CHAPTER-6

EVOLUTION

Topic-1

Origin of Life on Earth and Various Related Evidences

Concepts Covered • *Theories of origin of life, Urey-Miller experiment Evolution and it's evidences.*

Revision Notes

- Evolution is an orderly change from one form to another.
- **Evolutionary Biology :** Study of history of development of newer life forms from pre-existing ones.

Origin of Life

- Big Bang theory state that the universe originated about 20 billion years ago by a thermonuclear explosion (big bang) of a dense entity.
- The earth was formed about 4.5–5 billion years ago.
- There was no atmosphere on early earth.
- Water vapour, CH_4, CO_2 and NH_3 released from molten mass covered the surface.

  $H_2O \rightarrow H_2 + O_2$

  $NH_3 + O_2 \rightarrow NO +$ water

  $CH_4 + O_2 \rightarrow CO_2 +$ Water
- Then the ozone layer was formed.
- As it cooled, the water vapour condensed to fell as rain to form oceans.

Theories of Origin of Life

(i) Abiogenesis states that life originated from a simple organic compound :

- It states that life came out of decaying and rotting matter like straw, mud, etc.
- **Louis Pasteur** (1864) demonstrated that life comes from pre-existing life and dismissed abiogenesis theory.
- He showed that in pre-sterilised flasks, life did not come from killed yeast while in another flask open to air, new living organisms arose.

Mnemonics

Concept : Theories of Origin of life

Mnemonic : All **B**oys **C**ome in **S**chool it's **Compulsory**

Interpretation: Abiogenesis, Biogenesis, Cosmic theory, Special creation theory, **C**hemical evolution theory

Key Words

Spores : They are minute, One-celled reproductive unit which give rise to a new individual without sexual reproduction.

Progeny : Offspring or children.

Panspermia : Units of life in the forms of spores, which were transferred to earth from outer space (as believed by some scientists).

(ii) Biogenesis

- It was proposed by **Francisco Redi, Spallanzani** and **Louis Pasteur**.
- It states that life originates from pre-existing life.

(iii) Cosmic Theory (Theory of Panspermia)

- It states that the units of life (**spores**) were transferred to different planets including Earth.

(iv) Theory of Special Creation

- It states that living & non-living things are created by some supernatural power (God).

(v) Theory of Chemical Evolution of life

- It was proposed by **Oparin** and **Haldane**.
- It states that the first form of life was originated from non-living inorganic and organic molecules such as CH_4, NH_3, H_2O, sugars, proteins, nucleic acids, etc.
- "Abiogenesis first, but biogenesis ever since".
- **Two hypothetical proposals of Oparin-Haldane's theory are :**
  (i) C**hemical evolution** from inorganic to organic molecules.
  (ii) **First life** formed by assembly and interaction of organic molecules.
- This theory is also known as primary abiogenesis.

Urey-Miller Experiment

- **Harold Urey** & **Stanley Miller** conducted an experiment to prove the theory of chemical evolution.
- They created a condition similar to that of primitive earth (i.e., high temperature, volcanic storms, reducing atmosphere devoid of oxygen but containing compounds of carbon, hydrogen, nitrogen and water.
- 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 were formed.
- In similar experiments, others observed the formation of sugars, nitrogen bases, pigments and fats.
- First non-cellular form of life originated 3 billion years ago.
- They were RNA, proteins, polysaccharides, etc.

Evolution of Life Forms – Various Theory

- Based on observations made during a sea voyage in a survey ship called H.M.S. Beagle round the world, **Charles Darwin** concluded that existing living forms share similarities to varying degrees not only among themselves but also with life forms that existed millions of years ago.
- There had been extinctions of different life forms in the years gone by just as new forms of life, arose at different periods of the history of the earth.
- There has been a gradual evolution of life forms due to variation in characteristics.
- Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors etc.) would outbreed others that are less-endowed to survive under such natural conditions or fitness of the individual or population.
- Fitness, according to Darwin, refers ultimately and only to reproductive fitness.
- Hence, those who are a better fit in an environment, leave more **progeny** than others.
- These, therefore, will survive more and hence are selected by nature.
- He called it natural selection and implied it as a mechanism of evolution.

Key Fact

Alfred Russel Wallace (1823-1913) was a British naturalist and geographer, He independently proposed a theory of evolution due to natural selection. This prompted Charles Darwin to publish his own theory.

The modern synthetic theory : The modern synthetic theory is also known as Neo- Darwinian theory which merges the theory of Darwinian evolution with Mendelian genetics given by many evolutionary biologists such as such as T. Dobzhansky, Sewall Wright, G.I. Stebbins, Ernst Mayr. This theory provide a new definition of evolution as "the change occurring in the allele frequencies within the populations" which emphasises the genetic basis of evolution.

Factors of modern synthetic theory:

- Mutation
- Genetic recombination
- Genetic drift
- Natural selection
- Isolation
- **Alfred Wallace**, a naturalist who worked in the Malay Archipelago also came to similar conclusions around the same time.
- All the existing life forms share similarities and share common ancestors.
- However, these ancestors were present at different periods in the history of the earth.
- The geological history of the earth closely correlates with the biological history of the earth.

Evidences for Evolution

1. Palaeontological Evidences

- The study of fossils is known as paleontology.
- Fossils are remnants of life forms or the parts found preserved in rocks (earth crust).
- Fossils 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* having reptilian and avian characteristics.
  - **(c)** To study extinct animals e.g., Dinosaurs.
  - **(d)** To study about the 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 periods.

2. Morphological and Anatomical Evidences

- Comparative anatomy and morphological evidences showed that different forms of animals have some common structural features. This can be explained as follows :

(a) Homologous Organs and Homology

- Homologous organs are the organs having fundamental similarity in structure and origin but different in functions. This phenomenon is called homology. e.g., Human hand, Whale's flippers, Bat's wings, and Cheetah's foot.
- All these perform different functions but are constructed on the same fundamental plan.
- Homology can be seen in the skeleton (e.g., humerus, radius, ulna, carpals, metacarpals & phalanges), heart, blood vessels, excretory system, brain, etc.

- **Homology in Plants :**
  - **(i)** The thorns of *Bougainvillea* and tendrils of *Cucurbita*.
  - **(ii)** The origin of homologous organs is due to divergent evolution.
  - **(iii)** The divergent evolution is the process by which related species become less similar in order to survive and adapt to different environmental conditions.
  - **(iv)** Homology indicates common ancestry.

(b) Analogous Organs and Analogy

- Analogous organs are organs having similar function but different structure and origin. This phenomenon is called analogy.
- **Examples**
  - **(i)** Wings of insects (formed of a thin flap of chitin) and wings of birds (modified forelimbs).
  - **(ii)** Eyes of Octopus (retina from skin) and mammals (retina from the embryonic brain).
  - **(iii)** Flipper of Penguins and Dolphins.
  - **(iv)** Sweet potato (modified root) and Potato (modified stem).
  - **(v)** Trachea of insects (from ectoderm) and lungs of vertebrates (from endoderm).
- The origin of analogous organs is due to convergent evolution.
- The convergent evolution is the process by which unrelated species become more similar to survive and adapt in similar environmental conditions.

3. Adaptive Radiation (Biogeographical Evidences)

- Adaptive radiation (evolution by adaptation) is the evolution of closely related species in a given geographical area starting from a point. e.g.,
  (a) Darwin's finches (seen in Galapagos Islands).
  (b) Australian marsupials.
  (c) Placental mammals in Australia.
- When more than one adaptive radiation occurs in an isolated geographical area, this leads to convergent evolution e.g., Australian Marsupials and Placental mammals.

4. Biochemical Evidences

- Similarities in proteins and genes.
- Similarities in other biomolecules and metabolism.

5. Evidences for Evolution by Natural Selection

- Natural selection is the process by which the organisms that are best suited for their environment survive and reproduce.
- **Examples of natural selection : Industrial Melanism (In England) :**

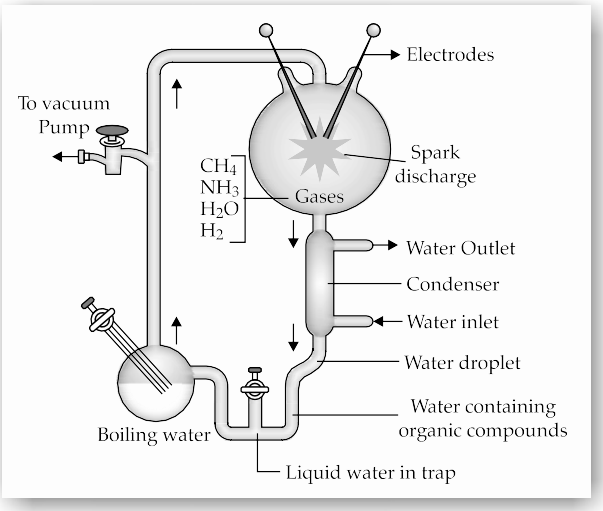
Before Industrialisation (1850s) :

- There were more white-winged moths (*Biston betularia*) on trees than dark-winged or melanised moths (*Biston carbonaria*).
- **Reason :** White coloured lichen covered the trees. In that background, the white-winged moths survived but the dark coloured moths were easily spotted out and picked out by predators.

After industrialisation (1920) :

- More dark-winged moths and less white-winged moths.
- **Reason :** The tree trunks became dark due to pollution by industrial smoke and soot. No growth of lichens. Under this condition, the white winged moth did not survive because the predators identified them easily against dark background. Dark winged moth survived because of suitable dark background.
- Excess use of herbicides, pesticides, antibiotics or drugs, etc., resulted in the selection of resistant varieties (natural selection by anthropogenic action).

IMPORTANT DIAGRAM :



Miller and Urey's Experiment

Example 1

Q. Select two pairs from the following which exhibit divergent evolution. Give reasons for your answers.
(i) Forelimbs of cheetah and mammals
(ii) Flippers of dolphins and penguins.
(iii) Wings of butterflies and birds.
(iv) Forelimbs of whale and mammals.

Sol. • The two pairs of animal that exhibit divergent evolution are:
(i) Forelimbs of cheetah and mammals.
(iv) Forelimbs of whales and mammals.

All these animals show similarities in pattern of bones of forelimb but they perform different functions. They have similar anatomical structure.

Hence, the same structural organs in these animals have developed in different directions because of adaptations to their different requirements. This shows that the divergent evolution and that the structures/ organs are homologous.

Topic-2

Evolutionary Theories, It's Mechanism and Evolution of Man

Concepts Covered • *Theory of Biological Evolution, Hardy - Weinberg Principle, Human Evolution*

Revision Notes

1. **Darwinism (Theory of Natural Selection)**
   - It was proposed by **Charles Darwin (1859) in his book "Origin of Species".**
   - It is based on two key concepts namely,

   (a) Branching descent (**Adaptive radiation**)
   (b) Natural selection (**Convergent evolution**)

   (a) Branching Descent
   - It explains that all organisms are modified descendants of previous life forms.

   (b) Natural Selection
   - Consider a bacterial colony (say A) growing on a given medium.
   - If the medium composition is changed, only a part of the population (say B) can survive under new conditions. This variant population outgrows the others and appears as new species i.e. B is better than A under new condition.
   - Nature selects for fitness.
   - The work of **Thomas Malthus** on principle of populations (1794) was influenced by **Darwin**.
   - **Natural selection is based on the following facts :**
     (a) Heritable minor variations.
     (b) Over production by organisms.
     (c) Limited natural resources.
     (d) Struggle for existence for food and space.
     (e) Survival of the fittest.
   - Population size grows exponentially if everybody reproduces maximally (e.g., bacterial population).
   - In fact, population size is limited due to competition for resources (Struggle for existence).
   - Only some survives (Survival of the fittest).
   - Darwin said that the organisms with heritable variations make resource utilisation better.
   - They reproduce and leave more progeny.
   - It leads to a change in population characteristics and new forms appear.

Key Words

Adaptive Radiation: It is the process of evolution of different species starting from a point in a geographical area and finally radiating to other areas of geography.

Convergent Evolution: It is the evolutionary process where anatomically different structures in different group of organisms evolve towards the same function.

Natural Selection: It is the process of occurring in nature that acts over a number of generations and slowly increases the proportion of those individuals which are adapted to the environment due to their heritable characters.

Mechanism of Evolution
- Darwin ignored about origin of variation and mechanism of speciation.

Mutation Theory
- **Hugo de Vries** (1901) proposed Mutation Theory of evolution in his book "Mutation theory".
- He conducted some experiments on *Oenothera lamarckiana* (evening primrose) and believed that evolution takes place through mutation and not by minor variation.
- Evolution for Darwin was gradual while for de Vries it is a sudden / spontaneous process. He believed mutation caused speciation and hence called it **saltation** (single step large mutation).

Differences between Darwinian Variation & Mutation

Darwinian Variation	Mutation
It shows minor variation.	It shows large variation.
It is slow and directional.	It is random, sudden and directionless.
It showed gradual evolution.	It showed discontinuous evolution and speciation by saltation.
It is caused by reshuffling of genes.	It is caused by change in the genetic material.

- **Hardy - Weinberg Principle**
  - It says that allele frequencies in a population are stable and constant from generation to generation.
  - The gene pool (total genes and their alleles in a population) remains constant. This is called genetic equilibrium (Hardy-Weinberg equilibrium).

Mnemonics

Concept: Factors Affecting Hardy- Weinberg Equilibrium

Mnemonic: 3G Modern Network

Interpretation: Gene migration, Genetic drift, Genetic recombination, Mutation, Natural selection.

- Sum total of all the allelic frequencies = 1. e.g., In a diploid, p and q are the frequencies of alleles A & a respectively.
- The frequency of $AA = p^2$ (i.e., the probability of an allele A with frequency p is the product of the probabilities, i.e., p^2)
- The frequency of $aa = q^2$
- The 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 causes disturbance in genetic equilibrium. This is due to evolution.

- **Factors Affecting Hardy-Weinberg Equilibrium :** There are time basic processes which may bring about the change in Hardy Weinberg equilibrium and bring about the variations at the genetic level as follows :

(a) Gene Migration
- Gene flow from one population to another.
- Here, gene frequencies change in both populations.
- There would be a gene flow if migration happens multiple times.

(b) Genetic Drift
- The accidental gene flow 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
- Mutations result in formation of new phenotypes.
- Over few generations, this leads to speciation.

(d) Genetic Recombination
- It is the reshuffling of gene combinations during crossing over resulting in genetic variation.

(e) Natural Selection : It is the major factor which adds variations in the population, change the gene frequencies in the **gene pool** resulting in the formation new **gene pool**. These are of three types namely, Stabilising selection, Directional selection and Disruptive selection.

(i) Stabilising Selection : Here, more individuals acquire average character value and variation is reduced.

(ii) Directional Selection : Here, individuals of one extreme are more favoured.

(iii) Disruptive Selection : Individuals of both the extremes are favoured. It produces two peaks that may lead to the development of two different populations.

Key Fact

Basic unit of natural selection is individual. *Australopithecus* is considered as the connecting link between man and apes.

- **Origin and Evolution of Man (Human ancestry)**

(i) *Dryopithecus* & *Ramapithecus* (15 mya)
- **(a)** Hairy.
- **(b)** Walked like gorillas and chimpanzee.
- **(c)** ***Dryopithecus :*** ape-like.
- **(d)** ***Ramapithecus :*** man-like.
- **(e)** Fossils of man-like bones found in Ethiopia and Tanzania.
- **(f)** Man-like primates (3-4 mya) : Height up to 4 feet.

(ii) *Australopithecus* (2 mya)
- In East African grasslands.
- Hunted with stone weapons.
- Ate fruits.

(iii) *Homo habilis*
- First human-like being (hominid).

- Brain capacity : 650-800 cc.
- Did not eat meat.

(iv) *Homo erectus* (1.5 mya)

- Large brain (900 cc) : Ate meat.

(v) Neanderthal man : 40,000 - 1 lakh yrs ago :

- Brain 1400 cc.
- Lived in East and Central Asia.
- Used hides to protect their body.
- Buried their dead.

(vi) *Homo sapiens* (Modern man) : Evolution took place during 10,000 to 75,000 years ago.

- Pre-historic cave art developed about 18,000 years ago.
- Agriculture and settlements : 10,000 years ago.

Example 2

Q. Write two differences between *Homo erectus* and *Homo habilis*.

Sol. (a) Differences between *Homo erectus* and *Homo habilis* are as follows:

Homo erectus	***Homo habilis***
Had a large brain around 900 cc.	Had brain capacities between 650-800 cc.
Walked in an upright posture.	Stooped over while walking.
Probably ate meat.	Probably did not eat meat.