CHAPTER-7
EVOLUTION

Topic-1

Origin of Life on the Earth and Related Evidence

Concepts Covered ● *Theories of Origin of Life* ● *Experimental Evidence for Abiogenic Molecular Evolution of Life* ● *Evidence of Evolution*

Revision Notes

- Evolution is an orderly change from one form to another.
- Evolutionary Biology is the study of the history of life forms on the Earth.
- **Origin of Life**
  - Big Bang theory states that universe originated about 20 billion years ago, by a thermonuclear explosion (big bang) of a dense entity.
  - The Earth was formed about 4.5 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.
  - The UV rays from the Sun broke up water to hydrogen and oxygen and the lighter H_2 escaped. Oxygen combined with ammonia and methane to form water, CO_2 and others.

    $H_2O \rightarrow H_2 + O_2$
    $NH_3 + O_2 \rightarrow$ water + NO
    $CH_4 + O_2 \rightarrow CO_2 + H_2O$
  - Then the ozone layer was formed.
  - As it cooled, the water vapour led to to rain which filled the depression on Earth's surface, forming water bodies like oceans.
- **Theories of Origin of Life**

1. Theory of Spontaneous Generation (Abiogenesis)

- The spontaneous genesis of life from non-living substances (i.e., the theory of abiogenesis, *Gr., a = not + bios= life + genesis=origin)* was the most convincing concept regarding the origin of life till 17th century.
- It states that life came out of decaying and rotting matter like straw, mud, etc.
- It was believed that the frogs, toads, snakes and field mice arose from the mud; parasites, beetles and flies arose from the sweat and manure, aphids and other insects arose under the influence of heat and moisture from plant juices and microorganisms arose spontaneously from air or water.
- Experiments performed by **Francesco Redi**, **Spallanzani** and the French Microbiologist **Louis Pasteur** went well against the theory of spontaneous generation of life and thus this theory became obsolete.

2. Biogenesis

- Biogenesis (*Gr., bios= life + genesis=origin*) is based on the theory that life can only come from life, and it refers to any process by which a life form can give rise to other life forms. For instance, a chicken laying eggs, which hatch and become a baby chicken.
- It was proposed by Francesco Redi, Spallanzani and Louis Pasteur.
- It states that life originates from pre-existing life only.
- Louis Pasteur demonstrated that nothing developed in meat broth in sterilised and sealed flasks. Microorganisms did grow on open, sterilised flasks. He also used swan-neck flasks with fermentable broth. The structure of the flask allowed the air to enter while the dust particles were made to stick to the long curving tube and therefore were prevented from reaching the broth. Despite the air entering the flask, nothing grew on the broth. Conversely, microorganisms grew on the broth when the flask was tilted sideways. This caused the broth to touch the tube wall contaminated with dust. This disproved the notion that microorganisms could spontaneously form from the air. Instead, the microorganisms on the dust caused the spoilage of the broth.

3. Cosmic theory (Theory of Panspermia)

- This theory was proposed by Richter and supported by Arrhenius.
- It states that the units of life (called spores) were transferred to different planets including Earth. Panspermia is a hypothesis which says that life came from outside the Earth, i.e., from another celestial body.
- Units of life in the form of so-called spores were transferred to Earth from outer space as believed by some scientists.

4. Theory of special creation

- It states that living and non-living things were created by some supernatural power (God).
- These forms were designed according to their surroundings and have existed unchanged from the time they were formed.
- The greatest supporter of this theory was Father Suarez.

5. Theory of chemical evolution

- It was proposed by Oparin and Haldane.
- It states that the first form of life originated from non-living inorganic and organic molecules such as CH_4, NH_3, H_2O, sugars, proteins, RNA, nucleic acids, etc.
- It states "**Abiogenesis** first, but biogenesis ever since".

Experimental Evidence for Abiogenic Molecular Evolution of Life

➢ **Urey–Miller Experiment**

- Harold C. Urey and Stanley L. Miller conducted an experiment to prove theory of chemical evolution.
- They created a condition similar to that of primitive Earth (i.e., high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, H_2O, and H_2, etc.)
- They operated 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, pigment and fats.
- First non-cellular form of life originated 3 billion years ago.
- They were RNA, proteins, polysaccharides, etc.
- Many scientists believe chemical evolution, i.e., formation of biomolecules preceded the appearance of the first cellular forms of life. All early single celled life forms originated in water environment only.

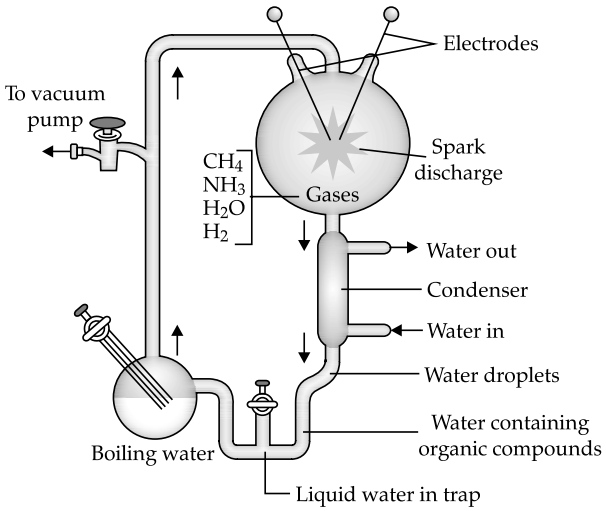


Fig. 7.1: Showing Urey–Miller Experiment

➢ **Evolution of Life Forms—A Theory**

- Based on observations made during a sea voyage in a sail 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.
- The fitness, according to Darwin, refers ultimately and only to reproductive fitness. Hence, those who are 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.
- Alfred Wallace, a naturalist who worked in 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.

Evidence for Evolution

- **Evidence of evolution come from:**
  - **(i)** Palaeontology
  - **(ii)** Comparative anatomy and morphology
  - **(iii)** Biochemical/Physiology
  - **(iv)** Biogeographical evidence
  - **(v)** Embryology

1. **Palaeontological Evidence**
   - The study of fossils is known as **palaeontology**.
   - Fossils are the remains or traces of animal and plant life of the past, found embedded in rock either as petrified hard parts or as moulds, casts or tracks.
   - Rocks form sediments and a cross-section of the Earth's crust indicates the arrangement of sediments one over the other during the long history of the Earth.
   - Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment.
   - **Significance of Fossils**
   - To study phylogeny (evolutionary history or race history), e.g., Horse evolution.
   - To study the connecting link between two groups of organisms, e.g., *Archaeopteryx*.
   - To study about extinct animals, e.g., Dinosaurs
   - 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.

   The discovered fossils of the horse, elephant, camels and humans provide their ancestral history. The number of toes decreased for greater speed, size gradually increased and teeth adapted to eat grass.

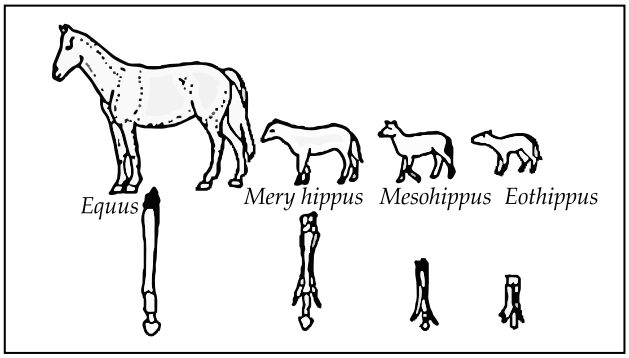


Fig. 7.2: Fossil record of bone of hind legs of horses from *Eohippus* to *Equus* showing a decrease in the number of toes

2. **Morphological and Anatomical evidence**
   - Though organisms of different species and groups are quite different from each other, they still retain certain common features. Morphological evidence for evolution are derived from –
     - **(i)** Homologous and analogous organs
     - **(ii)** Vestigial organs
     - **(iii)** Connecting links
   - The comparative study of various organs in different groups of vertebrates exhibits common features which show that they evolved from a common ancestor.
   - This can be explained as follows:

   (a) Homologous Organs and Homology: Homologous organs are the organs having fundamental similarities in structure and origin but different in functions. This phenomenon is called **homology**, e.g., Human hand, Whale's flippers, Bat's wing and Cheetah's foot.

   - Forelimbs of vertebrates are a good example of homologous organs. They are built on the same fundamental plan yet they appear different and perform different functions.
   - In each case, the forelimb consists of humerus, radius and ulna, carpals, metacarpals and phalanges. This basic similarity in the structure of the apparently different forelimbs of different kinds of vertebrates is due to the fact that all these limbs have evolved from a common type called the pentadactyl (five-fingered) limb.

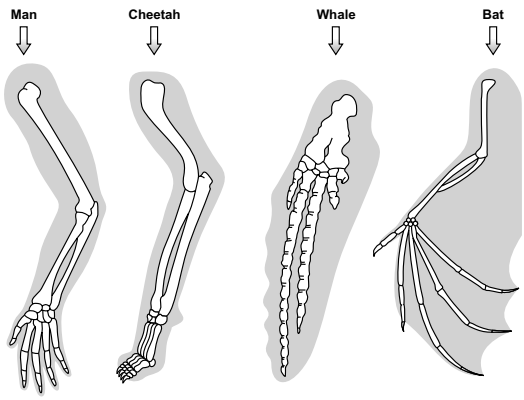


Fig. 7.3: Example of homologous organs in animals

- Homology can also be seen in heart, blood vessels, excretory system, brain, etc.
- Homology found in different animals indicates their evolution from common ancestors. The process in which species diverged after origin from common ancestor giving rise to new species adapted to new habitats and ways of life is called **adaptive radiation**. Such species, exhibit a large number of homologous organs.
- Homology shows divergent evolution, e.g., Adaptive radiation gave rise to a variety of marsupials in Australia.
- Divergent evolution is the development of different functional structures from a common ancestral form is called divergent evolution, e.g., Development of Homologous organs.
- Examples of homology in Plants: The thorns of *Bougainvillea* and tendrils of *Cucurbita.*

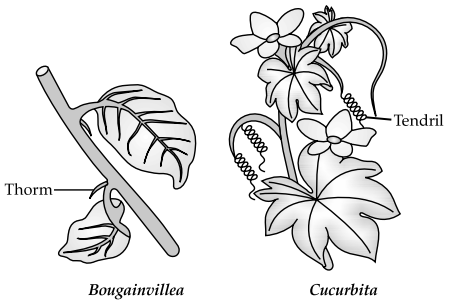


Fig. 7.4: Example of homologous organs in plants

- The divergent evolution is the process by which related species become less similar in order to survive and adapt to different environmental condition.
- **Biochemical Homology:** Similarities in proteins and genes performing similar functions among diverse organisms give hints to common ancestry. These biochemical similarities point to the same ancestry as structural similarities among diverse organisms.

(b) Analogous Organs and Analogy: Analogous organs are the organs having similar functions but different structures and origins. This phenomenon is called analogy.

- Examples:
  - **(i)** Wings of insects (formed of a thin flap of chitin) and wings of birds (modified forelimbs) and bats.

Fig. 7.5: Wings of insects and wings of birds

  - **(ii)** Eyes of Octopus (retina from skin) and eyes of mammals (retina from 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 in order to survive and adapt in similar environmental condition.
- Development of similar adaptive functional structures in unrelated groups of organisms is called **convergent evolution**. For example, some of the marsupials of Australia resemble equivalent placental mammals that live in similar habitats of other continents. When adaptive convergence is found in closely related species, it is called **parallel evolution**.
- Analogous organs do not show common ancestry but they show evolution.

(c) **Vestigial Organs:** Vestigial organ is any small degenerated or imperfectly developed (non-functional) organ or part which may have been complete and functional in some ancestor.

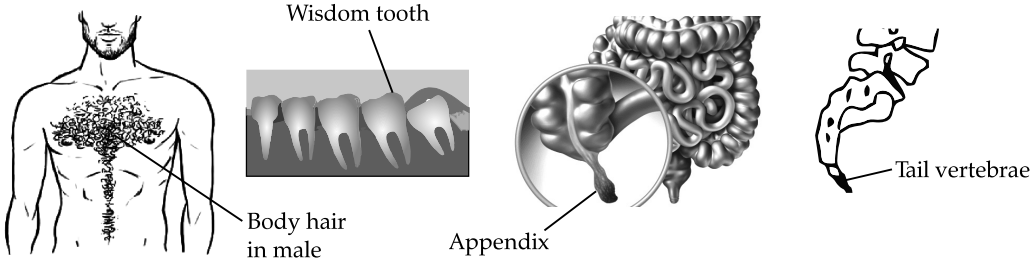


Fig. 7.6: Some vestigial organs in human body

- The only rational explanation for the presence of these non-functional organs is that they have been inherited from ancestors in which they were functional.

(d) **Connecting Links:** The animals or plants which possess characters of two different groups of organisms are known as connecting links. The connecting links establish continuity in the series of organisms by proving that one group has evolved from the other. A good example is that of a fossil bird ***Archaeopteryx***, which was a connecting link between reptiles and birds. This bird had a beak with teeth and a long tail (with bones) like the lizards. It had feathers on **the wings and on** their body like the birds.

Evidence from Embryology

- An embryology is the study of the development of an organism.
- The aspects of embryology which support the doctrine of organic evolution are:
  - Similar stages of early development (morula, blastula or gastrula) in all animals.
  - The embryos of all vertebrates are similar in shape and structure in their early stages.
  - All vertebrates start their life from a single cell, the zygote.
  - All of them during their life history, pass through two-layered blastula and three-layered gastrula stage and then through fish like stage with gill-slits.

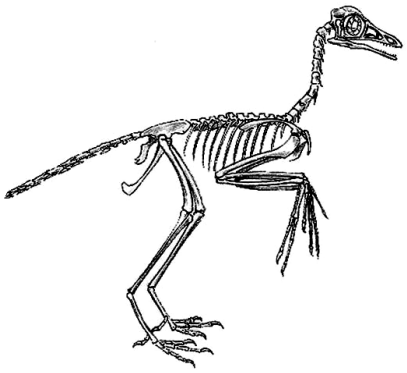


Fig. 6.7: An extinct bird - *Archaeopteryx*

- All the different aspects of embryology strongly support the fact that the different classes of vertebrates had common ancestors.
- **Ernst Haeckel's biogenetic law:** This law states that "*ontogeny* [development of the embryo] *recapitulates phylogeny* [development of race]. Example: Vertebrate head at embryonic stage has vestigial gill slits like fishes.

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 and radiating to other areas of geographic geographical areas habitations.
- Example:
  (a) Darwin's Finches (birds seen in Galapagos Islands); varieties of small black birds with altered beaks evolved on same island.
  (b) Australian marsupials; a number of different marsupials evolved from an ancestral stock within the Australian island continent.
  (c) Placental mammals in Australia; varieties of placental mammals, each appearing to be similar to a corresponding marsupial.

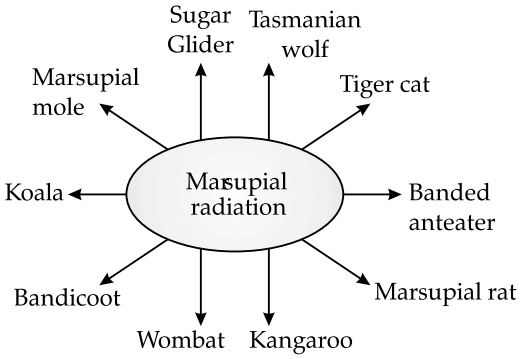


Fig. 7.8: Adaptive radiation of marsupials of Australia

- When more than one adaptive radiation appears in an isolated geographical area, this may be called as convergent evolution.

  For example, Australian Marsupials and Placental mammals show convergent evolution.
- **Parallel evolution:** When more than one adaptive radiation appeared to have occurred in an isolated geographical area then it is called parallel evolution, e.g., Australian marsupials and placental mammals (corresponding).

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

- **Evidence for Evolution by Natural Selection**
  - Natural selection is the process by which the organisms that are best suited for their environment, survive and reproduce.
  - Many examples of natural selection in action are available now. Given below are three such examples.

- **Example 1: DDT resistant mosquitoes:** About 50 years back, the mosquito population had been kept in control with the help of DDT. Thereafter, it was found that mosquitoes could not be killed with DDT any longer. They are DDT-resistant mosquitoes. What had happened was that a gene mutation (variation) had conferred on the mosquitoes, the ability to resist the effect of DDT. While DDT killed other mosquitoes, those with the gene mutation survived and slowly within a few generations DDT-resistant mosquitoes replaced the DDT-sensitive ones. In other words, the DDT resistant mosquitoes 'reproduced differentially' by the action of natural selection.
- **Example 2: Metal tolerance in grasses:** Certain metal residues sometimes collect in the soil near some industries using heavy metals. Being poisonous, they kill the grasses. However, resistant grasses are found to evolve a metal tolerance.
- **Example 3: Industrial melanism**

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:** Thick growth of almost while coloured lichen covered the trees. In that background the white winged moths survived but the dark coloured moths were picked out by predators.

After industrialisation (1920):

- There were more dark winged moths and less white winged moths.
- **Reason:** The tree trunks became dark due to industrial smoke and soot. The growth of lichens was hampered due to pollution. Under this condition, the white winged moth did not survive because the predators identified them easily. Dark winged moth survived as they were able to camouflage themselves because of suitable dark background.

- **Example 4: Natural selection by anthropogenic action:** Excess use of herbicides, pesticides, antibiotics or drugs, etc., resulted in selection of resistant varieties.
    - **Molecular evidence of evolution:** These pieces of evidence show common ancestry based on parallel nucleic acid and amino acid sequences as well as universal genetic codes, e.g., Human and Chimpanzee DNA is 98.2% same and protein cytochrome c is similar.

A Brief Account of Evolution

- **2000 mya:** First cellular forms of life appeared on Earth.
- **500 mya:** Invertebrates formed
- **350 mya:** Jawless fish evolved probably, fish with stout and strong fins evolved which can move on lands as well as go back to water.
- **320 mya:** Sea weeds and few plants existed probably.
- **In 1938:** Fish caught in south Africa happened to be a coelacanth which was thought to be extinct. These animals are called lobefins (evolved into first amphibians).
- **200 mya:** Some land reptiles went back into water to evolve into fish like reptiles, e.g. *Ichthyosaurus*. Land reptiles were Dinosaurs. Biggest Dinosaour: *Tyrannosaurus rex* (20 feet in height, had huge dagger like teeth.)
- First mammals were like shrews-They were small sized, viviparous intelligent.

Evolution of Man

- About 15 mya, primates called *Dryopithecus* and *Ramapitheus* were existing.
- ***Dryopithecus:*** Were more ape-like, lived in Asia, Africa and Europe. Walked semierect, Hand and Skull were monkey like.
- ***Ramapithecus:*** First man-like, walked straight on legs, not taller than 4 feet.
- ***Australopithecus:*** 2 mya, lived in east African grassland, hunted with stones, ate fruits, Teeth larger.
- ***Homo habilis:*** 2 mya, brain capacity 650–800cc, did not eat meat, dentition like humans.
- ***Homo erectus:*** 1.5 mya, brain capacity 900cc, ate meat, walked erect.
- **Cro-Magnon Man:** Discovered in 1868, Cro-Magnon was among the first fossils to be recognized as belonging to our own species—*Homo sapiens*. First ones to have prominent chins, made tools and cave paintings.
- ***Homo sapiens:*** 5 lakhs years ago, in Africa, and spread to all parts of world. Neanderthal man: 40,000–1,00,000 years ago, brain capacity 1400cc, broad forehead, lived in caves, used hides to protect their bodies.

Key Terms

- **Analogous Organs:** Those organs which perform the same function but are dissimilar in their basic structural plan and developmental origin.
- **Fossils:** These are the remains or impressions of organisms that lived in the remote past.
- **Homologous Organs:** Those organs which have similar basic structural plan and developmental origin, but look different and perform different functions.
- **Convergent Evolution:** It is the evolutionary process where anatomically different structures in different group of organisms evolve towards the same function
- **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.
- **Evolutionary biology:** The study of history of life forms on earth.
- **Abiogenesis:** Origin of life from non-living materials.
- **Biogeny:** Origin of first life.
- **Biopoiesis:** Origin of life.
- **Protobiogenesis:** Biochemical origin of life.
- **Chemogeny:** Origin and development of different types of organic molecules.
- **Cognogeny:** Development of different forms of life.
- **Eobiont:** Cell like structure capable of self-duplication.
- **Nebula:** Condensed mass of dust and gas.
- **Artificial Selection:** It is the process carried out by man to select better plants and animals.
- **Biogeography:** The study of patterns of distribution of plants and animals in different parts of earth.
- **Panspermia:** Units of life in the forms of so called spores, which were transferred to earth from outer space (as believed by some scientists).
- **Organic (Biological) Evolution:** Changes in the characteristics/features of organisms or groups of such populations over a number of generations.

Mnemonics

1. **Concept: Homologous Organs**
   Mnemonic: Vijay's **H**overing **B**all and **B**at for **T**est **C**ricket **T**oday **L**et us **W**in the match **B**y **C**atch
   Interpretation: Vertebrate **H**earts or **B**rains. (In plants also, the) ***B****ougainvillea's* **T**horn ***C****ucurbita's* **T**endrils, **L**imbs of **W**hale, **B**ats and **C**heetah

2. **Concept: Analogous Organs**
   Mnemonic: All **P**eople **o**f **D**ehradun **a**nd **F**rance **a**re **S**weet **a**nd **P**eaceful **W**ho give **B**est **B**reads **a**nd **M**any **O**ptions **o**f **E**gg dishes
   Interpretation: Penguins and **D**olphins **F**lippers, **S**weet **P**otato and **P**atato, Wings of **B**irds and **B**utterflies, Mammals and **O**ctopus **E**yes

3. **(a) Concept: To memorise** the **Eras:**
   Mnemonics: Please Pay **M**y **C**ash!
   Interpretation: Precambrian, **P**aleozoic, **M**esozoic, **C**enozoic
   (b) Concept: To **memorise the Periods:**
   Mnemonics: Come Over **S**ome **D**ay, **M**aybe **P**lay **P**oker **T**hree **J**acks **C**an **T**ake **Q**ueen
   Interpretation: Cambrian**, O**rdovician, **S**ilurian, **D**evonian, **M**ississippian, **P**ennsylvanian, **P**ermian, **T**riassic, **J**urassic, **C**retaceous, **T**ertiary, **Q**uaternary:
   (c) Concept: To **memorise the Epochs of Cenozoic Era:**
   Mnemonics: Place Eggs **O**n **M**ira's **P**late **P**lease **H**arish.
   Interpretation: Paleocene, **E**ocene, **O**ligocene, **M**iocene, **P**liocene, **P**leistocene, **H**olocene (or Recent):

Topic-2 Evolutionary Theories and Mechanism

Concepts Covered • *Theories of Biological Evolution* • *Mechanism of Evolution*

Revision Notes

Theories of Biological Evolution

- Based on the evidence of evolution, various theories have been put forth regarding evolution of life. The most important are the theory postulated by Lamarck and Darwin

1. Lamarckism (Theory of Inheritance of Acquired Characters)

- According to Lamarck's postulation of evolution, the acquired characters achieved by an organism during their life time can be transferred or transmitted to offspring. Even in the offspring, these modifications become pronounced depending upon continuous use or disuse of the organs. After certain generations, the offspring produced become totally different from their original parents giving new species.
- The environment factors force the living organisms to change and adopt themselves accordingly.
- On the basis of transmission of acquired characters, whole postulation is known as "theory of inheritance of acquired characters".
- The theory of inheritance of acquired character is simply known as Lamarckism. This theory consists of following postulates:

(i) The environment changes regularly due to different geological or bio-physical processes. The change in environment greatly affects the habit, habitat and composition of living organisms. This change in environment increases the possibility of new organisms with respect to various habitats.

(ii) Use and disuse of organs:

- The use and disuse of any organ affects the development of organ and body too.
- According to change in environment, body tends to increase the size of the organ which are used most frequently and continuously. It means the frequently used organs become more developed and become more strong and large.
- When the organ is not in continuous use, it gradually reduces in size and disappears or remains as less developed form (Vestigial form).

(iii) Inheritance of acquired characters:

- All the changes occurred in an organism are preserved within the body. These acquired characters are then transmitted to their offspring through the gametes.
- This inheritance of acquired characters is due to use and disuse of organs. Therefore, after many generations, new species are formed which are distinctly different from their ancestors.

- **Evidence to prove or support Lamarckism:**
  - There are some examples by which theory of evolution can be best explained in favour of Lamarck.

(i) Long necked giraffe:

- **Long necked giraffe:** The evolution of long necked giraffe took place from short-necked giraffe due to continuous stretching of the neck muscles in order to find food from tall trees. In the beginning, the short-necked giraffe used to eat the grasses.
- Later on, sources of grass on land reduced and it forced to eat the leaves of tall trees stretching of neck is continuous and is gradually transmitted to offspring.

(ii) Loss of limb of snake:

- The continuous creeping through holes and crevices made snakes body elongated and due to continuous disuse of limbs because they hinder while creeping in burrows results in loss of their limbs.
- In the same way, vestigial organs in human and other animals show disuse of those organs.

(iii) Web of hind limbs of frog:

- Development of webs on hind limbs of frog and ducks for swimming in water because they used more continuously in search of food.

2. Darwinism (Theory of Natural Selection)

- It was proposed by Charles Darwin.
- It is based on two key concepts namely,

(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 condition. 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 populations influenced Darwin.
- **Natural selection is based on the following facts:**
  - **(i)** Heritable minor variations.
  - **(ii)** Over production by organisms.
  - **(iii)** Limited natural resources.
  - **(iv)** Struggle for existence.
  - **(v)** 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 survive (Survival of the fittest).
- Darwin said that the organisms with heritable variation and which make resource utilisation better will enable only those to reproduce and leave more progeny.
- It leads to a change in population characteristics and new forms appear.

Mechanism of Evolution

- Darwin ignored about origin of variation and mechanism of speciation.
- **Mutation Theory:** Hugo de Vries proposed Mutation Theory of evolution.
- 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 Hugo de Vries believed mutation caused speciation and hence called it saltation (single step large mutation)
- **Differences between Darwinian Variation and Mutation are**

S.No.	Darwinian Variation	Mutation
1.	It shows minor variation.	It shows large variation.
2.	It is slow and directional.	It is random, sudden and directionless.
3.	It showed gradual evolution.	It showed speciation by saltation.

- **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).
  - Sum total of all the allelic frequencies = 1
  - Example, 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 A$a = 2pq$
  - 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, 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.
    - There would be a gene flow if migration happens multiple times.
  - **(b) Genetic Drift:** It occurs in small populations when a part breaks off from a large population. Only representative genes of the large population are present which undergo change at a right time and the small population may evolve into a new sub-species or species.
    - The accidental gene flow causing change in frequency.
    - Sometimes, the change in allele 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,** which is a sudden genetic change.
    - It may be a change in a single gene (genic mutation or point mutation) or may affect many genes (chromosomal mutation)

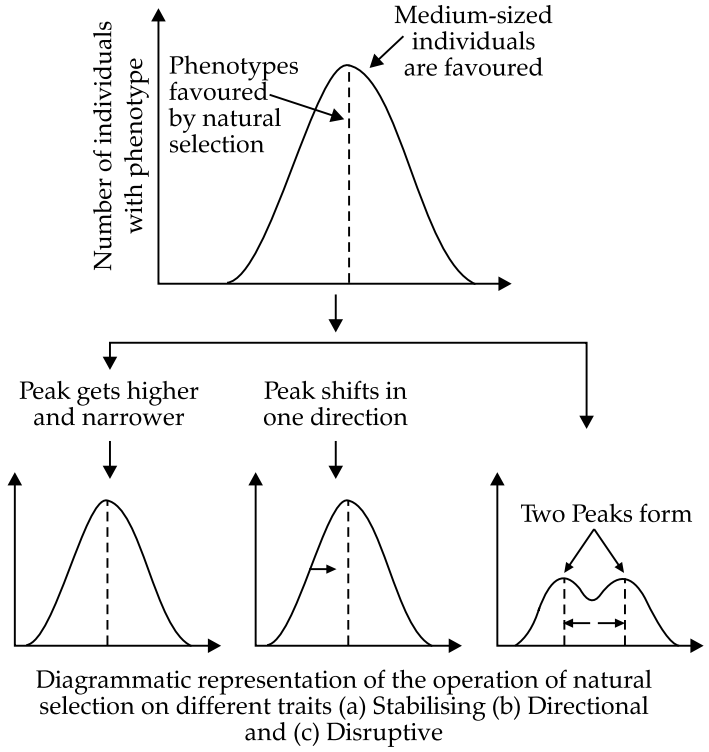
- Mutations result in formation of new phenotypes.
- Over few generations, this leads to speciation.

➢ **Genetic Recombination**

- It occurs in sexually reproducing organisms at every reproduction. The chromosomes and thus genes of the parents mix at random during zygote formation. That is why offspring of same parents are different from each other as they have different combinations of parental genes? Variation is also brought about when crossing over occurs during gamete formation.

➢ **Natural Selection**

- Natural selection is a process in which heritable variations enabling better survival are enabled to reproduce and leave greater number of progeny.
- These are of three types namely, stabilising selection, directional selection and disruptive selection.
  - **(i) Stabilising selection:** Here, more individuals acquire mean character value and variation is reduced.
  - **(ii) Directional selection:** Here, individuals of one extreme are more favoured.
  - **(iii) Disruptive selection:** It eliminates most of the individuals acquire peripheral character value at both ends of the distribution curve.



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

Fig. 7.9

Key Terms

- **Genetic Recombination:** It is the exchange of genetic material between different organisms which leads to production of offspring with combinations of traits that differ from those found in either parent.
- **Mutation:** It is the sudden appearance of variations.
- **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.
- **Speciation:** It is the process of formation of new species from the pre-existing species.
- **Hardy–Weinberg Principle:** It states that the allele frequencies in a population are stable and remain constant from generation to generation.
- **Gene pool:** Sum total of all the genes in a population.
- **Atavism:** It is a modification of a biological structure whereby an ancestral trait reappears after having been lost through evolutionary change in previous generations.

Mnemonics

1. **Concept:** Factors affecting Hardy-Weinberg Equilibrium
   Mnemonic: Grand **M**other, **G**rand Daughter **M**eet Great **R**oyals **N**ear **S**ociety
   Interpretation: Gene **M**igration, **G**enetic drift, **M**utation, **G**enetic **R**ecombination, **N**atural **S**election.

2. **Concept:** Hardy-Weinberg **equilibrium:** Causes for deviations from it.
   Mnemonic: Mudra **M**ichael **D**oes Not **S**moke"
   Interpretation: Mutations**, D**rift, **N**on-random mating, **S**election

3. **Concept:** Human evolution
   Mnemonics: Doctor **R**am in **A**ustralia **H**ave researched **E**volution on **N**ew **H**umans.
   Interpretation:

D*ryopithecus*	—	Doctor
R*amapithecus*	—	Ram in
A*ustralopithecus*	—	Australia
Homo ***h****abilis*	—	Have researched
Homo ***e****rectus*	—	Evolution on
Homo ***n****eanderthalensis*	—	New
H*omo* ***s****apiens*	—	Humans

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