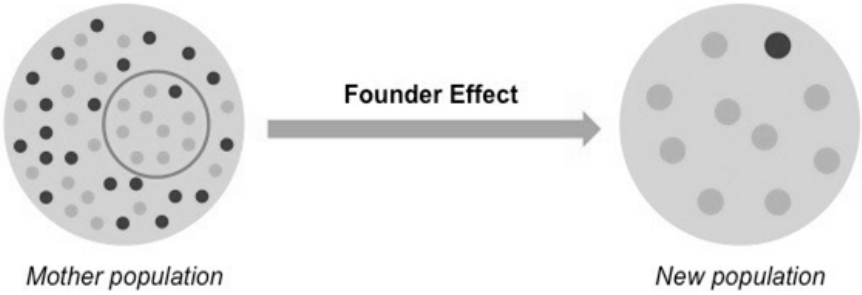


Fig: Founder Effect – Gene Pool Comparison

Fixation of new mutations:

- Genetic drift fixes new alleles, genes that arise by mutation, from time to time and eliminate the original gene, thereby changing the genetic make up of small population.

(III) RECOMBINATION

- Gene recombination is also an important source of variations.
- It occurs during crossing over at the time of meiosis, free assortment (selection) of genes at the time of gamete formation, random union of gametes at the time of fertilization and even chromosomal aberrations
- They cause reshuffling of gene recombinations which provide new combinations of existing genes and alleles.
- This is the entity of gene recombination.
- Gene recombination can occur not only between genes but also within genes resulting in the formation of a new allele.
- Since it adds new alleles and combination of alleles to the gene pool, it is an important process during evolution which causes variations.

(IV) NATURAL SELECTION:

Natural selection is the change in the composition of a gene pool in response to a differentially selective environmental pressure

- The frequency of one particular phenotype in relation to another will be a product of the type of selection that is occurring

<u>Stabilising Selection</u>

- Where an intermediate phenotype is favoured at the expense of both phenotypic extremes
- This results in the removal of extreme phenotypes (phenotypic distribution becomes centrally clustered to reflect homogeneity)
- Operates when environmental conditions are stable and competition is low
- An example of stabilising selection is human birth weights (too large = birthing complications ; too small = risk of infant mortality)

<u>Directional Selection</u>

- Where one phenotypic extreme is selected at the cost of the other phenotypic extreme
- This causes the phenotypic distribution to clearly shift in one direction (towards the beneficial extreme)
- Operates in response to gradual or sustained changes in environmental conditions
- Directional selection will typically be followed by stabilising selection once an optimal phenotype has been normalised
- An example of directional selection is the development of antibiotic resistance in bacterial populations

<u>Disruptive Selection</u>

- Where both phenotypic extremes are favoured at the expense of the intermediate phenotypic ranges

- This causes the phenotypic distribution to deviate from the centre and results in a bimodal spread
- This occurs when fluctuating environmental conditions (e.g. seasons) favour the presence of two different phenotypes
- Continued separation of phenotypic variants may eventually split the population into two distinct sub-populations (speciation)
- An example of disruptive selection is the proliferation of black or white moths in regions of sharply contrasting colour extremes

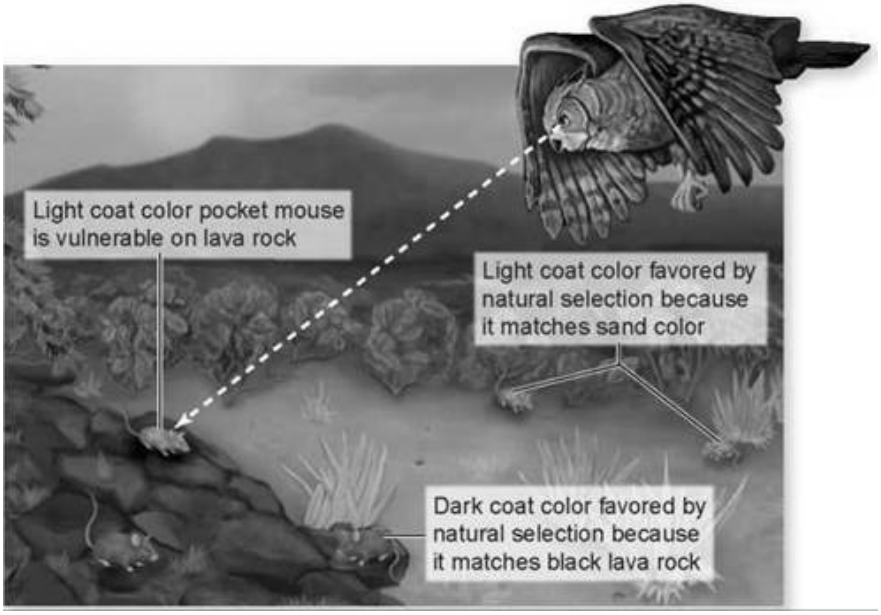


Fig. Selection for coat color in mice.

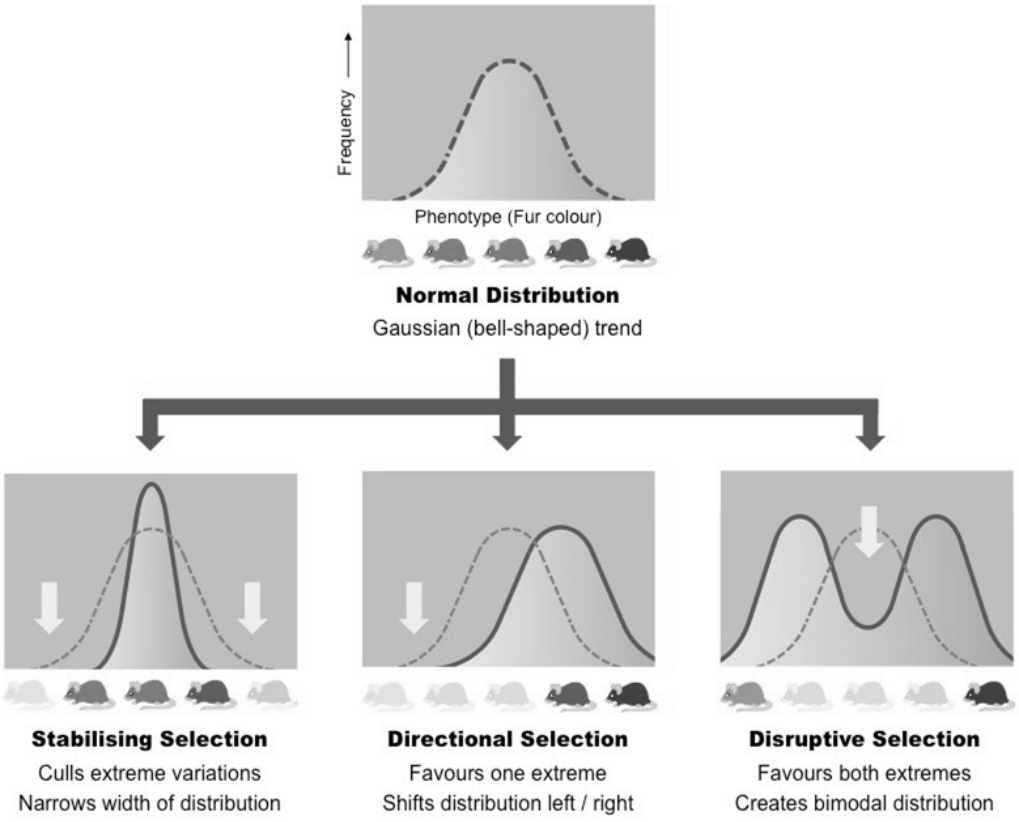
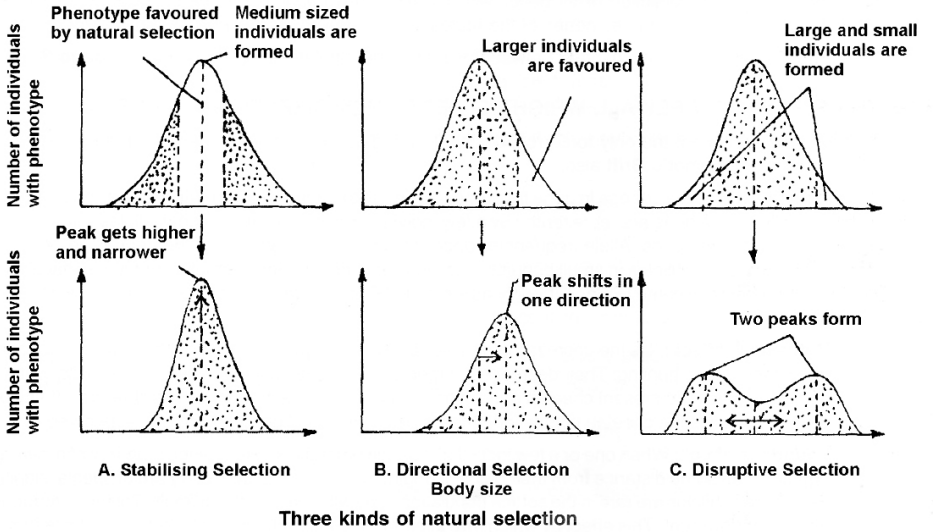


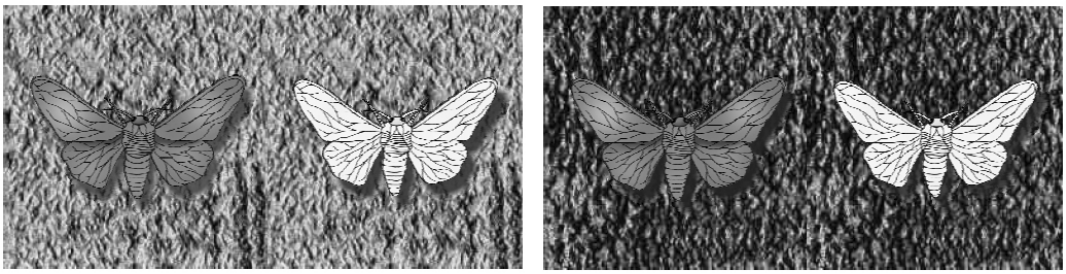
Fig: Types of Selection – Stabilising, Directional and Disruptive



Examples of Natural Selection-Industrial Melanism

- First studied by R.A. Fisher and E.B. Ford and in recent time by H.B.D. Kettlewell.
- One of the most striking examples, which demonstrates the action of natural selection, is the industrial melanism in England.
- The peppered moth *Biston betularia,* with a dull grey colour or white was abundant in England before the Industrial Revolution
- A black coloured form of the same moth (melanic, a dominant mutant differing in a single gene), *carbonaria,* was very rare.
- Within a couple of hundred years, however, the proportion of *carbona ria* increased to almost 90 per cent.
- The moths rest on tree trunks.

- Before the Industrial Revolution, the tree trunks used to be covered with grey coloured lichen.
- The dull grey moth easily blended with this background, while the black moth stood out conspicuously, and was therefore more susceptible to predation by birds.
- With the advent of the Industrial Revolution, large-scale burning of coal became common.
- The enormous amount of smoke produced resulted in the deposition of particulate matter on tree trunks, turning them black.
- As a result, the grey moths now became more conspicuous than the black variety, and hence more susceptible to predation.
- The frequency of black coloured moths in the population therefore increased.
- Gradual replacement of coal by oil and electricity, as well as the improved methods of controlling soot production, reduced the soot desposition on the trees.
- Conditions then became more suitable for the survival of grey moths, consequently their frequency once again increased.
- Thus, reduction in pollution is now correlated with reverse evolution.
- Industrial melanism, as this phenomenon is called, is thus a particularly interesting example which clearly brings out the action of natural selection.
- This has been observed in about 70 different species of moths, and in several other European countries as well.



(a) (b)

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

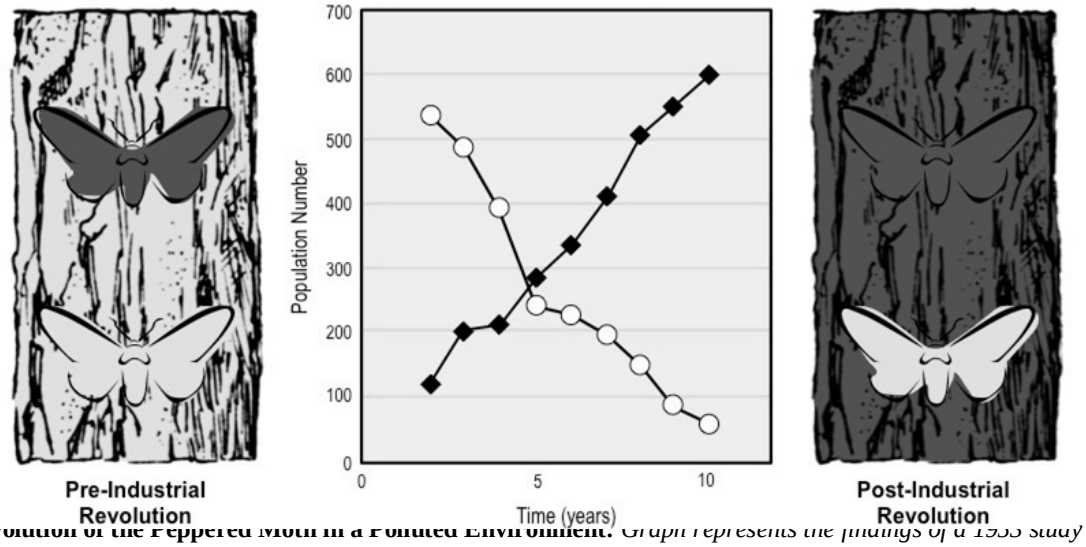


Fig: Evolution of the Peppered Moth in a Polluted Environment: *Graph represents the findings of a 1953 study by Bernard Kettlewell comparing peppered moth populations in polluted and non-polluted regions*

- This understanding is supported by the fact that in areas where industrialisation did not occur. *e.g.*, in rural areas, the count of melanic moths was low.
- This showed that in a mixed population, those that can better-adapt, survive and increase in population size.

- Remember that no variant is completely wiped out.
- 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.

(a) Change In Genotypic Frequencies

- If the alleles for grey and black colours are denoted by G and B, the genotypes of the moths would be GG, GB and BB.
- Since B is dominant, GB and BB will be black.
- Due to greater predation by birds on the black (melanic) phenotype the proportion of B in the population was maintained at a much lower value than G.

(b) Resistance of Mosquitoes to Pesticides

- Mosquitoes have always been a major health hazard, especially as they are responsible for the spread of diseases such as malaria and filaria.
- When DDT was first introduced to control mosquitoes, it was tremendously successful; most mosquitoes were sensitive to DDT and were therefore killed.
- However, DDT has now become ineffective against mosquitoes.
- This is explained as follows:
    - ✓ In the original population of mosquitoes, some individuals were resistant to DDT.
    - ✓ However, in the absence of DDT, such resistant individuals were few because they had no advantage over the DDT-sensitive mosquitoes.
    - ✓ However, when DDT was used on a large-scale, only the resistant genotypes were able to survive and reproduce.
    - ✓ As a result, over a period of time, almost the entire population came to consist of the resistant type, which made DDT quite ineffective.
    - ✓ Evolution is thus a change in gene frequencies in the population in response to changes in the environment-in this case the introduction of DDT.
    - ✓ The principle of natural selection thus helps us to understand, why such chemical insecticides would remain useful only for a limited time

(c) Sickle Cell Anaemia Is an example of balancing selection.

(i) In few RBCs, 1-2% became sickle shaped during lack of oxygen.

(ii) 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; because the malarial parasite spends a part of the life cycle in the RBC; if they

enter into the RBC which are sickle shaped, they will die.

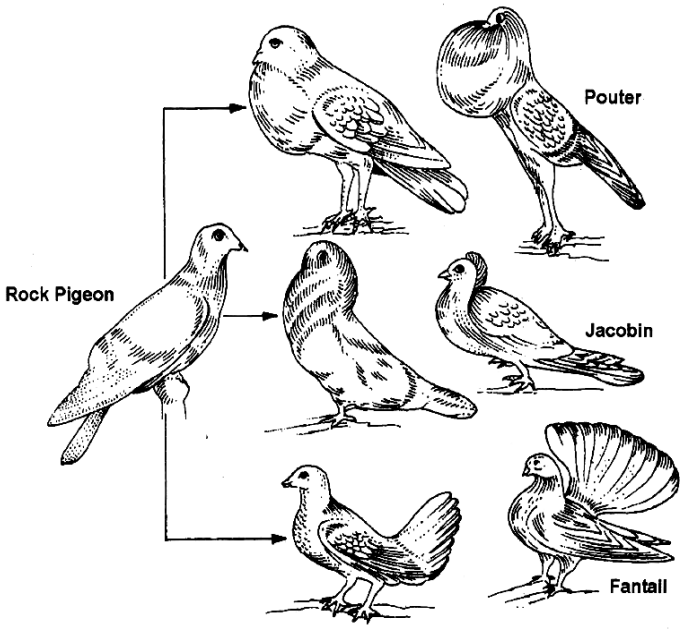
(iii) The women who are heterozygote have higher fertility; that's why natural selection has not eliminated the allele.

(iv) The loss of deleterious recessive genes through deaths of hornozygotes (Hb^S / Hb^S) is being balanced by the gain resulting from successful reproduction by heterozygotes in malaria prone areas. For this reason, the selection is called balancing selection.

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

(V) ARTIFICIAL SELECTION

- Some genetic variability is always present in a population.
- Some alleles make organisms better adapted to the environment, and thus make them more successful in survival and reproduction.
- As a result, the frequency of such alleles in a population gradually increases.
- This is called **selection**; these alleles are thus 'selected' over the other alleles.
- This process operating in natural populations is therefore called **'Natural Selection'**.
- The process of natural selection, acting on variability inherent in the population, over millions of years, has given rise to the great diversity we see in the biological world



Variation among breeds of domestic pigeons.

Ancestry of different breeds can be traced to wild rock pigeon. (Artificial Selection)

- Man has been using a similar process for improving the qualities of domesticated plants and animals for centuries.

- Plant-breeding and animal-breeding are very similar to the action of natural selection, the difference being that the role of nature is played by man.
- The criteria for selection are based on human interests.

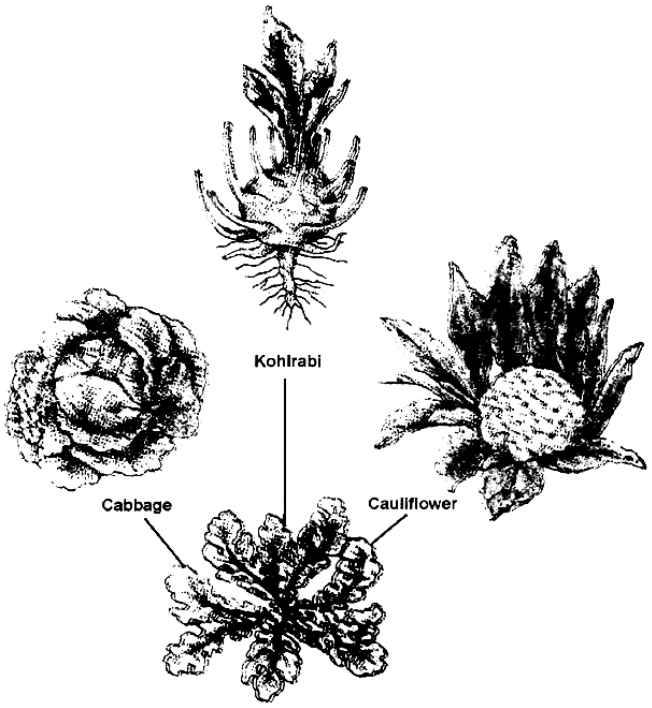


Fig: Cabbage, Cauliflower, Kohlrabi are descendants of a common ancestor, colewort

(Artificial Selection)

- To obtain cows with high milk yield, the dairy scientists monitor milk production of a large number of cows.
- Only the calves produced by cows which are high-yielders, are chosen to breed and form the next generation.
- When this process is repeated *(i.e.*, artificial selection is applied) for many generations, a population of cows with high milk yield is obtained.
- Here, the work of selection is done by man.

(VI) SPECIATION AND ISOLATION

- 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 severed from other populations of the parent species and gene flow no longer occurs.
- Speciation can take place in two modes based on the geographical relationship of a new species to its ancestral species.
- The degree of divergence between geographically separated populations will gradually increase the longer they are separated
- As the genetic divergence between the related populations increase, their genetic compatibility consequently decreases
- Eventually, the two populations will diverge to an extent where they can no longer interbreed if returned to a shared environment

- When two populations can no longer interbreed and produce fertile, viable offspring they are considered to be separate species
- The evolutionary process by which two related populations diverge into separate species is called **speciation.**

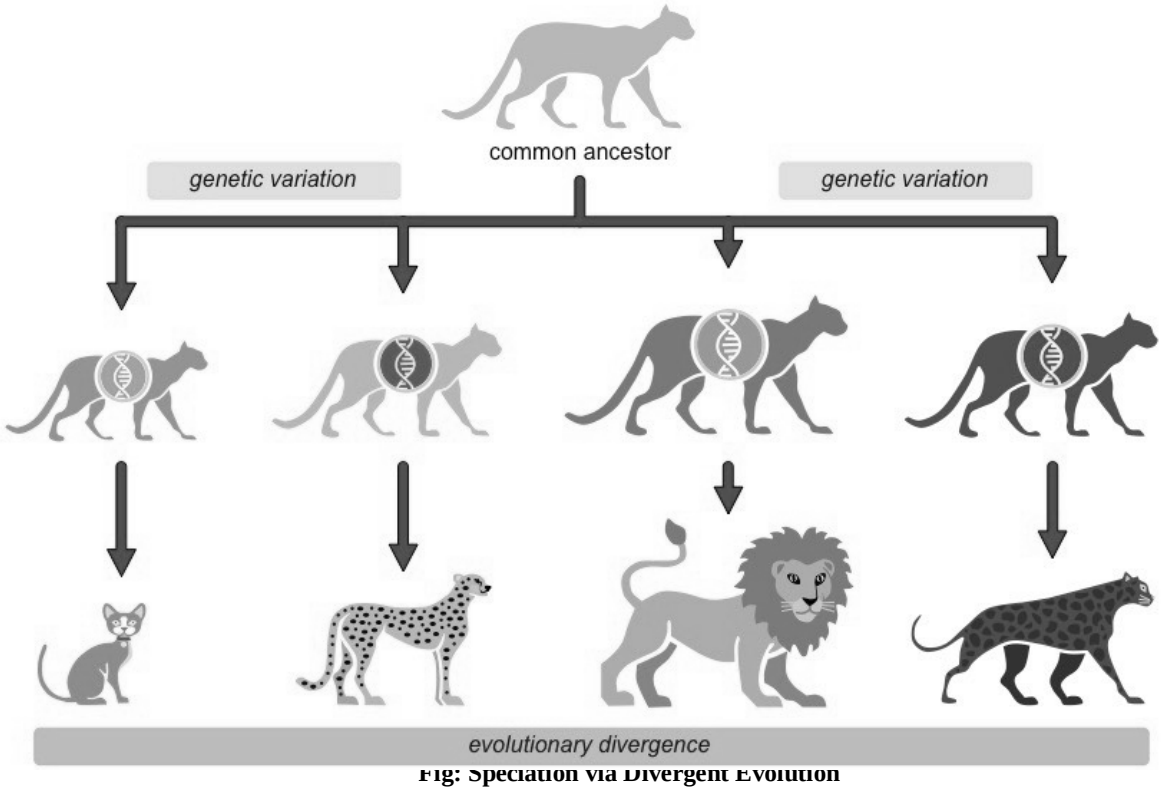


Fig: Speciation via Divergent Evolution

1. When a population, formerly continuous in range, splits into two or more geographically isolated populations 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, a small number of individuals may colonise a new habitat which is geographically separated from the original range

Darwin's finches that formed separate species in the Galapagos islands and the Australian marsupials that radiated to form new species are its examples.

2. 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.

3. Species concept:

- Species is the basic unit of classification.
- The term was coined by John Ray (1693).
- Most taxonomists define species as morphologically distinct and reproductively isolated natural population or group of populations where individuals resemble one another more closely than with members of other species, have a similar anatomy, karyotype and biochemicals, interbreed freely and form a genetically closed system. There are three basic concepts about the species.

4. Morphospecies concept:

- It is the earliest concept of species.
- Davis and Heywood (1963) have defined it as "assemblage of individuals with morphological features in common and separable from other such assemblages by correlated morphological discontinuities in a number of features."
- However, the number of morphological characters chosen for separating species varies from taxonomist to taxonomist.
- "Lumpers" will combine all the populations with broadly similar traits into a single species while "Splitters" will separate various populations with even minor morphological differences into distinct species

5. Biological species concept:

- Though first proposed by Buffon (1753), biological species concept was formulated by Mayr(1942).
- According to it, a biospecies (biological species, Biological Species Concept) is sexually interbreeding or potentially interbreeding group of individuals which is reproductively isolated from other species and is therefore, separated from others by absence of genetic exchange.
- Normally species are distinct from one another by both morphological traits and reproductive isolation.
- However, **sibling species** are those distinct species which are almost identical morphologically but are distinct from each other due to absence of interbreeding, *e.g.*, *Drosophila pseudoobscura* and *D. persimilis.*
- Biological species concept is, therefore, mainly based on absence of cross fertilisation between members of two species.
- Cross fertilisation tests carried out by taxonomists between individuals of morphological and geographically separated populations have, resulted in revision of species and grouping of many of them into single species, *e.g.*, several species of

North American sparrows as subspecies and races of a single song sparrow, *Passarella melodia.*

- The only problem of using reproductive isolation is the absence of sexual reproduction in several organisms -prokaryotes, some protists, some fungi, some plants *(e.g.,* commercial Banana) and animals.
- Further, cross fertilisation experiments cannot be performed on such a large number of species that occur in varied geographical areas.
- Reproductive isolation cannot be used as a criterion in case of fossils.
- The living organisms and fossils can be grouped only on the basis of their morphology and biochemistry.
- Mayr (1987) has named morphologically grouped asexual species as **paraspecies** while Ghiselin (1987) has named them **pseudospecies.**

6. Evolutionary species concept:

- All evolutionary taxonomist have been in search of a proper definition of species which is basic unit of classification.
- One such definition has been given by Simpson.
- According to Simpson (1961) "an evolutionary species is a lineage (an ancestor-descendent sequence of population) evolving separately from others and with its own unitary evolutionary role and tendencies."
- The concept stresses on evolutionary isolation with sexual isolation being its one aspect.
- It is more dependent on differences which can be morphological, genetical, behavioural and ecological, to know evolutionary distance.
- However, evolution does not occur simultaneously in all the traits.
- Neither its rate nor direction (in which it is occurring) are the same

7. **Reproductive isolation** may be defined as the existence of intrinsic barrier to the interbreeding in 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 populations.*

8. 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. Horses and donkeys are two different species; a hybrid, mule, **is produced from the mating of a male donkey and a mare (female horse).**

9. *Similarly, mating between stallion (male horse) and female donkey results in a hybrid called hinny. Both mule and hinny are sterile.*

10. 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 hybridisation between these species has evolved during their long isolation from each other Natural selection has not favoured a reduction in hybridisation for the simple reason that no hybridisation has been possible. Other examples 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.

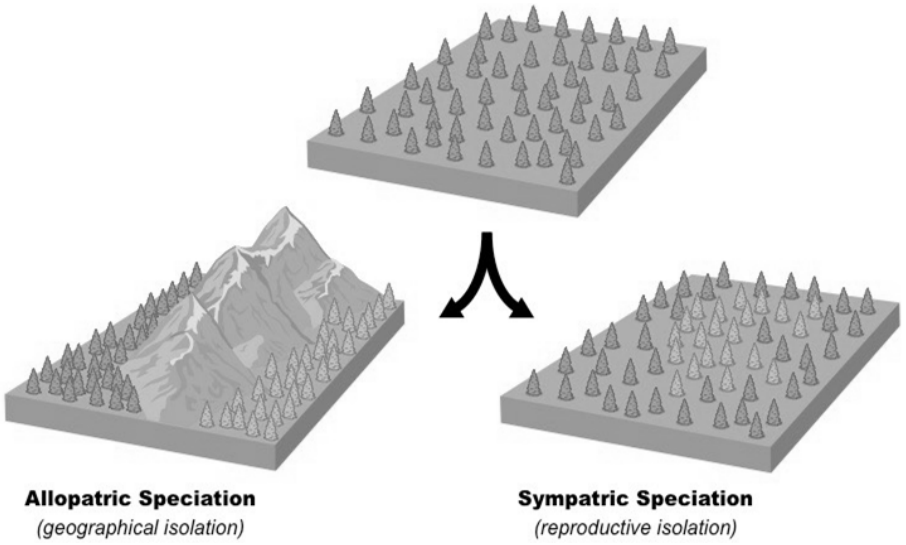


Fig: Allopatric versus Sympatric Speciation

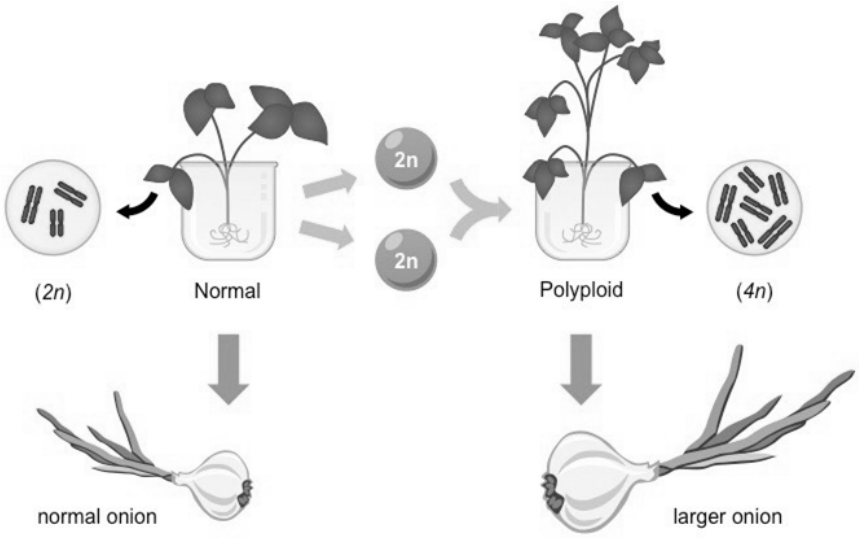


Fig: Hybrid Vigour in Polyploids as a Result of Increased Gene Dosage

EXTINCTION

Extinction is the total cessation of a species or higher taxon level, reducing biodiversity

- ➔ It can result gradually, as one population of organisms progressively evolve into something else (*phyletic extinction*)
- ➔ Alternatively, a species may not leave any identifiable descendents and simply cease to exist (*abrupt extinction*)
- ➔ Extinction can be caused by a range of factors, including habitat degradation, predation, disease or natural disaster
- ➔ Over 99% of species that have ever existed on Earth are now extinct
- ➔ Mass extinction events are categorised by an unusually high number of species dying out in a relatively short period
- ➔ There have been five commonly recognised mass extinction events in the history of the Earth
- ➔ **Mass Extinction Events**
  1. *Ordovician–Silurian mass extinction* (~450 million years ago): Approximately 60 – 70% of all species wiped out
  2. *Late Devonian mass extinction* (~370 million years ago): Over 75% of all species wiped out

3. *Permian mass extinction* (~250 million years ago): Roughly 96% of all species were wiped out
4. *Triassic mass extinction* (~200 million years ago): Over 50% of all species were wiped out
5. *Cretaceous mass extinction* (~65 million years ago): Approximately 80% of all species wiped out

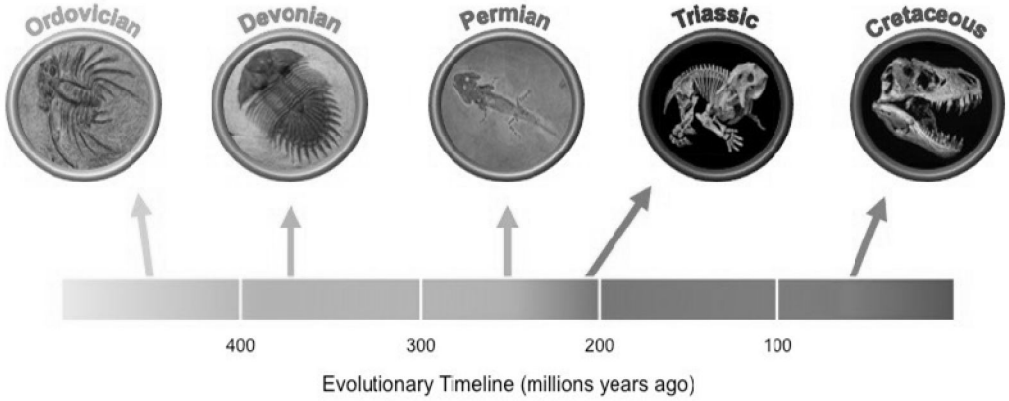


Fig: Timeline of Mass Extinction Events

(VII) BARRIERS TO HYBRIDISATION

Prezygotic Mechanisms: (Prevent mating or formation of zygote)

1. ***Ecological isolation :*** Two species live in different habitats and do not meet. (One may be living in fresh water and the other in the sea).
2. ***Temporal isolation :*** Breeding seasons or flowering time may be different in the two species.
3. ***Behavioural isolation:*** The males of one animal species are unable to recognise the females of another species as potential mates.
4. ***Mechanical isolation:*** The structural differences in genitalia of individuals belonging to different animal species interfere with mating.
5. **Gametic isolation :** The sperms and ova of different species of animals are unable to fuse. In plants, the pollen coming from a different species may be rejected by the stigma.

Postzygotic Mechanisms : A hybrid zygote is formed but it may not develop into a viable fertile adult.

1. ***Hybrid Inviability :*** Hybrid zygotes fail to develop. In plants, embryos arising from interspecific crosses abort.
2. ***Hybrid sterility :*** Hybrid adults do not produce functional gametes. (Mules and hinny are common examples in mammals. Several hybrid ornamental plants are sterile.)
3. ***Hybrid breakdown :*** The offspring of hybrids are inviable or infertile

(VII) NEUTRAL THEORY OF EVOLUTION

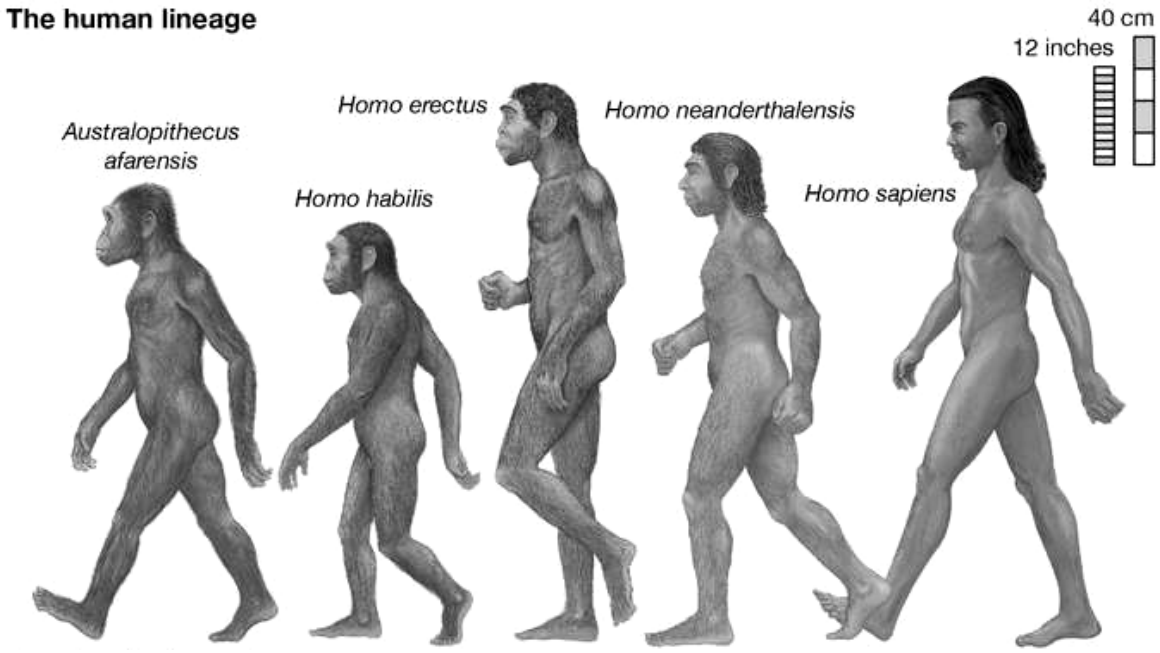
- According to Kimura most of the mutations are neutral, and are not eliminated from the population.
- This is against natural selection.
- Kimura proposed that speciation is not due to selection of advantageous genotypes no but elimination of deleterious alleles and random selection of neutral alleles.
- It emphasized that most mutations are of neutral value and genetic drift is responsible

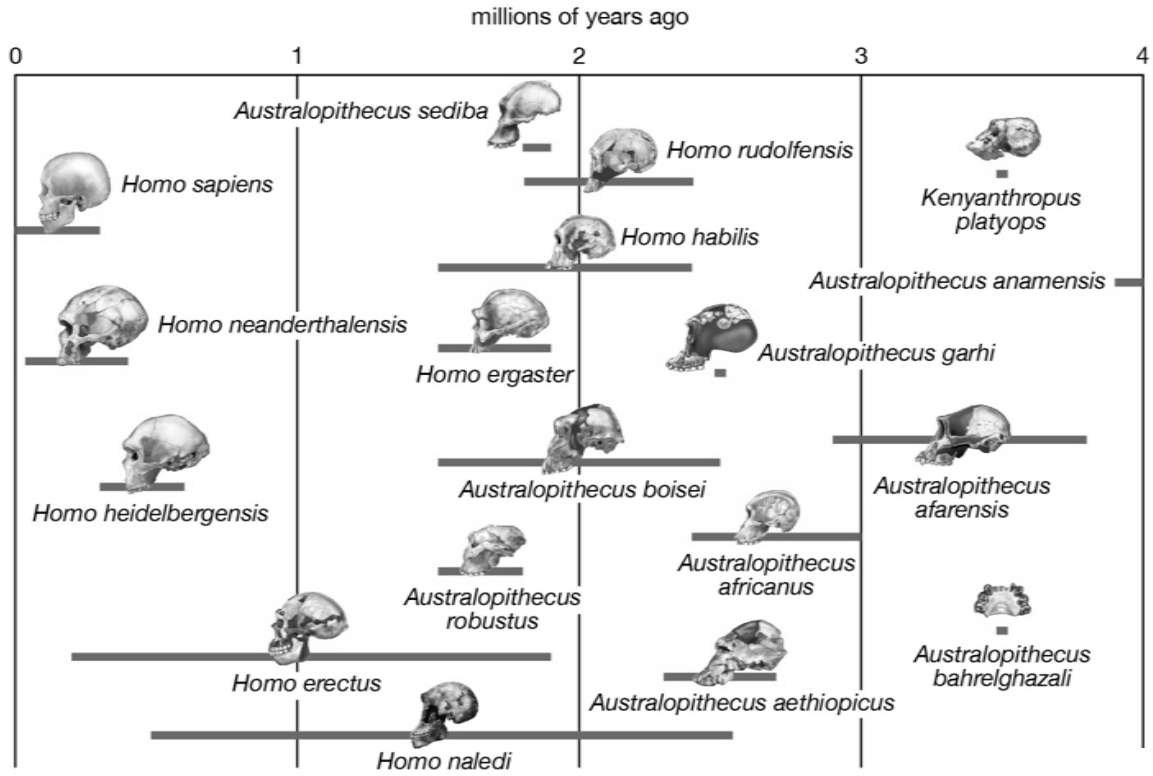
for divergence.

- It means that all mutations are alike in adaptive value.
- It is only chance or random drift which delineates a novel collection of mutants into a group divergent from the parental population.

(a) HUMAN EVOLUTION

The primates include **Prosimians** (Lemurs, tarsiers and related forms) and **Anthropoids** (Monkeys, apes and Human). They are descended from small rodent like or insectivorous mammals that evolved about 80 million years ago.





Order primata is divided into 2 sub orders.

(A) Prosimians : - **Lemur** - Evolved in Medagaskar 3

Loris - Evolved in China 2 **Closest relation to human**

Tarsiers - Evolved in Indonesia 1

They are prosimian ancestors of human,

(B) Anthropoids : - Monkeys

Apes

Human

Monkeys : - 2 types

(1) Old world monkeys : - Rhesus (Macaca), Baboon (Old world = **Africa. Asia**)

(1) Tail, non prehensile tail.

(2) Narrow flat nose with downward direction of nostril.

(3) U-shaped Jaw.

(4) Dental formula same as human $\frac{2123}{2123} = 32$

(5) Menstruation cycle is present in female.

(2) New world monkeys : - spider monkey, marmosets (New world = **South & Middle**

America)

(1) Long, prehensile tail

(2) Protruding nose with upward direction of nostril

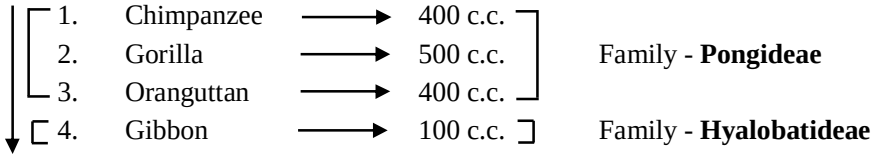
(3) U-shaped jaw

(4) Dental formula $\frac{2133}{2133} = 36$

(5) Menstruation cycle absent but estrous cycle is present.

So, Old world monkeys are more closer to human.

Apes : - 4 types



Human - Hominideae Family

Similarities between man and apes : -

(1) Tail absent
(2) Erect posture
(3) Grasping hands
(4) Hairs are present on body
(5) Larger head, more cranial capacity
(6) More intelligent than other animals
(7) Facial muscles are present for expression of surprise, pleasure.
(8) Menstruation cycle is present in female of both
(9) Blood group of AB series are present in both.
(10) Composition of Hb is same in both. **Only one amino acid is different in human and Gorilla.**
(11) **Chromosomal similarities :**

(i) No. of chromosomes are approximately same in man and apes.
Apes = 48
Man = 46

(ii) DNA contents and DNA matching is same in both. This similarity is
100% with Chimpanzee
94% with Gibbon
88% with Rhesus monkey

(iii) Banding pattern of chromosome is same in both.
Banding techniques enable the identification of individual chromosomes and their parts.

Banding pattern of ch. no. 3, 6 of human and chimpanzee is 100% similar.

Comparisons have been made between banding pattern of chromosomes of man and those

of the great apes.

Somatic cells of human contain 46 chromosomes (44 Autosomes and 2-sex chromosomes).

The diploid number of chromosomes in Gorilla, chimpanzee and Oranguttan is 48.

The total amount of DNA in human diploid cells and that of the great apes are dissimilar.

Similarity in the fine structural organization of the chromosomes is understood only in terms of a common origin for man and chimpanzee.

Apes	Human
1. Semi erect posture	*1. Complete erect posture*
2. Shorter neck and embedded.	*2. Long and erect neck*
3. Thick growth of hairs on complete body	*3. Only on certain body part*
4. Less cranial capacity (650 c.c.)	*4. More cranial capacity (1300-1600 c.c.)*
5. Less intelligent	*5. More intelligent*
6. Forelimbs longer than hind limbs	*6. Forelims are shorter than hindlimb*
7. 'U' shaped jaw	*7. Semi circular jaw*
8. Chin absent	*8. Chin present*
9. Thumb is parallel to palm	*9. Thumb is opposable*
10. Elongated pelvic girdle	*10. Broad pelvic girdle*
11. Less hair on body	*11. More hairs on body*

HUMAN EVOLUTION :

(1) Propliopithecus : - Origin & evolution in Oligocene epoch so called as Oligocene apes. Evolution about 30-35 million years ago.

(2) Aegyptopithecus : - Origin and evolution in late Oligocene and Miocene epoch so called as Miocene apes.

(3) Proconsul : - Its fossils were discovered by Leakey from East Africa near Victoria lake in Kenya from Miocene rocks. It walked on its four legs (considered as common ancestor of man and apes).

(4) Dryopithecus : - Evolution ≈15-20 million years ago.

- Direct ancestor of modern day apes.
- They were forest dwellers spending most of the time one the trees.
- Origin & evolution in **Miocene epoch.**
- Semi erect posture
- Quadra pedal locomotion, forlimbs longer than hind limbs.
- Thick growth of hair
- U shaped jaws
- Teeth larger and sharper

– By nature vegetarian, fruit eater

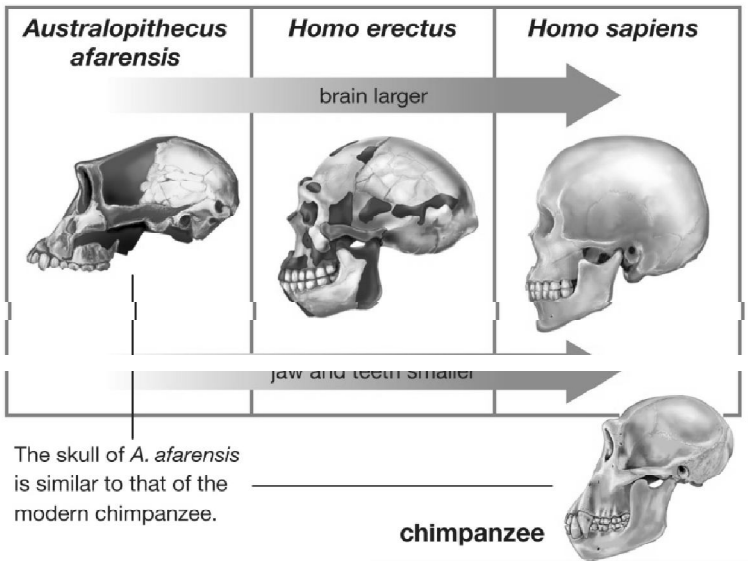
(5) Ramapithecus
(6) Shivapithecus] Fossils discovered by **Lewis** from **Shivalik** hills in India

(7) Kenyapithecus] Fossils discovered from **Kenya** by **Leakey.**

– Origin and evolution in **Pliocene epoch.**

– They are considered as ancestors of human but in characteristics same as Dryopithecus, but spending most of the time on the land.

(8) Australopithecus :- Prof. Raymond dart discovered a fossil of skull of 5-6 year old baby from the old Pliocene rocks of **Tuang region** (S. Africa). He named it **Tuang baby**, later on he renamed it **A. africanus.**



- About 3-2 million years ago it lived in East African grasslands.
- Evidences shows they hunted with stone. Probably ate fruits.
- It was an apeman because it have many characters of man and apes so it is also considered as **connecting link between apes and man.**
- An example of how fossils provide evidence of evolution can be established by comparing hominin skeletons
- *Australopithecus* is an early hominin ancestor that first appears in the fossil record approximately 4 million years ago
- Comparing these fossils to the bone structure of modern man (*Homo sapiens*) demonstrates key evolutionary changes.
- These evolutionary trends (from *Australopithecus* to *Homo sapiens*) include:

Structural Change	Evolutionary Advantage
More downward-facing foramen magnum	Facilitated transition to bipedalism (walking upright without use of hands) – needs to maintain an erect posture – increases weight-bearing on lower limbs – hands available for tool manipulation – head no longer most anterior part of body
S-shaped curvature of spine	
Longer leg : arm length ratio	
Larger heel bone and alignment of big toe	
Shift in position of gluteal muscles	
Reduced brow ridge and jaw protrusion	
Larger cranial capacity	Increased intellectual prowess
Smaller teeth and narrower jaw	Changed dietary requirements (more meat)
Lower and broader pelvis	Altered birthing patterns (for larger infants)
Marked reduction in body hair	Reflects use of fur clothing from hunting
Increased average height	Consequence of improved diet

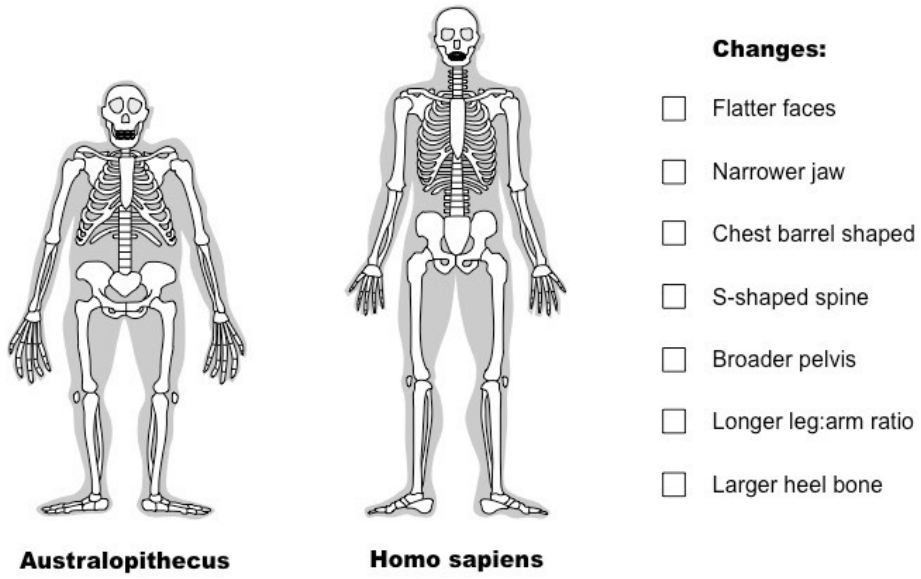


Fig: Comparison of Hominin Fossils

Apes like characters :

- Less cranial capacity – 400 – 500 c.c.
- Thick growth of hair on body
- Prognathous.

Man like characters :

- Complete erect posture **(first man who stood erect)**
- Forelimb shorter than hindlimbs.
- **Bipedal locomotion (first man)**
- Some other varities of Australopithecus were also discovered by some other scientist.
- A. boisei [zinjanthropus] by Leakey from East Africa [Tanzania]
- A. afaransis [Lucy] by Donald Johanson from Ethiopea.

PREHISTORIC MAN : -

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

(1) Homo habilis : - The Tool maker or Handy man.

- First human being like
- Its fossils were discovered by **Dr. Leakey** from 2 million years old rocks in Africa
- Cranial capacity - 650 – 800 c.c.
- Complete erect posture
- Prognathous
- **First man who made tools of stones for hunting animals.**
- By nature omnivorous, also show cannibalism

(2) Homo erectus : - direct ancestor of homo sapiens

- Origin and evolution, 1.5 million years ago.
- Java man
- Peking man
- Heidelberg man (Branch from main line of Human evolution)

Java man :

Homo erectus erectus name given by **Mayer.**

or **Pithecanthropus erectus** given by **Dubois.**

- They used Tools of bones and stones
- Lived in caves
- Fossil obtain from central java by **Eugene Dubois.**
- Cranial capacity – 900 c.c.
- **First man who used fire for hunting, protection and cooking**
- Chin absent, Jaw Prognathous
- Complete erect posture
- Omnivorous, cannibalism have also found.
- **It is also known as erect ape man**

Peking man : - Homo erectus pekinensis name given by **Mayer**

Sinanthropus erectus name was given by **Davidson Black**

- **W.C. Pai** discovered the fossil of peking man from China.
- Lived in caves
- Cranial capacity – 1100 c.c.
- Chin absent, Jaw Prognathous
- Used sharp **chisel shaped tools** of stones, bones for cutting and killing animals.
- Omnivorous, cannibalism has been also found

– Used fire for cooking meat and for protection.

Heidelberg man : -

A fossil of lower jaw obtain from **Heidelberg in germany** it was discovered by **Ottoschotensack.**

– Cranial capacity – 1300 c.c.
– Origin & evolution – in Pleistocene epoch. It is believed that this species was evolved as a branch from main line of evolution and got extinct after some time

(3) Homo sapiens : -

– Neanderthal man
– Cromagnon man - Direct ancestor of modern man
– Homo sapiens sapiens - **Modern man (Man of today)**

(i) Neanderthal man : - Homo sapiens neanderthalensis

– Origin & evolution before a 30,000 – 1 lakh years
– Fossils were discovered by **C. fulhrott from Neanderthal vally of Germany.**
– They live in huts.
– Cranial capacity 1400 c.c
– Complete erect posture
– Prognathous
– Ceremonial burial of dead body
– Used animals skin as cloths
– Beginning of development of speech center.
– By nature – omnivorous.
– **First man believed in ''immortality of soul''**

(ii) Cromagnon man : - Homo sapiens fossils

– Origin and evolution **34000 years ago.**
– Fossils discovered **from Cromagnon rocks of France**
– Lived in caves
– Cranial capacity - 1650 c.c. **(maximum)**
– Complete erect posture
– Well developed speech centre
– Orthognathous jaw.
– Used animal skin as cloth.
– **This man was hunter and used domesticated dogs in hunting, so domestication of animals started by cromagnon man.**
– **Known for cave paintings.**
– **Regarded as the direct ancestor of modern man.**

– By nature **carnivorous.**

(iii) Homo sapiens sapiens (Modern man) : - Man of today

– 10,000 years ago.

– Cranial capacity 1450 cc

– Complete erect body posture

– Orthognathous

– Well developed speech centre, developed languages.

– Less hairs on body as compared to fossil man

– Omnivorous.

– It is believed that modern man evolved in Africa.

– **Agriculture was also started by them.**

Special Point :

The course of cultural evolution is divided in to three age.

Palaeolithic – Age of tools of stones and bones.

Mesolithic – Age of animals husbandry, language, reading, writing.

Neolithic

(i) Bronze age – Age of agriculture, knowledge and use of clothes.

(ii) Iron age – Present age is also known as Iran age.

Man of future : - homo sapiens futuralis

– **Dr. Shapiro** named man of future as Homo futuralis

– Taller and hairless body

– Tomb like head and larger brain.

– With no fifth finger

Special Point : -

(1) **Anthropology :-** Study of evolutionary history of man.

(2) **Ethology : -** Study of animal babbits and behaviour.

(3) **Hylobates hoolock :-** (The Gibbon) is the only ape found in India (forests of Assam)

(4) **Races of human - 4 types - Caucasoid, Negroid, Mongoloid, Australoid.**

(5) **Hobit : -** Recently **Rechard Roberts** scientist discovered a **18,000 years** old fossil of a lady form **flors island situated near Australia.** He gave name it to **Hobit/Dwarf man/Homo florasiansis.**

Ancestory line of Human

↓

Propliopithecus

↓

Aegyptopithecus

↓

Proconsul

↓

Dryopithecus/ Ramapithecus Shivapithecus + Kenyapithecus

↓ → apes

Australopithecus

↓

Homo habilis

↓

Homo erectus Java man/ peking man/ Homo heidelberg

↓ → Homo Neanderthalensis

Cro-magon man

↓

Homo sapiens sapiens

Memories

- ***Cope's Law:*** *It states that there is a tendency for animals to increase in size during the long course of evolution.*
- ***Bergman's Law :*** *It states that warm blooded animals become larger in the northern and colder parts of their range.*
- ***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:*** *(Gause, 1934) or the Competitive exclusion Principle (Hardin, 1960). It states that two species having the same ecological requirements cannot continue to occupy indefinitely the same habitat.*
- ***Gloger's rule:*** *It states that among warm blooded animals, those living in warm and moist climate develop more melanin pigment (are darker than animals in cold, dry climates) whereas forms in dry, hot climates have more yellow and red pigment.*
- ***Jordan's rule:*** *Temperature also influences the morphology of certain fishes and is found to have some relation with the number of vertebrae. Fishes inhabiting water of low temperature tend to have more vertebrae than those of warmer water.*