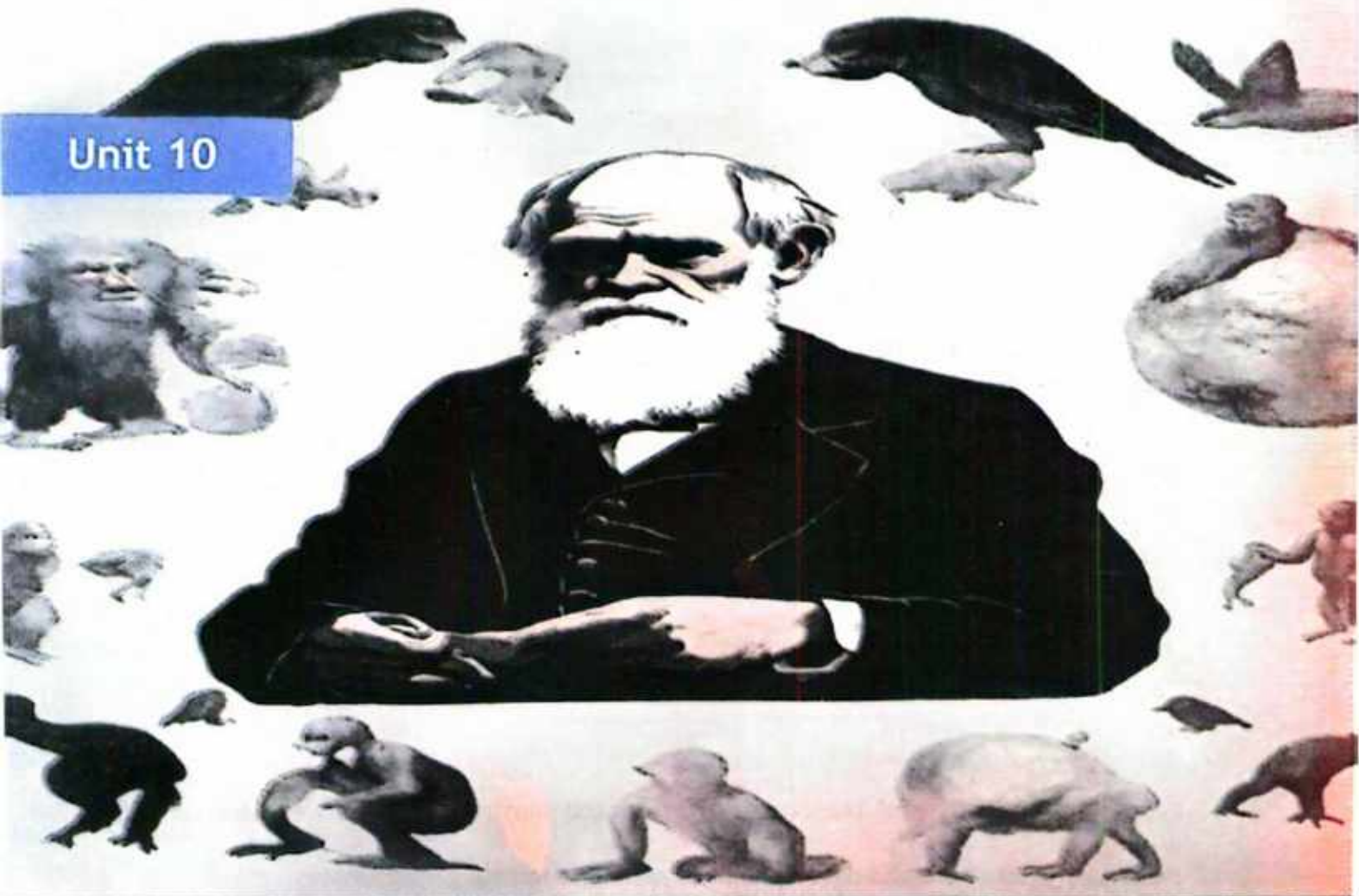


## Unit 10



# EVOLUTION

SLOs: After completing this lesson, the student will be able to:

1. Explain the theory of evolution by natural selection with examples
2. Discuss briefly the observations Darwin made during his voyage on HMS Beagle
3. Describe the evidence of evolution with regards to the following:
  - o Palaeontology (fossil record)
  - o Comparative anatomy (homologous structures, vestigial structures)
  - o Selective breeding
4. Describe speciation
5. Describe sources of variations which can lead to speciation and evolution

The number of species of living things on earth currently exceeds a million. Each species has its own manner of living and working. Some species appear to be highly similar to one another, whereas others do not. In many ways, a horse and a zebra are similar. Both of them, however, have some traits not present in the other. Through the process of progressive transformation, all of the species alive today evolved from earlier ones. One definition of evolution is a change that occurs to living things over time:

## 10.1 VARIATION AND EVOLUTION

### 10.1.1. VARIATION

The term variation refers to the differences in traits displayed by members of the same species. For instance, although all domestic cats are members of the same species, they differ greatly in terms of size, coat colour, eye colour, hair length, and other characteristics. Variations are beneficial for living organism as it helps in increasing their chances of survival of the particular organisms. These are desirable variations as it helps them be more advanced and immune. Variations can sometime lead to a genetic defect hence becoming a harmful and an undesirable variation.

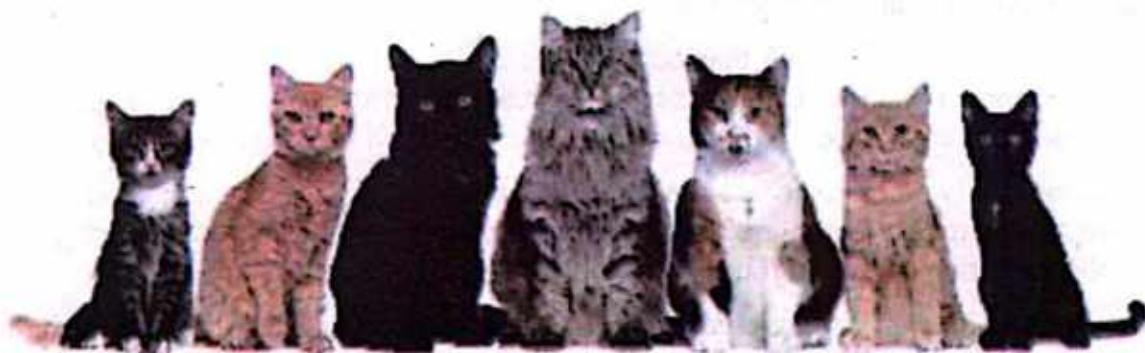


Figure 10.1: Variations in domestic cats

You are already aware of the meiotic process. Meiosis along with other factors serve as the main sources of variation. They are as follows:

1. Genetic recombination results from crossing over during gamete development.
2. Different chromosome combinations in gametes are formed by independent collections of chromosomes.
3. The process of fertilization in which one of the countless sperms fuses with an egg.
4. A mutation in the gamete-forming germ cells.
5. Gene flow, or the transfer of genes from one population of a species to another.

### 10.1.2. EVOLUTION

According to scientists, the Earth is more than four billion years old. New life forms developed from unicellular organisms. All current living things developed gradually from earlier ones. Evolution is the gradual alteration of a population's or species' traits over time in response to the environmental conditions. Evolutionary changes can always be passed on to next generations.

### How variation promote evolution?

Some individuals of a population may have an advantage over other members as a result of population variations. These individuals will be able to have more progeny. Consequently, the population will gradually see more instances of that specific variant. With these variations, they will have a better chance of surviving and procreating. That's evolution.

An inherited trait or group of traits that increases an organism's chances of survival in specific environmental conditions is known as an adaptation. Members of a specie's population will compete with one another for resources. Only the healthiest, fittest, and strongest will survive and reproduce. If food or water is in little supply, there is little room for sharing, and there aren't many available partners.

### 10.1.3. Theory Natural Selection

Natural selection is the process through which organisms who possess traits that are helpful for reproduction in a certain environment produce more children in the following generation. As a result, they gradually expand the population's genetic diversity. Natural selection theory is based on:

1. **Overproduction:** All living creatures are very fertile so that their populations could grow quickly to produce large number of offspring.
2. **Competition:** We can observe that population sizes do not rise to a very high level even after overproduction. The numbers largely stay constant. This is because food supplies and other resources are scarce. As a result, there is competition for resources and food.
3. **Variations:** No two organisms are the same. They will not have the same opportunities to survive and reproduce as others. A large portion of this diversity is heritable. Such qualities are inherited from parents through the genes of the offspring.
4. **Natural selection:** Only those organisms who live and reproduce can give rise to the next generation. And only those organisms with the desirable variations will live till reproductive age. The population will have more advantageous genetic variations and fewer harmful ones after many generations. Natural selection is essentially an elimination process. Only fittest organisms will survive.

After a five-year voyage around the world in the ship HMS Beagle, Charles Darwin put forth the Theory of Natural Selection in 1838. In 1859, he released a book titled "On the Origin of Species by Natural Selection" recording his observations.

Charles Darwin was able to create his theory of natural selection when he visited the Galapagos Islands. He found a number of finch species that varied from island to island. He noticed that the form of the birds' beaks varied depending on the kind of food they ate. Darwin believed that the processes of speciation and adaptation were linked. The overall accumulation of adaptations in different environments, isolated from the original environment by geographic barriers, would lead to the formation of a new species from an ancestral form. The two groups could differ sufficiently over many generations to be classified as two different species. Darwin identified three basic patterns in biological diversity: (1) global, (2) local, and (3) variation over time in species.

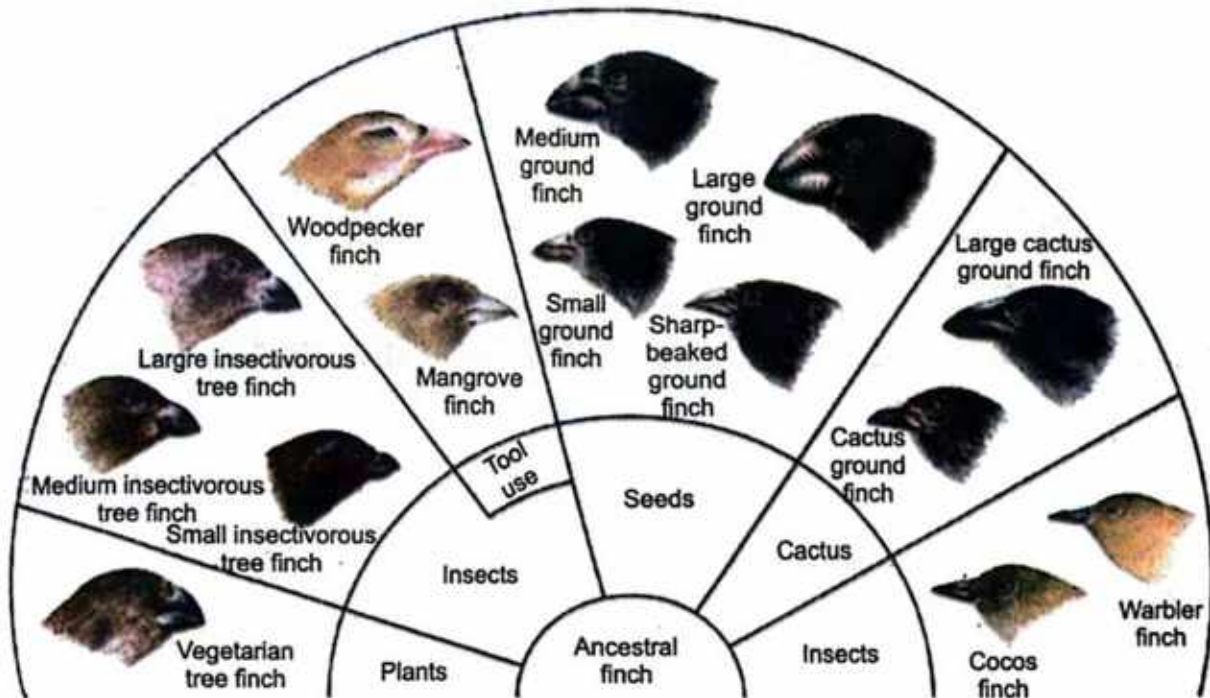


Fig 10.2. Darwin's observation of finches at Galapagos islands

Natural selection causes population-wide changes in gene frequencies over time; as a result, individuals with more advantageous traits will be more prevalent in the population and individuals with less advantageous traits will be less prevalent. In Britain, the **Industrial Melanism** of the peppered moth (*Biston betularia*) is a strong indicator of natural selection.

#### Analysing a case study of Variation and Selection

The phrase "Changes in the environment can bring about changes in a population by natural Selection" is supported by evidence.

All reported variants of the peppered moth (*Biston betularia*) in the UK up until 1848 had light colours with dark patches. A dark-coloured moth was discovered in 1848, and by 1895, dark-coloured moths made up 95% of the peppered moth population. This variety's dark colour resulted from a mutation.

The moths fly at night and rest on tree trunks throughout the day. The light-coloured lichens growing on the tree trunks blended in with the colour of the light-coloured moth, giving it excellent concealment from predator birds. As the industrial revolution progressed, sulphur dioxide pollution from coal burning drove out lichens that were growing on trees in industrial locations, exposing the darker bark.

The predator birds can now easily locate and consume the light-coloured moths that are resting on dark-coloured trunks. Light-coloured moths are "seen and eaten by the birds" when they settle on dark-coloured trunks. The birds are serving as snoopers. The dark colour was the adaptive variable that resulted in the selection advantage. 90% of the peppered moth population in England during the industrial era of pollution was black. 'Industrial Melanism' is the name given to the specific phenomenon. After the 1950s, England's industrial pollution was reduced, and as a result, the number of light-coloured moths also increased.



(a): Unpolluted environment



(b): Polluted environment

Fig. 10.3 (a) The light and dark coloured forms of the peppered moth are resting on a lichen-covered tree. (b) The light and dark coloured forms of the peppered moth are resting on a lichen free tree trunk, which was darkened by industrial air pollution.

Analysis: (1) The variation (change in bark colour) is an illustration of variation that is subject to selection (by the birds) in a changing environment.

(2) It demonstrates the truth of evolution.

(3) It points out that evolution and natural selection operate on the basis of genetic change within a population

## 10.2. EVIDENCES OF EVOLUTION

The evidence for evolution is compelling and extensive. Looking at every level of organization in living systems, biologists see the signature of past and present evolution.

### 10.2.1. Evidence from Palaeontology

In addition to offering strong evidence that ancient species were distinct from modern ones, fossils also show the evolution of organisms across time. To determine how long ago an organism lived in relation to another, scientists classify and age fossils from all around the world. The resulting fossil record shows the evolution of form over millions of years and tells the tale of the past. For example, researchers have found extremely comprehensive records demonstrating how humans and horses have evolved.

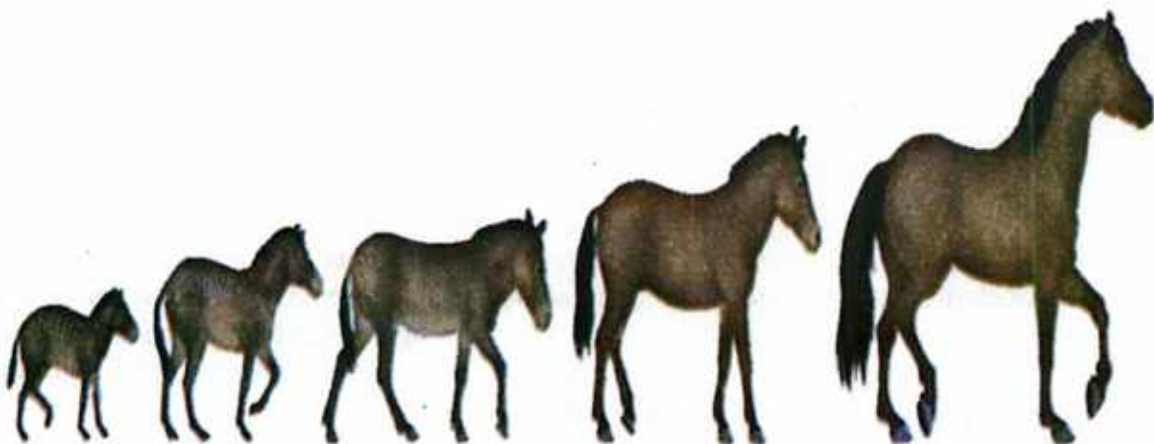


Figure 10.4: Evolution of modern horse

### 10.2.2. Evidence from Comparative Anatomy

The existence of structures in creatures with the same fundamental shape is another type of evidence supporting evolution. For example, due to their origin in the appendages of a common ancestor, the bones in the limbs of a human, dog, bird, and whale all share the same general structure. The shapes and sizes of these bones have evolved over time in different animals, but their general structure has remained the same. These similar parts are known as homologous structures.

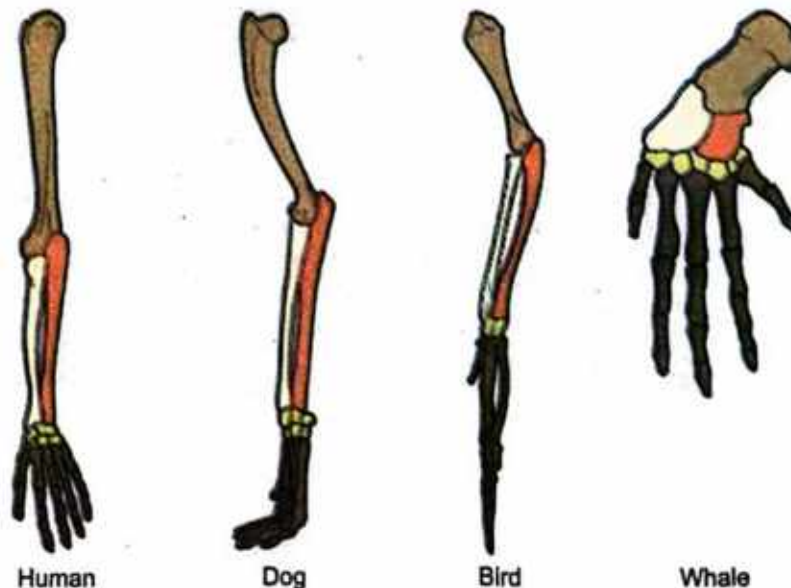


Fig 10.5: Homologous structure of bones of limbs of mammals

Some organisms possess such organs that don't appear to have any function at all now and are likely just the remains from a previous common ancestor. Vestigial organs are these inactive, non-functional structures that have lost their use over time. Wings on flightless birds, leaves on some cacti, and appendix in humans are a few examples of vestigial organs.

### 10.3.3. Evidence from Selective breeding

Artificial selection is the practice of breeding domesticated and genetically enhanced plants and animals to produce offspring with desired genetic features. Selective breeding is the current name for artificial selection. Selective breeding and hybridization are the two techniques used to develop desired features in plants and animals.

### 10.2.4. Improving plants by selection

Farmers have been using selection to create plants with desired features for ages. They frequently choose varieties that will cause the plants to grow larger, more quickly, be drought-resistant, etc.

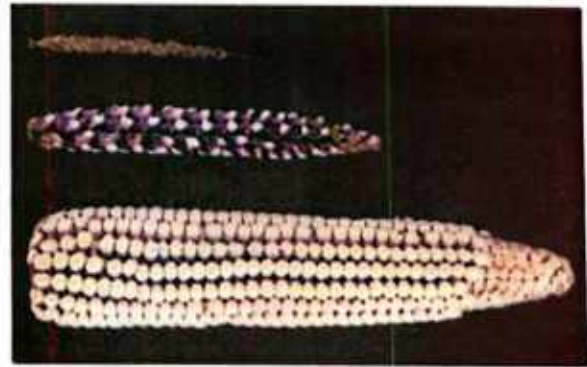
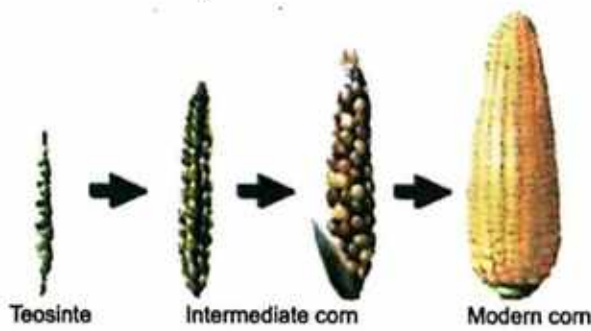
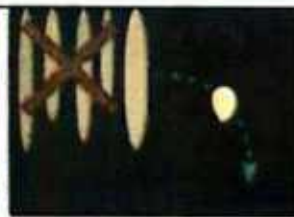


Figure 10.6 Improving Plants by selection

**Artificial selection produces crops with higher yields**



1. Natural variation occurs in the wild population.



2. Seeds for the next generation are chosen only from individuals with the most desirable traits.



3. Repeat this process for several generations.



4. Over time, the yield of the crop increases.

**Improving animals by selection**

Animals have also been subjected to selection. Cows that generate a lot of milk and high-quality meat are chosen for selective breeding. They serve as parents for the following generation. In this manner, a breed of cow that can produce more milk than the original breed is created.

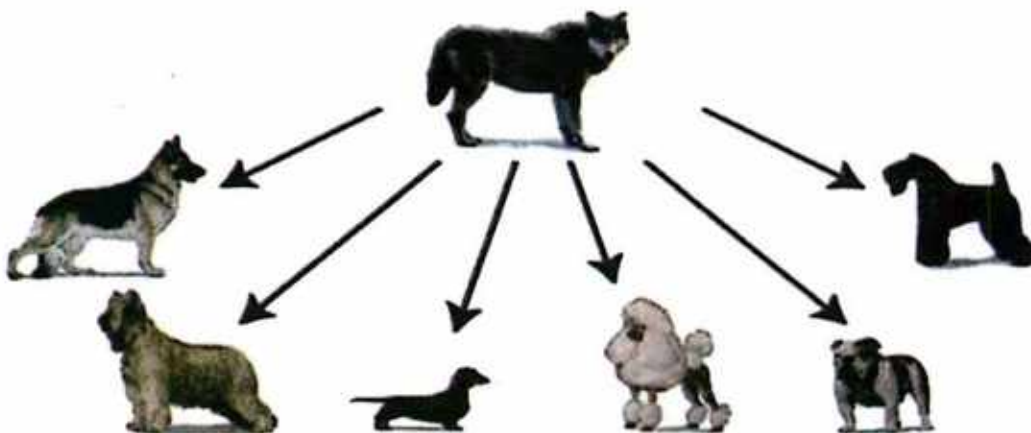


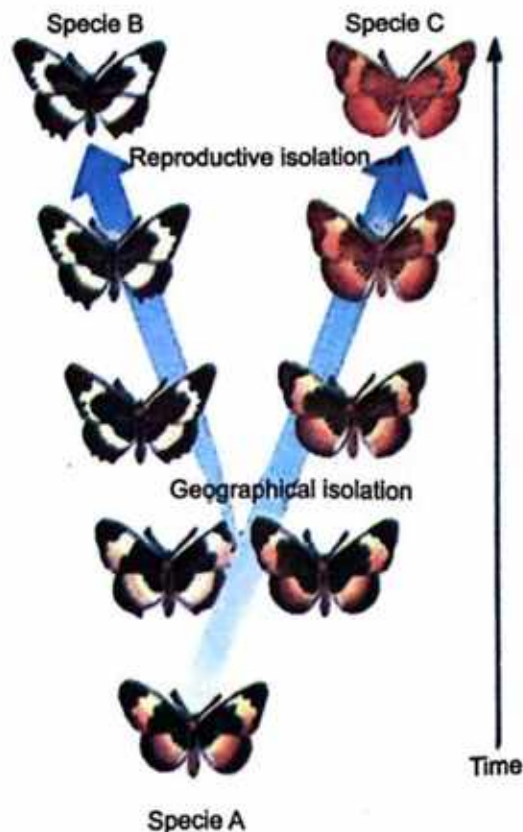
Fig. 10.7 : Dog breeds produced from wolf by artificial selection

**Table 10.1. Comparing Natural Selection and Artificial Selection**

| Natural Selection                                              | Artificial selection                                                     |
|----------------------------------------------------------------|--------------------------------------------------------------------------|
| Selection occurs when natural environmental condition changes. | It is selected by man.                                                   |
| Varieties are produced by mutations.                           | Varieties are produced by selective breeding.                            |
| It operates in natural population.                             | It operates in domesticated population.                                  |
| It is a slow process and takes thousand to millions of years.  | It is a fast process and results are immediate (in the next generation). |
| It is responsible for the great biological diversity.          | It is responsible for new varieties different from starting generation.  |

### 10.3 SPECIATION

The evolutionary process by which new biological species arise is called **speciation**. Two groups that originate from the same ancestor can become very different over time if they live in different places. When a species gets split into two geographical regions, the process of speciation starts. Each adapts to its own environmental conditions. After a while, individuals from one group can no longer reproduce with the other group. Ultimately, two new species have evolved from one.

**Fig 10.8. Speciation**

## SUMMARY

1. The differences in traits displayed by members of the same species is called variation.
2. Meiosis along with other factors serve as the main sources of variation.
3. Evolution is the gradual change of a population's or species' traits over time in response to the environmental conditions.
4. An inherited trait or group of traits that increases an organism's chances of survival in specific environmental conditions is known as an adaptation.
5. Natural selection is the process through which organisms who possess traits that are helpful for reproduction in a certain environment produce more children in the following generation.
6. After a five-year voyage around the world in the ship HMS Beagle, Charles Darwin put forth the Theory of Natural Selection.
7. The evidence of evolution is provided by palaeontology (fossil record), comparative anatomy (homologous structures, vestigial structures) and selective breeding.
8. The evolutionary process by which new biological species arise is called speciation.

## EXERCISE

## Section I: Multiple Choice Questions

Select the correct answer:

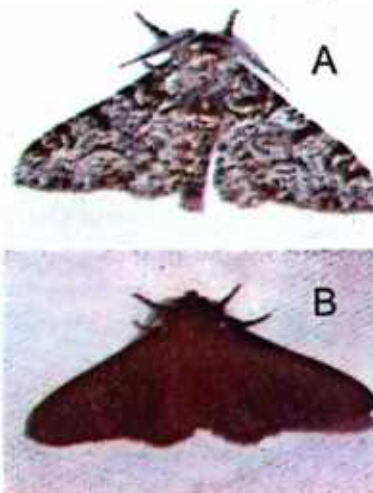
1. The process of ----- and ----- generate variation, and ----- produces adaptation to the environment.
  - A) sexual recombination ----- natural selection ----- mutation
  - B) genetic drift ----- mutation ----- sexual recombination
  - C) mutation ----- sexual recombination ----- natural election
  - D) mutation ----- natural selection ----- genetic drift
2. Natural selection is sometimes described as "survival of the fittest." Which of the following most accurately measures an organism's fitness?
  - A) its mutation rate
  - B) how many fertile offspring it produces
  - C) its ability to withstand environmental extremes
  - D) how much food it is able to make or obtain.
3. The smallest biological unit that can evolve over time is
 

|                  |                            |
|------------------|----------------------------|
| (A) a specie     | (B) an individual organism |
| (C) an ecosystem | (D) a population           |
4. Which of the following pairs of structures is least likely to represent homology?
  - (A) the wings of a bat and the forelimbs of a human
  - (B) the haemoglobin of a baboon and that of a gorilla
  - (C) the brain of a cat and that of a dog
  - (D) the wings of a bird and those of an insect

5. Organisms produce many more offspring that can possibly survive on the limited amount of resources available to them. The offspring that are most likely to survive are those that:
- (A) are born first and grow fastest
  - (B) are largest and most aggressive
  - (C) have no natural predators
  - (D) are best adapted to the environment
6. Natural selection operates to produce changes in:
- (A) individuals
  - (B) populations
  - (C) races
  - (D) genes
7. Speciation is the evolutionary process by which:
- (A) a new population is formed
  - (B) a new breed is formed
  - (C) a new specie is formed
  - (D) a new race is formed
8. A mutation is:
- (A) a change in appearance
  - (B) a change in behaviour
  - (C) a change in gene
  - (D) a change in the environment
9. farmers have bred Neli- Ravi buffalo to produce more milk than older breeds. Which process was used to produce these cattle?
- (A) adaptation
  - (B) natural selection
  - (C) genetic engineering
  - (D) selective breeding
10. Which results from the process of natural selection and adaptation?
- (A) artificial selection
  - (B) evolution
  - (C) reproduction
  - (D) selective breeding

### Section II: Short Answer Questions

1. Explain the homologous structures in plants.
2. Why the theory of evolution was attributed to Darwin?
3. What is meant by descent with modification?
4. The diagram shows two varieties of moths in England.



- a. Which variety was more common when there was more air pollution? Give reason as well.
- b. Which variety is more common in England nowadays? Give reason as well.
5. Define/Describe/Explain briefly:  
evolution, homologous organs, speciation, natural selection, artificial selection, industrial melanism, palaeontology, comparative anatomy, vestigial organs, selective breeding,
6. Differentiate between natural and artificial selection.

### Section III: Extensive Answer Questions

1. What is variation? Explain the sources of variation.
2. Assess selection as a possible means of evolution.
3. Explain the theory of evolution by natural selection with examples.
4. Discuss briefly the observations Darwin made during his voyage on HMS Beagle.
5. Describe speciation.
6. Describe the evidence of evolution according to palaeontology.
7. How comparative anatomy proves evolution?
8. Describe the evidence of evolution according to Selective breeding.
9. A species of snail may have a yellow, pink or brown shell. Each colour shell may have dark bands, or have no bands. The snails are eaten by birds. Following observations were made:
  - Most snails living on a plain background have no bands.
  - Most snails living on green background are yellow.
  - Most snails living on rough background have bands.
  - (a) Suggest an explanation of these observations.
  - (b) Predict the colour of snails living on dead leaves.
  - (c) Suggest which colour snails will be in summer and autumn.
10. Many small volcanic islands are located near South America; these are called Galapagos islands. There is only one species of finches on South America continent but there are 14 species of finches on Galapagos islands. Why there are more species on Galapagos islands as compared to main land?

## Glossary

**A.F.A King:** An American scientist who listed twenty observations in 1883 about spread of malaria.

**Abu Usama Aljahiz:** he described 350 species of animals.

**Accessory Whorls:** Additional floral structures beyond the essential reproductive parts, including sepals and petals, which may serve protective or attractive functions.

**Acetyl CoA:** Acetyl-CoA is an important biochemical molecule in cellular respiration. It is produced from Pyruvic acid and carries two carbon atoms to Kreb's cycle.

**Actinomycete:** A group of bacteria characterized by filamentous growth and their ability to produce antibiotics.

**Active site:** The part of the enzyme where the substrate binds.

**Active Transport:** Energy-requiring process by which substances are transported across cell membranes against their concentration gradient.

**Adenosine Tri Phosphate (ATP):** Molecule responsible for storing and transferring energy within cells.

**Adhesion:** Attraction between different molecules, such as water and the walls of xylem vessels.

**Aerobic respiration:** Respiration, which occurs in the presence of oxygen.

**Agriculture:** is the science of improving farming methods.

**Amino acid:** Compound which are the building blocks of proteins.

**Anabolism:** The building up complex substances from simpler ones.

**Anaerobic :** growing or metabolizing only in the absence of molecular oxygen.

**Anatomy:** I study of the internal structure of the organisms.

**Andrea Caesalpino:** He divided plants into fifteen groups and called them genera.

**Androecium:** The male reproductive organ of a flower, consisting of one or more stamens, each comprising a filament and an anther where pollen is produced.

**Angiosperms:** A diverse group of flowering plants characterized by enclosed seeds within fruits.

**Animalia:** are multicellular heterotrophic eukaryotes.

**Anopheles:** A mosquito (female) that spread plasmodium the malarial parasite in man.

**Anther:** The part of the stamen where pollen grains containing male gametes are produced.

**Antipodals:** Three cells in the embryo sac of flowering plants, located at the opposite end of the micropyle, possibly playing a role in embryo development.

**Apoenzyme :** protein portion of an enzyme that requires the presence of a specific co-factor to become a complete functional enzyme.

**Apomixis:** A form of asexual reproduction in plants where seeds are produced without fertilization.

**Archaea:** A domain that consists of single cell prokaryotic organisms.

**Artificial Vegetative Propagation:** A method of plant reproduction that involves human intervention, such as cutting, grafting, or tissue culture, to produce genetically identical clones of a parent plant.

**Ascent of Sap:** Process by which water and nutrients are transported from roots to leaves in plants.

**Asexual Reproduction:** Reproduction that does not involve the fusion of gametes, resulting in offspring genetically identical to the parent organism.

**Autophagy:** A process in which cell eats its own organelles which are damaged or no more needed.

**Bacteria:** A domain that are microscopic, single-celled organisms that exist in their millions, in every environment, both inside and outside other organisms.

**Bacteria:** Microscopic, single-celled organisms belonging to the domain Bacteria, exhibiting diverse metabolic capabilities and ecological roles.

**Binary Fission:** A form of asexual reproduction in bacteria and some other single-celled

organisms, where a parent cell divides into two identical daughter cells.

**Binomial nomenclature:** the biological system of naming the organisms. In it the name is composed of two terms. The first term indicates the genus and the second term indicates the species of the organism.

**Biochemistry:** study of chemical constituents found in an organism and chemical reactions taking place in the living organism.

**Biodiversity:** the variety of organisms on earth.

**Bio-economics:** study of biology from economic point of view.

**Bioelements:** The elements found in all living organisms.

**Biogeography:** study of distribution of plants and animals in different geographical regions of the world.

**Biological method:** the series of steps that are used to solve a biological problem.

**Biology:** Study of living organisms.

**Biophysics:** applies approaches and methods traditionally used in physics to study biological phenomena.

**Biostatistics:** the application of statistical techniques to scientific research in the field of biology.

**Biotechnology:** is the use of living organisms or their components to make useful products.

**Botany:** study of plants.

**Bryophyllum:** A genus of succulent plants known for their ability to produce plantlets along the margins of their leaves.

**Bryophytes:** Non-vascular plants including mosses, liverworts, and hornworts, characterized by their lack of specialized vascular tissues.

**Bud:** A small, undeveloped shoot containing embryonic tissue that can grow into a leaf, flower, or shoot.

**Bulbs:** Underground storage organs consisting of layers of fleshy leaves surrounding a central bud, capable of producing new shoots.

**Callus:** Undifferentiated plant tissue formed in response to injury or tissue culture, capable of developing into roots, shoots, or other structures.

**Calvin cycle:** Cyclic series of reactions in the chloroplast stroma in photosynthesis which fixes carbon dioxide and produces carbohydrates.

**Calyx:** The outermost whorl of a flower, typically consisting of sepals.

**Canadian Pondweed (Elodea):** Aquatic plant commonly used in experiments to demonstrate photosynthesis and cellular respiration.

**carbon fixation:** the initial steps in the C3 cycle in which carbon dioxide reacts with the ribulose biphosphate to form a stable organic molecule.

**Carolus Linnaeus:** He grouped species according to similar physical characteristics

**Carpel:** The female reproductive organ of a flower, comprising the stigma, style, and ovary, where ovules are located.

**Casparian Strips:** Bands of suberin in the cell walls of the endodermis, preventing water and solute movement between cells.

**Catabolism:** The breakdown of complex substances to simpler substances in a cell with the release of energy.

**Centromere:** Constructed region of a chromosome where sister chromatids are attached to one another and where the chromosomes attaches to a spindle fibre.

**chitin (kytin):** a nitrogen-containing structural polysaccharide that forms the exoskeleton of insects and the cell walls of many fungi.

**Chlorosis:** A condition in plants characterized by yellowing of leaves due to insufficient chlorophyll production.

**Chromatids:** One of the two identical parts of chromosomes.

**Chromatin:** the complex of DNA, protein, and RNA that makes up eukaryotic chromosomes.

**Chromosomes** condensed thread like structures in the nucleus of cell, composed of chromatin and containing the genes.

**Chromosomes:** Thread like structures in the nucleus, which carry the genes.

**Chrysanthemum:** A genus of flowering plants in the family Asteraceae, cultivated for their ornamental flowers.

**Citrate (citric acid):** a 6-carbon organic acid.

**Citric acid cycle:** series of chemical reactions in aerobic cellular respiration with the release of metabolic energy which is used to produce ATP; also known as the Krebs cycle and the

**tricarboxylic acid (TCA) cycle.**

**Class:** a group of related orders.

**Classification:** grouping of organisms

**Clone:** Genetically identical individuals produced through asexual reproduction, such as vegetative propagation.

**Coenzyme A (CoA):** organic cofactor responsible for transferring groups derived from organic acids.

**Co-enzymes:** Non-protein organic molecule that aids the action of the enzyme to which it is loosely bound.

**Cofactor:** a non-protein substance needed by an enzyme for normal activity; some cofactors are inorganic (usually metal ions;) others are organic cofactors, known as coenzymes.

**Cohesion:** Attraction between molecules of the same substance, such as water molecules sticking together.

**Companion Cells:** Specialized cells associated with sieve tube elements in the phloem, assisting in nutrient transport.

**Compensation Point of Photosynthesis:** Light intensity at which the rate of photosynthesis equals the rate of respiration in plants.

**Computational biology:** applies computational methods to analyze large collections of biological data.

**Concentration Gradient:** Difference in concentration of a substance between two regions.

**Contractile vacuoles:** A special kind of vacuole found in small freshwater animals or animal like protists to remove out extra water.

**Corms:** Underground storage stems similar to bulbs but lacking fleshy leaves, used for storing nutrients and producing new shoots.

**Corolla:** The whorl of a flower consisting of petals, often serving to attract pollinators.

**Cortex:** Region of tissue in plant roots and stems between the epidermis and vascular tissue, involved in storage and transport.

**Cotyledons:** The seed leaves of a plant embryo, which may store nutrients and facilitate early growth.

**Cristae:** Small finger like projections formed by the inner membrane of mitochondria.

**Cross pollination:** Pollination involving the transfer of pollen from the stamen of one flower

to the stigma of another flower on a different plant.

**Crossing over:** The reciprocal exchange of genetic material between non-sister chromatids of homologous chromosomes during prophase I of meiosis.

**Culex:** A mosquito that spreads malarial parasite in birds.

**Cuticle:** Waxy, waterproof layer covering the outer surface of leaves and stems.

**Cuticular Transpiration:** Transpiration through the waxy cuticle covering leaf surfaces.

**Cytology:** study of the structure and functions of the cell.

**Dead Organic Matter:** Decomposed organic material, providing nutrients for plant growth.

**Dead Plant Debris:** Non-living plant material, including leaves, stems, and roots, resulting from natural processes or decay.

**Deduction:** are the logical consequences of the hypothesis.

**Denaturation:** Loss of normal shape by an enzyme so that it no longer functional caused by an abnormal pH and high temperature.

**Dengue fever:** caused by dengue virus and spread by *Aedes aegypti*.

**deoxyribonucleic acid (DNA):** double stranded nucleic acid; contains genetic information coded in specific sequences of its constituent nucleotides.

**Diffusion:** Passive movement of molecules from an area of higher concentration to an area of lower concentration.

**Dipeptide:** a compound consisting of two amino acids linked by a peptide bond.

**Disaccharide:** Sugar that contains two units of a monosaccharide e.g., maltose.

**Domain:** is a group of kingdoms or taxonomic category above the kingdom

**Double fertilization:** A unique reproductive process in flowering plants where two sperm nuclei fertilize different nuclei within the embryo sac, leading to the formation of both an embryo and endosperm.

**Ecology:** interrelationship of organisms and their environment.

**Egg:** The female gamete produced by the ovary of a flower.

**Electron transport chain:** Chain of electron carriers in the cristae of mitochondria. The electron release energy as they pass down the chain and this is used to produce ATP

**Embryo Sac:** The female gametophyte of a flowering plant, containing the egg cell and other supportive cells.

**Embryo:** The early developmental stage of a multicellular organism, typically contained within a seed.

**Embryology:** study of the development of an organism from a fertilized egg.

**Embryonic Root:** The primary root that emerges from the seed embryo during germination.

**Embryonic Stem:** Undifferentiated cells within the embryo capable of developing into various specialized cell types.

**Endodermis:** Innermost layer of the root cortex, regulating the movement of water and nutrients into the vascular tissue.

**Endosmosis:** Inward movement of water across a semipermeable membrane.

**Endosperm Nucleus:** The central cell within the embryo sac that undergoes fertilization to form the endosperm.

**Endosperm:** Nutrient-rich tissue formed during double fertilization in flowering plants, providing nourishment to the developing embryo.

**Enzymes:** Organic catalyst usually a protein that speeds up a reaction in cell due to its particular shape.

**Epicotyl:** The region of the embryonic stem located above the cotyledons, which develops into the shoot system of the plant.

**Epidermis:** Outermost layer of cells covering plant surfaces, providing protection and regulating water loss.

**Eukarya:** is a domain or a large taxonomy group that is made up of organisms that contain a nucleus within their cells.

**Evolution** the gradual alteration of a population's or species' traits over time in response to the environmental conditions.

**Exosmosis:** Outward movement of water across a semipermeable membrane.

**Exospores:** Spores produced externally by certain fungi, allowing for dispersal and reproduction.

**Explant:** A tissue sample taken from a plant for use in tissue culture or regeneration experiments.

**Facilitated Diffusion:** Movement of molecules across a membrane facilitated by transport proteins.

**Family:** s a group of related genera.

**Farming:** is the growth of crops and animals to provide food, wool and other products.

**Female gametophyte:** The haploid generation in the life cycle of a plant that produces female gametes, typically found within the ovule of a flower.

**Fertilization:** The fusion of male and female gametes to form a zygote, initiating the development of a new organism.

**Fibrous adventitious roots:** Roots originating from plant parts other than the primary root, forming a fibrous root system.

**Filament:** The slender stalk of a stamen that supports the anther.

**Fishery:** raising or harvesting fish and other aquatic life.

**Floral Buds:** Undeveloped flower structures containing floral meristems.

**Floral Leaves:** Modified leaves of a flower, including sepals, petals, stamens, and carpels.

**Flowers:** Reproductive structures of angiosperms, typically consisting of sepals, petals, stamens, and carpels.

**Forestry:** is the science of planting, managing and caring for forests.

**Functional megaspore:** The surviving megaspore within the ovule that undergoes further development into the female gametophyte.

**Fungi:** are eukaryotic organisms that are saprotrophic decomposers. Mostly fungi are multicellular. Some fungi are unicellular.

**Gametes:** Haploid reproductive cells, including sperm and egg cells, capable of fusion during sexual reproduction.

**Gametophyte:** The haploid generation in the life cycle of a plant, producing gametes through mitosis.

**Generative Nucleus:** The nucleus within a pollen grain that divides to produce sperm cells.

**Genetic uniformity:** The condition where offspring are genetically identical to the parent organism, as seen in clones.

**Genetics:** Study of genes, and heredity in organisms is called genetics.

**Genus:** a group of related species.

**Germination:** The process by which a seed embryo begins to grow and develop into a new plant.

**Glycerol:** a three-carbon alcohol, with a hydroxyl group on each carbon; a component of neutral fats and phospholipids.

**Glycolysis:** The breakdown of glucose during cellular respiration, which results in the formation of ATP and pyruvate.

**Grapevines:** Vines of the genus *Vitis*, cultivated for their fruit, used in winemaking and culinary applications.

**Guanine (gwan'een):** a nitrogenous purine base that is component of nucleic acids

**Gymnosperms:** A group of seed-producing plants characterized by naked seeds, typically enclosed within cones.

**Gynoecium:** The female reproductive organ of a flower, comprising one or more carpels.

**Haemoglobin:** Iron contains protein in red blood cells that combines with oxygen and transports oxygen.

**Haplo-diplontic lifecycle:** A life cycle characteristic of higher plants, alternating between a haploid gametophyte and a diploid sporophyte generation.

**Hilum:** The scar on a seed marking the point of attachment to the ovary wall.

**Histology:** microscopic study of tissues of organisms.

**Histones:** Proteins on which DNA coils to form chromatin fibers and chromosomes.

**Homeostasis** The tendency to maintain a stable, relatively constant internal environment.

**Homologous chromosomes:** Chromosome pair of the same length, centromere position and staining pattern that possess genes for the same traits at corresponding loci. One homologous chromosome is inherited from one parent and second from the other parent.

**Homologous chromosomes:** Similar chromosomes having the same appearance and containing genes for the same trait.

**Horticulture:** it means the art of gardening.

**Humidity:** Amount of water vapor present in the air.

**Hydrilla:** Submerged aquatic plant often used in studies of

**Hydrogen carbonate Indicator:** Chemical solution used to detect the presence of carbon dioxide in photosynthesis experiments.

**Hydrostatic pressure:** Pressure exerted by a fluid due to its weight and gravity.

**Hypocotyl:** The region of the embryonic stem located below the cotyledons, which develops into the root system of the plant.

**Hypothesis:** a tentative explanation of the observations that might be true.

**Immunology:** ability of the body to protect itself from foreign substances and cells including infectious microbes.

**Internodes:** The segments of a stem between nodes.

**Interphase:** Phase of cell cycle from the formation of a cell till the start of next division.

**Intracellular digestion:** A process in which complex substances are digested within a cell.

**intron:** In eukaryotes, a non expressed (noncoding) portion of a gene, that is excised from the RNA transcript. The coding portion of a gene is called exon.

**Ivy:** A genus of climbing or creeping vines in the family Araliaceae, commonly used for ornamental purposes.

**John Ray:** He published important works on the classification of plants.

**Kingdom:** the largest taxon or rank.

**Krebs cycle:** The series of reactions during which pyruvate the end product of glycolysis enters the cycle to form citric acid and is finally oxidized to carbon dioxide also called citric acid cycle. It occurs inside mitochondria.

**Law:** A theory that has been verified and appears to have wide application

**Lenticels:** Pores in the bark of woody stems, allowing gas exchange between internal tissues and the atmosphere.

**Lenticular transpiration:** transpiration through lenticels, small openings in the bark of woody stems.

**Lipase:** fat-digesting: enzyme.

**Macromolecules:** A large organic molecule having many functional groups.

**Macronutrients:** Essential nutrients required by plants in relatively large quantities, including nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.

**Male gametophyte:** The haploid generation in the life cycle of a plant that produces male gametes, typically found within pollen grains.

**Marine biology:** study of organisms that live in sea.

**Megasporangia:** Structures within the ovule that produce megaspores, which develop into female gametophytes.

**Megaspores:** Haploid spores produced by megasporangia, which give rise to the female gametophyte.

**Meiosis:** The process of cell division that reduces the chromosome number by half, leading to the formation of gametes.

**Mesophyll cells:** Cells in the interior of leaves responsible for photosynthesis.

**Messenger RNA (mRNA):** RNA that specifies the amino acid sequence of a protein; transcribed from DNA.

**Metabolism:** All the chemical reactions that take place within a living organism.

**Microbiology:** Study of micro-organisms e.g., viruses, bacteria etc.

**Micronutrients:** Essential nutrients required by plants in small quantities, including iron, manganese, zinc, copper, molybdenum, boron, and chlorine.

**Micropropagation:** A method of plant propagation involving the growth of plant tissues under sterile conditions to produce clones.

**Micropyle:** The opening in the integuments of an ovule through which the pollen tube enters during fertilization.

**Microsporangia:** Structures within the anther that produce microspores, which develop into pollen grains.

**Microspores:** Haploid spores produced by microsporangia, which develop into pollen grains.

**Moisture:** Water content in the environment, essential for plant growth and metabolic processes.

**Molecular biology:** study of biology at molecular level.

**Morphology:** study of the size, shape, and structure of animals, plants, and microorganisms.

**Myoglobin:** a haemoglobin-like oxygen transferring protein found in muscle.

**NAD<sup>+</sup>/NADH:** oxidized and reduced forms, respectively, of nicotinamide adenine dinucleotide; it is a coenzyme that transfers electrons in catabolic pathways, including cellular respiration.

**NADP<sup>+</sup>/NADPH:** oxidized and reduced forms, respectively, of nicotinamide adenine dinucleotide phosphate; coenzyme that acts as an electron (hydrogen) transfer agent, particularly in anabolic pathways, including photosynthesis.

**Natural selection** the process through which organisms who possess traits that are helpful for reproduction in a certain environment produce more children in the following generation.

**Natural vegetative propagation:** Plant reproduction that occurs without human intervention, such as through the growth of runners or rhizomes.

**Necessary whorls:** The essential floral structures required for sexual reproduction, including stamens and carpels.

**neutral fat:** a lipid used for energy storage, consisting of a glycerol covalently bonded to one, two or three fatty acids.

**Nitrogen Depleted Soils:** Soil lacking sufficient nitrogen for plant growth.

**Nitrogenous Compounds:** Chemical compounds containing nitrogen, essential for various biological processes in plants.

**Nodes:** Points on a stem where leaves, branches, or flowers originate.

**Nucleoside** (new'klee-oh-side): molecule consisting of a nitrogenous base (purine or pyrimidine) and a pentose sugar.

**Nucleosomes** (new'k-lee-oh-somz): repeating units of chromatin structure, each consisting of a length of DNA wound around a complex of eight histone molecules (two of four different types) plus a DNA linker region associated with a fifth histone protein.

**Nucleotide** (noo'klee-oh-tide): a molecule composed of one or more phosphate groups, a 5-

carbon sugar (ribose or deoxyribose) and nitrogenous base (purine or pyrimidine).

**Nutrient:** Substances essential for the growth and maintenance of organisms, including plants, obtained from the environment.

**Nutrition:** The process by which organisms acquire and utilize nutrients for growth, metabolism, and other biological functions.

**Offspring:** The new generation of organisms produced through reproduction.

**Order:** group of related families.

**Organ systems** groups of organs with related functions.

**Organic Solutes:** Organic compounds dissolved in plant fluids, contributing to osmotic regulation and nutrient transport.

**Organs:** Structures made up of two or more tissues organized to carry out a particular function.

**Ovary:** The swollen basal portion of the carpel containing ovules, which develop into seeds after fertilization.

**Ovule:** The structure within the ovary of a flower that contains the female gametophyte and develops into a seed after fertilization.

**Oxidation:** The loss of an electron by an atom or a molecule.

**Oxidation-reduction:** A chemical reaction in which one atom or molecule gains an electron while the other atom or molecule involved in the reaction loses an electron.

**Oxidative phosphorylation:** Process by which ATP production is tied to an electron transport system that uses oxygen as the final acceptor, occurs in mitochondrion.

**Oxygen:** A gas essential for aerobic respiration and metabolic processes in plants.

**P680:** chlorophyll a molecules that serve as the reaction centre of Photosystem II, named by their absorption peak at 680 nm.

**P700:** chlorophyll a molecules that serve as the reaction centre of Photosystem I, named by their absorption peak at 700 nm.

**Parthenogenesis:** A form of asexual reproduction in which an unfertilized egg develops into a new individual.

**Passive Transport:** Movement of substances across cell membranes without the use of energy.

**Pathology:** study and diagnosis of disease.

**Pathology:** study and diagnosis of diseases.

**Pectin:** A structural fiber found in the cell wall of plants.

**Pedicle:** The stalk that supports a single flower or inflorescence.

**Pentose:** a sugar molecule containing five carbons.

**Pepsin :** an enzyme produced in the stomach that initiates digestion of protein.

**Peptide bond:** a distinctive covalent carbon-to-nitrogen bond that links amino acids in peptides and proteins.

**Peptide:** a compound consisting of a chain of amino acid groups. A dipeptide consists of two amino acids, a polypeptide of many amino acids.

**Peptidoglycan:** a modified protein or peptide possessing an attached carbohydrate; component of the bacterial cell wall.

**Pericycle:** Tissue layer in plant roots giving rise to lateral roots.

**Petals:** Modified leaves of a flower, often brightly colored to attract pollinators.

**Pharmacology:** study of drugs.

**Phloem Sap:** Sugary fluid transported through the phloem, containing sugars, amino acids, and other organic compounds.

**phosphodiester linkage:** covalent linkage between two nucleotides in a strand of DNA or RNA; includes a phosphate group bonded to the sugars of two adjacent nucleotides.

**Phospholipids:** fatlike substances in which there are two fatty acids and a phosphorus-containing group attached to glycerol; major components of cellular membranes.

**Photolysis** the photochemical splitting of water in the light-dependent reactions of photosynthesis, catalyzed by a specific enzyme.

**Photometer:** Instrument used to measure light intensity.

**Photon:** a particle of electromagnetic radiation; one quantum of radiant energy.

**photophosphorylation:** the production of ATP in photosynthesis.

**Photosynthesis:** Process by which green plants and some other organisms convert light energy into chemical energy, producing oxygen and carbohydrates from carbon dioxide and water.

**Photosystem:** a group of chlorophyll molecules,

**accessory pigments**, and associated electron acceptors that emits electrons in response to light; located in the thylakoid membrane (in photoautotrophic eukaryotes).

**Phylum**: a group of related classes.

**Physiology**: study of the functions of various organs of the organisms.

**Pistil**: The female reproductive organ of a flower, comprising one or more carpels.

**Pith**: Central tissue in the stems of certain plants, primarily involved in storage and support.

**Plant Physiology**: The study of how plants function and the processes that occur within them.

**Plantae**: members of kingdom plantae are eukaryotic multicellular and autotrophic with chloroplasts containing chlorophyll.

**Plantlet**: A small, immature plant produced asexually from a parent plant.

**Plasmodium**: A microorganism and parasite that causes malaria in man.

**Plumule**: The embryonic shoot located above the cotyledons in a seed.

**Polar Nuclei**: Two nuclei in the central cell of the embryo sac that fuse with a sperm nucleus during double fertilization to form the endosperm.

**Pollen Grains**: Microscopic structures produced by the anthers of flowers, containing male gametes.

**Pollen Sacs**: Structures within the anthers that contain pollen grains.

**Pollen Tube**: A tubular structure that grows from a pollen grain into the ovule to deliver sperm cells during fertilization.

**Pollination**: The transfer of pollen from the anther to the stigma of a flower, facilitating fertilization.

**Polymer**: A molecule built up from repeating sub units of the same general type (monomers) such as protein, nucleic acid or polysaccharides.

**Polypeptide**: a compound consisting of many amino acids linked by peptide bonds.

**Polysaccharide** (pol-ee-sak'ah-ride): a carbohydrate consisting of many monosaccharide subunits; examples are starch,

glycogen, and cellulose.

**Primary root**: The first root to emerge from a plant embryo, forming the basis of the root system.

**Prokaryotes**: Organisms whose cells lack a defined nucleus.

**Proteins**: A large complex organic compound composed of amino acids.

**Protista**: include eukaryotic organisms with unicellular or colonial organization.

**Protozoa**: Single-celled eukaryotic organisms belonging to the kingdom Protista, exhibiting diverse forms and lifestyles.

**Pteridophytes**: A group of seedless vascular plants, including ferns and horsetails, characterized by the presence of vascular tissues.

**Purines** (pure'eenz): nitrogenous bases with carbon and nitrogen atoms in two attached rings; components of nucleic acids, ATP, NAD<sup>+</sup>, and certain other biologically active substances. Examples are adenine and guanine.

**Radicle**: The embryonic root of a plant embryo, which develops into the primary root.

**Recombinant DNA**: any DNA molecule made by combining genes from different organisms.

**Reproduction**: The process by which organisms produce offspring, ensuring the continuation of their species.

**Rhizomes**: Underground stems that grow horizontally, producing roots and shoots at nodes to propagate plants.

**Rhizopus**: A genus of filamentous fungi commonly found on decaying organic matter, known for its rapid growth and asexual reproduction.

**Ribonucleic acid (RNA)**: a family of single-stranded nucleic acids that function mainly in protein synthesis.

**Ribulose biphosphate (RuBP)**: a 5-carbon phosphorylated compound with a high energy potential reacts with carbon dioxide in the initial step of the Calvin cycle.

**Ribulose biphosphate**: A five carbon phosphorylated compound with a high energy potential reacts with carbon dioxide in the initial step of Calvin cycle.

**Ripened Ovary:** The matured and enlarged base of the carpel containing seeds, often forming the fruit.

**Ripened Ovule:** The matured ovule containing the fertilized embryo, often forming the seed.

**Root Hairs:** Tiny, hair-like extensions of root epidermal cells, increasing surface area for nutrient absorption.

**Rootstock:** The underground portion of a grafted plant that provides the root system.

**Rubisco:** common name of ribulose biphosphate carboxylase, the enzymes the reaction of carbon dioxide with ribulose biphosphate in the Calvin cycle.

**Rubisco:** Common name of ribulose biphosphate, carboxylase, the enzyme that catalysis the reaction of carbon dioxide with ribulose biphosphate in the Calvin cycle.

**Runners:** Horizontal stems that grow above ground and produce new plants at nodes along their length.

**Science:** A system of knowledge about the physical, chemical, and biological universe and the things that occur in it is called science.

**Scientific method:** an approach for solving scientific problem.

**Scion:** The aboveground portion of a grafted plant that provides the shoot system.

**Secondary Nucleus:** The nucleus within the central cell of the embryo sac that fuses with a sperm nucleus during double fertilization to form the endosperm.

**Seed Coat:** The protective outer covering of a seed, derived from the integuments of the ovule.

**Seed Leaves:** The cotyledons of a germinating seed, which provide nutrients for early seedling growth.

**Selectively Permeable:** Property of membranes allowing certain substances to pass while restricting others.

**Self-Pollination:** Pollination that occurs within the same flower or between flowers of the same plant, leading to fertilization.

**Sepals:** Leaf-like structures at the base of a flower, collectively known as the calyx, typically serving to protect the flower bud.

**Sieve Tubes:** Tubular structures in phloem tissue, responsible for transporting organic nutrients.

**Sink:** Plant organ or tissue importing sugars for storage or growth.

**Source:** Plant organ or tissue exporting sugars to other parts of the plant.

**Speciation** the evolutionary process by which new biological species arise.

**Species:** a group of similar organisms capable of interbreeding.

**Sperm nuclei:** Haploid nuclei within pollen grains that fuse with egg nuclei during fertilization.

**Sporangia:** Structures within plants where spores are produced through meiosis.

**starch:** a polysaccharide composed of alpha glucose subunits; made by plants for energy storage.

**Stem cells:** Mother cells which give rise to cells of other types.

**Stomata:** Small pores in the epidermis of leaves and stems, regulating gas exchange and water loss.

**Stomatal transpiration:** Transpiration through openings called stomata on leaf surfaces.

**Suberin:** Waxy substance found in the cell walls of the endodermis, creating a waterproof barrier.

**substrate:** a substance on which an enzyme acts; a reactant in an enzymatically catalyzed reaction.

**Systematics:** scientific study of diversity of organisms and their evolutionary relationship.

**Aristotle:** the first person who classified the living organisms.

**TACT theory:** Theory explaining the movement of water through plants, involving transpiration, adhesion, cohesion, and tension.

**Tap root:** Primary root in certain plants that grows straight down and gives rise to lateral roots.

**Taxa:** The group into which organisms are classified.

**Taxonomy:** Is concerned with identification, naming and classification of organisms.

**Tension:** Pulling force exerted on water molecules in the xylem due to transpiration.

**Tissues** groups of similar cells that work together on a specific task.

**Tournefort:** He introduced the taxa of class and species

**Tracheids:** Type of elongated cells in xylem tissue responsible for water transport in gymnosperms and ferns.

**Transfer RNA (tRNA):** RNA molecules that bind to specific amino acids and serve as adapter molecules in protein synthesis. The tRNA anticodons bind to complementary mRNA codons.

**Translocation:** Movement of sugars and other organic compounds through a plant, primarily in the phloem.

**Transpiration pull:** Force created by transpiration, causing water to move upward through the xylem.

**Transpiration:** Loss of water vapor from plant surfaces, primarily through stomata.

**Tricylglycerol:** a neutral fat consisting of a glycerol combined chemically with three fatty acids; also called triglyceride.

**triose:** a sugar molecule containing three carbons

**Turgor:** Pressure exerted by the fluid contents of plant cells against the cell wall, providing support and rigidity.

**Variation** the differences in traits displayed by members of the same species.

**Vascular bundles:** Strands of xylem and phloem tissues responsible for transporting water, nutrients, and sugars throughout the plant.

**Viruses:** are at the borderline of living and nonliving. There are not included in any domain or kingdom under modern classification.

**Woese:** introduced a three domains system of classification.

**Xylem Vessel:** Tubular structure in xylem tissue, conducting water and minerals upward from roots to shoots in angiosperms.

**Zoology:** Study of animals.

## ABOUT THE AUTHORS

### Prof. Jawaid Mohsin Malik

Prof. Jawaid Mohsin Malick was born on 8th February 1945 in the province of Bihar. Malik is the title given to his ancestor Syed Ibrahim by the King Muhammad Tughlaq. Syed Ibrahim was a saint, the commander in chief of the army and conqueror of Bihar. Syed Ibrahim is the descendent of Hazrat Ghos-e-Azam, Syed Abdul Qadir Jilani (رحمة الله عليه) at the seventh generation. The ancestors of Syed Ibrahim migrated from Iraq to Afghanistan and settled in the village 'But Nagar' near Ghazni. Prof. Jawaid is a former head of the department of Zoology, F.G. Postgraduate College, H-8, Islamabad where he served for more than twenty five years. He is also a former Principal, Federal Government College, H-9, F-10/4 Islamabad, and Director Colleges and Director Administration, Federal Directorate of Education, Islamabad. In 1968 he did his post-graduation in Zoology with specialization in Entomology from Dhaka University, East Pakistan (former). He taught various classes for more than forty five years in various capacities. He has also worked as Education Officer, in Nigeria for four years. He has successfully completed the 61st advance course in administration and development held in 1996 at National Institute of Public administration (NIPA), Karachi. In 1995, he was awarded a shield by the honourable Mr. Rafiq Tarrar, the then President of Pakistan, for his services to humanity. He published four research papers in Science Journals of Pakistan on Butterflies of Pakistan. He has contributed articles on science and sports in Urdu and English dailies of Islamabad. He is co-author and managing author of more than forty five textbooks on General Science and Biology as well as Biology Practical Notebooks. He has travelled to Singapore, Thailand, Indonesia, India, Bangladesh, UAE, Saudi Arabia, Egypt, Italy, Holland, UK, Qatar, USA and Nigeria. He has also served as a National Consultant, Science Education, JICA sponsored project for the promotion of Student Centred and Inquiry Based (SCIB) learning, National Institute of Science and Technical Education, Ministry of Education, Islamabad.

### Ms. Ruqayya Shaikh

Ruqayya Shaikh did her M.Sc and M.Phil in Animal Sciences from Quaid-i-Azam University, Islamabad. She started her professional career as a Zoology lecturer at Islamabad College for girls, F-6/2, Islamabad. At present she is working as Associate Professor in the same institute. She has been teaching General Science to secondary school classes, Biology to SSC, HSSC and BS classes, Zoology to B.Sc classes for the last two decades. Recently she certified in instructional leadership, College of Education, University of Massachusetts, USA.

She was the part of the General science Curriculum development team, Grade 4-8, under National Curriculum council. She worked as text book reviewer for General science Grade 4, General Science Grade 5, Biology HSSC I and Biology HSSC II. She served as FBISE Biology course committee member. The author conducted a number of teacher training programs. She is the author of General Science 6, 7 and Biology 9 and 10. Her video lectures of General Science and Biology are available on youtube channel Ruqayya Shaikh ICG.

### Dr. Kashif Ali

Dr. KASHIF ALI is Associate Professor, coordinator at center of excellence and Vice Principal at IMCB, F-7/3, Islamabad. Dr. Kashif did MSc (Zoology), M.Phil (Developmental biology) and PhD (Molecular Genetics and Cancer cell Biotechnology). He received Indigenous and IRSIP merit Fellowship from HEC for PhD studies at Pakistan and UK. He completed his PhD research from

COMSATS University Islamabad and Cardiff University-Peking University Cancer Institute, Cardiff, UK. He has multiple, well cited publications in international research journals.

He has 23 year experience of Biology teaching at SSc and HSSc levels and has also been teaching to BS, and MS classes at QAU and Bahria University Islamabad. He has been awarded best biology teacher award (2023) by FDE. He received multiple teaching trainings from different national and international training institutes including National Academy of Higher Education (NAHE), Professional Competency Enhancement Program for Teachers (PCEPT), Cisco Networking Academy Islamabad and Incheon metropolitan city office of education, Incheon, South Korea.

He has been working as member of committee of courses, super checker, paper setter and judge in scientific exhibitions at FBISE, master trainer for teacher training at FDE, book reviewer at National curriculum council (NCC) and member interview committee of FPSC for selection of faculty.

### **Abid Ali Mughal**

Mr. Abid Ali Mughal is currently the Assistant Professor and Head of the Biology Department at Islamabad Model College for Boys H-9 Islamabad. He completed his M.Sc (Hons) in Plant Sciences from the University of Sindh Jamshoro in 2002, where he was awarded the Vice Chancellor's Medal for achieving first position. From 2002 to 2003, he served as a Research Fellow at PAEC's Nuclear Institute of Agriculture Tandojam. In 2003, he began his teaching career as a lecturer in Botany at F.G. Degree College Wah Cantt. His research interests include investigating factors affecting tDNA transfer from Agrobacterium to Soybean for his M.Phil in Biotechnology, and studying the effects of chronic exposure to antibiotics on rural populations for his Ph.D. in Environmental Sciences. Mr. Mughal has presented his research papers at international conferences in Lithuania, the Netherlands, and France. He is the Co-author of NBF Biology for grades 11 & 12 according to the curriculum 2006, and the Principal author of Biology for grade 12 of KPK textbook board based on Curriculum 2006. His interactive video lectures covering all biology topics are available on his website [www.BiologyGuardian.com](http://www.BiologyGuardian.com) and YouTube channel [www.youtube.com/c/BiologyGuardian](http://www.youtube.com/c/BiologyGuardian). Currently, he is a member of the Course Committee of SSC and HSSC Biology in the Federal Board and a Co-opted member of the Board of Studies of Botany at Quaid-i-Azam University Islamabad.

### **Mr. Sajid Ali Shah**

Mr Sajid Ali Shah has done MSc Zoology from Azad Jammu Kashmir University, Muzaffarabad and M.Phil in Biochemistry from Quaid i Azam University Islamabad. He is currently serving as an Associate Professor at Islamabad College for Boys, G-6/3, Islamabad. Previously, he served as a Lecturer at IMCB G-10/4 Islamabad and FG College for Men, H-9, Islamabad. He is author of 2nd Year Biology Khyber Pakhtoonkhwa text book, Biology 9th and 10th published by NBF (National Book Foundation). He has been reviewer of F.Sc. Biology I, II by NBF, model books General Science 4th and 5th by NBF, Oxford TE series and Paramount Publishers.