NCERT XI BIOLOGY NOTES AND SOLUTIONS

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NCERT XI Biology Notes and Answers

Contents

1. The Living World

Characteristics of Living Beings

Growth: Growth is an important feature of living beings. Growth can be seen in some non-living things; like a cloud. But the growth in non-living things happens because of accumulation of matter from outside. On the other hand, the growth in a living being happens because of internal processes, i.e. cell division. Most of the plants show indeterminate growth, while the growth in animals is definite.

Reproduction: All living beings produce their offspring through the process of reproduction. Reproduction is important for continuing the lineage of a species. There are two main types of reproduction, viz. sexual and asexual.

Metabolism: The chemicals within a living organism undergo a continuous change. This process is called metabolism. Metabolism is composed of two processes, viz. anabolism and catabolism.

a. Anabolism: The process of synthesis of any substance is called anabolism, e.g. photosynthesis.
b. Catabolism: The process of breaking up of a substance is called catabolism, e.g. respiration.

Response to External Stimuli: All living organisms respond to external stimuli. Light, heat, chemicals, other organisms, etc. are examples of external stimuli. Response to external stimuli is important for the survival of an organism.

Nomenclature and Identification:

An organism is known by different names in different languages. It would be impossible for any person to remember the names of an organism in all the languages. Hence, there is need for a uniform system of nomenclature of organisms. A uniform system of nomenclature and identification helps the scientists in systematic study of living beings. ICBN (International Code for Botanical Nomenclature) applies to the plants and ICZN (International Code for Zoological Nomenclature) applies to the animals.

General Rules for Nomenclature:

- Biological names are usually written in Latin. They are written in italics.
- A biological name usually contains two terms. The first term shows the genus, while the second term shows the species.
- Biological name is underlined, when it is handwritten.
- The first term of the biological name begins with a capital letter. The second and the subsequent terms begin with the small letter.

Taxonomic Categories

Various steps of the classification hierarchy are called taxonomic categories. Each category represents a particular rank and is usually called the taxon.

Species: A group of individuals in which the individuals can interbreed among themselves is called species. Members of a species have a large number of similar characters. For example; all the tigers are called Panthera tigris. Since all of them can interbreed hence, they are kept under one species.

Genus: A group of closely related species is called genus. Example; Lion (Panthera leo), leopard (Panthera pardus) and tiger (Panthera tigris) are members of the genus Panthera. Similarly, potato, tomato and brinjal belong to the genus Solanum.

Family: A group of closely related genera is called a family. For example; potato and chili belong the family Solanaceae. Similarly, the genus Panthera and the genus Felis belong to the family Felidae.

Order: A group of closely related families is called order. For example; Convolvulaceae and Solanaceae are plant families which belong to the order Polymoniales. Similarly, Felidae and Concidae belong the order Carnivora.

Class: The group of closely related orders is called class. For example; orders Primata and Carnivora belong to the class Mammalia.

Phylum: A group of closely related classes is called phylum. In the Plant Kingdom; the term phylum has been replaced with division. For example; pisces, amphibia, reptilia, aves and mammalia belong to the Phylum Chordata.

Kingdom: The group of all the related phyla is called the Kingdom. For example; all autotrophic organisms which are eukaryotic and contain chloroplast are kept under the Plant Kingdom. Similarly, all heterotrophic organisms which are eukaryotic and lack a cell wall are kept under Animal Kingdom.

NCERT Solution

Question – 1- Why are living organisms classified?

Answer: There is a huge diversity among living beings. This makes it a challenge to systematically study them. Classification helps in systematic study of the living beings. Systematic study of living beings not only helps the scientists but also the common people; because new scientific discoveries finally benefit the humankind.

Question – 2 - Why are the classification systems changing every now and then?

Answer: Any scientific theory evolves over a period of time. When a new theory disproves an existing theory, it takes the place of the existing theory. Classification system has also evolved through various stages. When scientists could identify some new attributes; they incorporated in the classification system and thus system could be changed.

Question – 3 - What different criteria would you choose to classify people that you meet often?

Answer: We can classify people on the basis of their education, profession, hobbies, native place, gender, etc.

Question – 4 - What do we learn from identification of individuals and populations?

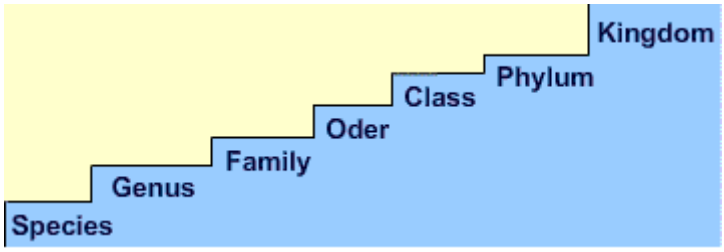
Answer: Through identification of individuals and populations; we can learn about the native place, mother tongue, costumes, food habit, religion, caste, etc.

Question – 5 - Given below is the scientific name of Mango. Identify the correctly written name.

- Mangifera Indica
- Mangifera indica
- Answer: Mangifera indica

Question – 6 - Define a taxon. Give some examples of taxa at different hierarchical levels.

Answer: A particular level of hierarchy in the classification of living beings is called a taxon. Following is the representation of taxa at different levels:



Question – 7 - Can you specify the correct sequence of taxonomic categories?

a. Species , Order, Phylum, Kingdom
b. Genus, Species, Order, Kingdom
c. Species, Genus, Order, Phylum

Answer: (a) and (c) show the correct order.

Question – 8 - Define the following terms:

(a) Phylum

Answer: A group of closely related classes is called phylum. In the Plant Kingdom; the term phylum has been replaced with division. For example; pisces, amphibia, reptilia, aves and mammalia belong to the Phylum Chordata.

(b) Class

Answer: The group of closely related orders is called class. For example; orders Primata and Carnivora belong to the class Mammalia.

(c) Family

Answer: A group of closely related genera is called a family. For example; potato and chili belong the family Solanaceae. Similarly, the genus Panthera and the genus Felis belong to the family Felidae.

(d) Order

Answer: A group of closely related families is called order. For example; Convolvulaceae and Solanaceae are plant families which belong to the order Polymoniales. Similarly, Felidae and Concidae belong the order Carnivora.

(e) Genus

Answer: A group of closely related species is called genus. Example; Lion (Panthera leo), leopard (Panthera pardus) and tiger (Panthera tigris) are members of the genus Panthera. Similarly, potato, tomato and brinjal belong to the genus Solanum.

Question – 9 - How is a key helpful in the identification and classification of an organism?

Answer: A pair of two contrasting characters is called key. While identifying a particular species or any other taxon; we need to select one of the characters and reject another. For example; presence or absence of notochord indicates if the animal belongs to chordata or not.

Question – 10 - Illustrate the taxonomical hierarchy with suitable examples of a plant and an animal.

Answer: Following two examples of show taxonomical hierarchy:

Classification of Human

- Phylum: Chordata
- Class: Mammalia
- Order: Primata
- Family: Hominidae
- Genus: Homo
- Species: Homo sapiens

Classification of Mango

- Phylum: Angiosperm
- Class: Dicotyledons
- Order: Sapindales
- Family: Anacardiaceae
- Genus: Mangifera
- Species: Mangifera indica

2. Biological Classification

Artificial Classification System:

This system was proposed by Linneaus. It was based on vegetative characters and androecium structure.

Natural Classification System: This system was used by George Bentham and Joseph Dalton Hooker. This system was based on natural affinities among organisms. In this system, both external and internal features were considered.

Two Kingdom Classification; as proposed by Linneaus:

- Animal Kingdom
- Plant Kingdom

Five Kingdom Classification; as proposed by R.H. Whittaker (1969):

This is the most accepted system of classification. The five kingdoms are as follows:

- Monera
- Protista
- Fungi
- Plantae and
- Animalia

The main criteria for classification used by Whittaker:

- Cell Structure
- Thallus Organization
- Mode of Nutrition
- Reproduction and
- Phylogenetic Relationships

Characters	Kingdoms				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Cell wall is non-cellular and is composed of polysachharides and amino acids.	Cell wall is present in some organisms.	Cell wall is present but is not made up of cellulose.	Cell wall is made up of cellulose.	Cell wall is absent.
Nuclear membrane	Absent	Present	Present	Present	Present
Body organization	Cellular level of organization	Cellular level of organization	Multicellular + loose tissue	Tissue level and organ level	Tissue level, organ level and organ system level
Mode of nutrition	Autotrophic and heterotophic. Chemosynthesis and photosynthesis is present among autotrophs. Saprophytic and parasitic mode is present among heterotrophs.	Autotrophic (photosynthesis) and heterotrophic.	Heterotophic (saprophytic and parasitic)	Autotrophic (photosynthesis)	Heterotrophic (holozoic, saprophytic, etc.)

KINGDOM MONERA

The bacteria are kept under the Kingdom Monera. They are prokaryotic and possess cell wall. The cell wall is composed of polysaccharides and amino acids. Bacteria can be autotrophic and heterotrophic. The autotrophic bacteria can be chemosynthetic or photosynthetic. The heterotrophic bacteria can be saprophytic or parasitic.

Based on their shape, bacteria are classified into four types:

a. Spherical bacteria are called Coccus (pl.: cocci),
b. Rod-shaped bacteria are called Bacillus (pl.: bacilli),
c. Comma-shaped bacteria are called Vibrium (pl.: vibrio) and
d. Spiral shaped bacteria are called Spirillum (pl.: spirilla)

Archaebacteria: The archaebacteria live in some of the harshest habitats. The different structure of their cell wall helps them in surviving in extreme conditions. Based on their habitats, the archaebacteria are classified as follows:

a. Halophiles: They live in extremely salty areas.
b. Thermoacidophiles: They live in hot spring.
c. Methanogens: They live in marshy areas. They also live in the guts of the ruminant animals. They are responsible for the production of methane from the dung of these animals.

Eubacteria: They are also called the 'true bacteria'. They possess a rigid cell wall, and a flagellum (in motile bacteria). The cyanobacteria are also called 'blue-green algae' because they contain chlorophyll. The cyanobacteria can be unicellular or filamentous. They can live solitary or in colonies. The colony of cyanobacteria is usually surrounded by a gelatinous sheath. Some of the cyanobacteria are capable of nitrogen-fixation, e.g. Nostoc and Anabaena.

Heterotrophic: These are the most abundant in nature. Most of them have economic significance for human beings. While many of them are beneficial for humans, many others are quite harmful.

Reproduction in Bacteria:

Binary fission is the usual mode of reproduction in bacteria. Under unfavourable conditions, they reproduce by spore formation. They also reproduce by adopting a primitive type of DNA transfer from one bacterium to another. This is similar to sexual reproduction.

KINGDOM PROTISTA

They are eukaryotes and unicellular. Some of them have flagella or cilia for locomotion. Reproduction is asexual and sexual. Sexual reproduction is by a process of cell fusion and zygote formation. Kingdom Protista is divided into following groups:

Chrysophytes:

The diatoms and golden algae (desmids) are included in this group. They are found in freshwater and marine habitats. They are microscopic and float passively in water currents and hence are considered as planktons. Organisms which cannot swim against the current are called planktons. Most of the chrysophytes are photosynthetic.

The cell walls in diatoms form two thin overlapping shells; which fit together as the two parts of a soapbox. The cell walls are embedded with silica and hence are indestructible. Due to this, the diatoms leave behind a large amount of cell wall deposits in their habitat. The cell wall accumulation of diatoms; over billions of years is called 'diatomaceous earth'. This soil is gritty and hence is used in polishing, filtration of oils and syrups. Diatoms are the main 'producers' in the oceans.

Dianoflagellates:

They are usually marine and photosynthetic. Depending on the main pigments in their cells; they appear yellow, green, brown, blue or red. Stiff cellulose plates are present on the outer surface of cell wall in dianoflagellates. Two flagella are present in most of them. One flagellum lies longitudinally and another transversely in a furrow between the wall plates.

Euglenoids:

Most of them live in freshwater habitat in stagnant water. Cell wall is absent in them and instead there is a protein rich layer; called pellicle. The pellicle makes their body flexible. Two flagella; one short and another long; are present. They are photosynthetic; but behave as heterotrophs in the absence of sunlight. Example: Euglena.

Slime Moulds:

These are saprophytic. They body moves along decaying twigs and leaves and feeds on organic material. Under favourable conditions, they form an aggregation called plasmodium. The plasmodium may grow and spread over several feet. Under unfavourable conditions, the plasmodium differentiates and forms fruiting bodies. The fruiting bodies bear spores at their tips. True walls are present on the spores. The spores are extremely resistant and survive for many years. The spores are dispersed by air currents.

Protozoans:

They are heterotrophs and live as predators or parasites. The protozoans are classified into following four major groups:

a. Amoeboid protozoans: The amoeboid protozoans live in freshwater, sea water or in moist soil. They produce pseudopodia for locomotion and for capturing food. The marine forms have silica shells on their surface. Some of them are parasites, e.g. Entamoeba histolytica.

b. Flagellated protozoans: They are either free-living or parasitic. Flagella is present for locomotion. Many of them are parasites, e.g. Trypanosoma.

c. Ciliated protozoans: They are aquatic. Cilia are present for locomotion. A cavity (gullet) is present which opens to the outside of the cell surface. The coordinated movement of cilia facilitates the entry of food-laden water into the gullet. Example: Paramoecium.

d. Sporozoans: The sporozoans have an infectious spore-like stage in their life cycle. Example: Plasmodium.

KINGDOM FUNGI:

The fungi are filamentous; except yeast (unicellular). The body consists of long, slender thread-like structures; called hyphae. The network of hyphae is called mycelium. Some hyphae are continuous tubes which are filled with multinucleated cytoplasm. Such hyphae are called coenocytic hyphae. The other type of hyphae has septae or cross-walls. The cell wall of fungi is composed of chitin and polysachharides.

Most of the fungi are heterotrophic and are saprophytes. Some are parasites. Some of the fungi also live as symbionts. Some of the symbiont fungi live as lichens; in association with algae. Some of the symbiont fungi live as mycorrhiza; in association with roots of higher plants.

Reproduction in Fungi:

Reproduction by vegetative means takes place by fragmentation, fission and budding. Some fungi reproduce asexually by forming spores which are called conidia or sporangiospores or zoospores.

Sexual reproduction is by oospores, ascospores and basidiospores. The spores are produced in distinct structures called fruiting bodies.

The sexual cycle involves three steps which are as follows:

a. Plasmogamy: This involves fusion of protoplasm between two motile or non-motile gametes.
b. Karyogamy: This involves fusion of two nuclei.
c. Formation of haploid spores: This happens because of meiosis in zygote.

During sexual reproduction, two haploid hyphae of compatible mating types come together and fuse. In some fungi, the fusion of two haploid cells immediately results in a diploid cell (2n). In other fungi (ascomycetes and basidiomycetes), an intervening dikaryotic stage occurs. In this stage, two nuclei are present in each cell. This condition is called dikayron. The parental nuclei fuse at a later stage and the cells become diploid. Reduction division in the fruiting bodies leads to the formation of haploid spores.

On the basis of morphology of mycelium, mode of spore formation and fruiting bodies; Kingdom Fungi is divided into following classes:

Phycomycetes:

The members of phycomycetes are found in aquatic habitats and on decaying wood in moist and damp places. They can also be found as obligate parasites on plants.

Mycelium: Aseptate and coenocytic.

Reproduction:

- Asexual reproduction is by zoospores (motile) or by aplanospores (non-motile). These spores are endogeneously produced in sporangium.
- Zygospores are formed by fusion of two gametes. The gametes can be similar (isogamous) or dissimilar (anisogamous).

Examples: Mucor, Rhizopus and Albugo (the parasitic fungi on mustard).

Ascomycetes:

They are commonly known as sac-fungi. They are unicellular or multicellular. They are saprophytic, decomposers, parasitic or coprophilous. Those growing on dung are called coprophilous.

Mycelium: Branched and septate.

Reproduction:

Asexual spores are exogenously produced on the special mycelium called conidiophores. Sexual spores are called ascospores. They are produced endogenously in sac like asci. These asci are arranged in various kinds of fruiting bodies called ascocarps.

Examples: Aspergillus, Claviceps, Neurospora, yeast, penicillium, morels, baffles, etc.

Basidiomycetes:

They grow in soil, on logs and tree stumps. Some of them also grow in living plant bodies as parasites. Mushrooms, bracket fungi or puffballs are the commonly known forms.

Mycelium: Branched and septate.

Reproduction:

Asexual spores are usually absent. Vegetative reproduction by fragmentation is common. Sex organs are absent. But plasmogamy is brought about by fusion of two vegetative cells of different strains. The resultant structure is dikaryotic which finally forms the basidium. Karyogamy and meiosis are responsible for formation of four basidiospores in a basidium. The basiodiospores are exogenously produced. Basidia are arranged in fruiting bodies called basidiocarps.

Examples: Agaricus (mushroom), Ustilago (smut) and Puccinia (rust).

Deuteromycetes:

They are usually known as imperfect fungi because only the asexual or vegetative phase of them is known. A large number of deuteromycetes are decomposers, while some members are parasites.

Mycelium: Branched and septate.

Examples: Alternaria, Colletotrichum and Trichoderma.

KINGDOM PLANTAE

All eukaryotes which have chloroplast are kept under this kingdom. Most of them are autotrophic; but some are heterotrophic. Cell wall is mainly composed of cellulose.

The life cycle of plants has two distinct phases; the diploid saprophytic and the haploid gametophytic phase. These phases alternate with each other. The lengths of the haploid and diploid phases vary among different groups of plants. This phenomenon is called Alternation of Generation.

KINGDOM ANIMALIA:

All multicellular eukaryotes which lack cell wall and are heterotrophs are kept under this kingdom. The animals indirectly or directly depend for food on plants. They follow the holozoic mode of nutrition. Holozoic nutrition involves ingestion of food and use of internal cavity for digestion of food. Most of the animals are capable of locomotion. Sexual reproduction is by copulation of male and female which is followed by embryological development.

VIRUSES, VIROIDS AND LICHENS:

Virus is non-cellular organism. It is characterized by an inert crystalline structure outside the living cell. Once a virus infects a living cell, it begins to replicate and kills the host in the process. Virus is considered as a borderline case between living and non-living.

The name virus was given by Pasteur D. J. Ivanowsky (1892). M. W. Beijerinek (1898) demonstrated that the extract of infected tobacco plants could cause infection in healthy plants. He called the fluid from the infected plant as Contagium vivum fluidum (infectious living fluid). W. M. Stanley (1935) demonstrated that viruses could be crystallized and the crystals mainly consist of proteins.

Viruses also contain genetic material; which can be either RNA or DNA. Both RNA and DNA cannot be present in the same virus. Plant infecting viruses usually have single-stranded RNA and animal infecting viruses usually have double-stranded RNA or double-stranded DNA. Bacteriophages (bacterial viruses) usually have double-stranded DNA.

The protein coat on the virus is called capsid. It is made up of small subunits called capsomeres. The capsid protects the nucleic acid. The capsomeres are arranged in helical or polyhedral geometric forms.

Mumps, small pox, herpes, influenza and AIDS are examples of viral diseases in humans. In plants; viral infection leads to the symptoms; like mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth.

NCERT Solution

Question – 1- Discuss how classification systems have undergone several changes over a period of time?

Answer: Scientific classification of living beings was first done by Aristotle. He used morphological characters as the basis of classification. He classified the living beings into plants and animals. He further classified the plant into trees, shrubs and herbs. He further classified the animals on the basis of presence of absence of red blood.

After that, Linnaeus proposed two kingdoms, i.e. Plant Kingdom and Animal Kingdom.

But there were certain organisms which could be kept in both of the kingdoms or could not be kept in either of the kingdoms. Hence, a need was felt for a better system of classification. At present, the Five Kingdom Classification is the most accepted one. This was proposed by Robert Whittaker in 1969. Whittaker used phylogenetic relationship to classify the living beings.

Question – 2 - State two economically important uses of:

(a) Heterotrophic bacteria

Answer: Curd and antibiotic are made by using heterotrophic bacteria.

(b) Archaebacteria

Answer: Methanogens are responsible for production of biogas which can be used as fuel. The archaebacteria which live in extreme conditions give us a clue about the beginning of life on earth.

Question – 3 - What is the nature of cell-walls in diatoms?

Answer: The cell walls in diatoms form two thin overlapping shells; which fit together as the two parts of a soapbox. The cell walls are embedded with silica and hence are indestructible.

Question – 4 - Find out what do the terms ‘algal bloom’ and ‘red-tides’ signify.

Answer: A rapid increase in the population of microscopic algae in an aquatic habitat is called algal bloom. The algal bloom involving the dianoflagellates is called the ‘red tide’ because of its red hue. Red tide can be harmful for other aquatic life forms.

Question – 5 - How are viroids different from viruses?

Answer: The free RNAs without the protein coat are called viroids, while virus have a protein coat to protect the genetic material.

Question – 6 - Describe briefly the four major groups of Protozoa.

Answer: Four major groups of Protozoa is as follows:

a. Amoeboid protozoans: The amoeboid protozoans live in freshwater, sea water or in moist soil. They produce pseudopodia for locomotion and for capturing food. The marine forms have silica shells on their surface. Some of them are parasites, e.g. Entamoeba histolytica.
b. Flagellated protozoans: They are either free-living or parasitic. Flagella is present for locomotion. Many of them are parasites, e.g. Trypanosoma.
c. Ciliated protozoans: They are aquatic. Cilia are present for locomotion. A cavity (gullet) is present which opens to the outside of the cell surface. The coordinated movement of cilia facilitates the entry of food-laden water into the gullet. Example: Paramoecium.
d. Sporozoans: The sporozoans have an infectious spore-like stage in their life cycle. Example: Plasmodium.

Question – 7 - Plants are autotrophic. Can you think of some plants that are partially heterotrophic?

Answer: Pitcher plant, Venus fly trap and bladderwort are examples of partially heterotrophic plants.

Question – 8 - What do the terms phycobiont and mycobiont signify?

Answer: Lichens are the symbiotic association of fungi and algae. The algal part of lichen is called phycobiont and the fungal part is called mycobiont. The mycobiont part provides minerals and support, while the phycobiont part provides nutrition.

Question – 9 - Give a comparative account of the classes of Kingdom Fungi under the following:

(a) Mode of nutrition

- Answer: Phycomycetes are obligate parasites or saprophytes.
- Ascomycetes are saprophytes or parasites or coprophilous.
- Basidiomycetes are saprophytes or parasites.
- Deuteromycetes are manly saprophytes, some are parasites.

(b) Mode of reproduction

- Answer: In phycomycetes, asexual reproduction is by zoospores (motile) or by aplanospores.
- In ascomycetes, asexual spores (conidia) and sexual spores (ascospores) are produced.

- In basidiomycetes, vegetative reproduction takes place by fragmentation. Plsamogamy is also seen.
- In deuteromycetes, only vegetative reproduction is seen.

Question – 10 - What are the characteristic features of Euglenoids?

Answer: Most of them live in freshwater habitat in stagnant water. Cell wall is absent in them and instead there is a protein rich layer; called pellicle. The pellicle makes their body flexible. Two flagella; one short and another long; are present. They are photosynthetic; but behave as heterotrophs in the absence of sunlight.

Question – 11 - Give a brief account of viruses with respect to their structure and nature of genetic material. Also name four common viral diseases.

Answer: Virus contains genetic material surrounded by a protein capsule. The protein coat on the virus is called capsid. It is made up of small subunits called capsomeres. The capsid protects the nucleic acid. The capsomeres are arranged in helical or polyhedral geometric forms.

The genetic material can be either RNA or DNA. Both RNA and DNA cannot be present in the same virus. Plant infecting viruses usually have single-stranded RNA and animal infecting viruses usually have double-stranded RNA or double-stranded DNA. Bacteriophages (bacterial viruses) usually have double-stranded DNA.

Four common viral diseases are: Common cold, mumps, jaundice and influenza.

3. Plant Kingdom

Phylogenetic Classification:

At present phylogenetic classification systems based on evolutionary relationships between the various organisms are acceptable. This assumes that organisms belonging to the same taxa have a common ancestor. We now use information from many other sources too to help resolve difficulties in classification. These become more important when there is no supporting fossil evidence.

Numerical Taxonomy: Numerical Taxonomy is based on all observable characteristics. Number and codes are assigned to all the characters and the data are then processed. In this way each character is given equal importance and at the same time hundreds of characters can be considered.

Cytotaxonomy: Cytotaxonomy that is based on cytological information like chromosome number, structure, behaviour and chemotaxonomy that uses the chemical constituents of the plant to resolve confusions, are also used by taxonomists these days.

ALGAE

Habit & Habitat: Algae are simple and thalloid organisms. They are mainly aquatic organisms and live in freshwater and marine habitats. They bear chlorophyll. Some of the algae also occur in association with fungi (as lichen) and animals (e.g. on sloth bear).

Size: Some of them are unicellular, e.g. Chlamydomonas. Some algae live in colonies, e.g. Volvox. Some algae are in filamentous form, e.g. Ulothrix and Spirogyra. Some of the marine forms make massive plant bodies, e.g. kelps.

Reproduction: Vegetative, asexual and sexual methods of reproduction are present in algae.

Vegetative Reproduction: Vegetative reproduction takes place by fragmentation. During vegetative reproduction, a thallus divides into many fragments and each fragment develops into a thallus.

Asexual Reproduction: Asexual reproduction takes place by different kinds of spores; in algae. Zoospores are the most common type of spore. The zoospores are flagellated and hence are motile. They give rise to new plants on germination.

Sexual reproduction: Fusion of gametes is involved in sexual reproduction. There are following types of fusion of gametes in algae:

a. Isogamous Fusion: In this case, the gametes are similar in size, e.g. Spirogyra. The gametes can be flagellated or non-flagellated.
b. Anisogamous Fusion: In this case, the gametes are dissimilar in size, e.g. some species of Chlamydomonas.
c. Oogamous Fusion: In this case, the female gamete is large and non-motile, while the male gamete is small and motile, e.g. volvox and focus.

Economic Importance of Algae:

- Almost 50% of carbon fixation on earth is carried out by algae. Thus, they are among the large producers on the earth; especially in aquatic habitat. About 70 species of marine algae are used as food, e.g. Porpyra, Laminaria and Sargassum.

- Some marine brown and red algae produce large amounts of hydrocolloids. Hydrocolloids are water holding substances and are used commercially.
- Agar; which is obtained from Gelidium and Gracilaria is used as culture medium in laboratories. It is also used in making ice-cream and jelly.
- Chlorella and Spirullaina are used as food supplements; even during space travel.

The algae are divided into three main classes, viz. Chlorophyceae, Phaeophyceae and Rhodophyceae.

CHLOROPHYCEAE

Characteristics: They are commonly called green algae. Plant body can be unicellular, colonial or filamentous. Dominance of chlorophyll a and b means that chlorophyceae are usually grass green. The chloroplasts may be discoid, plate-like, reticulate, cup-shaped, spiral or ribbon-shaped. Storage bodies; called pyrenoids are found in most of the members. Pyrenoids store protein and starch. Food is also stored in the form of oil droplets in some algae. Cell wall is usually rigid and is composed of an inner layer of cellulose and an outer layer of pectose.

Reproduction: Vegetative reproduction happens by fragmentation or by formation of different types of spores. Asexual reproduction takes place by flagellated zoospores which are produced in zoosporangia. Sexual reproduction can be isogamous, anisogamous or oogamous.

Common Examples: Chlamydomonas, Volvox, Ulothrix, Spirogyra and Chara

PHAEOPHYCEAE

Characteristics: They are also called brown algae. They are found in marine habitats. The brown algae can range from simple branched, filamentous forms to profusely branched forms. Chlorophyll a, c, carotenoids and xanthophyll are the pigments found in phaeophyceae. Colour can vary from olive green to various shades of brown. The colour variation depends on the amount of xanthophyll and fucoxanthin.

Food is stored as complex carbohydrates; in the form of laminarin or mannitol. The cell wall of vegetative cells is composed of cellulose and is covered by a gelatinous coating of algin. Protoplast contains plastids, centrally located vacuole and nucleus.

Plant body is usually attached to the substratum by a holdfast. The plant body has a stalk, stipe and leaf-like fond.

Reproduction: Vegetative reproduction is by fragmentation. Asexual reproduction takes place by biflagellate zoospores. Sexual reproduction can be isogamous, anisogamous or oogamous. Fusion of gametes can happen in water or within the oogonium. Gametes are pyriform (pear-shaped) and bear two laterally attached flagellum.

Common Examples: Ectocarpus, Dictyota, Laminaria, Sargassum and Fucus

RHODOPHYCEAE

Characteristics: These are commonly called red algae. The red pigment, r-phycoerythrin is predominant in rhodopytes. Most of them are marine species and are mainly found in warm areas. They are found

in well-lit regions close to the surface of water as well as at great depths. The thallus is multicellular in most of the cases. Food is stored as floridean starch.

Reproduction: Vegetative reproduction is by fragmentation and it is the most prevalent method of reproduction. Asexual reproduction is by non-motile spores. Sexual reproduction is oogamous. Post-fertilisation development is complex.

Common Examples: Polysiphonia, Porphyra, Gracilaria and Gelidium.

BRYOPHYTES

Habits & Habitats: Bryophytes include the various mosses and liverworts which are usually found in moist shaded areas in the hills. Bryophytes are also called amphibians of the plant kingdom because they can live on soil but need water for sexual reproduction. They are usually found in damp, humid and shaded localities.

Characteristics: The plant body is thallus-like and can be prostrate or erect. The plant body is attached to the substratum by unicellular or multicellular rhizoids. True roots, stem or leaves are absent. However, root-like, leaf-like or stem-like structures may be present.

Reproduction: The main plant body is haploid in bryophytes. The main plant body is called gametophyte because it produces gametes. Sex organs are multicellular. Male sex organ is called antheridium and produces biflagellate antherozoids. The female sex organ is called archegonium and produces a single egg. Antherozoids are released into water for fertilization. After fertilization, zygote does not immediately divide meiotically. Zygote produces a multicellular body called sporophyte. Sporophyte is attached to the photosynthetic gametophyte so that it can get nourishment from the gametophyte. Some cells of the sporophyte undergo meiosis to produce haploid spores. The spores germinate to produce gametophyte.

Economic Importance of Bryophytes:

- Peat is obtained from species of Sphagnum which is a moss. Peat has been in use as fuel. Peat is also used as packing material for shipment of living materials; because peat has good capacity to hold water.
- Mosses are among the first organisms to colonise rocks and thus play an important role in soil formation. Some mosses also prevent soil erosion which may happen because of rains; as they form dense mats on soil.

The bryophytes are divided into two classes, viz. liverworts and mosses.

LIVERWORTS

Characteristics: They usually grow in moist and shady habitats. The plant body is thalloid. Thallus is dorsiventral and closely appressed to the substrate. Some members have tiny leaf-like appandages in two rows on the stem-like structures.

Reproduction: Asexual reproduction takes place by fragmentation, or by formation of specialized structures called gemmae. A gemma is a green, multicellular, asexual bud. A gemma develops in small receptacles called gemma cup. The gemma gets detached from the parent body and germinates to form a new individual.

In case of sexual reproduction; male and female sex organs are produced either on the same or on different thalli. The sporophyte is differentiated into a foot, seta and capsule. Spores are produced after meiosis. These spores germinate to produce free-living gametophytes.

MOSSES

Characteristics: Gametophyte is the predominant stage of the life cycle of moss. The gametophyte consists of two stages, viz. protonema stage and leafy stage.

Protonema develops from the spore. It is creeping, branched and usually filamentous.

The leafy stage develops from the protonema as a lateral bud. The leafy stage consists of upright, slender axes bearing spirally arranged leaves. It is attached to the soil through multicellular and branched rhizoids. The leafy stage bears the sex organs.

Reproduction: Vegetative reproduction takes place by fragmentation and budding in the secondary protonema.

In case of sexual reproduction, antheridia and archegonia are produced at the apex of the leafy shoots. After fertilization, the zygote develops into a sporophyte. The sporophyte consists of a foot, seta and capsule. The capsule contains spores. Spores are formed after meiosis. There is an elaborate mechanism of spore dispersal in mosses.

Common Examples: Funaria, Polytrichum and Sphagnum

PTERIDOPHYTES

Characteristics: Pteridophytes are found in cool, damp and shady places. Some of them may also proliferate in sandy soil. The main plant body is a sporophyte. It is differentiated into true root, stem and leaves. Well-differentiated vascular tissues are present. Small leaves called microphylls are found in some pteridophytes, e.g. Selaginella. Large leaves called megaphylls are found in some others, e.g. ferns. Sporophyte bears sporangia which are subtended by leaf-like appendages called sporophylls. In some cases, the sporophylls may form distinct compact structures called strobili or cones, e.g. Selaginella, Equisetum.

Reproduction: Spores are produced by the mother cells in sporangia; through meiosis. The spores germinate and produce thalloid gametophyte called prothallus. The prothallus is inconspicuous, small but multicellular. The prothallus is free-living and usually photosynthetic.

The gametophytes need cool, damp and shady places to grow. Due to this specific requirement, pteridophytes are spread to limited areas to narrow geographical regions.

The gametophyte bears antheridia and archegonia. Transfer of antheroizoids is facilitated by water. The zygote produces a multicellular well-differentiated sporophyte.

Most of the pteridophytes are homosporous, i.e. they produce spores of similar type. Some pteriophytes are heterosporous, e.g. Selaginella and Salvinia. In heterospory, the megaspore germinates to produce female gametophyte, while the microspore germinates to produce the male gametophyte. This event is a precursor of the seed habit in higher plants.

The pteridophytes are divided into four classes, viz. Psilopsida, Lycopsida, Sphenopsida and Pteropsida.

GYMNOSPERMS

Characteristics of Gymnosperms

The ovules in gymnosperms are not enclosed by an ovary wall. The seeds too are not covered, i.e. naked. Gymnosperms include medium-sized or tall trees and shrubs.

These plants usually have tap roots. Roots of some plants have fungal association in the form of mycorrhiza, e.g. pinus. In some other plants, small specialized roots; called coralloid roots; are associated with nitrogen-fixing cyanobacteria, e.g. cycas.

The stems are unbranched (Cycas) or branched (Pinus, cedrus). Leaves can be simple or compound. The pinnate leaves in cycas persist for a few years. The leaves are well adapted to withstand extremes of temperature, humidity and wind. Needle-like leaves of conifer reduce surface area and thus reduce transpiration. Thick cuticle and sunken stomata also help in preventing water loss.

Reproduction In Gymnosperms

Gymnosperms are heterosporous. Haploid microspores and megaspores are produced. Spores are produced within sporangia. Sporangia are borne on sporophylls which are arranged spirally along an axis. The Sporophylls form lax or compact strobili or cones.

Male Cone:

The male strobili are called microsporangiate. Microspores develop into a male gametophytic generation which is highly reduced and is confined to only a limited number of cells. This small-sized gametophyte is called pollen grain.

Female Cone:

The female strobili are called megasporangiate. The male or female cones can be found on the same tree (pinus) or on different trees (cycas). The megaspore mother cell is differentiated from one of the cells of the nucellus. Nucellus is protected by envelopes and the composite structure and is called an ovule. Meiotic division in the megaspore mother cell produces four megaspores. One of the megaspores develops into a multicellular female gametophyte. The female gametophyte bears two or more archegonia or female sex organs. The female gametophyte is retained within the megasporangium.

Fertilization:

The pollen grains are released from the microsporangium and carried by air currents. They come in contact with the opening of the ovules on the female cone. A pollen tube develops in the pollen grain. The male gamete travels through the pollen tube to reach near the mouth of archegonia. After fertilization, zygote develops into an embryo. The ovule develops into seed.

ANGIOSPERMS

Characteristics of Angiospersm

These are also called the “Flowering Plants”. Male and female gametes are developed in specialized structures called flowers. The seeds are enclosed by fruits. They are a very large group of plants and are found in a wide range of habitats. The angiosperms can be microscopic (Wolfia) to over 100 metre tall trees. They are highly important for us because we get food, fodder, fuel, medicines, and many other useful products from them.

Angiosperms are divided into two classes, viz. dicotyledon and monocotyledon.

Reproduction In Angiosperms

Male Sex Organ: Stamen is the male sex organ in the flower. A stamen is composed of a slender filament and an anther at the top. The anthers produce pollen grains through meiosis.

Female Sex Organs: Pistil or carpel is the female sex organ in a flower. The pistil consists of an ovary. The ovary may enclose one or many ovules. The embryo sac is formed by meiosis. Each embryo sac has a three-celled egg apparatus, three antipodal cells and two polar nuclei. The egg apparatus has one egg cell and two synergids. The polar nuclei finally fuse to produce a diploid secondary nucleus.

Pollination: Transfer of pollen grains to stigma is called pollination. Pollination is facilitated by various agents; like wind, water, animals, insects, etc.

Fertilization: Pollen grain germinates on the stigma and produces a pollen tube. The pollen tube pierces through the stigma and style and reaches the ovule. The male gametes are discharged near the embryo sac. One of the male gametes fuses with the egg cell and forms a zygote. The other male gamete fuses with the diploid secondary nucleus to produce the triploid Primary Endosperm Nucleus (PEN). This event is called Double Fertilisation because of the involvement of two fusions. Double fertilization is unique to angiosperms.

Embryo: The zygote develops into an embryo and the PEN develops into endosperm. Endosperm provides nutrition to the developing embryo. Synergids and antipodals degenerate after fertilization. Ovules develop into seeds and ovaries develop into fruits.

Alteration of generations

Both haploid and diploid cells in plants can undergo mitosis. Due to this, formation of haploid and diploid plant bodies becomes possible. The haploid plant body produces gametes and it represents a gametophyte. After fertilization, the zygote undergoes mitosis and produces a diploid sporophytic plant body. The diploid sporophytic plant produces haploid spores by meiosis. The spores then undergo mitosis and form a haploid plant body once again.

Thus, during the life cycle of any sexually reproducing plant, there is an alternation of generations between gametophyte and sporophyte. This phenomenon is called alternation of generations.

But different groups of plants differ in relative length and size of haploid or diploid generations. Such variations are as follows:

Haplontic: In such plants, a free-living gametophyte is the dominant photosynthetic phase. In this case, the sporophytic generation is represented only by the one-celled zygote. There is no free-living sporophyte. The zygote undergoes meiosis to form haploid spores. The spores then undergo mitosis to form the gametophyte. Examples: Volvox, Spirogyra and some species of Chlamydomonas.

Diplontic: In this case, the diploid sporophyte is the dominant photosynthetic phase of the plant. The gametophyte is represented by the single to few-celled haploid gametophyte. Gymnosperms and angiosperms show this pattern.

Haplo-diplontic: In this case, both phases are multicellular and free-living. Bryophytes and pteridophytes follow this pattern.

NCERT Solution

Question – 1 - What is the basis of classification of algae?

Answer: The presence or absence of pigments is the main basis of classification of algae.

Chlorophyceae: Chlorophyll a and b are present in them and impart green colour. Chlorophyceae are also called ‘blue-green algae’.

Phaeophyceae: Chlorophyll a and c and fuxoxanthin are present. Fucoxanthin imparts brown colour. Phaeophyceae are also called ‘brown algae’.

Rhodophyceae: Chlorophyll a and d and phycoerythrin are present. Phycoerythrin imparts red colour. Rhodophyceae are also called ‘red algae’.

Question – 2 - When and where does reduction division take place in the life cycle of a liverwort, a moss, a fern, a gymnosperm and an angiosperm?

Answer: In case of liverwort, moss and fern; the saprophytic plant produces haploid spores after meiosis. In case of gymnosperm and angiosperm, meiosis takes place in antheridium and ovary; for the formation of pollen grains and ovules.

Question – 3 - Name three groups of plants that bear archegonia. Briefly describe the life cycle of any one of them.

Answer: Gymnosperms are heterosporous. Haploid microspores and megaspores are produced. Spores are produced within sporangia. Sporangia are borne on sporophylls which are arranged spirally along an axis. The Sporophylls form lax or compact strobili or cones.

Male Cone: The male strobili are called microsporangiate. Microspores develop into a male gametophytic generation which is highly reduced and is confined to only a limited number of cells. This small-sized gametophyte is called pollen grain.

Female Cone: The female strobili are called megasporangiate. The male or female cones can be found on the same tree (pinus) or on different trees (cycas). The megaspore mother cell is differentiated from one of the cells of the nucellus. Nucellus is protected by envelopes and the composite structure and is called an ovule. Meiotic division in the megaspore mother cell produces four megaspores. One of the megaspores develops into a multicellular female gametophyte. The female gametophyte bears two or

more archegonia or female sex organs. The female gametophyte is retained within the megasporangium.

Fertilization: The pollen grains are released from the microsporangium and carried by air currents. They come in contact with the opening of the ovules on the female cone. A pollen tube develops in the pollen grain. The male gamete travels through the pollen tube to reach near the mouth of archegonia. After fertilization, zygote develops into an embryo. The ovule develops into seed.

Question – 4 - Mention the ploidy of the following:

a. Protonemal cell of a moss;
   Answer: Haploid

b. Primary endosperm nucleus in dicot,
   Answer: Triploid

c. Leaf cell of a moss;
   Answer: Haploid

d. Prothallus cell of a ferm;
   Answer: Haploid

e. Gemma cell in Marchantia;
   Answer: Diploid

f. Meristem cell of monocot,
   Answer: Diploid

g. Ovum of a liverwort,
   Answer: Diploid

h. Zygote of a fern.
   Answer: Zygote

Question – 5 - Write a note on economic importance of algae and gymnosperms.

Answer: Economic Importance of Algae:

- Almost 50% of carbon fixation on earth is carried out by algae. Thus, they are among the large producers on the earth; especially in aquatic habitat. About 70 species of marine algae are used as food, e.g. Porpyra, Laminaria and Sargassum.
- Some marine brown and red algae produce large amounts of hydrocolloids. Hydrocolloids are water holding substances and are used commercially.
- Agar; which is obtained from Gelidium and Gracilaria is used as culture medium in laboratories. It is also used in making ice-cream and jelly.
- Chlorella and Spirullaina are used as food supplements; even during space travel.

Economic Importance of Gymnosperms:

- They are widely used as ornamental plants.
- Fibres from conifer are used as paper pulp.

- Conifers are widely used in reforestation projects.
- Turpentine and rosin are made from conifer resin.
- Commercially useful oils are produced from many conifers, e.g. juniper, pine, fir, etc.

Question – 6 - Both gymnosperms and angiosperms bear seeds, then why are they classified separately?

Answer: The seeds of gymnosperm are naked, while those of angiosperms are covered. Hence, they are kept in different groups.

Question – 7 - What is heterospory? Briefly comment on its significance. Give two examples.

Answer: Some pteriophytes are heterosporous, e.g. Selaginella and Salvinia. In heterospory, the megaspore germinates to produce female gametophyte, while the microspore germinates to produce the male gametophyte. This event is a precursor of the seed habit in higher plants.

Question – 8 - Explain briefly the following terms with suitable examples:-

(a) Protonema

Answer: A protonema forms the earliest stage of a bryophyte life cycle. It is a thread-like chain of cells. Protonema is formed just after the germination of spores. It subsequently develops into a leafy gametophyte.

(b) Antheridium

Answer: An antheridium is the male sex organ of a plant. It produces the male gametes. It is present in the gametophyte phase of lower plants, but is present in the sporophyte phase of higher plants.

(c) Archegonium

Answer: Archegonium is a structure which is present in the gametophyte phase of some plants. The archegonium produces the female gamete.

(d) Diplontic

Answer: In this case, the diploid sporophyte is the dominant photosynthetic phase of the plant. The gametophyte is represented by the single to few-celled haploid gametophyte. Gymnosperms and angiosperms show this pattern.

(e) Sporophyll

Answer: A leaf or cluste of leaves which bears sporangia is called sporophyll. Sporophylls can produce microspores or megaspores as the case may be.

(f) Isogamy

Answer: In this case, the gametes are similar in size, e.g. Spirogyra. The gametes can be flagellated or non-flagellated.

4. Animal Kingdom

Basis of Classification

Levels of Organisation

1. Cellular Level: In case of cellular level organization, a single cell is responsible for all the metabolic activities. Cellular level organization is present in unicellular animals and some of the muclticellular animals.
2. Tissue Level: In case of tissue level organization, a group of cells is responsible for all the metabolic activities, e.g. coelenterates.
3. Organ Level: In case of organ level organization, some specialized organs are present for some specific functions, e.g. Platyhelminthes.
4. Organ System Level: In organ system level organization, complex organ systems are present for various functions, e.g. mollusca, chordate.

Symmetry

Some of the animals are almost asymmetrical. Their body cannot be divided into two equal halves from any plane, e.g. sponges.

Radial Symmetry: In case of radial symmetry, any plane passing through the central axis divides the body into two identical halves, e.g. coelenterates, ctenophores, echinoderms, etc.

Bilateral Symmetry: In case of bilateral symmetry, the body can be divided into two identical halves only through a single plane, e.g. annelida, arthropoda, etc.

Diploblastic and Triploblastic Organisation

When the cells are arranged in two embryonic layers, the animal is called a diploblastic animal. The two layers are; ectoderm and endoderm. Mesoglea; which is an undifferentiated layer is present between the ectoderm and endoderm. Example: coelenterates.

When the cells are arranged in three embryonic layers, the animal is called triploblastic animal. The three layers are; ectoderm, mesoderm and endoderm. Examples: Platyhelminthes to chordates.

Coelom

The body cavity; which is lined by mesoderm is called coelom.

Coelomates: If coelom is present, the animal is called coelomate, e.g. annelids, molluscs, arthropods, echnioderms, hemichordates and chordates.

Pseudoceolomates: If the body cavity is not lined by mesoderm but the mesoderm is present as scattered pouches in between the ectoderm and endoderm, the animal is called pseudocoelomate, e.g. aschelminthes.

Acoelomates: When the body cavity is absent, the animal is called acoelomate, e.g. platyhelminthes.

Segmentation

The body of some animals is externally and internally divided into segments with serial repetition of at least some organs. For example; the body of the earthworm shows metameric segmentation. This phenomenon is called metamerism.

Notochord

Notochord is a mesodermally derived rod-like structure. It is formed on the dorsal side during embryonic development in some animals. If notochord is present then the animal comes under chordates. An animal without notochord is called non-chordate, e.g. porifera to echinoderms.

CLASSIFICATION OF ANIMALS

PHYLUM – PORIFERA

These are also known as sponges. They are usually found in marine habitat. Most of the poriferans are asymmetrical. Cellular level organization is present in these animals. 'Pores on the body' is the main feature of these animals.

Water Transport System in Sponges: Water transport system is a distinguishing feature of sponges. Water enters the body through minute pores on the body wall. Water enters into a central cavity (spongocoel) and then goes out through the osculum. The water transport system helps in gathering food, in exchange of gases and in excretion. The spongocoel and canals are lined by collar cells or choanocytes. Digestion is intracellular. A skeleton made up of spicules or sponging fibres supports the body.

Reproduction: These are hermaphrodite animals, i.e. sexes are not separate. While sexual reproduction is by gamete formation, asexual reproduction is by fragmentation. Fertilization is internal and development is indirect.

PHYLUM – COELENTERATA (CNIDARIA):

These are aquatic animals and most of them live in marine habitat. They can be sessile or free-swimming. The body is radially symmetrical. Body is composed of a cavity which has only one opening. Stinging capsules or nematocytes are present on the tentacles. Cnidoblasts are used for anchorage, defense and for capturing the prey.

Tissue level organization is present in cnidarians. They are diploblastic animals. Digestion is extracellular and intracellular. Some of the cnidarians have a skeleton composed of calcium carbonate, e.g. corals.

There are two basic body forms in the cnidarians, viz. polyp and medusa. Polyp is sessile and cylindrical form, e.g. Hydra, Adamsia, etc. Medussa is umbrella-shaped and free-swimming, e.g. Aurelia (Jelly Fish). Some cnidarians exist in both forms and exhibit alternation of generations, i.e. metagenesis. In this case, the polyp produces the medusa asexually and the medusa produces the polyp sexually.

Common Examples: Physalia (Portuguese man-of-war), Adamsia (Sea anemone), Pennatula (Sea-pen), Gorgonia (Sea-fan) and Meandrina (Brain coral).

PHYLUM – CTENOPHORA

These are commonly known as sea walnuts or comb jellies. These are exclusively marine animals. The body is radially symmetrical and diploblastic. Tissue level organization is present. There are eight eternal rows of ciliated comb plates on the body. These rows help in locomotion. Digestion is both extracellular and intracellular. Bioluminescence is well-developed in ctenophores.

Reproduction: These are hermaphrodite animals. Reproduction is only through sexual means. Fertilisation is external and development is indirect.

Common Examples: Pleurobrachia and Ctenoplana.

PHYLUM – PLATYHELMINTHES

Habit and Habitat: These are also called flatworms because of dorso-ventrally flattened body. Most of the flatworms live as endoparasites in animals; including human bodies. They are bilaterally symmetrical, triploblastic and acoelomate animals. Organ level organization is present in them.

Hooks and suckers are present in the parasitic forms. Some of the flatworms absorb nutrients from the host directly through their body surface. Osmoregulation and excretion are carried on by specialized cells called flame cells.

Reproduction: Flatworms are hermaphrodite animals. Fertilization is internal and development is indirect. Some members have the ability for regeneration, e.g. planaria.

Common Examples: Taenia solium (Tapeworm), Fasciola (Liverfluke)

PHYLUM – ASCHELMINTHES

Habit and Habitat: These are also called roundworms because their body appears circular in cross-section. They can be free living, aquatic and terrestrial. Some of them are parasitic in plants and animals. Organ system level of organization is present. The roundworms are bilaterally symmetrical, triploblastic and pseudocoelomate.

Digestive System: Alimentary canal is complete. Well developed muscular pharynx is present. There is an excretory tube to remove wastes through excretory pore.

Reproduction: The roundworms are dioecious, i.e. sexes are separate. Females are usually longer than males. Fertilization is internal and development can be direct or indirect.

Common Examples:- Ascaris (Round Worm), Wuchereria (Filaria worm), Ancylostoma (Hookworm).

PHYLUM – ANNELIDA

Habit and Habitat: The annelids are aquatic or terrestrial. The aquatic annelids are found in marine and freshwater habitats. Most of them are free-living, while some can be parasitic. Organ system level organization is present. Body is bilaterally symmetrical, coelomate and triploblastic. The body is metamerically symmetrical. The body is distinctly divided into segments or metameres.

Longitudinal and circular muscles are present to help in locomotion. Aquatic annelida possess lateral appendages (parapodia) which facilitates swimming, e.g. Nereis. Closed circulatory system is present.

Nephridia are present for excretion and osmoregulation. The neural system is composed of paired ganglia which are connected by lateral nerves to a double ventral nerve cord.

Reproduction: Earthworms and leeches are hermaphrodite, while nereis is dioecious.

Common Examples:- Nereis, Pheretima (Earthworm) and Hirudinaria (Blood sucking leech).

PHYLUM – ARTHROPODA

The presence of joint appendages is the reason for name arthropoda. This is the largest phylum of Animalia and over two-thirds of all known species on the earth are arthropods.

Organ system level of organization is present. Body is bilaterally symmetrical, triploblastic, segmented and coelomate.

Structure: The body consists of head, thorax and abdomen. Body is covered with exoskeleton made up of chitin. Respiration is carried out by gills, book gills, book lungs or tracheal system. Open circulatory system is present. Sensory organs; like antennae, eyes, statocysts (balance organs) are present. Eyes can be compound or simple. Malpighian tubules are the excretory organs.

Reproduction: Most of the arthropods are dioecious. Fertilisation is usually internal and development can be direct or indirect. Most of them are oviparous.

Common Examples:- Economically important insects – Apis (Honey bee), Bombyx (Silkworm), Laccifer (Lac insect) Vectors – Anopheles, Culex and Aedes (Mosquitoes) Gregarious pest – Locusta (Locust) Living fossil – Limulus (King crab).

PHYLUM – MOLLUSCA

Mollusca is the second largest phylum of Animalia. They are terrestrial or aquatic. The aquatic molluscs live in marine or freshwater habitats. Organ system level organization is present. Body is bilaterally symmetrical, triploblastic and coelomate.

The body is covered by a shell which is made up of calcium carbonate. Body is unsegmented with a distinct head, muscular foot and visceral hump. A mantle is formed over the visceral hump by a soft and spongy layer of skin. The space between the hump and the mantle is called mantle cavity. Feather-like gills are present in the mantle cavity. The gills facilitate respiration and excretion. Sensory tentacles are present in the anterior head region. File-like rasping organ; called radula is present in the mouth for feeding.

Reproduction: These are usually dioecious and oviparous. Development is indirect.

Common Examples:- Pila (Apple snail), Pinctada (Pearl oyster), Sepia (Cuttlefish), Loligo (Squid), Octopus (Devil fish), Aplysia (Seahare), Dentalium (Tusk shell) and Chaetopleura (Chiton).

PHYLUM – ECHINODERMATA

Ehinodermates have an endoskeleton made up of calcareous ossicles. Due to this, the body is covered with spines. These are marine animals. Organ system level organization is present. Adults are radially

symmetrical but larvae are bilaterally symmetrical. Body is triploblastic and coelomate. Digesive system is complete. Mouth is present on the ventral side and anus is present on the dorsal side.

Water canal system is the most distinctive feature of echinoderms. The water canal system helps in locomotion, capture and transport of food and respiration. Excretory system is absent.

Reproduction: These are dioecious animals. Fertilisation is usually external. Development is indirect. Larvae are free-swimming.

Common Examples:- Asterias (Star fish), Echinus (Sea urchin), Antedon (Sea lily), Cucumaria (Sea cucumber) and Ophiura (Brittle star).

PHYLUM – HEMICHORDATA

This phylum has a small group of animals which look like worms. Organ system level organization is present. Body is bilaterally symmetrical, triploblastic and coelomate. The body is cylindrical and consists and anterior proboscis, a collar and a long trunk.

Open circulatory system is present. Gills are present for respiration. Proboscis gland is the excretory organ.

Reproduction: These are dioecious animals. Fertilisation is external and development is indirect.

Common Examples:- Balanoglossus and Saccoglossus.

PHYLUM – CHORDATA

The main features of chordates are the presence of notochord, a dorsal hollow nerve cord and paired pharyngeal gill slits. The body is bilaterally symmetrical, triploblastic, coelomate. Organ system level of organization is present. Closed circulatory system is present. A post anal tail is present.

Phylum Chordata is divided into three subphyla which are as follows:

1. Urochordata or Tunicata,
2. Cephalochordata and
3. Vertebrata.

Subphyla Urochordata and Cephalochordata are usually referred to as protochordates. These are exclusively marine animals. In Urochordata, notochord is present only in larval tail. In Cephalochordata, the notochord extends from head to tail region and is persistent throughout the life.

Common Examples:- Urochordata – Ascidia, Salpa, Doliolum; Cephalochordata – Branchiostoma (Amphioxus or Lancelet).

VERTEBARATA

Notochord is present during the embryonic period only. After that, the notochord is replaced by a cartilaginous or bony vertebral column in the adult.

A ventral muscular heart is present as the main organ of the circulatory system. The heart can have two, three or four chambers. Kidneys are present for excretion and osmoregulation. Paired appendages are present for locomotion.

Difference between chordates and non-chordates	
Chordates	Non-chordates
Notochord present	Notochord absent.
Pharynx is perforated by gill slits.	Gill slits absent.
Heart is ventral.	Heart is dorsal (if present).
Post anal tail is present.	Post anal tail is absent.

Phylum chordata can be divided into two sub-phyla, viz. agnatha and gnathostomata.

Sub-phylum Agnatha: Jaws are absent.

Sub-Phylum Gnathostomata: Jaws are present.

There is only one class; Cyclostomata in the sub-phylum Agnatha. Gnathostomata is divided into two super-classes, viz. pisces and tetrapoda. Fins are present in pisces for locomotion. Four limbs are present in tetrapoda for locomotion. Super-class tetrapoda is further divided into four classes, viz. amphibia, reptilia, aves and mammalia.

CLASS – CYCLOSTOMATA

All the existing members of the class Cyclostomata are ectoparasites on some fishes. The body is elongated. There are 6 -15 pairs of gill slits for respiration. A sucking and circular mouth is present. The body is devoid of scales and paired fins.

Cranium and vertebral column are composed of cartilage. Closed circulatory system is present.

Reproduction: They are marine animals but migrate to freshwater for spawning. They die within a few days of spawning. The larvae return to the ocean after metamorphosis.

Common Examples: Petromyzon (Lamprey) and Myxine (Hagfish).

CLASS – CHONDRICHTHYES

These are also known as cartilaginous fish because of cartilaginous endoskeleton. These are marine animals. Mouth is ventrally located. Notochord is present throughout the life. Gill slits are separate and operculum (gill cover) is absent. Skin is tough and has minute placoid scales. Teeth are modified placoid scales and are backwardly directed. Jaws are very powerful. These are predaceous animals. Air bladder is absent and hence the animal has to swim constantly to avoid sinking.

There are two chambers in the heart. Some animals of this class have electric organs, e.g. torpedo. Some animals, on the other hand, possess poison sting, e.g. Trygon. They are cold-blooded (poikilothermous) animals.

Reproduction: These are dioecious animals. The pelvic fins in males bear claspers. Fertilization is internal and many of them are viviparous.

Common Examples: Scoliodon (Dog fish), Pristis (Saw fish), Carcharodon (Great white shark), Trygon (Sting ray).

CLASS – OSTEICHTHYES

These are also called bony fishes because of bony endoskeleton. The body is streamlined. Mouth is usually terminal. There are four pairs of gills which are covered by operculum on each side. The skin is covered with cycloid/ctenoid scales. Air bladder is present which helps in buoyancy. The heart is two-chambered. They are cold-blooded animals.

Reproduction: These are dioecious animals. Fertilization is usually external and development is direct. Most of the bony fishes are oviparous.

Common Examples:- Marine – Exocoetus (Flying fish), Hippocampus (Sea horse); Freshwater – Labeo (Rohu), Catla (Katla), Clarias (Magur); Aquarium – Betta (Fighting fish), Pterophyllum (Angel fish).

CLASS – AMPHIBIA

The amphibians can live both in aquatic and terrestrial habitats. They need water for fertilization. Two pairs of limbs are present in most of the amphibians. Body is divided into head and trunk. Tail can be present in some of them. The skin is moist and scales are absent. Eyelids are present on the eyes. A tympanum represents the ear. There is a common chamber; called cloaca; in which the alimentary canal, urinary tract and reproductive tract open. Respiration is by gills, lungs and through skin.

There are three chambers in the heart (two auricles and one ventricle). These are cold-blooded animals.

Reproduction: These are dioecious animals. Fertilization is external and development can be direct or indirect. These are oviparous animals.

Common Examples:- Bufo (Toad), Rana (Frog), Hyla (Tree frog), Salamandra (Salamander), Ichthyophis (Limbless amphibia).

CLASS – REPTILIA

These animals show creeping or crawling mode of locomotion. Most of them are terrestrial animals. The body is covered by dry and cornified skin, epidermal scales (scutes). Tympanum represents ear. Limbs are in two pairs; when present.

Three-chambered heart is present in most of the reptiles. Crocodiles have four-chambered heart. These are cold-blooded animals.

Reproduction: These are dioecious animals. Fertilization is internal and development is direct. These are oviparous animals.

Common Examples:- Chelone (Turtle), Testudo (Tortoise), Chameleon (Tree lizard), Calotes (Garden lizard), Crocodilus (Crocodile), Alligator (Alligator). Hemidactylus (Wall lizard), Poisonous snakes – Naja (Cobra), Bangarus (Krait), Vipera (Viper).

CLASS – AVES

Presence of feathers and wings are the characteristic features of Aves. The forelimbs are modified into wings. The hind limbs usually have scales and are modified for walking, swimming or clasping the tree branches. Skin is dry without glands, but oil gland is present at the base of the tail. Beaks are present.

The endoskeleton is composed of bones. Long bones are pneumatic, i.e. are hollow with air cavities. Air cavities in the long bones help in weight reduction and this is an important flight adaptation. Crop and gizzard are the additional chambers in the digestive tract.

There are four chambers in the heart. They are warm-blooded (homoiothermous) animals. Respiration is by lungs, and air sacs; connected to lungs; supplement respiration.

Reproduction: These are dioecious animals. Fertilization is internal and development is direct. They are oviparous animals.

Common Examples:- Corvus (Crow), Columba (Pigeon), Psittacula (Parrot), Struthio (Ostrich), Pavo (Peacock), Aptenodytes (Penguin), Neophron (Vulture).

CLASS – MAMMALIA

Presence of mammary glands is the most unique feature of these animals. The young ones are nourished by the mammary glands. Hairs are present on the skin and external ears are present. Different types of teeth are present in the jaw. The two pairs of limbs are adapted for walking, running, climbing, burrowing, swimming or flying.

There are four chambers in the heart. They are warm-blooded animals. Respiration is by lungs.

Reproduction: They are dioecious animals. Fertilization is internal and development is direct. Most of them are viviparous.

Common Examples:- Oviparous - Ornithorhynchus (Platypus);

Viviparous - Macropus (Kangaroo), Pteropus (Flying fox), Camelus (Camel), Macaca(Monkey), Rattus (Rat), Canis (Dog), Felis (Cat), Elephas (Elephant), Equus (Horse), Delphinus (Common dolphin), Balaenoptera (Blue whale), Panthera tigris (Tiger), Panthera leo (Lion).

Distinct Characters of 4 classes of the Superclass Tetrapoda:

1. Amphibia: Capable of living on both land and water but need water for some stages of the life cycle. Respiration is through lungs, skin and gills. These are cold-blooded animals.
2. Reptilia: Creeping or crawling mode of locomotion. The skin is hard with scale like structures. These are cold-blooded animals.
3. Aves: Pneumatic bones, feathers and wings are the important flight adaptations. Forelimbs are modified into wings. These are warm-blooded animals.
4. Mammal: Milk is produced by the mammary glands in females and is utilised for nourishing the young ones. Hairs are present on the skin. External ears are present. These are warm-blooded animals.

NCERT Solution

Question 1. What are the difficulties that you would face in classification of animals, if common fundamental features are not taken into account?

Answer: Using the common fundamental features helps in segregating the animals in different groups. Let us take the example of presence or absence of notochord. This feature helps us in grouping the animals among chordates and non-chordates. Similarly, two or three embryonic layers are taken for grouping the animals under diploblastic and triploblastic categories. Use of fundamental features in classification paves the way for further segregation of animals among different sub-groups.

Question 2:- If you are given a specimen, what are the steps that you would follow to classify it?

Answer: Steps to Follow for Classification:

- The first step should be look for the presence or absence of vertebral column.
- The next step would be to identify the level of organization.
- The next step should be to look for symmetry, i.e. radial or bilateral or asymmetrical.
- The next step would be to look for presence or absence of body cavity.

Question 3:- How useful is the study of the nature of body cavity and coelom in the classification of animals?

Answer: The nature of coelom gives important clue for classification of animals. The absence of coelom means that the animal has not developed a division of labour for various biological activities. On the other hand, the presence of coelom shows further evolution from simple to more complex organism.

Question 4. Distinguish between intracellular and extracellular digestion?

Answer: In case of intracellular digestion, digestion takes place inside the cell. Digestive enzymes are secreted in the food vacuole where food is digested. Absorption and assimilation are also intracellular in this case. Food is simple in this case.

In case of extracellular digestion, digestion takes place outside the cell. A rudimentary or developed alimentary canal may be present for facilitating extracellular digestion. Extracellular digestion is more evolved than intracellular digestion. Complex food can be utilised in this case.

Question 5. What is the difference between direct and indirect development?

Answer: When the young one resembles the adult animal, then it is the case of direct development. But when the young one looks entirely different than the adult animal, it is the case of indirect development. An animal may pass through several forms during indirect development, e.g. frog and silk moth.

Question 6. What are the peculiar features that you find in parasitic platyhelminthes?

Answer: Hooks and suckers are present in parasitic platyhelminthes. Suckers facilitate the sucking of blood from the host.

Question 7. What are the reasons that you can think of for the arthropods to constitute the largest group of the animal kingdom?

Answer: Arthropoda is the first phylum in which animals have properly developed organ systems. Elaborate organ system helped the arthropods in surviving in diverse conditions. Moreover, the arthropods are the earliest among the animals with well developed organ system. These are the reasons that arthropoda is the largest phylum in the animal kingdom.

Question 8. Water vascular system is the characteristic of which group of the following:

(a) Porifera (b) Ctenophora (c) Echinodermata (d) Chordata

Answer: (a) Porifera and (c) Echinodermata

Question 9. “All vertebrates are chordates but all chordates are not vertebrates”. Justify the statement.

Answer: Presence of notochord at some stage of life is the key feature of chordates. Notochord is present in vertebrates in the embryonic stage and hence all vertebrates are chordates. But in some of the chordates, notochord may persist throughout the life. Hence, all chordates are not vertebrates.

Question 10. How important is the presence of air bladder in Pisces?

Answer: Air blassed helps the bony fishes in buoyancy.

Question 11. What are the modifications that are observed in birds that help them fly?

Answer: Following are the modifications in birds that help them fly:

- Pneumatic or hollow bones reduce weight.
- Forelimbs are modified into wings.
- Streamlined body helps in flying.
- Uricotelic excretion helps in minimizing the need for carrying water and thus helps in weight reduction.

Question 12. Could the number of eggs or young ones produced by an oviparous and viviparous mother be equal? Why?

Answer: In case of oviparous animals, eggs are exposed to the vagaries of nature and also face the danger of predators. Hence, a larger number of eggs needs to be laid to ensure survival of the species.

In case of viviparous animals, the foetus develops to a size that it can have better chances of survival after birth. Moreover, development of foetus requires more resources from the female’s body. Hence, a smaller number of offsprings are produced by viviparous animals.

Question 13. Segmentation in the body is first observed in which of the following:

(a) Platyhelminthes (b) Aschelminthes (c) Annelida (d) Arthropoda

Answer: (c) Annelida

Question14. Match the following:

Column I	Column II
(a) Operculum	1. Ctenophora
(b) Parapodia	2. Mollusca
(c) Scales	3. Porifera
(d) Comb plates	4. Reptilia
(e) Radula	5. Annelida
(f) Hairs	6. Cyclostomata and chondrichthyes
(g) Choanocytes	7. Mammalia
(h) Gill slits	8. Osteichthyes

Answer: (a) → 8, (b) → 5, (c) → 4, (d) → 1, (e) → 2, (f) → 7, (g) → 3, (h) → 6

Question 15. Prepare a list of some animals that are found parasitic on human beings

Answer: Ascaris, Wucheraria, Acylostoma, Taenia, Fasciola

5. Morphology of Flowering Plants

ROOT

There are three types of root system, viz. tap root system, fibrous root system and adventitious root system.

Tap Root System:

This type of root system is mainly present in dicotyledonous plants. Direct elongation of the radicle results in formation of primary root. The primary root bears secondary, tertiary, etc. roots. The primary root; along with its branches; makes the tap root system, e.g. mustard, banyan, etc.

Fibrous Root System:

This type of root system is mainly present in monocotyledonous plants. The primary root is short lived after germination. This is replaced by a large number of roots and all of them emerge from the base of the stem. Such roots constitute the fibrous root system, e.g. wheat, paddy, grass, etc.

Adventitious Roots:

Sometimes, roots arise from some other plant parts (other than radicle). Such roots are called adventitious roots. Adventitious roots are used for various purposes; like vegetative propagation, mechanical support, etc.

Functions of Roots:

- Absorption of water and minerals
- Providing anchorage to the plant
- Food storage
- Hormone synthesis

Regions of the Root:

Root Cap: The root is covered at the tip by a thimble like structure. This structure is called root cap. The root cap protects the tender root apex when it makes its way through the soil.

Region of Elongation: This region lies a few millimeters above the root cap. This is the region of meristematic activity. The cells in this region are very small, have thin wall and dense protoplasm. Since this the meristematic region, so the cells divide rapidly. The cells near this region undergo rapid elongation and enlargement. These cells are responsible for the growth of root in length.

Region of Maturation: This region is just above the region of elongation. The cells from the region of elongation differentiate and mature, and then form the region of maturation. The root hairs come out in this region. Root hairs are part of the root epidermis.

Modifications of Root

Root modification for food storage: Tap roots of turnip and carrot and adventitious roots of sweet potato are examples of modification of root for food storage.

Modification for support:

In banyan trees, hanging roots come out from branches. The hanging roots then go into the soil to provide additional support to the huge banyan tree. Such roots are called prop roots. In case of a maize plant, roots emerge out from the lower node of the stem and go into the ground. Such roots are called stilt roots and provide additional support.

Modification for respiration:

In plants which grow in swamps, many roots come out vertically above the ground. These are hollow roots and are called pneumatophores. They facilitate exchange of gases in the roots.

STEM

The ascending part of the plant axis is called stem. The stem bears branches, leaves, flowers and fruits. The stem develops from the plumule of the embryo. Nodes and internodes are present on the stem. Leaves and branches come out from the nodes. The portion between two consecutive nodes is called internode. The buds on stem can be terminal or axillary. Young stem is usually green in colour and subsequently becomes woody and brown.

Functions of Stem:

- Bearing branches, leaves, flowers and fruits.
- Conduction of water and minerals.
- Green stems also carry out photosynthesis.
- Food storage, support, protection and vegetative propagation.

Modifications of Stem

Modification for food storage: The underground stems of potato, ginger, turmeric, zamikand, Colocasia, etc. are modified for food storage. Such modifications are the tools of perenation to tide over unfavourable conditions.

Modifications for climbing: In some plants, stem tendrils develop form axillary buds. These are slender and spirally coiled structures. A tendril helps the plant to climb to a support, e.g. cucumber, pumpkin, grapevine, etc.

Modification for defence: In some plants, the axillary buds are modified into woody, straight and pointed thorns. Such thorns protect the plant from browsing animals, e.g. Citrus, Bougainvillea.

Modification for photosynthesis: In some plants of arid regions, the stems are modified into flattened or fleshy cylindrical structures. The flattened structure can be seen in Opuntia and the cylindrical structure can be seen in Euphorbia. Such structures contain chlorophyll and photosynthesis happens in them.

Modification for vegetative propagation: Stems are modified for vegetative propagation in many plants.

- In some plants, the underground stems spread to new areas and give rise to new plants when the older plants die, e.g. grass and strawberry.

- In some plants, lateral branches come out from the main axis. These branches arch downward to touch the ground; after some growth. These branches then give rise to new plants, e.g. mint and jasmine.
- In some aquatic plants, a lateral branch bears a bunch of leaves and a tuft of roots at nodes. New plants emerge from such nodes, e.g. Pistia and Eichhornia.
- In some plants, the lateral branches emerge from the basal and underground portion of the main stem. Such branches grow horizontally beneath the soil and come out upward to give rise to leafy shoots, e.g. banana, pineapple and Chrysanthemum.

LEAF

A leaf is laterally borne out of the stem. It is usually a flattened structure. The leaf develops at the node. It bears a bud in its axil. The axillary bud subsequently develops into a branch. Leaves originate from shoot apical meristem. They are arranged in acropetal order.

Main parts of leaf are; leaf base, petiole and lamina.

The leaf is attached to the stem by the leaf base. It may bear two lateral small leaf-like structures called stipules. In monocot plants, the leaf base expands to form a sheath. The sheath partially or completely covers the stem.

In some leguminous plants, the leaf base may be swollen. The swollen portion is called the pulvinus. The petiole helps to hold the leaf blade to light. Petiole is flexible and thus allows the lamina to flutter in the wind. This helps in bringing fresh air to the leaf surface and has a cooling effect.

The lamina is expanded green portion of leaf. Veins and veinlets are present on the lamina. The arrangement of veins on a leaf is called venation. There are two types of venation, viz. reticulate and parallel.

a. Reticulate Venation: When the veins and veinlets form a network, this is called reticulate venation. Reticulate venation is usually seen in dicot plants.
b. Parallel Venation: When the veins are parallel to each other, this is called parallel venation. Parallel venation is usually seen in monocot plants.

Types of Leaves

Simple Leaves: When the lamina is entire or when incised; the incisions do not touch the midrib; then the leaf is called simple leaf, e.g. mango, guava, etc.

Compound Leaves: When the incisions on the lamina reach upto the midrib; breaking it into a number of leaflets, then the leaf is called compound leaf, e.g. neem.

A simple way to differentiate between compound and simple leaves is to look for the axillary bud. The bud is always present in case of a leaf but is absent in case of a leaflet.

There are two types of compound leaves, which are as follows:

a. Pinnately Compound Leaf: In this case, a number of leaflets are present on the rachis (common axis). The rachis represents the midrib, e.g. neem.

b. Palmately Compound Leaf: In this case, the leaflets are attached at a common point; at the tip of petiole, e.g. silk cotton.

Phyllotaxy: The arrangement of leaves on the stem or branch is called phyllotaxy. There are three types of phyllotaxy, which are as follows:

a. Alternate: In this type of leaf arrangement, a single leaf arises at each node in alternate manner, e.g. China rose, mustard, sunflower, etc.
b. Opposite: In this type of leaf arrangement, a pair of leaves arise at each node. The leaves lie opposite to each other in this case, e.g. Calotropis, guava, etc.
c. Whorled: In this type of leaf arrangement, more than two leaves arise at a node, e.g. Alstonia.

Modification of Leaves

Tendrils: In some plants, leaves are modified into tendrils to assist in climbing, e.g. pea.

Spines: In some plants, leaves are modified into spines for defence, e.g. cactus. The leaf spine in cacti and in some other xerophytes also helps in reducing water loss by preventing transpiration.

Bulb: In some plants, the leaves are modified into bulb for food storage, e.g. garlic and onion.

INFLORESCENCE

The arrangement of flowers on floral axis is called inflorescence. There are two major types of inflorescence, viz. racemose and cymose.

Racemose Inflorescence: In this type of inflorescence the main axis continues to grow. Flowers are borne laterally in acropetal succession. In case of acropetal succession, the older flowers are at base and the younger flowers are at top.

Cymose inflorescence: In this type of inflorescence, the main axis terminates in a flower. Hence, the growth is limited in cymose inflorescence. Flowers are borne in basipetal order; in this case, which means that the older flowers are at top and younger flowers are at the base.

FLOWER

The flower is a reproductive part of an agiospermic plant. The flower serves the purpose of sexual reproduction. In a typical flower, there are four kinds of whorls. These whorls are successively arranged on the swollen end of the stalk or pedicel. The swollen end of the stalk is called thalamus or receptacle.

Whorls of Flower:

Calyx: The outermost whorl of a flower is called calyx. It is composed of sepals. Sepals are usually green and leaf-like structures. The sepals protect the flower during the bud stage. Calyx is called gamosepalous when sepals are united and is called polysepalous when sepals are free.

Corolla: The second whorl of a flower is called corolla. It is composed of petals. Petals are usually brightly coloured. The bright colours attract the insects and birds for pollination. Corolla is called gamopetalous when petals are united and is called polypetalous when petals are free. Corolla can be tubular, bell-shaped, funnel-shaped or wheel-shaped.

Androecium: The third whorl of a flower is called androecium. It is composed of stamens. A stamen is composed of a stalk and an anther. An anther is usually a bilobed structure. There are two chambers (pollen sacs) in each lobe of an anther. Pollen sacs produce pollen grains. A sterile stamen is called staminode.

Gynoecium: The central whorl of a flower is called gynoecium. It is composed of one or more carpels. A carpel is composed of three parts. The basal swollen portion is called ovary. The long tubular part over ovary is called style and the flat top at the style is called stigma. The style is the receptive surface for pollen grains. Each ovary bears one or more ovules which are attached to a flattened, cushion-like placenta.

Both androecium and gynoecium are present in a bisexual flower, but either of them is present in a unisexual flower.

Symmetry of flowers

1. Actinomorphic: When a flower shows radial symmetry, it is called an actinomorphic flower, e.g. mustard, datura, chilli, etc.
2. Zygomorhphic: When a flower shows bilateral symmetry, it is called a zygomorphic flower, e.g. pea, gulmohar, bean, Cassia, etc.
3. Asymmetric: When a flower cannot be divided into two equal halves from any plane, it is called asymmetric flower, e.g. canna.

Floral parts may be present in multiples of 3, 4 or 5 in a flower. Depending on this, a flower can be trimerous, tetramerous or pentamerous.

Bracteate Flower: The reduced leaf at the base of a flower is called a bract. A flower with bract is called bracteate flower.

Ebracteate Flower: A flower without a bract is called an ebracteate flower.

Types of Flower Based on Position of Ovary

Hypogynous Flower: When the ovary occupies the highest position and other floral parts are below it, the flower is called hypogynous. In this case, the ovary is said to be superior, e.g. mustard, China rose, brinjal, etc.

Perigynous Flower: When the ovary and other parts of the flower are situated at the same level, the flower is called perigynous. In this case, the ovary is said to be half-inferior, e.g. plum, rose, peach, etc.

Epigynous Flower: When the ovary occupies the lowest position and other floral parts are situated above it, the flower is called epigynous flower. In this case, the thalamus grows upwards and completely covers the ovary. In this case, the ovary is said to be inferior, e.g. guava, cucumber, etc.

Aestivation

The mode of arrangement of sepals or petals; with respect to the other members of the same whorl is called aestivation. Following are the main types of aestivation:

a. Valvate: When sepals or petals just touch one another at the margin and don't overlap, this arrangement is called valvate, e.g. Calotropis.
b. Twisted: When the margin of one sepal or petal overlaps the margin of the next and so on, this arrangement is called twisted, e.g. China rose, okra, cotton, etc.
c. Imbricate: When the margins of sepal or petal overlap one another but the overlapping does not follow a set pattern, this arrangement is called imbricate, e.g. Cassia and gulmohar.
d. Vexillary: When the largest petal overlaps the two lateral petals; which in turn overlap the two smallest anterior petals, this arrangement is called vexillary. The largest petal is called the standard, the lateral petals are called wings and the smallest petals are called keel. Examples: pea and bean.

Type of Attachment of Androecium

a. Epipetalous: When stamens are attached to the petals, this arrangement is called epipetalous, e.g. brinjal.
b. Epiphyllous: When stamens are attached to the perianth, this arrangement is called epiphyllous, e.g. lily.

Arrangement of Stamens

a. Monoadelphous: When stamens are united into one bunch, they are called monoadelphous, e.g. China rose.
b. Diadelphous: When stamens are arranged in two bundles, they are called diadelphous, e.g. pea.
c. Polyadelhpous: When stamens are in more than two bundles, they are called polyadelphous, e.g. citrus.

Arrangement of Gynoecium:

a. Aporcarpous: When carpels are free, they are called apocarpous, e.g. lotus and rose.
b. Syncarpous: When carpels are fused, they are called syncarpous, e.g. mustard and tomato.

Placentation

The arrangement of ovules in the ovary is called placentation. There are different types of placentation which are as follows:

a. Marginal: When the placenta forms a ridge along the ventral suture of the ovary and ovules are borne on this ridge; in two rows, this arrangement is called marginal, e.g. pea.
b. Axile: When the placenta is axial and the ovules are attached to it in a multiclocular ovary, this arrangement is called axile, e.g. China rose, tomato and lemon.
c. Parietal: When ovules develop on the inner wall of the ovary or on peripheral part, this arrangement is called parietal, e.g. mustard and argemone.
d. Central: When ovules develop on the central axis and septa are absent, this arrangement is called free-central, e.g. dianthus and primrose.
e. Basal: When the placenta develops at the base of the ovary and a single ovule is attached to it, this arrangement is called basal, e.g. sunflower, marigold.

FRUIT

Fruit is a mature, ripened ovary which develops after fertilization. If a fruit develops without fertilization, it is called parthenocarpic fruit.

A fruit usually consists of a wall and seeds. The wall of the fruit is called pericarp. The pericarp can be dry or fleshy. A fleshy pericarp is differentiated into three layers, viz. epicarp, mesocarp and endocarp.

SEED

Ovules develop into seeds after fertilization. A seed is composed of a seed coat and an embryo. The embryo is composed of a radicle, an embryonal axis and one or two cotyledons.

Structure of a Dicotyledonous Seed

1. The outermost covering of the seed is called seed coat. The seed coat is composed of two layers. The outer layer is called testa and the inner layer is called tegmen.
2. There is a scar on the seed coat through which the developing seed was attached to the fruit. This scar is called hilum. There is a small pore above the hilum; called micropyle.
3. The embryo lies within the seed coat. It is composed of an embryonal axis and two cotyledons. Cotyledons are usually fleshy and contain reserve food materials.
4. Radicle and plumule are present at the two ends of the embryonal axis.

Endosperm is present in some seeds. Such seeds are called endospermous. When endosperm is not present in mature seeds, the seeds are called non-endospermous.

Structure of Monocotyledonous Seed

Monocoltyedonous seeds are usually endospermic, but some are non-endospermic, e.g. orchids.

In the seeds of cereals, the seed coat is membranous and is usually fused with the fruit wall.

The endosperm is bulky and stores food. The outer covering of endosperm separates the embryo by a proteinous layer. This layer is called aleurone layer.

The embryo of monocot seed is small. It is situated at one end of the endosperm. It consists of one large and shield-shaped cotyledon which is known as acutellum. There is a short embryonal axis; with radicle and plumule.

The plumule and radicle are enclosed in sheaths which are respectively called coleoptiles and coleorrhiza.

SEMI-TECHNICAL DESCRIPTION OF A TYPICAL FLOWERING PLANT

The semi-technical description of a typical flowering plant should be brief. It should be written in simple and scientific language. It should be in proper sequence. The description begins with habit, vegetative characters and then floral characters, inflorescence and floral parts.

After describing various parts of plant, a floral diagram and a floral formula are presented. The floral formula is represented by some symbols. In the floral formula, **Br** stands for bracteate **K** stands for calyx , **C** for corolla, **P** for perianth, **A** for androecium and **G** for Gynoecium, $\underline{G}$ for superior ovary and $\overline{G}$ for inferior ovary, ♂ for male, ♀ for female , for bisexual plants, ⊕for actinomorphic and % for zygomorphic nature of flower.

Fusion of floral part is indicated by enclosing the figure within bracket. Adhesion of floral parts is indicated by drawing a line above the symbols of the floral parts. A floral diagram gives the information about the number of different parts of a flower, their arrangement and their relation with one another. The position of the mother axis is shown by a dot on top of the floral diagram. Different whorls of the flower are drawn in correct sequence.

DESCRIPTION OF SOME IMPORTANT FAMILIES

Fabaceae

This family was earlier called Papilonoideae, a subfamily of family Leguminosae. It is distributed all over the world.

Vegetative Characters :- Trees, shrubs, herbs; root with root nodules

Stem :- erect or climber

Leaves :- alternate, pinnately compound or simple; leaf base, pulvinate; stipulate; venation reticulate.

Floral characters

Inflorescence :- racemose

Flower :- bisexual, zygomorphic

Calyx :- sepals five, gamosepalous; imbricate aestivation

Corolla :- petals five, polypetalous, papilionaceous, consisting of a posterior standard, two lateral wings, two anterior ones forming a keel (enclosing stamens and pistil), vexillary aestivation

Androecium :- ten, diadelphous, anther dithecous

Gynoecium :- ovary superior, mono carpellary, unilocular with many ovules, style single

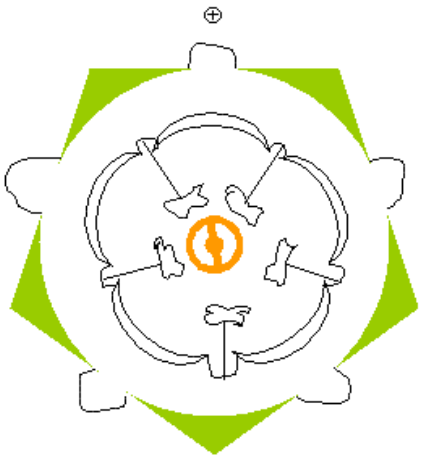
Fruit :- legume; seed: one to many, non-endospermic

Floral Formula: ⊕ ♂ $K_{(5)}\ C_{1+2+(2)}\ A_{(9)+1}\ G_{1}$

Economic importance: Many plants belonging to the family are sources of pulses (gram, arhar, sem, moong, soyabean; edible oil (soyabean, groundnut); dye (indigofera); fibres (sunhemp); fodder (Sesbania, Trifolium), ornamentals (lupin, sweet pea); medicine (muliathi).

Solanaceae

It is a large family, commonly called as the 'potato family'. It is widely distributed in tropics, subtropics and even temperate zones.



Vegetative Characters :- Plants mostly, herbs, shrubs and small trees

Stem :- herbaceous rarely woody, aerial; erect, cylindrical, branched, solid or hollow, hairy or glabrous, underground stem in potato (Solanum tuberosum)

Leaves :- alternate, simple, rarely pinnately compound, exstipulate; venation reticulate

Floral Characters

Inflorescence :- Solitary, axillary or cymose as in Solanum

Flower :- bisexual, actinomorphic

Calyx :- sepals five, united, persistent, valvate aestivation

Corolla :- petals five, united; valvate aestivation

Androecium :- stamens five, epipetalous

Gynoecium :- bicarpellary, syncarpous; ovary superior, bilocular, placenta swollen with many ovules

Fruits :- berry or capsule

Seeds :- many, endospermous

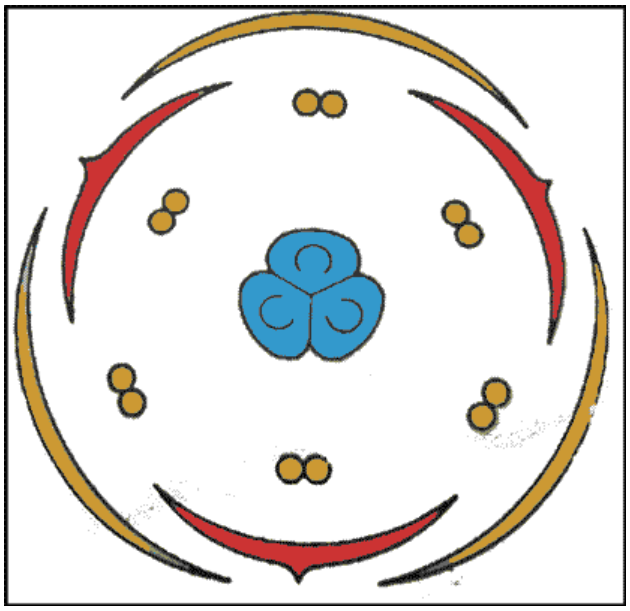
Floral Formula

$\oplus \, \delta \, K_5 \widehat{A_5 C_5} \underline{G_2}$

Economic Importance :- Many plants belonging to this family are source of food (tomato, brinjal, potato), spice (chilli); medicine (belladonna, ashwagandha); fumigatory (tobacco); ornamentals (petunia).

Liliaceae

Commonly called the 'Lily family' is a characteristic representative of monocotyledonous plants. It is distributed world wide.



Vegetative characters :- Perennial herbs with underground bulbs/corms/ rhizomes

Leaves :- mostly basal, alternate, linear, exstipulate with parallel venation

Floral characters

Inflorescence :- solitary / cymose; often umbellate clusters

Flower :- bisexual; actinomorphic

Perianth :- petal six (3+3), often united into tube; valvate aestivation

Androcium :- stamen six, (3+3)

Gynoecium :- tricarpellary, syncarpous, ovary superior, trilocular with many ovules; axile placentation

Fruit :- capsule, rarely berry

Seed :- endospermous

Floral Formula: $\oplus\ \male\ P_{3+3}\ A_{3+3}\ \underline{G}_{(3)}$

Economic Importance :- Many plants belonging to this family are good ornamentals (tulip, Gloriosa), source of medicine (Aloe), vegetables (Asparagus), and colchicine (Colchicum autumnale).

NCERT Solution

Question 1. What is meant by modification of root? What type of modification of root is found in the:

(a) Banyan tree (b) Turnip (c) Mangrove trees

Answer: Sometimes, roots are modified to serve some functions other than its main function of providing anchorage and absorption of water and minerals.

a. Banyan Tree: In banyan trees, hanging roots come out from branches. The hanging roots then go into the soil to provide additional support to the huge banyan tree. Such roots are called prop roots.
b. Turnip: The tap root in turnip is modified for food storage.
c. Mangrove trees: Mangrove trees are found in marshy area. In such plants, many roots come out vertically above the ground. These are hollow roots and are called pneumatophores. They facilitate exchange of gases in the roots.

Question 2. Justify the following statements on the basis of external features:

(i) Underground parts of a plant are not always roots.

Answer: In some plants, stems are also underground for some additional purpose; like food storage and vegetative propagation. Presence of scaly leaves on potato and ginger shows that they are not roots rather stems.

(ii) Flower is a modified shoot.

Answer: Flower comes out of stem hence it is a shoot. It serves the special purpose of sexual reproduction. Hence, flower is called a modified shoot.

Question 3. How is a pinnately compound leaf different from a palmately compound leaf?

Answer: Leaflets are present on a common axis (rachis); in case of pinnately compound leaves. In palmately compound leaves, the leaflets originate from the apex of the midrib.

Question 4. Explain with suitable examples the different types of phyllotaxy.

Answer: Phyllotaxy: The arrangement of leaves on the stem or branch is called phyllotaxy. There are three types of phyllotaxy, which are as follows:

a. Alternate: In this type of leaf arrangement, a single leaf arises at each node in alternate manner, e.g. China rose, mustard, sunflower, etc.
b. Opposite: In this type of leaf arrangement, a pair of leaves arise at each node. The leaves lie opposite to each other in this case, e.g. Calotropis, guava, etc.
c. Whorled: In this type of leaf arrangement, more than two leaves arise at a node, e.g. Alstonia.

Question: 5. Define the following terms:

(a) aestivation (b) placentation (c) actinomorphic (d) zygomorphic (e) superior ovary (f) perigynous flower (g) epipetalous stamen

Answer:

a. Aestivation: The mode of arrangement of sepals or petals; with respect to the other members of the same whorl is called aestivation.
b. Placentation: The arrangement of ovules in the ovary is called placentation.
c. Actinomorphic: When a flower shows radial symmetry, it is called an actinomorphic flower, e.g. mustard, datura, chilli, etc.
d. Zygomorphic: When a flower shows bilateral symmetry, it is called a zygomorphic flower, e.g. pea, gulmohar, bean, Cassia, etc.
e. Superior Ovary or Hypogynous Flower: When the ovary occupies the highest position and other floral parts are below it, the flower is called hypogynous. In this case, the ovary is said to be superior, e.g. mustard, China rose, brinjal, etc.
f. Perigynous Flower: When the ovary and other parts of the flower are situated at the same level, the flower is called perigynous. In this case, the ovary is said to be half-inferior, e.g. plum, rose, peach, etc.
g. Epipetalous Stamens: When stamens are attached to the petals, this arrangement is called epipetalous, e.g. brinjal.

Question 6. Differentiate between

(a) Racemose and cymose inflorescence

Answer:

Racemose	Cymose
Main axis continues to grow.	Main axis terminates.
Flowers are arranged in acropetal order.	Flowers are arranged in basipetal order.

(b) Fibrous root and adventitious root

Answer:

Fibrous roots	Adventitious roots
Arise from embryonal axis.	Do not come from embryonal axis.
Main function is absorption of minerals and water.	It can provide additional support and can carry out vegetative propagation.

(c) Apocarpous and syncarpous ovary

Answer: Carpels are free in apocarpous ovary, while they are fused in syncarpous ovary.

Question 7. Describe modifications of stem with suitable examples.

Answer: Modifications of Stem

Modification for food storage: The underground stems of potato, ginger, turmeric, zamikand, Colocasia, etc. are modified for food storage. Such modifications are the tools of perenation to tide over unfavourable conditions.

Modifications for climbing: In some plants, stem tendrils develop form axillary buds. These are slender and spirally coiled structures. A tendril helps the plant to climb to a support, e.g. cucumber, pumpkin, grapevine, etc.

Modification for defence: In some plants, the axillary buds are modified into woody, straight and pointed thorns. Such thorns protect the plant from browsing animals, e.g. Citrus, Bougainvillea.

Modification for photosynthesis: In some plants of arid regions, the stems are modified into flattened or fleshy cylindrical structures. The flattened structure can be seen in Opuntia and the cylindrical structure can be seen in Euphorbia. Such structures contain chlorophyll and photosynthesis happens in them.

Modification for vegetative propagation: Stems are modified for vegetative propagation in many plants, e.g. grass, berry, dahlia, etc.

Question 8. What is a flower? Describe the parts of a typical angiosperm flower.

Answer: The flower is a reproductive part of an agiospermic plant. The flower serves the purpose of sexual reproduction. In a typical flower, there are four kinds of whorls. These whorls are successively arranged on the swollen end of the stalk or pedicel. The swollen end of the stalk is called thalamus or receptacle.

Whorls of Flower:

Calyx: The outermost whorl of a flower is called calyx. It is composed of sepals. Sepals are usually green and leaf-like structures. The sepals protect the flower during the bud stage. Calyx is called gamosepalous when sepals are united and is called polysepalous when sepals are free.

Corolla: The second whorl of a flower is called corolla. It is composed of petals. Petals are usually brightly coloured. The bright colours attract the insects and birds for pollination. Corolla is called gamopetalous when petals are united and is called polypetalous when petals are free. Corolla can be tubular, bell-shaped, funnel-shaped or wheel-shaped.

Androecium: The third whorl of a flower is called androecium. It is composed of stamens. A stamen is composed of a stalk and an anther. An anther is usually a bilobed structure. There are two chambers (pollen sacs) in each lobe of an anther. Pollen sacs produce pollen grains. A sterile stamen is called staminode.

Gynoecium: The central whorl of a flower is called gynoecium. It is composed of one or more carpels. A carpel is composed of three parts. The basal swollen portion is called ovary. The long tubular part over ovary is called style and the flat top at the style is called stigma. The style is the receptive surface for pollen grains. Each ovary bears one or more ovules which are attached to a flattened, cushion-like placenta.

Question 9. How do the various leaf modifications help plants?

Answer: Modification of Leaves

Tendrils: In some plants, leaves are modified into tendrils to assist in climbing, e.g. pea.

Spines: In some plants, leaves are modified into spines for defence, e.g. cactus. The leaf spine in cacti and in some other xerophytes also helps in reducing water loss by preventing transpiration.

Bulb: In some plants, the leaves are modified into bulb for food storage, e.g. garlic and onion.

6. Anatomy of Flowering Plants

Tissues

A group of cells with common origin is called a tissue. The cells of a tissue usually perform a common function.

Types of Tissue:

There are two main types of plant tissues, viz. meristematic tissue and permanent tissue.

MERISTEMATIC TISSUES:

The cells in the meristematic tissue have the capability to divide. Meristematic tissue is found in growth regions of plants, e.g. root tip, shoot tip, buds, etc. The meristematic tissues are further divided into two types, viz. primary and secondary meristems.

Primary Meristems: The meristematic tissues which appear early in the life of a plant and which are responsible for the formation of primary plant body; are called primary meristem. There are two types of primary meristem, viz. apical meristem and intercalary meristem.

(a) Apical Meristem: As the name suggest, the apical meristem is found at the apex of root and stem. During the formation of leaves and elongation of stem, some cells of the apical meristem are left behind from the shoot tip. These cells constitute the axillary bud. Axillary buds are capable of forming a branch or a flower.

(b) Intercalary Meristem: The intercalary meristem is found between mature tissues. In grasses, the intercalary meristem helps in regenerating parts which were removed by the grazing animals.

PERMANENT TISSUES:

The newly formed plant cells become specialized and lose the ability of cell division. Such cells are called permanent or mature cells and form the permanent tissues. There are two types of permanent tissues, viz. simple tissue and complex tissue.

Simple Tissue: All the cells in a simple tissue are of only one type. Simple tissue is further divided into three types, viz. parenchyma, collenchyma and sclerenchyma.

(a) Parenchyma: The cells of parenchyma are usually isodiametric. They can be spherical, oval, round, polygonal or elongated in shape. The cell wall is thin and is made up of cellulose. Cells of parenchyma are either closely packed or have small intercellular spaces. Photosynthesis, storage and secretion are the main functions of parenchyma. Moreover, the bulk of the plant is made up of parenchyma.

(b) Collenchyma: Cells of collenchyma are thickened at corners because of deposition of cellulose, hemicellulose and pectin. The cells can be oval, spherical and polygonal. Collenchyma is present in layers below the epidermis in dicotyledonous plants. Collenchyma provides mechanical strength; alongwith flexibility to certain plant parts, like stalk of a leaf.

(c) Sclerenchyma: The cells of sclerenchyma are long, narrow and have thick and lignified cell walls. There can be a few or numerous pits in sclerenchyma. Cells of sclerenchyma are usually dead with our without protoplast. Sclerenchyma can be either fibres or sclereids. The thick-walled elongated and

pointed cells in sclerenchyma are called fibres. The fibres usually occur in groups. The spherical, oval or cylindrical cells with very narrow lumen; in sclerenchyma are called sclereids. Sclereids are usually found in the fruit walls of nuts, pulp of fruits like guava, pear and sapota; seed coats of legumes and leaves of tea. The gritty texture of pear or guava is because of sclereids. The main function of sclerenchyma is to provide mechanical support.

Complex Tissues:

A complex plant tissue is made up of more than one type of cells. There are two types of complex plant tissues, viz. xylem and phloem.

(a) Xylem: Xylem is composed of four elements, viz. tracheids, vessels, xylem fibres and xylem parenchyma.

- Tracheids: These are elongated or tube-like cells. They have thick and lignified walls and tapering ends. The tracheid cells are dead and protoplasm is absent. Tracheids and vessels are the main conducting elements in flowering plants.
- Vessel: These are long, cylindrical tube-like structures. These are made up of many cells which are called vessel members. Each vessel member has lignified walls and a large central cavity. Protoplasm is absent in vessel cells. The vessel members are interconnected through perforations in their common walls. The presence of vessels is a characteristic feature of angiosperms.
- Xylem Fibres: The xylem fibres have highly thickened walls and obliterated central lumens. Septa may be present or absent in xylem fibres.
- Xylem Parenchyma: The xylem parenchyma is composed of living cells which are thin-walled. The cell wall of xylem parenchyma is made up of cellulose. Xylem parenchyma stores food in the form of starch or fat, and some other substances like tannins. Parenchymatous cells facilitate the radial conduction of water in plants.

Primary xylem is of two types, viz. protoxylem and metaxylem. Protoxylem are the first formed primary xylem elements, while the metaxylem are formed later.

Endarch: The protoxylem lies towards the pith in stem and the metaxylem lies towards the periphery. This type of primary xylem is called endarch.

Exarch: The protoxylem lies towards the periphery in roots and the metaxylem lies towards the pith. This type of primary xylem is called exarch.

Transportation of water and minerals from roots to different plant parts is the main function of xylem. Xylem also provides mechanical strength.

(b) Phloem: The phloem; in angiosperms; is composed of four elements, viz. sieve tube, companion cells, phloem parenchyma and phloem fibres. In case of gymnosperms, the phloem has albuminous cells and sieve cells. Sieve tubes and companion cells are absent in the phloem in gymnosperms.

Sieve Tube: The sieve tube elements are long, tube-like structures. They are arranged longitudinally. The end walls of sieve tubes are perforated to form sieve plates. A mature sieve element has a peripheral cytoplasm and a large vacuole but no nucleus. The nucleus of the companion cell controls the function of sieve element.

Companion Cells: These are specialized parenchymatous cells. The companion cells are closely associated with sieve tube elements. There is a common pit field in the common longitudinal wall between the sieve tube element and companion cell. These piths connect both of them. The companion cell helps in maintaining the pressure gradient in the sieve tubes.

Phloem Parenchyma: The cells of phloem parenchyma are elongated, tapering cylindrical cells. The cells have dense cytoplasm and nucleus. Cell wall is composed of cellulose and has pits. Plasmodesmatal connections exist between the cells through these pits. Phloem parenchyma stores food and other substances like resin, latex and mucilage. Phloem parenchyma is usually absent in monocotyledonous.

Phloem Fibre: These are also called bast fibres and are made up of sclerenchyma. Phloem fibres are usually absent in primary phloem but present in secondary phloem. The phloem fibres are much elongated, unbranched and have pointed, needle-like apices. Phloem fibres of jute, flax and hemp are commercially used.

The primary phloem which is first formed consists of narrow sieve tubes and is called protophloem. The later formed phloem has bigger sieve tubes and is called metaphloem.

THE TISSUE SYSTEM

There are three types of tissue systems in plants, viz. epidermal tissue system, ground tissue system and vascular tissue system.

Epidermal Tissue System:

The outer covering of the plant body is formed of epidermal tissue system. The epidermal tissue system is composed of epidermal cells, stomata and edidermal appendages (trichomes and hairs).

Epidermis: The outermost layer of the primary plant body is called epidermis. The epidermis is made up of elongated, compactly arranged cells. These cells form a continuous layer. There is usually a single layer of cells in the epidermis. The epidermal cells are parenchymatous. In these cells, a small amount of cytoplasm lines the cell wall and a large vacuole is present. The outer surface of epidermis is usually covered with a waxy cuticle. The cuticle prevents the loss of water. However, cuticle is absent in roots.

Stomata: The minute pores present in the epidermis of leaves are called stomata. A stoma is composed of two guard cells; which are bean-shaped. The guard cells are dumbbell-shaped in grasses. The outer wall of guard cells is thin and the inner walls are highly thickened. Chloroplast is present in the guard cells. The guard cells regulate the opening and closing of stomata. A few specialized epidermal cells may be present near the guard cells. These specialized cells are called subsidiary cells. The stomatal aperture, guard cells and subsidiary cells together make the stomatal apparatus. Transpiration and exchange of gases are regulated by stomata.

Hairs: The root hairs are unicellular elongations of the epidermal cells. They absorb water and minerals from the soil. The epidermal hairs on stem are called trichomes. The trichomes are usually multicellular. They can be branched or unbranched. They can be soft or stiff. The trichomes prevent water loss through transpiration. Some of the trichomes may be secretory.

The Ground Tissue System

Tissues; other than epidermis and vascular bundles; make the ground tissue. The ground tissue is composed of simple tissues. Parenchyma is usually present in the cortex, pericycle, pith and medullary rays; in the primary stems and roots. The ground tissue in leaves is composed of thin-walled, chloroplast containing cells. This is called the mesophyll; in leaves.

The Vascular Tissue System

The vascular tissue system is composed of complex tissues.

Vascular Tissue in Dicot Stem: In dicotyledonous stem, cambium is present between phloem and xylem. Because of the presence of cambium, the vascular bundle in dicot stem is capable of forming secondary xylem and phloem. Hence, these are called open vascular bundles.

Vascular Tissue in Monocot Stem: Cambium is absent in monocot stem. Hence, secondary xylem or phloem is not formed in monocot stem.

Radial Arrangement of vascular bundle: This type of arrangement is present in roots. In this case, xylem and phloem are arranged in an alternate manner on different radii.

Conjoint arrangement of vascular bundle: This type of arrangement is present in stems and leaves. In this case, the xylem and phloem are on the same radius. In this case, the phloem is usually located on the outer side of xylem.

ANATOMY OF DICOTYLEDONOUS AND MONOCOTYLEDONOUS PLANTS

Dicotyledonous Root

Epidermis: The epidermis forms the outermost layer. Unicellular root hairs are present. The cortex is composed of many layers of thin-walled parenchyma; with intercellular spaces. The innermost layer of the cortex is called endodermis.

Endodermis: This is composed of a single layer of barrel-shaped cells. Intercellular space is absent. The tangential as well as radial walls of endodermis have a deposition of water-impermeable, waxy material; called suberin; in the form of casparian strips. A few layers of thick-walled parenchymatous cells lie next to the endodermis. This is called pericycle. The cells of the pericycle initiate lateral roots and vascular cambium during secondary growth. The pith is small and inconspicuous.

Vascular Bundle: There are usually two to four patches of xylem and phloem. A cambium ring develops between the xylem and phloem at a later stage. All tissues on the inner side of the endodermis constitute the stele.

Monocotyledonous Root

The anatomy of monocot root is similar to dicot root in many aspects. Epidermis, cortex, endodermis, pericycle, vascular bundles and pith are present. There are usually more than six xylem bundles in the monocot root. Pith is large and well developed. Secondary growth does not happen in monocot roots.

Dicotyledonous Stem

Epidermis: The epidermis is covered with a thin layer of cuticle. Trichomes and stomata may be present.

Cortex: The cortex is made up of the multiple layers of cells between epidermis and pericycle. There are three sub-zones in the cortex. The outer sub-zone is called hypodermis. The hypodermis is composed of a few layers of collenchyma. The middle layer is composed of thin-walled parenchyma with distinct intercellular spaces. The innermost layer is called endodermis.

Endodermis: The cells are rich in starch grains and hence this layer is also called the starch sheath. Pericycle is present on the inner side of endodermis and above the phloem. The pericycle is in the form of semi-lunar patches of sclerenchyma.

Medullary Rays: Layers of radially placed parenchyma between the vascular bundles are called medullary rays.

Vascular Bundle: A large number of vascular bundles are arranged in a ring. It is important to remember that the ring-like arrangement of vascular bundles is the characteristic of dicot stem. Each vascular bundle is conjoint, open. Protoxylem is endarch. The pith is composed of rounded parenchymatous cells; with large intercellular spaces.

Monocotyledonous Stem

The hypodermis in a monocot stem is made up of sclerenchyma. A large number of vascular bundles are scattered. Each vascular bundle is surrounded by a sclerenchymatous bundle sheath. Ground tissue is distinct and is made up of parenchyma. Vascular bundles are conjoint and closed. Peripheral vascular bundles are usually smaller than the centrally located vascular bundles. Phloem parenchyma is absent. Water-containing cavities are present within the vascular bundles.

Dorsiventral (Dicotyledonous) Leaf

There are three main parts in the leaf lamina of a dorsiventral leaf, viz. epidermis, mesophyll and vascular system.

Epidermis: The epidermis covers both the upper and lower surfaces. The upper epidermis is called adaxial epidermis, while the lower one is called abaxial epidermis. Cuticle is distinct. A higher number of stomata are present on the abaxial epidermis than on the adaxial epidermis. Stomata may be absent also in the adaxial epidermis.

Mesophyll: The tissue between the two epidermises is called mesophyll. The mesophyll is composed of parenchyma and contains chlorophyll. There are two types of cells in the mesophyll, viz. palisade parenchyma and spongy parenchyma. The palisade parenchyma is placed adaxially. It is made up of elongated cells; which are arranged vertically and parallel to each other. The spongy parenchyma is situated below the palisade parenchyma and extends to the lower epidermis. There are numerous large spaces and air cavities between the cells of spongy parenchyma.

Vascular Bundle: The vascular bundles can be seen in the veins and the midrib. Vascular bundles are surrounded by a layer of thick-walled bundle sheath cells. Vascular bundles are of different sizes because of reticulate venation.

Isobilateral (Monocotyledonous) Leaf

The anatomy of isobilateral leaf is similar to that of dorsiventral leaf in many aspects. Stomata are present on both the surfaces of an isobilateral leaf. The mesophyll is not differentiated into palisade and spongy parenchyma.

Certain adaxial epidermal cells; along the veins in grasses; are modified into large, empty, colourless cells. These are called bulliform cells. When the bulliform cells absorb water and become turgid, the leaf surface is exposed. When the bulliform cells become flaccid, the leaves curl inwards to minimize water loss.

Vascular bundles are of similar size, because of parallel venation. However, the vascular bundle of the main vein is somewhat bigger.

SECONDARY GROWTH

Primary Growth: The growth in length of stem and roots is called primary growth. Primary growth happens because of activities in the apical meristem.

Secondary Growth: The increase in girth is called secondary growth. The tissues which are involved in secondary growth are; the two lateral meristems (vascular cambium and cork cambium).

Vascular Cambium:

The vascular cambium is responsible for cutting off vascular tissues. In case of young stem; it is present in patches as a single layer between the xylem and phloem. It forms a complete ring at a later stage.

In dicot stems, the cambium which is present between primary xylem and primary phloem is called intrafascicular cambium. The cells of medullary rays near these intrafascicular cambium become meristematic and form interfascicular cambium. This leads to the formation of a continuous ring of cambium.

Activity of Cambial Ring: The cambial ring becomes active and starts cutting off new cells; both on the inner and the outer sides. The cells which are cut off towards the pith mature into secondary xylem. The cells which are cut off towards the periphery mature into secondary phloem. The cambium is usually more active on the inner side than on the outer side. Hence, a large number of secondary xylem is produced compared to the secondary phloem. The secondary xylem; thus produced soon forms a compact mass.

Due to continued formation and accumulation of secondary xylem, the primary and secondary phloems gradually get crushed. But the primary xylem more or less remains intact, in or around the centre. At some places, a narrow band of parenchyma is formed by the cambium. This band of parenchyma passes through the secondary xylem and secondary phloem in radial directions. These are called secondary medullary rays.

Spring wood and autumn wood:

Various physiological and environmental factors control the activity of cambium. Climatic conditions are not uniform through the year; in temperate regions. Cambium is very active during the spring season, while it is less active during the winters. Hence, during spring; a large number of xylem elements are formed which have wider vessels. During winter, fewer xylem elements are formed which have narrow vessels. The wood formed during summer is called spring wood or early wood, while the wood formed during winter is called autumn wood or late wood.

Spring wood is lighter in colour and has a lower density. The autumn wood is darker in colour and has a higher density.

The two kinds of wood appear as alternate concentric rings in transverse section of a trunk or branch of a tree. These are called annual rings and can provide rough estimate of the age of the tree.

Heartwood and sapwood:

In old trees, the greater part of secondary xylem is dark brown. This happens because of deposition of organic compounds; like tannins, resins, oils, gums, aromatic substances and essential oils in the innermost layers of the stem. Due to the presence of these substances, the wood becomes hard, durable and resistant to attacks by microorganisms and insect. This region is composed of dead elements with highly lignified walls. The wood in this region is called heartwood. The heartwood does not conduct water, but gives mechanical support to the stem. The peripheral region of the secondary xylem is lighter in colour. This is known as sapwood. Conduction of water and minerals takes place through sapwood.

Cork Cambium: When the girth of the stem increases due to secondary growth, the outer cortical and epidermal layers get broken. These layers need to be replaced by new protective layers. To fulfill this need, a meristematic tissue develops in the cortex region. This meristematic tissue is called cork cambium or phellogen.

Phellogen is composed of a couple of layers. This is made up of narrow, thin-walled and nearly rectangular cells.

The phellogen cuts off cells on both sides. The outer cells differentiate into cork or phellem. The inner cells differentiate into secondary cortex or phelloderm. Cork is impervious to water due to suberin deposition in the cell wall. The cells of secondary cortex are parenchymatous. Phellogen, phellem and phelloderm are collectively called periderm.

Due to activity of the cork cambium, pressure builds up on the remaining layers which are peripheral to phellogen. These layers finally die and slough off.

Bark: All tissues which lie exterior to the vascular cambium are called bark; in common language. Bark formed early in the season is called soft bark, while one formed late in the season is called hard bark.

Lenticels: The phellogen cuts off closely arranged parenchymatous cells on the outer side instead of cork cells. This happens at certain regions. These parenchymatous cells soon rupture the epidermis. This leads to the formation of lens-shaped openings called lenticels. Lenticels permit exchange of gases. Lenticels are usually found in woody trees.

Secondary Growth in Roots

The vascular cambium of the dicot root is completely secondary in origin. It originates from the tissue which is located just below the phloem bundles. A portion of pericycle tissue; above the protoxylem; forms a complete and continuous wavy ring. It subsequently becomes circular. Rest of the steps are similar as in dicot stem.

Secondary growth takes place in stems and roots of gymnosperms. But secondary growth does not happen in monocotyledonous.

NCERT Solution

Question 1. State the location and function of different types of meristems.

Answer:

Type of meristem	Location	Function
Apical meristem	Root apex and shoot apex	Longitudinal growth.
Intercalary meristem	Between mature tissues	Repair
Secondary meristem	On the periphery of root and stem	Secondary growth

Question 2. Cork cambium forms tissues that form the cork. Do you agree with this statement? Explain.

Answer: Cork cambium is a meristematic tissue which develops in the cortex region of mature stem. Cork cambium is formed to replace the broken epidermal layer of stem. The cells cut off on the outer side by cork cambium become cork. Hence, it can be said that the cork cambium is a tissue which forms cork.

Question 3. Explain the process of secondary growth in the stems of woody angiosperms with the help of schematic diagrams. What is its significance?

Answer: The cambial ring becomes active and starts cutting off new cells; both on the inner and the outer sides. The cells which are cut off towards the pith mature into secondary xylem. The cells which are cut off towards the periphery mature into secondary phloem. The cambium is usually more active on the inner side than on the outer side. Hence, a large number of secondary xylem is produced compared to the secondary phloem. The secondary xylem; thus produced soon forms a compact mass.

While the cambial ring forms the major portion during secondary growth in woody stem, the broken epidermal layer is replaced by the activity of cork cambium.

Secondary growth is necessary for growth in girth of the stem. Moreover, secondary growth also provides additional mechanical strength to the stem.

Question 4. Cut a transverse section of young stem of a plant from your school garden and observe it under the microscope. How would you ascertain whether it is a monocot stem or a dicot stem? Give reasons.

Answer: If the vascular bundles are arranged in a ring then it is a dicot stem. If the vascular bundles are scattered, then it is a monocot stem.

Question 5. The transverse section of a plant material shows the following anatomical features - (a) the vascular bundles are conjoint, scattered and surrounded by a sclerenchymatous bundle sheaths. (b) phloem parenchyma is absent. What will you identify it as?

Answer: Monocot stem

Question 6. Why are xylem and phloem called complex tissues?

Answer: Since xylem and phloem are composed of more than one type of cells, hence they are called complex tissues.

Question 7. What is stomatal apparatus? Explain the structure of stomata with a labeled diagram.

Answer: The minute pores present in the epidermis of leaves are called stomata. A stoma is composed of two guard cells; which are bean-shaped. The guard cells are dumbbell-shaped in grasses. The outer wall of guard cells is thin and the inner walls are highly thickened. Chloroplast is present in the guard cells. The guard cells regulate the opening and closing of stomata. A few specialized epidermal cells may be present near the guard cells. These specialized cells are called subsidiary cells. The stomatal aperture, guard cells and subsidiary cells together make the stomatal apparatus. Transpiration and exchange of gases are regulated by stomata.

Question 8. Name the three basic tissue systems in the flowering plants. Give the tissue names under each system.

Answer:

1. Epidermal Tissue System: Epidermis, Stomata
2. Ground or Fundamental Tissue System: Paranchyma, Sclerenchyma and Collenchyma
3. Vascular or Conducting Tissue System: Phloem and Xylem

Question 9. How is the study of plant anatomy useful to us?

Answer: The study of plant anatomy helps us in understanding the internal structure of a plant. We learn to appreciate the vast complexity of structures in a simple looking plant. Study of plant anatomy also helps us in understanding the evolution which has taken place among the plants.

Question 10. What is periderm? How does periderm formation take place in the dicot stems?

Answer: The meristematic tissue which develops to replace the worn out epidermis of dicot stem is called cork cambium or phellogen. The phellogen cuts off cells on both sides. The outer cells differentiate into cork or phellem. The inner cells differentiate into secondary cortex or phelloderm. Cork is impervious to water due to suberin deposition in the cell wall. The cells of secondary cortex are parenchymatous. Phellogen, phellem and phelloderm are collectively called periderm.

Question 11. Describe the internal structure of a dorsiventral leaf with the help of labeled diagrams.

Answer: Dorsiventral (Dicotyledonous) Leaf

There are three main parts in the leaf lamina of a dorsiventral leaf, viz. epidermis, mesophyll and vascular system.

Epidermis: The epidermis covers both the upper and lower surfaces. The upper epidermis is called adaxial epidermis, while the lower one is called abaxial epidermis. Cuticle is distinct. A higher number of stomata are present on the abaxial epidermis than on the adaxial epidermis. Stomata may be absent also in the adaxial epidermis.

Mesophyll: The tissue between the two epidermises is called mesophyll. The mesophyll is composed of parenchyma and contains chlorophyll. There are two types of cells in the mesophyll, viz. palisade parenchyma and spongy parenchyma. The palisade parenchyma is placed adaxially. It is made up of elongated cells; which are arranged vertically and parallel to each other. The spongy parenchyma is situated below the palisade parenchyma and extends to the lower epidermis. There are numerous large spaces and air cavities between the cells of spongy parenchyma.

Vascular Bundle: The vascular bundles can be seen in the veins and the midrib. Vascular bundles are surrounded by a layer of thick-walled bundle sheath cells. Vascular bundles are of different sizes because of reticulate venation.

7. Structural Organization In Animals

Tissue:

A group of cells which is formed to carry out specific task is called a tissue.

Formation of tissues is the first step towards division of labour in multicellular animals. Subsequently, a group of tissues forms an organ and a group of organs forms the organ system.

ANIMAL TISSUES

There are four major types of animal tissues, viz. epithelial, connective, muscular and neural tissues.

EPITHELIAL TISSUE

Tissues which provide covering to the inner and outer linings of various organs are called epithelial tissue. The cells in the epithelial tissue are compactly packed. There is little intercellular matrix in the epithelial tissue.

The epithelial tissues are further divided into two main types, viz. simple epithelium and compound epithelium.

Simple Epithelium: The simple epithelium is composed of a single layer of cells. It is present in the lining of body cavities, ducts and tubes.

Compound Epithelium: The compound epithelium is composed of more than one layer of cells. The compound epithelium serves the protective function. Compound epithelium is present in skin, in the lining of buccal cavity, pharynx, ducts of salivary glands and pancreatic ducts.

The simple epithelium can be further divided into three types, viz. squamous, cuboidal and columnar.

Squamous Epithelium: The squamous epithelium is made up of flattened cells with irregular boundaries. Squamous epithelium is present in the walls of blood vessels and air sacs of lungs. They form a diffusion boundary.

Cuboidal Epithelium: The cuboidal epithelium is composed of cube-like cells. The cuboidal epithelium is usually found in ducts of glands and tubular parts of nephrons. The main functions of cuboidal epithelium are secretion and absorption.

Columnar Epithelium: The columnar epithelium is composed of tall and slender cells. The nuclei of the columnar cells are located at the base. Microvilli may be present on the free surface. Columnar epithelium is present in the lining of stomach and intestine. They help in secretion and absorption.

Ciliated Epithelium: Sometimes, cilia may be present in columnar or cuboidal epithelium. In that case, they are called ciliated epithelium. The cilia move particles or mucus in a specific direction over the epithelium. They are present in the inner surface of hollow organs; like bronchioles and fallopian tubes.

CONNECTIVE TISSUE

The connective tissues are most abundant and widely distributed in the body of complex animals. The connective tissues support and link other tissues or organs of the body. The cells of the connective

tissue secrete fibres of structural proteins; called collagen or elastin. But blood is an exception; in which no structural fibre is secreted. The structural fibres provide strength, elasticity and flexibility to the tissue. The cells of the connective tissue also secrete polysaccharides. These polysachharides accumulate between cells and fibres and act as matrix (ground substance).

There are three types of connective tissues, viz. loose connective, dense connective and specialized connective tissues.

Loose Connective Tissue: The cells and fibres are loosely arranged in a semi-fluid matrix; in loose connective tissue. Areolar tissue is an example of loose connective tissue. Areolar tissue is present beneath the skin. It usually makes the support framework for epithelium. It contains fibroblasts, macrophages and mast cells. Adipose tissue is another example of loose connective tissue. Adipose tissue is usually located beneath the skin. The cells of the adipose tissue are specialized to store fat.

Dense Connective Tissue: The cells and fibres are compactly packed in dense connective tissue. The orientation of fibres can be regular or irregular. On this basis, the dense connective tissue is called dense regular or dense irregular connective tissue. In dense regular connective tissue, the collagen fibres are present in rows between many parallel bundles of fibres, e.g. tendons and ligaments. Tendons attach muscles to bones, while ligaments attach one bone to another. In dense irregular tissue, fibroblasts and fibres are oriented in irregular pattern. Dense irregular tissue is present in skin.

Specialised Connective Tissue: Cartilage, bones and blood are the specialized connective tissues.

Cartilage: The matrix of cartilage is solid and pliable and resists compression. The cells of cartilage are called chondrocytes. Chondrocytes are enclosed in small cavities within the matrix. Most of the cartilages in vertebrae embryo are replaced by bones in adulthood.

Bones: The matrix of bones is hard and non-pliable. The matrix is rich in calcium salts and collagen fibres; which give strength to the bone. The bone cells are called osteocytes. Osteocytes are present in spaces; called lacunae. The bone marrow in some bones is the site of production of blood cells.

Blood: Blood is a fluid connective tissue. It contains plasma, blood cells and platelets. Blood is the main circulating fluid which helps in transport of various substances.

MUSCLE TISSUE

A muscle is made of many long, cylindrical fibres which are arranged in parallel rays. The muscle fibres are composed of very fine fibrils; called myofibril. The muscle fibres can contract and relax in a coordinated fashion. Thus, muscles play an important role in movement and locomotion.

There are three types of muscles, viz. skeletal, smooth and cardiac muscles.

Skeletal Muscle: The skeletal muscle is closely attached to skeletal bones. Skeletal muscle fibres are bundled together in a parallel fashion. Several bundles of muscle fibres are covered by a sheath of tough connective tissue. Striations are present in skeletal muscles and hence they are also called striated muscles. The voluntary movements are facilitated by skeletal muscles. Skeletal muscles quickly get tired.

Smooth Muscle: The smooth muscle fibres are spindle-shaped. Striations are absent on smooth muscle. Various smooth muscle fibres are held together by cell junctions. They are bundled together in a sheath of connective tissue. Smooth muscles are present in those organs which are not under our

conscious control. Smooth muscles can carry on their activity for a longer duration, as compared to skeletal muscles.

Cardiac Muscle: The muscles in the heart are called cardiac muscles. Cardiac muscles are multinucleated and have striations. The muscle fibres are held together by cell junctions. Communication junctions (intercalated discs) are present at some fusion points. These communication junctions allow the cells to contract as a unit. Due to this, when one cell receives a signal to contract, its neighbours are also stimulated to contract. Cardiac muscles keep on contracting and relaxing continuously throughout the life.

Neural Tissue

Neural tissue is made of neurons. Neurons are excitable cells. The neuroglial cell protects and supports neurons. Neuroglia make up more than half of the volume of the neural tissue in human body.

When a neuron is stimulated, an electrical disturbance is generated. The electrical disturbance travels along its plasma membrane. When a disturbance arrives at a neuron's endings, it triggers events which may cause stimulation of inhibition of adjacent neurons and other cells. Thus, neural signals are transmitted to different parts of the body.

EARTHWORM

Habit and Habitat: Earthworm is a reddish brown terrestrial invertebrate. It lives in the upper layer of moist soil. Pheretima and Lumbricus are the common Indian earthworms.

Morphology of Earthworm

Earthworm has a long cylindrical body which is divided into more than a hundred short segments or metameres.

Dorsal Surface: There is a dark median mid-dorsal line; along the longitudinal axis; on the dorsal surface of the body. This line marks the dorsal blood vessel.

Ventral Surface: Genital openings mark the ventral surface of the body of an earthworm.

Segments of Earthworm:

- The anterior end consists of the mouth and the prostomium. Prostomium is a lobe which serves as a covering of the mouth. It also acts as a wedge to force open cracks in the soil. The prostomium has sensory function as well.
- The first body segment is called peristomium or buccal segment. The peristomium contains the mouth.
- In a mature worm, segments 14 – 16 are covered by a prominent dark band of glandular tissue. This band is called clitellum. Based on the relative position of clitellum, the body is divided into three main regions, viz. preclitellar, clitellar and postclitellar segments.
- Genital Openings: On the ventro-lateral sides of the inter-segmental groves; between 5th – 9th segments; four pairs of spermathecal apertures are situated. On the mid-ventral line of 14th segment, a single female genital pore is present. On the ventro-lateral sides of the 18th segment, a pair of male genital pores is present.

Locomotion in Earthworm

There are 5 rows of S-shaped setae in each body segment. The setae are embedded in the epidermal pits in the middle of each segment. Setae are absent in the first segment, clitellum and last segment. Setae can be extended or retracted and facilitate locomotion.

Anatomy of Earthworm

Body Wall: The body wall of earthworm is covered by thin non-cellular cuticle. Epidermis lies below the cuticle. This is followed by two muscle layers; circular and longitudinal. The innermost layer is the coelomic epithelium. The epithelium is composed of a single layer of columnar epithelial cells. The epithelial cells contain gland cells as well.

Alimentary Canal: The alimentary canal is a straight tube. It runs between the first to last segment. Mouth is terminal and opens into the buccal cavity (1- 3 segments). The mouth leads into muscular pharynx.

Pharynx continues into oesophagus (5-7 segments) which is a small narrow tube. The oesophagus continues into a muscular gizzard (8-9 segments). The gizzard helps in grinding the food. The stomach extends from 9th – 14th segments.

Decaying leaves and organic matter; mixed with soil; are the foods of the earthworm. The humic acid; present in humus; is neutralized by the calciferous glands in the stomach.

The intestine continues from the 15th segment to the last segment. On the 26th segment, a pair of short and conical caecae project from the intestine. Between 26th -35th segments, internal median fold of dorsal wall is present in the intestine. This internal fold is called typhlosole. The typhlosole increases the area of absorption in the intestine.

The alimentary canal opens to the exterior by a small rounded aperture; called anus.

Blood Vascular System: Closed type blood vascular system is present in earthworm. The blood vascular system is composed of a heart, blood vessels and capillaries. Smaller blood vessels supply the gut, nerve cord and body wall. Blood glands are present on the 4th, 5th and 6th segments. The blood glands produce blood cells and haemoglobin. Blood cells are phagocytic in nature. Exchange of gases occurs through moist body surface into the blood stream.

Excretory System: Nephridia are the excretory organs in earthworm. Nephridium is composed of coiled tubules. There are three types of nephridia, viz. septal, integumentary and pharyngeal nephridia.

Septal Nephridia: These are present on both sides of intersegmental septa of segment 15 to the last. The septal nephridia open into intestine.

Integumentary Nephridia: These are attached to the lining of the body wall of segment 3 to the last. The integumentary nephridia open on the body surface.

Pharyngeal Nephridia: These are present as paired tufts in the 4th, 5th and 6th segments.

A neprhidium is a funnel-like structure. It collects excess fluid from coelomic chamber. The tube at the end of the funnel carries the wastes into the digestive tube; through a pore on the surface in the body wall.

Nervous System: The nervous system is composed of a ventral pair of nerve cord. Ganglia are arranged in each segment on this paired nerve cord. The nerve cord in the anterior region (3rd and 4th segments) bifurcates and encircles the pharynx to join the cerebral ganglia. This forms a dorsal nerve ring.

Sensory System: There is no eye in the earthworm. But light and touch sensitive receptor cells are present. Chemoreceptors are also present. The sense receptors are present on the anterior part of the body.

Reproductive System: Earthworm is hermaphrodite.

Male Reproductive System: There are two pairs of testes present in the 10th and 11th segments. The vasa deferentia run up to the 18th segment; where they join the prostatic duct. Two pairs of accessory glands are present in the 17th and 19th segments. The common prostate and spermatic duct opens to the exterior by a pair of male genital pores. The male genital pores are present on the ventro-lateral side of the 18th segment. Four pairs of spermathecae are located in 6th to 9th segments. During copulation, spermatozoa are stored in the spermathecae.

Female Reproductive System: One pair of ovaries is attached at the inter-segmental septum of the 12th and 13th segments. Ovarian funnels are present beneath the ovaries. The ovarian funnels continue into oviduct. They join together and open on the ventral side as a single median female genital pore on the 14th segment.

Fertilization & Development: During mating, a mutual exchange of sperms occurs between two worms. Mature sperm and egg cells and nutritive fluid are deposited in cocoons produced by the gland cells of clitellum. Cocoons are deposited in soil. Fertilization and development occur within the cocoons. After about 3 weeks, each cocoon produces two to twenty baby worms. The average number of baby worms from a cocoon is four. Development is direct.

Economic Importance: Earthworms are called ‘Friends of Farmers’. They burrow in the soil and make it porous. It helps in respiration and penetration of developing plant roots. Earthworms are also used as bait in fishing.

COCKROACH

MORPHOLOGY

Periplaneta americana is the common species of cockroach. An adult cockroach is about 34 – 53 mm long. Wings extend beyond the tip of the abdomen in males. The body is segmented into three distinct regions, viz. head, thorax and abdomen.

The whole body is covered by a brown coloured hard exoskeleton which is made up of chitin. In each segment, the exoskeleton has hardened plates; called sclerites. The sclerites are called tergites; dorsally; and sternites; ventrally. The ventral and dorsal sclerites are joined together by a thin and flexible articular membrane. This is called arthrodial membrane.

Body Segments in Cockroach

Head: The head is triangular in shape. It lies anteriorly at right angles to the longitudinal body axis. The head is formed by the fusion of six segments. The flexible neck facilitates movement in all directions. A pair of compound eyes is present in the head capsule. Membranous sockets lie in front of eyes and a pair of thread-like antennae arises from them. Antennae have sensory receptors.

Mouth Parts: The mouth parts are at the anterior end of the head. The mouth parts consist of a labrum (upper lip), a pair of mandibles, a pair of maxillae and a labium (lower lip). A median flexible lobe lies in the cavity which is enclosed by the mouth parts. This lobe acts as tongue (hypopharynx).

Thorax: The thorax consists of three parts, viz. prothorax, mesothorax and metathorax. The head is connected with the thorax by a short extension of prothorax; called neck. Each thoracic segment bears a pair of walking legs. The first pair of wings arises from mesothorax and the second pair arises from metathorax. Forewings are called tegmina. They are opaque dark and leathery and cover the hind wings when at rest. The hind wings are transparent, membranous and are used in flight.

Abdomen: The abdomen consists of 10 segments. In females, the 7th segment is boat shaped. The 7th sternum; together with the 8th and 9th sterna; forms a brood or genital part. The anterior part of the genital part contains the female gonopore, spermathecal pores and collateral glands. In males, the genital pouch lies at the hind end of abdomen. It is bound dorsally by the 9th and 10th terga and ventrally by the 9th sternum. It contains the dorsal anus, ventral male genital pore and gonapophysis. A pair of short, thread-like anal styles is present in males. In both sexes, the 10th segment bears of pair of jointed filamentous structures called anal cerci.

ANATOMY

Alimentary Canal: The alimentary canal is divided into three regions, viz. foregut, midgut and hindgut. The mouth opens into a short tubular pharynx. The pharynx opens into a narrow tubular oesophagus. The oesophagus opens into a sac-like structure called crop. Food is stored in the crop. The crop is followed by gizzard and proventriculus. The gizzard has an outer layer of thick circular muscles and thick inner cuticle; forming six highly chitinous plate called teeth. Food particles are ground in the gizzard. The entire foregut is lined by cuticle. At the junction of foregut and midgut, a ring of 6 – 8 blind tubules are present. These are called gastric or hepatic cecae and secrete digestive juice. The hindgut is broader than the midgut. The hindgut is differentiated into ileum, colon and rectum. The rectum opens through anus.

Blood Vascular System: The blood vascular system is an open type. Blood vessels are poorly developed. They open into space (haemocoel). Visceral organs located in the haemocoel are bathed in blood (haemolymph). The haemolymph is composed of colourless plasma and haemocytes. The heart consists of elongated muscular tubes which lie along mid-dorsal line of thorax and abdomen. The heart is differentiated into funnel-shaped chambers; with ostia on either side. The blood from sinuses enters the heart through ostia and is pumped anteriorly to the sinuses again.

Respiratory System: The respiratory system consists of a network of trachea. The tracheae open through 10 pairs of small holes; called spiracles. The spiracles are present on the lateral side of the body. Tracheal tubes are subdivided into tracheoles. They carry oxygen to all the parts. The opening of the spiracles is regulated by sphincters. Exchange of gases takes place by diffusion.

Excretory System: Malpighian tubules are the excretory organs. Each tubule is lined by glandular and ciliated cells. They absorb nitrogenous wastes and convert them into uric acid. Uric acid is excreted out through the hindgut. Additionally, fat body, nephrocytes and urecose glands also help in excretion.

Nervous System: The nervous system of cockroach consists of a series of fused, segmentally arranged ganglia. The ganglia are joined by paired longitudinal connectives on the ventral side. Three ganglia lie in the thorax and six in the abdomen. The nervous system in cockroach is spread throughout the body. In the head region, the brain is represented by supra-oesophageal ganglion. It supplies nerves to antennae and compound eyes.

Sense Organs: Antennae, eyes, maxillary palps, labial palps, anal cerci, etc. are the sense organs in cockroach. The compound eyes are situated at the dorsal surface of head. Each eye consists of about 2000 hexagonal ommatidia. Presence of several ommatidia gives mosaic vision to the cockroach. This gives more sensitivity but less resolution. This type of vision is common during night.

Reproductive System:

Cockroaches are dioecious.

Male Reproductive System: The male reproductive system of cockroach consists of a pair of testes. The testes lie on each lateral side in the 4th – 6th abdominal segments. A thin vas deferens arises from each testis. It opens into ejaculatory duct through seminal vesicle. The ejaculatory duct opens into male gonopore which is situated ventral to anus. A typical mushroom-shaped gland is present in the 6th-7th abdominal segments. It is an accessory reproductive gland. Male gonapophysis or phallomeres represent the external genitalia. These are made up of chitin. They are asymmetrical structures and surround the male gonopore. The sperms are stored in the seminal vesicles. The sperms are glued together in the form of bundles called spermatophores. Spermatophores are discharged during copulation.

Female Reproductive System: The female reproductive system of cockroach consists of two large ovaries. The ovaries lie laterally in the 2nd – 6th abdominal segments. Each ovary is formed of a group of eight ovarian tubules or ovarioles. They contain a chain of developing ova. Oviducts from each ovary unite into a single median oviduct. This is also called vagina and it opens into the genital chamber. A pair of spermatheca is present in the 6th segment which opens into the genital chamber.

Fertilization: Sperms are transferred through spermatophores. The fertilized eggs are encased in capsules; called ootheca. An ootheca is a dark reddish to blackish brown capsule. It is about 8 mm long. The oothecae are dropped or glued to a suitable surface; usually at a place with high relative humidity or near a food source. On an average, 9 – 10 ootehcae are produced by a female. Each ootheca contains 14 – 16 eggs. Development is indirect and is paurometabolous. Development through nymph stage is called paurometabolous. The nymph resembles the adults. The nymph grows by moulting about 13 times to reach the adult form. Wing pads are seen in the penultimate stage of development but wings are present only in adults.

Significance for Human: Most of the species are wild and have no economic importance. Some species live in and around human habitat. They destroy food and contaminate food with their excreta. Many bacterial diseases can be transmitted by food contamination by cockroaches.

FROG

In India, the most common species of frog is Rana tigrina. The frogs are cold-blooded or poikilotherms. They have the ability to camouflage. The frogs also show mimicry as a tool for protection. During summers, the frogs live in summer sleep (aestivation) and during winters, they live in winter sleep (hibernation).

MORPHOLOGY

The skin of frog is moist and slippery due to the presence of mucus. The dorsal side of body is usually olive green with dark irregular spots. The skin on the ventral side is uniformly pale yellow.

The body of a frog is divisible into head and trunk. A pair of nostrils is present above the mouth. Eyes are bulged and covered by a nictitating membrane. These membranes protect the eyes while the frog is under water. Ears are represented by membranous tympanum on either side of the eyes.

The forelimbs and hind limbs help in swimming, walking, leaping and burrowing. The hind limbs have five digits. The hind limbs are large and more muscular than forelimbs. The forelimbs have four digits. Webbed digits help in swimming. Sexual dimorphism is present in frogs. Sound producing vocal sacs and a copulatory pad (on the first digit of the fore limb) are present in male frogs.

ANATOMY

Digestive System: The alimentary canal is short because frogs are carnivorous. The alimentary canal is composed of buccal cavity, pharynx, oesophagus, stomach, intestine and rectum. The rectum opens out by cloaca. Liver produces bile and the pancreas produces pancreatic juice. Digestive enzymes are present in the pancreatic juice. The bilobed tongue helps in capturing prey.

Digestion: Gastric juices and HCl are secreted in the stomach; where partial digestion of food takes place. Bile and pancreatic juice are received in the duodenum. Bile emulsifies fat. Pancreatic juices digest carbohydrates and protein. Final digestion takes place in the intestine.

Absorption: Numerous finger-like folds are present in the inner wall of intestine. These are called villi and microvilli and facilitate absorption of food. The undigested food goes to the rectum from where it is expelled out through cloaca.

Respiration: Frogs respire through lungs when they are on land. The exchange of gases takes place through skin when the frog is in water. The lungs are a pair of elongated, pink-coloured, sac-like structures. Lungs are present in the upper part of the thorax. During aestivation and hibernation, exchange of gases takes place through skin.

Blood Vascular System: The vascular system is closed type and is well developed. Lymphatic system is also present in frogs. The blood vascular system of frog is composed of a heart, blood vessels and blood. The lymphatic system consists of lymph, lymph channels and lymph nodes.

Heart: The heart is situated in the upper part of the body cavity. There are three chambers in the heart of frog. There are two atria and one ventricle. The heart is covered by a membrane; called pericardium. A triangular structure; called sinus venosus; joins the right atrium. Blood from the vena cava reaches the sinus venosus. The ventricle opens into a sac-like conus arteriosus on the ventral side of the heart.

Arteries and Veins: Arteries carry blood from the heart to all parts of the body. The veins carry blood from all parts of the body to the heart. Hepatic portal system and renal portal system are present in frogs. The hepatic portal system is a system of special venous connection between liver and intestine. The renal portal system is a system of special venous connection between the kidneys and the lower parts of the body.

Blood: The blood is composed of plasma and cells. RBCs and WBCs and platelets are present in the blood of frogs. RBCs are nucleated and contain haemoglobin. Lymph lacks few proteins and RBCs and hence is different from blood.

Excretory System: The excretory system is composed of a pair of kidneys, ureters, cloaca and urinary bladder. The kidneys are compact, dark red and bean-like structures. The kidneys are situated a little posteriorly in the body cavity; on both sides of the vertebral column.

Each kidney is composed of several nephrons. Two ureters emerge from the kidneys in the male frogs. In males, the ureters act as urogenital duct and opens into the cloaca. In females, the ureters and oviduct open separately in the cloaca. The frog is a ureotelic animal.

Control & Coordination: Frog has a highly evolved neural system and endocrine glands.

Coordination By Hormones: Hormones are secreted by various endocrine glands and facilitate chemical coordination. The main endocrine glands in frog are; pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenal and gonads.

Nervous System: The nervous system is organized into central nervous system, peripheral nervous system and autonomic nervous system.

Central Nervous System: The central nervous system is composed of the brain and the nerve cord. The brain is enclosed in a bony structure; called brain box or cranium. The brain is divided into forebrain, midbrain and hindbrain.

Forebrain includes olfactory lobes, paired cerebral hemispheres and unpaired diencephalon.

A pair of optic lobes is present in the midbrain.

The hindbrain consists of cerebellum and medulla oblongata. The medulla passes out through the foramen magnum and continues into the spinal cord. The spinal cord is enclosed in the vertebral column.

Ten pairs of cranial nerves arise from the brain.

Sense Organs: Organs of touch (sensory papillae), taste buds, olfactory receptors (in nasal epithelium), eyes and internal ears are the sense organs of frog. The eyes and internal ears are well developed, but the rest of the sense organs are cellular aggregations around nerve endings.

Frogs have simple eyes. The ear also serves as the organ of balancing (equilibrium).

Reproductive System:

Male Reproductive Organs: The male reproductive system of frog is composed of a pair of yellowish ovoid testes. The testes are adhered to the upper part of kidneys by a double fold of peritoneum called merorchium. There 10 – 12 vasa efferentia arising from the testes. They enter the kidneys on their side and open into Bidder's canal. Finally, it communicates with the urinogenital duct which comes out of the kidneys. The urogenital ducts open into the cloaca. The cloaca is used to pass faecal matter, urine and sperms to the exterior.

Female Reproductive Organs: There is a pair of ovaries which are situated near kidneys. There is no functional connection between the ovaries and the kidneys. The oviducts open separately into the cloaca. A female frog can lay 2500 to 3000 ova at a time.

Fertilization: Fertilisation is external and takes place in water. Development is indirect and the larva is called tadpole.

Significance for Humans: Frogs eat insects and thus protect the crops. Frogs serve as an important link in the food chain and hence maintain the ecosystem. Frog meat is used as delicacy in some countries.

NCERT Solution

Question 1. Answer in one word or one line.

(i) Give the common name of Periplanata americana.

Answer: Cockroach

(ii) How many spermathecae are found in earthworm?

Answer: 2 spermathecae are found in earthworm.

(iii) What is the position of ovaries in cockroach?

Answer:- 2nd to 6th abdominal segment.

(iv) How many segments are present in the abdomen of cockroach?

Answer:- 10 segments.

(v) Where do you find Malpighian tubules?

Answer:- Malpighian tubules are the main excretory organs of the cockroach.

Question 2. Answer the following:

(i) What is the function of nephridia?

Answer: Excretion

(ii) How many types of nephridia are found in earthworm based on their location?

Answer: There are of three types of nephridia in the earthworm, viz. septal nephridia, integumentary nephridia and pharyngeal nephridia.

Question 4. Distinguish between the followings

(a) Prostomium and peristomium

Answer: Prostomium is the frontmost part of the earthworm. This is not called a true segment as it doesn't contain typical organs of an annelida. The true segment of the earthworm's body begins from the peristomium.

(b) Septal nephridium and pharyngeal nephridium

Answer: Septal nephridia are present on both sides of intersegmental septa of earthworm, while pharyngeal nephridia are present in the 4th, 5th and 6th segments. They are same; in terms of structure and function.

Question 5. What are the cellular components of blood?

Answer: Red Blood Cells and White Blood Cells.

Question 6. What are the following and where do you find them in animal body.

(a) Chondrocytes

Answer: The cells of cartilage are called chondrocytes.

(b) Axons:

Answer: The tail like portion of the neuron is called axon.

(c) Ciliated epithelium:

Answer: Ciliated epithelium are present in the inner surface of hollow organs; like bronchioles and fallopian tubes.

Question 7. Describe various types of epithelial tissues with the help of labelled diagrams.

Answer: The epithelial tissues are further divided into two main types, viz. simple epithelium and compound epithelium.

Simple Epithelium: The simple epithelium is composed of a single layer of cells. It is present in the lining of body cavities, ducts and tubes.

Compound Epithelium: The compound epithelium is composed of more than one layer of cells. The compound epithelium serves the protective function. Compound epithelium is present in skin, in the lining of buccal cavity, pharynx, ducts of salivary glands and pancreatic ducts.

The simple epithelium can be further divided into three types, viz. squamous, cuboidal and columnar.

a. Squamous Epithelium: The squamous epithelium is made up of flattened cells with irregular boundaries. Squamous epithelium is present in the walls of blood vessels and air sacs of lungs. They form a diffusion boundary.
b. Cuboidal Epithelium: The cuboidal epithelium is composed of cube-like cells. The cuboidal epithelium is usually found in ducts of glands and tubular parts of nephrons. The main functions of cuboidal epithelium are secretion and absorption.

Columnar Epithelium: The columnar epithelium is composed of tall and slender cells. The nuclei of the columnar cells are located at the base. Microvilli may be present on the free surface. Columnar epithelium is present in the lining of stomach and intestine. They help in secretion and absorption.

Question 8. Distinguish between

(a) Simple epithelium and compound epithelium

Answer: Simple epithelium is composed of one layer of cells, while compound epithelium is composed of more than one layer of cells.

(b) Cardiac muscle and striated muscle

Answer: Cardiac muscles are present in the heart, while striated muscles are present in articulatory joints. Cardiac muscle fibres are branched, while striated muscle fibres are unbranched. Cardiac muscles continuously contract and relax throughout the life, while striated muscles show movement as and when required.

(c) Dense regular and dense irregular connective tissues

Answer: The cells and fibres are loosely arranged in a semi-fluid matrix; in loose connective tissue. The cells and fibres are compactly packed in dense connective tissue. Areolar tissue is an example of loose connective tissue, while tendon and ligament are examples of dense connective tissue.

(d) Adipose and blood tissue

Answer: Adipose tissue is an example of loose connective tissue, while blood tissue is a specialized connective tissue. Adipose tissue is usually located beneath the skin. The cells of the adipose tissue are specialized to store fat. Blood facilitates transportation of various materials in the body.

(e) Simple gland and compound gland

Answer: Simple gland is composed of single cell, while compound gland is composed of multiple cells.

Question 9. Mark the odd one in each series:

(a) Areolar tissue; blood; neuron; tendon

Answer: Neuron is not a connective tissue

(b) RBC; WBC; platelets; cartilage

Answer: Cartilage is not part of blood

(c) Exocrine; endocrime; salivary gland; ligament

Answer: Ligament is not part of gland

(d) Maxilla; mandible; labrum; antennae

Answer: Antennae is not a masticating part of cockroach

Question - 10. Match the terms in column I with those in column II:

Column I	Column II
(a) Compound epithelium	1. Alimentary canal
(b) Compound eye	2. Cockroach
(c) Septal nephridia	3. Skin
(d) Open circulatory system	4. Mosaic vision
(e) Typhlosole	5. Earthworm
(f) Osteocytes	6. Phallomere
(g) Genitalia	7. Bone

Answer: (a) → 3, (b) → 4, (c) → 5, (d) → 2, (e) → 1, (f) → 7, (g) → 6

Question 11. Mention breifly about the circulatory system of earthworm

Answer: Closed type blood vascular system is present in earthworm. The blood vascular system is composed of a heart, blood vessels and capillaries. Smaller blood vessels supply the gut, nerve cord and body wall. Blood glands are present on the 4th, 5th and 6th segments. The blood glands produce blood cells and haemoglobin. Blood cells are phagocytic in nature. Exchange of gases occurs through moist body surface into the blood stream.

Question 13. Mention the function of the following

(a) Ureters in frog

Answer: The ureters act as urinogenital duct male frogs. In females, the ureter is separate from the oviduct and only carries urine.

(b) Malpighian tubules

Answer: Excretion is performed by Malpighian tubules in cockroaches.

(c) Body wall in earthworm

Answer: The body wall of the earthworm facilitates exchange of gases.

8. Cell: The Unit of Life

Unicellular organisms are capable of independent existence and they can perform the essential functions of life. Anything less than a complete cell does not ensure independent living. Hence, cell is called the fundamental structural and functional unit of life.

CELL THEORY

The cell theory was first proposed by Matthias Schleiden (1838) and Theodore Schwann (1839). Rudolf Virchow (1855) later added the concept of formation of cells; to this theory. The cell theory is as follows:

a. All living organisms are composed of cells and products of cells.
b. All cells arise from pre-existing cells.

AN OVERVIEW OF CELL

A typical animal cell is bound by a plasma membrane, while cell wall is also present in a typical plant cell. A dense membrane bound structure is present inside a typical cell. This structure is called nucleus. The nucleus contains the chromosomes. Chromosomes contain the genetic material DNA.

Prokaryotic Cell: Membrane bound nucleus is absent in prokaryotic cell. Moreover, membrane bound organelles are also absent in prokaryotic cells. Bacteria are examples of prokaryotic cell.

Eukaryotic Cell: Membrane bound nucleus is present in eukaryotic cell. Moreover, membrane bound organelles are present in eukaryotic cells. Cells of protista, fungi, plantae and animalia are eukaryotic cells.

Structure of Prokaryotic Cell

Prokaryotic cells are usually smaller than eukaryotic cells. They multiply more rapidly than eukaryotic cells. The four basic shapes of bacteria are bacillus (rod-like), coccus (spherical), vibrio (comma shaped) and spirillum (spiral).

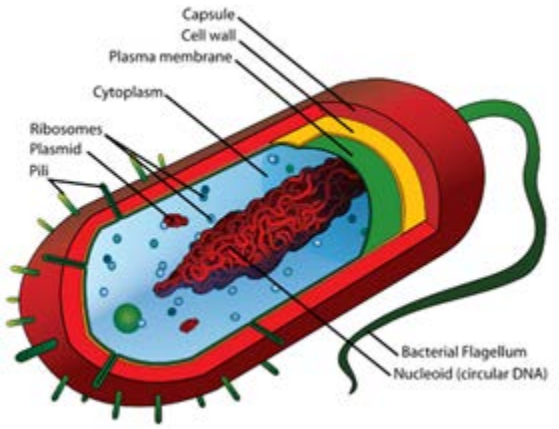


Fig: Prokaryotic Cell

Cell wall is present in all prokaryotic cells. The genetic material is naked, i.e. not enveloped by a nuclear membrane. Genomic DNA (single chromosome/circular DNA) mark the nuclear material. Additionally,

there may be small circular DNA outside the genomic DNA in some bacteria. These smaller DNA are called plasmids. The plasmid DNA confers some unique phenotypic characters to such bacteria. Resistance to antibiotics is one of those characters.

Cell Envelope: The cell envelope is chemically complex in most of the prokaryotes. The cell envelope is composed of three layers which are tightly bound. The outermost layer is glycocalyx, the middle layer is the cell wall and the innermost layer is the plasma membrane.

Gram Positive and Gram Negative Bacteria:

On the basis of differences in the cell envelopes and their response to Gram stain; bacteria are divided into two categories, viz. gram positive and gram negative. The bacteria which take up the Gram stain are called gram positive bacteria. The bacteria which do not take up the Gram stain are called gram negative bacteria.

Different bacteria have different types of glycocalyx; in terms of composition and thickness. It could be a loose sheath or could be thick and tough. The cell wall prevents the bacterium from bursting or collapsing. Plasma membrane in prokaryotes is similar as in eukaryotes.

Mesosomes:

A special membranous structure is formed by the extensions of plasma membrane into the cell. This is called the mesosome. These extensions are in the form of vesicles, tubules and lamellae. The mesosomes help in cell wall formation, DNA replication and distribution to daughter cells. They also help in respiration, secretion process, to increase the surface area of the plasma membrane and enzymatic content.

In some prokaryotes, there are other membranous extensions into the cytoplasm. These are called chromatophores and contain pigments, e.g. in cyanobacteria.

Flagella: Bacterial cells can be motile or non-motile. Thin filamentous extensions from cell wall are present in motile bacteria. These extensions are called flagella. The bacterial flagellum is composed of three parts; filament, hook and basal body.

Pili and fimbriae are also present on the surface of bacteria. Pili are elongated tubular structures made of special protein. Fimbriae are small bristle like fibres sprouting out of the cell. In some bacteria, they help attach the bacteria to rocks in streams and also to the host tissues.

Ribosomes: Ribosomes are associated with the plasma membrane in prokaryotes. They are about 15 nm by 20 nm in size. They are made of two subunits; 50S and 30S. These two subunits together form 70S prokaryotic ribosomes. Ribosomes are the site of protein synthesis.

Inclusion bodies: Reserve materials in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies. They lie free in cytoplasm, e.g. phosphate granules, cyanophycean granules and glycogen granules.

EUKARYOTIC CELLS

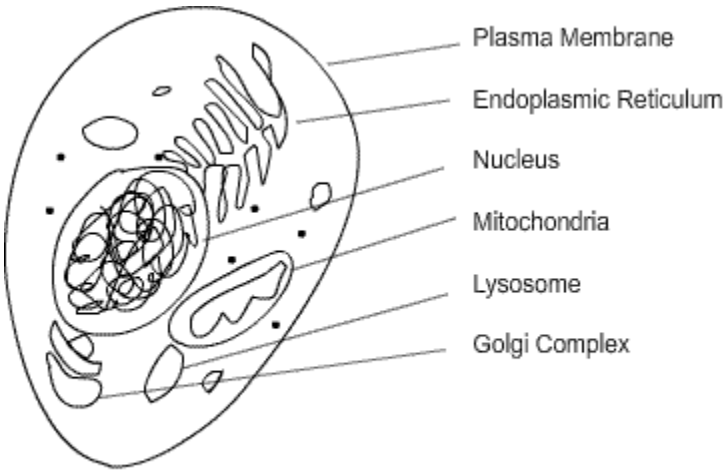


Fig: A typical animal cell

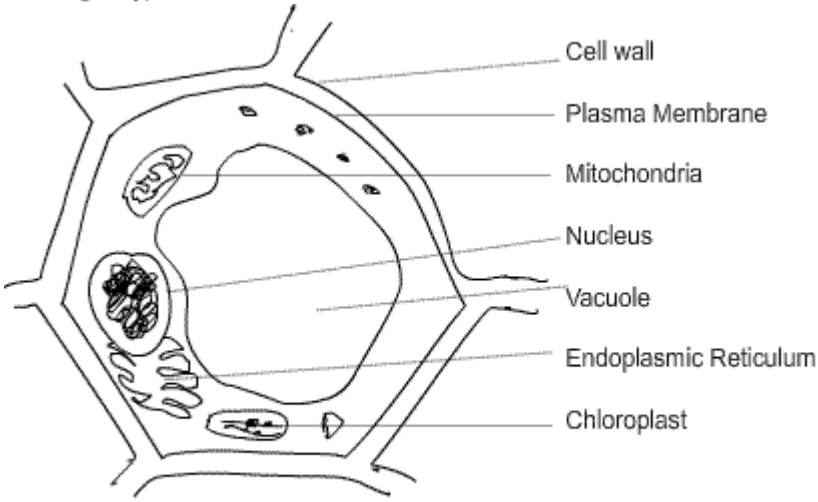


Fig: A typical plant cell

Following cell organelles are present in eukaryotic cells:

Cell Membrane

The cell membrane is composed of lipids which are arranged in a bilayer. The polar heads of lipids are towards the outer side and the hydrophobic ends are towards the inner side. This ensures protection of the non-polar tail of saturated hydrocarbons from the aqueous environment. Additionally, proteins and carbohydrates are also present in plasma membrane. The ratio of protein and lipids varies considerable in different types of cells. The peripheral proteins lie on the surface of the membrane, while the integral proteins lie partially of completely buried in the membrane.

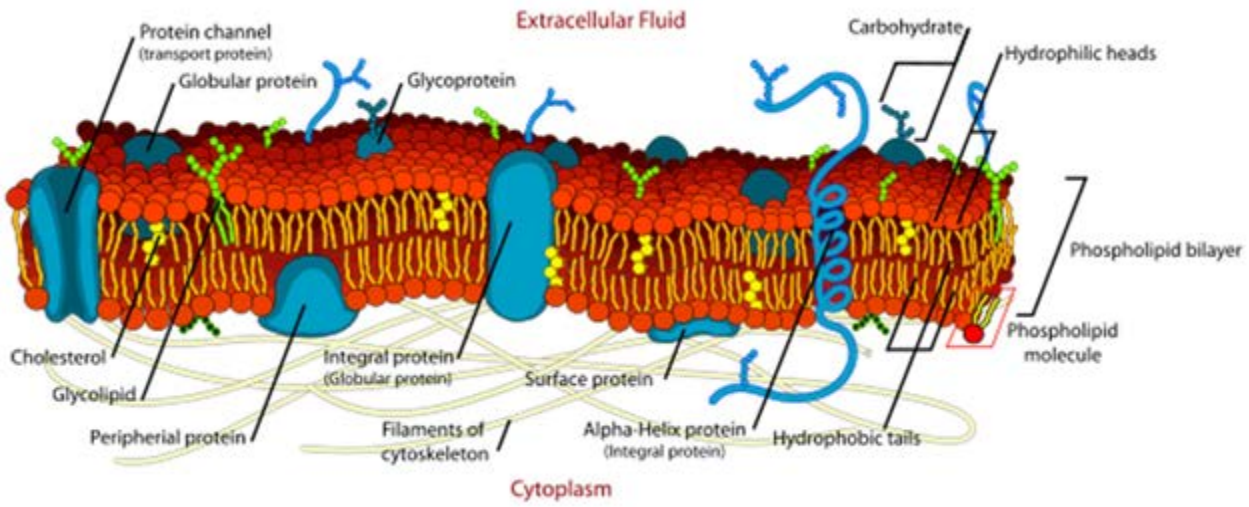


Fig: Plasma Membrane

Image Ref: Wikicommons

Fluid Mosaic Model: This model was proposed by Singer and Nicolson (1972) and is the most widely accepted model of plasma membrane. According to this model, lipids are present as quasi-fluid. Lateral movement of proteins within the bilayer is possible because of the quasi-fluid nature of the lipid bilayer. The fluid nature of the membrane is also important from many aspects; like cell growth, formation of intercellular junctions, secretion, endocytosis, cell division, etc.

Functions of Plasma Membrane: Transport of molecules across it is one of the most important functions of plasma membrane. Plasma membrane is selectively permeable. Many molecules can move across the membrane without any requirement of energy. The movement without the expense of energy is called passive transport. Passive transport takes place through diffusion and osmosis. Polar molecules need a carrier protein of the membrane to be transported across against concentration gradient. This type of transport is dependent on energy and is called active transport.

Cell Wall

The cell wall is a non-living rigid structure and forms an outer covering for the plasma membrane of fungi and plants. The cell wall in algae is made up of cellulose, galactans, mannans and minerals; like calcium carbonate. The cell wall of plants is made up of cellulose, hemicelluloses, pectins and proteins. The cell wall of a young plant cell is called the primary wall and is capable of growth. When the cell matures, this capability diminishes and a secondary wall is formed on the inner side of the cell.

The middle lamella is a layer mainly composed of calcium pectate. This holds or glues the different neighbouring cells together. The cell wall and middle lamellae may be traversed by plasmodesmata. Plasmodesmata connect the cytoplasm of neighbouring cells.

Endomembrane System

The endomembrane system is composed of endoplasmic reticulum, golgi complex, lysosomes and vacuoles. Functions of these cell organelles are coordinated with each other and hence they form the endomembrane system. Mitochondria, chloroplast and peroxisomes are not a part of the endomembrane system.

The Endoplasmic Reticulum (ER)

The Endoplasmic Reticulum is a network of tiny tubular structures which are scattered in the cytoplasm. The ER divides the intracellular space into two distinct compartments, viz. luminal and extra-luminal. The compartment inside the ER is called luminal compartment, while the compartment in the cytoplasm is called extra-luminal compartment.

Smooth ER: Ribosomes are absent on the surface of smooth ER. Smooth ER are the major sites of lipid synthesis.

Rough ER: Ribosomes are present on the surface of rough ER. Rough ER is quite common in those cells which are actively involved in protein synthesis. They are extensive and continuous with the outer membrane of the nucleus.

Golgi apparatus

Camillo Golgi (1898) was the first to observe densely stained reticular structures near the nucleus. These structures were later named after him. The Golgi Complex consists of many flat, disc-shaped sacs or cisternae. The cisternae are 0.5μm to 1.0μm in diameter. The cisternae are stacked parallel to each other and are concentrically arranged near the nucleus. The convex face of cisternae is called cis and it is the forming face. The concave face of cisternae is called trans and is the maturing face. The cis and trans faces are interconnected.

Functions of Golgi Complex: Packaging of materials is the main function of Golgi Complex. The materials are then delivered to the intracellular targets or secreted outside the cell. The materials come from the ER; in the form of vesicles; and fuse with the cis face. Then they move towards the trans face.

Lysosomes

The membrane bound vesicles formed by the process of packaging in the Golgi apparatus are called lysosomes. Lysosomes usually contain various hydrolytic enzymes. These enzymes are capable of digesting carbohydrates, proteins, lipids and nucleic acids.

Vacuoles

Membrane bound space found in the cytoplasm is called vacuole. A vacuole contains water, sap, excretory product and other useless materials. The vacuole is bound by a single membrane; called tonoplast. The vacuole can occupy up to 90% of the volume in a plant cell. In plant cells, the tonoplast facilitates the transport of a number of ions and other materials against concentration gradient into the vacuole. Hence, their concentration is significantly higher in the vacuole than in the cytoplasm.

Mitochondria

Mitochondrion is sausage-shaped or cylindrical structure. The diameter of mitochondria is 0.2-1.0μm (average 0.5μm) and length is 1.0-4.1μm. A mitochondrion is bound by two membranes. The two membranes divide the lumen of mitochondria into outer and inner compartments. The inner compartment is called the matrix. The inner membrane forms numerous finger-like infoldings; called cristae. The cristae increase the surface area.

Functions of Mitochondria: Aerobic respiration takes place in mitochondria. Energy is produced in the form of ATP and stored in the mitochondria. The matrix of mitochondria also has single circular DNA molecule, a few RNA molecules, ribosomes and the components needed for the synthesis of proteins. Mitochondria can replicate itself by fission.

Plastids

Plastids are found in all plant cells and in euglenoides. Plastids bear some specific pigments and hence impart characteristic colours. Based on the type of pigments, plastids can be classified into chloroplasts, chromoplasts and leucoplasts.

a. Chloroplast: They contain chlorophyll and carotenoid pigments. These pigments are responsible for trapping light energy which is required for photosynthesis.
b. Chromoplast: They contain fat soluble carotenoid pigments; like carotene, xanthophylls and others. Different plant parts get bright colours; like yellow, orange or red; because of the pigments in chromoplast.
c. Leucoplast: These are colourless plastids. They store various nutrients. The leucoplast which stores carbohydrates is called amyloplast. The leucoplast which stores oil and fats is called elaioplast. The leucoplast which stores proteins is called aleuroplast.

Structure of Chloroplast

Chloroplasts are lens-shaped, oval, spherical, discoid or even ribbon-like. Their number can vary from 1 per cell (as in Chlamydomonas) to 20 – 40 (as in the mesophyll of leaves).

Chloroplast is bound by two membranes. The inner membrane of chloroplast is less permeable. The space within the inner membrane of chloroplast is called the stroma. A number of organized flattened membranous sacs are present in the stroma. These flattened sacs are called thylakoids. The thylakoids are arranged in stacks called grana. There are flat membranous tubules connecting the thylakoids of the different grana. The membrane of the thylakoids encloses a space called a lumen.

The stroma contains enzymes required for the synthesis of carbohydrates and proteins. The stroma of chloroplast also contains double stranded DNA molecules and ribosomes. The ribosomes of the chloroplasts are smaller (70S) than the cytoplasmic ribosomes (80S).

Ribosomes

Ribosomes were first observed under electron microscope by George Palade (1953). Ribosomes are composed of RNA and proteins. The eukoryotic ribosomes are 80S, while the prokaryotic ribosomes are 70S. In this case, ‘S’ stands for sedimentation coefficient or Svedberg’s Unit. It is an indirect measure of density and size of ribosome. Both 70S and 80S ribosomes are composed of two subunits.

Cytoskeleton

The cytoskeleton is composed of an elaborate network of filamentous proteinaceous structures in cytoplasm. Cytoskeleton is involved in many functions; like mechanical support, motility, maintenance of the shape, etc.

Cilia and Flagella

Cilia and flagella are hair-like outgrowths of the cell membrane. Cilia are smaller than flagella. Cilia work like oars and facilitate movement of either the cell or the surrounding fluid. Flagella are responsible for cell movement. Flagella in prokaryotes are structurally different from those in eukaryotes.

A flagellum or a cilium is covered with plasma membrane. Their core is called the axoneme. The axoneme has a number of microtubules running parallel to the long axis. There are usually nine pairs of radially arranged peripheral microtubules and a pair of centrally located microtubules. Such an arrangement of microtubules is called the 9 + 2 array. The central tubules are connected by bridges and are also enclosed by a central sheath. The central sheath is connected to one of the tubules of each peripheral doublets by a radial spoke. Thus, there are nine radial spokes. The peripheral doublets are also interconnected by linkers. Cilium and flagellum emerge from basal bodies; which are centriole-like structures.

Centrosome and Centrioles

Centrosome usually contains two cylindrical structures which are called centrioles. They are surrounded by amorphous pericentriolar materials. Both the centrioles in a centrosome lie perpendicular to each other. They are made up of nine evenly spaced peripheral fibrins of tubulin protein. Each peripheral fibril is a triplet. Each is linked to the adjacent triplets. The central part of the proximal region of the centriole is also made up of protein. The central part is called the hub. The hub is connected with tubules of the peripheral triplets by radial spokes. The radial spokes are made up of protein. Centrioles form the basal bodies of cilia and flagella and spindle fibres. The centrioles give rise to spindle apparatus during cell division in animal cells.

Nucleus

Nucleus was first described by Robert Brown in 1831. Nucleus is enclosed by a double-membrane nuclear envelope. The space between the two membranes is called the perinuclear space. The perinuclear space forms a barrier between the nucleic materials and cytoplasmic materials. The outer membrane is usually continuous with the endoplasmic reticulum. Ribosomes are present on the outer membrane of nuclear envelope.

The nuclear membrane is interrupted by minute pores at various places. These pores provide passage to RNA and protein molecules. Usually, there is only one nucleus in a cell, but some variations can also be observed. Some mature cells even lack nucleus.

The fluid inside the nucleus is called nucleoplasm or nuclear matrix. The nucleoplasm contains nucleolus and chromatin. The nucleoli are spherical structures. Nucleolus is not a membrane bound structure. Synthesis of ribosomal RNA takes place in the nucleolus.

Nucleus also contains chromatin fibres; which are distinct during some stages of cell division. The chromatin contains DNA and some basic proteins; called histones; some non-histones and also RNA.

Chromosome: A chromosome has a primary constriction called centromere. Disc-shaped structures; called kinetochores; are present on the sides of the centromere. On the basis of position of the centromere, chromosomes can of four types, viz. metacentric, sub-metacentric, acrocentric and telocentric.

When the centromere divides the chromosomes into two identical arms, it is called metacentric chromosome. When the centromere is slightly away from the middle, it is called sub-metacentric chromosome. When the centromere divides the chromosome into a smaller and another much larger arm, it is called acrocentric chromosome. When the centromere is at the tail, it is called telocentric chromosome.

Microbodies

Many membrane bound minute vesicles are present in both plant and animal cells. They contain various enzymes and are called microbodies.

NCERT Solution

Question – 1 - Which of the following is not correct?

a. Robert Brown discovered the cell.
b. Schleiden and Schwann formulated the cell theory.
c. Virchow explained that cells are formed from pre-existing cells.
d. A unicellular organism carries out its life activities within a single cell.

Answer: (a) Robert Brown discovered the cell.

Question – 2 - New cells generate from

a. Bacterial fermentation
b. Regeneration of old cells
c. Pre-existing cells
d. Abiotic materials

Answer: (c) Pre-existing cells

Question – 3 - Match the following

Column I	Column II
(a) Cristae	1. Flat membranous sacs in stroma
(b) Cisternae	2. Inflodings in mitochondria
(c) Thylakoids	3. Disc-shaped sacs in Golgi apparatus

Answer: (a) → 2, (b) → 3, (c) → 1

Question – 4 - Which of the following is correct:

a. Cells of all living organisms have a nucleus.
b. Both animal and plant cells have a well defined cell wall.
c. In prokaryotes, there are no membrane bound organelles.
d. Cells are formed de novo from abiotic materials.

Answer: (c) In prokaryotes, there are no membrane bound organelles

Question – 5 - What is a mesosome in a prokaryotic cell? Mention the functions that it performs.

Answer: A special membranous structure is formed by the extensions of plasma membrane into the cell. This is called the mesosome. These extensions are in the form of vesicles, tubules and lamellae. The mesosomes help in cell wall formation, DNA replication and distribution to daughter cells. They also help in respiration, secretion process, to increase the surface area of the plasma membrane and enzymatic content.

Question – 6 - How do neutral solutes move across the plasma membrane? Can the polar molecules also move across it in the same way? If not, then how are these transported across the membrane?

Answer: Neutral solutes move across the plasma membrane through passive transport, i.e. by diffusion and osmosis. But polar molecules need a carrier protein of the membrane to be transported across against concentration gradient. This type of transport is dependent on energy and is called active transport.

Question – 7 - Name two cell-organelles that are double membrane bound. What are the characteristics of these two organelles? State their functions and draw labeled diagrams of both.

Answer: Mitochondria and chloroplast are two examples of double-membrane bound cell organelles. These two organelles have self-replicating capabilities. Mitochondria are the site of aerobic respiration. Chloroplasts are the site of photosynthesis.

Question – 8 - What are the characteristics of prokaryotic cells?

Answer: Membrane bound nucleus is absent in prokaryotic cell. Moreover, membrane bound organelles are also absent in prokaryotic cells. Bacteria are examples of prokaryotic cell.

Question – 9 - Multicellular organisms have division of labour. Explain.

Answer: In a unicellular organism, a single cell is responsible for all the life processes. This is called cellular level of organization. This can be seen in some simple multicellular organisms as well. But in most of the multicellular organism, there are different groups of cells to carry different functions. Thus, formation of tissues paves the way for division of labour in multicellular organisms.

Question – 10 - Cell is the basic unit of life. Discuss in brief.

Answer: Unicellular organisms are capable of independent existence and they can perform the essential functions of life. Anything less than a complete cell does not ensure independent living. Hence, cell is called the fundamental structural and functional unit of life.

Question – 11 - What are nuclear pores? State their function.

Answer: The nuclear membrane is interrupted by minute pores at various places. These are called nuclear pores. These pores provide passage to RNA and protein molecules.

Question – 12 - Both lysosomes and vacuoles are endomembrane structures, yet they differ in terms of their functions. Comment.

Answer: The functions of lysosomes and vacuoles are coordinated with the functions of other members of the endomembrane system. Hence, they are part of the endomembrane system. As they are different organelles, so their functions are also different. Lysosomes digest various substances, while vacuoles facilitate expulsion of waste products from the cell.

Question – 13 - Describe the structure of the following with the help of labelled diagrams: (i) Nucleus (ii) Centrosome

Answer: Nucleus: Nucleus is enclosed by a double-membrane nuclear envelope. The space between the two membranes is called the perinuclear space. The perinuclear space forms a barrier between the nucleic materials and cytoplasmic materials. The outer membrane is usually continuous with the endoplasmic reticulum. Ribosomes are present on the outer membrane of nuclear envelope.

Centrosome: Centrosome usually contains two cylindrical structures which are called centrioles. They are surrounded by amorphous pericentriolar materials.

Question – 14 - What is a centromere? How does the position of centromere form the basis of classification of chromosomes? Support your answer with a diagram showing the position of centromere on different types of chromosomes.

Answer: A chromosome has a primary constriction called centromere. On the basis of position of the centromere, chromosomes can of four types, viz. metacentric, sub-metacentric, acrocentric and telocentric.

When the centromere divides the chromosomes into two identical arms, it is called metacentric chromosome. When the centromere is slightly away from the middle, it is called sub-metacentric chromosome. When the centromere divides the chromosome into a smaller and another much larger arm, it is called acrocentric chromosome. When the centromere is at the tail, it is called telocentric chromosome.

9. Biomolecules

Analysis Of Chemical Composition: For this, a living tissue is taken. The tissue is ground in trichloroacetic acid (Cl_3CCOOH); by using pestle and mortar. The slurry is then filtered through a cloth. The filtrate contains acid-soluble pool and the retentate contains acid-insoluble fraction. Organic compounds are found in the acid-soluble pool, while inorganic substances are found in acid-insoluble fraction.

Biomolecules: All the carbon compounds which are obtained from living tissues are called biomolecules.

AMINO ACIDS:

Amino acids are organic compounds which contain an amino group and an acidic group as substituents on the same carbon, i.e. α-carbon. Due to this, they are called α-amino acids. The amino acids are substituted methanes. There are four substituent groups which occupy the four valency positions. These groups are; hydrogen, carboxyl group, amino group and a variable group; called R group. The nature of the R-group governs a particular type of amino acids.

However, there are only 21 types of amino acids which occur in proteins. The R-group in these proteinaceous amino acids could be of various types. The amino, carboxyl and the R functional groups decide the chemical and physical properties of an amino acid.

Amino acid with a hydrogen is called glycine, one with a methyl group is called alanine, one with hydroxyl methyl group is called serine, etc. Based on the number of amino and carboxyl group, the amino acids can be acidic, basic or neutral. A particular feature of amino acid is the ionizable nature of $–NH_2$ and –COOH groups. Hence, structure of amino acids changes in solutions of different pH.

LIPIDS:

Lipids are usually insoluble in water. Lipids can be simple fatty acids and some lipids have phosphorous and phosphorylated organic compounds in them. Lipids; containing phosphorus; are called phospholipids. A fatty acid has a carboxyl group attached to an R group. The R group can be a methyl or ethyl or higher number of CH_2 group (1 carbon to 19 carbons).

Fatty acids could be saturated or unsaturated. Many lipids have both glycerol and fatty acids. In this case, the fatty acids are found esterified with glycerol. They can be monoglycerides, diglycerides and triglycerides. On the basis of melting points, they can be termed as fats and oils. Oils have lower melting points while fats have higher melting points.

There are a number of carbon compounds; with heterocylic rings; found in living organisms. Some of them are nitrogenous bases, e.g. adenine, guanine, cytosine, uracil and thymin. When a nitrogenous base is attached to a sugar, it is called a nucleoside, e.g. adenosine, guanosine, thymidine, uridine and cytidine. If a phosphate group is also found esterified to the sugar then they are called nucleotides, e.g. adenylic acid, thymidylic acid, guanylic acid, uridylic acid and cytidylic acid.

Primary Metabolites: Metabolites which have identifiable functions are called primary metabolites. They play known key roles in normal physiological processes. All the primary metbaolites are found in animal cells.

Secondary Metabolites: There are certain metabolites about which we do not have enough information to suggest their role in physiological processes. Such metabolites are called secondary metabolites. Secondary metabolites are not found in animal cells.

Primary Metabolites	Secondary Metabolites
Sugar	Pigments: Carotenoids, Anthocyanins
Amino Acids	Alkaloids: Morphine, Codeine
Fats	Terpenoids: Monoterpenes, Diterpenes
Nitrogen Bases	Essential Oils
Nucleotides	Toxins: Abrin, Ricin
Nucleosides	Lectins: Concalavalin A
	Drugs: Vinblastin, Curcumin
	Polymer Substances: Rubber, Gum Cellulose

Mircomolecules: Biomolecules with molecular eights less than one thousand Dalton are called micromolecules or simple as biomolecules.

Biomacromolecules: Biomolecules with molecular weights more than one thousand Dalton are called biomacromolecules. These are found in the acid-insoluble fraction.

Proteins

Protein is a polymer of amino acids. Based on similar or different monomers repeating in a protein, it is classified as homopolymer and heteropolymer. When same monomer is repeated in the protein, it is called homopolymer. When different monomers are present in the protein, it is called heteropolymer.

Essential Amino Acids: Some amino acids are essential for our health. But our body does not make them and they need to be supplemented through diet. Such amino acids are called essential amino acids. Collagen is the most abundant protein in the animal world. Ribulose biphosphate Carboxylase-Oxygenae (RUBISCO) is the most abundant protein in the whole biosphere.

Some Proteins and their functions	
Protein	Function
Collagen	Intercellular ground substance.
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights pathogens
Receptor	Sensory reception
GLUT-4	Enables glucose transport into cells

POLYSACCHARIDES

The long chains of sugars are called polysachharides. If a polysaccharide is made up of similar monosaccharides, it is called homopolymer, e.g. cellulose. If a polysaccharide is made up of different monosachharides, it is called heteropolymer.

The right end of a polysaccharide chain is called the reducing end and the left end is called the non-reducing end.

Starch forms helical secondary structures. Starch can hold I_2 (iodine) molecules in helical portion. Cellulose does not contain complex helices and hence cannot hold I_2 .

In a polysaccharide chain, the right end is called the reducing end and the left end is called the non-reducing end. Starch forms helical secondary structures. In fact, starch can hold I2 molecules in the helical portion.

NUCLEIC ACIDS

A nucleic acid is composed of nucleotide. There are three chemically distinct components in a nucleotide. One of them is a heterocyclic compound, the second is a monosaccharide and the third is phosphoric acid or phosphate.

The heterocyclic compounds; present in nucleic acids are the nitrogenous bases, viz. adenine, guanine, uracil, cytosil and thymine. Adenine and Guanine are substituted purines, while uracil, cytosil and thymine are substituted pyrimidines.

Based on the presence of purine or pyrimidine, the heterocyclic ring is called purine and pyrimidine. Polynucleotides contain either ribose sugar or 2' deoxyribose sugar. If ribose sugar is present then the nucleic acid is called ribonucleic acid (RNA). If deoxyribose sugar is present then the nucleic acid is called deoxyribose nucleic acid (DNA).

STRUCTURE OF PROTEINS

Primary Structure: The sequence of amino acids is called the primary structure of a protein. The left end is represented by the first amino acid, while the right end is represented by the last amino acid. The first amino acid is also called N-terminal amino acid. The last amino acid is called C-terminal amino acid.

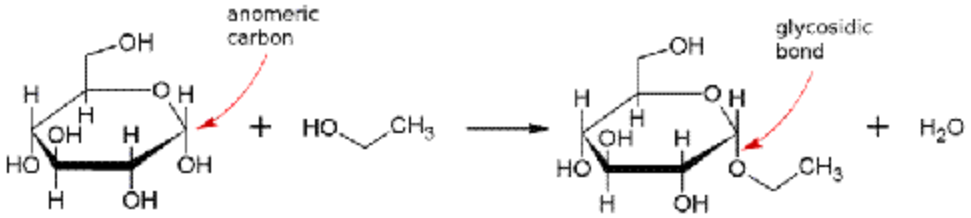
Secondary Structure: The protein is not a linear chain of amino acids rather the chain would bend at some places and even form helices. Regularly repeating local structures gives secondary structure to protein.

Tertiary Structure: The overall shape of a protein molecule; and the spatial relationship of the secondary structures to one another; is called tertiary structure of protein. In other words, the various folds which give three dimensional appearances to protein form its tertiary structure.

Quaternary Structure: The manner in which the individual folded polypeptides are arranged with respect to each other is called quaternary structure of protein.

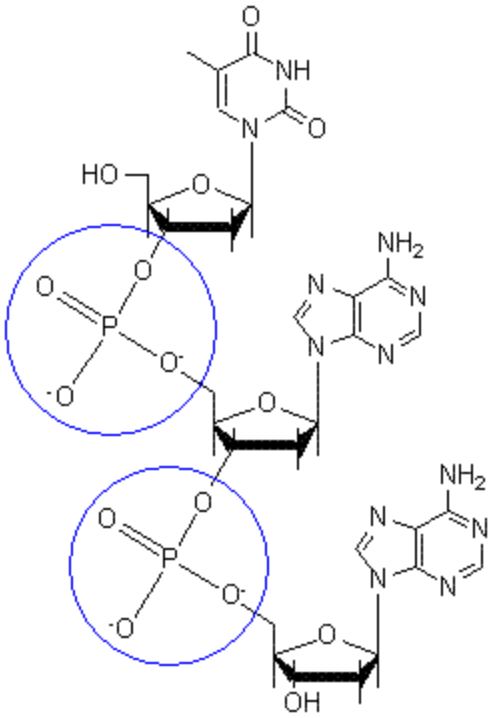
NATURE OF BOND LINKING MONOMERS IN A POLYMER

Glycosidic Bond: Certain type of functional group which joins a sugar molecule to another group is called glycosidic bond. Another group may or may not be another carbohydrate.



Peptide Bond: A chemical bond formed between two molecules; when the carboxyl group of one molecule reacts with the amine group of another molecule; is called peptide bond (amide bond). A molecule of water is released during this reaction. This is a dehydration synthesis reaction and usually occurs between two amino acids. This is also known as a condensation reaction. The resulting CO – NH bond is called a peptide bond. The resulting molecule is called an amide. The four atom functional group – C (=O)NH – is called an amide group or a peptide group.

Phospho-diester Bond: A group of strong covalent bonds between a phosphate group and two other molecules over two ester bonds is called a phosphor-diester bond. Phosphodiester bonds make the backbone of the strands of DNA and hence are central to all life on Earth. In DNA and RNA, the phosphodiester bond is the linkage between the 3' carbon atom of one sugar molecule and the 5' carbon atom of another.



DYNAMIC STATE OF BODY CONSTITUENTS – CONCEPT OF METABOLISM

Metabolism: All the biomolecules are constantly being changed into some other biomolecules and also made from some other biomolecules. The turnover of biomolecules takes place continuously. All these reactions are together called metabolism.

Anabolism: When a complex biomolecule is synthesized from simple biomolecules through a biological process, the process is called anabolism. Energy is utilised during anabolism.

Catabolism: When a complex biomolecule is disintegrated to produce simple biomolecules through a biological process, the process is called catabolism. Energy is released during catabolism.

Metabolic Pathway: Metabolites are converted into each other in a series of linked reactions. Such a series of linked reactions is called metabolic pathway. Every chemical reaction in the metabolic pathways is a catalysed reaction. The metabolic pathways are either linear or circular. These pathways crisscross each other; which means there are traffic junctions. But the interlinked metabolic traffic is very smooth and no single mishap has been reported for healthy conditions.

The Living State: All living organisms exist in a steady state; characterized by concentrations of each of the biomolecules. The steady state is a non-equilibrium state. It can be said that the living process is a constant effort to prevent falling into equilibrium. Without metabolism, there cannot be a living state.

ENZYMES

An enzyme is a catalyst which is utilised in metabolic reactions. Almost all enzymes are proteins.

"Lock and Key" Model: The lock and key model was suggested by Emil Fischer in 1894. Emil Fischer postulated that both the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another. This model explains the specificity of enzyme. But this model fails to explain the stabilization of the transition state which an enzyme achieves.

Induced Fit Model: This is the most accepted model and is a modification over the lock and key model. The induced fit model was proposed by Daniel Koshland in 1958. According to this model, since enzymes are rather flexible structures; the active site is continually reshaped by interactions with the substrate when the substrate interacts with the enzyme. In some cases, the substrate molecule also changes shape slightly when it enters the active site. The active site continues to change until the substrate is completely bound. The final shape and charge is determined at this point of enzyme-substrate reaction.

There are many differences between enzyme catalysts and inorganic catalysts. Inorganic catalysts work efficiently at high temperatures and high pressures, enzymes get damaged at high temperatures (above 40°C). But enzymes which are isolated from thermophilic organisms show thermal stability.

Mechanisms of Enzymatic Actions

- Enzyme lowers the activation energy by creating an environment in which the transition state is stabilized.
- Enzyme lowers the energy of the transition state by creating an environment with the opposite charge distribution to that of the transition state. But an enzyme does this without distorting the substrate.
- Enzyme provides an alternative pathway.
- Enzyme reduces the reaction entropy charge by bringing substrates together in the correct orientation to react.
- Increase in temperatures speeds up reactions. But if the enzyme is heated too much, its shape deteriorates and it regains it shape only when the temperature comes back to normal. Some enzymes work best at low temperatures, e.g. thermolabile.

The catalytic cycle of an enzyme action can be described in the following steps:

1. The substrate binds to the active site of the enzyme, fitting into the active site.
2. The binding of the substrate induces the enzyme to alter its shape, fitting more tightly around the substrate.
3. The active site of the enzyme breaks the chemical bonds of the substrate and the new enzyme-product complex is formed.
4. The enzyme releases the products of the reaction and the free enzyme is ready to bind to another molecule of the substrate.

Factors Affecting Enzyme Activity

Temperature and pH: Enzymes usually function in a narrow range of temperature and pH. Each enzyme shows its highest activity at optimum temperature and optimum pH. Beyond that range, the activity declines. Low temperature preserves the enzyme temporarily in inactive state, while high temperature destroys the enzyme.

Concentration of Substrate: The velocity of enzymatic action at first rises with an increase in substrate concentration. But the velocity of reaction does not rise once it reaches a maximum velocity (Vmax). This happens because there are fewer molecules of enzyme and no free enzyme molecule is left to bind with the additional substrate molecules.

Effect of Inhibitor: When the inhibitor closely resembles the substrate and inhibits the activity of an enzyme, it is known as competitive inhibitor. Because of its close structural similarity with the substrate, the inhibitor competes with the substrate for the binding site on the enzyme. Such competitive inhibitors are often used in the control of bacterial pathogens.

Classification and Nomenclature of Enzymes

Enzymes are divided into 6 classes each with 4-13 subclasses and named accordingly by a four-digit number.

Oxidoreductases/dehydrogenases: Enzymes which catalyse oxidoreduction between two substrates S and S'.

Transferases: Enzymes catalysing a transfer of a group, G (other than hydrogen) between a pair of substrate S and S'.

Hydrolases: Enzymes catalysing hydrolysis of ester, ether, peptide, glycosidic, C-C, C-halide or P-N bonds.

Lyases: Enzymes that catalyse removal of groups from substrates by mechanisms other than hydrolysis leaving double bonds.

Isomerases: Includes all enzymes catalysing inter-conversion of optical, geometric or positional isomers.

Ligases: Enzymes catalysing the linking together of 2 compounds, e.g., enzymes which catalyse joining of C-O, C-S, C-N, P-O etc. bonds.

Co-factors

In many cases, non-protein constituents are bound to the enzyme which makes the enzyme catalytically inactive. Such non-protein constituents are called cofactors. In such cases, the protein portion of the enzyme is called the apoenzyme. There are three kinds of cofactors, viz. prosthetic groups, co-enzymes and metal ions.

Prosthetic Groups:

Prosthetic groups are organic compounds. They are distinguished from other cofactors in that they are tightly bound to the apoenzyme. For example, in peroxidase and catalase, which catalyze the breakdown of hydrogen peroxide to water and oxygen, haem is the prosthetic group and it is a part of the active site of the enzyme.

Co-enzymes:

Co-enzymes are also organic compounds but their association with the apoenzyme is only transient. A co-enzyme's association; with apoenzyme; usually occurs during the course of catalysis. Moreover, co-enzymes serve as co-factors in a number of different enzyme catalyzed reactions. The essential chemical components of many coenzymes are vitamins, e.g., coenzyme nicotinamide adenine dinucleotide (NAD) and NADP contain the vitamin niacin.

Metal Ions: A number of enzymes require metal ions for their activity. Such metal ions form coordination bonds with side chains at the active site and at the same time form one or more cordination bonds with the substrate, e.g., zinc is a cofactor for the proteolytic enzyme carboxypeptidase. Catalytic activity is lost when the co-factor is removed from the enzyme which proves that they play a crucial role in the catalytic activity of the enzyme.

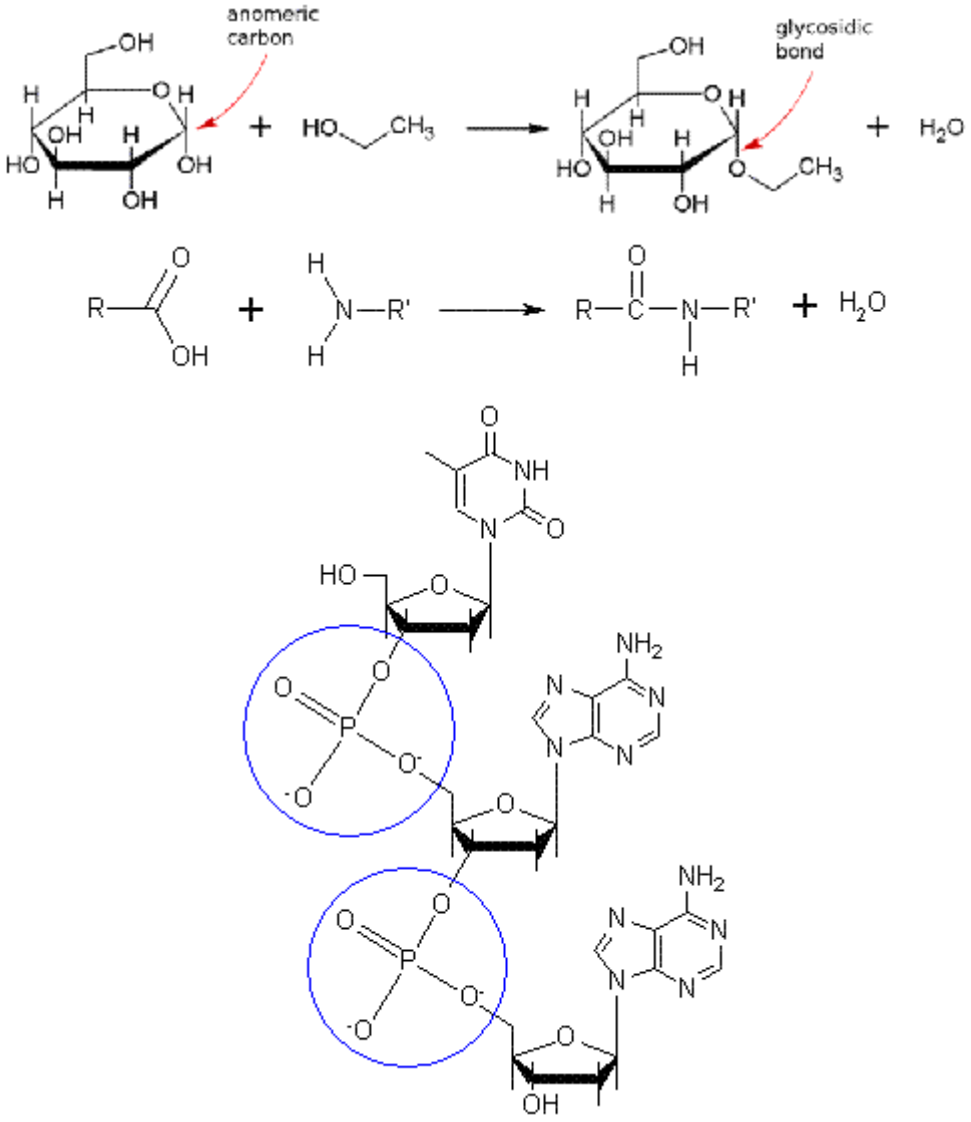
NCERT Solution

Question – 1 - What are macromolecules? Give examples.

Answer: Biomolecules with molecular weights more than one thousand Dalton are called biomacromolecules. These are found in the acid-insoluble fraction. Examples: Protein, polysaccharides, lipids, etc.

Question – 2 - Illustrate a glycosidic, peptide and a phospho-diester bond.

Answer:



Question – 3 - What is meant by tertiary structure of proteins?

Answer: The overall shape of a protein molecule; and the spatial relationship of the secondary structures to one another; is called tertiary structure of protein. In other words, the various folds which give three dimensional appearances to protein form its tertiary structure.

Question – 4 - Find and write down structures of 10 interesting small molecular weight biomolecules. Find if there is any industry which manufactures the compounds by isolation. Find out who are the buyers.

Answer:

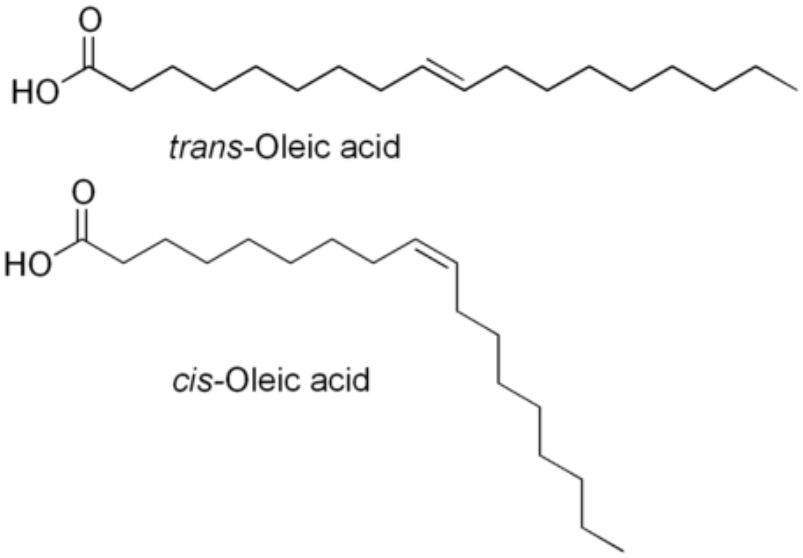


Fig: Fatty acids

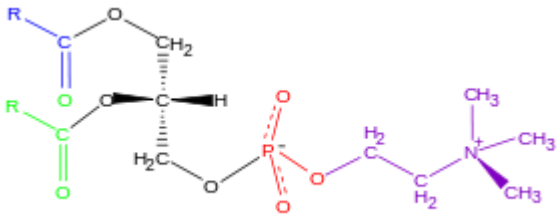


Fig: A phospholipid

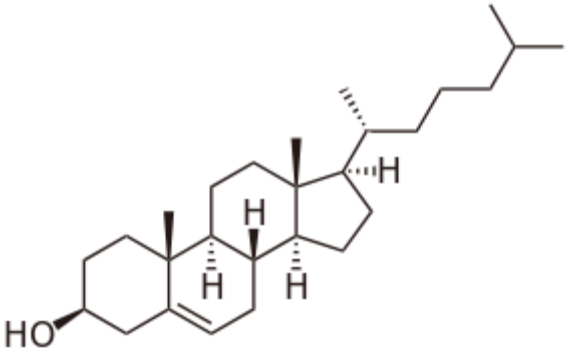


Fig: Cholesterol

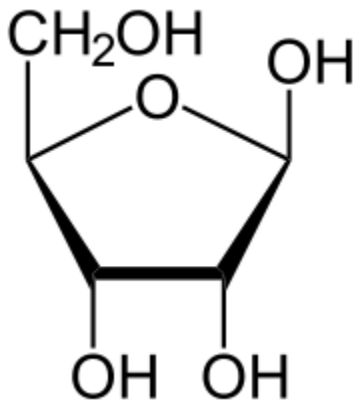


Fig: Ribose

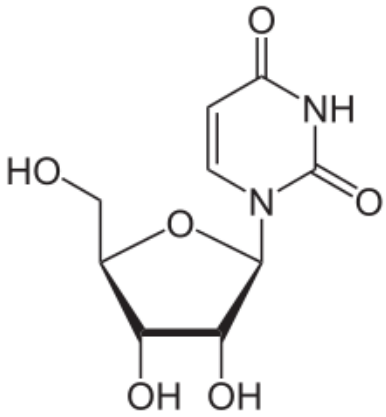


Fig: Uridine

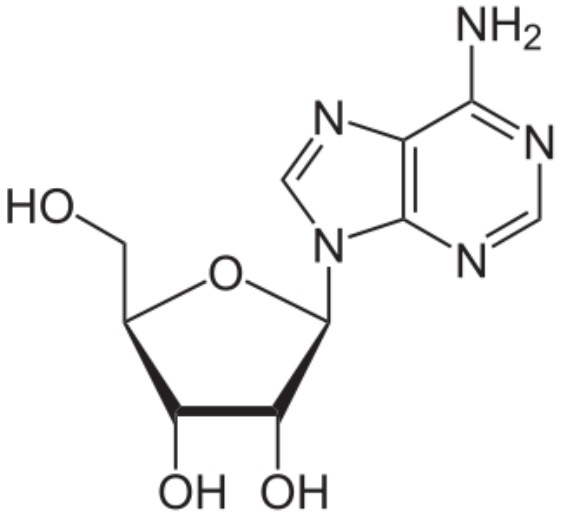


Fig: Adenosine

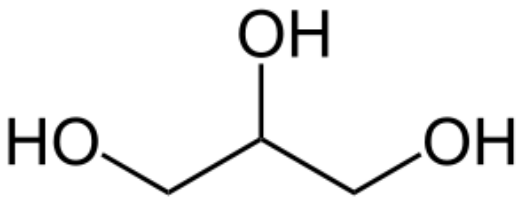


Fig: Glycerol

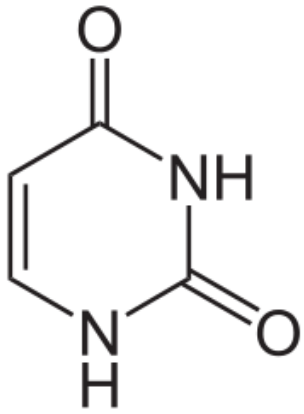


Fig: Uracil

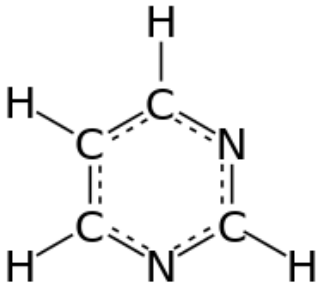


Fig: Pyrimidine

Fat is manufactured by isolation. Many hormones are also manufactured by isolation. Pharmaceutical and consumer goods industry can be the major buyers of these products.

Question – 5 - Proteins have primary structure. If you are given a method to know which amino acid is at either of the two termini (ends) of a protein, can you connect this information to purity or homogeneity of a protein?

Answer: If the same amino acid is present at both ends of protein, then it is a homopolymer. The protein is not pure in that case. On the other hand, a heteropolymer is a pure protein.

Question – 6 - Find out and make a list of proteins used as therapeutic agents. Find other applications of proteins (e.g., Cosmetics etc.)

Answer: Contraceptive pills are hormones and hence are proteins. Additionally, there are many protein supplements available in the market. Collagen is a protein which is used as an additive in various food and cosmetics.

Question – 7 - Explain the composition of triglyceride.

Answer: When fatty acids are found esterified with glycerol, they are called glycerides. Presence of three esterified bonds makes them triglycerides.

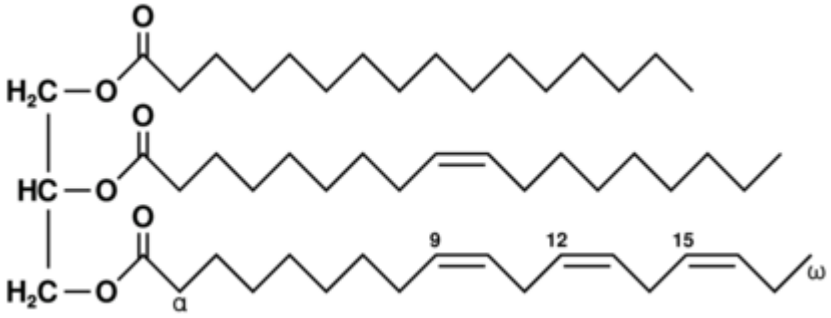


Fig: An unsaturated fat Triglyceride

In this figure, the left side is composed of glyceride. The right side is composed of palmitic acid, ocleic acid and alpha-linolenic acid; from top to bottom.

Question – 8 - Can you describe what happens when milk is converted into curd or yoghurt, from your understanding of proteins?

Answer: Nearly 80% of milk protein is casein. Proteases act on the soluble portion of casein, i.e. K-casein. These leads to coagulation of milk protein and curd is formed.

Question – 9 - Attempt titrating an amino acid against a weak base and discover the number of dissociating (ionizable) functional groups in the amino acid.

Answer: When amino acid is titrated against a weak base, it ionizes into NH2 (amine group) and COOH (carboxylic group).

Question – 10 - Draw the structure of the amino acid, alanine.

Answer:

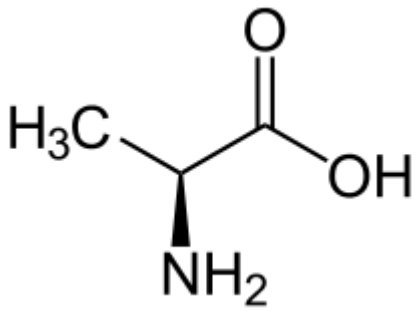


Fig: Alanine

Question – 11 - What are gums made of? Is Fevicol different?

Answer: Natural gum is a polysaccharide of natural origin. It has high viscosity even at low concentration. Fevicol is a synthetic glue. Synthetic glue is usually made of polymers which are dissolved in a solvent. When the adhesive is exposed, the solvent evaporates; resulting in hardening of the adhesive. Synthetic adhesives come in various strengths and are used accordingly.

Question – 12 - Find out a qualitative test for proteins, fats and oils, amino acids and test any fruit juice, saliva, sweat and urine for them.

Answer: Qualitative tests for proteins, fats and oils are as follows:

Biuret Test: Biuret test is done for protein. Appearance of violet colour in the solution confirms the presence of protein. Biuret ($H_2NCONHCONH_2$) reacts with copper ion in a basic solution and gives the violet colour.

Liebermann-Burchard Test: This test is done for cholesterol. The reagent is a mixture of acetic anhydride and sulphuric acid. Appearance of green colour confirms the presence of cholesterol.

Grease Test: This test is done for certain oils. This is a simple test which involves rubbing the given sample on cloth or paper. Appearance of a translucent spot shows the presence of oil.

Question – 13 - Find out how much cellulose is made by all the plants in the biosphere and compare it with how much of paper is manufactured by man and hence what is the consumption of plant material by man annually. What a loss of vegetation!

Answer: As per a UN report of 2006, about 312 million tons of carbon is stored as biomass of plants. About 10% of the total available cellulose is used in paper making. This appears as a small figure; compared to the total biomass. But when the lost forest cover is replaced by monoculture plantations, it makes the situation grim. Moreover, wood is also cut for many other purposes. Hence, there is a huge loss of vegetation every year.

Question – 14 - Describe the important properties of enzymes.

Answer: Enzymes are biological catalysts. No metabolic reaction takes place without an enzyme. Enzymes are highly specific to the substrates. Unlike inorganic catalysts, enzymes are susceptible to high temperatures and cease to act after optimum temperature. Enzymes greatly hasten the rate of metabolic reactions.

10. Cell Cycle and Cell Division

Phases of Cell Cycle

The cell cycle is divided into two basic phases:

a. Interphase: The phase between subsequent cell divisions is called the interphase. The interphase lasts for more than 95% of the cell cycle.
b. M Phase (Mitosis phase): The actual cell division takes place in the M phase. The M phase lasts for less than 5% of the cell cycle. The M phase is composed of two major steps, viz. karyokinesis and cytokinesis. Division of nucleus happens during karyokinesis. Division of cytoplasm happens during cytokinesis.

The interphase is further divided into three phases, which are as follows:

a. G_1 phase (Gap 1): During this phase, the cell is metabolically active and continuously grows.
b. S phase (Synthesis): During this phase, DNA synthesis or replication takes place. The amount of DNA becomes double during this phase, but the number of chromosomes remains the same.
c. G_2 phase (Gap 2): During this phase, protein synthesis takes place.

Quiescent Stage (G_0): Cells which do not divide further, exit G1 phase to enter an inactive stage. This stage is called quiescent stage (G_0) of the cell cycle. The cells in this stage remain metabolically active but do not undergo division. But these cells can resume division as and when required.

M PHASE

Mitosis is divided into four stages, viz. Prophase, Metaphase, Anaphase and Telophase

Prophase

- Condensation of chromosomal material takes place. A chromosome is seen to be composed of two chromatids. The chromatids are attached together at the centromere.
- Spindle fibres are formed.
- Various cell organelles; like golgi bodies and ER cannot be seen during this staged. Nucleolus and nuclear envelope also disappear.

Metaphase

- All the chromosomes come to lie at the equator.
- In each chromosome, one chromatid is connected to the spindle fibre from one pole and another chromatid is connected to the spindle fibre from another pole.
- The plane of alignment of chromosomes during this phase is called metaphase plate.

Anaphase

- Centromeres split which results in separation of chromatids.
- After that, chromatids move to opposite poles.

Telophase

- The chromosomes form clusters at opposite poles. They become inconspicuous.

- Nuclear envelope is formed around the chromosome clusters.
- Nucleolus, golgi complex and ER are also formed.

Cytokinesis

Division of cytoplasm is achieved by cytokinesis. In animal cell, a furrow appears in the plasma membrane. The furrow gradually deepens and finally joins in the centre. Thus, the cytoplasm is divided into two parts. In plant cells, cell wall formation begins in the centre. This grows outwards to meet the existing lateral walls and thus, the cytoplasm is divided into two parts.

Significance of Mitosis

- Mitosis results in the formation of new cells which are required for growth and repair.
- Mitosis results in the formation of two daughter cells; which have identical genetic makeup, similar to the mother cell.

MEIOSIS

- Meiosis involves two sequential cycles of nuclear and cell division, but only a single cycle of DNA replication. Meiosis is divided into meiosis I and meiosis II.
- Meiosis I begins after the S phase, and meiosis II follows meiosis I.
- Pairing of homologous chromosomes happens during meiosis which results in recombination of genes.
- Four haploid daughter cells are formed at the end of meiosis.

Meiosis I	Meiosis II
Prophase I	Prophase II
Metaphase I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II

MEIOSIS I

Prophase I:

Prophase in meiosis I is typically longer and more complex than the prophase in meiosis II. Prophase I is subdivided into five phases, viz. Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Leptotene:

- During this stage, the chromosomes become gradually visible under light microscope. Compaction of chromosomes continues throughout this phase.

Zygotene:

- Chromosomes start pairing together. This process is called synapsis. The paired chromosomes are called homologous chromosomes.
- Formation of synapsis is accompanied by the formation of synaptonemal complex.

- The synaptonemal complex by a pair of homologous chromosomes is called a bivalent or a tetrad.

Pachytene:

- Bivalent chromosomes clearly appear as tetrads, at this stage.
- Recombination nodules appear. These nodules are the sites at which crossing over takes place between non-sister chromatids of the homologous chromosomes.
- Exchange of genetic materials between two homologous chromosomes takes place during crossing over. This leads to recombination of genetic materials on the two chromosomes.

Diplotene:

- Synapotnemal complex is dissolved at this stage.
- The recombined homologous chromosomes of the bivalent separate from each other; except at the site of crossing over.
- The X-shaped structures; thus formed; are called chiasmata.

Diakinesis:

- Chiasmata is terminated at this stage.
- Meiotic spindles are formed to prepare the homologous chromosomes for separation.
- Nucleolus disappears and nuclear envelope breaks down by the end of diakinesis.

Metaphase I:

- The bivalent chromosomes are aligned on the equatorial plate.
- Spindle fibres from opposite poles attach to the pair of homologous chromosomes.

Anaphase I:

- Homologous chromosomes separate, but sister chromatids remain attached at their centromeres.

Telophase I:

- Nuclear membrane and nucleolus reappear.
- This is followed by cytokinesis and this stage is called the diad of cells.
- The stage between the two meiosis divisions is called interkinesis. Interkinesis is usually short lived.

MEIOSIS II

Prophase II: Meiosis II resembles the mitotic cell division. It begins immediately after cytokinesis. Nuclear membrane disappears. Chromosomes again become compact.

Metaphase II: The chromosomes align at the equator. Spindle fibres from the opposite poles get attached to the kinetochores of sister chromatids.

Anaphase II: Centromeres split and sister chromatids move towards the opposite poles.

Telophase II: The two groups of chromosomes get enclosed by nuclear envelope. This is followed by cytokinesis; resulting in the formation of four daughter cells.

Significance of Meiosis:

- Conservation of specific chromosome number of each species is achieved across successive generations in sexually reproducing organisms through meiosis.
- Meiosis helps in increasing the genetic variations in the population of organisms from one generation to the next.

Difference between mitosis and meiosis	
Mitosis	Meiosis
This type of division takes place in somatic cells.	This type of division takes place in gametic cells.
Two daughter cells are formed.	Four daughter cells are formed.
No. of chromosomes remains diploid in daughter cells.	Number of chromosomes becomes haploid in daughter cells.
Mitosis is necessary for growth and repair.	Meiosis is necessary for sexual reproduction.
Crossing over does not take place.	Crossing over takes place.

NCERT Solution

Question – 1- What is the average cell cycle span for a mammalian cell?

Answer: 24 hours

Question – 2 - Distinguish cytokinesis from karyokinesis.

Answer: Division of cytoplasm takes place during cytokinesis, while division of nucleus takes place during karyokinesis.

Question – 3 - Describe the events taking place during interphase.

Answer: The interphase is divided into three phases, which are as follows:

a. G_1 phase (Gap 1): During this phase, the cell is metabolically active and continuously grows.
b. S phase (Synthesis): During this phase, DNA synthesis or replication takes place. The amount of DNA becomes double during this phase, but the number of chromosomes remains the same.
c. G_2 phase (Gap 2): During this phase, protein synthesis takes place.

Question – 4 - What is G0 (quiescent phase) of cell cycle?

Answer: Quiescent Stage (G_0): Cells which do not divide further, exit G1 phase to enter an inactive stage. This stage is called quiescent stage (G_0) of the cell cycle. The cells in this stage remain metabolically active but do not undergo division. But these cells can resume division as and when required.

Question – 5 - Why is mitosis called equational division?

Answer: The number of chromosomes in daughter cells is same as in mother cell, so mitosis is called equational division.

Question – 6 - Name the stage of cell cycle at which one of the following events occur:

(a) Chromosomes are moved to spindle equator.

Answer: Metaphase

(b)Centromere splits and chromatids separate.

Answer: Anaphase

(c)Pairing between homologous chromosomes takes place.

Answer: Zygotene

(d)Crossing over between homologous chromosomes takes place.

Answer: Pachytene

Question – 7 - Describe the following: (a) synapsis (b) bivalent (c) chiasmata Draw a diagram to illustrate your answer.

Answer: The pairing of chromosomes during zygotene is called synapsis. The synaptonemal complex formed by a pair of homologous chromosomes is called bivalent. The X-shaped structure, formed during crossing over is called chiasmata.

Question – 8 - How does cytokinesis in plant cells differ from that in animal cells?

Answer: In animal cell, a furrow appears in the plasma membrane. The furrow gradually deepens and finally joins in the centre. Thus, the cytoplasm is divided into two parts. In plant cells, cell wall formation begins in the centre. This grows outwards to meet the existing lateral walls and thus, the cytoplasm is divided into two parts.

Question – 9 - Find examples where the four daughter cells from meiosis are equal in size and where they are found unequal in size.

Answer: The four daughter cells formed after microsporogenesis in flowering plants are equal in size. The four daughter cells formed after megasporogenesis in flowering plants are unequal in size.

Question – 10 - Distinguish anaphase of mitosis from anaphase I of meiosis.

Answer: The centromere splits during anphase of mitosis, while it does not split during anaphase I of meiosis.

Question – 11 - List the main differences between mitosis and meiosis.

Answer:

Difference between mitosis and meiosis	
Mitosis	Meiosis
This type of division takes place in somatic cells.	This type of division takes place in gametic cells.
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No. of chromosomes remains diploid in daughter cells.	Number of chromosomes becomes haploid in daughter cells.
Mitosis is necessary for growth and repair.	Meiosis is necessary for sexual reproduction.
Crossing over does not take place.	Crossing over takes place.

Question – 12 - What is the significance of meiosis?

Answer: Significance of Meiosis:

- Conservation of specific chromosome number of each species is achieved across successive generations in sexually reproducing organisms through meiosis.
- Meiosis helps in increasing the genetic variations in the population of organisms from one generation to the next.

Question – 13 - Discuss with your teacher about

(a)Haploid insects and lower plants where cell-division occurs, and

Answer: Male bees, wasps and ants are haploid as they are produced from unfertilized eggs.

(b)Some haploid cells in higher plants where cell-division does not occur.

Answer: Cell division does not happen in synergids and antipodal cells; in the ovule.

Question – 14 - Can there be mitosis without DNA replication in ‘S’ phase?

Answer: There cannot be mitosis without DNA replication, because additional DNAs are required for the formation of new cells.

Question – 15 - Can there be DNA replication without cell division?

Answer: DNA replication can take place without cells division; as in case of formation of new mitochondria and chloroplasts.

Question – 16 - Analyse the events during every stage of cell cycle and notice how the following two parameters change

(a)Number of chromosomes (N) per cell

Answer: Number of chromosomes becomes half after meiosis.

(b)Amount of DNA content (C) per cell

Answer: Amount of DNA becomes double after S phase.

11. Transport in Plants

Diffusion:

When molecules move from higher concentration to lower concentration in a random manner, the movement is called diffusion. The movement of substances through diffusion is a passive transport. Diffusion is a slow process and is not dependent on a 'living' system.

Factors affecting diffusion:

- Concentration gradient,
- Permeability of membrane; separating the substances
- Temperature and Pressure

Facilitated Diffusion:

While non-polar substances diffuse through the membrane, the polar substances move with help of special proteins. This process is called facilitated diffusion. Special proteins help the substances move against concentration gradient and this is energy dependent process. The energy for this is supplied by ATP. Facilitated diffusion happens with the help of proteins which are selective in nature. Such a transport is also sensitive to inhibitors.

Carrier proteins form porin channels in the outer membranes of plastids, mitochondria and some bacteria. The porin channels allow the molecules up to the size of small proteins to pass through molecule bound to the transport protein. The transport protein then rotates and releases the molecule inside the cell. For example; water channels are made up of eight different types of aquaporins.

Symports and Antiports: Some carrier proteins allow diffusion only if two types of molecules move together. When both the molecules cross the membrane in the same direction, it is called symport. When the molecules move in opposite directions, it is called antiport. When a molecule moves across a membrane independent of other molecules, the movement is called uniport.

Active Transport: Energy pumps are used against a concentration gradient; in case of active transport. Active transport is carried out by membrane proteins. Pumps are proteins which use energy to carry substances across the cell membrane. The rate of transport reaches the maximum when all the protein transporters are being used or are saturated.

Comparison of different transport mechanisms			
Property	Simple diffusion	Facilitated transport	Active transport
Requires special membrane protein	No	Yes	Yes
Highly selective	No	Yes	Yes
Transport saturates	No	Yes	Yes
Uphill transport	No	No	Yes
Requires ATP energy	No	No	Yes

PLANT-WATER RELATIONS

Water Potential: Water molecules possess kinetic energy. A system with higher concentration of water has a higher kinetic energy or water potential (Ψw). Pure water has the highest water potential. Solutions have lower water potential than pure water. Movement happens from higher water potential to lower water potential.

Solute Potential: All solutions have a lower water potential because of the dissolved solutes. The magnitude of lowering of water potential is called solute potential (Ψs). It is important to remember that solute potential is always negative. For a solution at atmospheric pressure:

Water potential = Solute potential

Pressure Potential: If a pressure; greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. This happens because of pressure potential which develops due to increased pressure. Pressure potential is usually positive. Pressure potential is expressed as Ψp.

$\Psi w = \Psi s + \Psi p$

Osmosis: Diffusion of water across a semipermeable membrane is called osmosis. The net direction and rate of osmosis depends on pressure gradient and concentration gradient. Water moves from higher concentration to its lower concentration until equilibrium is achieved. The two chambers across the semi-permeable membrane have the same water potential at equilibrium.

Plasmolysis:

When a plant cell is placed in hypertonic solution, the plant cell loses water and hence it loses the turgor pressure. This makes the cell flaccid. The plant cells wilt in this condition. Further water loss results in plasmolysis. At this point, the pressure decreases to an extent where the protoplasm of the cell peels away from the cell wall. This leaves gaps between the cell wall and the membrane. This can also lead to cytorrhysis or complete collapse of the cell wall. Plasmolysis can be reversed by putting the cell in hypotonic solution.

When a plant cell is placed in hypotonic solution, the cell gains water and thus gains turgor pressure. This leads to the cell getting swollen. But the rigidity of the cell wall prevents the cell from bursting.

Plasmolysis rarely happens in nature and can only occur in extreme conditions. There can be two types of plasmolysis, viz. concave and convex plasmolysis. Convex plasmolysis is always irreversible, while concave plasmolysis is reversible.

Imbibition: When water is absorbed by solids (colloids), resulting in an enormous increase in volume, this is called imbibition. Seeds swell up because of this process.

LONG DISTANCE TRANSPORT OF WATER

Long distance transport of water in plants happens in bulk. This is called translocation.

Absorption of Water

Absorption of water from the soil happens through root hairs. Root hairs are extensions of the root epidermis and have thin walls. Water enters the root hairs because of osmosis. Presence of numerous root hairs increases the surface area and hence enhances the absorption of water.

Movement of water into deeper root layers:

The further movement of water takes place by two distinct pathways, viz. apoplast pathway and symplast pathway.

Apoplast Pathway: The free diffusional space outside the plasma membrane is the apoplast. This is interrupted by the Casparian strip in roots, air spaces between plant cells and the cuticula of the plant. The apoplast is formed by the continuum of cell walls of adjacent cells as well as the extracellular spaces. The apoplast pathway facilitates the transport of water and solutes across a tissue or organ.

Symplast Pathway: The inner side of the plasma membrane is the symplast. The symplast pathway is made continuous because of the presence of plasmodesmata across the cell walls of adjacent cells. Small molecules; such as sugars, amino acids and ions; flow through symplast pathway. Larger molecules are also transported through this route with the help of actin structures.

The symplast pathway allows direct cytoplasm to cytoplasm flow of water and other nutrients along concentration gradient.

Water Movement up a Plant

Root Pressure: When various ions from the soil are actively transported into the vascular tissues of the roots, water also follows. This increases the pressure inside the xylem. This positive pressure is called root pressure. The root pressure can push water up to small heights in the stem.

Guttation: In some plants, under the conditions of low evaporation, water comes out from the tips of leaves. Such loss of water in its liquid phase is called guttation. Guttation takes place in smaller plants only.

Limitations of Root Pressure: Root pressure can only provide a modest push. Hence root pressure does not play a major role in water movement in tall plants. Root pressure contributes towards reestablishment of continuous chains of water molecules in the xylem; which often break under enormous tensions created by transpiration pull.

Transpiration Pull: The evaporative loss of water by plants is called transpiration. Transpiration mainly occurs through stomata. Stomata are usually open during daytime and remain close during the night.

Opening and Closing of Stomata: A change in the turgidity of guard cells results in closing or opening of stomata. The inner wall of the guard cell; towards the stomatal aperture; is thick and elastic. An increase in turgidity results in the thin outer walls to bulge out. This forces the inner wall into a crescent shape and results in opening of stoma. The orientation of the microfibrils in the cell walls of the guard cells also helps in opening of stomata. These meicrobifibrils are radially oriented and thus make it easy for the stoma to open up. A loss in turgidity of the guard cells, leads to resumption of shape of the elastic inner wall of the guard cell and the stoma closes.

Factors Affecting Transpiration: Temperature, light, humidity, wind speed, number and distribution of stomata, number of stomatal aperture with guard cells open, water status of the plant, canopy structure, etc.

Transpiration creates a suction force inside the xylem. This suction force is called transpiration pull. This is powerful enough to pull the water column from beneath. Adhesion, cohesion and surface tension

are the important physical properties of water which further help in the upward movement of water through xylem.

Cohesion: Mutual attraction between water molecules is called cohesion.

Adhesion: Attraction of water molecules to polar surfaces is called adhesion.

Surface Tension: Any liquid has a tendency to occupy the least possible surface area. This property is called surface tension.

The above mentioned properties impart high tensile strength to water. The high tensile strength imparts an ability to resist a pulling force and high capillarity. The ability to rise in tubes is called capillarity. The thin tubes of xylem work like capillary tubes.

Adhesion-cohesion and capillarity result in formation of a continuous column of water molecules inside the xylem. This water column is pulled up because of transpiration pull. Thus, the adhesion-cohesion-transpiration pull theory explains the rise of water in very tall trees.

Uptake and Transport of Mineral Nutrients

Minerals cannot be passively absorbed by roots. There are two main reasons for this.

a. Minerals are present as charged particles in soil. They cannot move across cell membranes.
b. Concentration of minerals in the soil is usually lower than the concentration of minerals in the root.

Hence, minerals need to be actively absorbed by the epidermal cells. Specific proteins in the membranes of root hairs actively pump ions from the soil to the epidermal cells.

Translocation of Mineral Ions: Minerals ions reach xylem through active or passive uptake, or a combination of both. Their further movement through the xylem is alongwith the transpiration stream. The growing regions of the plant are the main sinks for mineral elements. Mineral ions are frequently mobilized; especially from older, senescing parts. Phosphorus, sulphur, nitrogen and potassium are the most readily mobilized elements. However, elements which are structural components are not mobilized, e.g. calcium.

Some elements are also transported in organic forms in plants.

PHLOEM TRANSPORT:

Food is transported through phloem; from source to sink. Leaf usually plays the role of source and storage organs are the sinks. But there can be role reversal when new leaves emerge during early spring. Thus, movement of substances through phloem is bi-directional.

The phloem sap is mainly composed of water and sucrose, but other sugars, hormones and amino acids may also be present.

The Pressure Flow Or Mass Flow Hypothesis:

- When glucose is prepared at the source, it is converted to sucrose.

- The sucrose moves into the companion cells and then into the living phloem sieve tube cells; through active transport. This process of loading at the source produces a hypertonic condition in the phloem.
- Water; from the adjacent xylem; moves into the phloem, by osmosis. This results in an increase of osmotic pressure. It forces the phloem sap to areas of lower pressure, i.e. towards the sink. The osmotic pressure must be reduced at the sink.
- Active transport moves the sucrose out of the phloem sap into the cells in the sink. Once the sugar is removed, the osmotic pressure decreases and water moves out of the phloem.

NCERT Solution

Question – 1- What are the factors affecting the rate of diffusion?

Answer: Factors affecting diffusion are; Concentration gradient, Permeability of membrane; separating the substance, Temperature and Pressure.

Question – 2 - What are porins? What role do they play in diffusion?

Answer: Carrier proteins form porin channels in the outer membranes of plastids, mitochondria and some bacteria. The porin channels allow the molecules up to the size of small proteins to pass through molecule bound to the transport protein and thus allow facilitated diffusion.

Question – 3 - Describe the role played by protein pumps during active transport in plants.

Answer: Energy pumps are used against a concentrations gradient; in case of active transport. Active transport is carried out by membrane proteins. Pumps are proteins which use energy to carry substances across the cell membrane. The rate of transport reaches the maximum when all the protein transporters are being used or are saturated.

Question – 4 - Explain why pure water has the maximum water potential.

Answer: Water molecules possess kinetic energy. A system with higher concentration of water has a higher kinetic energy or water potential (Ψw). Hence, pure water has the highest water potential.

Question – 5 - Differentiate between the following:

(a)Diffusion and Osmosis

Answer: Osmosis is a type of diffusion. When diffusion happens across a semi-permeable membrane, it is called osmosis. Semi-permeable membrane is not necessary in all cases of diffusion.

(b)Transpiration and Evaporation

Answer: Evaporative loss of water from plants is called transpiration, while conversion of water into vapour at any temperature is called evaporation.

(c) Osmotic Pressure and Osmotic Potential

Answer: The pressure which needs to be applied to prevent the inward flow of water across a semi-permeable membrane. In other words, the minimum pressure needed to negate the osmosis is called

osmotic pressure. On the other hand, the ability of a solution to suck in water from across a semi-permeable membrane is called osmotic potential.

(d) Imbibition and Diffusion

Answer: Random movement of molecules to attain concentration equilibrium is called diffusion. When osmosis happens in a way that solids (colloids) take up water, it is called imbibition.

(e)Apoplast and Symplast pathways of movement of water in plants.

Answer:

Apoplast pathway	Symplast pathway
The free diffusional space outside the plasma membrane is called apoplast.	The inner side of plasma membrane is called symplast.
Formed by continuum of cell walls.	Is made continuous because of plasmodesmata.
Water and solutes are usually transported through this.	Smaller molecules are transported through this.

(f)Guttation and Transpiration.

Answer: Exudation of water from smaller plants; under low evaporation conditions; is called guttation. Evaporative loss of water from plants is called transpiration. In guttation, water comes out in liquid form; while in transportation, water comes out in gaseous form.

Question – 6 - Briefly describe water potential. What are the factors affecting it?

Answer: Water molecules possess kinetic energy. A system with higher concentration of water has a higher kinetic energy or water potential (Ψw). Pure water has the highest water potential. Solutions have lower water potential than pure water. Solute potential and pressure potential are the two factors which affect water potential.

Question – 7 - What happens when a pressure greater than the atmospheric pressure is applied to pure water or a solution?

Answer: If a pressure; greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. This happens because of pressure potential which develops due to increased pressure.

Question – 8 - With the help of well-labelled diagrams, describe the process of plasmolysis in plants, giving appropriate examples.

Answer: When a plant cell is placed in hypertonic solution, the plant cell loses water and hence it loses the turgor pressure. This makes the cell flaccid. The plant cells wilt in this condition. Further water loss results in plasmolysis. At this point, the pressure decreases to an extent where the protoplasm of the cell peels away from the cell wall. This leaves gaps between the cell wall and the membrane. This can also lead to cytorrhysis or complete collapse of the cell wall. Plasmolysis can be reversed by putting the cell in hypotonic solution.

Question – 9 - Explain what will happen to a plant cell if it is kept in a solution having higher water potential.

Answer: A hypotonic solution has higher water potential. When a plant cell is placed in hypotonic solution, the cell gains water and thus gains turgor pressure. This leads to the cell getting swollen. But the rigidity of the cell wall, prevents the cell from bursting.

Question – 10 - How is the mycorrhizal association helpful in absorption of water and minerals in plants?

Answer: Mycorrhiza is a symbiotic association of a fungus with a root system. The hyphae form a network around young roots and thus increase the surface area. This helps in getting access to more water and minerals for the plants.

Question – 11 - What role does root pressure play in water movement in plants?

Answer: Root pressure can only provide a modest push. Hence root pressure does not play a major role in water movement in tall plants. Root pressure contributes towards reestablishment of continuous chains of water molecules in the xylem; which often break under enormous tensions created by transpiration pull.

Question – 12 - Describe transpiration pull model of water transport in plants. What are the factors influencing transpiration? How is it useful to plants?

Answer: Transpiration creates a suction force inside the xylem. This suction force is called transpiration pull. This is powerful enough to pull the water column from beneath. Adhesion, cohesion and surface tension are the important physical properties of water which further help in the upward movement of water through xylem.

Factors Affecting Transpiration: Temperature, light, humidity, wind speed, number and distribution of stomata, number of stomatal aperture with guard cells open, water status of the plant, canopy structure, etc.

Transpiration helps the plants in following ways:

- Supplies water which is required for photosynthesis.
- Has cooling effect on leaves.
- Helps in maintaining the turgidity and shape of plant parts.

Question – 13 - Discuss the factors responsible for ascent of xylem sap in plants.

Answer: Cohesion: Mutual attraction between water molecules is called cohesion.

Adhesion: Attraction of water molecules to polar surfaces is called adhesion.

Surface Tension: Any liquid has a tendency to occupy the least possible surface area. This property is called surface tension.

The above mentioned properties impart high tensile strength to water. The high tensile strength imparts an ability to resist a pulling force and high capillarity. The ability to rise in tubes is called capillarity. The thin tubes of xylem work like capillary tubes.

Question – 14 - What essential role does the root endodermis play during mineral absorption in plants?

Answer: Minerals need to be actively absorbed by the epidermal cells. Specific proteins in the membranes of root hairs actively pump ions from the soil to the epidermal cells.

Question – 15 - Explain why xylem transport is unidirectional and phloem transport bi-directional.

Answer: Water transported through xylem is utilised in photosynthesis and most of the water is lost through transpiration. Renewed demand for water is once again supplied through the same channel. Hence, transport through xylem is unidirectional. In case of phloem transport, food is transported from source to sink. Leaves are the usual source and storage organs are the usual sink. But the storage organs become source when new buds emerge during early spring. In that case, a reverse flow of food is required. Hence, movement through phloem is bi-directional.

Question – 16 - Explain pressure flow hypothesis of translocation of sugars in plants.

Answer: The pressure flow or mass flow hypothesis:

When glucose is prepared at the source, it is converted to sucrose.

The sucrose moves into the companion cells and then into the living phloem sieve tube cells; through active transport. This process of loading at the source produces a hypertonic condition in the phloem.

Water; from the adjacent xylem; moves into the phloem, by osmosis. This results in an increase of osmotic pressure. It forces the phloem sap to areas of lower pressure, i.e. towards the sink . The osmotic pressure must be reduced at the sink.

Active transport moves the sucrose out of the phloem sap into the cells in the sink. Once the sugar is removed, the osmotic pressure decreases and water moves out of the phloem.

Question – 17 - What causes the opening and closing of guard cells of stomata during transpiration?

Answer: A change in the turgidity of guard cells results in closing or opening of stomata. The inner wall of the guard cell; towards the stomatal aperture; is thick and elastic. An increase in turgidity results in the thin outer walls to bulge out. This forces the inner wall into a crescent shape and results in opening of stoma. The orientation of the microfibrils in the cell walls of the guard cells also helps in opening of stomata. These meicrobifibrils are radially oriented and thus make it easy for the stoma to open up. A loss in turgidity of the guard cells, leads to resumption of shape of the elastic inner wall of the guard cell and the stoma closes.

12. Mineral Nutrition

Criteria for Essentiality

- The element is absolutely necessary for supporting normal growth and reproduction.
- In the absence of essential elements, plants cannot complete their life cycle or set the seeds.
- The essential element must be specific and is not replaceable by another element.
- The element must be directly involved in metabolism.

Types of Essential Elements:

There are 17 essential elements in plants. Additionally, some other elements; like sodium, silicon, cobalt and selenium are required by higher plants. There are two types of essential elements, viz. macronutrients and micronutrients.

Macronutrients: Elements which are present in large amounts in plant tissues are called macronutrients. They are in excess of 10 mmole per kg of dry matter. Carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium and magnesium are the macronutrients.

Micronutrients: Elements which are present in small amounts, i.e. less than 10 mmole per kg of dry matter are called micronutrients. Iron, manganese, copper, molybdenum, zinc, copper, boron, chlorine and nickel are the micronutrients.

Categories of Essential Elements:

a. As components of biomolecules, e.g. carbon, hydrogen, oxygen and nitrogen. These are structural elements of cells.
b. As components of energy-related chemical compounds, e.g. magnesium in chlorophyll and phosphorous in ATP.
c. Elements which activate or inhibit enzymes, e.g. Mg^{2+} activates RUBISCO and phosphenol pyruvate carboxylase. Similarly, Zn^{2+} activates alcohol dehydrogenase.
d. Elements which alter osmotic potential of a cell, e.g. potassium plays an important role in opening and closing of stomata.

Role of Macro- and Micro-nutrients:

Nitrogen: Nitrogen is the mineral which is required by plants in the greatest amount. Nitrogen is mainly absorbed as NO_3^-, but some amounts are also taken up as NO_4^+ or NH_4^+. Nitrogen is one of the major constituents of protein, nucleic acids, vitamins and hormones.

Phosphorous: This is absorbed by plants in the form of phosphate ions; either as $H_2PO_4^-$ or HPO_4^-. Phosphorous is a constituent of cell membranes, some proteins, nucleic acids and nucleotides. Phosphorous is also required for all phosphorylation reactions.

Potassium: Potassium is absorbed as potassium ion (K^+). This is required in more quantities by the meristematic tissues. Potassium helps in maintaining an anion-cation balance in cells. Potassium is involved in protein synthesis, opening and closing of stomata, activation of enzymes and maintenance of cell turgidity.

Calcium: Calcium is absorbed in the form of calcium ions (Ca^{2+}). Calcium is required by meristematic tissues and differentiating tissues. Calcium is utilised in the synthesis of cell wall. Calcium is also required for the formation of mitotic spindle. Certain enzymes are activated by calcium.

Magnesium: Magnesium is absorbed in the form of magnesium ions (Mg^{2+}). Magnesium activates the enzymes of respiration and photosynthesis. Magnesium is involved in the synthesis of DNA and RNA. It is a constituent of the ring structure of chlorophyll. It also helps in maintaining the ribosome structure.

Sulphur: Sulphur is absorbed in the form of sulphate ion (SO_4^{2-}). Sulphur is present in two amino acids; cysteine and mthionine. Sulphur is the main component of several coenzymes, vitamins and ferredoxin.

Iron: Iron is absorbed in the form of ferric ions (Fe^{+3}). Iron is the micronutrient which is required in the largest amount. Iron is an important component of proteins which are involved in electron transfer chain. Iron plays an important role in the formation of chlorophyll.

Manganese: Manganese is absorbed in the form of manganous ions (Mn^{+2}). Manganese activates many enzymes which are involved in photosynthesis, respiration and nitrogen metabolism. Splitting of water molecule during photosynthesis is facilitated by manganese.

Zinc: Zinc is absorbed in the form of zinc ions (Zn^{+2}). Zinc activates various enzymes; like carboxylase. Zinc is required in the synthesis of auxin.

Copper: Copper is absorbed in the form of cupric ions (Cu^{+2}). Copper is essential for overall metabolism in plants. Copper is associated with certain enzymes in redox reactions.

Boron: Boron is absorbed as BO_3^{3-} or $B_4O_7^{2-}$.Boron is required for uptake and utilization of calcium, membrane functioning, pollen germination, cell elongation, cell differentiation and carbohydrate translocation.

Molybdenum: Molybdenum is absorbed in the form of molybdate ions (MoO_2^{2+}). Molybdenum is a component of various enzymes; like nitrogenase and nitrate reductase.

Chlorine: Chlorine is absorbed in the form of chloride ion. Along with Na^+ and K^+, chlorine helps in determining solute concentration and in anion-cation balance. Chlorine also plays an important role in splitting of water.

Deficiency Symptoms of Essential Elements

There are different symptoms for deficiency of different elements. When a deficient mineral is provided to the plant, the symptoms disappear. But if the deficiency continues, it may lead to the death of the plant.

Appearance of deficiency also depends on the mobility of the element in the plant. Some elements are actively mobilized in plants and are exported to young developing tissues. Deficiency of such elements first appears in the older tissues. For example; the deficiency symptoms of nitrogen, potassium and magnesium are first seen in the senescent leaves. This happens because these elements are mobilized to younger leaves.

Some elements are relatively immobile in plants. These elements are not transported out of the mature organs. Deficiency of such elements first appears in younger parts of the plant, e.g. sulphur and calcium.

Some deficiency symptoms in plants are; chlorosis, necrosis, stunted plant growth, premature fall of leaves and buds and inhibition of cell division.

Chlorosis: Loss of chlorophyll is called chlorosis. This results in yellowing of leaves. Chlorosis is caused by the deficiency of N, K, Mg, S, Fe, Mn, Zn and Mo.

Necrosis: Death of tissue; particularly leaf tissue; is called necrosis. Necrosis is caused by the deficiency of Ca, Mg, Cu and K.

Deficiency of N, K, S and Mo causes stunted growth because of inhibition of cell division. Deficiency of N, S and Mo delays flowering.

Toxicity of Micronutrients

If a mineral ion concentration in tissues reaches to a level that it reduces the dry weight of tissues by about 10%, the mineral then becomes toxic. It is difficult to identify the symptoms of toxicity. Sometimes, excess of an element may inhibit the uptake of another element. For example; the symptom of manganese toxicity is the appearance of brown spots surrounded by chlorotic veins. Manganese competes with iron and magnesium for uptake. Manganese also inhibits calcium translocation in shoot apex. Hence, excess of manganese results in deficiency of iron, magnesium and calcium. So, the apparent symptoms of manganese toxicity are in fact the deficiency symptoms of iron, magnesium and calcium.

MECHANISM OF ABSORPTION OF ELEMENTS

Absorption of minerals takes place in two main phases. In the first phase, passive absorption takes place through apoplast pathway. In the second phase, absorption takes place through symplast pathway. The first phase involves passive transport (facilitated diffusion), while the second phase involves active transport. After that, minerals are transported through xylem.

NITROGEN CYCLE

Nitrogen is available in limited amount in soil. Plants have to compete with microbes for this form of nitrogen. Hence, nitrogen is a limiting nutrient for plants.

Lightning and ultraviolet radiations provide energy to convert gaseous nitrogen into oxides of nitrogen (NO, NO_2 and N_2O). Atmospheric nitrogen oxides also come from industrial combustions, forest fires, automobile exhausts and power stations.

Decomposition of organic nitrogen of dead plants and animals leads to the formation of ammonia. This process is called ammonificaiton. Most of this ammonia is converted into nitrate by soil bacteria, while some of the ammonia vaporizes and re-enters the atmosphere.

Conversion of ammonia into nitrate; by soil bacteria takes place in following steps:

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$$
$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

Biological Nitrogen Fixation (BNF): In this process, the atmospheric nitrogen is converted to ammonia by an enzyme called nitrogenase. This can be shown by following equation:

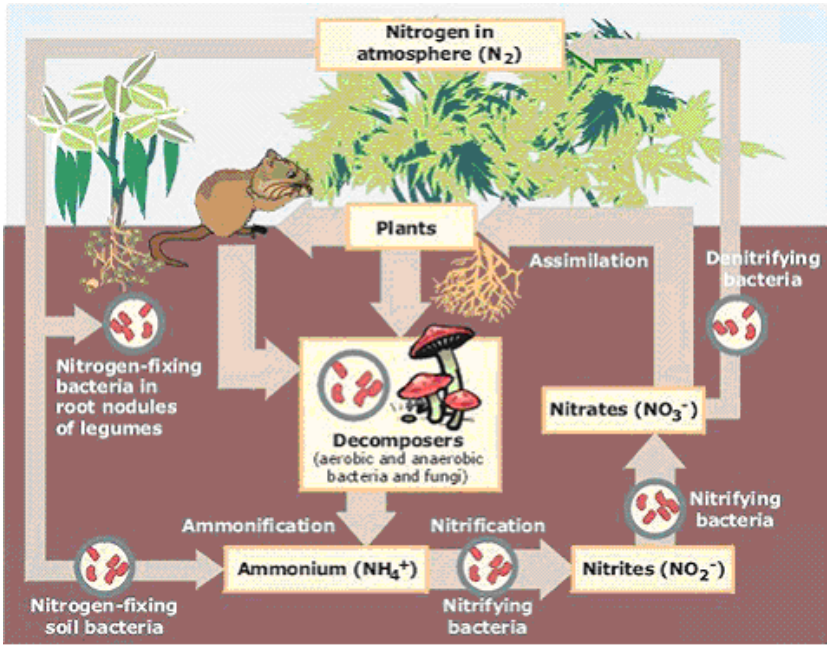
N2 + 6H+ + 6e− → 2NH3

This process is coupled with the hydrolysis of 16 equivalents of ATP. This is also accompanied by the co-formation of one molecule of H_2.

In free-living diazotrophs, the nitrogenase-generated ammonium is assimilated into glutamate through the glutamine synthetase or glutamate synthase pathway. Many nitrogen-fixing organisms exist only in anaerobic conditions; because the enzymes responsible for nitrogenase action are highly susceptible to destruction by oxygen.

Symbiotic Biological Fixation of Nitrogen

The plants of the legume family (Fabaceae) are the major contributors towards nitrogen fixation. The root nodules of these plants harbor the Rhizobium bacteria. These bacteria produce nitrogen compounds which help the plant to grow properly. When the plant dies, the fixed nitrogen is released into the soil. Thus nitrogen becomes available for other plants.



NCERT Solution

Question 1: ‘All elements that are present in a plant need not be essential to its survival’. Comment.

Answer: An element should fulfill certain criteria to be categorized as essential element. Otherwise, it cannot be considered as essential elements. Out of the numerous elements present in plants, only 17 are considered as essential elements.

Question 2: Why is purification of water and nutrient salts so important in studies involving mineral nutrition using hydroponics.

Answer: Purification of water and nutrient salt is important to rule out other influencing factors. Use of pure nutrients and water will help in obtaining accurate scientific results.

Question 3: Explain with examples: macronutrients, micronutrients, beneficial nutrients, toxic elements and essential elements.

Answer: Macronutrients: Elements which are present in large amounts in plant tissues are called macronutrients. They are in excess of 10 mmole per kg of dry matter. Carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium and magnesium are the macronutrients.

Micronutrients: Elements which are present in small amounts, i.e. less than 10 mmole per kg of dry matter are called micronutrients. Iron, manganese, copper, molybdenum, zinc, copper, boron, chlorine and nickel are the micronutrients.

Beneficial Elements: Apart from the 17 essential elements, many other elements are required by plants. For example; sodium, silicon, cobalt and selenium are required by higher plants.

These are called beneficial elements.

Toxic Elements: If a mineral ion concentration in tissues reaches to a level that it reduces the dry weight of tissues by about 10%, the mineral then becomes toxic. This shows that any element can become toxic if it crosses a certain threshold in plants.

Question 4: Name at least five different deficiency symptoms in plants. Describe them and correlate them with the concerned mineral deficiency.

Answer: Following are the five deficiency symptoms and related minerals:

a. Yellowing of lower leaves: Magnesium deficiency
b. Pale green leaves: Nitrogen deficiency
c. Purple leaf tints with bronze or brown leaf edges: Potassium deficiency
d. Reddish purple undersides of leaves: Phosphorous deficiency
e. White deposits on leaves: Carbon dioxide deficiency

Question 5: If a plant shows a symptom which could develop due to deficiency of more than one nutrient, how would you find out experimentally, the real deficient mineral element?

Answer: For this, we need to tabulate all the available symptoms in different parts of the plant. Then the symptoms are compared with the symptom table; to arrive at a conclusion about the deficiency of a specific element.

Question 6: Why is that in certain plants deficiency symptoms appear first in younger parts of the plant while in others they do so in mature organs?

Answer: Appearance of deficiency also depends on the mobility of the element in the plant. Some elements are actively mobilized in plants and are exported to young developing tissues. Deficiency of such elements first appears in the older tissues. For example; the deficiency symptoms of nitrogen,

potassium and magnesium are first seen in the senescent leaves. This happens because these elements are mobilized to younger leaves.

Question 7: How are the minerals absorbed by the plants?

Answer: Absorption of minerals takes place in two main phases. In the first phase, passive absorption takes place through apoplast pathway. In the second phase, absorption takes place through symplast pathway. The first phase involves passive transport (facilitated diffusion), while the second phase involves active transport. After that, minerals are transported through xylem.

Question 8: What are the conditions necessary for fixation of atmospheric nitrogen by Rhizobium. What is their role in N2 -fixation?

Answer: Rhizobium bacteria need symbiotic association with legume plants to carry out nitrogen fixation. Root nodules contain the necessary enzymes for nitrogen fixation and thus enable rhizobium to fix nitrogen. The enzyme nitrogenase facilitates the conversion of nitrogen into ammonia which is the first stable product of nitrogen fixation. Ammonia is then converted into glutamic acid. Glutamic acid is then utilised by plants to make amino acids; which are then utilised to make protein.

Question 9: What are the steps involved in formation of a root nodule?

Answer: Development of root nodules happens in following steps:

a. Rhizobium bacteria contact a susceptible root hair and divides near it.
b. Successful infection of the root hair results in curling of the root hair.
c. The infected thread carries the bacteria to the inner cortex. The bacteria get modified into rod-shaped bacteroids and cause inner cortical and pericycle cells to divide. Division and growth of cortical and pericycle cells lead to nodule formation.
d. A mature nodule is complete with vascular tissues. The vascular tissues of the nodule are continuous with those of the root.

Question 10: Which of the following statements are true? If false, correct them:

(a) Boron deficiency leads to stout axis.

Answer: True

(b) Every mineral element that is present in a cell is needed by the cell.

Answer: Out of all the mineral elements, only 17 are considered as essential elements.

(c) Nitrogen as a nutrient element, is highly immobile in the plants.

Answer: Nitrogen is highly mobile in plants.

(d) It is very easy to establish the essentiality of micronutrients because they are required only in trace quantities.

Answer: True

13. Photosynthesis in Higher Plants

Photosynthesis is a process in which the plants use light energy to make carbohydrate from carbon dioxide and water. The overall reaction of photosynthesis can be given in a simple form as follows:

$$6CO_2 + 6H_2O \xrightarrow{sunlight+chlorophyll} C_6H_{12}O_6 + 6O_2$$

In green plants, water is the hydrogen donor and it undergoes oxidation to produce oxygen.

Photosynthesis occurs in two stages, viz. light reaction and dark reaction. The light reaction is light-dependent. Light energy is captured in this stage and is utilised to make the energy-storage molecules ATP and NADPH. Dark reaction is light-independent reaction. Dark reaction is utilised to capture and reduce carbon dioxide. Dark reaction doesn't mean that it happens in the absence of light.

CHLOROPLAST

Chloroplast is the cell organelle where photosynthesis takes place in plants and algae. A typical plant cell may contain about 10 to 100 chloroplasts.

Chloroplast is enclosed by a membrane. This membrane is composed of an inner, outer and an intermediate membrane. An aqueous fluid; called stroma is present within the membrane.

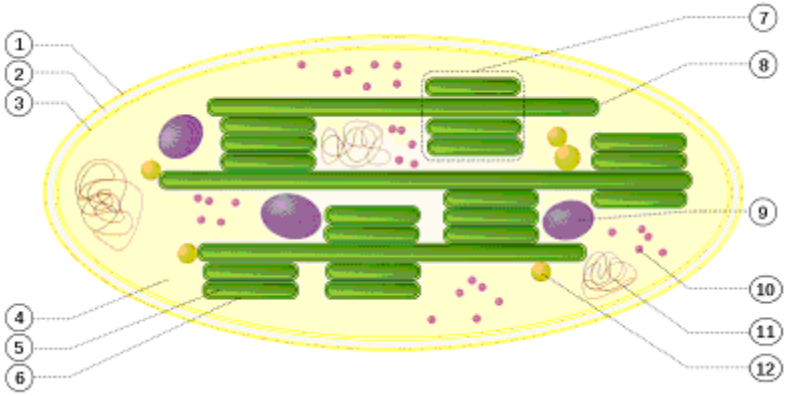
Stacks of thylakoids are present in the stroma. A stack is called a granum. Thylakoids are the sites of photosynthesis.

A thylakoid is a flattened disc. It is bound by a membrane. The lumen or thylakoid space is present within the membrane. The tyhlakoid membrane is the site of photosynthesis. It contains integral and peripheral membrane protein complexes. Pigments which absorb light energy are also present on the membrane. The protein complexes and the pigments form the photosystems.

Chlorophyll is the main pigment to absorb light. Additionally, carotenes and xanthophylls are also used by plants to absorb light energy. Algae also use chlorophyll for absorbing light.

These pigments are embedded in plants and algae in special antenna-proteins. The pigments are ordered in these proteins so that they can work in perfect coordination. Such a protein is also called a light-harvesting complex.

All the cells in the green parts of a plant have chloroplasts but most of the energy is captured in the leaves. The mesophyll of the leaf can contain between 450,000 and 800,000 chloroplasts for every square millimeter of leaf. The surface of the leaf is uniformly coated with a water-resistant waxy cuticle which protects the leaf from excess evaporation of water. It also decreases the absorption of ultraviolet or blue light to reduce heating. The epidermal layer of the leaf is transparent. It allows light to pass through to the palisade mesophyll cells where most of the photosynthesis takes place.



LIGHT REACTION

The light reaction is also called the Photochemical phase. It includes light absorption, water splitting, oxygen release and the formation of high-energy chemical intermediates (ATP and NADPH). Many complexes are involved in the process.

The pigments are organized into two discrete photochemical light harvesting complexes (LHC) within the Photosystem I (PS I) and Photosystem II (PS II). The photosystems are named in the sequence of their discovery and it has nothing to do with their function during the light reaction.

Each photosystem has all the pigments; except one molecule of chlorophyll a. The single chlorophyll a molecule forms the reaction centre. In PS I the reaction centre chlorophyll a has an absorption peak at 700 nm, hence it is called PS700. In PS II the absorption maxima is at 680 nm and hence it is called PS680.

THE ELECTRON TRANSPORT

The reaction centre in PS II absorbs 680 nm wavelength of red light. This causes electrons to become excited and jump into an orbit farther from the atomic nucleus. These electrons are picked up by an electron acceptor and sent to an electrons transport system consisting of cytochromes.

In terms of an oxidation-reduction potential scale, this movement of electrons is downhill. The electrons are not used up as they pass through the electron transport chain. They are passed on to the pigments of PS I.

At the same time, electrons in the reaction centre of PS I are also excited when they receive red light of wavelength 700 nm. They are then transferred to another acceptor molecule which has a greater redox potential.

Z Scheme: These electrons are then moved downhill again, to a molecule of energy-rich NADP+. The addition of these electrons reduces NADP+ to NADPH+H+. This whole transfer of electrons from PS II to the acceptor, to PS I, to another acceptor and finally to NADP+ is called the Z scheme, because of its characteristic shape.

Splitting of Water

Water is split into H^+, [O] and electrons. The splitting of water is associated with PS II. This creates oxygen. Photosystem II provides replacement for electrons removed from PS I.

$$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$$

Cyclic and Non-cyclic Photo-phosphorylation

Synthesis of ATP from ADP and inorganic phosphate in the presence of light is called photophosphorylaton.

When the two photosystems work in a series; first PS II and then the PS I; a process called non-cyclic photophosphorylation occurs.

When only PS I is functional, the electron is circulated within the photosystem and the cyclic flow of electrons leads to phosphorylation. The stroma lamellae are the possible location of phosphorylation. The stroma lamellae lack PS II and NADP reductase enzyme. The excited electron does not pass on to NADP+ but is cycled back to the PS I complex. Hence, the cyclic flow results only in the synthesis of ATP but not of NADPH+H+. Cyclic photophsophorylation also occurs when only light of wavelengths beyond 680 nm are available for excitation.

Chemiosmotic Hypothesis

Synthesis of ATP in chloroplast can be explained by chemiosmotic hypothesis. The way it happens in respiration, ATP synthesis during photosynthesis happens because of development of a proton gradient across a membrane, i.e. membrane of the thylakoid. The following steps are involved in development of proton gradient across the thylakoid membrane.

- When the electrons move through the photosystems, protons are transported across the membrane. The primary acceptor of electron is located towards the outer side of the membrane. It transfers its electrons no to an electron carrier but to an H carrier. Due to this, it removes a proton from the stroma while transporting an electron. When electron is passed to the electron carrier on the inner side of the membrane, the proton is released into the inner side or the lumen side of the membrane.
- The NADP reductase enzyme is located on the stroma side of the membrane. Protons are also necessary for the reduction of NADP+ to NADPH+H+. These protons are also removed from the stroma.
- Thus, protons in the stroma decrease in number and accumulate in the lumen. This results in development of a proton gradient across the thylakoid membrane. Additionally, there is a measurable decrease in pH in the lumen.
- The breakdown of this gradient leads to release of energy. The movement of protons across the membrane to the stroma results in breakdown of this gradient. The movement of protons takes place through the transmembrane channel of the F0 of the ATPase.
- The ATPase enzyme consists of two parts. One part is called the F0 and is embedded in the membrane. This forms a transmembrane channel which carries out facilitated diffusion of protons across the membrane. The other portion is called F1. It protrudes on the outer surface of thylakoid membrane on the lumen side.
- The breakdown of the gradient provides enough energy to cause a change in the F1 particle of the ATPase which results in synthesis of several molecules of energy-packed ATP.

To summarise, it can be said that chemiosmosis requires a membrane, a proton pump, a proton gradient and ATPase. Energy is utilised to pump protons across a membrane, to create a gradient or protons within the thylakoid membrane. ATPase has a channel. This channel allows diffusion of protons back across the membrane. The diffusion of protons releases enough energy to activate ATPase enzyme. The ATPase enzyme catalyses the formation of ATP. NADPH and the ATP are used in the

biosynthetic reaction which takes place in the stroma. This reaction is responsible for fixing CO_2 and for synthesis of sugars.

ATP and NADPH

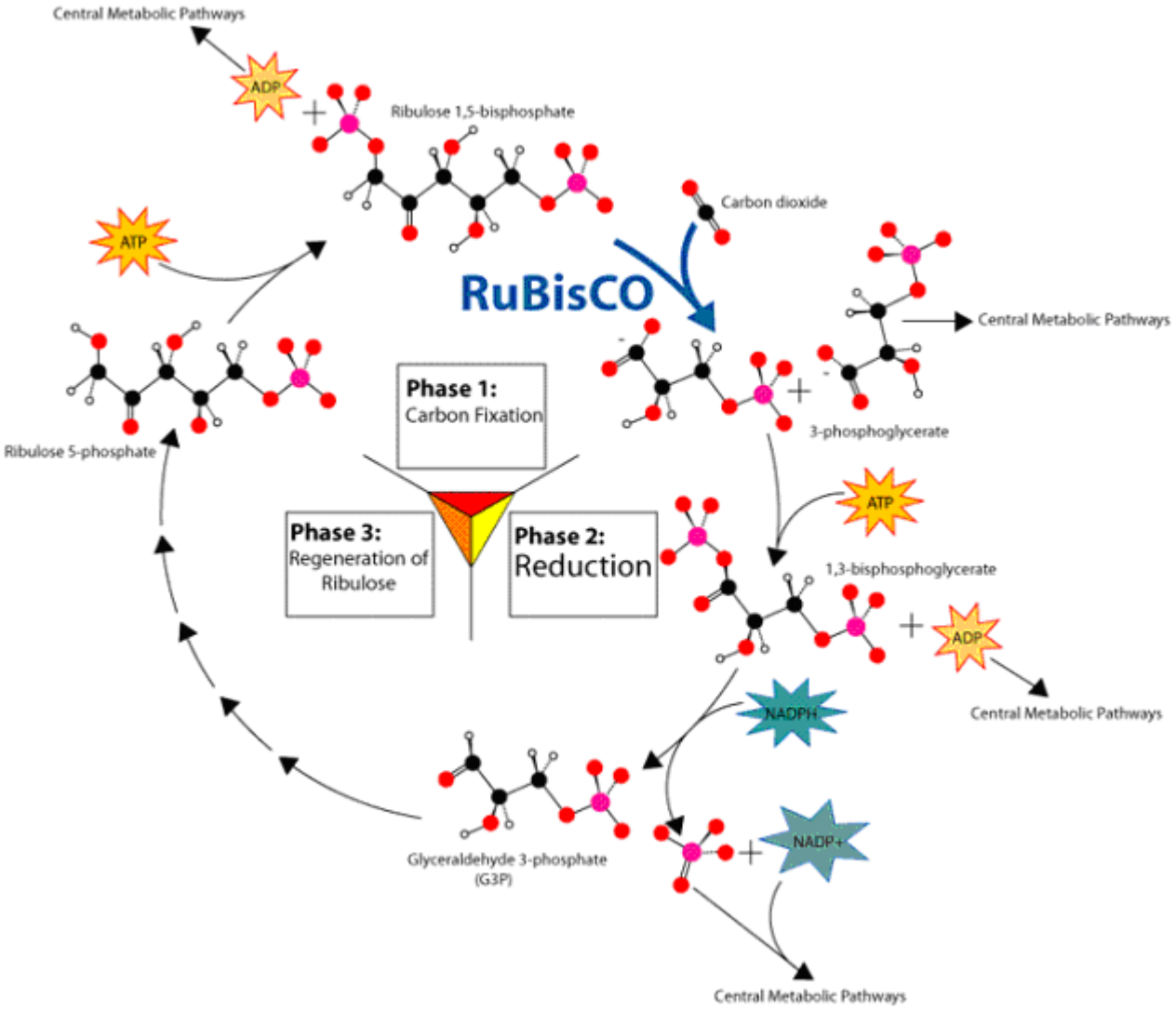
The products of light reaction are ATP, NADPH and O_2. The oxygen diffuses out of the chloroplast. ATP and NADPH are used to drive the processes which lead to the synthesis of food. These processes depend on the products of light reaction; apart from being dependent on CO_2 and H_2O.

The Calvin Cycle

The Calvin cycle can be described under three stages: carboxylation, reduction and regeneration.

A. Carboxylation: Fixation of CO_2 into a stable organic intermediate is called carboxylation. In this step, carbon dioxide is utilised for the carboxylation of RuBP. The enzyme RuBP carboxylase catalyses this reaction. The reaction results in the formation of two molecules of 3-PGA. This enzyme is also called RuBP carboxylase-oxygenase or RuBisCO; because it also has an oxygenation activity.
B. Reduction: This step involves utilization of 2 molecules of ATP for phosphorylation and two of NADPH for reduction of each CO_2 molecule fixed. For the removal of one molecule of glucose from the pathway, fixation of six molecules of CO_2 and 6 turns of the cycle are required.
C. Regeneration: This step involves regeneration of CO_2 acceptor molecule RuBP. This is necessary for the cycle to continue without interrutption. This step requires one ATP for phosphorylation to form RuBP.

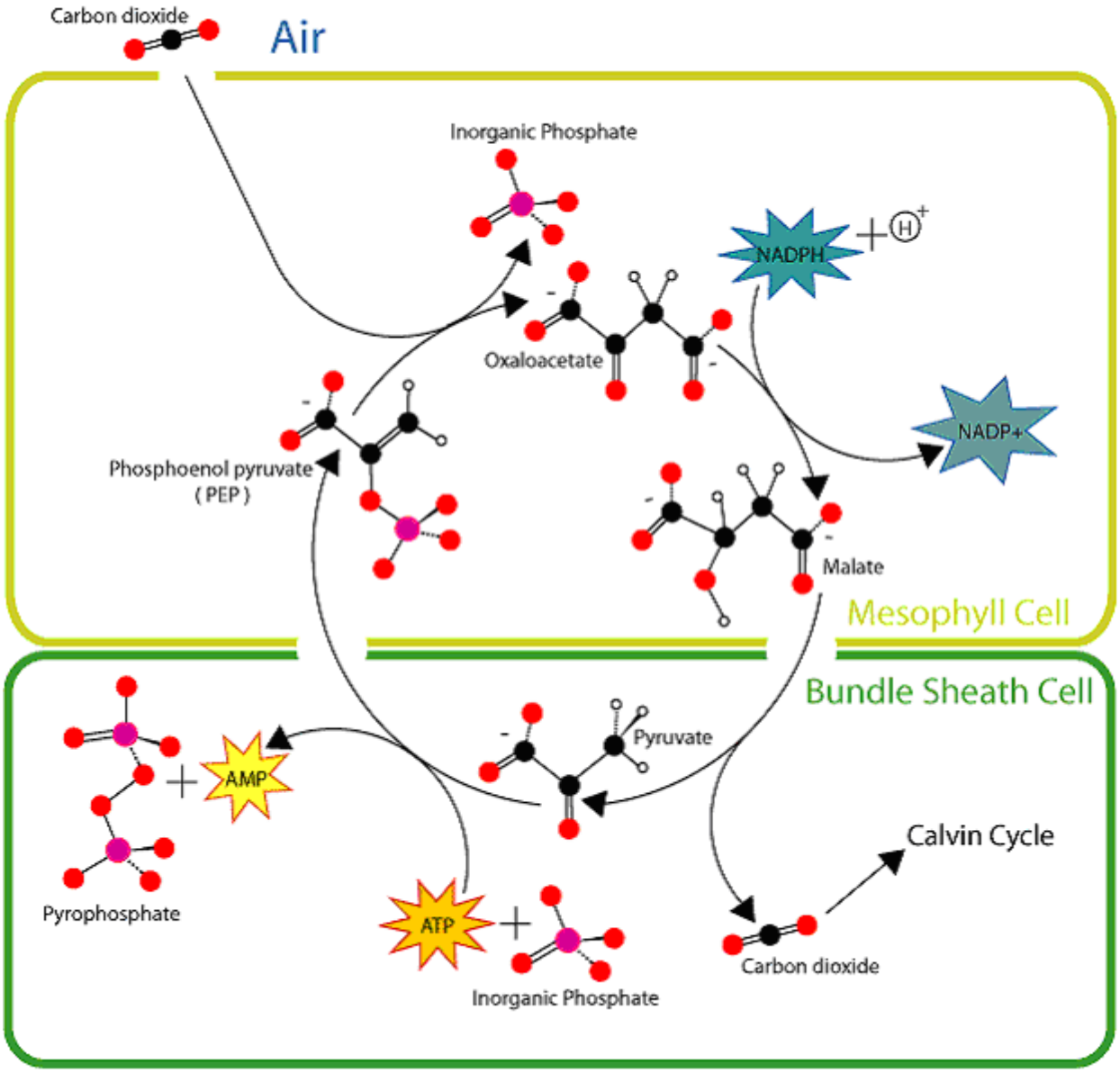
Thus, for each CO_2 molecule entering the Calvin Cycle, 3 molecules of ATP and 2 of NADPH are required. Cyclic phosphorylation probably takes place to meet this difference in number of ATP and NADPH used in the dark reaction.



(ref: http://en.wikipedia.org/wiki/File:Calvin-cycle3.png accessed on 10th Oct 2009)

THE C4 PATHWAY

Plants which are adapted to dry tropical regions use the C4 pathway. While 3-PGA is the first carbon fixation product in C3 plants, it is oxaloacetic acid (4 carbon atoms) which is the first carbon fixation product in C4 plants. However, the main biosynthetic pathway remains the Calvin cycle; as in C3 plants.



Kranz Anatomy: In C4 plants, large cells are found around the vascular bundles. These are called sheath cells. Leaves have special anatomy; called Kranz anatomy. The bundle sheath cells may form several layers around the vascular bundles. The cells are characterized by large number of chloroplasts, thick walls (impervious to gaseous exchange) and no intercellular spaces.

This pathway is known as Hatch and Slack Pathway. It happens in following steps.

- Phoshpenol pyruvate (PEP) which is a 3-carbon molecule is the primary CO2 acceptor. It is present in the mesophyll cells. The enzyme PEP carboxylase or PEPcase is responsible for this fixation. RuBisCO enzyme is absent in mesophyll cells. Oxaloacetic acid (OAA) is formed in the mesophyll cells.
- Then other 4-carbon compounds; like malic acid or aspartic acid are formed in the mesophyll cells. These are then transported to the bundle sheath cells. These C4 acids are broken down in the bundle sheath cells; to release CO_2 and a 3-carbon molecule.
- The 3-carbon molecule is transported back to the mesophyll. In the mesophyll, it is converted into PEP again. Thus, the cycle is completed.

- The CO_2 released in the bundle sheath cells enters the Calvin cycle. The bundle sheath cells are rich in RuBisCO but lack PEPcase.

PHOTORESPIRATION

RuBisCO is the most abundant enzyme in the world. Its active site can bind to both CO_2 and O_2. But RuBisCO has a much greater affinity for CO_2 than O_2. The relative concentration of O_2 and CO_2 determines which of them will bind to the enzyme.

In C3 plants, some oxygen binds to RuBisCO and hence CO_2 fixation is decreased. The RuBP; in this case; binds with oxygen to form one molecule of PGA and phosphogylcolate. This happens in a pathway called photorespiration. In the photorespiratory pathway, neither the sugar nor the ATP is synthesized. Rather utilization of ATP results in the release of CO_2. Even NADPH is not synthesized in the photorespiratory pathway. Thus, it is a wasteful process.

Photorespiration does not occur in C4 plants. They have a mechanism which increases CO2 concentration at the enzyme site. This happens when the C4 acid from the mesophyll is broken down in the bundle cells to release CO_2. Thus, intracellular concentration of CO_2 is increased. This ensures that the RuBisCO functions as a carboxylase; with minimum oxygenase activity.

FACTORS AFFECTING PHOTOSYNTHESIS

Blackman's (1905) Law of Limiting Factors:

"If a chemical process is affected by more than one factor, then its rate will be determined by the factor which is nearest to its minimal value: it is the factor which directly affects the process if its quantity is changed."

Light: At low intensities of light, there is a linear relationship between incident light and carbon fixation. At high intensities of light, the rate does not show further increase because other factors become limiting. Increase in incident light beyond a point results in the breakdown of chlorophyll and a decrease in photosynthesis.

Carbon dioxide Concentration: Carbon dioxide is a major limiting factor for photosynthesis. It is important to remember that carbon dioxide is in very low concentration in the atmosphere (0.03 – 0.04%). Increase in concentration up to 0.05% can increase carbon fixation. An increase beyond this level can be damaging over longer periods.

Temperature: The dark reactions are controlled by temperature because they are enzymatic. Light reactions are also sensitive to temperature but to a much lesser extent. The C4 plants have a much higher temperature optimum than C3 plants. The temperature optimum for a particular plant also depends on it natural habitat. Tropical plants have a higher temperature optimum than temperate plants.

Water: The effect of water is more on the plant rather than directly on photosynthesis. Water stress results in closing of stomata and; thus in reduced availability of CO_2. Water stress also leads to wilting of leaves. Wilting of leaves means reduced surface area and reduced metabolic activity in leaves.

NCERT Solution

Question – 1- By looking at a plant externally can you tell whether a plant is C3 or C4? Why and how?

Answer: Plants which are adapted to dry climates follow the C4 pathway. While this knowledge can be helpful in telling a C4 or a C3 plant, external features hardly provide a clue for this. However, histological study of bundle sheath in the leaves can easily give clue about the plant type.

Question – 2 - By looking at which internal structure of a plant can you tell whether a plant is C3 or C4? Explain.

Answer: Bundle sheath; around the vascular bundle.

Question – 3 - Even though a very few cells in a C4 plant carry out the biosynthetic – Calvin pathway, yet they are highly productive. Can you discuss why?

Answer: C4 plants avoid photorespiration and thus avoid the wastage of ATP. Thus there is more efficient utilization of the resources. This helps a C4 plant to produce more food compared to a C3 plant.

Question – 4 - RuBisCO is an enzyme that acts both as a carboxylase and oxygenase. Why do you think RuBisCO carries out more carboxylation in C4 plants?

Answer: In C4 plants, RuBisCO is not wasted in oxygenation and hence it carries out more carboxylation.

Question – 5 - Suppose there were plants that had a high concentration of Chlorophyll b, but lacked chlorophyll a, would it carry out photosynthesis? Then why do plants have chlorophyll b and other accessory pigments?

Answer: Pigments; other than chlorophyll a are also capable of absorbing light energy. Hence, photosynthesis will take place even in the absence of chlorophyll a. Other accessory pigments work as additional pigments to trap solar energy.

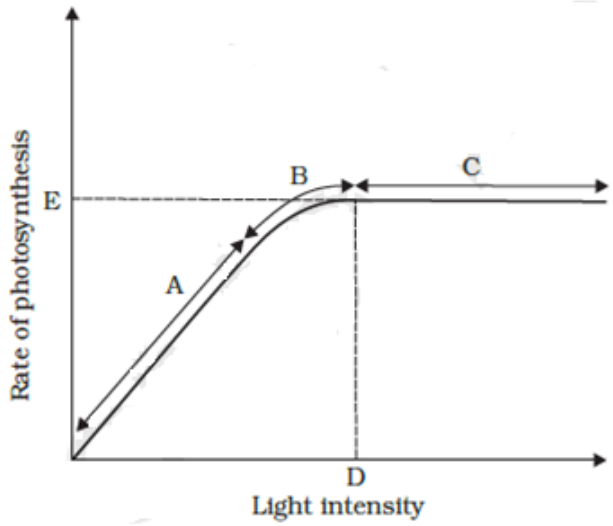
Question – 6 - Why is the colour of a leaf kept in the dark frequently yellow, or pale green? Which pigment do you think is more stable?

Answer: Chlorophyll is unable to absorb energy in the absence of light and thus loses its stability. This leads to yellowing of leaves. The yellowing of leaves also shows that xanthophylls is more stable.

Question – 7 - Look at leaves of the same plant on the shady side and compare it with the leaves on the sunny side. Or, compare the potted plants kept in the sunlight with those in the shade. Which of them has leaves that are darker green ? Why?

Answer: The leaves which face more light are darker green than those which face less light. This happens because of increased concentration of chlorophyll in the presence of light.

Question – 8 - Figure 13.10 shows the effect of light on the rate of photosynthesis. Based on the graph, answer the following questions:



(a) At which point/s (A, B or C) in the curve is light a limiting factor?

Answer: At point A

(b) What could be the limiting factor/s in region A?

Answer: Carbon dioxide and water; apart from light.

(c) What do C and D represent on the curve?

Answer: C is the stage beyond which light is not a limiting factor. D is the line beyond which intensity of light has no effect on the rate of photosynthesis.

Question – 9 - Give comparison between the following:

(a) C3 and C4 pathways

Answer: The first carbon fixation product is PGA (3-carbon atom) in C3 pathway, while it is oxaloacetic acid (4-carbon atom) in C4 pathway. The C4 pathway is more efficient than the C3 pathway; in terms of making glucose.

(b) Cyclic and non-cyclic photophosphorylation

Answer: Both the photosystems are involved in non-cyclic photophosphorylation, while only PS I is functional in cyclic photophosphorylation. Non-cyclic photophosphorylation happens in the lamella of grana, while cyclic photophosphorylation occurs in the lamella of stroma. Both ATP and $NADPH+H^+$ are synthesized in non-cyclic photophosphorylation, while only ATP is synthesized in cyclic photophosphorylation.

(c) Anatomy of leaf in C3 and C4 plants

Answer: Bundle sheath is present in C4 leaves, while it is absent in C3 leaves. The cells of C4 leaves have a large number of chloroplasts, thick walls and no intercellular spaces.

14. Respiration in Plants

Exchange of Gases in Plants:

Plants do not have great demands for gaseous exchange. The rate of respiration in plants is much lower than in animals. Large amounts of gases are exchanged only during photosynthesis, and leaves are well equipped for that. The distance travelled by gases in plants is not much and hence diffusion is enough to meet the need. Hence, plants do not have specialized organs for exchange of gases. Lenticels and stomata serve as the openings through which exchange of gases takes place in plants.

Respiration:

The complete combustion of glucose yields energy during respiration. Most of the energy produced during respiration is given out as heat. CO_2 and H_2O are the end products of respiration.

$$C_6H_{12}O_6 + 6CO_2 \rightarrow 6CO_2 + 6H_2O + Heat$$

The energy produced during respiration is also used for synthesizing other molecules. To ensure the adequate supply of energy for synthesis of different molecules; plants catabolise the glucose molecule in such a way that not all the liberated energy goes out as heat. Glucose is oxidized in several small steps. Some steps are large enough to ensure that the released energy can be coupled with ATP synthesis.

Steps of Respiration:

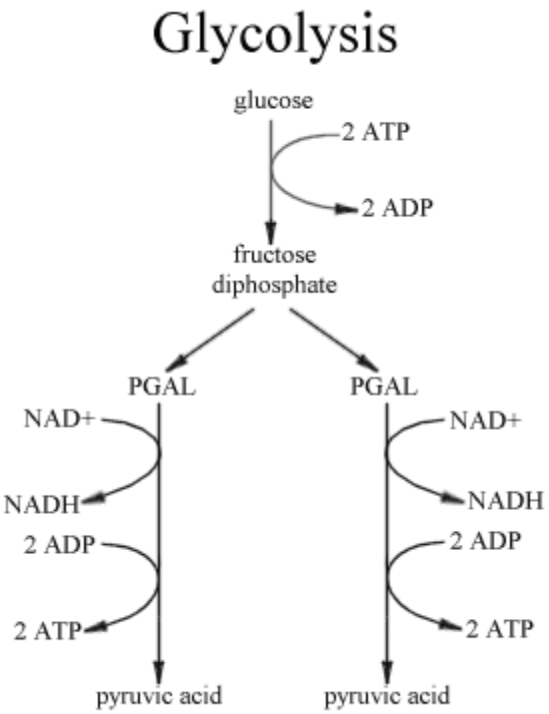
Respiration happens in two main steps in all living beings, viz. glycolysis and processing of pyruvate. Glycolysis involves breaking down glucose into pyruvate. This is common in all living beings. Further processing of pyruvate depends on the aerobic or anaerobic nature of an organism. In anaerobic respiration, pyruvate is further processed to produce either lactic acid or ethyl alcohol. There is incomplete oxidation of glucose in anaerobic respiration. In aerobic respiration, pyruvate is further processed to produce carbon dioxide and water; alongwith energy. There is complete oxidation of glucose in case of aerobic respiration.

GLYCOLYSIS

The scheme of glycolysis was given by Gustav Embden, Otto Meyerhof and J Parnas. Due to this, it is also called the EMP Pathway. Glycolysis takes place in the cytoplasm.

Glucose undergoes partial oxidation in glycolysis; to form two molecules of pyruvic acid. Four molecules of pyruvic acid are formed after partial oxidation of one molecule of glucose during this process.

- First of all, glucose and fructose undergo phosphorylation to produce glucose-6-phosphate. The enzyme hexokinase facilitates this process. Two molecules of ATP are utilised during phosphorylation of one molecule of glucose. Two molecules of fructose-6-phosphate are formed at the end of this step.
- Fructose-6-phosphate is then converted into PGAL (Phosphoglyceraldehyde). Each molecule of PGAL then undergoes various steps to finally produce Pyruvic Acid. Four molecules of ATP are produced during this conversion. Since two molecules of ATP were utilised during phosphorylation of glucose, hence net production of ATP at the end of glycolysis is two for each molecule of glucose.



Fate of Pyruvic Acid: Pyurvic acid further undergoes subsequent processes which are different for anaerobic and aerobic conditions.

FERMENTATION:-

Endogenous electron acceptors are used for oxidation of organic compounds during fermentation. This is in contrast to aerobic respiration in which exogenous electron acceptors are used. Anaerobic does not necessarily mean absence of oxygen, rather it can also take place even in the presence of oxygen.

Sugar is the most common substrate of fermentation. Ethanol, lactic acid and hydrogen are the common fermentation products. However, other compounds can also be produced by fermentation, e.g. butyric acid and acetone. Apart from taking place in yeast and many other anaerobes, fermentation also takes place in mammalian muscles. In our muscle cells, fermentation takes place during intense exercise; to meet out the excess demand of oxygen.

AEROBIC RESPIRATION

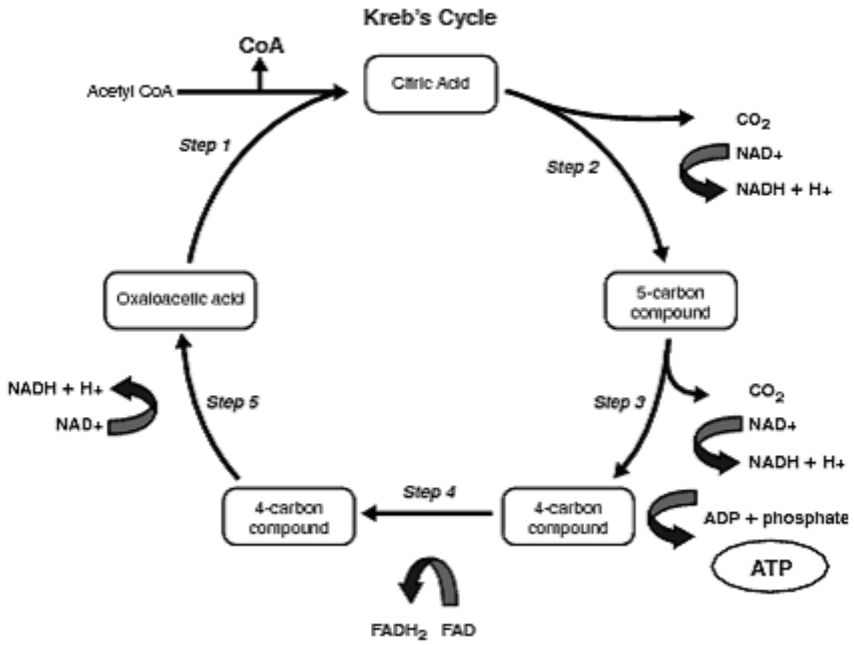
Aerobic respiration takes place within the mitochondria. Following are the main steps in aerobic respiration:

- Stepwise removal of all the hydrogen atoms leads to complete oxidation of pyruvate. This leaves three molecules of CO_2. This step takes place in the matrix of mitochondria.
- Electrons removed from hydrogen atoms are passed on to molecular O_2. This happens with simultaneous synthesis of ATP. This step takes place in the inner membrane of mitochondria.
- Pyruvate enters the mitochondira matrix and undergoes oxidative decarboxylation. This involves a complex set of reactions which are catalysed by pyruvic dehydrogenase.

$$Pyruvic\ acid + CoA + NAD^+ \xrightarrow[Pyruvate]{Mg^{2+}} dehydrogenase \longrightarrow AcetylCoA + NADH + H^+$$

During this process, two molecules of NADH are produced from the metabolism of two molecules of pyruvic acid (produced from one glucose molecule during glycolysis).

After this, acetyl CoA enters a cyclic pathway. This pathway is called tricarboxylic acid cycle or Citric Acid Cycle or Krebs' Cycle. This was first explained by Hans Krebs.



Kreb's Cycle

- The TCA cycle starts with the condensation of acetyl group with oxaloacetic acid (OAA) and water to yield citric acid. This reaction is catalysed by the enzyme citrate synthase and a molecule of CoA is released. Citrate is then isomerised to isocitrate.
- It is followed by two successive steps of decarboxylation. These steps of decarboxylation lead to the formation of α-ketoglutaric acid and then succinyl-CoA.
- After that, succinyl-CoA is oxidised to OAA allowing the cycle to continue. During this step, a molecule of GTP is synthesised. This is a substrate level phosphorylation.
- In a coupled reaction GTP is converted to GDP with the simultaneous synthesis of ATP from ADP. Moreover, there are three points in the cycle where NAD^+ is reduced to $NADH+H^+$ and one point where FAD^+ is reduced to $FADH_2$.
- The continued oxidation of acetic acid via the TCA cycle requires the continued replenishment of oxaloacetic acid. It also requires regeneration of NAD^+ and $FAD^+$from NADH and $FADH_2$ respectively.

Electron Transport System (ETS) and Oxidative Phosphorylation

The next steps are to release and utilize the energy stored in $NADH+H^+$ and $FADH_2$. This is accomplished when they are oxidised through the electron transport system and the electrons are passed on to O_2 resulting in the formation of H_2O.

The metabolic pathway through which the electron passes from one carrier to another, is called the electron transport system (ETS). This pathway is present in the inner mitochondrial membrane.

- Electrons from NADH (produced in the mitochondria matrix) are oxidized by an NADH dehydrogenase (Complex I). After that, electrons are transferred to ubiquinone which is located within the inner membrane.
- Ubiquinone also receives reducing equivalents via $FADH_2$ (Complex II). $FADH_2$ is generated during oxidation of succinate in the citric acid cycle.
- The reduced ubiquinone (ubiquinol) is then oxidised with the transfer of electrons to cytochrome c via cytochrome bc1 complex (complex III).
-

  Cytochrome c is a small protein attached to the outer surface of the inner membrane and acts as a

- mobile carrier for transfer of electrons between complex III and IV.
- Complex IV refers to cytochrome c oxidase complex containing cytochromes a and a3, and two copper centres.
- When the electrons pass from one carrier to another via complex I to IV in the electron transport chain, they are coupled to ATP synthase (complex V). This coupling is necessary for the production of ATP from ADP and inorganic phosphate. The nature of the electron donor decides the number of ATP molecules synthesized.

Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while oxidation of one molecule of $FADH_2$ produces 2 molecules of ATP.

Although the aerobic process of respiration takes place only in the presence of oxygen, the role of oxygen is limited to the terminal stage of the process. But since oxygen drives the whole process by removing hydrogen from the system, the presence of oxygen is vital.

Yet, the presence of oxygen is vital, since it drives the whole process by removing hydrogen from the system. Oxygen acts as the final hydrogen acceptor.

During photophosphorylation, light energy is utilised for the production of proton gradient. But in respiration, the energy of oxidation-reduction is utilised for the production of proton gradient. Hence, this process is called oxidative phosphorylation.

The energy released during the electron transport system is utilised in synthesizing ATP with the help of ATP synthase (Complex V). This complex is composed of two major components, viz. F1 and F0. The F1 headpiece is a peripheral membrane protein complex. It contains the site for synthesis of ATP. F0 is an integral membrane protein complex which forms the channel through which protons cross the inner membrane. The passage of protons through the channel is accompanied by catalytic site of the F1 component for the production of ATP. For each ATP produced, $2H^+$passed through F0 down the electrochemical proton gradient.

The Respiratory Balance Sheet

The respiratory balance sheet gives theoretical value about net gain of ATP for every glucose molecule oxidized. The calculations for respiratory balance sheet are based on some assumptions which are as follows:

- There is a sequential and orderly pathway in which one substrate makes the next substrate. Glycolysis, TCA cycle and ETS pathway follow one after another.

- NADH is synthesized in glycolysis and is transferred into the mitochondria. The NADH undergoes oxidative phosphorylation within the mitochondria.
- None of the intermediates in the pathway are utilised to synthesise any other compound.
- Glucose is the only substrate undergoing respiration. No other alternative substrates are entering in the pathway at any stage.

But these assumptions may not be valid in a living system because all pathways work simultaneously. There can be a net gain of 36 ATP molecules during aerobic respiration of one molecule of glucose.

Amphibolic Pathway

Glucose is the most favoured substrate for respiration. Other substrates can also be respired but they do not enter the respiratory pathway at the first step. Respiratory process involves both catabolism and anabolism; because breakdown and synthesis of substrates are involved. Hence, respiratory pathway is considered as an amphibolic pathway rather than a catabolic one.

Respiratory Quotient

The ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration is called the respiratory quotient (RQ) or respiratory ratio. The RQ for carbohydrates is 1. The RQ for fat and protein is less than 1.

$$Respiratory\ Quotient = \frac{Volume\ of\ CO_2\ evolved}{Volume\ of\ O_2\ Consumed}$$

Reaction for respiration of fat:

$$2(C_{51}H_{98}O_6) + 145O_2 \rightarrow 102CO_2 + 98H_2O$$

$$RQ\ of\ Fat = \frac{102CO_2}{145O_2} = 0.7$$

NCERT Solution

Question – 1- Differentiate between

(a) Respiration and Combustion

Answer: Respiration is a type of combustion. But while combustion is an uncontrolled process, respiration is controlled with high precision. Respiration takes place inside the cells of living beings, while combustion can take place anywhere.

(b) Glycolysis and Krebs' cycle

Answer: Breakdown of glucose into pyruvic acid is called glycolysis, while further processing of pyruvic acid through aerobic route is called Krebs' cycle. Glycolysis happens in all living beings, while Krebs' cycle happens in aerobes only. Glycolysis happens in cytoplasm, while Krebs' cycle happens in mitochondria.

(c) Aerobic respiration and Fermentation

Answer: Anaerobic respiration is also called fermentation. Ethanol and lactic acid are the major products of fermentation.

Question – 2 - What are respiratory substrates? Name the most common respiratory substrate.

Answer: A compound which is oxidized during respiration is called respiratory substrate. Glucose is the most common respiratory substrate.

Question – 3 - Give the schematic representation of glycolysis?

Answer: Refer to the chapter notes

Question – 4 - What are the main steps in aerobic respiration? Where does it take place?

Answer: Aerobic respiration takes place within the mitochondria. Following are the main steps in aerobic respiration:

- Stepwise removal of all the hydrogen atoms leads to complete oxidation of pyruvate. This leaves three molecules of CO2. This step takes place in the matrix of mitochondria.
- Electrons removed from hydrogen atoms are passed on to molecular O2. This happens with simultaneous synthesis of ATP. This step takes place in the inner membrane of mitochondria.

Pyruvate enters the mitochondira matrix and undergoes oxidative decarboxylation. This involves a complex set of reactions which are catalysed by pyruvic dehydrogenase.

Question – 5- Give the schematic representation of an overall view of Krebs' cycle. Answer: Refer to chapter notes

Question – 6 - Explain ETS.

Answer: The metabolic pathway through which the electron passes from one carrier to another, is called the electron transport system (ETS). This pathway is present in the inner mitochondrial membrane.

- Electrons from NADH (produced in the mitochondria matrix) are oxidized by an NADH dehydrogenase (Complex I). After that, electrons are transferred to ubiquinone which is located within the inner membrane.
- Ubiquinone also receives reducing equivalents via FADH2 (Complex II). FADH2 is generated during oxidation of succinate in the citric acid cycle.
- The reduced ubiquinone (ubiquinol) is then oxidised with the transfer of electrons to cytochrome c via cytochrome bc1 complex (complex III).
- Cytochrome c is a small protein attached to the outer surface of the inner membrane and acts as a mobile carrier for transfer of electrons between complex III and IV.
- Complex IV refers to cytochrome c oxidase complex containing cytochromes a and a3, and two copper centres.
- When the electrons pass from one carrier to another via complex I to IV in the electron transport chain, they are coupled to ATP synthase (complex V). This coupling is necessary for the production of ATP from ADP and inorganic phosphate. The nature of the electron donor decides the number of ATP molecules synthesized.

Question – 7 - Distinguish between the following:

(a) Aerobic respiration and Anaerobic respiration

Answer: Aerobic respiration needs oxygen, while anaerobic respiration does not need oxygen. There is complete oxidation of glucose in aerobic respiration, while it is incomplete in anaerobic respiration. Lactic acid and ethanol are the main products of anaerobic respiration, while carbon dioxide is the end product of aerobic respiration.

(b) Glycolysis and Fermentation

Answer: Breakdown of glucose into pyruvic acid is called glycolysis, while further processing of pyruvic acid in anaerobes is called fermentation.

(c) Glycolysis and Citric acid Cycle

Answer: Breakdown of glucose into pyruvic acid is called glycolysis, while further processing of pyruvic acid through aerobic route is called Citric acid cycle. Glycolysis happens in all living beings, while Citric acid cycle happens in aerobes only. Glycolysis happens in cytoplasm, while Citric acid cycle happens in mitochondria.

Question – 8 - What are the assumptions made during the calculation of net gain of ATP?

Answer: The calculations for respiratory balance sheet are based on some assumptions which are as follows:

- There is a sequential and orderly pathway in which one substrate makes the next substrate. Glycolysis, TCA cycle and ETS pathway follow one after another.
- NADH is synthesized in glycolysis and is transferred into the mitochondria. The NADH undergoes oxidative phosphorylation within the mitochondria.
- None of the intermediates in the pathway are utilised to synthesise any other compound.
- Glucose is the only substrate undergoing respiration. No other alternative substrates are entering in the pathway at any stage.

Question – 9 - Discuss “The respiratory pathway is an amphibolic pathway.”

Answer: Respiratory process involves both catabolism and anabolism; because breakdown and synthesis of substrates are involved. Hence, respiratory pathway is considered as an amphibolic pathway rather than a catabolic one.

Question – 10 - Define RQ. What is its value for fats?

Answer: The ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration is called the respiratory quotient (RQ) or respiratory ratio. The RQ for carbohydrates is 1. The RQ for fat and protein is less than 1.

$$Respiratory\ Quotient = \frac{Volume\ of\ CO_2\ evolved}{Volume\ of\ O_2\ Consumed}$$

Reaction for respiration of fat:

$$2(C_{51}H_{98}O_6) + 145O_2 \rightarrow 102CO_2 + 98H_2O$$

$$RQ\ of\ Fat = \frac{102CO_2}{145O_2} = 0.7$$

Question – 11 - What is oxidative phosphorylation?

Answer: During photophosphorylation, light energy is utilised for the production of proton gradient. But in respiration, the energy of oxidation-reduction is utilised for the production of proton gradient. Hence, this process is called oxidative phosphorylation.

Question – 12 - What is the significance of step-wise release of energy in respiration?

Answer: The energy produced during respiration is also used for synthesizing other molecules. To ensure the adequate supply of energy for synthesis of different molecules; plants catabolise the glucose molecule in such a way that not all the liberated energy goes out as heat. Glucose is oxidized in several small steps. Some steps are large enough to ensure that the released energy can be coupled with ATP synthesis.

15. Plant Growth and Development

Growth: A permanent and irreversible increase in size of an organ or its part or even of an individual cell is called growth. Growth is usually accompanied by metabolic process; which occur at the expense of energy.

Indeterminate Nature of Plant Growth: Plants retain the capacity for unlimited growth throughout their life. This becomes possible because of the presence of meristems at certain locations in the plant body. This type of growth in which new cells are always being added is called the open form of growth.

Phases of Growth: The growth can be divided into three phases, viz. meristematic, elongation and maturation.

a. Meristematic Phase: The constantly dividing cells of the root apex and the shoot apex represent the meristematic phase of growth. The cells of meristematic region are rich in protoplasm and posses large conspicuous nuclei. The cell walls of these cells are primary in nature, thin and cellulosic; with abundant plasmodesmatal connections.
b. Elongation Phase: The proximal cells which are just next to the meristematic zone represent the phase of elongation. In this phase, there is increased vacuolation, cell enlargement and new cell wall deposition.
c. Maturation Phase: Next to the phase of elongation lies the maturation zone. The cells of this zone attain their maximal size in terms of wall thickening and protoplasmic modifications.

Growth Rate: The increased growth per unit time is called growth rate. The growth rate can be arithmetic or geometrical.

Arithmetic Growth Rate: In this type of growth, only one daughter cell continues to divide after the mitosis. Another daughter cell differentiates and matures. Elongation of root at a constant rate is an example of arithmetic growth. Mathematically, the arithmetic growth rate can be shown as follows:

$L_t = L_0 + rt$

Here, L_t is length at time ‘t’, L_0 is length at time 0 and r is the rate per unit time.

Geometrical Growth Rate: In most of the cases, the initial growth is slow and is called the lag phase. After this, the growth is quite rapid and at an exponential rate. This phase is called the log or exponential phase. In this phase, both the daughter cells (formed after mitosis) continue to divide. The last phase marks a slowed down growth. This happens because of limited nutrient supply. This phase is called the stationary phase. The graph of the geometric growth gives a sigmoid curve.

The exponential growth can be mathematically represented as follows:

$W_1 = W_0 e^{rt}$

Here, W_1 = final size (weight, height, number etc.), W_0 = initial size at the beginning of the period, r = growth rate, t = time of growth and e = base of natural logarithms

Conditions for Growth

- Water: Plant growth is closely linked to water status of the plant. Water is required for cell enlargement and also for turgidity. Turgidity helps in extension growth in cells. Moreover, water provides the medium for enzymatic activities needed for growth.
- Oxygen: Oxygen is another important factor for growth. Oxygen helps in releasing energy which is utilised in growth activities.
- Nutrients: Various nutrients are also required by plants for synthesis of protoplasm.
- Temperature: A range of optimum temperature is also necessary for growth in a plant. Any deviation from the optimum range can be detrimental for the survival of plant.

DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION

Differentiation: The process which leads to maturation of cells is called differentiation. During differentiation, a few or major changes happen in protoplasm and cell walls of the cells. Let us take example of tracheary element. The cells of a tracheary element lose their protoplasm and develop a very strong, elastic, lignocellulosic secondary cell walls. These changes help the tracheary element to carry water to long distances even under extreme tension.

Dedifferentiation: A differentiated cell can regain its capacity for cell division under certain conditions. This phenomenon is called dedifferentiation. Formation of interfascicular cambium and cork cambium from fully differentiated parenchyma cells is an example of dedifferentiation.

Redifferentiation: A dedifferentiated plant cell once again loses its capacity to divide and becomes mature. This phenomenon is called redifferentiation.

Plasticity: Some plants show different growth pathways in response to environment or to phases of life to form different types of structures. This ability of plants is called plasticity. For example; the leaves of coriander are of different shape at a younger stage than at a mature stage. This phenomenon is called heterophylly. Heterophylly can also be seen in cotton and larkspur. Leaves of buttercup are of different shapes when they grow in water than when they grow in air. This is another example of plasticity.

PLANT GROWTH REGULATORS

Auxins: Auxin was first isolated from human urine. The term ‘auxin’ is applied to the indole-3-acetic acid (IAA), and to other natural and synthetic compounds which have certain growth regulating properties. Auxins are usually produced by the growing apices. IAA and IBA (Indole Butyric Acid) have been isolated from plants. Naphthalene Acetic Acid (NAA) and 2, 4 – D (2, 4-dichlorophenoxyacetic) are synthetic auxins.

Functions of Auxins:

- Auxins help to initiate rooting in stem cuttings. This property is widely used for plant propagation by stem cuttings.
- Auxins promote flowering. Auxins help to prevent fruit and leaf drop at early stages but promote abscission of older and mature leaves and fruits.
- Apical Dominance: In most of the higher plants, the growing apical bud inhibits the growth of lateral buds. This phenomenon is called apical dominance. Farmers remove shoot tips to ensure the growth of lateral buds. This practice is widely used in tea plantations and in hedge-making.
- Auxins induce parthenocarpy, e.g. in tomatoes. Auxins are widely used as herbicides, e.g. 2, 4-D is widely used to kill dicotyledonous weeds. It is also used to prepare seed-free lawns by gardeners. Auxins also control xylem differentiation and help in cell division.

Gibberellins: There are more than 100 gibberellins. They are denoted as GA1, GA2, GA3 and so on. Giberellic Acid (GA3) was one of the first gibberellins to be discovered. All gibberellins are acidic.

Functions of Gibberellins:

- Gibberellins cause an increase in length of axis. They cause fruit elongation and also delay senescence. Thus, gibberellins can be helpful in keeping the fruits for a longer duration on tree. In brewing industry, GA3 is used to speed up the malting process.
- Spraying sugarcane crop with gibberellins increases the length of stem. This helps in increasing the yield by as much as 20 tonnes per acre.
- Gibberellins are sprayed on juvenile conifers to hasten the maturity period. This leads to early seed production. Gibberellins also promote bolting in beet, cabbages and many plants with rosette habit. Internode elongation just prior to flowering is called bolting.

Cytokinins: Cytokinins have specific effects on cytokinesis. Kinetin was discovered from autoclaves of herring sperm DNA. Kinetin does not occur naturally in plants. Zeatin is a naturally occurring cytokinin which was isolated from corn-kernels and coconut milk.

Cytokinins are synthesized in the regions of rapid cell division. It helps to produce new leaves, chloroplast in leaves, lateral shoot growth and adventitious shoot formation. Cytokinins help in overcoming the apical dominance. Cytokinins promote nutrient mobilization which helps in the delay of leaf senescence.

Ethylene: Ethylene is a simple gaseous PGR. It is synthesised in large amounts by tissues undergoing senescence and ripening fruits.

- Horizontal growth of seedlings, swelling of axis and apical hook formation (in dicot seedlings) are some of the examples of activities of ethylene.
- Ethylene promotes senescence and abscission; especially of leaves and flowers. It is highly effective in fruit ripening.
- Ethylene breaks seed and bud dormancy. It initiates germination in peanut seeds. It initiates sprouting of potato tubers.
- Ethylene promotes rapid internode/petiole elongation in deep water rice plants.
- Ethylene also promotes root growth and root hair formation.
- Ethylene is one of the most widely used PGR in agriculture. It is used to initiate flowering and for synchronizing fruit-set in pineapples. It also induces flowering in mango. It is used for hastening fruit ripening in tomatoes and apples. It accelerates abscission in flower and fruits.

Abscisic Acid: ABA is a plant growth inhibitor. It plays a major role in seed development, maturation and dormancy. ABA stimulates closure of stomata and increases the tolerance of plants to various types of stresses. Hence, it is also called the stress hormone.

Photoperiodism: Flowering in certain plants depends on a combination of light and dark exposures and also on the relative duration of light and dark periods. This response of plants is called photoperiodism.

Flowering is an important step towards seed formation. Hence, phtoperiodism plays an important role in plant evolution.

Vernalisation: In some plants, flowering is quantitatively or qualitatively dependent on exposure to low temperature. This phenomenon is called vernalisation. Flowering is promoted during the period of low temperature because of vernalisation.

Many important crops; like wheat, barley, rye, etc. also have spring varieties. The spring variety is normally planted in the spring and come to flower and produce grain before the end of the growing season. But winter varieties of these plants would normally fail to bear flower if they are planted in spring. Such plants are planted in autumn so that they can flower during winter and bear seeds during spring. Such plants are usually harvested during mid-summer. Biennial plants also show vernalisation.

NCERT Solution

Question – 1- Define growth, differentiation, development, dedifferentiation, redifferentiation, determinate growth, meristem and growth rate.

Answer: Growth: A permanent and irreversible increase in size of an organ or its part or even of an individual cell is called growth.

Differentiation: The process which leads to maturation of cells is called differentiation. During differentiation, a few or major changes happen in protoplasm and cell walls of the cells.

Development: All the changes which an organism goes through during its life cycle become parts of development. In case of a flowering plant, right from seed germination to seed bearing, each stage is a part of the development process.

Dedifferentiation: A differentiated cell can regain its capacity for cell division under certain conditions. This phenomenon is called dedifferentiation. Formation of interfascicular cambium and cork cambium from fully differentiated parenchyma cells is an example of dedifferentiation.

Redifferentiation: A dedifferentiated plant cell once again loses its capacity to divide and becomes mature. This phenomenon is called redifferentiation.

Determinate Growth: When growth stops after a certain phase, this type of growth is called determinate growth.

Meristem: The plant tissue which has the ability to divide is called meristematic tissue. The region with such tissues is called meristem.

Growth Rate: The increased growth per unit time is called growth rate.

Question –2 - Why is not any one parameter good enough to demonstrate growth throughout the life of a flowering plant?

Answer: Different parts of a plant grow in different ways. There could be one way of measuring growth for a stem, while there could be a different way of measuring growth in a leaf. Different plants can be of different sizes and measurement of growth should be done in different ways in them. Hence, there cannot be one parameter to measure growth in different plants or even at different stages of the life cycle of a flowering plant.

Question –3 - Describe briefly:

(a) Arithmetic growth

Answer: In this type of growth, only one daughter cell continues to divide after the mitosis. Another daughter cell differentiates and matures. Elongation of root at a constant rate is an example of arithmetic growth. Mathematically, the arithmetic growth rate can be shown as follows:

$L_t = L_0 + rt$

Here, L_t is length at time 't', L_0 is length at time 0 and r is the rate per unit time.

(b) Geometric growth

Answer: In most of the cases, the initial growth is slow and is called the lag phase. After this, the growth is quite rapid and at an exponential rate. This phase is called the log or exponential phase. In this phase, both the daughter cells (formed after mitosis) continue to divide. The last phase marks a slowed down growth. This happens because of limited nutrient supply. This phase is called the stationary phase. The graph of the geometric growth gives a sigmoid curve.

The exponential growth can be mathematically represented as follows:

$W_1 = W_0 e^{rt}$

Here, W1 = final size (weight, height, number etc.), W0 = initial size at the beginning of the period, r = growth rate, t = time of growth and e = base of natural logarithms

(c) Sigmoid growth curve

Answer: The S-shaped curve on graph; to show geometric growth is called the sigmoid growth curve.

(d) Absolute and relative growth rates

Answer: When growth is measured in absolute terms, e.g. in terms of length or weight, it is called absolute growth. When growth is measure in terms of comparative terms; like percentage growth; it is called relative growth.

Question –4- List five main groups of natural plant growth regulators. Write a note on discovery, physiological functions and agricultural/horticultural applications of any one of them.

Answer: Auxins, gibberellins, cytokinins, ethylene and abscisic acid are the main groups of PGR.

Auxins: Auxin was first isolated from human urine. The term 'auxin' is applied to the indole-3-acetic acid (IAA), and to other natural and synthetic compounds which have certain growth regulating properties. Auxins are usually produced by the growing apices. IAA and IBA (Indole Butyric Acid) have been isolated from plants. Naphthalene Acetic Acid (NAA) and 2, 4 – D (2, 4-dichlorophenoxyacetic) are synthetic auxins.

Functions of Auxins:

- Auxins help to initiate rooting in stem cuttings. This property is widely used for plant propagation by stem cuttings.
- Auxins promote flowering. Auxins help to prevent fruit and leaf drop at early stages but promote abscission of older and mature leaves and fruits.

Question – 5 - What do you understand by photoperiodism and vernalisation? Describe their significance.

Answer: Photoperiodism: Flowering in certain plants depends on a combination of light and dark exposures and also on the relative duration of light and dark periods. This response of plants is called photoperiodism.

Flowering is an important step towards seed formation. Hence, phtoperiodism plays an important role in plant evolution.

Vernalisation: In some plants, flowering is quantitatively or qualitatively dependent on exposure to low temperature. This phenomenon is called vernalisation. Flowering is promoted during the period of low temperature because of vernalisation.

Question – 6 - Why is abscisic acid also known as stress hormone?

Answer: Abscisic acid helps plants to withstand stress and hence they are also known as stress hormone. For example; ABA closes stomata and thus helps in reducing water loss due to transpiration.

Question – 7 - 'Both growth and differentiation in higher plants are open'. Comment.

Answer: In higher plants, some of the cells retain their capacity of cell division. Hence, growth is of open type. Moreover, some of these cells always undergo differentiation after some rounds of cell division. Hence, the scope of differentiation is also open. Thus, it can be said the both growth and differentiation in higher plants are open.

Question – 8 - 'Both a short day plant and a long day plant can produce can flower simultaneously in a given place'. Explain.

Answer: Flowering in some plants depends on relative durations of light and dark periods. A short day plant requires a longer dark period, while a long day plant requires a longer light period. But flowering can happen simultaneously in them.

Question – 9 - Which one of the plant growth regulators would you use if you are asked to:

(a) Induce rooting in a twig

Answer: Auxins

(b) Quickly ripen a fruit

Answer: Ethylene

(c)Delay leaf senescence

Answer: Cytokinin

(d) Induce growth in axillary buds

Answer: Cytokinin

(e)‘Bolt’ a rosette plant

Answer: Gibberellins

(f) Induce immediate stomatal closure in leaves.

Answer: Abscisic Acid

Question –10 - Would a defoliated plant respond to photoperiodic cycle? Why?

Answer: Leaves are the sites of perception of light/dark duration. Hence, a defoliated plant would not respond to photoperiodic cycle.

Question –11 -What would be expected to happen if:

(a) GA3 is applied to rice seedlings

Answer: Hasten the growth of stem

(b) Dividing cells stop differentiating

Answer: Growth hormone is more prominent

(c) A rotten fruit gets mixed with unripe fruits

Answer: The rotten fruit would release ethylene which can hasten the ripening of unripe fruits.

(d) You forget to add cytokinin to the culture medium.

Answer: Cell division would be slower.

16. Digestion and Absorption

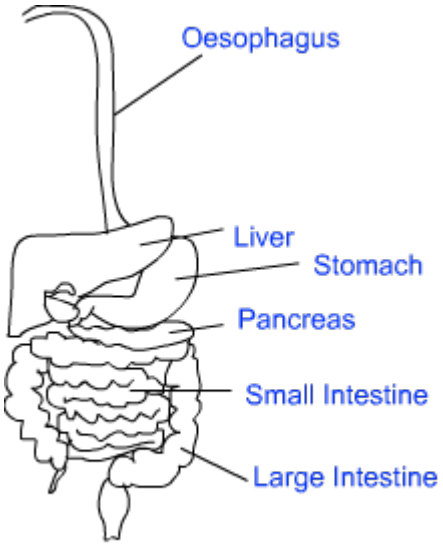
Food:

Food is a basic requirement of all living beings. Food provides energy for different activities in the body. Food also provides organic materials for growth and repair. Carbohydrates, proteins and fats are the major components of food and hence these are called macronutrients. Vitamins and minerals are required in small quantities and hence are called micronutrients. Water plays an important role in various metabolic processes. Water also prevents dehydration of the body.

Digestion:

The macromolecules in food cannot be utilised by our body in their original form. They need to be broken down and converted into simple substances so that they could be absorbed. The process of converting complex food into absorbable forms is called digestion. Various mechanical and biochemical methods are involved in digestion of food.

DIGESTIVE SYSTEM



Human Digestive System

The human digestive system consists of the alimentary canal and the associated glands.

Alimentary Canal: The alimentary canal begins with the mouth and ends in the anus. Mouth is situated at the anterior part and anus is situated at the posterior part of the body. The alimentary canal can be divided into five main parts, viz. mouth, oesophagus, stomach, small intestine and large intestine.

Buccal Cavity: The mouth opens into the buccal cavity or oral cavity. A muscular tongue and a number of teeth are present in the buccal cavity.

Thecodont: Each tooth is embedded in a socket of jaw bone. This type of attachment is called thecodont.

Dentition: The arrangement of different types of teeth in the jaws of an animal is called dentition. Two sets of teeth form during the lifetime of a human being. A set of temporary milk teeth or deciduous teeth

are formed when the child is about 6 months old. These teeth are replaced by a set of permanent teeth when the child is about 10 years of age.

Diphyodont: The type of dentition in which an animal gets two sets of teeth during its lifetime is called diphyodont. This type of dentition is present in most of the mammals.

Heterodont Dentition: When different types of teeth are present, this arrangement is called heterodont dentition.

Dentition in Humans: An adult human has four different types of teeth, viz. incisors (I), canine (C), premolars (PM) and molars (M). There are 32 permanent teeth in an adult human being.

Dental Formula: In human beings, each half of the upper and lower jaw has teeth in the order I, C, PM, M as represented by following dental formula:

$$\frac{2123}{2123}$$

Tongue: Tongue is a freely movable muscular organ. It is attached to the floor of the buccal cavity by the fernulum. Small projections; called papillae are present on the upper surface of the tongue. Some of the papillae bear the taste buds.

Pharynx: The oral cavity leads into the pharynx. The pharynx serves as a common passage for food and air.

Oesophagus: The oesophagus is a long tube which connects the buccal cavity to the stomach. A muscular sphincter; called gastrooesophageal sphincter regulates the opening of oesophagus into the stomach. A cartilaginous flap; called epiglottis; prevents the entry of food into the glottis during swallowing.

Stomach: Stomach is a J-shaped bag-like structure. It is situated in the upper left portion of the abdominal cavity. There are three major parts in the stomach, viz. the cardiac, fundic and pyloric regions. The oesophagus opens into the cardiac region of stomach. The pyloric region opens into the first part of small intestine.

Small Intestine: Small intestine is a long and highly coiled structure. It is divided into three regions, viz. duodenum, jejunum and ileum. The duodenum is U-shaped, jejunum is somewhat coiled and the ileum is highly coiled. The opening of the stomach into the duodenum is guarded by the pyloric sphincter.

Large Intestine: Ileum opens into the large intestine. The large intestine is somewhat shorter than the small intestine but has larger diameter. The large intestine consists of caecum, colon and rectum. Caecum is a blind sac which hosts some symbiotic microorganisms.

Appendix: This is a narrow finger-like tubular projection situated at the junction of small and large intestines. The vermiform appendix arises from caecum. Appendix is a vestigial organ.

Colon: Colon is divided into three parts, i.e. an ascending, a transverse and a descending part. The descending colon opens into the rectum. The rectum; in turn; opens out through the anus.

Wall of Alimentary Canal: The wall of the alimentary canal is made of four layers, viz. serosa muscularis, sub-mucosa and mucosa. Serosa is the outermost layer and is made up of a thin mesothelium with some connective tissues. The epithelium of visceral organs is called mesothelium. Muscularis is formed by smooth muscles which are usually arranged into an inner circular and outer longitudinal layer. An oblique muscle layer may be present in some regions. The sub-mucosal layer is formed of loose connective tissues.

DIGESTIVE GLANDS

Salivary Glands: There are three pairs of salivary glands, viz. parotids, sub-maxillary/submandibular and sbublinguals. The parotids are present in the cheek. The sub-maxillary/sub-madnibular is present in the jaws. The sublinguals are present below the tongue. The salivary glands secrete salivary juice into the buccal cavity.

Liver: Liver is the largest gland in the human body. It weighs about 1.2 to 1.5 kg in adult human. Liver is situated in the abdominal cavity, just below the diaphragm. There are two lobes in the liver. The functional and structural units of liver are the hepatic lobules. Hepatic cells are arranged in the form of cords in the hepatic lobules. Each lobule is covered by a thin connective tissue; called the Glisson's capsule. Hepatic cells produce bile. The bile passes through the hepatic ducts and is stored and concentrated in the gall bladder. The gall bladder is a thin muscular sac, situated above the liver. The duct of gall bladder (cystic duct); along with the hepatic duct forms the common bile duct.

The bile duct and the pancreatic duct open into the duodenum as the common hepato-pancreatic duct. The hepato-pancreatic duct is guarded by a sphincter called the sphincter of Oddi.

Pancreas:

Pancreas is a compound gland, i.e. both exocrine and endocrine. It is an elongated organ. This is situated between the limbs of the U-shaped duodenum. The exocrine portion of the pancreas secretes and alkaline pancreatic juice which contains various enzymes. The endocrine portion of the pancreas secretes hormones; insulin and glucagon.

NCERT Solution

Question – 1- Gastric juice contains

a. Pepsin, lipase and rennin
b. Trypsin, lipase and rennin
c. Trypsin, pepsin and lipase
d. Trypsin, pepsin and rennin

Answer: (a) Pepsin, lipase and rennin

Question – 2 - Succus entericus is the name given to

a. A junction between ileum and large intestine
b. Intestinal juice
c. Swelling in the gut
d. Appendix

Answer: (b) Intestinal juice

Question – 3 - Match column I with column II

Column I	Column II
(a) Bilirubin and biliverdin	1. Parotid
(b) Hydrolysis of starch	2. Bile
(c) Digestion of fat	3. Lipases
(d) Salivary gland	4. Amylases

Answer: (a) → 2, (b) → 4, (c) → 3, (d) → 1

Question – 4 - Why are villi present in the intestine and not in the stomach?

Answer: Major portion of absorption of food takes place in small intestine. Absorption in small intestine is also important because digestion is almost complete by the time food reaches ileum. Presence of villi in the stomach is not relevant because digestion is only partial in the stomach.

Question – 5 - How does pepsinogen change into its active form?

Answer: Pepsinogen changes into its active form by the action of hydrochloric acid.

$$Pepsinogen \xrightarrow{HCl} Pepsin$$

Question – 6 - What are the basic layers of the wall of alimentary canal?

Answer: The wall of the alimentary canal is made of four layers, viz. serosa muscularis, sub-mucosa and mucosa. Serosa is the outermost layer and is made up of a thin mesothelium with some connective tissues. The epithelium of visceral organs is called mesothelium. Muscularis is formed by smooth muscles which are usually arranged into an inner circular and outer longitudinal layer. An oblique muscle layer may be present in some regions. The sub-mucosal layer is formed of loose connective tissues.

Question – 7 - How does bile help in the digestion of fats?

Answer: Bile helps in emulsification of fats and also activates lipases. Thus, bile helps in digestion of fats.

Question – 8 - State the role of pancreatic juice in digestion of proteins.

Answer: Proteins, proteoses and peptones are acted upon by the proteolytic enzymes of pancreatic juices; as given below:

$$\begin{matrix} Proteins \\ Peptones \\ Proteoses \end{matrix} \xrightarrow{Trypsin/Chymotrypsin/carboxypeptidases} Dipeptides$$

Question – 9 - Describe the process of digestion of protein in stomach.

Answer: The proenzyme pepsinogen gets converted into the active enzyme pepsin; on exposure to hydrochloric acid. Pepsin converts proteins into proteoses and peptones (peptides).

$$Pepsinogen \xrightarrow{HCl} Pepsin + Protein \rightarrow Proteose + Peptone$$

Question – 10 - Give the dental formula of human beings.

Answer: In human beings, each half of the upper and lower jaw has teeth in the order I, C, PM, M as represented by following dental formula:

$$\frac{2123}{2123}$$

Question – 11 - Bile juice contains no digestive enzymes, yet it is important for digestion. Why?

Answer: Bile juice plays two important roles, i.e. of changing the medium of food from acidic to alkaline and of emulsifying the fat. Alkaline medium is necessary for action of enzymes in the succus entericus. Thus, bile is important for digestion.

Question – 12 - Describe the digestive role of chymotrypsin. Which two other digestive enzymes of the same category are secreted by its source gland?

Answer: Chymotrypsin completes the digestion of protein. Trypsin and carboxypeptidases are the two other enzymes of the same category secreted by its source gland.

Question – 13 How are polysaccharides and disaccharides digested?

Answer: Polysaccharides are hydrolysed by pancreatic amylase into disaccharides.

$$Polysachharides(starch) \xrightarrow{Amylase} Disachharides$$

Disaccharides are then digested by the enzymes in succus entericus into various monosachharides.

$$Maltose \xrightarrow{Maltase} Glucose + Glucose$$

$$Lactose \xrightarrow{Lactase} Glucose + Galactose$$

$$Sucrose \xrightarrow{Sucrase} Glucose + Fructose$$

Question – 14 - What would happen if HCl were not secreted in the stomach?

Answer: Acidic medium is necessary for the action of gastric enzymes. Moreover, it also kills various microbes which may be present in food. These actions would not be possible in the absence of hydrochloric acid.

Question – 15 - How does butter in your food get digested and absorbed in the body?

Answer: Butter is mainly composed of fat. Fat is digested by lipases.

$$Fats \xrightarrow{Lipases} Diglycerides \rightarrow Monoglycerides$$

Di and monoglycerides are then digested into fatty acids and glycerol.

$$Di\ and\ monoglycerides \xrightarrow{Lipases} Fatty\ acids + Glycerol$$

Question – 16 - Discuss the main steps in the digestion of proteins as the food passes through different parts of the alimentary canal.

Answer: The proenzyme pepsinogen; in stomach; gets converted into the active enzyme pepsin; on exposure to hydrochloric acid. Pepsin converts proteins into proteoses and peptones (peptides).

$$Pepsinogen \xrightarrow{HCl} Pepsin + Protein \rightarrow Proteose + Peptone$$

Proteins, proteoses and peptones are acted upon by the proteolytic enzymes of pancreatic juices (in small intestine); as given below:

$$\begin{matrix} Proteins \\ Peptones \\ Proteoses \end{matrix} \xrightarrow{Trypsin/Chymotrypsin/carboxypeptidases} Dipeptides$$

The enzymes in the intestinal juice act on dipeptides to make amino acids.

$$Dipeptides \xrightarrow{Dipeptidases} Amino\ acids$$

Question – 17 - Explain the term thecodont and diphyodont.

Answer: Thecodont: Each tooth is embedded in a socket of jaw bone. This type of attachment is called thecodont.

Diphyodont: The type of dentition in which an animal gets two sets of teeth during its lifetime is called diphyodont. This type of dentition is present in most of the mammals.

Question – 18 - Name different types of teeth and their number in an adult human.

Answer: Different types of teeth and their number in an adult human are as follows:

Incisors: 8

Canine: 4

Premolars: 8

Molars: 12

Question – 19 - What are the functions of liver?

Answer: Function of liver can be broadly categorized into two types, viz. synthesis and breakdown.

Synthesis:

- A large part of amino acid synthesis happens in liver.
- Liver has many roles in carbohydrate metabolism and lipid metabolism.
- Main part of protein metabolism, synthesis and degradation takes place in liver.
- Liver produces coagulation factors I (fibrinogen), II (prothrombin), V, VII, IX, X and XI. It also produces protein C, protein S and antithrombin.
- Liver is the main site of RBC production during the first trimester of foetus.
- Liver produces bile.

Breakdown

- Breakdown of insulin and other hormones, haemogloin, some toxic substances and conversion of ammonia into urea takes place in liver.

17. Breathing and Exchange of Gases

Respiration:

The process of exchange of O_2 (from the atmosphere) with CO_2 (produced by cells) is called breathing. This process is commonly known as respiration.

Respiratory Organs:

- Mechanisms of breathing vary among different animal groups. It usually depends on the habitat and level of organization.
- In case of lower invertebrates, exchange of gases takes place by simple diffusion over the entire body surface, e.g. sponges, coelenterates, flatworms, etc.
- The moist cuticle of earthworms facilitates exchange of gases.
- Insects have a network of tubes through which air is transported within the body. These tubes are called tracheae.
- Gills are special vascularised structures which are present in most of the aquatic arthropods and mollusks.
- In terrestrial animals, vascularised bags; called lungs; are present for the exchange of gases.

HUMAN RESPIRATORY SYSTEM

The human respiratory system is composed of following organs:

Pharynx: There is a pair of external nostrils which open out above the upper lips. The nostrils lead to a nasal chamber through the nasal passage. The nasal chamber opens into nasopharynx. Nasopharynx is a part of pharynx. Pharynx is the common passage for food and air.

Larynx: Nasopharynx opens through glottis of the larynx into the trachea. Larynx is a cartilaginous box which helps in sound production. Due to this, larynx is also called the sound box. There is a thin elastic cartilaginous flap; called epiglottis. The epiglottis covers the glottis during swallowing. This prevents the entry of food into the larynx.

Trachea: Trachea is a straight tube which extends up to the mid-thoracic cavity. The trachea divides at the level of 5th thoracic vertebra into right and left primary bronchi.

Bronchi: Each bronchus undergoes repeated divisions to form secondary and tertiary bronchi and bronchioles. They finally end up in very thin terminal bronchioles. The tracheae, bronchi and the initial bronchioles are supported by incomplete cartilaginous rings. Each terminal bronchiole gives rise to a number of very thin alveoli. An alveolus is an irregular-walled and vascularised bag-like structure.

Lungs: The lungs are composed of the branching network of bronchi, bronchioles and alveoli. Each lung is covered by a double-layered pleura. The pleura is filled with pleural fluid. The pleural fluid reduces friction on the lung surface. The outer pleural membrane is in close contact with the thoracic lining. The inner pleural membrane is in contact with the lung surface.

Conducting Part of Respiratory System: The conducting part is constituted by the external nostrils, pharynx, larynx, bronchi and the terminal bronchioles. The conducting part transports the atmospheric air to the alveoli. This part also clears the air from foreign particles, humidifies and brings the air to body temperature.

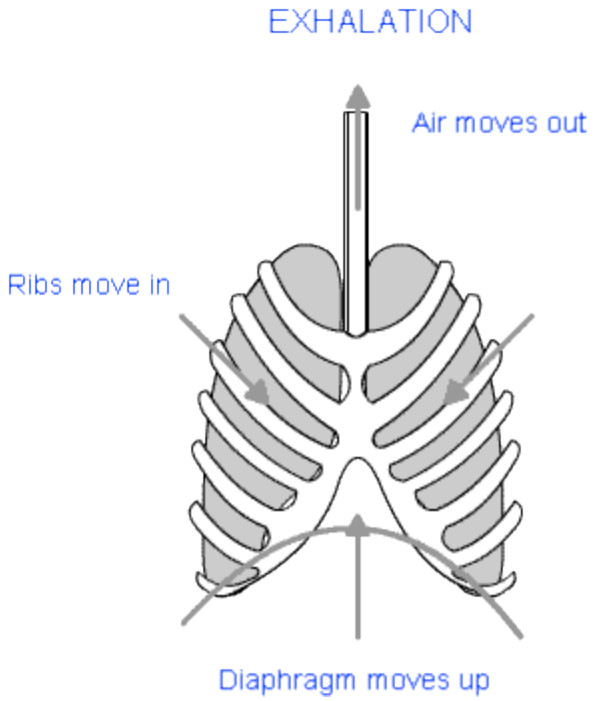
Exchange Part of Respiratory System: The exchange part of the respiratory system is composed of the alveoli and their ducts. Actual diffusion of O_2 and CO_2 (between blood and atmospheric air) takes place in the exchange part of the respiratory system.

Thoracic Chamber: The lungs are situated in the thoracic chamber. This is anatomically an air-tight chamber. The thoracic chamber is formed dorsally by the vertebral column, ventrally by the sternum, laterally by the ribs and on the lower side by the dome-shaped diaphragm. Any change in the volume of the thoracic cavity would be reflected in the lung cavity. This is possible because of the typical anatomical setup of lungs in thorax. Such an arrangement is essential for breathing, because we cannot directly alter the pulmonary volume.

Steps of Respiration:

- Breathing or pulmonary ventilation facilitates intake of atmospheric air and expulsion of alveolar air.
- Diffusion of gases takes place across alveolar membrane.
- Oxygen is transported to the tissue by blood.
- Diffusion of O_2 and CO_2 takes place between blood and tissues.
- Catabolism leads to utilization of O_2 by the cells and release of CO_2.

MECHANISM OF BREATHING



Breathing involves two stages, viz. inspiration and expiration. The atmospheric air is drawn in during inspiration and the alveolar air is released out during expiration. The movement of air into and out of the lungs is facilitated by creating a pressure gradient between the lungs and the atmosphere. When the pressure within the lungs is less than the atmospheric pressure, inspiration takes place. When the intra-pulmonary pressure is higher than the atmospheric pressure, expiration takes place.

The pressure gradient is generated by the diaphragm and a specialized set of muscles. These special muscles are external and internal intercostals between the ribs.

Mechanism of Inspiration: Inspiration is initiated by the contraction of diaphragm. The contraction of diaphragm increases the volume of thoracic chamber in the antero-posterior axis. The external inter-costal muscles contract to lift up the ribs and the sternum. This causes an increase in the volume of the thoracic chamber in the dorso-ventral axis. The overall increase in the thoracic volume results in a similar increase in pulmonary volume. The increase in pulmonary volume decreases the intra-pulmonary pressure to less than the atmospheric pressure. This pressure gradient forces the air from outside to move into the lungs and inspiration takes place.

Mechanism of Expiration: Diaphragm and inter-costal muscles relax which results in the diaphragm and the sternum returning to their normal positions. This reduces the thoracic volume and thus the pulmonary volume. The reduction in pulmonary volume results in an increase in intra-pulmonary pressure to slightly above the atmospheric pressure, which causes the expulsion of air from the lungs, and expiration takes place.

RESPIRATORY VOLUMES AND CAPACITIES

Tidal Volume (TV): The volume of air inspired or expired during a normal respiration is called Tidal Volume. It is approximately 500 ml in a healthy man. This means that a healthy adult can inspire or expire about 6 to 8 litre of air per minute.

Inspiratory Reserve Volume (IRV): Additional volume of air, a person can inspire by a forcible inspiration is called Inspiratory Reserve Volume. This is about 2500 ml to 3000 ml in normal adult.

Expiratory Reserve Volume (ERV): Additional volume of air, a person can expire by a forcible expiration is called Expiratory Reserve Volume. This is about 1000 ml to 1100 ml in a normal adult.

Residual Volume (RV): The volume of air remaining in the lungs even after a forcible expiration is called Residual Volume. This is about 1100 ml to 1200 ml in a normal adult.

Inspiratory Capacity (IC): The total volume of air a person can inspire after a normal expiration is called Inspiratory Capacity. This includes the tidal volume and inspiratory reserve volume, i.e. IC = TV + IRV.

Expiratory Capacity (EC): The total volume of air a person can expire after a normal inspiration is called Expiratory Capacity. EC = TV + ERV.

Functional Residual Capacity (FRC): The volume of air which remains in the lungs after a normal expiration is called Functional Residual Capacity. FRC = ERV + RV.

Vital Capacity (VC): The maximum volume of air a person can breathe in after a forceful expiration is called Vital Capacity. This is also defined as the maximum volume of air a person can breathe out after a forceful inspiration. VC = ERV + TV + IRV.

Total Lung Capacity: Total volume of air accommodated in the lungs at the end of a forced inspiration is called Total Lung Capacity. Total Lung Capacity = VC + RV = (ERV + TV + IRV) + RV.

EXCHANGE OF GASES

Alveoli are the main sites of exchange of gases. However, exchange of gases also occurs between blood and tissues. The exchange of O_2 and CO_2 at these sites happens by simple diffusion which is mainly based on pressure/concentration gradient. Some important factors which can affect the rate of

diffusion are; solubility of gases and thickness of the membranes involved in diffusion. Pressure contributed by an individual gas in a mixture of gases is called partial pressure. It is represented as $pO_2$for oxygen and pCO_2 for carbon dioxide.

TRANSPORT OF GASES

Blood is the medium of transport for O_2 and CO_2. About 97% of oxygen is transported by RBCs. The remaining 3% of oxygen is carried in a dissolved state through the plasma. About 20-25% of carbon dioxide is transported by RBCs. About 70% of carbon dioxide is carried as bicarbonate and about 7% is carried in a dissolved state through plasma.

Transport of Oxygen

Oxygen can bind with haemoglobin in a reversible manner to form oxyhaemoglobin. Each haemoglobin molecule can carry a maximum of four molecules of oxygen. Binding of oxygen with haemoglobin is mainly related to the partial pressure of O_2. Partial pressure of CO_2, hydrogen ion concentration and temperature are the other factors which can interfere with this binding. When percentage saturation of haemoglobin with O_2 is plotted against pO_2, we get a sigmoid curve. This curve is called Oxygen Dissociation Curve. This curve is very useful in studying the effect of factors; like pCO_2, H^+ concentration, etc. on binding of O_2 with haemoglobin.

Transport of Carbon dioxide

The binding of carbon dioxide with haemoglobin is related to partial pressure of CO_2. The partial pressure of O_2 is a major factor which can affect this binding. In the tissues, pCO_2 is higher than pO_2 and hence more binding of carbon dioxide occurs at the tissue level. In the alveoli, pCO_2 is lower than pO_2 and hence dissociation of carbamino-haemoglobin takes place in the alveoli.

RBCs contain a very high concentration of the enzyme; carbonic anhydrase. Minute quantities of the same enzyme are present in plasma as well. This enzyme facilitates the following reaction.

$$CO_2 + H_2O \xleftrightarrow{carbonic\ anhydrase} H_2CO_3 \xleftrightarrow{carbonic\ anhydrase} HCO_3^- + H^+$$

At the tissue site, partial pressure of CO_2 is high due to catabolism. At this level, CO_2diffuses into blood and forms bicarbonate and hydrogen ions.

At the alveolar site, pCO_2 is low. At this level, the reaction proceeds in the opposite direction and thus carbon dioxide and water are formed. Thus, carbon dioxide trapped as bicarbonate at the tissue level and transported to the alveoli is released out as CO_2. Every 100 ml of deoxygenated blood delivers about 4 ml of CO_2 to the alveoli.

REGULATION OF RESPIRATION

The regulation of respiration is done by the neural system. The respiratory rhythm centre is present in the medulla and is mainly responsible for the regulation of respiration. Another region; called pneumotaxic centre is present in the pons. The pneumotaxic centre can moderate the functions of the respiratory rhythm centre.

A chemosensitive area is situated adjacent to the rhythm centre. This is highly sensitive to CO_2 and hydrogen ions. Increase in these substances can activate this chemosensitive area. This; in turn; gives

signal to the rhythm centre to make necessary adjustments in the respiratory process so that these substances can be eliminated.

Receptors associated with aortic arch and carotid artery can also recognize changes in CO_2 and H^+ concentration. These receptors send necessary signals to the rhythm centre for corrective actions.

It is important to remember that the role of oxygen in the regulation of respiratory rhythm is quite insignificant.

DISORDERS OF RESPIRATORY SYSTEM

Asthma: Asthma is a difficulty in breathing causing wheezing due to inflammation of bronchi and bronchioles. Constriction of bronchii leads to asthmatic attacks.

Emphysema: Emphysema is a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased. Smoking is a major cause of emphysema.

Occupational Respiratory Disorders: In some industries, a huge amount of dust is involved. The dust particles often get inside the lungs of the workers because the body's defence system is unable to cope with the huge amount of dust. Long term exposure can lead to severe lung damage. Workers usually wear masks to prevent the entry of dust particles inside their lungs.

NCERT Solution

Question 1. Define vital capacity. What is its significance?

Answer: Vital Capacity (VC): The maximum volume of air a person can breathe in after a forceful expiration is called Vital Capacity. This is also defined as the maximum volume of air a person can breathe out after a forceful inspiration. VC = ERV + TV + IRV.

Vital capacity of a person gives important clues while diagnosing a lung disease. Measurement of this capacity helps the doctor to decide about the possible causes of the diseases and about the line of treatment.

Question 2. State the volume of air remaining in the lungs after a normal breathing.

Answer: Functional Residual Capacity (FRC): The volume of air which remains in the lungs after a normal expiration is called Functional Residual Capacity. FRC = ERV + RV.

ERV=1000 to 1100 ml

RV = 1100 to 1200 ml

So, FRC = 2100 to 2300 ml

Question 3. Diffusion of gases occurs in the alveolar region only and not in the other parts of respiratory system. Why?

Answer: The exchange part of the respiratory system is composed of the alveoli and their ducts. Actual diffusion of O_2 and CO_2 (between blood and atmospheric air) takes place in the exchange part of the

respiratory system. The thin membrane of the alveoli is suited for diffusion of gases, while other parts of the respiratory system are not structured to serve this purpose. Hence, diffusion of gases takes place in the alveolar region only and not in the other parts of the respiratory system.

Question 4. What are the major transport mechanisms for CO_2? Explain.

Answer: The binding of carbon dioxide with haemoglobin is related to partial pressure of CO_2. The partial pressure of O_2 is a major factor which can affect this binding. In the tissues, pCO_2 is higher than pO_2 and hence more binding of carbon dioxide occurs at the tissue level. In the alveoli, pCO_2 is lower than pO_2 and hence dissociation of carbamino-haemoglobin takes place in the alveoli.

Question 5. What will be the pO_2 and pCO_2 in the atmospheric air compared to those in the alveolar air ?

i. pO_2 lesser, pCO_2 higher
ii. pO_2 higher, pCO_2 lesser
iii. pO_2 higher, pCO_2 higher
iv. pO_2 lesser, pCO_2 lesser

Answer:- (ii) pO_2 higher, pCO_2 lesser

Question 6. Explain the process of inspiration under normal conditions.

Answer: Inspiration is initiated by the contraction of diaphragm. The contraction of diaphragm increases the volume of thoracic chamber in the antero-posterior axis. The external inter-costal muscles contract to lift up the ribs and the sternum. This causes an increase in the volume of the thoracic chamber in the dorso-ventral axis. The overall increase in the thoracic volume results in a similar increase in pulmonary volume. The increase in pulmonary volume decreases the intra-pulmonary pressure to less than the atmospheric pressure. This pressure gradient forces the air from outside to move into the lungs and inspiration takes place.

Question 7. How is respiration regulated?

Answer: The regulation of respiration is done by the neural system. The respiratory rhythm centre is present in the medulla and is mainly responsible for the regulation of respiration. Another region; called pneumotaxic centre is present in the pons. The pneumotaxic centre can moderate the functions of the respiratory rhythm centre.

A chemosensitive area is situated adjacent to the rhythm centre. This is highly sensitive to CO_2 and hydrogen ions. Increase in these substances can activate this chemosensitive area.

This; in turn; gives signal to the rhythm centre to make necessary adjustments in the respiratory process so that these substances can be eliminated.

Receptors associated with aortic arch and carotid artery can also recognize changes in CO_2 and H^+ concentration. These receptors send necessary signals to the rhythm centre for corrective actions.

It is important to remember that the role of oxygen in the regulation of respiratory rhythm is quite insignificant.

Question 8. What is the effect of pCO_2 on oxygen transport?

Answer: Binding of oxygen with haemoglobin is mainly related to the partial pressure of O_2. Partial pressure of CO_2, hydrogen ion concentration and temperature are the other factors which can interfere with this binding. Increased partial pressure of CO_2 can increase haemoglobin's affinity towards oxygen and vice-versa is also true.

Question 9. What happens to the respiratory process in a man going up a hill?

Answer: A man going uphill has to exert more effort to climb. This increases the consumption of oxygen. As a result, the partial pressure of oxygen in haemoglobin decreases which creates more demand for oxygen. This is compensated by an increased breathing rate.

Question 10. What is the site of gaseous exchange in an insect?

Answer: Insects have a network of tubes through which air is transported within the body. These tubes are called tracheae. The tracheae open on the lateral surface of the animal through minute pores; called spiracles.

Question 11. Define oxygen dissociation curve. Can you suggest any reason for its sigmoidal pattern?

Answer: When percentage saturation of haemoglobin with O_2 is plotted against pO_2, we get a sigmoid curve. This curve is called Oxygen Dissociation Curve.

Oxygen has a high affinity with haemoglobin. Binding of initial molecules of oxygen is difficult, but binding of subsequent molecules becomes easier. This is evident by the rising trend in the initial phases of the sigmoid curve. Once the oxygen binding reaches its optimum level, haemoglobin cannot take up any more oxygen molecules and hence the graph shows a plateau phase. These are the reasons for S-shape of the graph.

Question 12. Have you heard about hypoxia? Try to gather information about it, and discuss with your friends.

Answer: Lack of adequate oxygen supply to whole body or a part is called hypoxia. Hypoxia generally happens because of a mismatch between oxygen demand and supply.

Question 13. Distinguish between

(a) IRV and ERV

Answer: The additional volume of air which can be forcefully inspired is called IRV, while the additional volume of air forcefully expired is called ERV. In a normal adult, the IRV is about 2500 ml to 3000 ml, while the ERV is about 1000 ml to 1100 ml.

(b) Inspiratory capacity and Expiratory capacity.

Answer: The total volume of air which can be inspired after a normal expiration is called Inspiratory Capacity, while the total volume of air which can be expired after a normal inspiration is called expiratory capacity. IC = TV + IRV, while EC = TV + ERV.

(c) Vital capacity and Total lung capacity.

Answer: The maximum volume of air which a person can breathe in after a forced expiration is called Vital Capacity, while the total volume of air accommodated in the lungs at the end of a forced inspiration is called Total Lung Capacity.

VC = ERV + TV + IRV

TLC = RV + (ERV + TV + IRV)

Question 14. What is Tidal volume? Find out the Tidal volume (approximate value) for a healthy human in an hour.

Answer: Tidal Volume (TV): The volume of air inspired or expired during a normal respiration is called Tidal Volume. It is approximately 500 ml in a healthy man. This means that a healthy adult can inspire or expire about 6 to 8 litre of air per minute.

Tidal Volume = 500 ml

Respiration rate = 12 per minute

Hence, Tidal Volume in 1 hour = 500 ml x 12 x 60 minute = 360000 ml = 360 litre

18. Body Fluids and Circulartion

Blood:

Blood is a connective tissue which is composed of a fluid matrix (plasma) and formed elements.

Plasma

Plasma is a straw-coloured and viscous fluid. Plasma constitutes about 55% of the blood. About 90% of plasma is water and about 6-8% is composed of proteins. The major plasma proteins are; fibrinogen, globulins and albumins. Fibrinogen play important role in blood coagulation. Globulins are mainly involved in defense mechanism and albumins help in osmotic balance. Small amounts of minerals; like Na^+, Ca^{++}, Mg^{++}, HCO_3^- and Cl^-; are also present in plasma. Plasma also contains glucose, amino acids, lipids, etc. because these substances are always in transit in the body. Factors for clotting of blood are present in the plasma in an inactive form. Plasma without the clotting factors is called serum.

Formed Elements

The formed elements constitute about 45% of the blood. Erythrocytes, leucocytes and platelets are collectively called formed elements.

Erythrocytes or Red Blood Cells (RBCs): The RBCs are the most abundant cells in blood. In a healthy adult, about 5 million to 5.5 million RBCs are present per cubic mm of blood. RBCs are formed in the read bone marrow in the adults. In most of the mammals, nucleus is absent in the RBCs. RBCs are biconcave in shape. The red colour is because of an iron containing protein complex; called haemoglobin. In a healthy adult, each 100 ml of blood contains 12-16 gm blood. The average lifespan of RBCs is 120 days. RBCs are finally destroyed in the spleen and hence, spleen is also called the graveyard of RBCs. RBCs play a significant role in transport of respiratory gases.

Leucocytes or White Blood Cells (WBCs): The WBCs are nucleated and are relatively lesser in number than RBCs. In a healthy adult about 6000-8000 WBCs are present per cubic mm of blood. Leucocytes are generally short lived.

There are two main categories of WBCs:

- Granulocytes , e.g., neutrophils, eosinophils and basophils
- Agranulocytes. e.g., Lymphocytes and monocytes.

a. Neutrophils: Neutrophils are the most abundant cells among WBCs and comprise about 60-65%.
b. Monocytes: Monocytes comprise about 6-8% of WBCs. Neutrophils and monocytes are phagocytic cells.
c. Basophils: Basophils secrete histamine, serotonin, heparin, etc. They are involved in inflammatory reactions.
d. Eosinophils: Eosinophils comprise 2-3% of WBCs. These resist infections and are also associated with allergic reactions.
e. Lymphocytes: Lymphocytes comprise about 20-25% of WBCs. There are two major types of lymphocytes, viz. B and T types. Both the types are responsible for immune responses of the body.

Platelets: Platelets are also known as thrombocytes. They are cell fragments produced from megakaryotcytes. Megakaryocytes are special cells in the bone marrow. Usually, one cubic mm of

blood contains 150,000-350,000 platelets. Platelets can release a variety of substances. Most of these substances are involved in blood coagulation.

BLOOD GROUPS

Two such groupings – the ABO and Rh – are widely used all over the world.

ABO Grouping

ABO grouping is based on the presence of absence of two surface antigens on the RBCs, viz. A and B. Antigens are chemicals which can induce immune response. The plasma also contains two natural antibodies. Antibodies are proteins produced in response to antigens.

Importance of Blood Group: During blood transfusion, the donor blood needs to be carefully matched with the blood of a recipient. Transfusion of unmatched blood can lead to severe problems of clumping, i.e. destruction of RBC.

Blood Groups and Donor Compatibility			
Blood Groups	Antigens on RBC	Antibodies in Plasma	Donor's Group
A	A	Anti-B	A, O
B	B	Anti-B	B, O
AB	AB	Nil	AB, O
O	Nil	Anti-A, B	O

The blood group O can be donated to persons with any other blood group and hence, an individual with O group is called universal donor. A person with AB blood group can accept blood from all blood groups and hence, such an individual is called universal recipient.

Rh Grouping

The Rh antigen is similar to one present in Rhesus monkeys. It is also observed on the surface of RBCs of majority (nearly 80%) humans. Such individuals are called Rh positive (Rh +ve). A person without Rh antigen is called Rh negative (Rh –ve).

Significance of Rh Group: An Rh -ve person, if exposed to Rh +ve blood, will form specific antibodies against the Rh antigens. Hence, Rh group should also be matched before transfusions.

Rh Incompatibility of Foetus and Mother: A special case of Rh incompatibility is observed between the Rh –ve blood of a pregnant mother with Rh +ve blood of the foetus. Rh antigens of the foetus do not get exposed to the Rh –ve blood of the mother in the first pregnancy because the two bloods are well separated by the placenta. But during the delivery of the first child, there is a possibility of exposure of the maternal blood to small amounts of Rh +ve blood from the foetus. In such an eventuality, the mother starts preparing antibodies against Rh in her blood. In case of her becoming pregnant again, the Rh antibodies from the mother (Rh –ve) can leak into the blood of the foetus (Rh +ve) and destroy the foetal RBCs. This can prove fatal to the foetus or can cause severe anemia and jaundice to the baby. This condition is called erythroblastosis foetalis. This can be avoided by administering anti-Rh antibodies to the mother immediately after the delivery of the first child.

Coagulation of Blood

Blood coagulates in response to an injury or trauma. Coagulation is a mechanism to prevent excessive loss of blood in case of injury. Clot is a dark reddish brown scum which is formed at the site of an injury over a period of time. This is formed by a network of threads called fibrins in which dead and damaged formed elements of blood are trapped.

Process of Blood Clotting: Inactive fibrinogen is present in the plasma. It is converted by the enzyme thrombin into active fibrin. Thrombin is formed from the inactive prothrombin. An enzyme complex, thrombokinase, is responsible for this conversion. This complex is formed by a series of linked enzymatic reactions (cascade process). The process involves a number of factors present in the plasma in an inactive state. An injury stimulates the platelets to release certain factors which activate the mechanism of coagulation. Calcium ions play a very important role in clotting.

Haemophilia: Haemophilia is a clotting disorder which prevents blood clotting. A person suffering from haemophilia is always at a risk of excessive blood loss in case of injury.

LYMPH (TISSUE FLUID)

When the blood passes through the capillaries in tissues, some water; along with many small water-soluble substances move out into the spaces between the cells. Larger proteins and most of the formed elements are left in the blood vessels. This fluid is called the interstitial fluid or tissue fluid. Exchange of nutrients, gases, etc. between the blood and the cells always occur through this fluid.

There is an elaborate network of vessels called the lymphatic system. The lymphatic system collects this fluid and drains it back to the major veins. The fluid present in the lymphatic system is called lymph.

Lymph is a colourless fluid. It contains specialized lymphocytes. Lymph also carries nutrients, hormones, etc. Fats are absorbed through lymph in the lacteals present in the intestinal villi.

CIRCULATORY PATHWAYS

There are two types of circulatory pathways in the animals, viz. open or closed.

Open Circulatory System:

In open circulatory system, blood pumped by the heart passes through large vessels and drained into open spaces or body cavities; called sinuses. This type of circulatory system is present in arthropods and molluscs.

Closed Circulatory System:

In closed circulatory system blood pumped by the heart is circulated through a closed network of blood vessels. This type of system is present in annelids and chordates. The closed circulatory system is more advantageous because the flow of fluid can be more precisely regulated.

Chambered Heart: A muscular chambered heart is present in all vertebrates. The fishes have a 2-chambered heart; with an atrium and a ventricle. Amphibians and reptiles have a 3-chambered heart; with two atria and one ventricle. But crocodiles have 4-chambered heart. Birds and mammals have 4-chambered heart; with two atria and two ventricles.

Single Circulation: In fishes, the heart pumps out deoxygenated blood to the gills. The oxygenated blood from the gills is supplied to the body parts. Deoxygenated blood is then returned from different body parts to the heart. In single circulation, the blood passes through the heart only once.

Incomplete Double Circulation: In amphibians and reptiles, incomplete double circulation is present. Oxygenated blood is received by the left atrium and deoxygenated blood is received by the right atrium. But, both the bloods get mixed up in the single ventricle which pumps out the mixed blood. In incomplete double circulation, the blood comes to the heart through two different routes, but goes out through a single route.

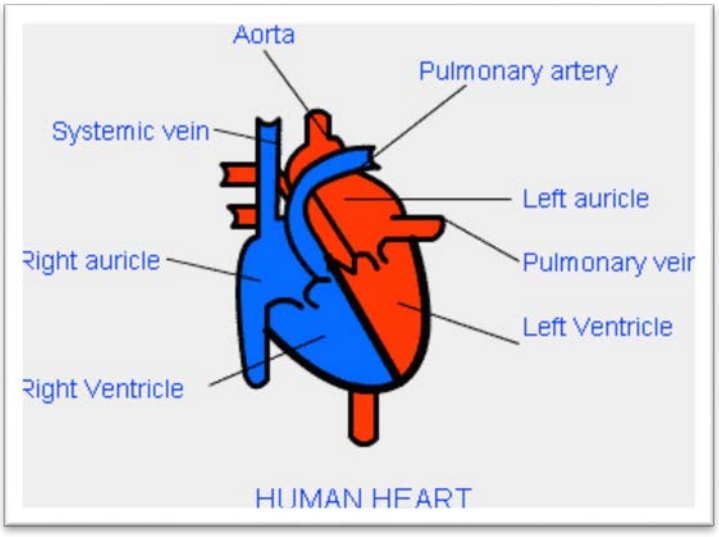
Complete Double Circulation: Complete double circulation is present in birds and mammals. In this case, the oxygenated blood is received by the left atrium and the deoxygenated blood is received by the right atrium. The oxygenated blood is pumped out through the left ventricle, while the deoxygenated blood is pumped out through the right ventricle. In complete double circulation, there are two separate pathways for oxygenated and deoxygenated bloods.

HUMAN CIRCULATORY SYSTEM

The human circulatory system is composed of a muscular heart, a network of closed branching blood vessels and blood.

Heart:

Location and Size: Heart is a mesodermally derived organ. It is situated in the thoracic cavity; in between the two lungs and slightly tilted to the left. It is the size of a clenched fist.



Structure: The heart is protected by a double-walled membrane; called pericardium. The pericardial fluid is filled in this membranous bag.

There are four chambers in the human heart:

a. The two upper chambers are called atria and are relatively smaller.
b. The two lower chambers are called ventricles and are relatively larger.

A thin, muscular wall separates the right and the left atria and is called the inter-atrial septum. A thick muscular wall separates the left and the right ventricles and is called the inter-ventricular septum. The atrium and ventricle on the same side are separate by a thick fibrous tissue; called the atrio-ventricular septum. Each of these septa has an opening through which the atrium and the ventricle of the same side are connected.

The opening between the right atrium and the right ventricle is guarded by a valve. This valve has three flaps or cusps and hence is called the tricuspid valve. Similarly, a bicuspid or mitral valve guards the opening between the left atrium and the left ventricle.

The openings of the right and the left ventricles into the pulmonary artery and the aorta; respectively; are provided with the semi-lunar valves. These valves allow the flow of blood in only one direction and prevent any backward flow.

Conduction of Heart Beat:

The heart is made of cardiac muscles. The walls of the ventricles are much thicker than the walls of the atria. A specialized cardiac musculature; called the nodal tissue is also distributed in the heart. The detail of these nodal tissues is as follows:

SA Node: The Sino-Atrial Node (SA Node) is present in the right upper corner of the right atrium.

AV Node: The atrio-ventricular node is present in the lower left corner of the right atrium; close to the atrio-ventricular septum.

Bundle of His: A bundle of nodal fibres; called atrio-ventricular bundle (AV Bundle); continues from the AVN and passes through the atrio-ventricular septa to emerge on the top of the inter-ventricular septum. Then, this bundle divides into a right and left bundle. These branches give rise to minute fibres throughout the ventricular musculature of the respective sides and are called Purkinje fibres. These fibres; along with right and left bundles; are known as Bundle of His.

Generation of Heart Beat: The nodal musculature is autoexcitable, which means it has the ability to generate action potentials without any external stimuli. The number of action potentials which could be generated per minute varies at different parts of the nodal system. The SA Node can generate the maximum number of action potentials, i.e. 70-75 per minute. The SA Node is responsible for initiating and maintaining the rhythmic contractile activity or beating of the heart. Due to this, the SA Node is called the pacemaker. The human heart normally beats 70-75 times per minute.

Cardiac Cycle

The sequential contraction and dilatation of different chambers of heart in a cyclical manner is called cardiac cycle. A cardiac cycle happens in following steps:

- All the four chambers of heart are in a relaxed state; to begin with. When the tricuspid and bicuspid valves are open, blood from the pulmonary veins and the vena cava flows into the left and the right ventricles respectively through the left and right atria. At this stage, the semilunar valves are closed.
- Now, the SA Node generates and action potential which stimulates both the atria to undergo a simultaneous contraction; the atrial systole. This increases the blood flow into the ventricles by about 30%.

- The action potential is conducted to ventricular side by the AV Node and AV bundle from where the Bundle of His transmits it through the entire ventricular musculature. This results in ventricular systole coinciding with the atrial diastole.
- Ventricular systole increases the ventricular pressure causing the closure of tricuspid and bicuspid valves due to the attempted backflow of blood into the auricles. With further increase in the ventricular pressure, the semilunar valves are forced open. Opening of the semilunar valves allows the blood from ventricles into the pulmonary artery (right side) and into the aorta (left side).
- Now the ventricles relax and the resultant fall in ventricular pressure causes the closure of semi-lunar valves. Closure of semi-lunar valves prevents the backflow of blood into the ventricles. With further reduction in ventricular pressure, the tricuspid and bicuspid valves are pushed open by the pressure in the atria exerted by the blood coming to atria.
- The whole cycle is repeated.

Stroke Volume: The volume of blood pumped by the heart in one cardiac cycle is called stroke volume. This is about 70 ml.

Cardiac Output: The volume of blood pumped by the heart in one minute is called the cardiac output. The average cardiac output is 5000 ml or 5 litre per minute.

Lub and Dub Sounds: Two prominent sounds are produced during each cardiac cycle. These sounds can be easily heard through a stethoscope. The first sound is called lub and is associated with the closure of the tricuspid and bicuspid valves. The second sound is called dub and is associated with the closure of the semi-lunar valves. These sounds are important for clinical diagnosis.

Electrocardiograph (ECG)

The graphical representation of the electrical activity of the heart during a cardiac cycle is called ECG. For obtaining an ECG, a patient is usually connected to the machine with three electrical leads; one to each wrist and to the left ankle. These leads continuously monitor the activity of heart.

Each peak in the ECG is identified with a letter from P to T (PQSRT) which corresponds to a specific electrical activity of the heart.

- The P-wave represents the electrical excitation or depolarization of the atria. Depolarisation of atria leads to atricular systole.
- The QRS complex represents the depolarization of the ventricles which initiates ventricular systole.
- The T-wave represents the return of the ventricles from excited to normal state (repolarisation). The end of T-wave marks the end of systole.

Any deviation in the normal POQRST pattern of ECG indicates towards possible heart ailment.

DOUBLE CIRCULATION

Pulmonary Circulation: The blood flow to and from the lungs is called pulmonary circulation. Deoxygenated blood goes to the lungs for oxygenation and then oxygenated blood comes back to the heart. Pulmonary circulation takes place through pulmonary artery and pulmonary vein.

Systemic Circulation: The oxygenated blood is pumped to different parts of the body through the aorta and various arteries. Deoxygenated blood is collected by veins and finally reaches the right auricle through vena cava. Thus, the arterial and venous blood supply comprises the systemic circulation.

Hepatic Portal Circulation: The hepatic portal system is a unique vascular connection which exists between the digestive tract and liver. Blood from the intestine is first sent to the liver through hepatic portal system and then to the systemic circulation.

Coronary Circulation: There is a special system of blood vessels which provide blood circulation exclusively to the cardiac muscles. This is called coronary circulation.

REGULATION OF CARDIAC ACTIVITY

Normal activities of the heart are intrinsically regulated, i.e. auto regulated by the nodal tissues. Due to this, the heart is called myogenic.

There is a special neural centre in the medulla which can moderate the cardiac function through autonomic nervous system (ANS). The sympathetic nervous system can increase the heart rate, can increase the strength of ventricular contraction and thus the cardiac output. On the other hand, the parasympathetic nervous system decreases the heart rate, and thus the cardiac output. Adrenal medullary hormone can also increase the cardiac output.

DISORDERS OF CIRCULATORY SYSTEM

High Blood Pressure (Hypertension): The normal blood pressure in human beings is 120/80 mm Hg. If the blood pressure is more than this range, this condition is called hypertension. If the blood pressure comes in the range of 140/90 mm Hg on repeated checks, then the person is diagnosed with hypertension. The higher value, i.e. 120 mm Hg shows the systolic blood pressure, while the lower value shows the diastolic blood pressure. Hypertension finally progresses into heart diseases and also affects vital organs; like brain and kidney.

Blood Pressure: The resistance offered by the lumen of the artery to the flow of blood is called blood pressure.

Coronary Artery Disease (CAD): Deposition of fat, cholesterol, calcium and fibrous tissues makes the lumen of the coronary artery narrower. This leads to coronary artery disease. This is also known as atherosclerosis. There is reduced blood supply to the cardiac muscles in this condition.

Angina: This is usually called angina pectoris; which means a pain in the chest region. Angina pectoris is a symptom of underlying heart disease. This happens because of mismatch in demand and supply of oxygen to the cardiac muscles.

Myocardial Infarction: This is commonly known as heart failure. When oxygen supply is obstructed to a part of the cardiac muscle for a prolonged period of a few minutes, it leads to cell death in that part. This is called myocardial ischemia and is accompanied by sudden stoppage of the beating of heart. The stoppage of the beating of heart is called heart attack or myocardial infarction.

NCERT Solution

Question 1. Name the components of the formed elements in the blood and mention one major function of each of them.

Answer:

Formed Elements in blood	Function
Erythrocytes (RBCs)	Transport of respiratory gases.
Leucocytes (WBCs)	• Neutrophils and monocytes are phagocytic cells and they destroy foreign materials. • Basophils are involved in inflammatory reactions. • Eosinophils resist infections and are also involved in allergic reactions. • Lymphocytes are responsible for immune response.
Platelets	Coagulation of blood

Question 2. What is the importance of plasma proteins?

Answer: The major plasma proteins are; fibrinogen, globulins and albumins. Fibrinogen play important role in blood coagulation. Globulins are mainly involved in defense mechanism and albumins help in osmotic balance.

Question 3. Match Column I with Column II:

Column I	Column II
(a) Eosinophils	(1) Coagulation
(b) RBC	(2) Universal recipient
(c) AB group	(3) Resist infections
(d) Platelets	(4) Contraction of heart
(e) Systole	(5) Gas transport

Answer: (a) → 3, (b) → 5, (c) → 2, (d) → 1, (e) → 4

Question 4. Why do we consider blood as a connective tissue?

Answer: Blood is mesodermally derived; as other connective tissues. Blood serves the purpose of connecting the body systems; by transporting substances. Moreover, blood too has a matric; like other connective tissues. Hence, blood is considered as a connective tissue.

Question 5. What is the difference between lymph and blood?

Answer:

Lymph	Blood
Lymph is interstitial fluid.	Blood flows through closed vessels.
WBCs are present.	WBCs and RBCs are present.
Lymph is colourless.	Blood is red.

Question 6. What is meant by double circulation? What is its significance?

Answer: Complete double circulation is present in birds and mammals. In this case, the oxygenated blood is received by the left atrium and the deoxygenated blood is received by the right atrium. The oxygenated blood is pumped out through the left ventricle, while the deoxygenated blood is pumped out through the right ventricle. In complete double circulation, there are two separate pathways for oxygenated and deoxygenated bloods. There is complete separation of oxygenated and deoxygenated blood in case of complete double circulation. This provides better efficiency to the organism in terms of energy generation.

Question 7. Write the differences between:

(a) Open and Closed system of circulation

Answer: The organs are directly bathed in blood in case of open circulatory system. In case of closed circulatory system, the blood is channelized through closed vessels.

(c) Systole and Diastole

Answer: Contraction of heart muscles is called systole, while dilatation is called diastole.

(d) P-wave and T-wave

Answer: P-wave marks the depolarization of atria, while T-wave marks the return of ventricles to repolarised state.

Question 8. Describe the evolutionary change in the pattern of heart among the vertebrates.

Answer: A muscular chambered heart is present in all vertebrates. The fishes have a 2-chambered heart; with an atrium and a ventricle. Amphibians and reptiles have a 3-chambered heart; with two atria and one ventricle. But crocodiles have 4-chambered heart. Birds and mammals have 4-chambered heart; with two atria and two ventricles.

Question 9. Why do we call our heart myogenic?

Answer: Normal activities of the heart are intrinsically regulated, i.e. auto regulated by the nodal tissues. Due to this, the heart is called myogenic.

Question 10. Sino-atrial node is called the pacemaker of our heart. Why?

Answer: The SA Node is responsible for initiating and maintaining the rhythmic contractile activity or beating of the heart. Due to this, the SA Node is called the pacemaker.

Question 11. What is the significance of atrio-ventricular node and atrio-ventricular bundle in the functioning of heart?

Answer: AV Node and AV Bundles are responsible for conduction of heart beat to different parts of the heart after initiation in the SA node.

Question 12. Define a cardiac cycle and the cardiac output.

Answer: Cardiac Cycle: The sequential contraction and dilatation of different chambers of heart in a cyclical manner is called cardiac cycle.

Cardiac Output: The volume of blood pumped by the heart in one minute is called the cardiac output. The average cardiac output is 5000 ml or 5 litre per minute.

Question 13. Explain heart sounds.

Answer: Lub and Dub Sounds: Two prominent sounds are produced during each cardiac cycle. These sounds can be easily heard through a stethoscope. The first sound is called lub and is associated with the closure of the tricuspid and bicuspid valves. The second sound is called dub and is associated with the closure of the semi-lunar valves. These sounds are important for clinical diagnosis.

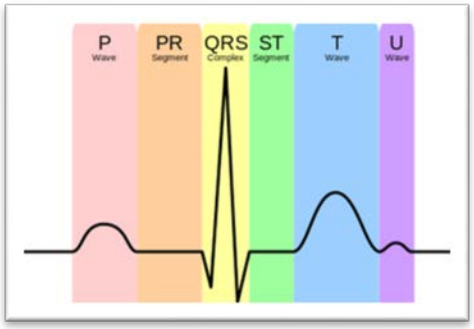
Question 14. Draw a standard ECG and explain the different segments in it.

Answer: Each peak in the ECG is identified with a letter from P to T (PQSRT) which corresponds to a specific electrical activity of the heart.

The P-wave represents the electrical excitation or depolarization of the atria. Depolarisation of atria leads to atricular systole.

The QRS complex represents the depolarization of the ventricles which initiates ventricular systole.

The T-wave represents the return of the ventricles from excited to normal state (repolarisation). The end of T-wave marks the end of systole.



19. Excretory Products and their Elimination

Animals accumulate ammonia, urea, uric acid, carbon dioxide, water and ions like Na^+, K^+, Cl^-, phosphate, sulphate, etc., either by metabolic activities or by other means like excess ingestion. These substances have to be removed totally or partially. The process of removal of these harmful substances is called excretion.

Ammonotelism: Ammonia is the most toxic form and requires large amount of water for its elimination. The process of excreting ammonia is Ammonotelism. Many bony fishes, aquatic amphibians and aquatic insects are ammonotelic in nature. Ammonia, as it is readily soluble, is generally excreted by diffusion across body surfaces or through gill surfaces (in fish) as ammonium ions. Kidneys do not play any significant role in its removal.

Ureotelic: Terrestrial adaptation necessitated the production of lesser toxic nitrogenous wastes like urea nd uric acid for onservation of water. Mammals, many terrestrial mphibians and marine fishes mainly xcrete urea and are called ureotelic animals. Ammonia produced by metabolism is converted into urea in the liver of these animals and released into the blood which is filtered an excreted out by the kidneys. Some amount of urea may be retained in the kidney matrix of some of these animals to maintain a desired osmolarity.

Uricotelic: Reptiles, birds, land snails and insects excrete nitrogenous wastes as uric acid in the form of pellet or paste with a minimum loss of water and are called uricotelic animals.

Different Types of Excretory Organs in Animals:

• **Protonephridia** or flame cells are the excretory structures in Platyhelminthes (Flatworms, e.g., Planaria), rotifers, some annelids and the cephalochordate – Amphioxus. Protonephridia are primarily concerned with ionic and fluid volume regulation, i.e., osmoregulation.

• **Nephridia** are the tubular excretory structures of earthworms and other annelids. Nephridia help to remove nitrogenous wastes and maintain a fluid and ionic balance.

• **Malpighian tubules** are the excretory structures of most of the insects including cockroaches. Malpighian tubules help in the removal of nitrogenous wastes and osmoregulation.

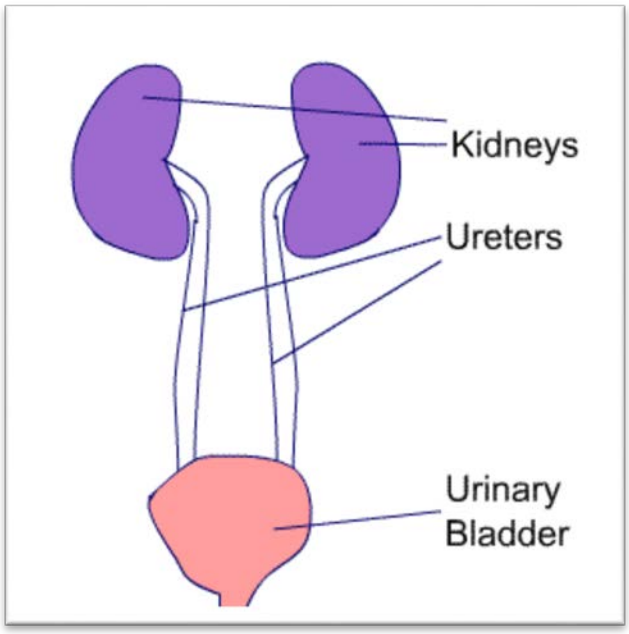
• **Antennal glands** or green glands perform the excretory function in crustaceans like prawns.

HUMAN EXCRETORY SYSTEM

In humans, the excretory system consists of a pair of kidneys, one pair of ureters, a urinary bladder and a urethra .

Kidneys:

Shape & Size: Kidneys are reddish brown, bean shaped structures situated between the levels of last thoracic and third lumbar vertebra close to the dorsal inner wall of the abdominal cavity. Each kidney of an adult human measures 10-12 cm in length, 5-7 cm in width, 2-3 cm in thickness with an average weight of 120- 170 g.



Structure: Towards the centre of the inner concave surface of the kidney is a notch called hilum through which ureter, blood vessels and nerves enter.

Inner Structure: Inner to the hilum is a broad funnel shaped space called the renal pelvis with projections called calyces. The outer layer of kidney is a tough capsule. Inside the kidney, there are two zones, an outer cortex and an inner medulla. The medulla is divided into a few conical masses (medullary pyramids) projecting into the calyces (sing.: calyx). The cortex extends in between the medullary pyramids as renal columns called Columns of Bertini.

Nephrons: Each kidney has nearly one million complex tubular structures called nephrons, which are the functional units. Each nephron has two parts – the glomerulus and the renal tubule.

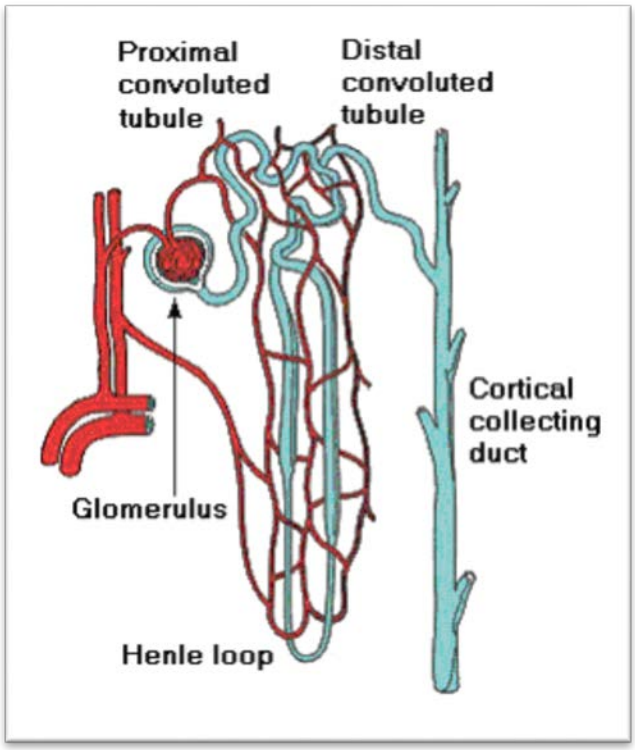
Glomerulus: Glomerulus is a tuft of capillaries formed by the afferent arteriole – a fine branch of renal artery. Blood from the glomerulus is carried away by an efferent arteriole. The renal tubule begins with a double walled cup-like structure called Bowman's capsule, which encloses the glomerulus. Glomerulus alongwith Bowman's capsule, is called the malpighian body or renal corpuscle.

Tubules: The tubule continues further to form a highly coiled network – proximal convoluted tubule (PCT). A hairpin shaped Henle's loop is the next part of the tubule which has a descending and an ascending limb. The ascending limb continues as another highly coiled tubular region called distal convoluted tubule (DCT). The DCTs of many nephrons open into a straight tube called collecting duct, many of which converge and open into the renal pelvis through medullary pyramids in the calyces. The Malpighian corpuscle, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle dips into the medulla.

Cortical Nephrons: In majority of nephrons, the loop of Henle is too short and extends only very little into the medulla. Such nephrons are called cortical nephrons.

Medullary Nephrons: In some of the nephrons, the loop of Henle is very long and runs deep into the medulla. These nephrons are called juxta medullary nephrons.

Vasa Recta: The efferent arteriole emerging from the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries. A minute vessel of this network runs parallel to the Henle's loop forming a 'U' shaped vasa recta. Vasa recta is absent or highly reduced in cortical nephrons.



URINE FORMATION

Urine formation involves three main processes namely:

1. Glomerular Filtration,

2. Reabsorption and

3. Secretion.

Glomerular Filtration: The glomerular capillary blood pressure causes filtration of blood through 3 layers, i.e., the endothelium of glomerular blood vessels, the epithelium of Bowman's capsule and a basement membrane between these two layers. The epithelial cells of Bowman's capsule called podocytes are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores. The diameter of efferent arteriole (arteriole bringing blood out of the glomerulus) is less than the diameter of afferent arteriole (arteriole taking blood inside the glomerulus). This difference in diameters creates a pressure which facilitates the filtration. Blood is filtered so finely through these membranes, that almost all the constituents of the plasma, except the proteins pass onto the lumen of the Bowman's capsule. Therefore, it is considered as a process of ultra filtration.

Glomerular Filtration Rate (GFR): The amount of the filtrate formed by the kidneys per minute is called glomerular filtration rate (GFR). GFR in a healthy individual is approximately 125 ml/minute, i.e.,

180 litres per day. On an average, 1100-1200 ml of blood is filtered by the kidneys per minute which constitute roughly 1/5th of the blood pumped out by each ventricle of the heart in a minute.

Regulation of GFR: The kidneys have built-in mechanisms for the regulation of glomerular filtration rate. One such efficient mechanism is carried out by juxta glomerular apparatus (JGA). JGA is a special sensitive region formed by cellular modifications in the distal convoluted tubule and the afferent arteriole at the location of their contact. A fall in GFR can activate the JG cells to release renin which can stimulate the glomerular blood flow and thereby the GFR back to normal.

Reabsorption: A comparison of the volume of the filtrate formed per day (180 litres per day) with that of the urine released (1.5 litres), suggest that nearly 99 per cent of the filtrate has to be reabsorbed by the renal tubules. This process is called reabsorption. The tubular epithelial cells in different segments of nephron perform this either by active or passive mechanisms. For example, substances like glucose, amino acids, Na^+, etc., in the filtrate are reabsorbed actively whereas the nitrogenous wastes are absorbed by passive transport. Reabsorption of water also occurs passively in the initial segments of the nephron . During urine formation, the tubular cells secrete substances like H^+, K^+ and ammonia into the filtrate. Tubular secretion is also an important step in urine formation as it helps in the maintenance of ionic and acid base balance of body fluids.

FUNCTION OF THE TUBULES

Proximal Convoluted Tubule (PCT): PCT is lined by simple cuboidal brush border epithelium which increases the surface area for reabsorption. Nearly all of the essential nutrients, and 70-80 per cent of electrolytes and water are reabsorbed by this segment. PCT also helps to maintain the pH and ionic balance of the body fluids by selective secretion of hydrogen ions, ammonia and potassium ions into the filtrate and by absorption of HCO_3^- from it.

Henle's Loop: Reabsorption in this segment is minimum. However, this region plays a significant role in the maintenance of high osmolarity of medullary interstitial fluid. The descending limb of loop of Henle is permeable to water but almost impermeable to electrolytes. This concentrates the filtrate as it moves down. The ascending limb is impermeable to water but allows transport of electrolytes actively or passively. Therefore, as the concentrated filtrate pass upward, it gets diluted due to the passage of electrolytes to the medullary fluid.

Distal Convoluted Tubule (DCT): Conditional reabsorption of Na+ and water takes place in this segment. DCT is also capable of reabsorption of HCO and selective secretion of hydrogen and potassium ions and NH_3 to maintain the pH and sodium potassium balance in blood.

Collecting Duct: This long duct extends from the cortex of the kidney to the inner parts of the medulla. Large amounts of water could be reabsorbed from this region to produce concentrated urine. This segment allows passage of small amounts of urea into the medullary interstitium to keep up the osmolarity. It also plays a role in the maintenance of pH and ionic balance of blood by the selective secretion of H^+ and K^+ions

MECHANISM OF CONCENTRATION OF THE FILTRATE

The Henle's loop and vasa recta play a significant role in this. The flow of filtrate in the two limbs of Henle's loop is in opposite directions and thus forms a counter current. The flow of blood through the two limbs of vasa recta is also in a counter current pattern. The proximity between the Henle's loop and vasa recta, as well as the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitium, i.e., from 300 $mOsmolL^{-1}$ in the cortex to about 1200 $mOsmolL^{-1}$ in the

inner medulla. This gradient is mainly caused by NaCl and urea. NaCl is transported by the ascending limb of Henle's loop which is exchanged with the descending limb of vasa recta. NaCl is returned to the interstitium by the ascending portion of vasa recta.

Similarly, small amounts of urea enter the thin segment of the ascending limb of Henle's loop which is transported back to the interstitium by the collecting tubule.

The above described transport of substances facilitated by the special arrangement of Henle's loop and vasa recta is called the counter current mechanism. This mechanism helps to maintain a concentration gradient in the medullary interstitium. Presence of such interstitial gradient helps in an easy passage of water from the collecting tubule thereby concentrating the filtrate (urine). Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

REGULATION OF KIDNEY FUNCTION

The functioning of the kidneys is efficiently monitored and regulated by hormonal feedback mechanisms involving the hypothalamus, JGA and to a certain extent, the heart.

• Osmoreceptors in the body are activated by changes in blood volume, body fluid volume and ionic concentration. An excessive loss of fluid from the body can activate these receptors which stimulate the hypothalamus to release antidiuretic hormone (ADH) or vasopressin from the neurohypophysis. ADH facilitates water reabsorption from latter parts of the tubule, thereby preventing diuresis.

• An increase in body fluid volum can switch off the osmoreceptors and suppress the ADH release to complete the feedback. ADH can also affect the kidney function by its constrictory effects on blood vessels. This causes an increase in blood pressure. An increase in blood pressure can increase the glomerular blood flow and thereby the GFR.

• The JGA plays a complex regulatory role. A fall in glomerular blood flow/glomerular blood pressure/GFR can activate the JG cells to release renin which converts angiotensinogen in blood to angiotensin I and further to angiotensin II. Angiotensin II, being a powerful vasoconstrictor, increases the glomerular blood pressure and thereby GFR. Angiotensin II also activates the adrenal cortex to release Aldosterone. Aldosterone causes reabsorption of Na+ and water from the distal parts of the tubule. This also leads to an increase in blood pressure and GFR. This complex mechanism is generally known as the Renin-Angiotensin mechanism.

• An increase in blood flow to the atria of the heart can cause the release of **Atrial Natriuretic Factor** (ANF). ANF can cause vasodilation (dilation of blood vessels) and thereby decrease the blood pressure. ANF mechanism, therefore, acts as a check on the rennin angiotensin mechanism.

MICTURITION

Urine formed by the nephrons is ultimately carried to the urinary bladder where it is stored till a voluntary signal is given by the central nervous system (CNS). This signal is initiated by the stretching of the urinary bladder as it gets filled with urine. In response, the stretch receptors on the walls of the bladder send signals to the CNS. The CNS passes on motor messages to initiate the contraction of smooth muscles of the bladder and simultaneous relaxation of the urethral sphincter causing the release of urine. The process of release of urine is called micturition and the neural mechanisms causing it is called the micturition reflex.

An adult human excretes, on an average, 1 to 1.5 litres of urine per day. The urine formed is a light yellow coloured watery fluid which is slightly acidic (pH-6.0) and has a characteristic odour. On an average, 25-30 gm of urea is excreted out per day. Various conditions can affect the characteristics of urine. Analysis of urine helps in clinical diagnosis of many metabolic discorders as well as malfunctioning of the kidney. For example, presence of glucose (Glycosuria) and ketone bodies (Ketonuria) in urine are indicative of diabetes mellitus.

ROLE OF OTHER ORGANS IN EXCRETION

Lungs: Lungs remove large amounts of CO_2 (18 litres/day) and also significant quantities of water every day.

Liver: Liver, the largest gland in our body, secretes bile containing substances like bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs. Most of these substances ultimately pass out alongwith digestive wastes.

Skin: The sweat and sebaceous glands in the skin can eliminate certain substances through their secretions. Sweat produced by the sweat glands is a watery fluid containing NaCl, small amounts of urea, lactic acid, etc. Though the primary function of sweat is to facilitate a cooling effect on the body surface, it also helps in the removal of some of the wastes mentioned above. Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum. This secretion provides a protective oily covering for the skin.

DISORDERS OF THE EXCRETORY SYSTEM

Kidney Failure: Malfunctioning of kidneys can lead to accumulation of urea in blood, a condition called uremia, which is highly harmful and may lead to kidney failure. In such patients, urea can be removed by a process called hemodialysis. Blood drained from a convenient artery is pumped into a dialysing unit after adding an anticoagulant like heparin. The unit contains a coiled cellophane tube surrounded by a fluid (dialyzing fluid) having the same composition as that of plasma except the nitrogenous wastes. The porous cellophane membrance of the tube allows the passage of molecules based on concentration gradient. As nitrogenous wastes are absent in the dialysis fluid , these substances freely move out, thereby clearing the blood. The blood is pumped back to the body through a vein after adding anti-heparin to it.

Renal Calculi: Stone or insoluble mass of crystallized salts (oxalates, etc.) formed within the kidney. These produce severe pain if they result in obstruction of urethra. Smaller sized calculi or stones are expelled by the body, while larger ones require surgical procedure to be expelled.

NCERT Solution

Question 1. Define Glomerular Filtration Rate (GFR)

Answer: Glomerular Filtration Rate (GFR): The amount of the filtrate formed by the kidneys per minute is called glomerular filtration rate (GFR). GFR in a healthy individual is approximately 125 ml/minute, i.e., 180 litres per day. On an average, 1100-1200 ml of blood is filtered by the kidneys per minute which constitute roughly 1/5th of the blood pumped out by each ventricle of the heart in a minute.

Question 2. Explain the autoregulatory mechanism of GFR.

Answer: Regulation of GFR: The kidneys have built-in mechanisms for the regulation of glomerular filtration rate. One such efficient mechanism is carried out by juxta glomerular apparatus (JGA). JGA is a special sensitive region formed by cellular modifications in the distal convoluted tubule and the afferent arteriole at the location of their contact. A fall in GFR can activate the JG cells to release renin which can stimulate the glomerular blood flow and thereby the GFR back to normal.

Question 3. Indicate whether the following statements are true or false:

(a) Micturition is carried out by a reflex.

TRUE

(b) ADH helps in water elimination, making the urine hypotonic.

FALSE

(c) Protein-free fluid is filtered from blood plasma into the Bowman's capsule.

TRUE

(d) Henle's loop plays an important role in concentrating the urine.

TRUE

(e) Glucose is actively reabsorbed in the proximal convoluted tubule.

TRUE

Question 4. Give a brief account of the counter current mechanism.

Answer: Counter Current Mechanism

The Henle's loop and vasa recta play a significant role in this. The flow of filtrate in the two limbs of Henle's loop is in opposite directions and thus forms a counter current. The flow of blood through the two limbs of vasa recta is also in a counter current pattern. The proximity between the Henle's loop and vasa recta, as well as the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitium, i.e., from 300 $mOsmolL^{-1}$ in the cortex to about 1200 $mOsmolL^{-1}$ in the inner medulla. This gradient is mainly caused by NaCl and urea. NaCl is transported by the ascending limb of Henle's loop which is exchanged with the descending limb of vasa recta. NaCl is returned to the interstitium by the ascending portion of vasa recta.

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Question 5. Describe the role of liver, lungs and skin in excretion.

Answer: ROLE OF OTHER ORGANS IN EXCRETION

Lungs: Lungs remove large amounts of CO_2 (18 litres/day) and also significant quantities of water every day.

Liver: Liver, the largest gland in our body, secretes bile containing substances like bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs. Most of these substances ultimately pass out alongwith digestive wastes.

Skin: The sweat and sebaceous glands in the skin can eliminate certain substances through their secretions. Sweat produced by the sweat glands is a watery fluid containing NaCl, small amounts of urea, lactic acid, etc. Though the primary function of sweat is to facilitate a cooling effect on the body surface, it also helps in the removal of some of the wastes mentioned above. Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum. This secretion provides a protective oily covering for the skin.

Question 6. Explain micturition.

Answer: Micturition: Urine formed by the nephrons is ultimately carried to the urinary bladder where it is stored till a voluntary signal is given by the central nervous system (CNS). This signal is initiated by the stretching of the urinary bladder as it gets filled with urine. In response, the stretch receptors on the walls of the bladder send signals to the CNS. The CNS passes on motor messages to initiate the contraction of smooth muscles of the bladder and simultaneous relaxation of the urethral sphincter causing the release of urine. The process of release of urine is called micturition and the neural mechanisms causing it is called the micturition reflex.

7. Match the items of column I with those of column II:

Column I	**Column II**
(a) Ammonotelism	**(i) Birds**
(b) Bowman's capsule	**(ii) Water reabsorption**
(c) Micturition	**(iii) Bony fish**
(d) Uricotelism	**(iv) Urinary bladder**
(e) ADH	**(v) Renal tubule**

Answer:

(a) Ammonotelism	(iii) Bony Fish
(b) Bowman's Capsule	(v) Renal Tubule
(c) Micturition	(iv) Urinary Bladder

(d) Uricotelism (i) Birds

(e) ADH (ii) Water Reabsorption

Question 8. What is meant by the term osmoregulation?

Answer: Osmoregulation is the regulation of blood volume, body fluid volume and ionic concentration. Following is the method of osmoregulation:

• Osmoreceptors in the body are activated by changes in blood volume, body fluid volume and ionic concentration. An excessive loss of fluid from the body can activate these receptors which stimulate the hypothalamus to release antidiuretic hormone (ADH) or vasopressin from the neurohypophysis. ADH facilitates water reabsorption from latter parts of the tubule, thereby preventing diuresis.

• An increase in body fluid volum can switch off the osmoreceptors and suppress the ADH release to complete the feedback. ADH can also affect the kidney function by its constrictory effects on blood vessels. This causes an increase in blood pressure. An increase in blood pressure can increase the glomerular blood flow and thereby the GFR.

Question 9. Terrestrial animals are generally either ureotelic or uricotelic, not ammonotelic, why ?

Answer: The process of excreting ammonia is Ammonotelism. Many bony fishes, aquatic amphibians and aquatic insects are ammonotelic in nature. Ammonia, as it is readily soluble, is generally excreted by diffusion across body surfaces or through gill surfaces (in fish) as ammonium ions. Kidneys do not play any significant role in its removal.

Terrestrial adaptation necessitated the production of lesser toxic nitrogenous wastes like urea and uric acid for conservation of water. Mammals, many terrestrial amphibians and marine fishes mainly excrete urea and are called ureotelic animals. Ammonia produced by metabolism is converted into urea in the liver of these animals and released into the blood which is filtered and excreted out by the kidneys. Some amount of urea may be retained in the kidney matrix of some of these animals to maintain a desired osmolarity. Reptiles, birds, land snails and insects excrete nitrogenous wastes as uric acid in the form of pellet or paste with a minimum loss of water and are called uricotelic animals.

Question 10. What is the significance of juxta glomerular apparatus (JGA) in kidney function?

Answer: Significance of Juxta Glomerular Apparaus (JGA):

The JGA plays a complex regulatory role. A fall in glomerular blood flow/glomerular blood pressure/GFR can activate the JG cells to release renin which converts angiotensinogen in blood to angiotensin I and further to angiotensin II. Angiotensin II, being a powerful vasoconstrictor, increases the glomerular blood pressure and thereby GFR. Angiotensin II also activates the adrenal cortex to release Aldosterone. Aldosterone causes reabsorption of Na+ and water from the distal parts of the tubule. This also leads to an increase in blood pressure and GFR. This complex mechanism is generally known as the Renin-Angiotensin mechanism.

11. Name the following:

(a) A chordate animal having flame cells as excretory structures

CEPHALOCHORDATA

(b) Cortical portions projecting between the medullary pyramids in the human kidney

COLUMNS OF BERTINI

(c) A loop of capillary running parallel to the Henle's loop.

VASA RECTA

Question 12. Fill in the gaps:

(a) Ascending limb of Henle's loop is **impermeable** to water whereas the descending limb is **permeable** to it.

(b) Reabsorption of water from distal parts of the tubules is facilitated by hormone**ADH.**

(c) Dialysis fluid contain all the constituents as in plasma except the **nitrogenous waste.**

(d) A healthy adult human excretes (on an average) **25 to 30** gm of urea/day.

20. Locomotion and Movement

TYPES OF MOVEMENT

Cells of the human body exhibit three main types of movements, namely, amoeboid, ciliary and muscular.

Amoeboid Movement:- Some specialised cells in our body like macrophages and leucocytes in blood exhibit amoeboid movement. It is effected by pseudopodia formed by the streaming of protoplasm (as in Amoeba). Cytoskeletal elements like microfilaments are also involved in amoeboid movement.

Ciliary Movement: Ciliary movement occurs in most of our internal tubular organs which are lined by ciliated epithelium. The coordinated movements of cilia in the trachea help us in removing dust particles and some of the foreign substances inhaled alongwith the atmospheric air. Passage of ova through the female reproductive tract is also facilitated by the ciliary movement.

Muscular Movement:- Movement of our limbs, jaws, tongue, etc, require muscular movement. The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms. Locomotion requires a perfect coordinated activity of muscular, skeletal and neural systems.

MUSCLE

Muscle is a specialised tissue of mesodermal origin. About 40-50 per cent of the body weight of a human adult is contributed by muscles. They have special properties like excitability, contractility, extensibility and elasticity. Muscles have been classified using different criteria, namely location, appearance and nature of regulation of their activities. Based on their location, three types of muscles are identified:

(i) Skeletal

(ii) Visceral

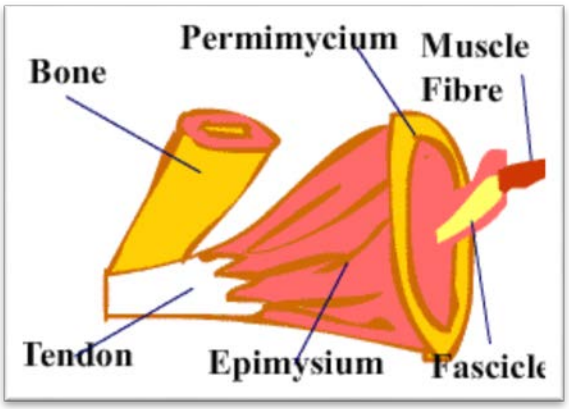
(iii) Cardiac.

Skeletal Muscles:- Skeletal muscles are closely associated with the skeletal components of the body. They have a striped appearance under the microscope and hence are called striated muscles. As their activities are under the voluntary control of the nervous system, they are known as voluntary muscles too. They are primarily involved in locomotory actions and changes of body postures.

Visceral Muscles: Visceral muscles are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc. They do not exhibit any striation and are smooth in appearance. Hence, they are called smooth muscles (nonstriated muscle). Their activities are not under the voluntary control of the nervous system and are therefore known as involuntary muscles. They assist, for example, in the transportation of food through the digestive tract and gametes through the genital tract.

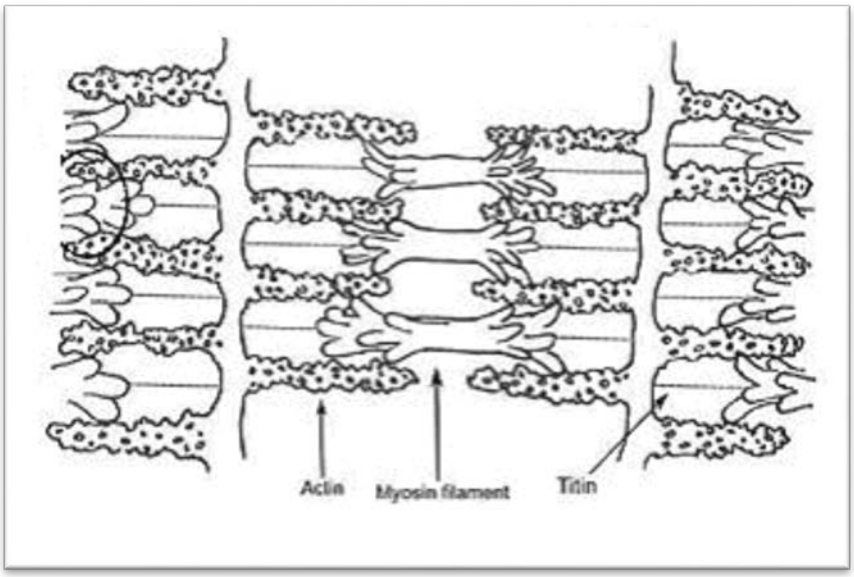
Cardiac Muscles: As the name suggests, Cardiac muscles are the muscles of heart. Many cardiac muscle cells assemble in a branching pattern to form a cardiac muscle. Based on appearance, cardiac muscles are striated. They are involuntary in nature as the nervous system does not control their activities directly.

Structure of Skeletal Muscle:



Each organised skeletal muscle is made of a number of muscle bundles or fascicles held together by a common collagenous connective tissue layer called fascia. Each muscle bundle contains a number of muscle fibres.

Each muscle fibre is lined by the plasma membrane called sarcolemma enclosing the sarcoplasm. Muscle fibre is a syncitium as the sarcoplasm contains many nuclei. The endoplasmic reticulum, i.e., sarcoplasmic reticulum of the muscle fibres is the store house of calcium ions. A characteristic feature of the muscle fibre is the presence of a large number of parallelly arranged filaments in the sarcoplasm called myofilaments or myofibrils. Each myofibril has alternate dark and light bands on it. A detailed study of the myofibril has established that the striated appearance is due to the distribution pattern of two important proteins – Actin and Myosin. The light bands contain actin and is called I-band or Isotropic band, whereas the dark band called ‘A’ or Anisotropic band contains myosin. Both the proteins are arranged as rod-like structures, parallel to each other and also to the longitudinal axis of the myofibrils.



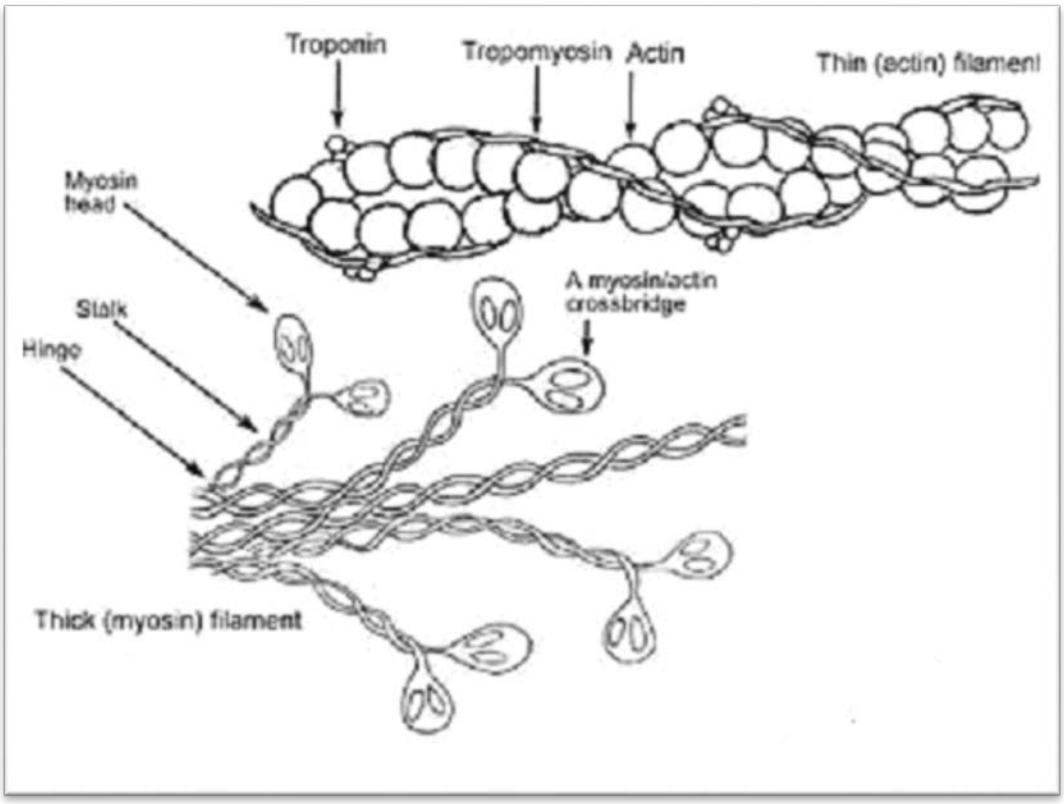
Actin filaments are thinner as compared to the myosin filaments, hence are commonly called thin and thick filaments respectively. In the centre of each ‘I’ band is an elastic fibre called ‘Z’ line which bisects it. The thin filaments are firmly attached to the ‘Z’ line. The thick filaments in the ‘A’ band are also held

together in the middle of this band by a thin fibrous membrane called ‘M’ line. The ‘A’ and ‘I’ bands are arranged alternately throughout the length of the myofibrils. The portion of the myofibril between two successive ‘Z’ lines is considered as the functional unit of contraction and is called a sarcomere.

In a resting state, the edges of thin filaments on either side of the thick filaments partially overlap the free ends of the thick filaments leaving the central part of the thick filaments. This central part of thick filament, not overlapped by thin filaments is called the ‘H’ zone.

Structure of Contractile Proteins

Each actin (thin) filament is made of two ‘F’ (filamentous) actins helically wound to each other. Each ‘F’ actin is a polymer of monomeric ‘G’ (Globular) actins. Two filaments of another protein, tropomyosin also run close to the ‘F’ actins throughout its length. A complex protein Troponin is distributed at regular intervals on the tropomyosin. In the resting state a subunit of troponin masks the active binding sites for myosin on the actin filaments.



Each myosin (thick) filament is also a polymerised protein. Many monomeric proteins called Meromyosins constitute one thick filament. Each meromyosin has two important parts, a globular head with a short arm and a tail, the former being called the heavy meromyosin (HMM) and the latter, the light meromyosin (LMM). The HMM component, i.e.; the head and short arm projects outwards at regular distance and angle from each other from the surface of a polymerised myosin filament and is known as cross arm. The globular head is an active ATPase enzyme and has binding sites for ATP and active sites for actin.

Mechanism of Muscle Contraction

Mechanism of muscle contraction is best explained by the sliding filament theory which states that contraction of a muscle fibre takes place by the sliding of the thin filaments over the thick filaments.

Muscle contraction is initiated by a signal sent by the central nervous system (CNS) via a motor neuron. A motor neuron alongwith the muscle fibres connected to it constitute a motor unit. The junction between a motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor-end plate. A neural signal reaching this junction releases a neurotransmitter (Acetyl choline) which generates an action potential in the sarcolemma. This spreads through the muscle fibre and causes the release of calcium ions into the sarcoplasm. Increase in Ca^{++} level leads to the binding of calcium with a subunit of troponin on actin filaments and thereby remove the masking of active sites for myosin.

Utilising the energy from ATP hydrolysis, the myosin head now binds to the exposed active sites on actin to form a cross bridge. This pulls the attached actin filaments towards the centre of 'A' band. The 'Z' line attached to these actins are also pulled inwards thereby causing a shortening of the sarcomere, i.e., contraction. It is clear from the above steps, that during shortening of the muscle, i.e., contraction, the 'I' bands get reduced, whereas the 'A' bands retain the length. The myosin, releasing the ADP and P1 goes back to its relaxed state. A new ATP binds and the cross-bridge is broken. The ATP is again hydrolysed by the myosin head and the cycle of cross bridge formation and breakage is repeated causing further sliding. The process continues till the Ca^{++} ions are pumped back to the sarcoplasmic cisternae resulting in the masking of actin filaments. This causes the return of 'Z' lines back to their original position, i.e., relaxation.

The reaction time of the fibres can vary in different muscles. Repeated activation of the muscles can lead to the accumulation of lactic acid due to anaerobic breakdown of glycogen in them, causing fatigue. Muscle contains a red coloured oxygen storing pigment called myoglobin. Myoglobin content is high in some of the muscles which gives a reddish appearance. Such muscles are called the Red fibres. These muscles also contain plenty of mitochondria which can utilise the large amount of oxygen stored in them for ATP production. These muscles, therefore, can also be called aerobic muscles.

On the other hand, some of the muscles possess very less quantity of myoglobin and therefore, appear pale or whitish. These are the White fibres. Number of mitochondria are also few in them, but the amount of sarcoplasmic reticulum is high. They depend on anaerobic process for energy.

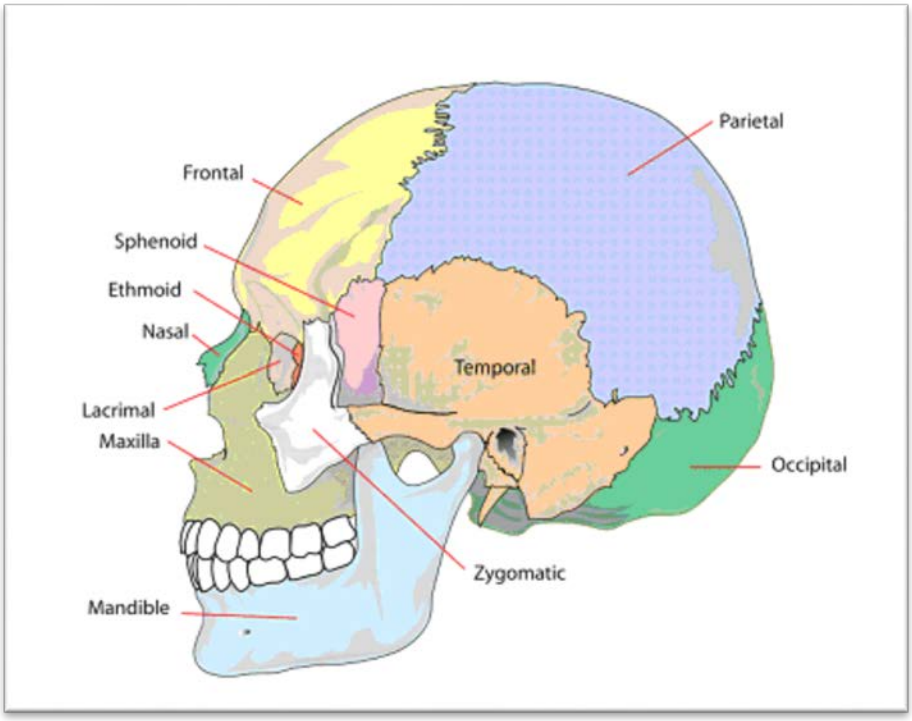
SKELETAL SYSTEM

Skeletal system consists of a framework of bones and a few cartilages. This system has a significant role in movement shown by the body. Bone and cartilage are specialised connective tissues. The former has a very hard matrix due to calcium salts in it and the latter has slightly pliable matrix due to chondroitin salts. In human beings, this system is made up of 206 bones and a few cartilages. It is grouped into two principal divisions – the axial and the appendicular skeleton.

Axial Skeleton: Axial skeleton comprises 80 bones distributed along the main axis of the body. The skull, vertebral column, sternum and ribs constitute axial skeleton.

Skull: The skull is composed of two sets of bones – cranial and facial, that totals to 22 bones. Cranial bones are 8 in number. They form the hard protective outer covering, cranium for the brain. The facial region is made up of 14 skeletal elements which form the front part of the skull. A single U-shaped bone called hyoid is present at the base of the buccal cavity and it is also included in the skull. Each middle ear contains three tiny bones – Malleus, Incus and Stapes, collectively called Ear Ossicles. The skull

region articulates with the superior region of the vertebral column with the help of two occipital condyles (dicondylic skull).



Vertebral Column: Our vertebral column is formed by 26 serially arranged units called vertebrae and is dorsally placed. It extends from the base of the skull and constitutes the main framework of the trunk. Each vertebra has a central hollow portion (neural canal) through which the spinal cord passes. First vertebra is the atlas and it articulates with the occipital condyles.

The vertebral column is differentiated into following regions starting from the skull:

1. cervical (7),

2. thoracic (12),

3. lumbar (5),

4. sacral (1-fused) and

5. coccygeal (1-fused) regions

The number of cervical vertebrae are seven in almost all mammals including human beings. The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back. Sternum is a flat bone on the ventral midline of thorax.

Rib Cage: There are 12 pairs of ribs. Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. It has two articulation surfaces on its dorsal end and is hence called bicephalic. First seven pairs of ribs are called true ribs. Dorsally, they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilage. The 8th, 9th and

10th pairs of ribs do not articulate directly with the sternum but join the seventh rib with the help of hyaline cartilage. These are called vertebrochondral (false) ribs. Last 2 pairs (11th and 12th) of ribs are not connected ventrally and are therefore, called floating ribs. Thoracic vertebrae, ribs and sternum together form the rib cage.

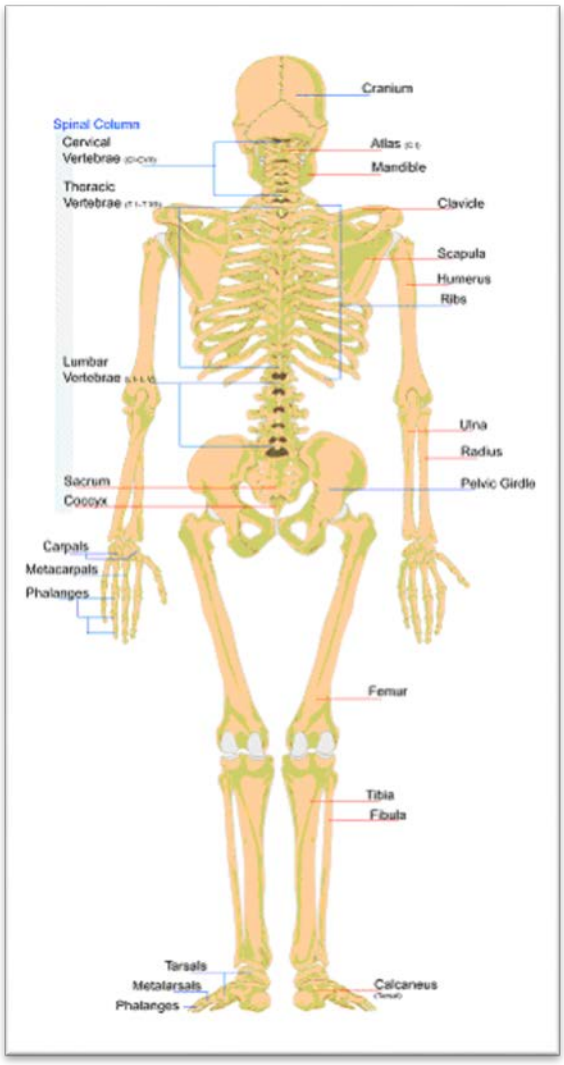
Appendicular Skeleton: The bones of the limbs alongwith their girdles constitute the appendicular skeleton. Each limb is made of 30 bones.

• The bones of the hand (fore limb) are humerus, radius and ulna, carpals (wrist bones – 8 in number), metacarpals (palm bones – 5 in number) and phalanges (digits – 14 in number).

• **Femur** (thigh bone – the longest bone), tibia and fibula, tarsals (ankle bones – 7 in number), metatarsals (5 in number) and phalanges (digits – 14 in number) are the bones of the legs (hind limb). A cup shaped bone called patella cover the knee ventrally (knee cap).

Girdle Bones: Pectoral and Pelvic girdle bones help in the articulation of the upper and the lower limbs respectively with the axial skeleton. Each girdle is formed of two halves. Each half of pectoral girdle consists of a clavicle and a scapula. Scapula is a large triangular flat bone situated in the dorsal part of the thorax between the second and the seventh ribs. The dorsal, flat, triangular body of scapula has a slightly elevated ridge called the spine which projects as a flat, expanded process called the acromion. The clavicle articulates with this. Below the acromion is a depression called the glenoid cavity which articulates with the head of the humerus to form the shoulder joint. Each clavicle is a long slender bone with two curvatures. This bone is commonly called the collar bone.

Pelvic girdle consists of two coxal bones. Each coxal bone is formed by the fusion of three bones – ilium, ischium and pubis. At the point of fusion of the above bones is a cavity called acetabulum to which the thigh bone articulates. The two halves of the pelvic girdle meet ventrally to form the pubic symphysis containing fibrous cartilage.



JOINTS

Joints are essential for all types of movements involving the bony parts of the body. Locomotory movements are no exception to this. Joints are points of contact between bones, or between bones and cartilages. Force generated by the muscles is used to carry out movement through joints, where the joint acts as a fulcrum. The movability at these joints vary depending on different factors. Joints have been classified into three major structural forms, namely, fibrous, cartilaginous and synovial.

Fibrous Joints: Fibrous joints do not allow any movement. This type of joint is shown by the flat skull bones which fuse end-to-end with the help of dense fibrous connective tissues in the form of sutures, to form the cranium.

Cartilaginous Joints: In cartilaginous joints, the bones involved are joined together with the help of cartilages. The joint between the adjacent vertebrae in the vertebral column is of this pattern and it permits limited movements.

Synovial Joints: Synovial joints are characterised by the presence of a fluid filled synovial cavity between the articulating surfaces of the two bones. Such an arrangement allows considerable movement. These joints help in locomotion and many other movements. Ball and socket joint (between

humerus and pectoral girdle), Hinge joint (knee joint), Pivot joint (between atlas and axis), Gliding joint (between the carpals) and Saddle joint (between carpal and metacarpal of thumb) are some examples.

DISORDERS OF MUSCULAR AND SKELETAL SYSTEM

Myasthenia gravis: Auto immune disorder affecting neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscle.

Muscular dystrophy: Progressive degeneration of skeletal muscle mostly due to genetic disorder.

Tetany: Rapid spasms (wild contractions) in muscle due to low Ca++ in body fluid.

Arthritis: Inflammation of joints.

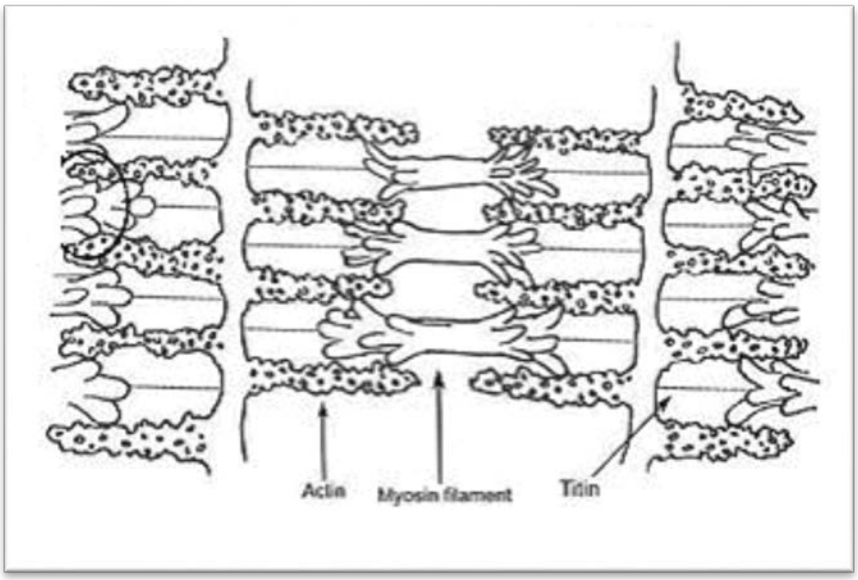
Osteoporosis: Age-related disorder characterised by decreased bone mass and increased chances of fractures. Decreased levels of estrogen is a common cause.

Gout: Inflammation of joints due to accumulation of uric acid crystals.

NCERT Solution

Question 1. Draw the diagram of a sarcomere of skeletal muscle showing different regions.

Answer:- Sacromere of Skeletal Muscle



Question 2. Define sliding filament theory of muscle contraction.

Answer:- Sliding Filament Theory of Muscle Contraction

Mechanism of muscle contraction is best explained by the sliding filament theory which states that contraction of a muscle fibre takes place by the sliding of the thin filaments over the thick filaments.

Question 3. Describe the important steps in muscle contraction.

Answer:- Muscle contraction is initiated by a signal sent by the central nervous system (CNS) via a motor neuron. A motor neuron alongwith the muscle fibres connected to it constitute a motor unit. The junction between a motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor-end plate. A neural signal reaching this junction releases a neurotransmitter (Acetyl choline) which generates an action potential in the sarcolemma. This spreads through the muscle fibre and causes the release of calcium ions into the sarcoplasm. Increase in Ca^{++} level leads to the binding of calcium with a subunit of troponin on actin filaments and thereby remove the masking of active sites for myosin.

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Question 4. Write true or false. If false change the statement so that it is true.

(a) Actin is present in thin filament

TRUE

(b) H-zone of striated muscle fibre represents both thick and thin filaments.

FALSE, H-zone represents thick filaments

(c) Human skeleton has 206 bones.

TRUE

(d) There are 11 pairs of ribs in man.

FALSE, There are 12 pairs of ribs in man

(e) Sternum is present on the ventral side of the body.

TRUE

5. Write the difference between:

(a) Actin and Myosin

(b) Red and White muscles

(c) Pectoral and Pelvic girdle

Answer:

(a) Actin and Myosin: Actin filaments are thinner as compared to the myosin filaments, hence are commonly called thin and thick filaments respectively. In the centre of each 'I' band is an elastic fibre called 'Z' line which bisects it. The thin filaments are firmly attached to the 'Z' line. The thick filaments in the 'A' band are also held together in the middle of this band by a thin fibrous membrane called 'M' line.

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On the other hand, some of the muscles possess very less quantity of myoglobin and therefore, appear pale or whitish. These are the White fibres. Number of mitochondria are also few in them, but the amount of sarcoplasmic reticulum is high. They depend on anaerobic process for energy.

(c) Pectoral and Pelvic Girdle: Pectoral girdle is situated in the pectoral region of the body. Each half of pectoral girdle consists of a clavicle and a scapula. Scapula is a large triangular flat bone situated in the dorsal part of the thorax between the second and the seventh ribs. The dorsal, flat, triangular body of scapula has a slightly elevated ridge called the spine which projects as a flat, expanded process called the acromion. The clavicle articulates with this. Below the acromion is a depression called the glenoid cavity which articulates with the head of the humerus to form the shoulder joint. Each clavicle is a long slender bone with two curvatures. This bone is commonly called the collar bone.

Pelvic girdle is situated in the pelvic region of the body. Pelvic girdle consists of two coxal bones. Each coxal bone is formed by the fusion of three bones – ilium, ischium and pubis. At the point of fusion of the above bones is a cavity called acetabulum to which the thigh bone articulates. The two halves of the pelvic girdle meet ventrally to form the pubic symphysis containing fibrous cartilage.

Question 6. What are the different types of movements exhibited by the cells of human body?

Answer: Cells of the human body exhibit three main types of movements, namely, amoeboid, ciliary and muscular.

Amoeboid Movement: Some specialised cells in our body like macrophages and leucocytes in blood exhibit amoeboid movement. It is effected by pseudopodia formed by the streaming of protoplasm (as in Amoeba). Cytoskeletal elements like microfilaments are also involved in amoeboid movement.

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Muscular Movement: Movement of our limbs, jaws, tongue, etc, require muscular movement. The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms. Locomotion requires a perfect coordinated activity of muscular, skeletal and neural systems.

Question 7. How do you distinguish between a skeletal muscle and a cardiac muscle?

Answer: Both cardiac and skeletal muscles are striated. Cardiac and skeletal muscles are "striated" in that they contain sarcomeres and are packed into highly-regular arrangements of bundles; smooth muscle has neither. While skeletal muscles are arranged in regular, parallel bundles, cardiac muscle connects at branching, irregular angles (called intercalated discs). Striated muscle contracts and relaxes in short, intense bursts, whereas smooth muscle sustains longer or even near-permanent contractions.

Question 8. Name the type of joint between the following:-

(a) atlas/axis

PIVOT JOINT

(b) carpal/metacarpal of thumb

SADDLE JOINT

(c) between phalanges

GLIDING JOINT

(d) femur/acetabulum

BALL AND SOCKET JOINT

(e) between cranial bones

FIBROUS JONT

(f) between pubic bones in the pelvic girdle

CARTILAGINOUS JOINT

21. Nervous Control and Coordination

Nervous System:-

The nervous system of all animals is composed of highly specialised cells called neurons which can detect, receive and transmit different kinds of stimuli.

HUMAN NERVOUS SYSTEM :-

The human nervous system is divided into two parts:

(i) Central Nervous System (CNS)

(ii) Peripheral Nervous System (PNS)

The CNS includes the brain and the spinal cord and is the site of information processing and control. The PNS comprises of all the nerves of the body associated with the CNS (brain and spinal cord). The nerve fibres of the PNS are of two types:

(a) Afferent Fibres

(b) Efferent Fibres

The afferent nerve fibres transmit impulses from tissues/organs to the CNS and the efferent fibres transmit regulatory impulses from the CNS to the concerned peripheral tissues/organs.

The PNS is divided into two divisions called somatic nervous system and autonomic nervous system. The somatic nervous system relays impulses from the CNS to skeletal muscles while the autonomic nervous system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body. The autonomic nervous system is further classified into sympathetic nervous system and parasympathetic nervous system.

NEURON AS STRUCTURAL AND FUNCTIONAL UNIT OF NERVOUS SYSTEM

A neuron is a microscopic structure composed of three major parts, namely, cell body, dendrites and axon.

Cell Body: The cell body contains cytoplasm with typical cell organelles and certain granular bodies called Nissl's granules.

Dendrites: Short fibres which branch repeatedly and project out of the cell body also contain Nissl's granules and are called dendrites. These fibres transmit impulses towards the cell body.

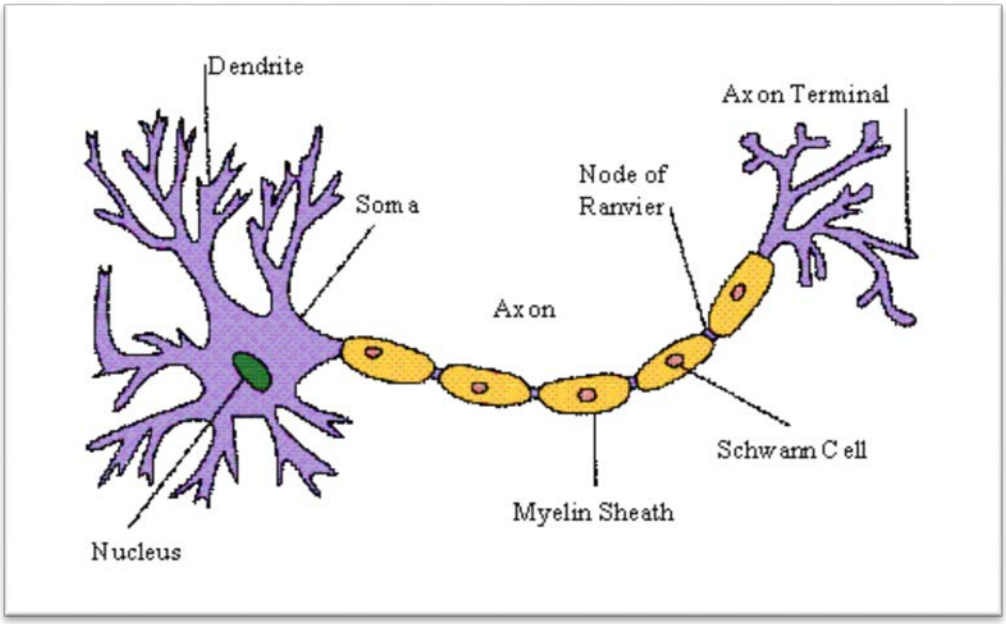
Axon: The axon is a long fibre, the distal end of which is branched. Each branch terminates as a bulb-like structure called synaptic knob which possess synaptic vesicles containing chemicals called neurotransmitters. The axons transmit nerve impulses away from the cell body to a synapse or to a neuro-muscular junction.

Based on the number of axon and dendrites, the neurons are divided into three types:

(a) Multipolar (with one axon and two or more dendrites; found in the cerebral cortex),

(b) Bipolar (with one axon and one dendrite, found in the retina of eye) and

(c) Unipolar (cell body with one axon only; found usually in the embryonic stage).



There are two types of axons, namely, myelinated and nonmyelinated. The myelinated nerve fibres are enveloped with Schwann cells, which form a myelin sheath around the axon. The gaps between two adjacent myelin sheaths are called nodes of Ranvier. Myelinated nerve fibres are found in spinal and cranial nerves. Unmyelinated nerve fibre is enclosed by a Schwann cell that does not form a myelin sheath around the axon, and is commonly found in autonomous and the somatic nervous systems.

Generation and Conduction of Nerve Impulse

Neurons are excitable cells because their membranes are in a polarized state. Different types of ion channels are present on the nervous membrane. These ion channels are selectively permeable to different ions. When a neuron is not conducting any impulse, i.e., resting, the axonal membrane is comparatively more permeable to potassium ions (K+) and nearly impermeable to sodium ions (Na+). Similarly, the membrane is impermeable to negatively charged proteins present in the axoplasm. Consequently, the axoplasm inside the axon contains high concentration of K+ and negatively charged proteins and low concentration of Na+.

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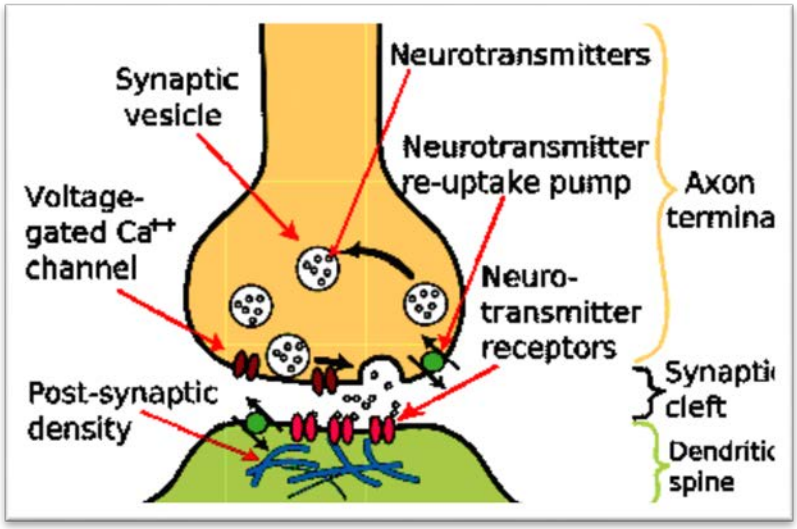
In contrast, the fluid outside the axon contains a low concentration of K^+, a high concentration of Na^+ and thus forms a concentration gradient. These ionic gradients across the resting membrane are maintained by the active transport of ions by the sodium-potassium pump which transports 3 Na^+ outwards for 2 K^+ into the cell. As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore is polarised. The electrical potential difference across the resting plasma membrane is called as the resting potential.

Conduction of Nerve Impulse: site is reversed, and an action potential is generated at site B. Thus, the impulse (action potential) generated at site A arrives at site BWhen a stimulus is applied at a site on the polarised membrane, the membrane at the site A becomes freely permeable to Na^+. This leads to a rapid influx of Na^+ followed by the reversal of the polarity at that site, i.e., the outer surface of the membrane becomes negatively charged and the inner side becomes positively charged. The polarity of the membrane at the site is thus reversed and hence depolarised. The electrical potential difference across the plasma membrane at the site A is called the action potential, which is in fact termed as a nerve impulse.

At sites immediately ahead, the axon (e.g., site B) membrane has a positive charge on the outer surface and a negative charge on its inner surface. As a result, a current flows on the inner surface from site A to site B. ptic neuron, which may or may not be separated by a gap called synaptic cleft. There are two types of synapses, namely, electrical synapses and chemical synapses. At electrical synapses, the membranes of pre- and post-synaptic neurons are in very close proximity. Electrical current can flow directly from one neuron into the other across these synapses. Transmission of an impulse across electrical synapses is very similar to impulse conduction along a single axon. Impulse transmission across an electrical synapse is always faster than that across a chemical synapse. Electrical synapses are rare in our system.

At a chemical synapse, the membranes of the pre- and post-synaptic neurons are separated by a fluid-filled space called synaptic The rise in the stimulus-induced permeability to Na^+ is extremely shortlived. It is quickly followed by a rise in permeability to K^+. Within a fraction of a second, K^+ diffuses outside the membrane and restores the resting potential of the membrane at the site of excitation and the fibre becomes once more responsive to further stimulation.

Transmission of Impulses generate a new potential in the post-synaptic neuron. The new potential developed may be either excitatory or inhibitory.



CENTRAL NERVOUS SYSTEM

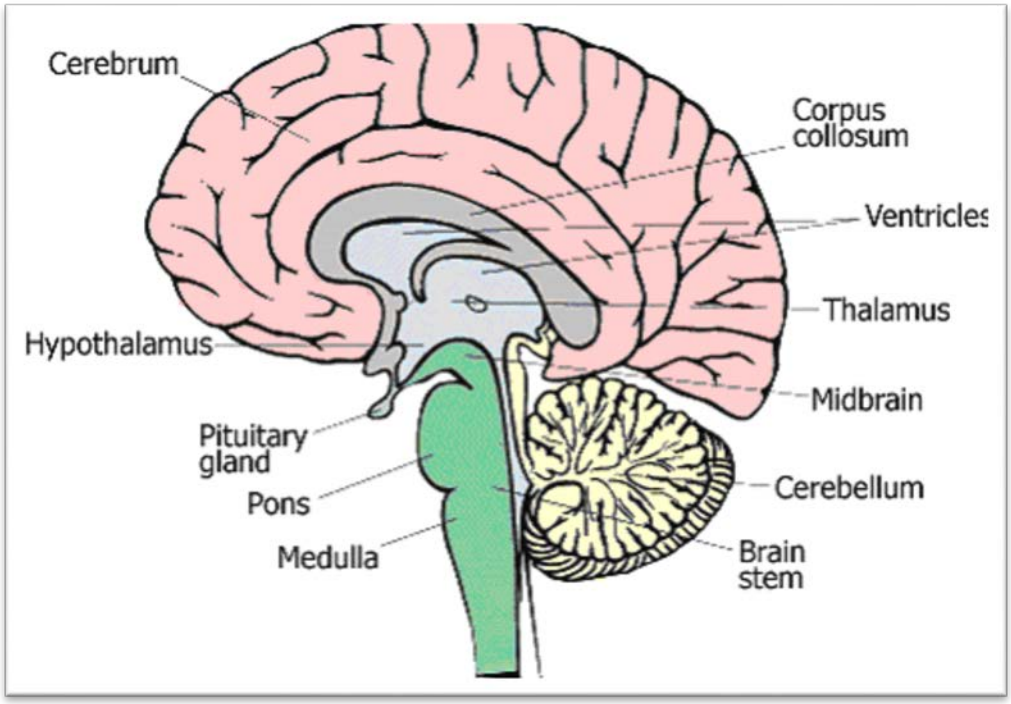
The brain is the central information processing organ of our body, and acts as the 'command and control system'. It controls the voluntary movements, balance of the body, functioning of vital involuntary organs (e.g., lungs, heart, kidneys, etc.), thermoregulation, hunger and thirst, circadian (24-hour) rhythms of our body, activities of several endocrine glands and human behaviour. It is also the site for processing of vision, hearing, speech, memory, intelligence, emotions and thoughts.

The human brain is well protected by the skull. Inside the skull, the brain is covered by cranial meninges consisting of an outer layer called dura mater, a very thin middle layer called arachnoid and an inner layer (which is in contact with the brain tissue) called pia mater. The brain can be divided into three major parts:

(i) Forebrain,

(ii) Midbrain, and

(iii) Hindbrain



Forebrain

The forebrain consists of cerebrum, thalamus and hypothalamus. Cerebrum forms the major part of the human brain. A deep cleft divides the cerebrum longitudinally into two halves, which are termed as the left and right cerebral hemispheres. The hemispheres are connected by a tract of nerve fibres called corpus callosum.

The layer of cells which covers the cerebral hemisphere is called cerebral cortex and is thrown into prominent folds. The cerebral cortex is referred to as the grey matter due to its greyish appearance. The neuron cell bodies are concentrated here giving the colour.

The cerebral cortex contains motor areas, sensory areas and large regions that are neither clearly sensory nor motor in function. These regions called as the association areas are responsible for complex functions like intersensory associations, memory and communication.

Fibres of the tracts are covered with the myelin sheath, which constitute the inner part of cerebral hemisphere. They give an opaque white appearance to the layer and, hence, is called the white matter.

The cerebrum wraps around a structure called thalamus, which is a major coordinating centre for sensory and motor signaling. Another very important part of the brain called hypothalamus lies at the base of the thalamus. The hypothalamus contains a number of centres which control body temperature, urge for eating and drinking. It also contains several groups of neurosecretory cells, which secrete hormones called hypothalamic hormones.

The inner parts of cerebral hemispheres and a group of associated deep structures like amygdala, hippocampus, etc., form a complex structure called the limbic lobe or limbic system. Along with the hypothalamus, it is involved in the regulation of sexual behaviour, expression of emotional reactions (e.g., excitement, pleasure, rage and fear), and motivation.

Midbrain

The midbrain is located between the thalamus/hypothalamus of the forebrain and pons of the hindbrain. A canal called the cerebral aqueduct passess through the midbrain. The dorsal portion of the midbrain consists mainly of four round swellings (lobes) called corpora quadrigemina. Midbrain and hindbrain form the brain stem.

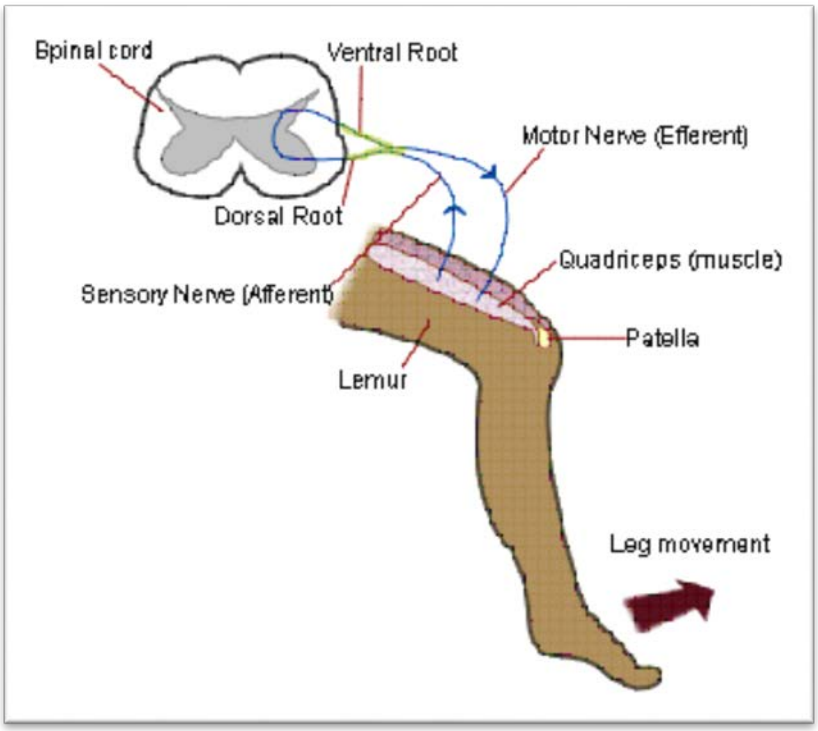
Hindbrain

The hindbrain comprises pons, cerebellum and medulla (also called the medulla oblongata). Pons consists of fibre tracts that interconnect different regions of the brain. Cerebellum has very convoluted surface in order to provide the additional space for many more neurons. The medulla of the brain is connected to the spinal cord. The medulla contains centres which control respiration, cardiovascular reflexes and gastric secretions.

REFLEX ACTION AND REFLEX ARC

You must have experienced a sudden withdrawal of a body part which comes in contact with objects that are extremely hot, cold pointed or animals that are scary or poisonous. The entire process of response to a peripheral nervous stimulation, that occurs involuntarily, i.e., without conscious effort or thought and requires the involvment of a part of the central nervous system is called a reflex action.

The reflex pathway comprises at least one afferent neuron (receptor) and one efferent (effector or excitor) neuron appropriately arranged in a series. The afferent neuron receives signal from a sensory organ and transmits the impulse via a dorsal nerve root into the CNS (at the level of spinal cord). The efferent nueuron then carries signals from CNS to the effector. The stimulus and response thus forms a reflex arc as shown below in the knee jerk reflex.



SENSORY RECEPTION AND PROCESSING

Eye

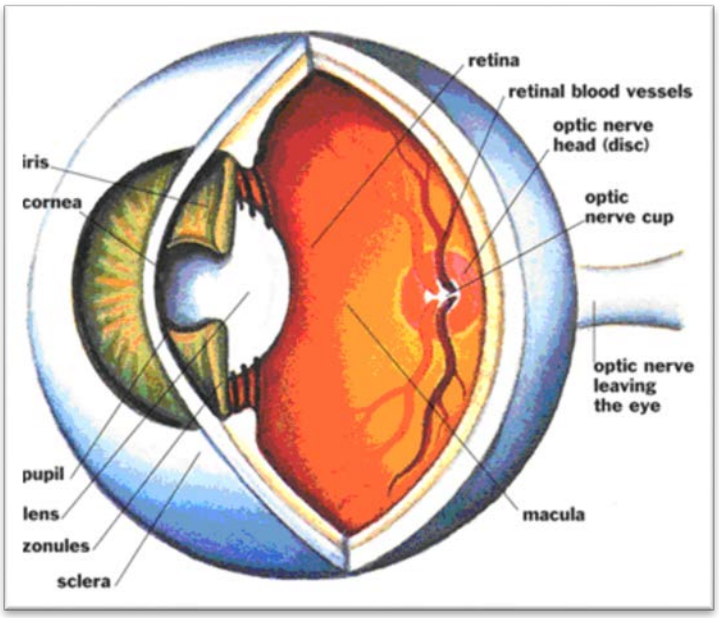
The adult human eye ball is nearly a spherical structure. The wall of the eye ball is composed of three layers.

The external layer is composed of a dense connective tissue and is called the sclera. The anterior portion of this layer is called the cornea.

The middle layer, choroid, contains many blood vessels and looks bluish in colour. The choroid layer is thin over the posterior two-thirds of the eye ball, but it becomes thick in the anterior part to form the ciliary body.

The ciliary body itself continues forward to form a pigmented and opaque structure called the iris which is the visible coloured portion of the eye.

The eye ball contains a transparent crystalline lens which is held in place by ligaments attached to the ciliary body. In front of the lens, the aperture surrounded by the iris is called the pupil. The diameter of the pupil is regulated by the muscle fibres of iris.



The inner layer is the retina and it contains three layers of cells – from inside to outside – ganglion cells, bipolar cells and photoreceptor cells.

There are two types of photoreceptor cells, namely, rods and cones. These cells contain the light-sensitive proteins called the photopigments. The daylight (photopic) vision and colour vision are functions of cones and the twilight (scotopic) vision is the function of the rods. The rods contain a purplish-red protein called the rhodopsin or visual purple, which contains a derivative of Vitamin A.

In the human eye, there are three types of cones which possess their own characteristic photopigments that respond to red, green and blue lights. The sensations of different colours are produced by various combinations of these cones and their photopigments. When these cones are stimulated equally, a sensation of white light is produced.

The optic nerves leave the eye and the retinal blood vessels enter it at a point medial to and slightly above the posterior pole of the eye ball. Photoreceptor cells are not present in that region and hence it is called he blind spot. At the posterior pole of the eye lateral to the blind spot, here is a yellowish pigmented spot called macula lutea with a central pit called the fovea. The fovea is a thinned-out portion of the retina where only the cones are densely packed. It is the point where the visual acuity (resolution) is the greatest.

The space between the cornea and the lens is called the aqueous chamber and contains a thin watery fluid called aqueous humor. The pace between the lens and the retina is called the vitreous chamber and is filled with a transparent gel called vitreous humor.

Mechanism of Vision

• The light rays in visible wavelength focussed on the retina through the ornea and lens generate potentials (impulses) in rods and cones.

• Light induces dissociation of the retinal from opsin resulting in changes in the structure of the opsin. This causes membrane permeability changes. As a result, potential differences are generated in he

photoreceptor cells. This produces a signal that generates action potentials in the ganglion cells through the bipolar cells.

• These action potentials (impulses) are transmitted by the optic nerves to the visual cortex area of the brain, where the nervous impulses are analysed and the image formed on the retina is recognised based on earlier memory and experience.

The Ear

The ears perform two sensory functions, hearing and maintenance of body balance. Anatomically, the ear can be divided into three major sections called the outer ear, the middle ear and the inner ear.

Outer Ear: The outer ear consists of the pinna and external auditory meatus (canal). The pinna collects the vibrations in the air which produce sound. The external auditory meatus leads inwards and extends up to the tympanic membrane (the ear drum). There are very fine hairs and wax-secreting sebaceous glands in the skin of the pinna and the meatus. The tympanic membrane is composed of connective tissues covered with skin outside and with mucus membrane inside.

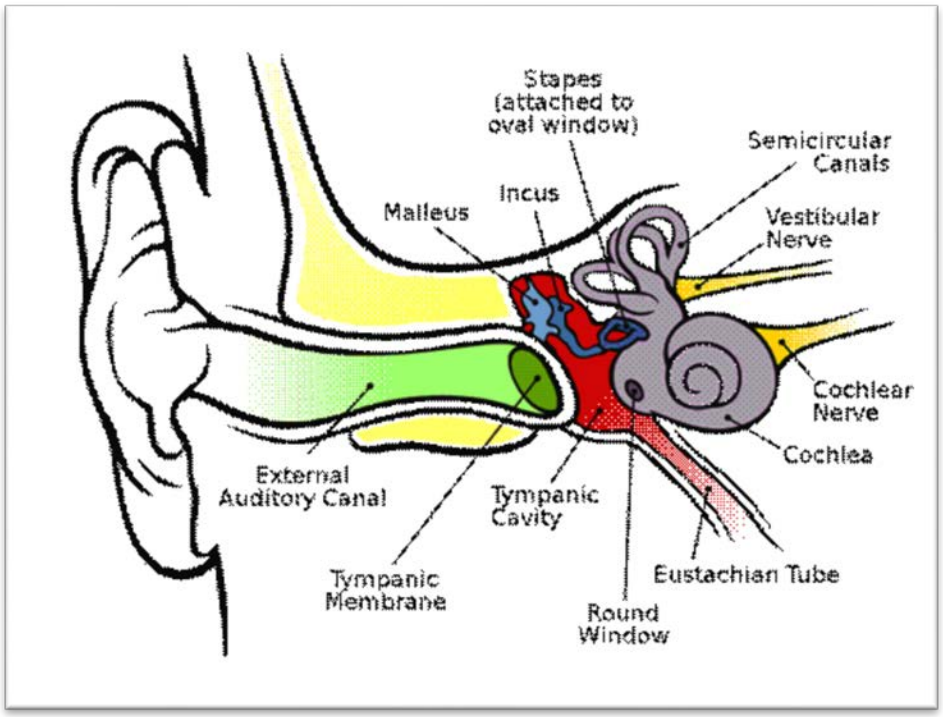
Middle Ear: The middle ear contains three ossicles called malleus, incus and stapes which are attached to one another in a chain-like fashion.

The malleus is attached to the tympanic membrane and the stapes is attached to the oval window of the cochlea. The ear ossicles increase the efficiency of transmission of sound waves to the inner ear.

An Eustachian tube connects the middle ear cavity with the pharynx. The Eustachian tube helps in equalising the pressures on either sides of the ear drum.

Inner Ear: The fluid-filled inner ear called labyrinth consists of two parts, the bony and the membranous labyrinths. The bony labyrinth is a series of channels. Inside these channels lies the membranous labyrinth, which is surrounded by a fluid called perilymph. The membranous labyrinth is filled with a fluid called endolymph. The coiled portion of the labyrinth is called cochlea.

The membranes constituting cochlea, the reissner’s and basilar, divide the surounding perilymph filled bony labyrinth into an upper scala vestibuli and a lower scala tympani. The space within cochlea called scala media is filled with endolymph. At the base of the cochlea, the scala vestibuli ends at the oval window, while the scala tympani terminates at the round window which opens to the middle ear.



The organ of corti is a structure located on the basilar membrane which contains hair cells that act as auditory receptors. The hair cells are present in rows on the internal side of the organ of corti. The basal end of the hair cell is in close contact with the afferent nerve fibres. A large number of processes called stereo cilia are projected from the apical part of each hair cell. Above the rows of the hair cells is a thin elastic membrane called tectorial membrane.

The inner ear also contains a complex system called vestibular apparatus, located above the cochlea. The vestibular apparatus is composed of three semi-circular canals and the otolith organ consisting of the saccule and utricle. Each semi-circular canal lies in a different plane at right angles to each other. The membranous canals are suspended in the perilymph of the bony canals. The base of canals is swollen and is called ampulla, which contains a projecting ridge called crista ampullaris which has hair cells. The saccule and utricle contain a projecting ridge called macula. The crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture.

NCERT Solution

Question 1. Briefly describe the structure of the following:

(a) Brain (b) Eye (c) Ear

Answer:

(a) Structure of Brain

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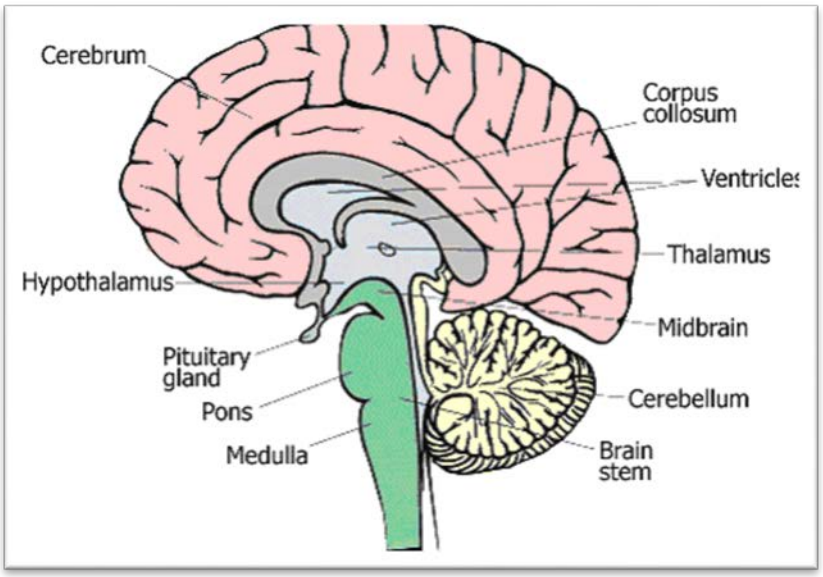

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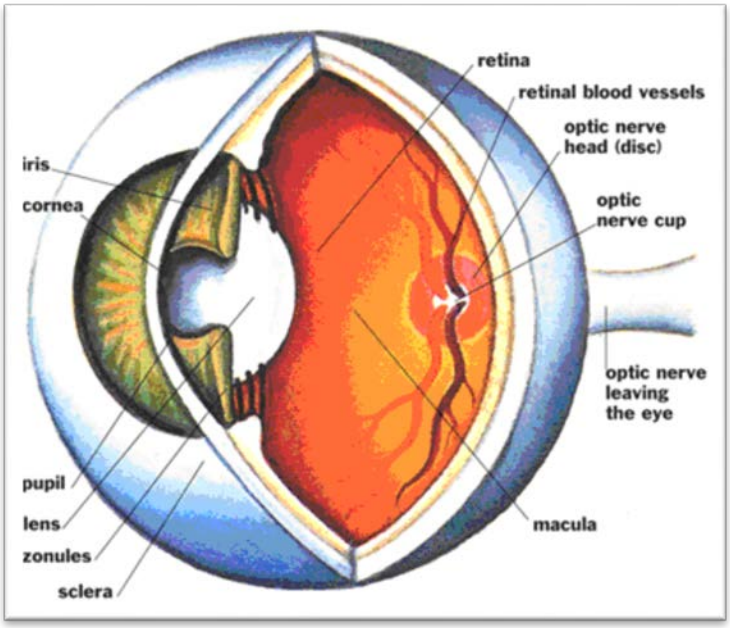

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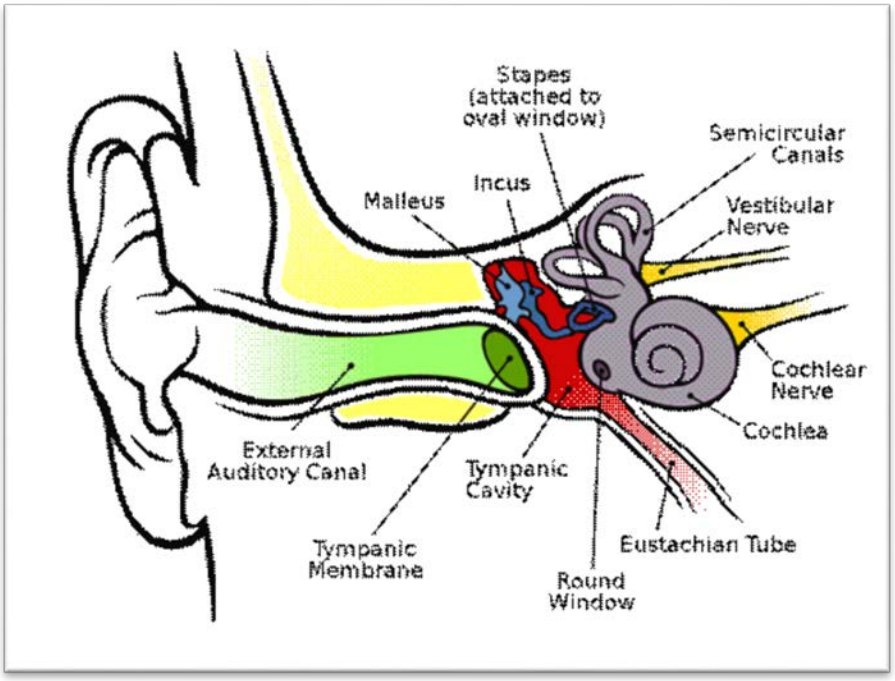

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Question 2. Compare the following:

(a) Central nervous system (CNS) and Peripheral nervous system (PNS)

(b) Resting potential and action potential

(c) Choroid and retina

Answer: (a) Central Nervous System and Peripheral Nervous System: The CNS includes the brain and the spinal cord and is the site of information processing and control. The PNS comprises of all the nerves of the body associated with the CNS (brain and spinal cord).

(b) Resting Potential and Action Potential: Neurons are excitable cells because their membranes are in a polarized state. Different types of ion channels are present on the nervous membrane. These ion channels are selectively permeable to different ions. When a neuron is not conducting any impulse, i.e., resting, the axonal membrane is comparatively more permeable to potassium ions (K^+) and nearly impermeable to sodium ions (Na^+). Similarly, the membrane is impermeable to negatively charged proteins present in the axoplasm. Consequently, the axoplasm inside the axon contains high concentration of K^+ and negatively charged proteins and low concentration of Na^+.

In contrast, the fluid outside the axon contains a low concentration of K^+, a high concentration of Na^+ and thus forms a concentration gradient. These ionic gradients across the resting membrane are maintained by the active transport of ions by the sodium-potassium pump which transports 3 Na^+ outwards for 2 K^+ into the cell. As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore is polarised. The electrical potential difference across the resting plasma membrane is called as the resting potential.

When a stimulus is applied at a site on the polarised membrane, the membrane at the site becomes freely permeable to Na^+. This leads to a rapid influx of Na^+ followed by the reversal of the polarity at that site, i.e., the outer surface of the membrane becomes negatively charged and the inner side becomes positively charged. The polarity of the membrane at the site is thus reversed and hence depolarised. The electrical potential difference across the plasma membrane at the site A is called the action potential, which is in fact termed as a nerve impulse.

(c) Choroid and Retina: The middle layer, choroid, contains many blood vessels and looks bluish in colour. The choroid layer is thin over the posterior two-thirds of the eye ball, but it becomes thick in the anterior part to form the ciliary body.

The inner layer is the retina and it contains three layers of cells – from inside to outside – ganglion cells, bipolar cells and photoreceptor cells.

Question 3. Explain the following processes:

(a) Polarisation of the membrane of a nerve fibre

(b) Depolarisation of the membrane of a nerve fibre

(c) Conduction of a nerve impulse along a nerve fibre

(d) Transmission of a nerve impulse across a chemical synapse

Answer:

(a) Polarisation of the membrane of a nerve fibre:

The fluid inside the membrane contains high concentration of K^+ and negatively charged proteins and low concentration of Na^+.

In contrast, the fluid outside the axon contains a low concentration of K^+, a high concentration of Na^+ and thus forms a concentration gradient.

These ionic gradients across the resting membrane are maintained by the active transport of ions by the sodium-potassium pump which transports 3 Na^+ outwards for 2 K^+ into the cell. As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore is polarised.

(b) Depolarisation of the membrane of a nerve fibre:

When a stimulus is applied at a site on the polarised membrane, the membrane at the site A becomes freely permeable to Na^+. This leads to a rapid influx of Na^+ followed by the reversal of the polarity at that site, i.e., the outer surface of the membrane becomes negatively charged and the inner side becomes positively charged. The polarity of the membrane at the site is thus reversed and hence depolarised.

(c) Conduction of a nerve impulse along a nerve fibre:

When a stimulus is applied at a site on the polarised membrane, the membrane at the site becomes freely permeable to Na^+. This leads to a rapid influx of Na^+ followed by the reversal of the polarity at that site, i.e., the outer surface of the membrane becomes negatively charged and the inner side becomes positively charged.

At sites immediately ahead, the axon membrane has a positive charge on the outer surface and a negative charge on its inner surface. As a result, a current flows on the inner surface from site A to site B.

On the outer surface current flows from site B to site A to complete the circuit of current flow. Hence, the polarity at the site is reversed, and an action potential is generated at site B. Thus, the impulse (action potential) generated at site A arrives at site B.

The sequence is repeated along the length of the axon and consequently the impulse is conducted.

The rise in the stimulus-induced permeability to Na^+ is extremely shortlived. It is quickly followed by a rise in permeability to K^+. Within a fraction of a second, K^+ diffuses outside the membrane and restores the resting potential of the membrane at the site of excitation and the fibre becomes once more responsive to further stimulation.

(d) Transmission of a nerve impulse across chemical synapse:

At a chemical synapse, the membranes of the pre- and post-synaptic neurons are separated by a fluid-filled space called synaptic cleft. Chemicals called neurotransmitters are involved in the transmission of impulses at these synapses. The axon terminals contain vesicles filled with these neurotransmitters. When an impulse (action potential) arrives at the axon terminal, it stimulates the movement of the synaptic vesicles towards the membrane where they fuse with the plasma membrane and release their neurotransmitters in the synaptic cleft. The released neurotransmitters bind to their specific receptors, present on the post-synaptic membrane. This binding opens ion channels allowing the entry of ions which can generate a new potential in the post-synaptic neuron. The new potential developed may be either excitatory or inhibitory.

Question 4. Give a brief account of:

(a) Mechanism of vision

(b) Mechanism of hearing

Answer: (a) Mechanism of Vision

• The light rays in visible wavelength focussed on the retina through the ornea and lens generate potentials (impulses) in rods and cones.

• Light induces dissociation of the retinal from opsin resulting in changes in the structure of the opsin. This causes membrane permeability changes. As a result, potential differences are generated in he photoreceptor cells. This produces a signal that generates action potentials in the ganglion cells through the bipolar cells.

• These action potentials (impulses) are transmitted by the optic nerves to the visual cortex area of the brain, where the nervous impulses are analysed and the image formed on the retina is recognised based on earlier memory and experience.

(b) Mechanism of Hearing:

The outer part of the ear collects sound. That sound pressure is amplified through the middle portion of the ear and, in land animals, passed from the medium of air into a liquid medium. The change from air to liquid occurs because air surrounds the head and is contained in the ear canal and middle ear, but not in the inner ear. The inner ear is hollow, embedded in the temporal bone, the densest bone of the body. The hollow channels of the inner ear are filled with liquid, and contain a sensory epithelium that is studded with hair cells. The microscopic "hairs" of these cells are structural protein filaments that project out into the fluid. The hair cells are mechanoreceptors that release a chemical neurotransmitter when stimulated. Sound waves moving through fluid push the filaments; if the filaments bend over enough it causes the hair cells to fire. In this way sound waves are transformed into nerve impulses.

Question 5. Answer briefly:

(a) How do you perceive the colour of an object?

(b) Which part of our body helps us in maintaining the body balance?

(c) How does the eye regulate the amount of light that falls on the retina.

Answer: (a) Cones are responsible for color vision. They require brighter light to function than rods require. There are three types of cones, maximally sensitive to long-wavelength, medium-wavelength, and short-wavelength light (often referred to as red, green, and blue, respectively, though the sensitivity peaks are not actually at these colors). The color seen is the combined effect of stimuli to, and responses from, these three types of cone cells.

(b) The Inner ear has three semi-circular canals forming cochlea. Cochlea is responsible for maintaining the body balance.

(c) The pupil in the eye functions like an aperture. This dilates in case of low light and constricts in case of intense light thereby regulating the amount of light falling on the retina.

Question 6. Differentiate between:

(a) Myelinated and non-myelinated axons

(b) Dendrites and axons

(c) Rods and cones

(d) Thalamus and Hypothalamus

(e) Cerebrum and Cerebellum

Answer: (a) Myelinated and non-myelinated axons: The myelinated nerve fibres are enveloped with Schwann cells, which form a myelin sheath around the axon. The gaps between two adjacent myelin sheaths are called nodes of Ranvier. Myelinated nerve fibres are found in spinal and cranial nerves. Unmyelinated nerve fibre is enclosed by a Schwann cell that does not form a myelin sheath around the axon, and is commonly found in autonomous and the somatic nervous systems.

(b) Dendrites: Short fibres which branch repeatedly and project out of the cell body also contain Nissl's granules and are called dendrites. These fibres transmit impulses towards the cell body.

Axon: The axon is a long fibre, the distal end of which is branched. Each branch terminates as a bulb-like structure called synaptic knob which possess synaptic vesicles containing chemicals called neurotransmitters. The axons transmit nerve impulses away from the cell body to a synapse or to a neuro-muscular junction.

(c) Rods and Cones: There are two types of photoreceptor cells, namely, rods and cones. These cells contain the light-sensitive proteins called the photopigments. The daylight (photopic) vision and colour vision are functions of cones and the twilight (scotopic) vision is the function of the rods. The rods contain a purplish-red protein called the rhodopsin or visual purple, which contains a derivative of Vitamin A.

(d) Thalamus and Hypothalamus: The cerebrum wraps around a structure called thalamus, which is a major coordinating centre for sensory and motor signaling. Another very important part of the brain called hypothalamus lies at the base of the thalamus. The hypothalamus contains a number of centres which control body temperature, urge for eating and drinking. It also contains several groups of neurosecretory cells, which secrete hormones called hypothalamic hormones.

(e) Cerebrum and Cerebellum: The cerebrum is located in the forebrain while cerebellum is located in the hind brain.

Question 7. The region of the vertebrate eye, where the optic nerve passes out of the retina, is called the

(a) fovea

(b) iris

(c) blind spot

(d) optic chaisma

Answer: (c) Blind Spot

Question 8. Distinguish between:

(a) afferent neurons and efferent neurons

(b) impulse conduction in a myelinated nerve fibre and unmyelinated nerve fibre

(c) aqueous humor and vitreous humor

(d) blind spot and yellow spot

(e) cranial nerves and spinal nerves.

Answer: (a) The afferent nerve fibres transmit impulses from tissues/organs to the CNS and the efferent fibres transmit regulatory impulses from the CNS to the concerned peripheral tissues/organs.

(b) The evolutionary need for the fast and efficient transduction of electrical signals in nervous system resulted in appearance of myelin sheaths around neuronal axons. Myelin sheath reduces membrane capacitance and increases membrane resistance in the inter-node intervals, thus allowing a fast, saltatory movement of action potentials from node to node. Myelination is found mainly in vertebrates, but an analogous system has been discovered in a few invertebrates, such as some species of shrimp. Not all neurons in vertebrates are myelinated; for example, axons of the neurons comprising autonomous (vegetative) nervous system are not myelinated in general.

The conduction velocity v of myelinated neurons varies roughly linearly with axon diameter whereas the speed of unmyelinated neurons varies roughly as the square root of diameter. Myelin has two important advantages: fast conduction speed and energy efficiency. Also, since the ionic currents are confined to the nodes of Ranvier, there is far fewer ions "leak" across the membrane, saving metabolic energy. This saving is a significant selective advantage, since the human nervous system uses approximately 20% of the body's metabolic energy.

(c) The space between the cornea and the lens is called the aqueous chamber and contains a thin watery fluid called aqueous humor. The pace between the lens and the retina is called the vitreous chamber and is filled with a transparent gel called vitreous humor.

(d) The optic nerves leave the eye and the retinal blood vessels enter it at a point medial to and slightly above the posterior pole of the eye ball. Photoreceptor cells are not present in that region and hence it is called he blind spot. At the posterior pole of the eye lateral to the blind spot, here is a yellowish pigmented spot called macula lutea with a central pit called the fovea. The fovea is a thinned-out portion of the retina where only the cones are densely packed. It is the point where the visual acuity (resolution) is the greatest.

(e) Cranial nerves are nerves that emerge directly from the brain stem in contrast to spinal nerves which emerge from segments of the spinal cord. Peripheral nerves are separated to achieve segmental innervation, cranial nerves are divided to serve one or a few specific functions in wider anatomical territories.

22. Chemical Coordination and Integration

ENDOCRINE GLANDS AND HORMONES

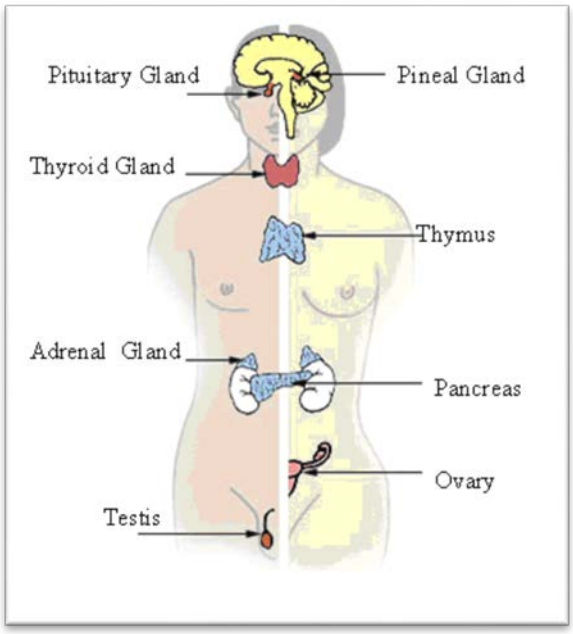
Endocrine glands lack ducts and are hence, called ductless glands. Their secretions are called hormones.

Hormones: Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.

HUMAN ENDOCRINE SYSTEM

The Hypothalamus

Hypothalamus is the basal part of diencephalon, forebrain and it regulates a wide spectrum of body functions. It contains several groups of neurosecretory cells called nuclei which produce hormones. These hormones regulate the synthesis and secretion of pituitary hormones. However, the hormones produced by hypothalamus are of two types, the releasing hormones (which stimulate secretion of pituitary hormones) and the inhibiting hormones (which inhibit secretions of pituitary hormones).



These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary. The posterior pituitary is under the direct neural regulation of the hypothalamus.

The Pituitary Gland

The pituitary gland is located in a bony cavity called sella tursica and is attached to hypothalamus by a stalk. It is divided anatomically into an adenohypophysis and a neurohypophysis. Adenohypophysis consists of two portions, pars distalis and pars intermedia.

The pars distalis region of pituitary, commonly called anterior pituitary, produces following hormones:

• **growth hormone (GH):-** Over-secretion of GH stimulates abnormal growth of the body leading to gigantism and low secretion of GH results in stunted growth resulting in pituitary dwarfism.

• **prolactin (PRL):-** Prolactin regulates the growth of the mammary glands and formation of milk in them.

• **thyroid stimulating hormone (TSH):** TSH stimulates the synthesis and secretion of thyroid hormones from the thyroid gland.

• **adrenocorticotrophic hormone (ACTH):** ACTH stimulates the synthesis and secretion of steroid hormones called glucocorticoids from the adrenal cortex.

• **luteinizing hormone (LH):** LH and FSH stimulate gonadal activity and hence are called gonadotrophins. In males, LH stimulates the synthesis and secretion of hormones called androgens from testis. In females, LH induces ovulation of fully mature follicles (graafian follicles) and maintains the corpus luteum, formed from the remnants of the graafian follicles after ovulation.

• **follicle stimulating hormone (FSH):-** In males, FSH and androgens regulate spermatogenesis. FSH stimulates growth and development of the ovarian follicles in females. MSH acts on the melanocytes (melanin containing cells) and regulates pigmentation of the skin.

Pars intermedia secretes only one hormone called melanocyte stimulating hormone (MSH). However, in humans, the pars intermedia is almost merged with pars distalis.

• Neurohypophysis (pars nervosa) also known as posterior pituitary, stores and releases two hormones called oxytocin and vasopressin, which are actually synthesised by the hypothalamus and are transported axonally to neurohypophysis. Oxytocin acts on the smooth muscles of our body and stimulates their contraction. In females, it stimulates a vigorous contraction of uterus at the time of child birth, and milk ejection from the mammary gland. Vasopressin acts mainly at the kidney and stimulates resorption of water and electrolytes by the distal tubules and thereby reduces loss of water through urine (diuresis). Hence, it is also called as anti-diuretic hormone (ADH).

The Pineal Gland

The pineal gland is located on the dorsal side of forebrain. Pineal secretes a hormone called melatonin. Melatonin plays a very important role in the regulation of a 24-hour (diurnal) rhythm of our body. For example, it helps in maintaining the normal rhythms of sleep-wake cycle, body temperature. In addition, melatonin also influences metabolism, pigmentation, the menstrual cycle as well as our defense capability.

Thyroid Gland

The thyroid gland is composed of two lobes which are located on either side of the trachea. Both the lobes are interconnected with a thin flap of connective tissue called isthmus. The thyroid gland is composed of follicles and stromal tissues. Each thyroid follicle is composed of follicular cells, enclosing a cavity.

These follicular cells synthesise two hormones, tetraiodothyronine or thyroxine (T4) and triiodothyronine (T3). Iodine is essential for the normal rate of hormone synthesis in the thyroid. Deficiency of iodine in our diet results in hypothyroidism and enlargement of the thyroid gland,

commonly called goitre. Hypothyroidism during pregnancy causes defective development and maturation of the growing baby leading to stunted growth (cretinism), mental retardation, low intelligence quotient, abnormal skin, deaf-mutism, etc. In adult women, hypothyroidism may cause menstrual cycle to become irregular. Due to cancer of the thyroid gland or due to development of nodules of the thyroid glands, the rate of synthesis and secretion of the thyroid hormones is increased to abnormal high levels leading to a condition called hyperthyroidism which adversely affects the body physiology.

Thyroid hormones play an important role in the regulation of the basal metabolic rate. These hormones also support the process of red blood cell formation. Thyroid hormones control the metabolism of carbohydrates, proteins and fats. Maintenance of water and electrolyte balance is also influenced by thyroid hormones. Thyroid gland also secretes a protein hormone called thyrocalcitonin (TCT) which regulates the blood calcium levels.

Parathyroid Gland

In humans, four parathyroid glands are present on the back side of the thyroid gland, one pair each in the two lobes of the thyroid gland. The parathyroid glands secrete a peptide hormone called parathyroid hormone (PTH). The secretion of PTH is regulated by the circulating levels of calcium ions.

Parathyroid hormone (PTH) increases the Ca^{2+} levels in the blood. PTH acts on bones and stimulates the process of bone resorption (dissolution/ demineralisation). PTH also stimulates reabsorption of Ca^{2+} by the renal tubules and increases Ca^{2+} absorption from the digested food. It is, thus, clear that PTH is a hypercalcemic hormone, i.e., it increases the blood Ca^{2+} levels. Along with TCT, it plays a significant role in calcium balance in the body.

Thymus

The thymus gland is a lobular structure located on the dorsal side of the heart and the aorta. The thymus plays a major role in the development of the immune system. This gland secretes the peptide hormones called thymosins. Thymosins play a major role in the differentiation of T-lymphocytes, which provide cell-mediated immunity. In addition, thymosins also promote production of antibodies to provide humoral immunity. Thymus is degenerated in old individuals resulting in a decreased production of thymosins. As a result, the immune responses of old persons become weak.

Adrenal Gland

Our body has one pair of adrenal glands, one at the anterior part of each kidney. The gland is composed of two types of tissues. The centrally located tissue is called the adrenal medulla, and outside this lies the adrenal cortex.

The adrenal medulla secretes two hormones called adrenaline or epinephrine and noradrenaline or norepinephrine. These are commonly called as catecholamines. Adrenaline and noradrenaline are rapidly secreted in response to stress of any kind and during emergency situations and are called emergency hormones or hormones of Fight or Flight. These hormones increase alertness, pupilary dilation, piloerection (raising of hairs), sweating etc. Both the hormones increase the heart beat, the strength of heart contraction and the rate of respiration. Catecholamines also stimulate the breakdown of glycogen resulting in an increased concentration of glucose in blood. In addition, they also stimulate the breakdown of lipids and proteins.

The adrenal cortex can be divided into three layers, called zona reticularis (inner layer), zona fasciculata (middle layer) and zona glomerulosa (outer layer). The adrenal cortex secretes many hormones, commonly called as corticoids. The corticoids, which are involved in carbohydrate metabolism are called glucocorticoids. In our body, cortisol is the main glucocorticoid. Corticoids, which regulate the balance of water and electrolytes in our body are called mineralocorticoids. Aldosterone is the main mineralocorticoid in our body.

Glucocorticoids stimulate, gluconeogenesis, lipolysis and proteolysis; and inhibit cellular uptake and utilisation of amino acids. Cortisol is also involved in maintaining the cardio-vascular system as well as the kidney functions. Glucocorticoids, particularly cortisol, produces antiinflamatory reactions and suppresses the immune response. Cortisol stimulates the RBC production.

Aldosterone acts mainly at the renal tubules and stimulates the reabsorption of Na+ and water and excretion of K+ and phosphate ions. Thus, aldosterone helps in the maintenance of electrolytes, body fluid volume, osmotic pressure and blood pressure. Small amounts of androgenic steroids are also secreted by the adrenal cortex which play a role in the growth of axial hair, pubic hair and facial hair during puberty.

Pancreas

Pancreas is a composite gland which acts as both exocrine and endocrine gland. The endocrine pancreas consists of ‘Islets of Langerhans’. There are about 1 to 2 million Islets of Langerhans in a normal human pancreas representing only 1 to 2 per cent of the pancreatic tissue. The two main types of cells in the Islet of Langerhans are called α-cells and β-cells. The α -cells secrete a hormone called glucagon, while the β-cells secrete insulin.

Glucagon is a peptide hormone, and plays an important role in maintaining the normal blood glucose levels. Glucagon acts mainly on the liver cells (hepatocytes) and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia). In addition, this hormone stimulates the process of gluconeogenesis which also contributes to hyperglycemia. Glucagon reduces the cellular glucose uptake and utilisation. Thus, glucagon is a hyperglycemic hormone.

Insulin is a peptide hormone, which plays a major role in the regulation of glucose homeostasis. Insulin acts mainly on hepatocytes and adipocytes (cells of adipose tissue), and enhances cellular glucose uptake and utilisation. As a result, there is a rapid movement of glucose from blood to hepatocytes and adipocytes resulting in decreased blood glucose levels (hypoglycemia). Insulin also stimulates conversion of glucose to glycogen (glycogenesis) in the target cells. The glucose homeostasis in blood is thus maintained jointly by the two – insulin and glucagons.

Prolonged hyperglycemia leads to a complex disorder called diabetes mellitus which is associated with loss of glucose through urine and formation of harmful compounds known as ketone bodies. Diabetic patients are successfully treated with insulin therapy.

Testis

A pair of testis is present in the scrotal sac (outside abdomen) of male individuals. Testis performs dual functions as a primary sex organ as well as an endocrine gland. Testis is composed of seminiferous tubules and stromal or interstitial tissue. The Leydig cells or interstitial cells, which are present in the intertubular spaces produce a group of hormones called androgens mainly testosterone. Androgens regulate the development, maturation and functions of the male accessory sex organs like epididymis,

vas deferens, seminal vesicles, prostate gland, urethra etc. These hormones stimulate muscular growth, growth of facial and axillary hair, aggressiveness, low pitch of voice etc. Androgens play a major stimulatory role in the process of spermatogenesis (formation of spermatozoa). Androgens act on the central neural system and influence the male sexual behaviour (libido). These hormones produce anabolic (synthetic) effects on protein and carbohydrate metabolism.

Ovary

Females have a pair of ovaries located in the abdomen. Ovary is the primary female sex organ which produces one ovum during each menstrual cycle. In addition, ovary also produces two groups of steroid hormones called estrogen and progesterone. Ovary is composed of ovarian follicles and stromal tissues. The estrogen is synthesised and secreted mainly by the growing ovarian follicles. After ovulation, the ruptured follicle is converted to a structure called corpus luteum, which secretes mainly progesterone.

Estrogens produce wide ranging actions such as stimulation of growth and activities of female secondary sex organs, development of growing ovarian follicles, appearance of female secondary sex characters (e.g., high pitch of voice, etc.), mammary gland development. Estrogens also regulate female sexual behaviour.

Progesterone supports pregnancy. Progesterone also acts on the mammary glands and stimulates the formation of alveoli (sac-like structures which store milk) and milk secretion.

HORMONES OF HEART, KIDNEY AND GASTROINTESTINAL TRACT

• Hormones are also secreted by some tissues which are not endocrine glands. For example, the atrial wall of our heart secretes a very important peptide hormone called atrial natriuretic factor (ANF), which decreases blood pressure. When blood pressure is increased, ANF is secreted which causes dilation of the blood vessels. This reduces the blood pressure.

• The juxtaglomerular cells of kidney produce a peptide hormone called erythropoietin which stimulates erythropoiesis (formation of RBC).

• Endocrine cells present in different parts of the gastro-intestinal tract secrete four major peptide hormones, namely gastrin, secretin, cholecystokinin (CCK) and gastric inhibitory peptide (GIP).

• Gastrin acts on the gastric glands and stimulates the secretion of hydrochloric acid and pepsinogen.

• Secretin acts on the exocrine pancreas and stimulates secretion of water and bicarbonate ions.

• Cholecystokinin or CCK acts on both pancreas and gall bladder and stimulates the secretion of pancreatic enzymes and bile juice, respectively.

• Gastric Inhibitory Peptide or GIP inhibits gastric secretion and motility.

• Several other non-endocrine tissues secrete hormones called growth factors. These factors are essential for the normal growth of tissues and their repairing/regeneration.

MECHANISM OF HORMONE ACTION

Hormones produce their effects on target tissues by binding to specific proteins called hormone receptors located in the target tissues only. Hormone receptors present on the cell membrane of the target cells are called membrane-bound receptors and the receptors present inside the target cell are called intracellular receptors, mostly nuclear receptors (present in the nucleus). Binding of a hormone to its receptor leads to the formation of a hormone-receptor complex. Each receptor is specific to one hormone only and hence receptors are specific. Hormone-Receptor complex formation leads to certain biochemical changes in the target tissue. Target tissue metabolism and hence physiological functions are regulated by hormones. On the basis of their chemical nature, hormones can be divided into groups:

(i) peptide, polypeptide, protein hormones (e.g., insulin, glucagon, pituitary hormones, hypothalamic hormones, etc.)

(ii) steroids (e.g., cortisol, testosterone, estradiol and progesterone)

(iii) iodothyronines (thyroid hormones)

(iv) amino-acid derivatives (e.g., epinephrine).

Hormones which interact with membrane-bound receptors normally do not enter the target cell, but generate second messengers (e.g., cyclic AMP, IP3, Ca^{++} etc) which in turn regulate cellular metabolism. Hormones which interact with intracellular receptors (e.g., steroid hormones, iodothyronines, etc.) mostly regulate gene expression or chromosome function by the interaction of hormone-receptor complex with the genome. Cumulative biochemical actions result in physiological and developmental effects.

NCERT Solution

Question 1 - Define the following:

(a) Exocrine gland

(b) Endocrine gland

(c) Hormone

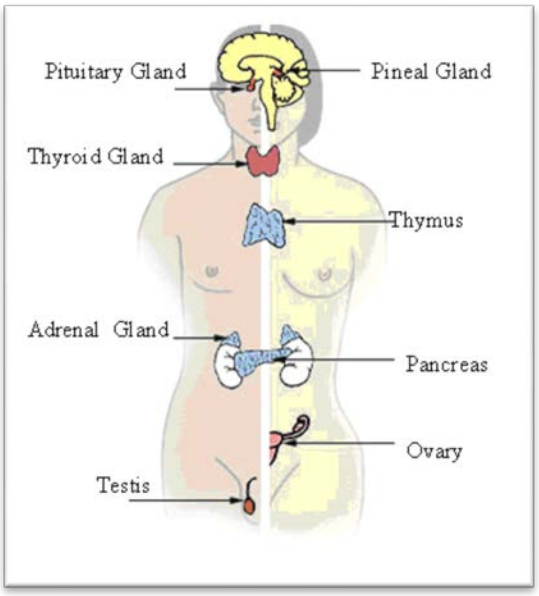
Answer:- (a) Exocrine Glands: These glands have ducts. They secreted their secretions through ducts.

(b) Endocrine Glands: Endocrine glands do not have ducts. They directly secrete their secretions.

(c) Hormone: Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.

Question 2. Diagrammatically indicate the location of the various endocrine glands in our body.

Answer:-



Question 3. List the hormones secreted by the following:

(a) Hypothalamus (b) Pituitary (c) Thyroid (d) Parathyroid (e) Adrenal (f) Pancreas (g) Testis (h) Ovary (i) Thymus (j) Atrium (k) Kidney (l) G-I Tract

Answer:-

(a) Hypothalamus: Releasing Hormone and Inhibiting Hormone

(b) Pituitary:

(i) Growth Hormone

(ii) Prolactin

(iii) Thyroid Stimulating Hormone

(iv) Adrenocorticotrophic Hormone

(v) Luteinizing Hormone

(vi) Follicle Stimulating Hormone

(vii) Melatonin

(c) Thyroid:

(i) Tetraiodothyronine

(ii) Triiodothyronine

(d) Parathyroid: Parathyroid Hormone

(e) Adrenal:

(i) Adrenalin or Epinephrine

(ii) Noradrinaline or Norepinephrine

(iii) Corticoids

(f) Pancreas:

(i) Glcuagon

(ii) Insulin

(g) Testis: Testosterone

(h) Ovary:

(i) Estrogen

(ii) Progesterone

(i) Thymus: Thymosin

(j) Atrium: Atrial Natriuretic Factor

(k) Kideny: Erythropoietin

(l) G I Tract:

(i) gastrin,

(ii) secretin,

(iii) cholecystokinin (CCK) and

(iv) gastric inhibitory peptide (GIP).

Question 4. Fill in the blanks:

Hormones	**Target gland**
(a) Hypothalamic hormones	Pituitary Gland
(b) Thyrotrophin (TSH)	Thyroid Gland
(c) Corticotrophin (ACTH)	Adrenal Cortex
(d) Gonadotrophins (LH, FSH)	Testis and Ovaries

(e) Melanotrophin (MSH) Pineal Gland

Question 5. Write short notes on the functions of the following hormones:

(a) Parathyroid hormone (PTH) (b) Thyroid hormones (c) Thymosins (d) Androgens (e) Estrogens (f) Insulin and Glucagon

Answer: (a) Function of Parathyroid Hormone: Parathyroid hormone (PTH) increases the Ca^{2+} levels in the blood. PTH acts on bones and stimulates the process of bone resorption (dissolution/ demineralisation). PTH also stimulates reabsorption of Ca^{2+} by the renal tubules and increases Ca^{2+} absorption from the digested food. It is, thus, clear that PTH is a hypercalcemic hormone, i.e., it increases the blood Ca^{2+} levels. Along with TCT, it plays a significant role in calcium balance in the body.

(b) Functions of Thyroid Hormones: Thyroid hormones play an important role in the regulation of the basal metabolic rate. These hormones also support the process of red blood cell formation. Thyroid hormones control the metabolism of carbohydrates, proteins and fats. Maintenance of water and electrolyte balance is also influenced by thyroid hormones. Thyroid gland also secretes a protein hormone called thyrocalcitonin (TCT) which regulates the blood calcium levels.

(c) Functions of Thymosins: Thymosins play a major role in the differentiation of T-lymphocytes, which provide cell-mediated immunity. In addition, thymosins also promote production of antibodies to provide humoral immunity.

(d) Functions of Androgen: Androgens regulate the development, maturation and functions of the male accessory sex organs like epididymis, vas deferens, seminal vesicles, prostate gland, urethra etc. These hormones stimulate muscular growth, growth of facial and axillary hair, aggressiveness, low pitch of voice etc. Androgens play a major stimulatory role in the process of spermatogenesis (formation of spermatozoa). Androgens act on the central neural system and influence the male sexual behaviour (libido). These hormones produce anabolic (synthetic) effects on protein and carbohydrate metabolism.

(e) Functions of Estrogen: Estrogens produce wide ranging actions such as stimulation of growth and activities of female secondary sex organs, development of growing ovarian follicles, appearance of female secondary sex characters (e.g., high pitch of voice, etc.), mammary gland development. Estrogens also regulate female sexual behaviour.

(f) Functions of Insulin and Glucagon: Glucagon is a peptide hormone, and plays an important role in maintaining the normal blood glucose levels. Glucagon acts mainly on the liver cells (hepatocytes) and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia). In addition, this hormone stimulates the process of gluconeogenesis which also contributes to hyperglycemia. Glucagon reduces the cellular glucose uptake and utilisation. Thus, glucagon is a hyperglycemic hormone.

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