# Heredity and Evolution

PART I

## Heredity

1. Offspring produced by asexual or sexual methods of reproduction resemble each other but they differ to some extent which may be easily marked or may be difficult to observe and identify.
    - **Heredity** refers to the similarities among the parents and the progeny.
    - **Variations** refer to differences among individual related by descent.
    - **Genetics** is the study of heredity and variation.
2. Variations are caused by (a) environmental factors and (b) genetic differences.
    - Changes in the **somatic** or non-reproductive cells are not heritable.
    - Heritable genetic variations are produced due to inaccuracies in DNA duplication during cell division.
    - **Genetic variations are transmitted** from parents to progeny leading to diversity among the progeny.
3. In organism reproducing by asexual methods these variations are transmitted to their progeny to a **limited extent**.
    - The variations spread faster among the progeny of organisms **reproducing sexually** because of recombination of characters.
    - **Recombination** of characters occurs due to:
      (a) Fusion of **gametes** arising from different parents.
      (b) **Exchange** of DNA between paternal and maternal chromosomes during meiosis.

**Accumulation of variations**

4. Variations in an individual may be advantageous, disadvantageous or neutral for an individual in the existing environment.
    - Advantageous variations are selected by nature (environment) in successive generations.
    - Disadvantageous variations are lost or remain in low frequency.
    - The progeny retains neutral variations as such.
    - With changes in the environment frequency of these variations is affected leading to diversity in the forms of life adapted to different environments.
    - Accumulation of these variations leads to evolution.

**Mendel's Experiments**

5. **Gregor Johann Mendel** proposed the laws of inheritance in 1866.
    - Mendel was an Austrian Monk and also a **teacher of science and mathematics**.
    - He applied his knowledge of science and mathematics to establish principles of genetics.
6. **Mendel** performed experiments on **garden pea** – ***Pisum sativam*** to study the mechanism of inheritance of characters.
    - Pea plants are easy to cultivate and have large flowers, so that cross-pollination can be easily performed under controlled conditions.
    - Pea plants are self-pollinated in nature.
    - Artificial cross-pollination gives rise to seeds that also survive and reproduce successfully.
    - Pea plants exhibit **well marked differences** (discrete variations) in characteristics in different varieties e.g. tall or dwarf plants; produce purple or white flowers; produce round or wrinkled seeds.
    - Intermediate expression of these characteristics is not observed in pea plants.
    - He selected tall and short pea plants for crossing and called them **parental generation** (P).
    - He obtained the progeny by cross-pollinating them and called the progeny of this cross **F1-first filial generation**.

- F1 progeny was allowed to self-pollinate and called as **F2-second filial generation**.

7. He found that when two plants with the opposing trails were crossed; one of the traits appeared in the F1 progeny. For example, when the tall plant was crossed with short plant F1 progeny constituted **of all** tall plants.
    - When F2 generation was obtained by selfing F1 progeny, **hidden trait** (short plants) **reappeared** in one fourth of the total number of progeny.
    - This showed that both the characters were present in F1 progeny but only tallness was expressed.
8. Mendel used the term **dominant** character for the character that **expressed** itself in F1 generation and **recessive** for the character, which **did not express** itself in F1 but **reappeared** in F2.
    - Mendel concluded that each of the character is controlled by **two factors** in an individual and called these unit factors or **alleles**.
    - Mendel represented dominant traits with **first alphabet** of the word in **capital** form. For example, tallness was represented by T and the recessive trait was represented with the same letter in small form, i.e. shortness by t.
    - He also used the term **genotype** for genetic constitution of an individual. For example, TT, Tt or tt.
    - He used term **phenotype** for external expression of the genotype. For example, tall or short.
    - A tall plant can be **homozygous** (having both alleles of same type TT) or **heterozygous** (having the two alleles of different types Tt).
    - Short plants having both recessive alleles are always **homozygous.**
    - A cross considering one pair of contrasting characters is called **dihybrid cross.**
9. On the basis of dihybrid crosses Mendel gave the **Principle of Independent Assortment**.
    - In a cross between tall plants having round seeds and short plants with wrinkled seeds, the progeny was all tall with round seeds.
    - Self-pollination in these F1 plants resulted in progeny of tall plants with round seeds.
    - Self-pollination in these F1 plants resulted in progeny of tall plants with round seeds, tall plants with wrinkled seeds, short plants with round seeds and short plants with wrinkled seed in the ratio of 9:3:3:1.
    - It indicated that height of pea plant and shape of seeds are independently inherited.
    - The principle of independent assortment thus states that **each pair of alleles segregates independently.**

**Expression of traits**

10. A section of DNA carrying the information for a structural or functional protein is called **gene**.
    - A **gene** is thus a sequence of nucleotides, which forms a molecule of DNA.
    - Cellular DNA contains information for the sequence of amino acids in a **protein.**
    - Structural and functional proteins determine the expression of a character, e.g. tallness of pea plant depends on the synthesis of enzyme which in turn regulates secretion of hormone gibberellin.
    - If the gene is **functional** the enzyme is produced, in turn the **hormone is produced** which makes the plant tall.
    - If the gene for tallness is altered the protein enzyme is not synthesized or synthesized inefficiently which affects the growth and the plant remains short.
    - Every individual has **two sets of genes**.
    - One set of genes is passed to each gamete by meiosis.
    - Each individual gets one set of genes from both parents all the time of fertilization.
    - Equal distribution of genes occurs because these **genes are located on chromosomes**, which occur in pairs of homologues.
    - Man has **23 pairs** of chromosomes in **body cells**.
    - The gametes contain a set of 23 chromosomes bearing the **entire set of genes**.

**Sex Determination**

11. **Sex determination** is the mechanism that controls expression of sex of an individual in a species.
    - Factors that determine sex of an individual can be (a) environmental factors and (b) genetic factors.
    - In some animals **environmental** factors determine the sex.
    - In some lizards, if fertilization eggs are kept at high temperature maleness is induced and at low temperature femaleness is induced.
    - Some molluscs become female if reared alone and become male if reared in the company of a female.
12. In human beings sex is **genetically determined**.
    - Human beings have 23 pairs of chromosomes.
    - 22 pairs are called autosomes.
    - The chromosomes in each pair of autosomes are similar in size and structure.
    - 23$^{rd}$ pair is called pair of **heterosomes** or **sex chromosomes.**
    - It determines the sex in human beings.
    - In female both the sex chromosomes called X chromosome are alike.

PART II

**Evolution**

1. **Evolution** is a gradual and orderly process of change in the forms of life from simple to complex that has given rise to the existing diversity of life.
    - Charles Darwin gave the concept of evolution as **descent with modification**.
    - Charles Darwin was a British naturalist who went for a voyage of word exploration for five years when he was only 22 years old.
    - He observed the diversity of life in a number of continents and islands.
    - His observations on the birds of Galapagos Islands situated off the coast of South America stimulated him to think about evolutionary process.
    - Darwin observed that variations existed in nature; and those, which helped the organism to adapt it to the environment, were passed on to the next generations.
    - He published his book, "**On the origin of Species by means of Natural Selection**". He explained the way population gets better adapted to the changed environments by natural selection.
    - He also conducted breeding experiments on domestic animals and also studied the role of earthworms in soil fertility after his return back home.
    - Darwin did not have an idea of how these variations arose.
2. **Variations** arise as a result of (a) errors in DNA copying or (b) sexual reproduction.
    - Variations are of two types (a) acquired and (b) inherited.
    - **Acquired** variations are changes that occur due to the **environmental factors** in the lifetime of an individual.
    - Acquired variation in somatic traits like decrease in average weight of animals due to starvation or changes in skin colour due to exposure to sunlight are not passed from generation to generation.
    - August Weismann removed the tails of mice by cutting them off for twenty-one generations but progeny born always had a tail; proving that changes in body cannot pass from generation to generation or change the genes of the germ cells.
    - The changes in DNA of non-reproductive tissues cannot be inherited because such tissues do not participate in sexual reproduction.
    - **Inherited variations** are changes in the genes of the germs cells and are passed down to successive generations.

- The experiences of an individual during his lifetime cannot be passed onto his progeny, and cannot direct evolution.
- Inherited variations may give **survival advantage**, may decrease chances of survival or may not have any survival advantage of disadvantage.

3. Evolution occurs due to changes in frequency of some inherited traits (genes) in a population over a period of time.
    - During **natural selection**, frequency of a gene having a survival advantage increases.
    - **Increase in the frequency** of such genes, results in evolution of populations that are better adapted to existing environment.
    - In small populations **accidents** can change the frequency of some genes, which do not have any survival value.
    - Change in the frequency of some gene caused by chance factor alone is called **Genetic drift.**
    - **Genetic drift** creates diversity without any adaptations.
4. Microevolution constitutes small but significant changes in common characteristics of population of a species.

**Speciation**

5. Speciation is the origin of new species from the existing ones.
    - **Speciation** takes place when variation is combined with geographical isolation.
    - A **species** consists of similar organisms capable of interbreeding among themselves to produce fertile offsprings.
    - **Population** is the group of individuals of species living in a particular area.
    - Interbreeding among individuals of different populations maintain **a free flow** of genes in these populations.
    - Sub-populations of a species sometimes get separated due to a **geographical barrier** like a river or mountain; the gene flow between them decreases; natural selection and genetic drift result in accumulation of differences in these isolated sub-populations.
    - Members of the two sup-populations gradually become incapable of reproducing with each other and become different **species.**

**Origin of life**

6. In 1929, J.B.S Haldane speculated that life must have originated from simple inorganic molecules, which were present on the Earth when it was formed.

7. Stanley L. Miller and Harold C. Urey provided experimental evidence in favour of this idea in 1953.
    - They simulated the conditions of ancient Earth in an experimental setup.
    - They observed that methane, ammonia and hydrogen sulphide and water vapours, when subjected to electric discharges in a reducing atmosphere for a few days; could give rise to amino acids that form protein molecules.

**Evolution and classification**

8. Classification is to place diverse forms of life into groups and sub-groups on the basis of similarities and differences among them.
    - It provides us an idea of diversity of life, interrelations among living beings and the order of evolution of life.
    - Classification refers to a particular form or function of organisms which is used to describe, identify and classify them.

- All organisms share some basis characteristics the cell is the basic unit characteristics. For example, the cell is the basic unit of life in all organisms.
- Most, but not all organisms share the next level of classification. For example, presence or absence of a well-defined nucleus in the cell.
- Cell is the basic unit of structure and function of living beings, therefore, it is prokaryotic or eukaryotic.
- Other characteristics of the organism depend upon the characteristics of cells which form tissues, organs, organ system and the organism.
- The basic characteristics for separation of major groups of organisms are:
  (a) Organisation of the cell, if it is prokaryotic or eukaryotic.
  (b) Orgnisation of the body f it is unicellular or multicellular.
  (c) If there is division of labour in multicellular body.
  (d) If they produce their own food by photosynthesis.
  (e) The way organs of the body develop and become specialized.
- Characteristics of body design are used for making sub-groups.

9. Hierarchy is the framework of classification in which these groups are arranged in the order of increasing or decreasing levels of similarities.
   - Organisms that originated first and have not changed much during the course of evolution are called primitive or lower organisms, e.g. bacteria.
   - Organisms that originated later and have changed much during the course of evolution are called advanced, e.g. primates.
10. **Evidence of Evolution**
    Different organisms have **similar characteristics** because they are either inherited from a common ancestor or these appear similar because they perform a common function.
    - **Homologous organs** are organs having same basic structure modified to perform different function in different organisms. Limbs of amphibians, reptiles, birds and mammals have same basic structure but they are modified to perform different functions.
    - Homologous characteristics also help us to identify an evolutionary relationship between apparently different species. Mammals are related to amphibians, reptiles and birds at some stage of evolution because of similarity in basic structure of their limbs.
    - All similarities in structure of body do not exhibit common ancestry.
      Wings of bats are formed by folds of skin stretched between elongated fingers while feathers all along the form wings of birds.
    - **Analogous organs** are organs which look similar because they perform same function, but they do not have some origin and basic structure.
      Wings of butterfly, wings of a bat and wings of birds look similar because they perform same function of flying but they do not have same origin and basic structure.
    - If we go in further details of anatomical structure of the wings of birds and wings of bats are formed by modification of limbs, which indicates common ancestry at an earlier stage.

**Fossils**

Fossils provide us direct evidence of the types or organisms (plants, animals and microbes) that existed at a particular geological time and help us to reconstruct the evolutionary process.

- Fossils are preserved remains or impressions of organisms that lived in the past.
- Age of fossils can be found out from the ratio of isotopes in the fossil containing rocks.
- Some fossils provide us links between existing groups of plants and animals for example feather imprints preserved along with dinosaur's bones indicate that birds have evolved from reptiles.

**Evolution by Stages**

11. Evolution of complex organs has taken place through a series of DNA changes (mutations), created by bit-by-bit over generations.
    - Structure of eye evolved through a series of stage.
        (a) ***Planaria*** is a flatworm having rudimentary eyes consisting of a few photosensitive cells which detect light.
        (b) **Insects** have well-developed eyes with mosaic vision.
        (c) ***Octopus*** (Mollusca) and vertebrates also have well-developed eyes.
        (d) The structure of the eye in each of these organisms is different, having separate evolutionary origin.
    - Structure of wings also evolved through a series of stages.
        (a) Feathers originated in dinosaurs for the first time and provided insulation in cold weather.
        (b) Birds adapted the feathers to flight later.
        (c) Fossils of a small dinosaur from the Dromaesaur family have imprints of feathers along bones of forearm and head.
        (d) This indicates the evolution of feathers in the initial stages were not useful for flying which means that a character that originated for one function evolved later to perform another function.
        (e) Fossils showing intermediate stages form connecting links between two groups and provide a direct evidence of evolution.
12. The process of evolution is visible through living examples of cultivated plants.
    - Man started cultivation of wild cabbage as a food plant two thousand years ago.
    - Plants with desired characters were selected and multiplied.
    - This process of artificial selection led to evolution of a number of different looking new varieties like cabbage, broccoli, cauliflower, kohlrabi, kale, Brussels sprout and red cabbage.
        (a) Cabbage has condensed apical bud with tightly packed leaves.
        (b) Broccoli has fleshy green flower heads arranged in a tree-like fashion on branches sprouting from a thick, edible stalk.
        (c) Cauliflower has condensed apical bud, which forms a spherical cluster of immature densely packed white flowers buds.
        (d) Kohlrabi has swollen, round stem that forms the edible part.
        (e) Kale has large green leaves. Central leaves do not form a head. It is closer to wild cabbage than all other domesticated forms.
        (f) Red cabbage is just like a cabbage. It has a red or purple coloured leaves due to a pigment called anthocyanin.
        (g) Brussels sprout has small (2-4 cm in diameter) leafy green heads resembling miniature cabbages.
13. Evolutionary relationships can be traced very accurately by comparing the DNA of different species.
    - More distantly related organisms accumulate greater number of differences in their DNA therefore it gives a direct estimate of how much the DNA has changed during the formation of these species.
    - Molecular phylogeny is now extensively used to define evolutionary relationships.

**Evolution as the Process of Creation of Diversity**

14. Diversity of forms of life has emerged as a result of environmental selection over time.
    - Evolution has progressed from simple to complex body designs with passage of time. But it is not the process of replacement of a lower form of life by another higher form.
    - Natural selection and genetic drift have led to the formation of populations that are reproductively isolated from the original populations.

- Evolution cannot be compared with technological progress wherein an old design is replaced by a new better design due to conscious human effort.
- Evolutionary sequence can be represented in the form of a tree having many branches at different stages rather than a straight ladder.
- Human beings are not at the top of evolutionary ladder. They represent a species originated quite recently in the diversity of evolving life.
- Human beings and chimpanzees have great similarities at even at molecular level. It does not mean humans have evolved from chimpanzees.
- Human beings and chimpanzees have a common ancestor a long time ago.
- The two species evolved in their own separate ways to give rise to the existing forms.

**Human Evolution**

15. Studies on human evolution provide evidences that all human beings have evolved from common ancestors.
    - Techniques like excavation, time dating, study of fossils and comparisons of DNA sequences are used to study human evolution.
    - According to available information humans are descendents of single species Homo sapiens that evolved in Africa and spread across the world in stages.
    - Some of the descendents spread across Africa, others slowly migrated spread across the planet, from Africa to West Asia, then to Central Asia, Eurasia, South Asia and East Asia.
    - They travelled down the islands of Indonesia and the Philippines to Australia, and crossed the Bering land bridge to the Americas.