EVOLUTION

Evolution is an orderly change from one form to another.
Evolutionary Biology is the study of evolutionary history of life forms.

ORIGIN OF LIFE

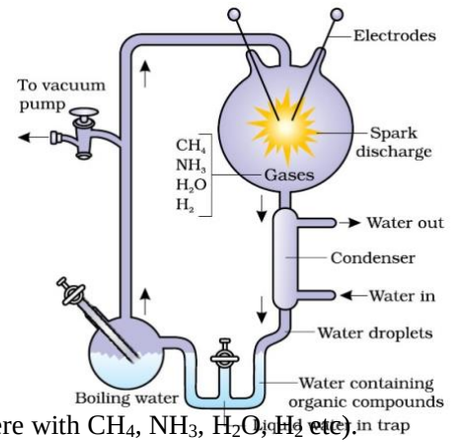
- **Big Bang Theory** states that universe originated about 20 billion years ago by a singular huge explosion.
- The earth was formed about **4.5 billion years** ago.
- There was no atmosphere on early earth. Water vapour, CH_4, CO_2 & NH_3 released from molten mass covered the surface.
- The UV rays from the sun broke up water into H_2 and O_2.
- Oxygen combined with NH_3 & CH_4 to form water, CO_2 etc.
- The ozone layer was formed. As it cooled, the water vapour fell as rain to form oceans.
- Life appeared almost **four billion years** ago.

THEORIES OF ORIGIN OF LIFE

1. **Theory of spontaneous generation (Abiogenesis):** states that, life came out of decaying and rotting matter like straw, mud etc.
   Louis Pasteur disproved this theory. He demonstrated that life comes only from pre-existing life.
   He showed that life did not come from killed yeast in a closed pre-sterilized flask. But in an opened flask, life (microbes) appeared.
2. **Biogenesis:** Proposed by **Francisco Redi, Spallanzani & Louis Pasteur**. It states that, life originates from pre-existing life. But it does not explain origin of first life.
3. **Cosmic theory (Theory of Panspermia):** It states that, the units of life (spores) were transferred to different planets including earth.
4. **Theory of special creation:** It states that, living things were created by some supernatural power (God).
5. **Theory of chemical evolution:** Proposed by **Oparin & Haldane.** It states that, the first form of life was originated from non-living inorganic & organic molecules such as CH_4, NH_3, H_2O, sugars, proteins, nucleic acids etc. i.e. *"Abiogenesis first, but biogenesis ever since".*

Urey-Miller experiment

- **Harold Urey & Stanley Miller** experimentally proved theory of chemical evolution. They created a condition like that of primitive earth (i.e. high temperature, volcanic storms, reducing atmosphere with CH_4, NH_3, H_2O, H_2 etc).



- They made electric discharge in a closed flask containing CH_4, NH_3, H_2 and water vapour at 800° C. As a result, some amino acids are formed.

In similar experiments, others observed formation of sugars, nitrogen bases, pigment and fats.

First **non-cellular forms** of life originated 3 billion years ago. They were **self-replicating metabolic capsule** containing RNA, proteins, Polysaccharides etc.

EVIDENCES FOR EVOLUTION

1. Paleontological evidences

Paleontology is the study of fossils.
Fossils are remnants of life forms found in rocks (earth crust). *They are written documents of evolution.*

Significance of fossils:

a. To study ***phylogeny*** (evolutionary history or race history). E.g. Horse evolution.
b. To study the ***connecting link*** between two groups of organisms. E.g. *Archaeopteryx.*
c. To study about ***extinct animals***. E.g. Dinosaurs.
d. To study about ***geological period*** by analysing fossils in different ***sedimentary rock layers.*** The study showed that life forms varied over time and certain life forms are restricted to certain geological time spans.

2. Morphological & Anatomical evidences

Comparative anatomy and morphology shows that different forms of animals have some common structural features. This can be explained as follows:

a. Homologous organs

- **Homologous organs** are the organs having fundamentally similar structure and origin but different functions. This phenomenon is called **Homology.**
- E.g. Human hand, Whale's flippers, Bat's wing & Cheetah's foot. These forelimbs have different functions but similar anatomical structures such as bones (e.g. humerus, radius, ulna, carpals, metacarpals & phalanges).
- Homology is also seen in heart, brain etc.
- **Homology in plants:** E.g. Thorns of *Bougainvillea* and tendrils of *Cucurbita*.
- The origin of homologous organs is due to ***Divergent evolution.*** It is the evolution by which **related species** become **less similar** to survive and adapt in different environmental condition.
- Homology indicates common ancestry.

b. Analogous organs

These are the organs having similar function but different structure & origin. This phenomenon is called **Analogy.** E.g.

- **Wings of insects** (formed of a thin flap of chitin) and **wings of birds** (modified forelimbs).
- **Eyes of Octopus** (retina from skin) and **mammals** (retina from embryonic brain).

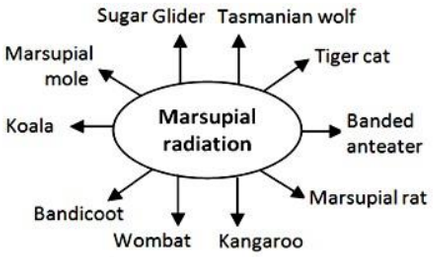
- **Flipper of Penguins** and **Dolphins**.
- **Sweet potato** (modified root) & **Potato** (modified stem).
- **Trachea of insects** (from ectoderm) and **lungs of vertebrates** (from endoderm).

Origin of analogous organs is due to ***Convergent evolution.*** It is the evolution by which **unrelated species** become more **similar** to survive and adapt in similar environmental condition.

3. Adaptive radiation (Biogeographical evidences)

Adaptive radiation (evolution by adaptation) is the evolution of different species from an ancestor in a geographical area starting from a point. It is a type of divergent evolution. E.g.

- Darwin's finches in Galapagos Islands.
- Australian marsupials (Marsupial radiation).
- Placental mammals in Australia.



When more than one adaptive radiation is appeared in an isolated geographical area, it results in ***convergent evolution.*** E.g. Australian Marsupials and Placental mammals.

Placental mammals	Australian Marsupials
Mole	Marsupial mole
Ant eater	Numbat (Ant eater)
Mouse	Marsupial mouse
Lemur	Spotted cuscus
Flying squirrel	Flying phalanger
Bobcat	Tasmanian tiger cat
Wolf	Tasmanian wolf

4. Biochemical evidences

- Organisms show similarities in proteins, genes, other biomolecules & metabolism. It indicates common ancestry.

5. Embryological evidences

- Proposed by **Ernst Haeckel.**
- He observed that all vertebrate embryos have some common features that are absent in adult.
- E.g. all vertebrate embryos (including human) develop vestigial gill slits just behind the head. But it is functional only in fish and not found in other adult vertebrates.
- However, **Karl Ernst von Baer** rejected this proposal. He noted that embryos never pass through the adult stages of other animals.

6. Evidences for evolution by natural selection

Natural selection is the process in which organisms with better favourable & heritable variation are survived and reproduced.

Some evidences are given below:

- **Industrial melanism:** In England, before industrialization (1850s), there were more white-winged moths (*Biston betularia*) on trees than dark winged or melanised moths (*Biston carbonaria*). After industrialization (1920), more dark-winged moths and less white winged moths were developed.

  Reason:

  Before industrialization: There was white lichens covered the trees. In that background, white winged moths survived but dark winged moths were picked out by predators.

  After industrialization: The tree trunks became dark due to industrial smoke and soot. No growth of lichens. So white winged moths did not survive because the predators identified them easily. Dark winged moth survived because of suitable dark background.
- Development of resistant varieties in organisms against ***herbicides, pesticides, antibiotics*** or ***drugs*** etc.

These are the examples for natural selection by **anthropogenic action** (evolution due to human activities).

THEORIES OF BIOLOGICAL EVOLUTION

Lamarckism (Theory of Inheritance of Acquired characters)

It is proposed by Lamarck. It states that evolution of life forms occurred by the inheritance of acquired characters.

Acquired characters are developed by use & disuse of organs.

- **Evolution by use of organs:** E.g. Long neck of giraffe is due to continuous elongation to forage leaves on trees. This acquired character was inherited to succeeding generations.
- **Evolution by disuse:** E.g. Disappearance of limbs in snakes.

This theory was eliminated out because it is proved that the characters are inherited only through genes.

Darwinism (Theory of Natural selection)

- Proposed by **Charles Darwin.**
- It was based on observations during a sea voyage in a sail ship called **H.M.S. Beagle.**
- **Alfred Wallace** (a naturalist worked in **Malay Archepelago)** had also come to similar conclusions.
- Work of **Thomas Malthus** on populations influenced Darwin.

Darwinism is based on 2 key concepts:

- **Branching descent:** It explains that all organisms are modified descendants of previous life forms.
- **Natural selection:** Consider a bacterial colony **A** growing on a given medium. If the medium composition is changed, only a part of the population can survive under new condition. This variant population (B) outgrows the others and appears as new species, i.e. **B is better than A under new condition.** Thus, nature selects for fitness.

Natural selection is based on the following facts:

- **Heritable minor variations:** It is either beneficial or harmful to the organisms.
- **Overproduction:** Population size grows exponentially due to maximum reproduction (E.g. bacterial population).
- **Limited natural resources:** Resources are not increased in accordance with the population size.
- **Struggle for existence:** It is the competition among organisms for resources so that population size is limited.
- **Survival of the fittest:** In struggle for existence, organisms with beneficial variations can utilize resources better. Hence, they survive and reproduce. This is called

Survival of the fittest. It leads to a change in population characteristics and new forms appear.

Darwin ignored about origin of variation and mechanism of evolution or speciation.

MECHANISM OF EVOLUTION

- **Hugo de Vries** proposed **Mutation Theory** of evolution.
- He conducted experiments on *Oenothera lamarckiana* (evening primrose) and believed that evolution takes place through mutation and not by minor variation.
- **Darwinian variation** is minor, slow and directional. It results in **gradual evolution.**
- **Mutational variation** is sudden, random & directionless. Here, speciation is by **saltation** (single step, large mutation).
- Mutation is the origin of variation for evolution.

HARDY-WEINBERG PRINCIPLE

- It states that *allele frequencies in a population are stable and is constant from generation to generation in the absence of disturbing factors.*
- The **gene pool** (total genes and their alleles in a population) remains a constant. This is called **genetic equilibrium (Hardy-Weinberg equilibrium).**
- Sum total of all the allelic frequencies = 1
- E.g. Consider, in a diploid, **p** & **q** are the frequencies of alleles **A & a** respectively.

Frequency of AA = p^2
Frequency of aa = q^2
Frequency of Aa = 2pq
Hence $p^2 + 2pq + q^2 = 1$ [binomial expansion of $(p+q)^2$]

Change of frequency of alleles in a population disturbs Hardy-Weinberg equilibrium. This change is due to evolution.

Factors affecting Hardy-Weinberg equilibrium

a. Gene migration: Gene flow from one population to another. Here gene frequencies change in both populations. Gene flow occurs if migration happens multiple times.

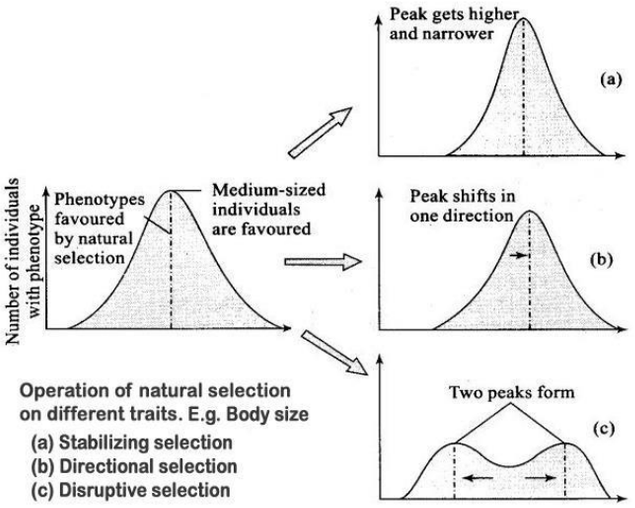
b. Genetic drift: The gene flow by chance causing change in frequency. Sometimes, the change in frequency is so different in the new sample of population that they become a different species. The original drifted population becomes founders and the effect is called **founder effect.**

c. Mutation: It results in formation of new phenotypes. Over few generations, this leads to speciation.

d. Genetic recombination: Reshuffling of gene combinations during crossing over resulting in genetic variation.

e. Natural selection: It is 3 types.

- **Stabilizing selection:** Here, more individuals acquire mean character value and variation is reduced.
- **Directional selection:** Individuals of one extreme (value other than mean character value) are more favoured.
- **Disruptive selection:** Individuals of both extremes (peripheral character value at both ends of the distribution curve) are more favoured.



Operation of natural selection on different traits. E.g. Body size
(a) Stabilizing selection
(b) Directional selection
(c) Disruptive selection

A BRIEF ACCOUNT OF EVOLUTION

The geological time scale includes 4 eras: **Proterozoic, Palaeozoic, Mesozoic & Cenozoic.**

1. Proterozoic era: 2500 - 541 million yrs ago (mya)

- **2000 mya:** First cellular forms of life appeared.
- Some of the cells had the ability to release O_2 as the light reaction in photosynthesis.
- Single celled organisms became multicellular organisms.

2. Palaeozoic era (540 - 252 mya)

- It has 6 periods: **Cambrian** (540 - 490 mya), **Ordovician** (490 - 443 mya), **Silurian** (425 mya), **Devonian** (405 mya), **Carboniferous** (360 mya) **& Permian** (285 mya).
- **500 mya:** Invertebrates were formed.
- **450 mya:** First land organisms (plants) appeared.
- **400 mya:** Arthropods invaded the land.
- **350 mya:** Jawless fishes were evolved.
  Lobefins (stout & strong finned fishes) could move on land and go back to water. They evolved to first amphibians (ancestors of modern day frogs & salamanders).

In 1938, a lobe-fin called **coelacanth** fish was caught in South Africa which was thought to be extinct.

- **320 mya:** Sea weeds and few plants were existed.
- Amphibians evolved to reptiles. They lay thick-shelled eggs (do not dry up in sun).
- **Giant ferns (Pteridophytes)** were present but they all fell to form coal deposits slowly.

3. Mesozoic era (252 - 66 mya)

- Age of reptiles and gymnosperms.
- It has 3 periods: **Triassic (230 mya), Jurassic (208 mya) & Cretaceous (144 mya).**
- **200 mya:** Some of the land reptiles went back into water to evolve into fish-like reptiles (E.g. *Ichthyosaurs*).
- The land reptiles were **dinosaurs (*Tyrannosaurus rex, Triceratops, Stegosaurus, Brachiosaurus* etc.)**
  T. rex was the largest dinosaur (20 feet in height, huge fearsome dagger-like teeth).
- Toothed birds were emerged.

4. Cenozoic era (66 - 0 mya)

- Age of Mammals & Angiosperms.
- It has 2 periods: **Tertiary (66 mya)** & **Quaternary (2 mya** - Age of man).
- **65 mya:** Dinosaurs suddenly disappeared. Some say climatic changes killed them. Some say most of them evolved into birds.
- First mammals were shrew-like. Their fossils are small sized.
- In South America, there were mammals resembling horse, hippopotamus, bear, rabbit etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna.
- Due to continental drift, Australian marsupials survived because of lack of competition from any other mammals.

ORIGIN AND EVOLUTION OF MAN

- **15 mya:** ***Dryopithecus*** & ***Ramapithecus.***
  Hairy. Walked like gorillas & chimpanzee.
  Dryopithecus: ape-like.
  Ramapithecus: man-like.
- **3-4 mya: Man-like primates** walked up right in eastern Africa. Height up to 4 feet. This belief is based on fossils of man-like bones found in Ethiopia & Tanzania.
- **2 mya:** ***Australopithecus.*** Lived in East African grass lands. Hunted with stone weapons. Ate fruits.
  Homo habilis: First human-like being (hominid).
  Brain capacity: 650-800 cc. Did not eat meat.
- **1.5 mya:** ***Homo erectus*** **(Java man).** Large brain (900 cc). Ate meat.
- **1 lakh - 40,000 yrs ago:** ***Homo neanderthalensis*** **(Neanderthal man).**
  Brain capacity: 1400 cc. Lived in East & Central Asia. Used hides to protect their body. Buried their dead.
- **75,000 - 10,000 yrs ago (ice age)*: Homo sapiens* (Modern man).**
  Pre-historic cave art developed about 18,000 years ago. E.g. Cave paintings at Bhimbetka rock shelter in Raisen district of Madhya Pradesh.
  Agriculture & settlements: 10,000 years ago.

Sequence of Human evolution:

Dryopithecus → Ramapithecus → Australopithecus → Homo habilis → H. erectus → H. neanderthalensis → H. sapiens

MODEL QUESTIONS

1. Match the following:

A	B	C
Charles Darwin	Chemical evolution	Use and disuse of organs
Lamarck	Natural selection	Abiogenic origin of life in ocean
Hugo de Vries	Biogenesis	*Oenothera lamarckiana*
Louis Pasteur	Inheritance of acquired characters	Survival of the fittest
Oparin & Haldane	Mutation	Disproved theory of spontaneous generation

2. Analyze the relationship between first two words and fill the fourth place.
   a. Homology: Divergent evolution Analogy: .....
   b. *Pisum sativum*: Mendel *Oenothera lamarckiana*: .....
3. Classify the following points into two categories. Give suitable titles.
   Random & directionless, Minor variation, Gradual evolution, Slow & directional, Large variation, Speciation by saltation
4. A bacterial infection was effectively controlled by using a specific antibiotic for a long time. But now- a- days this antibiotic is not found to be so effective. Give a scientific explanation for this phenomenon based on evolution.
5. Hardy- Weinberg Principle has a great contribution in population genetics.
   a. State Hardy- Weinberg Principle. b. What are the factors affecting genetic equilibrium?
   c. What is meant by Founder effect?
6. Select the correct order
   a. Paleozoic era → Proterozoic era → Mesozoic era → Coenozoic era
   b. Mesozoic era → Proterozoic era → Coenozoic era → Paleozoic era
   c. Proterozoic era → Paleozoic era → Mesozoic era → Coenozoic era
   d. Coenozoic era → Paleozoic era → Mesozoic era → Proterozoic era
7. Prepare a flowchart showing the evolution of man.