BRILLIANT PUBLIC SCHOOL , SITAMARHI

(Affiliated up to +2 level to C.B.S.E., New Delhi)

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XI-Biology Chapter Notes

Session : 2014-15

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1. The Living World

POINTS TO REMEMBER:

Characteristics of Living Organisms : Growth, reproduction, metabolism, cellular organization, consciousness (ability to sense environment), self-replicating and self regulation.

- Reproduction and growth are NOT defining properties.
- Metabolism, cellular organization and consciousness are defining properties.

Biodiversity : Term used to refer to the number of varieties of plant and animals on earth.

Nomenclature: standardize the naming of living organism such that a particular organism is known by the name all over the world.

Identification: nomenclature or naming is only possible when the organism is described correctly and we known to what organism the name is attached to.

Need for classification: To organize the vast number of plants and animals into categories that could be named, remembered, studied and understood.

Rules for Nomenclature:

- Latinized names are used, written in italics
- First word represents the genus, second word is species name.
- Printed in italics; if handwritten then underline separately.
- First word starts with capital letter while species name written in small letter.

ICBN: International Code of Botanical Nomenclature (for giving scientific name to plants.)

ICZN: International Code of Zoological Nomenclature (for giving scientific name to animals.)

Taxonomy: Study of principles and procedures of classification.

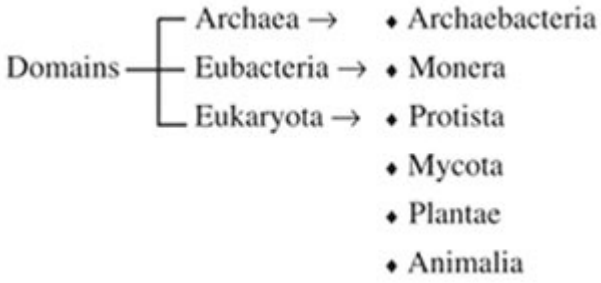
Binomial Nomenclature: Given by Carolus Linnaeus. Each scientific name has two components - Generic name + Specific epithet.

Systematics: It deals with classification of organisms based on their diversities and relationships among them. Term was proposed by Carolus Linnaeus who wrote 'Systema Naturae'.

Taxonomic Hierarchy: Arrangement of various steps (categories or taxa Species → Genus → Family → Order → Class → Phylum (for animals) /Division (for plants) Kingdom→

Species: All the members that can interbreed among themselves and can produce fertile offsprings are the members of same species. This is the bio-logical concept of species proposed by Mayer.

Three Domains of Life: Proposed by Carl Woese in 1990 who also proposed the six kingdom classification for living organisms. The three Do-mains are Archaea, Eubacteria and Eukarya.



Herbarium: Storehouse of dried, pressed and preserved plant specimen on sheets.

Botanical Garden: Collection of living plants for reference.

Taxonomical aids: Zoological Park (Places where wild animals are kept in protected environment.)

- **Keys** (Used for identification of plant and animals on the basis of similarities and dissimilarities.)
- **Fauna:** (Index to animal species found in a particular area)
- **Flora** (Index to plant species found in a particular area.)
- **Manuals** (Provide information for identification of name of species in an area.)
- **Monograph** (Contain information on one taxon.)

2. Biological Classification

POINTS TO REMEMBER :

SYSTEMS OF CLASSIFICATION :

- Earliest Classification was given by Aristotle. Divided plants into herbs, shrubs and trees. Animals into those with RBC's and those who do not have it.

Two kingdom classification :

- Given by Carolous Linnaeus − Plant kingdom and Animal kingdom.

Five kingdom classification :

- By R. H. Whittaker. Monera, Protista, Fungi, Plantae and Animalia are the five kingdoms.

Kingdom Monera :

Bacteria :

- Have bacteria a sole member.
- Bacteria can have shapes like: Coccus (spherical), Bacillus (rod-shaped), Vibrio comma shaped) and sprillum (spiral shaped).
- Bacteria found almost everywhere and can be Photosynthetic autotrophs, Chemosynthetic autotrophs or Heterotrophs.

Archaebacteria :

- Differs from bacteria having different cell wall structure.
- They live in most harsh habitats
- **Halophiles** (salt-loving)
- **Thermophiles** (in hot springs)
- **Acidophiles** (high acidic condition)
- **Methanogen** (marshy area)
- Methanogen are also found in the gut of ruminant and produces biogas.

Eubacteria :

- Called true bacteria having a rigid cell wall, and if motile a flagellum.
- They also known as blue green algae or **Cyanobacteria**.
- Cyanobacteria are **photosynthetic autotrophs**.
- Unicellular, colonial or filamentous, marine and terrestrial algae.
- Colonies are surrounded by **gelatinous sheath**.
- Some of these can fix atmospheric nitrogen by specialized cells called **heterocyst**, e.g. *Nostoc* and *Anabaena.*
- **Chemosynthetic autotrophs**: Oxidize various inorganic substances like nitrates/nitrites, ammonia and use released energy for their ATP production.
- Heterotrophic bacteria:
    - Mostly decomposer
    - Helpful in making curd from milk
    - Produce antibiotics

    - Symbiotically associated with leguminous plant and fix nitrogen.
    - Some are pathogen causing diseases like cholera, typhoid, and tetanus.
- Bacteria reproduce mainly by **fission**, also produce **spore** in unfavorable condition.
- Reproduce sexually by transfer of DNA form one bacteria to other, the process called **conjugation**.

Mycoplasma :

- Completely lack cell wall.
- Smallest living cells.
- Can survive without oxygen.
- Pathogenic in animals and plants.

Kingdom Protista :

- All are unicellular and eukaryotic.
- Mostly aquatic, can live in moist places.
- Forms a link between plants, animals and fungi.
- The cell contain nucleus and membrane bound organelles.

Chrysophytes :

- Includes diatoms and **golden algae** (desmids)
- Found in freshwater or marine water.
- Mostly planktonic (passive swimmer)
- Photosynthetic.
- Cell walls overlap to fit together like a soap box.
- Cell wall contains silica hence indestructible.
- Their accumulation forms '**Diatomaceous Earth'**.
- Used in polishing, filtration of oils and syrups.
- Diatoms are the chief '**producers'** in the oceans.

Dinoflagellates :

- Marine, photosynthetic.
- Cell wall has stiff cellulose plates.
- Appears yellow, green, brown, blue or red depending on the pigments.
- Have two flagella − one longitudinal and other transversely in a furrow between wall plates.
- Red Dinoflagellates (***Gonyaulax***) form **red tides.**

<u>Euglenoids</u> :

- Mostly fresh water form found in stagnant water.
- Instead of cell wall they have protein rich layer 'pellicle' which makes body flexible.
- They have two flagella one short and one long
- Photosynthetic in presence of sunlight but become heterotrophs if they do not get sunlight. e.g. *Euglena*

<u>Slime Moulds</u> :

- Saprophytic Protists
- Form aggregates to form plasmodium grow on decaying twigs and leaves.

- Plasmodium forms fruiting bodies bearing spores at their tips.
- Spores have true walls which are extremely resistant and survive for many years.

Protozoans :

- All protozoans are heterotrophs and live as predators or parasites.
- Believed to be primitive relatives of animals.
- These are divided into four major groups on the basis of locomotery organelle they have.

Amoeboid protozoans :

- Move and Catch prey using pseudopodia, e.g., Amoeba.
- Many forms have silica shells on their surface.
- Some of them are parasitic e.g. *Entamoeba.*

***Flagellated protozoans* :**

- Either free living or parasitic.
- They have flagella.
- Cause disease like sleeping sickness e.g., Trypanosome.

***Ciliated protozoans* :**

- These are aquatic, actively moving organisms due to presence of thousands of cilia. e.g., *Paramecium*.
- They have a cavity called gullet that opens to outside the cell.

***Sporozoans* :**

- Lack any locomotery organelle.
- All members are parasitic.
- Have infective spore like stage in life cycle, e.g., *Plasmodium* which causes Malaria.

KINGDOM FUNGI :

- With the exception of yeasts which are unicellular all others are multicellular and filamentous.
- Consists of long slender thread like structure called hypha.
- Non chlorophyllous
- Network of hyphae called mycelium.
- Uninucleated or multinucleated (coenocytic)
- Cell wall made of complex polysaccharide called **chitin**.
- Grow in warm and humid places.
- Saprophytic, parasitic, symbiotic (**Lichen**)
- Reproduce asexually by spores conidia sporangiospores or zoospores.
- Sexual reproduction is by oospores, ascospores and basidiospores.
- Sexual cycle involves the following thee steps:
- ***Plasmogamy***: fusion of protoplasms between two motile or non-motile gametes.
- ***Karyogamy***: fusion of two nuclei
- ***Meiosis***: zygote undergoes meiosis resulting haploid spores.

e.g., *Puccinia* (rust causing), *Penicillium*.

CLASSES OF FUNGI -

Phycomycetes **:**

- Found in aquatic habitat, on decaying wood in moist and damp places.
- Some of them are obligate parasite on plants.
- Mycelium is **aseptate** and **coenocytic**
- Asexual reproduction by zoospores (motile) or by aplanospores (nonmotile).
- Spores are produced endogenously in sporangium.
- **Zygospore** produced by fusion of gametes.

e.g., *Rhizopus, Albugo*.

Ascomycetes **:**

- Commonly known as **'sac fungi'.**
- Unicellular (yeasts) or multicellular (e.g. *Penicillium)*
- Saprophytic, decomposers, parasitic or coprophilous.
- Mycelium branched and septate.
- Asexual spores are called conidia produced exogenously on the conidiophores. Conidia on germination produce mycelium.
- Sexual spores are called ascospores produced endogenously in ascus produced inside fruiting body called**Ascocarp**.

e.g., *Aspergillus, Neurospora*.

(iii) ***Basidiomycetes***

- Common known forms called mushrooms, bracket fungi or puffballs.
- Mycelium septate and branched.
- Asexual spores generally are not found.
- Vegetative reproduction by fragmentation.
- Sexual reproduction by fusion of vegetative or somatic cells of different strains to form basidium produced in basidiocarp.
- Basidium produces four basidiospores after meiosis.

e.g., *Agaricus, Ustilago*.

Deuteromycetes :

- Called as '**Fungi Imperfecti'** as sexual form (perfect stage) is not known for them.
- Once sexual form is discovered the member is moved to Ascomycetes or Basidiomycetes.
- Mycelium is septate and branched.
- Are saprophytic, parasitic or decomposers.

e.g., *Alternaria, Colletotrichum*.

Viruses :

- They did not find a place in classification. Take over the machinery of host cell on entering it but as such they have inert crystalline structure. So, difficult to call them living or non-living.
- Pasteur gave the term 'Virus' i.e., poisonous fluid.
- D. J. Ivanowsky (1892) found out that certain microbes caused Tobacco Mosaic Disease in tobacco plant.

- M. W. Beijerinek (1898) called fluid as 'Contagium vivum fluidum' as extracts of infected plants of tobacco could cause infection in healthy plants.
- W. M. Stanely (1935) showed viruses could be crystallised to form crystals of protein which are inert outside their specific host.

Structure of Virus :

- Its a nucleoprotein made up of protein called Capsid. Capsid is made up of capsomeres arranged in helical or polygeometric forms. Have either DNA or RNA as genetic material which may be single or double stranded.
- Usually plant viruses have single stranded RNA; bacteriophages have double stranded DNA and animal viruses have single or double stranded RNA or double stranded DNA.

Diseases caused : Mumps, Small pox, AIDS etc.

Viroids :

- Infectious agent, free RNA (lack protein coat)
- RNA has low molecular weight.
- Causes potato spindle tuber disease.
- Discovered by **T. O. Diener in 1971**

Lichens :

- Symbiotic association between algal component (**Phycobiont**) and fungal component (**Mycobiont**). Algae provide food. Fungi provide shelter and absorb nutrients for alga.
- Good pollution indicators as they do not grow in polluted areas.

3. Plant Kingdom

POINTS TO REMEMBER :

CLASSIFICATION :

Artificial System of Classification :

- Used superficial morphological characters.
- Based on a few characteristics like habit, colors, number and shape of leaf.
- Mainly based on vegetative characters.
- Such system developed by Linnaeus.

Natural System of Classification :

- Based on natural affinities among organisms
- Included external as well as internal features like anatomy, embryology and phytochemistry.
- Developed by George Bentham and J. D. Hooker

Phylogenetic System of Classification :

- Based on evolutionary relationships between the various organisms.
- Organism belongs to same taxa have a common ancestors.
- Developed by Hutchinson.

***Numerical Taxonomy* :**

- Carried out using computers
- Based on all observable characteristics
- Data processed after assigning number and codes to all the characters.

***Cytotaxonomy* :**

- Based on cytological information.
- Gives importance to chromosome number, structure and behaviour.

Chemotaxonomy :

- Based on chemical constituents of the plants.

ALGAE :

- Chlorophyll bearing, simple, thalloid, autotrophic and mostly aquatic organisms. Moist stone, soils and wood are the other habitat.
- The size ranges from microscopic unicellular forms like *Chlamydomonas*, to colonial forms like *Volvox* and to filamentous forms like *Ulothrix* and *Spirogyra.* A few marine forms such as kelps, form massive plant bodies.
- Reproduce vegetatively by fragmentation.
- Reproduce asexually mostly by producing motile spore called **zoospores.**
- Reproduce sexually by producing gametes.

- ***Isogamous*:** both gametes are same size and motile
- ***Anisogamous*:** both gametes are dissimilar in size but motile.
- ***Oogamous*:** male gamete is smaller but motile, female gamete is large and non- motile.

Importance of Algae :

- At least half of the total carbon dioxide fixation on earth carried out by them.
- Increase oxygen level in the environment.
- Many species like *Laminaria*, *Sargassum* etc. are used as food.
- **Agar** obtained from *Gelidium* and *Gracilaria* is used in ice-creams and jellies and also used to culture bacteria.
- **Algin** obtained from brown algae and **carrageen** from red algae used commercially.
- *Chlorella* and *Spirullina* are unicellular algae, rich in protein and used as food supplement even by space travelers.

Algae divided into 3 classes :

Chlorophyceae :

- Commonly known as **Green algae**.
- Main pigment is chlorophyll 'a' and 'b'.
- Unicellular, colonial or filamentous.
- Cell wall has inner layer of cellulose and outer layer of pectose.
- Have **pyrenoid** as the storage body for starch and proteins.

e.g., *Chlamydomonas, Volvox, Spirogyra*.

Phaeophyceae :

- Commonly known as **Brown algae** and mainly found in marine habitat.
- They possess chlorophyll a, c, **carotenoid**, **xanthophylls** and **fucoxanthin**.
- Cell wall has cellulose and lignin or gelatinous coating of **algin.**
- Has **mannitol** and **laminarin** as reserve food material.
- Body divisible into **holdfast**, **stipe** and **frond**.
- Reproduce asexually by biflagellate pear-shaped zoospores.

e.g., *Ectocarpus, Fucus, Laminaria*.

Rhodophyceae :

- Commonly known as **red algae**.
- Red color is due to predominance of red pigment r-phycoerythrin in their body along with chlorophyll a, d.
- Found on surface as well as great depths in oceans.
- Cell wall made of cellulose, pectin and **polysulphate esters**.
- Reserve food material is **floridean starch** similar to amylopectin and glycogen in structure.
- Reproduce asexually by non motile spores and sexually by non motile gametes (**Oogamous** type)

e.g., *Polysiphonia, Porphyra, Gelidium*.

BRYOPHYTES : Amphibians of plant kingdom

- Occur in damp, humid places.

- Lack true roots, stem or leaves.
- Plant body attached to the soil by unicellular or multicellular rhizoids.
- Main plant body is haploid (n), or **gametophytic**.

REPRODUCTION IN BRYOPHYTES :

- Vegetative reproduction by **fragmentation**.
- Asexual reproduction by **gemmae** formed in **gemma cups**.

Sexual reproduction :

- Main plant body is **gametophyte**.
- The sex organs in bryophytes are multicellular.
- Male sex organ is called **antheridium** which produces biflagellate **antherozoids** as male gamete.
- Female sex organ is **archegonium** is flask shaped and produces a single egg.
- Fertilization takes place in water results in formation of zygote.
- The zygote developed into a multicellular body called **sporophyte** which remains **parasitic** on female gametophyte.
- The sporophyte differentiated into **foot**, **seta** and **capsule**.
- Some cells of the capsule undergo meiotic division to produce haploid spores. These spores germinated into an independent gametophyte.
- Moss gametophyte consists of two stages
- First stage is called **protonema stage** which developed from the spore and is creeping, green, branched.
- Second stage is **leafy stage** which developed from the protonema stage as a lateral bud. They consist of upright, slender axes bearing spirally arranged leaves.

Economic Importance :

- Food for herbaceous animals.
- Sphagnum in form of peat is used as fuel and also used for trans-shipment of living material as it has water holding capacity, prevent soil erosion, along with lichens are first colonizers on barren rocks.
- They decompose rocks making substrate for the growth of higher plant.

PTERIDOPHYTES :

- First terrestrial plant possesses vascular tissue like **xylem** and **phloem**.
- The plant body differentiated into true root, stem and leaf.
- The main plant body is **sporophytic**.
- Leaves may be small (**microphyll**) as in Selaginella or large (**macrophyll**) as in ferns.
- Sporangia having spores are subtended by leaf-like appendages called **sporophylls**. (Sporophylls may be arranged to form **strobili** or **cones**.)
- In Sporangia, the spore mother cells give rise to spores after meiosis.
- Spores germinate to form haploid gametophytic structure called **prothallus** which is free living, small, multicellular and photosynthetic.
- Prothallus bears **antheridia** and **archegonia** which bear **antherozoids** and **egg cell** respectively which on fertilization form zygote.
- Zygote developed into multicellular, well differentiated **sporophyte**.
- Most of pteridophytes produce similar kinds of spores hence called **homosporous.**
- Genera like *Selaginella* and *Salvinia* which produce two kind of spores, macro (large) and small (micro) spores are known as **heterosporous**. Microspore and macrospore germinate and gives rise to male and female gametophyte respectively.

- The female gametophytes in these plants are retained on the parent sporophyte for variable period. The development of zygote into young embryo takes place within the female gametophytes. This events is a precursor to the **seed habits** considered an important steps in evolution
- Pteridophytes further classified into four classes: Psilopsida (*Psilotum*), Lycopsida (*Selaginella*), Sphenopsida (*Equisetum*) and Pteropsida (*Pteris*).

GYMNOSPERMS :

- Have naked seeds as the ovules are not enclosed by any ovary wall and remain exposed both before and after fertilization.
- Gymnosperm includes medium-sized trees or tall trees and shrub.
- Root is generally tap root. May be associated with **myorrhiza.**
- Stem is branched (Pinus), or unbranched (Cycas).
- Leaves may be simple or compound.

REPRODUCTIONS :

- Gymnosperms are heterosporous. They produce haploid microspores and megaspores.
- **Male strobili or cone** has **microsporophylls** which bear **microsporangia** having microspores which develop into reduced gametophyte called **pollen grain**.
- **Female cone or strobili** has **megasporophylls** which bear **megasporongia** having **megaspores** which are enclosed within the **megasporangium** (Nucellus). One megaspore develops into female gametophyte bearing two or more**archegonia.**
- Pollen grains carried in air currents reach ovules, form pollen tube which reach archegonia and release male gametes which fertilize egg cell and form zygote which produce embryos. Ovules develop into seeds which are not covered.

ANGIOSPERMS :

- Called flowering plants and have seeds enclosed in fruits.
- Divided into two classes − Dicotyledons (have two cotyledons) and Monocotyledons (have one cotyledon).
- Smallest angiosperm: ***Wolfia*** (microscopic).
- Large tree: **Eucalyptus** over 100 meters.
- Reproductive organs developed in **flowers**.
- Male sex organs in a flower are called **stamens**.
- Stamen has **filament** and **anther**. Anthers on meiosis produce **pollen grains**. Pollen grains have two male gametes.
- Female sex organs are **pistil**.
- Pistil has **stigma**, **style** and **ovary**. Ovary has one or many ovule in which female gametophyte (**embryo sac**) develops by meiosis.
- Embryo sac has 7 cells and 8 nuclei. One **egg cell**, 2 **synergids**, 3 **antipodal** and one central cell having two polar nuclei.
- Pollen grain is carried by wind; water etc. reaches to stigma and produces pollen tube which enters embryo sac.

Double fertilization:

- **Syngamy**: One male gamete fuses with egg cell to form zygote which develops into embryo.
- **Triple fusion**: Other male gamete fuses with secondary nucleus (formed by fusion of two polar nuclei) which forms triploid primary endosperm nucleus (PEN). PEN develops into endosperm which nourishes the developing embryo.
- Ovules develop into seeds and ovaries into fruits.

Alternation of generation: Haploid gametophytic and spore producing sporophytic generation alternate with each other in this process.

- **Haplontic:** Gametophytic phase dominant. e.g., Chlamydomonas
- **Diplontic**: Sporophytic phase dominant. e.g., Angiosperms and Gymnosperms

- **Haplo-Diplontic**: Intermediate like stage where gametophytic and sporophytic stage partially dominates at different stages. e.g., Bryophytes and Pteridophytes.

Exceptions: Ectocarpus, Polysiphonia are Haplo-diplontic algae. Fucus is diplontic alga.

4. Animal Kingdom

POINTS TO REMEMBER :

Levels of organization :

- Cellular level
- Tissue level
- Organ level
- Organ system level

Circulatory System :

Open type: Blood pumped out through heart. Cells and tissues are directly bathed in it.

Closed type: Blood is circulated through vessels.

Symmetry :

- ***Asymmetrical*:** Cannot be divided into equal halves through median plane. e.g., Sponges.
- ***Radial symmetry***: Any plane passing through central axis can divide organism into equal halves. e.g., Hydra.
- ***Bilateral symmetry***: Only one plane can divide the organism into equal halves. e.g., Annelids and Arthropods.

CLASSIFICATION ON BASIS OF GERMINAL LAYERS :

- **Diploblastic:** Cells arranged in two embryonic layers i.e. external ectoderm and internal endoderm. (Mesoglea may be present in between ectoderm and endoderm) e.g., Coelenterates. (Cnidarians)
- **Triploblastic**: Three layers present in developing embryo i.e., ectoderm, endoderm and mesoderm. e.g., Chordates.
- **Coelom** (Body cavity which is lined by mesoderm)
- **Coelomates**: Have coelom e.g., Annelids, Chordates etc.
- **Pseudocoelomates:** No true coelom as mesoderm is present in scattered pouches between ectoderm and endoderm. e.g., Aschelminthes.
- **Acoelomates**: Body cavity is absent. E.g. Platyhelminthes.
- **Metamerism:** If body is externally and internally divided into segments with serial repetition of at least some organs then phenomenon is called metamerism. e.g., Earthworm.
- **Notochord**: Rod-like structure of mesodermal origin, formed during embryonic development on the dorsal side. e.g., Chordates.

PHYLUM PORIFERA :

- Also called sponges.
- Are usually marine and **asymmetrical**.
- Have **cellular level** of organization.
- Food gathering, respiratory exchange and removal of wastes occur through water **canal system**.
- Digestion **intracellular.**
- **Ostia** (minute pores on body), **spongocoel** (body cavity) and **osculum** help in water transport. They are lined by**choanocytes** (collar cells).
- Body wall has **spicules** and **spongin** fibers.
- Animals are **hermaphrodite**.
- Fertilization internal.

- Development is indirect, with larval stage which metamorphoses to adult. e.g., *Sycon, Euspongia*.

PHYLUM COELENTERATA :

- Also called Cnidarians.
- Are usually marine and radially symmetrical.
- Sessile or free-swimming.
- Have **tissue level** of organization
- Diploblastic.
- Presence of **cnidoblast**, for anchorage, defense and capture of prey.
- Central body cavity called **gastro-vascular cavity** or **coelenterone**.
- Digestion extracellular and intracellular.
- Blind sac type body plan, with one opening called **hypostome**.
- Body wall composed of calcium carbonate.
- Exhibit two body forms: **polyp** and **medusa** e.g., Hydra, Aurelia.
- Alternation of generation between body forms called **Metagenesis** occurs in *Obelia* where Medusa sexually reproduced and polyp asexually reproduced. •e.g., *Physalia, Adamsia*.

PHYLUM CTENOPHORA :

- Also called as **sea walnuts** or **comb jellies**.
- Are exclusively marine, radially symmetrical.
- Have tissue level organisation, are diploblastic.
- Digestion both extra and intracellular.
- Body has eight external rows of ciliated **comb plates** for locomotion.
- Show Bioluminescence (living organism emit light).
- Sexes are not separate i.e. hermaphrodite.
- Reproduce only by sexual methods.
- External fertilization.
- Indirect development

e.g., *Ctenoplana. Pleurobranchia*

PHYLUM PLATYHELMINTHES :

- Also called as '**flat worms'**.
- Have dorsoventrally flattened body.
- Mostly endoparasites in animals including human.
- Bilaterally symmetrical,
- **Triploblastic**
- Acoelomate
- Organ level organization.
- Absorb nutrients through body surface.
- Parasite forms have hooks and suckers.
- '**Flame cells'** help in osmoregulation and excretion.
- Fertilization internal. Many larval stages.
- *Planaria* has high **regeneration** capacity.

e.g., *Taenia, Fasciola*.

PHYLUM ASCHELMINTHES :

- Also called '**round worms'**.
- May be free living, parasitic, aquatic or terrestrial.
- Are bilaterally symmetrical, triploblastic, **Pseudocoelomates.**
- Alimentary canal complete (has muscular pharynx), wastes removed through excretory pore.
- Organ system level of organization.
- Sexes separate i.e. **dioecious.**
- Shows **sexual dimorphism**.
- Females longer than males.
- Fertilisation internal.
- Development direct or indirect.

e.g., Ascaris, Wuchereria.

PHYLUM ANNELIDA :

- Are aquatic or terrestrial, free-living or parasitic.
- Are bilaterally symmetrical, triploblastic,
- Organ-system level of organization
- **Metamerically** segmented body.
- Have longitudinal and circular muscles in body wall for locomotion.
- Aquatic annelid like *Nereis* has oar shaped **parapodia** for movement.
- Have **nephridia** for osmoregulation and excretion.
- Nervous system consists of paired ganglia connected by lateral nerves to a double ventral nerve cord.
- Circulatory system is closed type.
- Earthworm (*Pheretima*) and Leech (*Hirudinaria*) which are hermaphrodites (i.e., monoecious).
- Nereis an aquatic form is dioecious.
- Fertilization is external
- Development is direct or indirect.

PHYLUM ARTHROPODA :

- Largest phylum of Animalia includes insects.
- Are bilaterally symmetrical, triploblastic and organ system level of organization, coelomate and segmented body.
- Body divisible into **head, thorax, abdomen.**
- Body covered by a **chitinous exoskeleton**.
- They have **jointed appendages**.
- Respiration by **gills, book gills, lungs** or **tracheal system.**
- **Circulation is open type.**
- Excretion through **malpighian tubules**.
- Sensory organs: Antennae, eyes; Organs of balance: Statocysts.
- Mostly dioecious.
- Fertilisation internal.
- Are mostly oviparous.
- Development is indirect or direct. e.g., *Apis, Bombyx, Anopheles, Locusta, Limulus.*

PHYLUM MOLLUSCA :

- Second largest phylum of Animalia.
- Terrestrial or aquatic.
- Are bilaterally symmetrical, triploblastic and organ system level of organization, coelomate.
- Body divisible into **head, muscular foot** and **visceral hump** and is covered by a soft and spongy layer of skin called**mantle**.
- Unsegmented body.
- Body is covered by calcareous shell.
- Respiration and excretion by feather like gills (ctenedium) in mantle cavity.
- Head has sensory tentacles. **Radula**-file like rasping organ for feeding.
- Usually dioecious, dioecious, have indirect development.

e.g., *Pila, Pinctada, Octopus.*

PHYLUM ECHINODERMATA :

- Are spiny bodied organisms.
- Endoskeleton of **calcareous ossicles**.
- Are exclusively marine.
- Radially symmetrical in adult but bilaterally symmetrical in larval stage.
- Organ system level of organization.
- Triploblastic and **eucoelomate.**
- Digestive system complete. Mouth ventral, Anus on dorsal side.
- Food gathering, respiration, locomotion carried out by **water vascular system**.
- Excretory system is absent.
- Dioecious i.e. sexes are separate.
- Fertilization external. Development indirect (free swimming larva)

e.g., Asterias, Cucumaria.

PHYLUM HEMICHORDATA :

- Have small worm-like marine animals.
- Was earlier placed as sub-phylum of Phylum Chordata.
- Bilaterally symmetrical, triploblastic and coelomate.
- Body cylindrical, has proboscis, collar and trunk.
- Circulation is open type.
- Respiration by gills
- Excretion by proboscis gland.
- Sexes separate, external fertilization, indirect development.

e.g., *Balanoglossus*

PHYLUM CHORDATA :

- Presence of Notochord (between gut and nerve cord)
- Have dorsal hollow nerve chord.
- Have paired pharyngeal gill slits.
- Heart is ventral.
- Post anal tail present.
- Bilaterally symmetrical, triploblastic, and coelomate with organ system level of organization.
- Circulation is closed type.

SUB-PHYLA UROCHORDATA :

- Notochord present only in tail of larval stage. e.g., *Ascidia, Salpa, Doliolium*.

SUB-PHYLA CEPHALOCHORDATA :

- Notochord extends from head to tail. e.g., *Amphioxus.*

SUB-PHYLA VERTEBRATA :

- Have notochord only during embryonic period.
- Notochord gets replaced by bony or cartilaginous vertebral column.
- Have ventral muscular heart with two, three or four chambered.
- Paired appendages which may be fins or limbs.
- Kidneys for excretion and osmoregulation.

Division Agnatha (lack jaws) -

Class: Cyclostomata :

- Have sucking and circular mouth without jaws.
- Live as ectoparasites on some fishes.
- Devoid of scales, no paired fins.
- Cranium and vertebral column is cartilaginous.
- Marine habit but migrates to fresh water for spawning and die after spawning.
- Larva returns to ocean after metamorphosis.

e.g., *Petromyzon.*

Division Gnathostomata (Bear Jaws) -

SUPER-CLASS: PISCES -

Class 1: Chondrichthyes :

- Have cartilaginous endoskeleton.
- Mouth ventrally located.
- Notochord persists throughout life.
- Gill slits are separate and without operculum.
- Skin has **placoid scales.**
- Jaw contains teeth, which are modified placoid scales.
- Mostly predaceous.
- **Swim bladder absent.**
- Heart is two chambered. (one auricle and one ventricle)
- Some of them contain electric organs (e.g. Torpedo)
- Some possesses poison sting. (e.g. Trygon)
- Poikilotherm or cold blooded.
- Dioecious.
- Sexually dimorphic, male's pelvic fin bears claspers.
- Fertilization internal.

- Many of them viviparous.

e.g., *Torpedo, Trygon, Scoliodon*.

Class 2 : Osteichthyes :

- Includes both marine and fresh water fishes.
- Bony endoskeleton.
- Mouth is usually terminal.
- Four pairs of gill slits covered by operculum.
- Skin has cycloid/ctenoid scales.
- Air bladder is present for buoyancy.
- Heart is two chambered.
- Cold blooded animals.
- Dioecious.
- Sexually monomorphic.
- Fertilization external.
- Mostly oviparous
- Development is indirect.

e.g., *Hippocampus, Labeo, Catla, Betta*.

SUPER CLASS: TETRAPODA -

Class-1: Amphibia

- Can live in aquatic as well as terrestrial habitats.
- Most of them have two pairs of limbs.
- Body divisible into head and trunk.
- Skin moist, without scales.
- Tympanum represents ear.
- **Cloaca** is the common chamber where alimentary, urinary and reproductive tracts open.
- Respiration by gills, lungs or skin.
- Heart is 3-chambered.(two auricle and one ventricle)
- Cold blooded animals.
- Sexes separate.
- Fertilization is external and requires water.
- Oviparous. Indirect development.

    - e.g., *Bufo, Rana, Hyla.*

Class - 2: Reptilia

- Creeping or crawling mode of locomotion.
- Body has dry and cornified skin and epidermal scales or scutes.
- Tympanum represents ear.
- Limbs when present are two pairs.
- Mostly three chambered heart but 4-chambered in crocodiles.

- Snakes and lizards shed scales as skin cast.
- Poikilotherm.
- Sexes are separate.
- Fertilization internal.
- Oviparous. Direct development.

    - e.g., *Testudo, Naja, Vipera, Calotes.*

Class - 3: Aves

- Presence of feathers and most cay fly except flightless bird like ostrich.
- Jaw modified to beak without teeth.
- Forelimbs are modified into wings.
- Hind limbs have scales.
- No glands on skin except oil gland at base of tail.
- Endoskeleton bony with air cavities (pneumatic) and hollow bones to assist in flight.
- Digestive tract has additional chambers like crop and gizzard.
- Heart is four chambered.
- Homoiothermous or warm blooded, able to maintain constant temperature.
- Air sacs are connected to lungs to supplement respiration.
- Oviparous. Direct development.

    - e.g., *Columba, Struthio, Corvus*.

Class- 4: Mammalia

- Have mammary glands to nourish young ones by secreting milk.
- Have two pairs of limbs.
- Skin has hairs.
- External ears or pinna present.
- Different types of teeth in jaw.
- Heart is four chambered.
- Homoiothermous.
- Respiration by lungs.
- Sexes separate, fertilization internal.
- Viviparous or oviparous. Direct development.

e.g., Rattus, Canis Elephas, Equus. Oviparous mammal is Ornithorhynchus."

5. Morphology of Flowering Plants

POINTS TO REMEMBER :

- **Morphology:** The study of various external features of the organism is known as morphology.
- **Adaptation:** Any alteration in the structure or function of an organism or any of its part that results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment.
- **The Root**: The root is underground part of the plant and develops from elongation of radicle of the embryo.

Various types of root :

- **Tap root:**
  - Originated from the radicle.
  - Persistent in dicot plant. E.g. gram, pea , mango
- **Fibrous root**
  - Originates from the base of the stem.
  - Large number of roots replaces the primary root.
  - This type of root found in monocot plant. E.g. wheat, paddy, grass.
- **Adventitious root**
  - Roots developed from any part of the plant other than radicle.
  - Found in grass, *Monstera* and the banyan tree.

Function of root :

- Absorption of water and mineral from soil
- Anchorage of the plant body
- Storing reserve food material.
- Synthesis of plant growth regulators.

Regions of root :

- **Root Cap :** The root is covered at the apex by the thimble-like structure which protects the tender apical part.
- **Region of meristematic activity :**
  - Cells of this region have the capability to divide.
  - The cells of this region are very small, thin-walled and with dense protoplasm.
- **Region of elongation :**
  - Cells of this region are elongated and enlarged.
- **Region of Maturation :**
  - This region has differentiated into matured cells.
  - Some of the epidermal cells of this region form thread-like **root hairs,** which absorbs water and minerals from the soil.

Modifications of Root :

- Roots are modified for support, storage of food, respiration.
- For support : **Prop roots** in banyan tree, **stilt roots** in maize and sugarcane.
- For respiration: **pneumatophores** in Rhizophora (Mangrove).
- For storage of food: **Fusiform** (radish), **Napiform** (turnip), **Conical** (carrot).

The Stem :

- Stem is the aerial part of the plant and develops from **plumule** of the embryo.
- It bears **nodes** and **internodes.**
- Bears **bud,** may be **axillary** or **terminal**
- Main function is to spreading branches bearing leaves, flower and fruits.

Modifications of Stem :

- **For food storage**: Rhizome (ginger), Tuber (potato), Bulb (onion), Corm and Colocasia).
- **For support**: Stem **tendrils** of watermelon, grapevine, and cucumber.
- **For protection**: Axillary buds of stem of citrus, Bougainvillea get modified into pointed **thorns**. They protect the plants from animals.
- **For vegetative propagation**: Underground stems of grass, strawberry, lateral branches of mint and jasmine.
- **For assimilation of food**: Flattened stem of opuntia contains chlorophyll and performs photosynthesis.

The Leaf :

- Developed from shoot apical meristem, flattened, green structure.
- Manufacture the food by photosynthesis. It has bud in axil.
- A typical leaf has leaf base, petiole and lamina.
- Leaf attached to the stem by **leaf base.**
- May bear two small leaves like structure called **stipules**.
- Leaf base may swollen to form **pulvinus.**
- The structure that holds the leaf called **petiole**.
- The green expanded part of the leaf is called **lamina** or **leaf blade**.

Venation :

- The arrangement of veins and the veinlets in the lamina of leaf is termed as **venation.**
- Veinlets form a network – **reticulate venation**. (dicot leaf)
- Vein runs parallel to each other – **parallel venation**. (monocot leaf)

Types of leaf :

- A leaf is said to be **simple**, when its lamina is entire or when incised, the incisions do not touch the midrib.
- When the incisions of the lamina reach up to the midrib breaking it into a number of leaflets, the leaf is called **compound.**
- Bud present in the axil of petiole in both simple and compound leaf.
- Bud never present in the axil of the leaflets of compound leaf.
    - **Pinnately compound leaf:** number of leaflets present in a common axis called **rachis,** which represents the midrib of leaf.
    - **Palmately compound leaves**: leaflets are attached to the common point i.e. at the top of the petiole.

Phyllotaxy :

- It is the pattern of arrangement of leaves on the stem of branch.
    - **Alternate :** a single leaf arises from each node
    - **Opposite :** a pair of leaves arise at each node and lie opposite to each other.
    - **Whorled :** more than two leaves arise at a node and form a whorl.

Modifications of leaves : leaves are often modified to perform functions other than photosynthesis.

- Modified to **tendril** for climbing as in peas.
- Modified to **spines** for defense as in cacti.
- **Fleshy leaves** of onion store food.
- In Australian acacia, the leaves are small the short-lived. The **petioles** expanded, become green and synthesize food.
- In insectivorous plant leaves are modified to **trap insects** e.g. pitcher plant, Venus fly trap.

THE INFLORESCENCE : The arrangement of flowers on the floral axis of stem.

- **A flower is a modified shoot** –
  - Apical meristem changes to floral meristem.
  - Internodes do not elongate and the axis gets condensed.
  - The apex produces different kinds of floral appendages laterally at successive nodes instead of leaves.
- **Racemose :** the main axis continues to grow; the flowers are borne laterally in an acropetal succession.
- **Cymose :** the main axis terminates in flower, hence limited to grow. The flowers are borne in a basipetal order.

THE FLOWER :

- Atypical flower has **four** different kinds of whorls arranged successively on the swollen end of the stalk or pedicel called **thalamus** or **receptacle.**
  - The four whorls are:-
- **Calyx, corolla, Androecium and Gynoecium.**
- Calyx and corolla are accessory organs.
- Androecium and Gynoecium are reproductive organs.
- In flower like **lily**, the calyx and corolla are indistinct and are called **perianth.**
- **Bisexual**: flower having both Androecium and Gynoecium.
- **Unisexual:** flower having either stamens or carpel.

Symmetry :

- **Actinomorphic:** radially symmetrical.
- **Zygomorphic:** bilaterally symmetrical.
- **Asymmetrical:** when a flower cannot be divided into two equal half in any plane.

Pattern of flower :

- A flower may be **trimerous**, **tetramerous** or **pentamerous** when the floral appendages are in multiple of 3, 4 or 5 respectively.
- Reduced leaf found at the base of the pedicel are called **bract.**
- Flowers which bears bract are said to be **bracteates.**
- Flowers without bract are said to be **ebracteate.**

Position of floral parts on thalamus :

- **Hypogynous :**
  - Gynoecium occupies the highest position.
  - Other whorls are present below the Gynoecium.
  - Ovary is said to be superior. E.g. mustard, China rose and brinjal.
- **Epigynous :**

- The thalamus encloses the ovary.
- Thalamus fused with ovary.
- The other whorl arises above the ovary.
- Ovary is inferior. E.g. guava, cucumber, ray florets of sunflower.

- **Perigynous :**
  - Ovary is said to be half inferior.
  - The Gynoecium situated in the centre.
  - Other whorls located on the rim of the thalamus almost at the same level. E.g. plum, Rose, peach.

Parts of a flower :

Calyx :

- It is the outermost whorl
- Each member called sepals.
- Sepals are green leaf like protect the flower in the bud stage.
- **Gamosepalous:** sepals are united.
- **Polysepalous**: sepals are free.

Corolla :

- It is the second whorl of a flower.
- Each member called petal.
- Usually brightly colored to attract insect for pollination.
- **Polypetalous:** petals are free.
- **Gamopetalous**: petals are united or fused.

Aestivation : the mode of arrangement of sepals or petals in the floral bud with respect to the other members of the same whorl is known as aestivation.

- **Valvate :** sepals or petals in a whorl just touch one another at the margin, without overlapping. E.g. Calotropis.
- **Twisted :** one margin of the appendage overlaps that of the next one and so on. E.g. china rose.
- **Imbricate :** the margin of sepals or petals overlap one another but not in any particular direction as in Cassia and gulmohur.
- **Vexillary :** The large petal (standard) overlaps the two lateral petals (wings) which in turn overlap the two smallest anterior petals (keel).

Androecium :

- It is the male sex organ of the flower.
- Composed of stamens.
- Each stamen consists of a stalk or **filament** and an **anther.**
- Each anther is usually bilobed and each lobe has two chambers, **pollen sac.**
- Pollen grains are produced inside the pollen sacs.
- A sterile stamen is called **staminode.**
- **Epipetalous**: stamens attached to the petals. E.g. brinjal.
- **Epiphyllous:** stamens attached to the perianth. E.g. lily.
- **Polyandrous**: stamens are free.
- **Monoadelphous:** stamens united into one bunch or one bundle e.g. China rose.
- **Diadelphous**: stamens fused to form two bundles as in pea.
- **Polyadelphous**: stamens fused to form more than two bundles as in citrus.

Gynoecium :

- It is the female reproductive part of the flower.
- Members are called carpel.
- Each carpel has three parts namely stigma, style and ovary.
- **Ovary** is the enlarged basal part on which lies the elongated tube, the **style**.
- The stigma usually at the tip of the style.
- **Stigma** is the receptive surface for pollen grain.
- Each ovary bears one or more ovules.
- Ovule attached to a flattened cushion-like placenta in the ovary.
- When more than one carpel is present they may be:-
    - **Apocarpous**: all carpels are free. E.g. rose, lotus
    - **Syncarpous:** carpels fused. E.g. Tomato mustard.
- After fertilization:-
    - Ovules develop into seed.
    - Ovary developed into fruit.

Placentation : arrangement of ovules within the ovary is known as Placentation**.**

- Marginal: Placenta forms a ridge along the ventral suture of ovary.
- Axile: Margins of carpels fuse to form central axis.
- Parietal: Ovules develop on inner wall of ovary.
- Free central: Ovules borne on central axis, lacking septa.
- Basal: Placenta develops at the base of ovary.

THE FRUIT :

- It is the ripened or matured ovary after fertilization.
- Parthenocarpic fruits developed from the ovary without fertilization.
- Generally fruits consist of a wall or **pericarp** and seeds.
- Pericarp may be dry or fleshy.
- Pericarp differentiated into –
    - Outer epicarp.
    - Middle mesocarp.
    - Inner endocarp.
- Fruit developed from monocarpellary superior ovary and are one seeded. Such fruit is said to be **drupe** as in mango and coconut.
- Edible part of the mango is mesocarp.
- Mesocarp of coconut is fibrous.

THE SEED :

- After fertilization ovules developed into seed.
- A seed is made of seed coat and embryo.
- The embryo is made up of
    - A radicle
    - An embryonal axis
    - One or two cotyledons.

Structure of dicotyledonous seed :

- Outer most covering of seed is seed coat.
- Seed coat has –
    - **Outer testa**
    - **Inner tegmen.**
- The **hilum** is a scar on the seed coat, the point of attachment of developing seed with the fruit.
- Above the hilum is a small pore called the **micropyle.**
- Embryo present inside the seed coat, consists of -
    - An **embryonal axis.**
    - **Two cotyledons**
- Cotyledons are fleshy and store reserve food.
- At the two end of embryonal axis are present the **radicle** and the **plumule**.
- In some seed **endosperm** store the reserve food as in castor.
- Mature seed without endosperm called **non-albuminous** seed or **non**-**endospermous** as in bean, gram and pea.

Structure of monocotyledonous Seed :

- Generally monocotyledonous seeds are **endospermic,** orchids are non-endospermic.
- In seeds of cereals such as maize, the seed coat is fused with the fruit wall.
- The outer covering of separates the embryo by a proteinous layer called **aleurone layer.**
- Embryo is small and located one side of the endosperm and consists of
    - One large shield shaped cotyledon known as **scutellum.**
    - A short axis with **radicle** and **plumule.**
    - Plumule covered by a sheath called **coleoptile.**
    - Radicle covered by a sheath called **coleorhiza.**

6. Anatomy of Flowering Plants

POINTS TO REMEMBER :

- Study of internal structure of plant is called **anatomy.**
- In plants cells are the basic unit.
- Cells organized into tissues and tissues organized into organs.

THE TISSUES :

- A group of cells having common origin and perform one function.
- Plant tissues are classified into two types:-
    - **Meristematic tissue.**
    - **Permanent tissue**

Meristematic tissues :

- Growth in plants is restricted to specific regions with active cell division called meristems.

- Different types of meristems are:-
    - **Apical meristem:**
        - Occurs in the shoot and root tips.
        - Primary meristem
        - Increase the length of plant

    - **Intercalary meristem :**
        - Present in-between mature tissues.
        - Primary meristem
        - Occurs in grasses and regenerate parts removed by grazing.

    - **Lateral meristem:**
        - Occurs in the mature regions of roots and shoots.
        - Also known as secondary meristem.
        - Responsible for producing secondary tissues.
        - Fascicular vascular cambium, interfascicular cambium and cork cambium are example of lateral meristem.
- Axillary bud :
    - During formation of leaves and elongation of stem, some cells 'left behind' from shoot apical meristem, constitute the axillary bud.
    - Present in the axils of leaves and are capable for forming a branch or a flower.

Permanent tissues :

- Cells produced from primary or secondary meristem stop dividing and differentiated structurally and functionally, termed as **permanent cells.**

- A group of permanent cell constitutes the permanent tissues.
- Permanent tissues having similar in structure and function are called **simple tissues.**
- Permanent tissues having many different types of cells are called **complex tissues.**

Simple tissues :

- **Simple tissues made of only one type of cells.**

Parenchyma :

- Forms major component within organs.
- Cells are isodiametric.
- Thin cell wall made of cellulose.
- Cells may be spherical, oval, round, polygonal or elongated shape.
- Cells are closely packed or have small intercellular space.
- Perform various functions such as photosynthesis, storage, secretion.

Collenchyma :

- Found either in homogeneous layer of in patches.
- Cell wall thickened in the corner due to deposition of **cellulose, hemicelluloses and pectin.**
- Cells are oval, spherical or polygonal in shape
- Often contain **chloroplasts.**
- **No intercellular spaces**.
- Provide mechanical support to the growing part of the plant such as young stem and petiole of a leaf.

Sclerenchyma :

- Consists of long, narrow cells
- Cell wall is thick and lignified.
- Cell wall with few or numerous pits.
- Cells are usually dead and without protoplast.
- Provides mechanical support to the organs.
- Sclerenchymas are of two types on the basis of origin, form, structure.

Fibres :

- Thick walled
- Elongated and pointed cells
- Generally occurs in group in various parts of the plant.

Sclereids :

- Spherical, oval or cylindrical in shape.
- Highly thickened dead cells with very narrow cavities (lumen).
- Commonly found in fruit walls of nuts; pulp of guava, pear and sapota; seed coats of legumes and leaves of tea.

Complex tissues :

- Made of more than one type of cells and these work together as a unit.

- Xylem and phloem constitute the complex tissues in plants.

Xylem :

- Functions as conducting tissues for water and minerals from roots to stem and leaves.
- Provides mechanical support to the plant.
- It consists of four different kinds of elements:-
    - **Tracheids**
    - **Vessels**
    - **Xylem fibres and**
    - **Xylem parenchyma.**

- **Tracheids :**
    - Elongated or tube like cells.
    - Thick and lignified walls and tapering ends.
    - Cells are dead and without protoplasm.
    - Inner layers of cell walls have thickenings which vary in forms.

- **Vessels.**
    - Is a long cylindrical tube-like structure made up of many cells called vessel members.
    - Each with lignified walls and a large central cavity.
    - Cells are devoid of protoplasm.
    - Vessel members are interconnected through perforations in their common walls.
    - Presences of vessels are the characteristics of the angiosperm.

- **Xylem fibres :**
    - Have highly thickened walls and obliterated central lumen.
    - Either septate or aseptate.

- **Xylem Parenchyma :**
    - Cells are living and thin-walled.
    - Cell walls are made up of cellulose.
    - They stored food materials in the form of starch or fat.
    - Also store materials like tannins.
    - The radial conduction of water takes place by the ray parenchymatous cells.

- The primary xylem is of two types-
    - **Protoxylem**
    - **Metaxylem**.

- The first formed xylem elements are called **protoxylem.**
- The later formed primary xylem is called **metaxylem.**
- **Endarch**: the protoxylem lies towards pith and metaxylem towards the periphery of the organ (in stem)
- **Exarch**: in root the protoxylem lies towards periphery and metaxylem lies towards the centre.

Phloem :

- Transports food materials usually from leaves to other part of plant.
- It is composed of four elements:-
    - **Sieve tube elements.**
    - **Companion cells.**
    - **Phloem parenchyma.**
    - **Phloem fibres.**

- **Sieve tube elements :**
    - Long tube like structure arranged longitudinally
    - Associated with companion cells.
    - End walls are perforated to form sieve plates.
    - A mature sieve element possesses peripheral cytoplasm and a large vacuole but lacks nucleus.
    - The function of sieve elements controlled by nucleus of companion cells.

- **Companion cells :**
    - Specialized parenchymatous cells.
    - Closely associated with sieve tube elements.
    - Connected with sieve tube element by pit field.
    - Helps in maintaining pressure gradient in the sieve tubes.

- **Phloem parenchyma :**
    - Made up of elongated tapering cylindrical cells
    - Have dense cytoplasm and nucleus.
    - Cell wall made of cellulose and has pits through plasmodesmatal connections exist between the cells.
    - Store food materials and other substances like resins and latex and mucilages.
    - It is absent in monocotyledons.

- **Phloem fibres :**
    - Also known as bast fibres.
    - Made of sclerenchymatous cells.
    - Absent in primary phloem but present in secondary phloem.
    - Much elongated, unbranched and have pointed, needle like apices.
    - Cell wall is quite thick.
    - On maturity loose their protoplasm and become dead.
    - Phloem fibres of jute, flax and hemp are used commercially.

- The first formed primary phloem consists of narrow sieve tubes and referred as **protophloem.**
- The later formed phloem has bigger sieve tubes and is referred to as **metaphloem.**

THE TISSUE SYSTEM :

- On the basis of their structure and location there are three types of tissue systems.
    - Epidermal tissue system.
    - Ground or fundamental tissue system.
    - Vascular or conducting tissue system.

Epidermal tissue system :

- Forms the outermost covering of the whole plant body and comprises:
    - Epidermal cells.
    - Stomata
    - Epidermal appendages like trichomes and hairs.

- Epidermis consists of single layer parenchymatous cells.
- Cells are elongated, compactly arranged, which form continuous layer.
- Epidermis is usually single layered.
- Outside the epidermis covered with waxy thick layer called **cuticle.**
- Cuticle absent in epidermis of root.
- **Stomata** are the structure present in the epidermis of leaf.
- Stomata regulate the process of transpiration and gaseous exchange.

Stomata :

- Each **stoma** composed of two bean shaped cell called **guard cells.**
- In grasses the guard cells are dumb-bell shaped.
- Outer wall of guard cell is thin and inner wall is thick.
- Guard cell possesses chloroplast and regulates the opening and closing of stomata.
- Epidermal cells in the vicinity of guard cell called **subsidiary cells.**
- Stomatal aperture, guard cells and subsidiary cells together called **stomatal apparatus.**
- The **root hairs** are unicellular elongations of the epidermal cells and help absorb water and mineral from the soil.

Trichomes :

- On stem the epidermal hairs are called **trichomes.**
- Trichomes are usually multicellular.
- May be branched or unbranched and soft or stiff.
- Sometimes secretory.
- **Trichomes** help in preventing water loss due to transpiration.

The ground tissue system :

- All the tissues except epidermis and vascular bundles constitute the **ground tissue.**

- It consists of simple tissues such as parenchyma, collenchyma, Sclerenchyma.
- Parenchymatous cells are present in cortex, pericycle, pith and medullary rays.
- In leaves, the ground tissue consists of thin-walled chloroplast containing cells called **mesophyll.**

The vascular tissue system :

- Vascular system consists of complex tissues – xylem and phloem.
- Xylem and phloem together constitute the vascular bundle.
- In dicot presence of cambium between xylem and phloem called **open vascular bundle.**
- Vascular bundle without cambium is said to be **closed vascular bundle**.
- **Radial vascular bundle**: xylem and phloem arranged alternate manner on the different radii.
- **Conjoint vascular bundle:** xylem and phloem are situated at the same radius of vascular bundle.

ANATOMY OF DICORYLEDONOUS AND MONOCOTYLEDONOUS PLANTS :-

Dicotyledonous Root :

- The outermost layer is epidermis.
- Presence of unicellular **root hairs** in epidermis.
- The **cortex** constitutes many layer thin-walled parenchyma cells with **intercellular spaces.**
- The innermost layer of cortex is **endodermis.**
- Endodermis consists of single layered barrel-shaped cells without intercellular spaces.
- Presence of **casparian strip** in the endodermis.
- Next to endodermis there is few layer parenchymatous cells form **pericycle.**
- Initiation of **lateral root** and **vascular cambium** during secondary growth takes place from the cells of pericycle.
- The parenchymatous cells present in-between xylem and phloem is called **conjuctive tissue.**
- The number of xylem and phloem bundle is three or four.
- All the tissues on the inner side of endodermis such as pericycle, vascular bundles and pith constitute the **stele.**

Monocotyledonous Root :

- **Monocot root have similar tissues as in dicot except :-**
    - It contains more than six xylem bundles called polyarch.
    - Pith is large and well developed.
    - Do not undergo any secondary growth.

Dicotyledonous Stem :

- Outermost layer is **epidermis.**
- Epidermis covered with thin layer of **cuticle** and has **trichomes** and few **stomata.**
- The cells arranged in multiple layers in-between epidermis and pericycle constitute the **cortex.**

- **Cortex has three sub-zones :**
    - **Hypodermis:** a few layers of collenchymatous cells below epidermis.
    - **Cortical layers:** consists of rounded thin walled parenchymatous cells with intercellular spaces.
    - **Endodermis:** it is the innermost layer of cortex. Cells are rich in starch grains and are referred to as **starch sheath.**

- **Pericycle :** present on the inner side of the endodermis and above the phloem in the form of semi-lunar patches of Sclerenchyma.
- **Medullary rays:** a few layers of radially placed parenchymatous cells present in between vascular bundles.
- A large number of **vascular bundles** arranged in **a ring.**
- Each vascular bundle is **conjoint, open** and **endarch** protoxylem.
- The central portion of stem constitutes the **pith.**

Monocotyledonous Stem :

- **It has similar tissues with the dicot stem except in following-**
    - Sclerenchymatous hypodermis.
    - Vascular bundles are **scattered i**n the ground tissue.
    - Each vascular bundle is covered by **bundle sheath** cells.
    - Vascular bundles are **conjoint** and **closed**.
    - Peripheral vascular bundles are smaller than central one.
    - Phloem parenchyma is absent.
    - Water containing cavities are present within the vascular bundles.

Dorsiventral (Dicotyledonous) Leaf :

- Vertical section of a Dorsiventral leaf shows three main parts:
    - Epidermis.
    - Mesophyll cells.
    - Vascular systems.

- Epidermis covers both upper **(adaxial**) and lower (**abaxial**) surface of the leaf has a conspicuous cuticle.
- Abaxial surface has more stomata than the adaxial epidermis.
- Tissue between upper and lower epidermis called **mesophyll.**
- Mesophyll cells are two types:
    - **Palisade parenchyma**
    - **Spongy parenchyma**

- Adaxially placed **palisade parenchyma** is made up of elongated cells arranged vertically, parallel to each other.
- **Spongy parenchyma:** oval or round and loosely arranged cells below the palisade parenchyma.
- **Vascular bundles** are seen in the midrib and veins.
- The vascular bundles are surrounded by a layer of thick walled **bundle sheath cells.**

Isobilateral (Monocotyledonous) leaf :

- It is similar with Dorsiventral leaf in many respect except –
    - Stomata are equally distributed on upper and lower epidermis.
    - Mesophyll cells are not differentiated into palisade and spongy.

- In grasses, certain adaxial epidermal cells along the veins modified themselves into large, empty, colourless cells called **bulliform cells.**
- Causes rolling of leaves to reduce transpiration during water stress.

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7. Structural Organisation in Animals

POINTS TO REMEMBER :

Tissue : A group of similar cells along with intercellular substances which perform a specific function.

ANIMAL TISSUES :
Animal tissues are classified into four types:

- **Epithelial tissues.**
- **Connective tissues.**
- **Muscular tissues.**
- **Neural tissues.**

Epithelial tissues :

- These tissues commonly called epithelium.
- Has free surface, which faces either a body fluid or the outside environment.
- Cells are compactly packed with little intercellular matrix.
- There are two types of epithelial tissues:
    - **Simple epithelium.**
    - **Compound or stratified epithelium.**

- Simple epithelium is composed of a single layer of cells and functions as a lining for body cavities, ducts and tubes.
- The compound epithelium consists of two or more cell layers and has protective function as it does in our skin.

Simple epithelium, on the basis of modification, divided into three types:

- **Squamous**
- **Cuboidal**
- **Columnar**.

Squamous epithelium :

- Made of single thin layer of flattened cells with irregular boundaries.
- Found in the wall of blood vessels and air sacs of lungs.
- Functions as diffusion boundary.

Cuboidal epithelium :

- Composed of a single layer cube – like cells.
- Found in ducts of glands and tubular part of nephrons in kidneys.
- Main function is secretion and absorption.

Columnar epithelium :

- Composed of a single layer of tall and slender cells.
- Their nuclei located at the base.

- Free surface may have microvilli.
- Found in the lining of stomach and intestine
- Helps in absorption and secretion.

Ciliated epithelium :

- It is a modified Cuboidal or columnar epithelium.
- Cell bears cilia on their free surfaces.
- Found in the inner surface of hollow organs like bronchioles and fallopian tubes.
- Their function is to move particles or mucus in a specific direction over the epithelium.

Glandular epithelium :

- It is a modified Cuboidal or columnar epithelium.
- Get specialized for secretion.
- **Simple glands** having unicellular and isolated cells of alimentary canal.
- **Multicellular glands**: consisting of cluster of cells, as in salivary gland.
- **Exocrine gland**: the secretory product transported to a point by means of a duct. These glands secrete mucus, saliva, ear wax, milk, digestive enzymes etc
- **Endocrine gland**: commonly called as ductless gland, because the secretory products directly poured into blood. The glands secretes hormone.

Compound epithelium :

- Made of more than one layer of cells.
- Limited role in absorption and secretion.
- Main function is to provide protection against chemical and mechanical stresses.
- They cover the dry surface of skin, moist surface of buccal cavity, pharynx, inner lining of duct of salivary gland and pancreatic duct.

Cell junction :

- Cells of the epithelium are held together with little intercellular matrix.
- Cell junction provide structural and functional link between the cells
- **Tight junction**: help to stop substances from leaking across a tissue.
- **Adhering junctions**: perform cementing to keep neighboring cells together.
- **Gap junctions**: facilitate the cells to communicating the cytoplasm of adjoining cells, for rapid transfer of ions, small molecules.

Connective tissues :

- Most abundant and widely distributed tissues.
- Special function of linking and supporting other tissues/organs of the body.
- Connective tissues include cartilage, bone, adipose, and blood.
- In all connective tissue except blood, the cells secrete fibres of proteins called collagen and elastin.
- The fibre provides strength, elasticity and flexibility to the tissue.
- Presence of **ground substance** or **matrix** in between the cells, modified **polysaccharides.**

Loose connective tissue :

- Has cells and fibres loosely arranged in a semisolid ground substance.

Areolar tissue :

- **Areolar tissue** is one example of loose connective tissue.
- Present beneath the skin.
- It supports the framework for epithelium.
- It contains cell like **fibroblasts** (secretes fibres), **macrophages** and **mast cells.**

Adipose tissue:

- Another type of loose connective tissues.
- Located mostly beneath the skin.
- Cells of this tissue specialized to store fats called **adipocytes.**

Dense connective tissue :

- Fibres and fibroblasts are compactly packed.

Dense regular tissues :

- Orientation of fibres shows a regular pattern.
- The collagen fibres are present in rows between many parallel bundles of fibres.
- Tendons: joints muscles to bone.
- Ligaments: joins bone to bone are the examples.

Dense irregular tissues:

- Fibroblasts and many fibres are oriented differently.
- This tissue present in skin.

Specialized connective tissues :

- **Cartilage bone and blood are the special connective tissues.**

Cartilage:

- Intercellular material of cartilage is solid.
- **Chondrocytes** are the cells of cartilage.
- Pliable and resists compression.
- Cells are enclosed in small cavities within the matrix.
- Most of the cartilage of the embryo replaced by bones in adult.
- Cartilage present in nose tips, ear pinna, between adjacent vertebrae.

Bones:

- Have hard and non pliable matrix or ground substance.
- The matrix is rich in calcium salts and collagen fibers which give the bone its strength.
- Provides the structural frame of human body.
- Support and protect the soft tissues and organs.
- The bone cells called Osteocytes are present in fluid filled cavity called lacunae.
- Sustain body weight.

- Attached with skeletal muscles meant for locomotion.
- Bone marrow is the site of production of Red blood cells.

Muscular tissues:

- Each muscle is made of many long, cylindrical fibres arranged in parallel arrays.
- Each fibre composed of numerous fine fibrils, called myofibrils.
- Muscle fibres contracts in response to stimulus.
- Muscle plays a great role in movement and locomotion.

Skeletal muscle:

- Closed attached to the skeleton or bone and cartilage.
- Muscle cells are unbranched and multinucleated.
- A number of muscle fibres are bundled together in parallel fashion.
- A sheath of tough connective tissues encloses several bundles of muscle fibres.

Smooth muscle :

- The smooth muscle fibres tapers or pointed at both ends
- Do not show cross striation.
- Cell junctions hold them together.
- They are bundled together in a connective tissue sheath.
- Present in wall of blood vessels, stomach and intestine.
- They are involuntary in nature.

Cardiac muscles:

- Contractile muscular tissue present in heart.
- Cell junctions fuse the plasma membranes of cardiac muscles cells and make them stick together.
- Communication junction or intercalated discs at some fusion points allow the cells to contract as a unit.
- Muscle cells are branched and Uninucleated.

Neural tissues:

- Neural tissues exert greatest control over body's response to changing condition.
- Neurons are the units of nervous tissues.
- Neuroglial cells non-conducting and protects and support neurons.
- Neuroglia makes up more than one-half the volume of neural tissue.
- Electrical impulse is conducted through the plasma membrane of neuron.

EARTHWORM :

Morphology :

- Earthworm has long cylindrical body.
- The body divided into more than 100 equal segments called **metamere.**
- Mid-dorsal dark line indicates the dorsal blood vessel.
- The ventral surface is distinguished by **genital openings**.
- Anterior end consists of the mouth and prostomium.

- The first segment is called **peristomium**, which contain the **mouth.**
- In matured worm, segments 14-16 are covered by dark band of glandular tissue called **clitellum.**
- Body divisible into:
    - **Preclitellar.**
    - **Clitellar.**
    - **Postclitellar**

- **External apertures:**
    - Four pairs of spermathecal aperture 5th – 9th segments.
    - A female genital aperture- 14th segment.
    - A pair of male genital apertures in 18th segment.
    - Numerous nephridial pores on the skin of each segment.

- There are row of S- shaped **Setae** in each segment except 1st and last segment.
- Setae have principal role in locomotion.

ANATOMY :

Body wall :

- Body wall externally covered by thin non-cellular cuticle.
- Body wall contains epidermis below cuticle.
- Epidermis is made of single layer of columnar epithelium with secretory glands.
- Two layers of muscles (circular and longitudinal).

Digestive system:

- Alimentary canal is a straight tube between 1st and last segment.
- **Mouth** present in the 1st segment.
- Mouth opens into **buccal cavity** 1-3 segments.
- Buccal cavity leads into **muscular pharynx** in 4th segment.
- Narrow **oesophagus** at 5-7 segments.
- Muscular gizzard in 8-9 segments helps in grinding of ingested food.
- **Stomach** extended from 9-14 segments.
- **Calciferous gland** present in the stomach, neutralize the acidic nature of **humic acid** present in the humus.
- Intestine starts from 15th segment and continues till last segment.
- A pair of Intestinal caecae present in the 26th segment.
- Presence of internal median fold of dorsal wall of intestine called **typhlosole** between 26-35 segments.
- Typhlosole increases the surface area for absorption.
- Intestine opens to outside by means of anus.

Blood vascular system :

- Blood vascular system is closed type.
- Blood vascular system consists of:
    - Blood vessels

- Capillaries
- Heart.

- **Blood glands** present on 4th, 5th and 6th segments.
- Blood glands produce blood cells and haemoglobin.
- Haemoglobin dissolved in plasma instead of embedded in corpuscles.
- Blood cells are **Phagocytic** in nature.

Respiration:

- Earthworm lack specialized breathing devices.
- Gaseous exchange takes place through moist surface of skin.
- Transport of respiratory gases takes place in haemoglobin.

Excretory system:

- Excretory organs are segmentally arranged coiled tubules called **nephridia.**
- There are three types of nephridia:

- **Septal nephridia:**
  - Present on both side of intersegmental septa of segment 15 to last segment.
  - They opened into the intestine.

- **Integumentary nephridia.**
  - Attached to the lining of the body wall from 3th to last segment.
  - Opened into the body surface.

- **Pharyngeal nephridia:**
  - Present in three pairs in 4th, 5th and 6th segment.

- Nephridia regulate the volume and composition of body fluids.
- A nephridium starts with a ciliated funnel like structure called nephrostome, connected with a tubular part.

Nervous system :

- Represented by ganglia arranged segmentally on the ventral paired nerve cord.
- Nerve cord in the anterior region (3rd and 4th segments) bifurcates, laterally encircling the pharynx and joins the cerebral ganglia dorsally to form nerve ring.
- Segmental ganglia give rise to nerve fibres to the body organs.

Sensory organs :

- Possesses light and touch sensitive organs (receptor cells)
- Have specialized chemoreceptor, which reacts to chemical stimuli.
- Sense organs located in the anterior part of the body.

Reproductive system :

- Earthworm is hermaphrodite
- Two pairs of testes present in the 10th and 11th segments.
- Their vasa deferentia run upto 18th segment and joins with prostatic duct.
- Two pairs of accessory glands present one pair each in the 17th and 19th segment.
- The prostrate and spermatic duct (vasa dererentia) opens to exterior by a pair of male genital pore on the ventro-lateral side of the 18th segment.
- Four pairs of spermathecae are located in 6th – 9th segments.
- They receive and store spermatozoa during copulation.
- One pair of ovaries is attached at the inter-segmental septum of 12th and 13th segment.
- Ovarian funnel continued as oviduct, join together and open by a single female genital aperture on the 14th segment.
- Mutual exchange of sperm occurs between two worms during mating.
- Mature sperms and egg cells and nutritive fluid are deposited in the cocoons produced by gland cells of clitellum.
- Fertilization takes place inside the cocoon which deposited in soil,
- After three weeks each cocoon produces two to twenty baby worms.
- Development is direct without larval stage.

COCKROACH :

Morphology :

- Adults cockroach *Periplaneta americana* are about 34-53 cm long with wings that extended beyond the tip of the abdomen.
- Segmented body distinguished into head, thorax and abdomen.
- Entire body is covered by external chitinous exoskeleton.
- Each segment has hardened plates called sclerites (dorsal**tergites**, ventral **sternites**).
- Successive sclerites are joined by flexible articular membrane (arthrodial membrane)

Head :

- Head is formed by fusion of six segments, with flexible neck.
- The head bears a pair of compound eye, a pair of antennae.
- Antennae have sensory receptors.
- Head bears appendages meant for biting and chewing types of mouth parts.
- The mouth parts consists of:
    - A labrum (upper lip)
    - A pair of mandibles.
    - A pair of maxillae
    - A labium (lower lip)
    - A median flexible lobe acting as tongue (hypopharynx).

Thorax :

- Thorax consists of three parts – **prothorax, mesothorax and metathorax.**

- Each thoracic segment bears a pair of walking legs.
- First pair of wings arises from mesothorax and second pair from metathorax.
- The hind wings are transparent, membranous meant for flying.

Abdomen :

- The abdomen consists of 10 segments.
- In female the 7th segment is boat shaped and along with 9th and 10th segment it forms the broad or genital pouch.
- Genital pouch contains female gonopore, spermathecal pores and collateral glands.
- In male the genital pouch bounded dorsally by 9th and 10th terga and ventrally by the 9th sternum.
- Male bears a pair of anal style, absent in female.
- Anal cerci present in both sexes in 10th segment.

ANATOMY :

Digestive system :

- Alimentary canal divided into three regions; **foregut, midgut and hindgut.**
- The mouth opens into short **pharynx** leading to **oesophagus.**
- Oesophagus opens into a sac like **crop,** which store food.
- Crop is followed by **gizzard** or **proventriculus.**
- Gizzard contains chitinous teeth for grinding the food.
- The entire fore gut is lined by **cuticle.**
- A ring of 6-8 blind tubules called **hepatic or gastric caecae** present at the junction of foregut and midgut, which secretes **digestive juices**.
- Midgut is long tube like structure.
- At the junction of midgut and hindgut, another ring of 100-150 yellow coloured thin filamentous **Malpighian tubules**are present.
- Malpighian tubules are meant for excretion from haemolymph.
- The hindgut is broader and differentiated into **ileum, colon** and **rectum.**

Blood vascular system:

- Blood vascular system is open type.
- Blood vessels are poorly developed and open into space called **haemocoel.**
- Visceral organs located in the haemocoel and bathed in blood called **haemolymph.**
- The haemolymph composed of colourless plasma and haemocytes.
- Heart is elongated multichambered, funnel shaped with ostia.
- Blood enter into the heart through ostia and is pumped anteriorly into the sinuses.
- The haemocoel differentiated into three sinuses;
    - **Pericardial sinus.**
    - **Perivisceral sinus.**
    - **Perineural sinus.**

Respiratory system :

- The respiratory system consists of a network of trachea.
- Trachea opens to outside by 10 pairs of small holes called spiracles on lateral side of the body.
- Trachea gives rise to branching tubes called tracheal tubes which subdivided into tracheoles.
- Opening of spiracles regulated by valves.
- Movement of air takes place by diffusion and directly to the body cell.

Excretion:

- Excretion is performed by malpighian tubules.
- Each tubule is lined by glandular and ciliated cells.
- They absorb nitrogenous wastes from the haemocoel and converted into uric acid and poured into the hindgut.
- Hence cockroach is **uricotelic** in nature.
- Nephrocytes and uricose glands also assist in excretion.

Nervous system:

- Consists of a series of segmentally arranged ganglia joined by paired longitudinal double ventral nerve cord.
- Three ganglia lie in thorax and six in the abdomen.
- Head contain a bit of nervous system.
- The brain is represented by supra-oesophageal ganglion which innervates the compound eye and antennae.
- The sense organs are antennae, eyes maxillary palps, labial palps, anal cerci etc.
- Each compound eye consists of about 2000 hexagonal ommatidia.
- Each ommatidium forms a part of the image, called mosaic vision.

Reproductive system :

- Cockroaches are dioecious and sex organs are well developed.
- Male reproductive system consists of a pair of testes lying one on each in 4th and 6th segments.
- Vas deferens arises from each testis, opens into ejaculatory duct through seminal vesicle.
- Ejaculatory duct opens into the male gonopore situated ventral to anus.
- Accessory reproductive gland called mushroom gland present on 6th-7th segment.
- External genitalia represented by male **gonopophysis** or **phallomere.**
- Sperms are sorted in the seminal vesicles and are glued together in the form of bundles called **spermatophores**which are discharged during copulation.
- **The female reproductive system consists of two large ovaries present in 2nd – 6th abdominal segments.**
- Each ovary is formed a group of eight ovarian tubules or ovarioles, containing chain of developing ova.
- Oviduct of each ovary fused to form single median oviduct or vagina, which opens into genital chamber.
- A pair of spermatheca is present in the 6th segment which opens into genital chamber.
- Sperms are transferred through spermatophores.
- The fertilized eggs are encased in capsules called oothecae.
- Ootheca is dark reddish to blackish brown capsule about 3/8” long.
- On average, female produce 9-10 oothecae, each containing 14-16 eggs.
- Development is pourometabolous i.e development through nymphal stages.
- The nymph grows by molting about 13 times to reach the adult form.

FROG :

- Frog belongs to class Amphibia.
- Most common species in India is *Rana tigrina.*
- They are cold blooded animal; the body temperature varies according to environmental temperature.
- They have ability to change the body colour according to the environment.
- They undergo **hibernation (summer sleep)** and **aestivation (winter sleep).**

Morphology :

- The skin is smooth and moist, slippery due to **mucus.**

- Dorsal body is olive green with dark irregular spots.
- Ventral side of the body is uniformly pale yellow coloured.
- The frog never drinks water and absorb it through skin **(hygroscopic).**
- Body divisible into **head** and **trunk.** Neck is absent.
- On either side of the eyes a membranous tympanum (represents the external ear), to receive the sound waves.
- Forelimbs and hind limbs helps in swimming, leaping and burrowing.
- Fore limb have four digit and hind limb stronger and has five digits.
- Frog exhibit sexual dimorphism.
- Male frog distinguished from female frog:
    - Having sound producing vocal sac.
    - Copulatory pad or amplexury pad on the first digit of the fore limb.

Anatomy :

Digestive system :

- Digestive system consists of alimentary canal and digestive glands.
- Alimentary canal is short because frogs are carnivorous.
- Mouth opens into buccal cavity that leads into oesophagus through pharynx.
- Oesophagus is a short tube that opens into the stomach, which inturn continues as the intestine, rectum and finally opens outside by the cloaca.
- Liver secrete bile that stored in the gall bladder.
- Pancreas a digestive gland produces pancreatic juice containing digestive enzymes.
- Food is captured by bilobed tongue.
- Digestion of food takes place by the action of HCl and gastric juice secreted from the walls of the stomach.
- Partially digested food in the stomach is called **chyme.**
- Chyme passed from stomach to intestine, the duodenum.
- The duodenum receives the bile from gall bladder and pancreatic juice from pancreas through a common bile duct.
- Bile emulsifies fat and pancreatic juices digest carbohydrates and proteins.
- Final digestion takes place in intestine.
- Digested food is absorbed by intestinal villi and microvilli.
- The undigested food removed to outside through cloaca.

Respiratory system :

- In water frog respire through skin (cutaneous respiration)
- Exchange of respiratory gases takes place through diffusion.
- In land it respires through buccal cavity, skin and lungs.
- Respiration by lungs is called pulmonary respiration.
- During aestivation and hibernation it respires through skin.

Circulatory system :

- The blood vascular system includes heart, blood vessel and blood.
- The lymphatic system includes lymph, lymph nodes and lymphatic vessels.
- Heart is three chambered with two atria and one ventricle.
- Heart is covered by a membrane called **pericardium.**
- A triangular **sinus venosus** opens into right atrium. It receives the deoxygenated blood through vena cava.
- The ventricle opens into **conus atreriosus** on the ventral side of the heart.
- Form the conus atreriosus the blood circulated to different part of the body by arterial system.
- Blood collected from the body to the heart by venous system.

- Special venous connection between liver and intestine is called **hepatic portal system.**
- Venous connection between lower part of the body and kidney is called **renal portal system.**
- The blood is composed of plasma and cells.
- The blood cells are; erythrocytes (RBC), leucocytes (WBC) and Thrombocytes (Platelets).
- RBC is nucleated and contains hemoglobin.
- The lymph differs from in, it lack proteins and RBC.

Excretory system :

- The excretory system consists of a pair of kidneys, ureters, cloaca and urinary bladder.
- Each kidney composed of several **uriniferous tubules** or **nephrons.**
- The ureter arises from the kidney act as urinogenital duct which opens into cloaca in male.
- In female the ureters and oviduct open separately into the cloaca.
- Thin walled urinary bladder located ventral to rectum, opens to the cloaca.
- The frog excretes nitrogenous waste in the form of urea, hence **ureotelic.**

Control and coordination system :

- It includes both nervous and endocrine system.
- Chemical coordination is carried out by hormones secreted by endocrine glands.
- Endocrine glands found in frog are pituitary, thyroid, parathyroid, thymus, pineal body, pancreas, adrenal and gonads.
- The nervous system organized into;
    - Central nervous system- brain and spinal cord.
    - Peripheral nervous system – cranial and spinal nerves.
    - Autonomic nervous system – sympathetic and parasympathetic.

- There are 10 pairs of cranial nerves arises from the brain.
- Brain is enclosed in side the cranium.
- The brain differentiated into; fore brain, mid brain and hind brain.
- Fore brain includes;
    - Paired olfactory lobe.
    - Paired cerebral hemisphere
    - Unpaired diencephalon.

- The mid brain is characterized by a pair of optic lobes.
- Hind brain consists of cerebellum and medulla oblongata.
- Medulla oblongata passes through foramen of magnum and continues as spinal cord which runs inside the vertebral column.

Sense organs:

- Frog has different types of sense organs;
    - Organs of touch (sensory papillae)
    - Taste (taste buds)
    - Smell (nasal epithelium)
    - Vision (eye)
    - Hearing (tympanum with internal ear)

- Eye is well organized inside the orbit of the skull.
- Ear is an organ for hearing and equilibrium (balancing).

Male reproductive system:

- Consists of a pair of yellowish ovoid testes, attached to the upper part of kidneys, by **mesorchium.**
- Vasa efferentia are 10-12 in number arises from the testes.
- They enter into the kidney and opens into **Bidder's canal.**
- Bidder's canal communicates with the urinogenital duct that comes out of the kidneys and opens into the cloaca.
- The cloaca is a small median chamber that is used to pass faecal matter, urine and sperms to the exterior.

Female reproductive system:

- Includes a pair of ovaries present near the kidneys.
- A pair of oviduct arising from ovaries opens into the cloaca separately.
- A mature female lays 2500 to 3000 ova at a time.
- Fertilization is external i.e. in water
- Development is indirect involved a larval stage called **tadpole larva.**
- Tadpole larva metamorphoses into adult frog.

8. Cell: The Unit of Life

POINTS TO REMEMBER :

CELL THEORY :

- **Schieiden and Schwann** together formulated the cell theory.
- They proposed that the body of animal and plant are composed of cells and product of cells.
- **Rudolf Virchow (1855)** he modified and gives the final shape to the**cell theory.**
    - **All living organisms are composed of cells and products of cells.**
    - **All cells arise from pre-existing cells.**

PROKARYOTIC CELLS :

- Represented by bacteria, blue-green algae, mycoplasma and PPLO.
- Smaller and multiply more rapidly than eukaryotic cells.
- Four basic shape of bacteria are
    - Bacillus (rod like)
    - Coccus (spherical)
    - Vibrio (comma shaped)
    - Sprillum (spiral)

- All prokaryotes have a cell wall surrounds the plasma membrane.
- There is no well defined nucleus.
- Chromosome is single and circular, not enveloped by nuclear membrane.
- Presence of many small, circular, extra chromosomal and self replicable DNA called **plasmid.**
- Plasmid provides unique characteristic to the bacteria.
- One of the characteristic is **antibiotic resistant**.
- No membrane bound cell organelles.
- A specialized differentiated form of cell membrane called **mesosome** is present.

Cell envelope and its Modifications :

- Most prokaryotic cell have characteristic complex cell envelope.
- The cell envelops consists of tightly bound three layer structure;
    - The outermost glycocalyx.
    - Middle cell wall
    - Inner plasma membrane.

- According to the nature of the cell wall and behavior towards the stain developed by Gram, bacteria are **Gram positive**or **Gram negative**.
- Glycocalyx may for a loose sheath called **slime layer.**
- Glycocalyx may be thick and tough called the **capsule.**
- The cell wall determines the shape of the cell, strong structural support to prevent the bacterium from bursting and collapsing.
- Plasma membrane is semi-permeable in nature and interacts with outside world.
- A special membranous structure is the mesosome which is formed by extensions of plasma membrane into the cell.

- These extensions are in the form of vesicles, tubules and lamellae.
- They help in cell wall formation, DNA replication and distribution to the daughter cell.
- They also help in respiration and secretion.

- Some bacteria have filamentous extensions called flagella.
- Bacterial flagellum has three parts – **filament, hook** and **basal body.**
- **Pili** are elongated tubular structures made of a special protein.
- **Fimbriae** are small bristle like fibres sprouting out of the cell. Play role in adhesion.

Ribosome and inclusion bodies :

- Ribosomes are associated with the plasma membrane of the cell.
- Each ribosome (70 S) has two sub units; smaller (30 S) and large (50 S).
- Ribosomes are the site of protein synthesis.
- Several ribosomes attached to a single mRNA to form a chain called **polyribosome** or **polysome.**
- **Reserve materials are stored in the form of inclusion bodies.**
- Phosphate granules, cyanophycean granules and glycogen granules are the inclusion bodies.

EUKARYOTIC CELL :

- Eukaryotes include all the Protists, plants, animals and fungi.
- Extensive compartmentalization due to **membrane bound cell organelles.**
- Possess an organized **nucleus** with **nuclear envelope**.
- Have a variety of complex locomotory and **cytoskeletal structure**.
- Genetic materials are organized into **chromosomes.**
- The plant cell possess cell walls, plastids and a large central vacuole, which are absent in animal cell.
- Animal cells have **centrioles** which absent in plant cells.

Cell membrane :

- The cell membrane composed of lipids that arranged in bilayer.
- Lipids are arranged within the membrane with the **hydrophilic polar** head towards the outer sides and the**hydrophobic tails** towards the inner part.
- Non polar tail of **saturated hydrocarbons** is protected from the aqueous environment.
- The lipid component of the membrane mainly consists of **phophoglycerides.**
- Cell membrane also possesses protein and carbohydrates.
- Ratio of protein and lipids varies from cell to cell.
- Human erythrocyte plasma membrane contains 52 % protein and 40 % lipids.
- Membrane protein may be **integral** or **peripheral.**
- Peripheral protein lie on the surface and integral proteins are partially or totally buried in the membrane.
- The improved model of the structure of plasma membrane was proposed by singer and Nicolson (1972) widely accepted as **fluid mosaic model.**
- According to this the quasi fluid nature of lipid enables the lateral movement of proteins within the overall bilayer.

Function :

- Passive transport.
    - Simple diffusion

- Facilitated diffusion.

- Active transport.
- Phagocytosis
- Exocytosis.
- Pinocytosis.

Cell wall :

- A non-living rigid structure called cell wall present outside the plasma membrane of plant and fungal cell.
- Algae have a cell wall made of cellulose, galactans, mannans and minerals like calcium carbonate.
- Plant cell wall consists of cellulose, hemicelluloses, pectins and proteins.
- The cell wall of young plant is called **primary cell wall.**
- On maturity secondary cell wall formed inner to it.
- The middle lamella is a layer of calcium pectate which holds or glues the neighboring cells.
- The cell wall and middle lamella may traversed by **plasmodesmata**; the cytoplasmic connection between two adjacent cell.

The endomembrane system :

Endoplasmic reticulum :

- Network or reticulum of tiny tubular structures scattered in the cytoplasm, called **endoplasmic reticulum.**
- It divides the intracellular space into two distinct compartments:
  - **Luminal (inside the ER)**
  - **Extra luminal (cytoplasm).**

- The ER shows ribosomes attached to their outer surface called **Rough Endoplasmic reticulum (RER).**
- Endoplasmic reticulum without ribosome called **SER (smooth endoplasmic reticulum)**

Function:

- RER present in the cell actively involved in protein synthesis.
- SER is the site for synthesis of lipid, glycogen and steroid hormones.

Golgi apparatus:

- Camillo Golgi (1898) first observed this organelle, and named after him.
- It consists of many flat, disc shaped sacs or cisternae.
- These are staked parallel to each other.
- The Golgi cisternae are concentrically arranged near the nucleus with distinct convex ***cis***or the forming face and concave ***trans***or the maturing face.

Function:

- Principally responsible for packing of materials to be delivered intra-cellular target or intercellular target.

- Materials are packed in the form of vesicles, from the ER fuse with the cis face of the Golgi apparatus and move towards the trans face.
- Important site for the formation of glycoprotein and glycolipids.

Lysosomes:

- Membrane bound vesicular structure.
- Formed by Golgi body.
- Rich in all type **hydrolytic enzymes**, optimally active in acidic pH.
- These enzymes are capable to digesting carbohydrates, proteins, lipids and nucleic acids.

Vacuoles:

- The vacuole is the membrane-bound space found in the cytoplasm.
- It contains water, sap, excretory product.
- Vacuole is bounded by a single membrane called **tonoplast.**
- In plant cells the vacuole can occupy 90% of the volume.
- Tonoplast facilitates active transport of material from cytoplasm into the vacuole.
- In *Amoeba* the **contractile vacuole** is important for excretion and osmoregulation.
- In many protists, **food vacuoles** are formed by engulfing the food particles.

Mitochondria:

- The number of mitochondria varies according to the physiological activity of the cell.
- Each mitochondrion is a double membrane bound structure with outer and inner membrane, dividing its lumen into two aqueous compartments
    - Outer compartment.
    - Inner compartment.

- The inner compartment is called the matrix.
- The inner membrane forms a number of infoldings called the cristae towards the matrix.
- The cristae increase the surface area.
- Two membranes have their own specific enzymes associated with the mitochondrial function.
- Mitochondria are the site of aerobic respiration.
- They produce cellular energy in the form of ATP, hence called '**power house'** of the cell.
- The matrix also possess single circular DNA molecule and a few RNA molecules, ribosomes (70S), they synthesize their own protein.
- Mitochondria divide by fission.

Plastids :

- Plastids are found in all plant cells and in Euglenoids.
- They bear some specific pigment, impart specific colour to the plants.
- Based on the type of pigments plastids can be classified into
    - **Chloroplast**.
    - **Chromoplast**
    - **Leucoplast**.

- The chloroplasts contain **chlorophyll** and **carotenoid** pigments, traps solar energy for photosynthesis.
- In the chromoplasts fat soluble carotenoid pigments like carotene, xanthophylls are present.
- The leucoplasts are colourless plastids of varied shapes and size with stored nutrients.
    - **Amyloplast** - store carbohydrates.
    - **Elaioplasts** – store oils and fats.
    - **Aleuroplast** – store proteins and minerals.

- Chloroplasts are found in the **mesophyll cells** of the leaves.
- These are oval, spherical, discoid or even ribbon like organelles.
- Chloroplast is a double membrane organelle.
- The space limited by inner membrane is called **stroma.**
- A number of organized flattened membranous sacs called **thylakoid** are present in the stroma.
- Thylakoids are arranged like stakes of coins to form **grana.**
- There are flat membranous tubules called the **stroma lamellae** connecting the thylakoids of the different grana.
- They thylakoids enclose a space called **lumen.**
- **Chlorophyll** pigments are located in the thylakoids.
- Chloroplast contains enzymes required for the synthesis of carbohydrates and proteins.
- Stroma contains small circular **DNA** and **ribosomes.**

Ribosomes :

- Ribosomes are granular structure first observed by George Palade (1953).
- Composed of ribonucleic acid (RNA) and proteins.
- Non-membranous cell organelles.
- Eukaryotic ribosomes are 80S while the prokaryotic ribosomes are 70S.
- 'S' stands for sedimentation coefficient; measure of density and size.
- Both 70S and 80S ribosomes consists of two subunits.
- Primary function is protein synthesis hence called protein factory of the cell.

Cytoskeleton :

- An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively known as**cytoskeleton.**
- Cytoskeleton involved in many function such as mechanical support, motility, maintenance of the shape of the cell.

Cilia and Flagella :

- Cilia and flagella are hair-like outgrowths of the cell membrane.
- Cilia are small help in the movement of cell or surrounding fluid.
- Flagella are longer and responsible for cell movement.
- Cilia and flagella covered by plasma membrane.
- Their core called **axoneme,** possess a number microtubules running parallel to the long axis.
- The axoneme usually has nine pairs of doublets of radially arranged peripheral microtubules and a pair of centrally located microtubules.
- The central tubules are connected by bridges and are also enclosed by a central sheath, which is connected to one of the tubules of each peripheral doublet by radial spoke.
- The peripheral doublets are also interconnected by linkers.

- Both cilia and flagella emerge from centrioles-like structure called basal bodies.

Centrosome and centrioles :

- Centrosome is an organelle usually containing two cylindrical structures called centrioles.
- They are surrounded by amorphous pericentriolar materials.
- Both centrioles in a Centrosome lie perpendicular to each other.
- Each centriole has an organization like the cartwheel.
- They are made of nine evenly spaced peripheral fibrils of tubulin.
- Each of the peripheral fibril is a triplet.
- The adjacent triplets are also linked to each others.
- The central part of the centriole is called **hub.**
- The hub connected to peripheral triplets by radial **spokes.**
- The centriole forms the **basal body** for cilia, flagella and form **spindle fibres** during cell division.

Nucleus :

- Nucleus as a cell organelle was first described by **Robert Brown** in 1831.
- Materials inside the nucleus was stained by **Flemming** and named as **chromatin.**
- The interphase nucleus has highly extended and elaborates nucleoprotein fibres called chromatin.
- The nucleus also contains nuclear matrix and one or two spherical bodies called **nucleoli.**
- Nuclear envelope consists of two membranes with perinuclear space (10- 50 nm).
- The outer membrane remains continuous with endoplasmic reticulum.
- Presence of nuclear pore due to fusion of two membranes.
- Nuclear pores allow the movement of RNA and protein in both directions.
- The nuclear matrix or **nucleoplasm** contains nucleolus and chromatin.
- Nucleolus is the site for active ribosomal RNA synthesis.
- During cell division the chromatins condensed to form **chromosomes.**
- Chromatin contains DNA and some basic proteins called **histones, non-histone proteins** and some **RNA.**
- A single human cell contains approximately two meter long thread of DNA in 46 chromosomes.
- Each chromosome essentially has a primary constriction or the **centromere.**
- On each side of centromere there is disc shaped structures called **kinetochores.**

- Based on the position of the centromere chromosomes are classified into four types:-
    - **Metacentric:** centromere at the middle with two equal arms.
    - **Sub-Metacentric:** one short arm and one long arm.
    - **Acrocentric:** with extremely short arm and a very long arm.
    - **Telocentric:** with terminal centromere.

- A few chromosomes have non-staining constrictions at a constant location. This gives the appearance of a small fragment called the **satellite.**

9. Biomolecules

POINTS TO REMEMBER :

- **Biomolecules:** All the carbon compounds that we get from living tissues.
- **Macromolecules:** Molecules which have molecular weights less than one thousand dalton.
- **Amino acids:** Organic compounds containing an amino group and one carboxyl group (acid group) and both these groups are attached to the same carbon atom called α carbon.
- Twenty types of amino acids occur in proteins.
- Based on number of amino and carboxyl groups, amino acids can be:
    - **Acidic:** e.g. Glutamic acid
    - **Basic:** e.g. Arginine and lysine
    - **Neutral**: e.g. valine, alanine.

- **Aromatic amino acids** are tyrosine, phenylalanine, and tryptophan.
- Amino acids are ionizable into **zwitterionic** form.

Lipids :

- Water insoluble, containing C, H, O.
- They could be **simple fatty acids.**
- A fatty acid has a carboxyl group attached to an **R group.**
- The R group may be a methyl group ($-CH_3$) or ethyl ($-C_2H_5$) or higher number of-CH_2 group (1 carbon to 19 carbon). E.g**. palmitic acid** with 19 carbons, **arachidonic acid** has 20 carbons.
- Fatty acids could be **saturated** (without double bond) or **unsaturated** (with one more (c=c) double bond.
- Another example of lipid is **glycerol** which is **trihydroxy propane.**
- Many lipids may have both glycerol and fatty acids.
- Fatty acids esterified with glycerol to form **mono, di** or **triglycerides.**
- These are also called fats and oils based on the melting points.
- Oils have low melting points (e.g. **gingely oil).**
- **Phospholipids** are compound lipids with phosphorus and a phosphorylated organic compound. They are found in the cell membrane. e.g., **Lecithin.**

Nitrogen bases :

- Carbon compounds with heterocyclic rings.
- **Purine**: Adenine, Guanine.
- **Pyrimidine:** Cytosine, Uracil, Thymine.
- **Nucleoside:** Nitrogenous base + Sugar e.g., Adenosine, guanosine, thymidine Uridine and cytidine
- **Nucleotide:** Nitrogenous base + Sugar + Phosphate group. e.g., Adenylic acid, thymidylic acid, guanylic acid, uridylic acid and cytidylic acid.
- **Nucleic acid:** Polymer of nucleotides - DNA and RNA.

PRIMARY AND SECONDARY METABOLITES :

- **Primary metabolites :**
    - Have identified function.
    - Play known roles in physiological function.
    - Carbohydrates, amino acids, fats and oils, nitrogen bases are the example of primary metabolites.

- **Secondary metabolites :**
    - Have no definite function.
    - Have no direct role in normal physiology.
    - Alkaloid, favonoides, rubber, essential oils, antibiotics, coloured pigments. Scents, gums, spices are some example.

- **Biomacromolecules :** Biomolecules with molecular weights in the range of ten thousand daltons and above; found in acid insoluble fraction.
- Lipids are not strictly **macromolecules** as their molecular weights do not exceed 800 Da but form a part of the acid insoluble pool.

Proteins :

- Are polymers of amino acids linked by **peptide bond.**
- Is a **heteropolymer** not **homopolymer.**
- **Essential amino acids:** those can't be synthesized in our body, have to be supplied through our diet.
- **Non-essential amino acids:** our body can synthesize it from other sources.
- **Collagen** is the most abundant protein in animal.
- **Ribulose bisphosphate Carboxylase-Oxygenase (RUBISCO)** is most abundant protein in the whole biosphere.

POLYSACCHARIDES :

- Acid soluble pillet also has polysaccharides as another class of macromolecules.
- Polysaccharides are the long chain of sugars.
- **Cellulose** is homopolymer containing only glucose units.
- **Starch** is a variant of homopolymer of glucose which store energy.
- **Glycogen** is another homopolymer found in animal.
- **Inulin** is a polymer of **fructose.**
- In a polysaccharide chain the right end is called reducing end and left end is non-reducing end.
- Starch form helical secondary structure.
- Starch can hold Iodine (I_2) molecule in its helical portion hence gives blue colour.
- Cellulose dose not contain complex helices and hence cannot hold Iodine (I_2) and not give blue colour.
- Complex sugars have **amino-sugar** as building blocks. (Glucosamine, N-acetyl galactosamine.)
- Exoskeleton of arthropods made of complex sugar **called chitin.**
- Complex polysaccharides are heteropolymer.

STRUCTURE OF PROTEINS :

- **Primary structure**: Is found in the form of linear sequence of amino acids. First amino acid is called N-terminal amino acid and last amino acid is called C-terminal amino acid.
- **Secondary structure**: Polypeptide chain undergoes folding or coiling which is stabilized by hydrogen bonding. Right handed helices are observed. e.g., fibrous protein in hair nails.
- **Tertiary structure**: Long protein chain is folded upon itself like a hollow woolen ball. Gives a 3-dimensional view of protein, e.g., myosin.
- **Quaternary structure**: Two or more polypeptides with their folding and coiling are arranged with respect to each other. e.g., Human haemoglobin molecule has 4 peptide chains - 2α and 2β subunits.

NATURE OF BOND LINKING MONOMERS IN A POLYMER :

- **Peptide bondb :** Formed between the carboxyl (-COOH) group of one amino acid and the amino ($-NH_2$) group of the next amino acid with the elimination of water moiety.
- **Glycosidic bondb :**
    - Individual monosaccharides linked with each other to form polysaccharides.
    - This bond is also formed by dehydration.
    - Formed between two carbon atoms of two adjacent monosaccharides.

- **Phosphodiester bondbb :**
    - In a nucleic acid a phosphate moiety links the 3'-carbon of one sugar one nucleotide to the 5'-carbon of the sugar of the succeeding nucleotide.
    - The bond between the phosphate and hydroxyl group of sugar is an ester bond.
    - There is one such ester bond on either side, it is called Phosphodiester bond.

- **Anabolic pathways**: Lead to formation of more complex molecules from a simpler molecules with the consumption of energy. e.g., Protein from amino acids.
- **Catabolic pathway**: Lead to formation of simpler molecule from a complex molecule. e.g., Glucose → Lactic Acid.

ENZYMES :

- Are biocatalysts.
- Almost all enzymes are proteins.
- Ribozyme - Nucleic acids that behave like enzymes.
- Has primary, secondary and tertiary structure.
- Active site of an enzyme is a crevice or pocket into which substrate fits.
- Enzymes get damaged at high temperatures.
- Enzymes isolated from thermophilic organisms (live under high temperatures) are thermostable.
- Enzymes accelerate the reactions many folds.
- Enzymes lower the activation energy of reactions.
- The chemicals on which the enzyme acts called substrates.
- Enzyme converts substrates into products.

Nature of enzyme action :

- The substrate binds to the active site of the enzyme, fitting into the active site.
- The binding of the substrate induces the enzymes to alter its shape, fitting more tightly around the substrate.
- Active site now breaks the chemical bond of the substrate and enzyme-product complex is formed.
- The enzyme releases the product.

Factors affecting enzyme activity :

- **Temperature :**
    - Show highest activity at optimum temperature.
    - Activity declines above and below the optimum value.

- **pH :**
    - Enzymes function in a narrow range of pH.
    - Highest activity at optimum pH.

- **Concentration of substrate :**
    - The velocity of enzymatic reaction rises with increase in substrate concentration till it reaches maximum velocity (V max). Further increase of substrate does not increase the rate of reaction as no free enzyme molecules are available to find with additional substrate.

- **Enzyme inhibition**: When the binding of a chemical shuts off enzyme activity, the process is called inhibition and chemical is called inhibitor.
- **Competitive inhibition**: Inhibitor closely resembles the substrate in its molecular structure and inhibits the enzyme activity. E.g., inhibition of succinic dehydrogenase by malonate.

Classification of enzymes :

- **Oxidoreductase/dehydrogenases**: Catalyse oxidoreduction between 2 substrates.
- **Transferases**: Catalyse transfer of a group between a pair of substrates.
- **Hydrolases**: Catalyse hydrolysis of ester, ether, peptide, glycosidic, C-C, P-N bonds.
- **Lyases**: Catalyse removal of groups from substrates by mechanisms other than hydrolysis leaving a double bond in the product.
- **Isomerases**: Catalyse inter-conversion of optical, geometric or positional isomers.
- **Ligases**: Catalyse linking together of 2 compounds.

Cofactors :

- Non-protein constituents found to the enzyme to make it catalytically active.
- Protein portion of enzyme is called apoenzyme.
- **Prosthetic groups:** Are organic compounds tightly bound to apoenzyme. E.g., haem in peroxydase and catalase.
- **Co-enzymes**: Organic compounds which loosely bind with enzyme. E.g., NAD, NADP.
- **Metal ions**: Required for enzyme activity. Form coordination bond with side chains at active site and with substrate. E.g., zinc is a co-factor for enzyme enters stomach?

10. Cell Cycle and Cell Division

POINTS TO REMEMBER :

- **Cell cycle :** The sequence of events by which a cell duplicates its genome, synthesis the other constituents of the cell and eventually divides into two daughter cells.

Phases of cell cycle :

Interphase :

- **G_1 Phase**: Cell metabolically active and grows continuously.
- **S Phase**: DNA synthesis occurs, DNA content increases from 2C to 4C.but the number of chromosomes remains some (2N).
- **G_2 Phase**: Proteins are synthesized in preparation for mitosis while cell growth continues.
- **M Phase** (Mitosis Phase): Starts with nuclear division, corresponding to separation of daughter chromosomes (karyokinesis) and usually ends with division of cytoplasm (cytokinesis).
- **Quiescent stage (G_0)**: Cells that do not divide and exit G1 phase to enter an inactive stage called G_0. Cells at this stage remain metabolically active but do not proliferate.

MITOSIS :

- **Prophase :**
  - Replicated chromosomes, each consisting of 2 chromatids, condense and become visible.
  - Microtubules are assembled into mitotic spindle.
  - Nucleolus and nuclear envelope disappear.
  - Centriole moves to opposite poles.

- **Metaphase :**
  - Spindle fibres attached to kinetochores (small disc-shaped structures at the surface of centromers) of chromosomes.
  - Chromosomes line up at the equator of the spindle to form metaphase plate.

- **Anaphase :**
  - Centromeres split and chromatids separate.
  - Chromatids move to opposite poles.

- **Telophase :**
  - Chromosomes cluster at opposite poles.
  - Nuclear envelope assembles around chromosome cluster.
  - Nucleolus, Golgi complex, ER reform.

- **Cytokinesis :** Is the division of protoplast of a cell into two daughter cells after Karyokinesis (nuclear division).

- **Animal cytokinesis :** Appearance of furrow in plasma membrane which deepens and joins in the centre dividing cell cytoplasm into two.

- **Plant cytokinesis :** Formation of new cell wall begins with the formation of a simple precursor − cell plate which represents the middle lamella between the walls of two adjacent cells.

Significance of Mitosis :

- Growth − addition of cells.
- Maintenance of surface/volume ratio.
- Maintenance of chromosome number.
- Regeneration.
- Reproduction in unicellular organism.
- Repair and wound healing.

MEIOSIS :

- Specialized kind of cell division that reduces the chromosome number by half, resulting in formation of 4 haploid daughter cells.
- Occurs during gametogenesis in plants and animals.
- Involves two sequential cycles of nuclear and cell division called Meiosis I and Meiosis II.
- Interphase occurs prior to meiosis which is similar to interphase of mitosis except the S phase is prolonged.
- 4 haploid daughter cells are formed.

Meiosis I -

Prophase I : Subdivided into 5 phases.

Leptotene :

- Chromosomes make their as single stranded structures.
- Compaction of chromosomes continues.

Zygotene :

- Homologous chromosomes start pairing and this process of association is called **synapsis**.
- Chromosomal synapsis is accompanied by formation of **synaptonemal complex**.
- Complex formed by a pair of synapsed homologous chromosomes is called **bivalent** or **tetrad**.

Pachytene :

- Crossing over occurs between non-sister chromatids of homologous chromosomes.

Diplotene :

- Dissolution of synaptonemal complex occurs and the recombined chromosomes separate from each other except at the sites of crossing over. These X-shaped structures are called **chaismata.**

Diakinesis :

- Terminalisation of chaismata.
- Chromosomes are fully condensed and meiotic spindles assembled.
- Nucleolus disappears and nuclear envelope breaks down.

Metaphase I :

- Bivalent chromosomes align on the equatorial plate.
- Microtubules from opposite poles of the spindle attach to the pair of homologous chromosomes.

Anaphase I:

- Homologous chromosomes separate while chromatids remain associated at their centromeres.

Telophase I :

- Nuclear membrane and nucleolus reappear.
- Cytokinesis follows (diad of cells).

Interkinesis : Stage between two meiotic divisions. (Meiosis I and meiosis II)

Meiosis II -

Prophase II

- Nuclear membrane disappears.
- Chromosomes become compact.

Metaphase II

- Chromosomes align at the equator.
- Microtubules from opposite poles of spindle get attached to kinetochores of sister chromatids.

Anaphase II

- Simultaneous splitting of the centromere of each chromosome, allowing them to move towards opposite poles of the cell.

Telophase II

- Two groups of chromosomes get enclosed by a nuclear envelope.
- Cytokinesis follows resulting in the formation of tetrad of cells i.e., 4 haploid cells.

Significance of Meiosis

- Formation of gametes: In sexually reproducing organisms.
- Genetic variability

- Maintenance of chromosomal number: By reducing the chromosome number in gametes. Chromosomal number is restored by fertilisation of gametes.

11. Transport in Plants

POINTS TO REMEMBER :

- **Translocation :** Transport of substances in plants over longer distances through the vascular tissue (Xylem and Phloem) is called translocation.

- **Means of transport :** The transport of material into and out of the cells is carried out by a number of methods. These are diffusion, facilitated diffusion and active transport.

- **Diffusion :** Diffusion occurs from region of higher concentration to region of lower concentration across the permeable membrane. It is passive and slow process. No energy expenditure takes place.

- **Facilitated diffusion :** The diffusion of hydrophilic substances along the concentration gradient through fixed membrane transport protein without involving energy expenditure is called facilitated diffusion. For this the membrane possesses aquarporins and ion channels. No energy is utilized in this process.

Methods of Facilitated Diffusion :

- Some carrier or transport proteins allow diffusion only if two types of molecules moves together.
- **Symport**: both molecules cross the membrane in the same direction.
- **Antiport**: both molecule moves in opposite direction.
- **Uniport**: one type of molecule moves across the cell membrane.

Active transport :

- Active transport is carried by the movable carrier proteins (pumps) of membrane.
- Active transport uses energy to pump molecules against a concentration gradient from a low concentration to high concentration (uphill-transport).
- It is faster than passive transport.

Water potential :

- Water molecule possesses kinetic energy.
- The greater the concentration of water in a system, the greater is its kinetic energy or water potential.
- **Pure water has the highest water potential.**
- Water always moves from higher water potential to lower water potential.
- Water potential is denoted by Ψw (Psi) and measured in Pascals (Pa). The water potential of a cell is affected by solute potential (Ψs) and pressure potential (Ψp).
- $\Psi w = \Psi s + \Psi p$
- Water potential of pure water at standard temperature which is not under any pressure is taken to be zero (by convention).

Osmosis :

- Osmosis is movement of solvent or water molecules from the region of their higher diffusion pressure or free energy to the region of their lower diffusion pressure or free energy across a semi-permeable membrane.
- Water molecules move from higher water potential to lower water potential until equilibrium is reached.

Plasmolysis :

- Process of shrinkage of protoplasm in a cell due to exosmosis in hypertonic solution.
- **Turgor pressure**: a plant cell placed in hypotonic solution, water enters into it due endosmosis and the cytoplasm exert pressure against the cell wall called turgor pressure.
- Imbibition: Imbibition is the phenomenon of adsorption of water or any other liquid by the solid particles of a substance without forming a solution.

Some examples of Imbibition :

- If a dry piece of wood is placed in water, it swells and increases in its volume.
- If dry gum or pieces of agar-agar are placed in water, they swell and their volume increases.
- When seeds are placed in water they swell up.

Long distance transport of water :

- Mass flow: Mass flow is the movement of substances (water, minerals and food) in bulk from one point to another as a result of pressure differences between two points.
- Translocation: the bulk movement of substance through the conducting or vascular tissue is called translocation.

How do plants absorb water?

- Transport of water in plants: Water is absorbed by root hairs, then water moves upto xylem by two pathways − apoplast and symplast pathway.

- **Apoplast pathway :**
  - Movement of water takes place exclusively through the intercellular spaces and the walls of the cells.
  - Movement through the apoplast does not involve crossing the cell membrane.
  - Movement depends on the gradient.
  - The apoplast does not provide any barrier to water movement.
  - Water movement is trough mass flow.

- **Symplast pathway :**
  - System of interconnected protoplasts.
  - Neighboring cells are connected through cytoplasmic strands that extend through plasmodesmata.
  - Water enters into the cytoplasm by crossing the plasma membrane.
  - Intercellular movement is through the plasmodesmata.

- **Casparian strip :** endodermis is impervious to water because of a band of suberised matrix called casparian strip.

Water movement up a plant :

- **Root pressure :** A hydrostatic pressure existing in roots which push the water up in xylem vessels.

- **Guttation :** The water loss in its liquid phase at night and early morning through special openings of vein near the tip of leaves.

- **Transpiration pull :** The transport of water to the tops of trees occurs through xylem vessels. The forces of adhesion and cohesion maintain thin and unbroken columns of water in the capillaries of xylem vessels through which it travels upward. Water is mainly pulled by transpiration from leaves. (Cohesion-tension-transpiration pull Model)

- **Transpiration :** The loss of water through stomata of leaves and other aerial parts of plants in form of water vapour.

- Transpiration driven ascent of xylem sap depends on the following physical properties of water:
    - **Cohesion :** mutual attraction between water molecules.
    - **Adhesion :** attraction of water molecules to polar surface(such as the surface of tracheary elements)
    - **Surface tension :** water molecules are attracted to each other in the liquid phase more than to water in the gas phase.

Role of transpiration :

- Creates transpiration pull for absorption and transport of plants.
- Supplies water for photosynthesis.
- Transports minerals from the soil to all parts of the plants.
- Cools leaf surfaces, sometimes 10 to 15 degrees, by evaporative cooling.
- Maintains the shape and structure of the plants be keeping cells turgid.

Factors affecting transpiration : Temperature, light, humidity, wind speed, number and distribution of stomata, water status of plant.

Uptake and transport of mineral nutrients :

- Ions are absorbed by the roots by passive and active transport.
- The active uptake of ions requires ATP energy.
- Specific proteins in membranes of root hair cells actively pump ions from the soil into the cytoplasm of epidermal cells and then xylem.
- The further transport of ions to all parts of the plant is carried through the transpiration stream.

The Pressure or Mass Flow Hypothesis :

- The glucose is prepared at the source by the process of photosynthesis and is converted to sucrose (sugar).
- This sugar is then moved into sieve tube cells by active transport. It produces hypertonic condition in phloem.
- Water in the adjacent xylem moves into phloem by osmosis.
- Due to osmotic (turgor) pressure, the phloem sap moves to the areas of lower pressure.
- At the sink, osmotic pressure is decreased.

- The incoming sugar is actively transported out of the phloem and removed as complex carbohydrates (sucrose).
- As the sugar is removed, the osmotic pressure decreases, the water moves out of the phloem and returns to the xylem.

12. Mineral Nutrition

POINTS TO REMEMBER :

- **Autotrophs :** An organism that synthesize its required nutrients from simple and inorganic substances.
- **Heterotrophs :** An organism that cannot synthesize its own nutrients and depend on others.

Essential Mineral elements :

- More than sixty elements found in different plants.
- Some plant accumulates selenium, some other gold.

Criteria for Essentiality :

- Element absolutely necessary for normal growth and reproduction.
- In the absence of the element the plant can not complete their life cycle.
- Role of the element can not be replaced by any other elements.
- The element must be directly involved in the metabolism of plant.

Macronutrients : are generally present in the plants tissues in large amount (in excess of 10 mmole Kg^{-1} of dry matter).
Micronutrients : or trace elements are needed in very small amounts (less than 10 mmole Kg^{-1} of dry matter)

Four group of essential elements :

- As components of **biomolecules** and forms structural elements of cells (e.g. carbon, hydrogen, oxygen and nitrogen)
- As components of **energy-related** chemical compounds in plants. (magnesium in chlorophyll and phosphorous in ATP)
- Element that **activate** or **inhibit enzymes** (Mg^{2+}, Zn^{2+})
- Alter the **osmotic potential** of a cell. (K^{+})

Role of macro and micro-nutrients :

Nitrogen :

- Absorbed in the form of NO_2^- or NH_4^+
- Required by meristematic tissue and metabolically active tissue.
- Constituent of proteins, nucleic acids, vitamins and hormones.

Phosphorus :

- Absorbed in the form of H_2PO_4- or HPO_4^{2-}.
- Constituents of cell membrane certain proteins, all nucleic acids and required in **phosphorylation reaction**.

Potassium :

- Absorbed as potassium ion (K^{+})
- Required in meristematic tissues.
- Maintain cation and anion balance in cell.
- **Opening and closing** of stomata.
- Activation of enzyme.

- Maintenance of turgidity of cells.

Calcium :

- Absorbed in the form of calcium ions (Ca^{2+}).
- Required by meristematic and differentiating tissues.
- Used in synthesis of cell wall particularly as calcium pectate in **middle lamella**.
- Required during formation of **mitotic spindle.**
- Involved in normal functioning of cell membrane.
- Activate certain enzyme.
- Important role in regulating metabolic activity.

Magnesium :

- Absorbed in the form of Mg^{2+}.
- Activates enzymes of respiration, photosynthesis.
- Involved in the synthesis of DNA and RNA.
- Constituent of the **ring structure of chlorophyll**.
- Maintain **ribosome structure**.

Sulphur :

- Absorbed in the form of sulphate SO_4^{2-}.
- Present in two amino acids **cystine** and **methionine**
- Main constituent of several coenzyme, vitamins and ferredoxin.

Iron :

- Obtained in the form of ferric ions (Fe^{3+}).
- Required in larger amount in comparison to other elements.
- Constituent of proteins involved in the transfer of electron like **ferredoxin** and **cytochromes**.
- Activates catalase enzyme.
- Essential for formation of chlorophyll.

Manganese :

- Absorbed in the form of manganous ions (Mn^{2+}).
- Activates many enzymes of photosynthesis, respiration and nitrogen metabolism.
- **Photolysis of water** and evolution of oxygen during light reaction.

Zinc :

- Obtained in the form of Zn^{2+}.
- Activates enzymes like **carboxylase.**
- Required in **synthesis of auxin.**

Cupper :

- Absorbed in the form of cupric ions (Cu^{2+}).
- Essential for overall metabolism.

- Associated with enzyme involved in redox reactions.

Boron :

- Absorbed in the form of BO_3^{3-} or $B_4O_7^{2-}$.
- Required in **uptake and utilization of Ca^{2+}.**
- Pollen germination.
- Cell elongation.
- Cell differentiation.
- Carbohydrate translocation.

Molybdenum :

- Obtained in the form of molybdate ions (MoO_2^{2-}).
- Component of enzyme like **nitrogenase** and **nitrate reductase.**
- Required in nitrogen metabolism.

Chlorine :

- Absorbed in the form of chloride anion (Cl^-).
- Along with Na^+ and K^+ it determines the solute concentration.
- Maintain anion cation balance of the cell.
- Essential for **photolysis of water** during light reaction of photosynthesis.

Deficiency symptoms of essential elements :

- Critical concentration: the concentration of the essential element below which plant growth is retarded.
- The element is said to be deficient when present below the critical concentration.
- For the elements that are actively mobilized within the plant that show the deficiency symptoms in the older tissues. (nitrogen, potassium and magnesium)
- The deficiency symptoms tend to appear first in the young tissues whenever the elements are relatively immobile and are not transported out of the mature organs.(sulphur and calcium)
- Deficiency symptom includes chlorosis, necrosis, and stunted growth, premature fall of leaves and buds, and inhibition of cell division.
- **Chlorosis:** is the loss of chlorophyll.
- **Necrosis:** death of cells and tissues.

Toxicity of Micronutrients :

- Micronutrient required in low amount.
- Moderate decrease causes the deficiency symptoms.
- Moderate increase causes toxicity.
- Any mineral ion concentration in tissues that reduces the dry weight of the tissues by 10 percent is considered **toxic**.

Nitrogen cycle :

- **Nitrogen fixation**: conversion of molecular nitrogen into ammonia.
- **Biological nitrogen fixation**: Conversion of atmospheric into organic compounds by living organisms.
- **Ammonification:** decomposition of organic nitrogen of dead plants and animals into ammonia is called Ammonification. (***Nitromonas***bacteria)

- **Nitrification.** Ammonia oxidized into nitrite by ***Nitrosomonas***and***Nitrococcus*** bacteria. The nitrite further oxidized to nitrate with the help of ***Nitrobacter*.** These steps are called nitrification.

- **Assimilation:**
    - Nitrates absorbed by plant from soil and transported to the leaves.
    - In the leaves nitrates reduced to form ammonia that finally forms the amine group of amino acids.

- **Denitrification:** Nitrate in the soil is also reduced to molecular nitrogen. This process is carried by bacteria like***Pseudomonas*** and ***Thiobacillus.***

Biological nitrogen fixation :

- Reduction of nitrogen to ammonia by living organisms is called biological nitrogen fixation.
- The enzyme nitrogenase which catalyses the process are present in prokaryotes, called nitrogen fixer.
- Nitrogen fixing microbes could be free-living or symbiotic.
- Free-living nitrogen fixing aerobic microbes are ***Azotobacter*** and ***Beijernickia*.**
- Free-living nitrogen fixing anaerobic microbes are ***Rhodospirilium.***
- A number of cyanobacteria like ***Anabaena*** and ***Nostoc*** are free-living nitrogen fixer.

Symbiotic nitrogen fixation :

- Best example of symbiotic nitrogen fixation is observed in legume-Rhizobium bacteria.
- Rhizobium form root nodules in leguminous plants.
- ***Frankia*** also produces nitrogen-fixing nodules on the roots of non-leguminous plants (e.g. Alnus).
- Both Rhizobium and Frankia are free living in soil, but as symbiont, can fix atmospheric nitrogen.
- The root nodules contain pink coloured pigment contains a protein called **leg-haemoglobin.**

Nodule formation :

- Nodule formation involves a sequence of multiple interactions between Rhizobium and roots of the host plant.
- *Rhizobia* multiply and colonize the surroundings of roots and get attached to the epidermal and root hair cells.
- An infection thread is produced carrying the bacteria into the cortex of root.
- Bacteria released from the thread into the cells which differentiated into special nitrogen fixing cells.
- Nodule develops vascular connection for exchange of nutrients.
- The nodule contains an enzyme called **nitrogenase.**
- Nitrogenase is a Mo-Fe protein and catalyses the conversion of atmospheric nitrogen to ammonia.
- Nitrogenase is highly sensitive to molecular oxygen; it requires anaerobic condition.
- Nodule contains a special protein called **leg-haemoglobin**.
- Leg-haemoglobin acts as **oxygen scavenger** and provides anaerobic condition to the bacteria inside the nodules; protect the enzyme nitrogenase from oxidation.
- Ammonia synthesis by nitrogenase is energetically expensive process; 8 ATP required synthesizing each molecule of NH_3.

Fate of ammonia :

- At physiological pH, the ammonia is protonated to form NH_4+.
- Most of plant assimilated nitrate and ammonium ions.

- **Reductive amination**: the ammonia reacts with α-ketoglutaric acid and forms Glutamic acid.
- **Transamination:** it involves the transfer of amino group from one amino acid to the keto group of a keto acid.
- Glutamic acid is the main amino acid from which by the process of transamination other amino acids are synthesized.
- Two important amides – asparagines and glutamine found in the protein of plant.
- They are formed from two amino acids namely aspartic acid and Glutamic acid respectively.

13. Photosynthesis in Higher Plants

POINTS TO REMEMBER :

- Photosynthesis: Photosynthesis is an enzyme regulated anabolic process of manufacture of organic compounds inside the chlorophyll containing cells from carbon dioxide and water with the help of sunlight as a source of energy.

Historical Perspective :

- **Joseph Priestley (1770) :** Showed that plants have the ability to take up CO_2 from atmosphere and release O_2.
- **Jan Ingenhousz (1779) :** Release of O_2 by plants was possible only in sunlight and only by the green parts of plants.
- **Theodore de Saussure (1804) :** Water is an essential requirement for photosynthesis to occur.
- **Julius Von Sachs (1854) :** Green parts in plant produce glucose which is stored as starch.
- **T. W. Engelmann (1888) :** The effect of different wavelength of light on photosynthesis and plotted the first action spectrum of photosynthesis.
- **C. B. Van Niel (1931) :** Photosynthesis is essentially a light dependent reaction in which hydrogen from an oxidisable compound reduces CO_2 to form sugar. He gave a simplified chemical equation of photosynthesis.
- **Hill (1937) :** Evolution of oxygen occurs in light reaction.
- **Calvin (1954-55) :** Traced the pathway of carbon fixation.
- **Hatch and Slack (1965) :** Discovered C4 pathway of CO_2 fixation.

Site for photosynthesis :

- Photosynthesis takes place only in green parts of the plant, mostly in leaves.
- Within a leaf, photosynthesis occurs in mesophyll cells which contain the chloroplasts.
- Chloroplasts are the actual sites for photosynthesis.
- The thylakoids in chloroplast contain most of pigments required for capturing solar energy to initiate photosynthesis.
- The membrane system (grana) is responsible for trapping the light energy and for the synthesis of ATP and NADPH. Biosynthetic phase (dark reaction) is carried in stroma.

Pigments involved in photosynthesis:

- **Chlorophyll a :** (Bright or blue green in chromatograph). Major pigment, act as reaction centre, involved in trapping and converting light into chemical energy.
- **Chlorophyll b :** (Yellow green)
- **Xanthophylls :** (Yellow)
- **Carotenoid :** (Yellow to yellow-orange)
- In the **blue** and **red** regions of spectrum shows higher rate of photosynthesis.

What is light reaction?

- Light reactions or the 'Photochemical 'phase includes light absorption, splitting of water, evolution of oxygen and formation of high energy compound like ATP and NADPH.
- **Light Harvesting Complexes (LHC) :** The light harvesting complexes are made up of hundreds of pigment molecules bound to protein within the photosystem I (PSI) and photosystem II (PSII).
- Each photosystem has all the pigments except one molecule of chlorophyll 'a' forming a light harvesting system (antennae).
- The reaction centre (chlorophyll a) is different in both the photosystems.

- **Photosystem I (PSI) :** Chlorophyll 'a' has an absorption peak at 700 nm (P700).
- **Photosystem II (PSII) :** Chlorophyll 'a' has absorption peak at 680 nm (P680).

Process of photosynthesis :

- It includes two phases - Photochemical phase and biosynthetic phase.
- **Photochemical phase (Light reaction) :** This phase includes - light absorption, splitting of water, oxygen release and formation of ATP and NADPH.
- **Biosynthetic phase (Dark reaction) :** It is light independent phase, synthesis of food material (sugars).

The electron transport :

- In photosystem centre chlorophyll a absorbs 680 nm wavelength of red light causing electrons to become excited and release two electrons from the atomic nucleus.
- These electrons are accepted by primary electron acceptor i.e. **ferredoxin.**
- The electron from the ferredoxin passed to **electron transport system** consisting **cytochromes.**
- The electron moved in down hill in terms of redox potential by oxidation-reduction reactions.
- Finally the electron reached photosystem-I.
- Simultaneously electron released from photosystem-I is accepted by electron acceptor.
- Electron hole created in PS-I is filled up by the electron from PS-II.
- Electron from PS-I passed down hill and reduce NADP into $NADPH^{+} + H^{+}$.

Photolysis of water :

- PS-II loose electrons continuously, filled up by electrons released due to photolysis of water.
- Water is split into H^{+}, (O) and electrons in presence of light and Mn^{2+} and Cl^{-}.
- This also creates O_2 the bi-product of photosynthesis.
- Photolysis takes place in the vicinity of the PS-II.
- $2H_2O \rightarrow 4H^{+} + O_2 + 4e^{-}$.

Photophosphorylation :

- The process of formation of high-energy chemicals (ATP and NADPH).

Non Cyclic photophosphorylation :

- Two photosystems work in series – First PSII and then PSI.
- These two photosystems are connected through an electron transport chain (Z. Scheme).
- **ATP** and **NADPH + H^{+}** are synthesized by this process. PSI and PSII are found in lamellae of grana, hence this process is carried here.

Cyclic photophosphorylation :

- Only **PS-I** works, the electron circulates within the photosystem.
- It happens in the stroma lamellae **(possible location)** because in this region **PS-II** and **NADP reductase** enzyme are absent.
- Hence only ATP molecules are synthesized.

Chemiosmotic Hypothesis :

- Chemiosmotic hypothesis explain the mechanism of ATP synthesis in chloroplast.

- In photosynthesis, ATP synthesis is linked to development of a proton gradient across a membrane.
- The protons that are produced by the splitting of water are accumulated inside of membrane of thylakoids (in lumen).
- As the electron moves through the photosystem, protons are transported across the membrane.
- NADP reductase enzyme is located on the stroma side of the membrane, along with electrons from the acceptor it removes H+ from the stroma during reduction of NADPH + H^+.
- This creates proton gradients across the thylakoid membrane as well as a measurable decrease in pH in the lumen.
- ATPase has a channel that allows diffusion of protons back to stroma across the membrane.
- This releases energy to activate ATPase enzyme that catalyses the formation of ATP.

Biosynthetic phase in C3 plants :

- ATP and NADH, the products of light reaction are used in synthesis of food. The first CO_2 fixation product in C3 plant is 3-phosphoglyceric acid or PGA.
- In some other plants the first stable product is an organic acid called oxaloacetic acid a 4-C compound hence is called C4 plants.

The Calvin cycle :

- The CO_2 acceptor molecule is RuBP (Ribulose bisphosphate).
- The cyclic path of sugar formation is called Calvin cycle on the name of Melvin Calvin, the discoverer of this pathway. Calvin cycle proceeds in three stages:

- **Carboxylation :**
    - Carboxylation is the fixation of CO_2 into a stable organic intermediate.
    - CO_2 combines with Ribulose 1, 5 bisphosphate to form 3 PGA in the presence of **RuBisCo enzyme**.

- **Reduction :**
    - These are a series of reactions that lead to the formation of glucose.
    - 2 molecules of ATP for phosphorylation and two of NADPH for reduction per CO_2 molecule fixed.
    - The fixation of six molecules of CO_2 and 6 turns of the cycle are required for the formation of one molecule of glucose.

- **Regeneration :**
    - Regeneration of the CO_2 acceptor molecule RuBP is crucial if the cycle is to continue uninterrupted.
    - Regeneration steps required one ATP for phosphorylation to form RuBP.

- Hence for every CO_2 molecule entering the Calvin cycle, 3 molecules of ATP and 2 molecules of NADPH are required.

The C_4 pathway :

- Plants that are adapted to dry tropical regions have the C_4 pathway.
- C_4 oxaloacetic acid is the first CO_2 fixation product.
- These plants have special type of leaf anatomy, they tolerate higher temperatures.
- The leaf has two types of cells: mesophyll cells and Bundle sheath cells (Kranz anatomy).

- Initially CO_2 is taken up by phosphoenol pyruvate (PEP) in mesophyll cells and changed to oxaloacetic acid (OAA) in the presence of **PEP carboxylase**.
- Oxaloacetate is reduced to malate/asparate that reaches into bundle sheath cells.
- In the bundle sheath cells these C_4 acids are broken down to release CO_2 and a 3-carbon molecule i.e. pyruvic acid.
- The CO_2 released in the bundle sheath cell enters the C3 cycle because these cells are rich in enzyme Ribulose bisphosphate carboxylase-oxygenase **(RuBisCO).**
- The pyruvate formed in the bundle sheath cell transported back to the mesophyll cell, get phosphorylated to form phosphoenol pyruvate.

Photorespiration:

- The light induced respiration (evolution of CO_2) in green plants is called photorespiration.
- Active site of RuBisCO has active site for both O_2 and CO_2.
- In C3 plants some O_2 binds with RuBisCo and hence CO_2 fixation is decreased.
- In this process RuBP instead of being converted to 2 molecules of PGA, binds with O_2 to form one molecule of PGA and phosphoglycolate.
- In the photorespiratory pathway there is neither synthesis of sugar, nor of ATP. Rather it results in the release of $CO_2$with utilization of ATP.
- In the photorespiratory pathway there is no synthesis of ATP or NADPH.
- Therefore photorespiration is a wasteful process.
- In C_4 plant photorespiration does not occur:
    - RuBisCO enzyme is present in the bundle sheath cells.
    - Primary carboxylation is takes place in the mesophyll cell by PEP carboxylase.
    - CO_2 supplied to bundle sheath cell by C_4 acid intermediate.
    - Hence C_4 plants are photosynthetically more efficient than C3 plant.

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.

14. Respiration in Plants

POINTS TO REMEMBER :

- The breaking of C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called **respiration.**
- The compound that oxidized during this process is known as**respiratory substrates.**
- In the process of respiration the energy is released in a series of slow step-wise reactions controlled by enzymes and is trapped in the form of ATP.
- ATP acts as the energy currency of the cell.

Glycolysis :

- The term has originated from the Greek word, glycos =glucose, lysis = splitting or breakdown means breakdown of glucose molecule.
- It is also called **Embeden-Meyerhof-Paranus pathway**. (EMP pathway)
- It is common in both **aerobic** and **anaerobic** respiration.
- It takes place outside the mitochondria, in the **cytoplasm.**
- One molecule of glucose (Hexose sugar) ultimately produces two molecules of pyruvic acid through glycolysis.
- Glucose and fructose are phosphorylated to give rise to glucose-6-phosphate, catalyzed by **hexokinase.**
- This phosphorylated form of glucose is then isomerizes to produce **fructose-6-phosphate.**
- ATP utilized at two steps:
    - First in the conversion of glucose into glucose-6-phosphate
    - Second in fructose-6-phosphate→fructose 1, 6-diphosphate.

- The fructose-1, 6-diphosphate is split into dihydroxyacetone phosphate and 3-phosphoglyceraldehyde (DPGA).
- In one step where NADH + H^+ is formed form NAD^+; this is when 3-phosphogleceraldehyde (PGAL) is converted into 1, 3-bisphophoglyceric acid (DPGA).
- The conversion of 1, 3-bisphophoglyceric acid into 3-phosphoglyceric acid is also an energy yielding process; this energy is trapped by the formation of ATP.
- Another ATP synthesized when phosphoenolpyruvate is converted into pyruvic acid.
- During this process 4 molecules of ATP are produced while 2 molecules of ATP are utilized. Thus net gain of ATP is of 2 molecules.

FERMENTATION :

- There are three major ways in which different cells handle pyruvic acid produced by glycolysis:
    - Lactic acid fermentation.
    - Alcoholic fermentation.
    - Aerobic respiration.

- **Alcoholic fermentation :**
    - The incomplete oxidation of glucose to achieved under anaerobic conditions by sets of reactions where pyruvic acid is converted into CO_2 and ethanol.

- The enzyme pyruvic acid decarboxylase and alcohol dehydrogenase catalyze these reactions.
- $NADH + H^+$ is reoxidised into NAD^+.

- **Lactic acid fermentation:**
  - Pyruvic acid converted into lactic acid.
  - It takes place in the muscle in anaerobic conditions.
  - The reaction catalysed by lactate dehydrogenase.
  - $NADH + H^+$ is reoxidised into NAD^+.

- **Aerobic respiration:**
  - Pyruvic acid enters into the mitochondria.
  - Complete oxidation of pyruvate by the stepwise removal of all the hydrogen atoms, leaving three molecules of CO_2.
  - The passing on the electrons removed as part of the hydrogen atoms to molecular oxygen (O_2) with simultaneous synthesis of ATP.

AEROBIC RESPIRATION:

- The overall mechanism of aerobic respiration can be studied under the following steps :
- Glycolysis (EMP pathway)
- Oxidative Decarboxylation
- Krebs's cycle (TCA-cycle)
- Oxidative phosphorylation

Oxidative decarboxylation:

- Pyruvic acid formed in the cytoplasm enters into mitochondria.
- Pyruvic acid is converted into Acetyl CoA in presence of **pyruvate dehydrogenase complex.**
- The pyruvate dehydrogenase catalyses the reaction require several coenzymes, including NAD^+ and Coenzyme A.
- During this process two molecules of NADH are produced from metabolism of two molecules of pyruvic acids (produced from one glucose molecule during glycolysis).
- The Acetyl CoA (2c) enters into a cyclic pathway, tricarboxylic acid cycle.

Tri Carboxylic Acid Cycle (Krebs cycle) or Citric acid Cycle :

- This cycle starts with condensation of acetyl group with oxaloacetic acid and water to yield citric acid. This reaction is catalysed by citrate synthase.
- Citrate is isomerised to form isocitrate.
- It is followed by two successive steps of decarboxylation, leading to formation of α-ketoglutaric acid and then succinyl-CoA.
- In the remaining steps the succinyl CoA oxidized into oxaloacetic acid.
- During conversion of succinyl CoA to succinic acid there is synthesis of one GTP molecule.
- In a coupled reaction GTP converted to GDP with simultaneous synthesis of ATP from ADP.
- During Krebs cycle there production of :
  - 2 molecule of CO_2
  - 3 $NADH_2$
  - 1 $FADH_2$

    - 1 GTP.
- During the whole process of oxidation of glucose produce:
    - CO_2
    - 10 $NADH_2$
    - 2 $FADH_2$
    - 2 GTP.(2 ATP)

Electron transport system and oxidative phosphorylation :

- The metabolic pathway, through which the electron passes from one carrier to another, is called **Electron transport system**.
- it is present in the inner mitochondrial membrane.
- ETS comprises of the following:
    - Complex I – NADH Dehydrogenase.
    - Complex II – succinate dehydrogenase.
    - Complex III – cytochromes bc1
    - Complex IV – Cytochromes a-a_3 (cytochromes c oxidase).
    - Complex V – ATP synthase.

- $NADH_2$ produced in the citric acid cycle oxidized by NADH Dehydrogenase, and electrons are then transferred to ubiquinone located in the inner membrane.
- $FADH_2$ is oxidized by succinate dehydrogenase and transferred electrons to ubiquinone.
- The reduced ubiquinone is then oxidized with transfer of electrons to cytochrome *c* via cytochromes *bc1* complex.
- Cytochrome c is small protein attached to the outer surface of the inner membrane and acts as a mobile carrier for transfer electrons from complex III and complex IV.
- When electrons transferred from one carrier to another via complex I to IV in the electron transport chain, they are coupled to ATP synthase for the synthesis of ATP from ADP and Pi.
- One molecule of $NADH_2$ gives rise to 3 ATP.
- One molecule of $FADH_2$ gives rise to 2ATP.
- Oxygen plays a vital role in removing electrons and hydrogen ion finally production of H_2O.
- Phosphorylation in presence of oxygen is called oxidative phosphorylation.

Total ATP Production -

Process Total ATP produced :

- Glycolysis 2ATP + $2NADH_2$ (6ATP) = 8ATP
- Oxidative decarboxylation $2NADH_2$ (6ATP) = 6ATP
- Krebs's Cycle 2GTP (2ATP) + $6NADH_2$ (18ATP) + $2FADH_2$ (4ATP) = 24 ATP
- Energy production in prokaryotes during aerobic respiration = 38 ATP
- Energy production in eukaryotes during aerobic respiration = 38 − 2 = 36 ATP
- (2ATP are used up in transporting 2 molecule of pyruvic acid in mitochondria.)

Abbreviations :

ATP − Adenosine tri phosphate

ADP − Adenosine di phosphate

NAD − Nicotinamide Adenine dinucleotide

NADP − Nicotinamide Adenine dinucleotide Phosphate

NADH − Reduced Nicotinamide Adenine dinucleotide

PGA − Phosphoglyceric acid

PGAL − Phospho glyceraldehyde

FAD − Flavin adenine dinucleotide

ETS − Electron transport system

ETC − Electron transport chain

TCA − Tricarboxylic acid

OAA − Oxalo acetic acid

FMN − Flavin mono nucleotide

PPP − Pentose phosphate pathway

15. Plant Growth and Development

POINTS TO REMEMBER :

Growth :

- An irreversible permanent increase in size of an organ or its parts or even of an individual cell.
- Growth is accompanied by metabolic process that occurs at the expense of energy.

Plant growth is generally is indeterminate :

- Plants retain the capacity of unlimited growth throughout their life.
- This ability is due to the presence of meristems at certain locations in their body.
- The cells of such meristems have capacity to divide and self-perpetuate.
- The product eventually looses the capacity to divide and differentiated.
- Apical meristems responsible for primary growth of the plants and principally contribute to the elongation of the plants along their axis.
- The lateral meristem, vascular cambium and cork cambium appears later and responsible for the increase in the girth.

Phases of growth :

- The period of growth is generally divided into three phases
  - **Meristematic.**
  - **Elongation.**
  - **Maturation.**

- Root apex and shoot apex represent the meristematic phase of growth.
- The cells of this region are rich in protoplasm, possesses large conspicuous nuclei.
- Their cell walls are primary in nature, thin and cellulosic with abundant plasmodesmatal connection.
- The cells proximal to that region are the phase of elongation.
- Increased vacuolation, cell enlargement and new cell wall deposition are the characteristic of the cells in this phase.
- Further away from the zone of elongation is the phase of maturation.
- The cells of this zone attain their maximal size in terms of wall thickening and protoplasmic modifications.

Condition of growth :

- Water, oxygen and nutrients as very essential element for growth.
- Turgidity of cells helps in extension growth.
- Water also provides the medium for enzymatic activities needed for growth.
- Oxygen helps in releasing metabolic energy essential for growth activities.
- Nutrients are required by plants for synthesis of protoplasm and act as source of energy.

Differentiation, dedifferentiation and redifferentiation :

- The cells derived from root apical and shoot apical meristems and cambium differentiate and mature to perform specific functions.

- This act of maturation is termed as **differentiation.**
- During differentiation major changes takes place in their cell wall and protoplasm.
- Differentiated tracheary element cells loose their protoplasm, develop a very strong, elastic lignocellulosic secondary cell walls.
- The living differentiated cells, that by now have lost the capacity to divide can regain the capacity of division under certain condition is **dedifferentiation.**
- Development of interfascicular cambium and cork cambium from fully differentiated parenchymatous cells is the example of dedifferentiation.
- Cells produced by the dedifferentiated tissues again loose the capacity to divide and mature to perform specific function is called **redifferentiation.**

PLANT GROWTH REGULATORS :

Characteristics :

- The plant growth regulators are small, simple molecules of diverse chemical composition.
- They could be:
    - Indole compounds (indole-3-acetic acid, IAA);
    - adenine derivatives (N6-furfurylamino purine, kinetin)
    - derivatives of carotenoids (abscisic acid,ABA)
    - terpenes (gibberellic acid, GA_2)
    - Gases (ethylene, C_2H_4)

- One group of PGRs are involved in growth promoting activities such as cell division, cell enlargement, pattern formation, tropic growth, flowering, fruiting and seed germination. These are called plant growth promoters, e.g. auxin, gibberellins and cytokinin.

- Another group of PGRs play important role in plant responses towards to wounds and stresses of biotic and abiotic origin. They involved in inhibitory responses like dormancy and abscission, e.g. abscisic acid.

Discovery of plant growth regulators :

- Auxin was isolated by **F.W. Went** from tips of oat seedlings.

- The ‘bakane’ (foolish seedling) a disease of rice seedlings, was caused by a fungal pathogen ***Gibberalla fujikuroi***.

- **E. Kurosawa** reported the appearance of the symptom of the disease in uninfected rice seedlings when treated with sterile filtrate of the fungus. The active substance was later identified as **Gibberellic acid.**

- **Skoog and Miller** identified and crystallized the cytokinesis promoting active substance that they termed as **kinetin**.

- During mid 1960s three different kinds of inhibitors purified, i.e. inhibitor-B abscission II and dormin. Later all the three proved to be chemically identical and named as Abscisic acid (ABA).

- **Cousins**discovered a gaseous PGR called **ethylene** from ripened orange.

Physiological effect of plant growth regulators :

Auxin :

- The term auxin is applied to indole-3-acetic acid
- Generally produced by growing apices of the stems and roots.
- IAA and IBA have been isolated from plants.
- NAA and 2, 4-D (2, 4-dichlorophenoxyacetic acid) are synthetic auxin.
- Promote rooting in stem cutting.
- Promote flowering.
- Inhibit fruit and leaf drop at early stages.
- Promote abscission of older mature leaves and fruits.
- The growing apical bud inhibit the growth of lateral bud, the phenomenon is called **apical dominance**.
- Auxin induces parthenocarpy.
- Used as herbicides.
- Controls xylem differentiation.
- Promote cell division.

Gibberellins :

- Ability to cause an increase in length of axis is used to increase the length of grapes stalks.
- Gibberellins cause fruits like apple to elongate and improve its shape.
- Delay senescence
- GA3 is used to speed up the malting process in brewing industry.
- Gibberellins promote to increase length of stem in sugar cane.
- Promote early seed production.
- Promote bolting (internodes elongation) in beet, cabbages.

Cytokinins :

- Cytokinins have specific effects on cytokinesis.
- Zeatin isolated from corn-kernels and coconut milk.
- Promote cell division.
- Help to produce new leaves, chloroplast in leaves, lateral shoot growth
- Promote formation of adventitious shoot.
- Cytokinins help to overcome apical dominance.
- Promote nutrient mobilization.
- Delay senescence.

Ethylene :

- Ethylene is a simple gaseous PGR.
- Synthesized in the tissue undergoing senescence and ripening fruits.
- Promote horizontal growth of seedling.
- Promote swelling of axis and apical hook formation in dicot seedlings.
- Promote senescence and abscission of plant organs like leaf and flower.
- Increase rate of respiration during ripening of fruits, called **respiratory climactic.**
- Breaks seed and bud dormancy.
- Initiate germination.
- Promote rapid internodes elongation.
- Promote root growth and root hair formation.
- Used to initiate flowering and for synchronizing fruit-set.
- Induce flowering in mango.
- The source of ethylene is **ethephon.**
- Promote female flower in cucumbers thereby increasing the yield.

Abscisic acid :

- Regulates abscission and dormancy.
- Acts as general plant growth inhibitor and an inhibitor of plant metabolism.
- Inhibit seed germination.
- Stimulates the closure of stomata and increases the tolerance of plants to various kinds of stresses, hence called as**stress hormone.**
- Important role in seed development, maturation and dormancy.
- Inducing dormancy, ABA helps seeds to withstand desiccation and other factors unfavourable for growth.
- Acts as antagonist to Gas.

PHOTOPERIODISM :

- Some plants require a periodic exposure to light to induce flowering.
- Response of plants in terms of day/night in relation to flowering is called **photoperiodism.**
- **Long day plant**: plant requires the exposure to light for a period exceeding critical period.
- **Short day plant:** plant requires the exposure to light for a period less than critical period.
- **Day neutral plant:** there is no such correlation between exposure to light duration and induction of flowering response.
- The site of perception of light/dark duration is the leaves.

VERNALISATION :

- **Vernalisation:** There are plants for which flowering is either quantitatively or qualitatively dependent on exposure to low temperature.
- It prevents precocious reproductive development late in the growing season.
- Vernalisation refers to the promotion of flowering by a period of low temperature.

16. Digestion and Absorption

POINTS TO REMEMBER :

Digestion : enzymatic conversion of complex food substances to simple absorbable forms in the alimentary canal.

DIGESTIVE SYSTEM :

Includes:

- Alimentary canal
- Digestive glands or associated glands.

Alimentary canal :

- The alimentary canal begins with mouth and ends with anus.
- Mouth leads to buccal cavity or oral cavity.
- Oral cavity has teeth and muscular tongue.
- Each tooth embedded in a socket of jaw bone: such attachment called **thecodont.**
- **Diphyodont :** human has two sets of teeth in their life time:
    - **Milk teeth or deciduous teeth**
    - **Permanent teeth.**

- **Heterodont :** teeth are of unequal shape and size.
    - **Incisor (I)**
    - **Canine (C)**
    - **Premolar (PM)**
    - **Molar (M).**

- **Dental formula :** arrangement of teeth in each half of the upper jaw and lower jaw.

- **Dental formula of human adult is** $\frac{2123}{2123} \times 2 = 32$
- The hard chewing surface of the teeth made up of enamel.
- The tongue is a freely movable muscular organ attached to the floor of the oral cavity by the **frenulum.**
- The upper surface of tongue has small projections called papillae, some of which bears taste buds.
- The oral cavity leads into a short pharynx which serves as a common passage for food and air.
- Oesophagus and the trachea open into the pharynx.
- Opening of wind pipe or trachea called **glottis**, and that of oesophagus is called **gullet.**
- The cartilaginous **epiglottis** prevents the entry of food into the glottis during swallowing.
- Oesophagus connects pharynx with stomach.
- Opening of oesophagus is regulated by **gastro-oesophageal sphincter.**

- The stomach has three parts:
    - **Cardiac**: into which oesophagus opens.
    - **Fundus**: air filled portion of stomach.
    - **Pyloric**: portion opens into the small intestine.

- Small intestine distinguished into three parts:
    - **Duodenum**: 'U' shaped first part.
    - **Jejunum**: longer, coiled middle portion.
    - **Ileum**: highly coiled posterior part.

- The opening of stomach into the duodenum is guarded by **pyloric sphincter.**
- Large intestine consists of three parts:
    - **Caecum**
    - **Colon**
    - **Rectum.**

- Caecum is a small blind sac which hosts some symbiotic micro-organisms.
- Caecum has a finger-like blind tubular projection called **vermiform appendix.**
- The Caecum opens into colon, which has three distinct part-
    - **Ascending colon**
    - **Transverse colon**
    - **Descending colon**

- The descending colon opens into rectum which opens to out through anus.

Histolology of alimentary canal :

- Alimentary canal from oesophagus to rectum has four layers.
    - **Serosa.**
    - **Muscularis.**
    - **Sub mucosa.**
    - **Mucosa.**

- Serosa is the outermost layer and is made up of a thin mesothelium with some connective tissues.
- Muscularis is formed by smooth muscles arranged outer longitudinal and inner circular layers.
- Sub-mucosa is formed by loose connective tissues containing nerves, blood and lymph vessels.
- Mucosa is the innermost layer made of endothelium.
- Mucosa forms irregular folds (rugae) in the stomach and small finger like folding called **villi** in the small intestine.
- The cells lining the villi produce numerous microscopic projections called microvilli giving a brush border appearance.
- These modifications increase the surface area for absorption.

- Villi are supplied with a network of capillaries and a central lymphatic vessel called **lacteal**.
- Epithelial cells of mucosa contain secretory cells which secretes digestive enzymes.
- Mucosa also forms glands in the stomach (gastric gland)
- Mucosa forms crypts in between the bases of villi in the intestine called **Crypts of Lieberkuhn**.

Digestive glands :

- The digestive glands associated with the alimentary canal includes-
  - **Salivary gland**
  - **Liver**
  - **Pancreas.**

- There are three pairs of salivary gland present in the buccal cavity.
  - Parotid gland (below internal ear)
  - Sub-maxillary / submandibular (below lower jaw)
  - Sub-lingual (below tongue)

- All salivary glands produce saliva into the buccal cavity.

Liver :

- Largest gland of the body weighing about 1.2 to 1.5 kg in adult.
- Located below diaphragm and has two lobes.
- Structural and functional unit of liver is the **hepatic lobules**.
- Hepatic lobules consist of hepatic cells arranged in the form of cords.
- Each lobule is covered by a thin connective tissue sheath called **Glisson's capsule**.
- The bile secreted by the hepatic cells passes through the **hepatic ducts** and stored in the **gall bladder** in concentrated form.
- Bile from the gall bladder is transported by **cystic duct**.
- Cystic duct along with hepatic duct forms the **common bile duct**.
- Bile duct joined with pancreatic duct to form **hepato-pancreatic duct** which open into the duodenum.
- Hepato-pancreatic has a swelling portion called **ampulla of Vater**; the opening is guarded by **sphincter of Oddi.**

Pancreas :

- Pancreas is a compound **myxocrine gland** (both exocrine and endocrine) elongated organ situated between the limbs of 'U' shaped duodenum.
- The exocrine **aciner cells** secrete pancreatic juice containing enzymes.
- The endocrine **Islets of Langerhans** secrete hormones like insulin and glucagon.

DIGESTION OF FOOD :

- Digestion is accomplished by mechanical and chemical process.

In the buccal cavity :

- Buccal cavity performs two major functions;

- Mastication of food.
- Facilitation of swallowing.

- The teeth and tongue with the help of saliva masticate and mix up the food.
- The saliva composed of ;
  - Electrolytes (Na^+, K^+, Cl^- HCO^-_3)
  - Enzyme- salivary amylase or ptyalin.
  - Lysozyme.

- About 30% of starch is hydrolyzed into disaccharide (maltose) by salivary amylase in optimum pH 6.8).
- Lysozyme acts as antibacterial agent preventing infections.
- Mucus in the saliva helps in lubricating and adhering the masticated food particle into a **bolus**.
- The bolus is then passed into oesophagus through pharynx by swallowing or **deglutition**.
- By **peristalsis** the bolus from the oesophagus passed into the stomach.

In the stomach :

- The mucosa of stomach has gastric glands.
- Gastric glands have three major types of cells namely –
  - **Mucus neck cells** – secretes **mucus.**
  - **Peptic** or **chief** or **zymogen cells** – secretes proenzymes **pepsinogen**.
  - **Parietal** or **oxyntic cells** – secretes **HCl** and castles **intrinsic factor** (factor essential for absorption of vitamin B_{12})

- The stomach stores the food for 4-5 hours.
- The food mixed with the acidic gastric juice and form **chyme**.
- Pepsinogen converted into active pepsin in presence of HCl.
- Active pepsin converts proteins into **proteose** and **peptones** (peptides).
- Mucus and bicarbonate ions play important role in lubrication and protection of mucosal epithelium from excoriation by HCl and active enzymes.
- HCl provides the acidic pH of stomach (pH1.8)
- Rennin is an enzyme present in gastric juice helps in digestion of milk proteins.
- Small amount of lipases are present in gastric juice helps in digestion of fats.

$$\text{Protein} \xrightarrow{\text{Pepsin}} \text{Proteoses} + \text{Peptones}$$

$$\text{Milk caseinogen} \xrightarrow{\text{Rennin}} \text{Solid casein (curd)}$$

$$\text{Curd} \xrightarrow{\text{Pepsin}} \text{Peptone}$$

$$\text{Fat} \xrightarrow{\text{Lipase}} \text{Fatty acids}$$

In the intestine :

- Important secretion added to the intestine during digestion:
  - **Bile juice.**

- **Pancreatic juice.**
- **Intestinal juice or succus entericus.**

- The pancreatic juice contain following enzymes:
  - Trypsinogen
  - Chymotrypsinogen
  - Procarboxypeptidase.
  - Amylases
  - Lipases
  - Nucleases.

- Trypsinogen is activated by an enzyme, **enterokinase** secreted by intestinal mucosa into active trypsin.
- Active trypsin activates other enzymes in the pancreatic juice in the intestine.
- **The bile released into the duodenum contains –**
  - Bile pigments (bilirubin and bili-verdin)
  - Bile salts. (Bicarbonate, tourocholate, glycolate)
  - Cholesterol and
  - Phospholipids.

- Bile salt helps in **emulsification** of fat, i.e. breakdown fats into small micelles.
- Bile also activates lipases.
- The intestinal mucosa contains **goblet cells** which secrete mucus.
- The secretion of brush border cells of intestinal mucosa and the goblet cells constitute the **intestinal juice** or **succusentericus**.
- **The intestinal juice contains variety of enzymes –**
  - Disaccharidases (maltase, lactase and invertase)
  - Dipeptidases.
  - Lipases.
  - Nucleosidases.

- Sub-mucosal glands (**Brunner's glands**) also secrete alkaline fluid to counter act acidic chyme before secretion of bile and pancreatic juice.

Digestion in small intestine : Liver secretes bile.

$$\text{Fat} \xrightarrow{\text{Bile}} \text{Emulsification}$$

Pancreatic juice contains trypsin.

$$\text{Proteoses \& peptones} \xrightarrow{\text{Trypsin}} \text{Tri and dipeptides}$$
$$\text{Starch \& glycogen} \xrightarrow{\text{Amylase}} \text{Maltose}$$
$$\text{Emulsified fats} \xrightarrow{\text{Steapsin}} \text{Fatty acids \& glycerols}$$
$$\text{Maltose} \xrightarrow{\text{Maltase}} \text{Glucose}$$
$$\text{Poly peptides} \xrightarrow{\text{Carboxy peptidase}} \text{Tri and dipeptides}$$
$$\text{Nucleic acids} \xrightarrow{\text{Nuclease}} \text{Nucleotides} + \text{Nucleosides}$$

Functions of succus entericus :

$$\text{Dipeptides} \xrightarrow{\text{Dipeptidases}} \text{Amino acids}$$
$$\text{Maltose} \xrightarrow{\text{Maltase}} \text{Glucose} + \text{Glucose}$$
$$\text{Lactose} \xrightarrow{\text{Lactase}} \text{Glucose} + \text{Galactose}$$
$$\text{Sucrose} \xrightarrow{\text{Sucrase}} \text{Glucose} + \text{Fructose}$$
$$\text{Necleotides} \xrightarrow{\text{Nucleotidase}} \text{Nucleosides} \xrightarrow{\text{Nucleosidases}} \text{Sugars} + \text{Bases}$$
$$\text{Di and monoglycerides} \xrightarrow{\text{Lipases}} \text{Fatty acids} + \text{Glycerol}$$

ABSORPTION OF DIGESTED PRODUCTS :

- Absorption is the process by which the end product of digestion passes through the intestinal mucosa into the blood or lymph.
- Absorption is carried out by **passive**, **active** or **facilitated transport** mechanism.
- Glucose, amino acids and electrolytes are absorbed by simple diffusion into the blood in the concentration gradient.
- Fructose and some amino acids absorbed with the help of carrier ions like Na+. This is called facilitated diffusion.
- Active transport of digested food and electrolytes takes place against the concentration gradients hence require energy.

Absorption of fatty acid and glycerol.

- Fatty acids and glycerol being insoluble cannot be absorbed into blood.
- They are transported into mucosal epithelium and triglycerides are formed.
- Triglycerides are covered by a protein coat to form small fat globules called **chylomicron**, which are incorporated into the **lacteal** in the villi.
- These lymphatic vessels ultimately release the absorbed substances into the blood stream later on.

Assimilation and egestion :

- The absorbed substances finally reach the tissues which utilize them for their activities. This process is called**assimilation**.
- The digestive wastes, solidified into coherent **faeces** in the rectum and removed to outside periodically by the process called **defaecation**.

DISORDERS OF DIGESTIVE SYSTEM :

Jaundice :

- Affected organ is the liver.
- Skin and eyes turn yellow due to deposition of bile pigments.

Vomiting :

- Ejection of stomach contents through the mouth.
- It is controlled by the vomit centre in the medulla oblongata.
- A feeling of nausea precedes vomiting.

Diarrahoea :

- Abnormal frequency of bowel movement and increased liquidity of the faecal discharge.
- It reduces the absorption of food.

Constipation :

- The faeces are retained in the rectum as the bowel movements occurs irregularly.

Indigestion :

- The food is not properly digested leading to a feeling of fullness.

Causes are inadequate enzymes secretion, anxiety, food poisoning, over eating and spicy food.

17. Breathing and Exchange of Gases

POINTS TO REMEMBER :

- Breathing: (External respiration) the process of exchange of O_2 from the atmosphere with CO_2 produced by the cells.

RESPIRATORY ORGANS :

- Direct respiration by diffusion from the environment – sponges, coelenterates, flat worms etc.
- Cutaneous or by skin – earthworm.
- Tracheal system – insects.
- Gills – aquatic arthropods mollusks
- Lungs – terrestrial forms.

HUMAN RESPIRATORY SYSTEM:

- External nostril opens into the nasal chamber through nasal passage.
- The nasal chamber opens into the **nasopharynx**.
- Nasopharynx opens through **glottis** of the **larynx** into the **trachea**.
- Larynx is a cartilaginous box which produce sound hence called **sound box**.
- Cartilaginous **epiglottis** covers the glottis during swallowing to prevent entry of food into trachea.
- Trachea is a straight tube extending up to themed-thoracic cavity, which divides into right and left primary **bronchi** at the level of 5th thoracic vertebra.
- Each bronchus undergoes repeated divisions to form the secondary and tertiary bronchi and bronchioles ending up in very thin **terminal bronchioles**.
- Trachea, primary, secondary and tertiary bronchi and initial bronchioles are supported by cartilaginous rings.
- Each terminal bronchiole gives rise to a number of very thin, irregular-walled and vascularised bags like structures called **alveoli**.
- The branching network of bronchi, bronchioles and alveoli comprises the lungs.
- There are two lungs which are covered by a double layered pleura, with pleural fluid in them.
- Lungs are situated in the thoracic chamber which is anatomically a air tight chamber.
- The thoracic chamber is formed –
    - Dorsally by vertebral column.
    - Ventrally by sternum.
    - Laterally by ribs.
    - On the lower side by dome shaped diaphragm.

- Respiration involves in following steps –
    - Breathing or pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.
    - Diffusion of gases (O_2 and CO_2) across alveolar membrane.
    - Transport of respiratory gases by blood.
    - Diffusion of O_2 and CO_2 between blood and tissues.
    - Utilization of O_2 by the cells for catabolic reactions and resultant release of CO_2.

MECHANISM OF BREATHING :

Inspiration :

- Intake of atmospheric air into the lungs.
- It occurs if the pressure within the lungs (intra-pulmonary pressure) is lower than the atmospheric pressure.
- Contraction of diaphragm which increases the volume of thoracic chamber in the anterior posterior axis.
- The contraction of external intercostals muscles lifts up the ribs and the sternum causing an increase in the volume of thoracic chamber in the dorso ventral axis.
- It causes an increase in pulmonary volume decrease the intra-pulmonary pressure to less than the atmospheric pressure.
- It forces the air out side to move in to the lungs, i.e, **inspiration**.

Expiration :

- Relaxation of diaphragm and inter-costal muscles returns the diaphragm and sternum to their normal positions and reduce the thoracic and pulmonary volume.
- It increases in intrapulmonary pressure slightly above the atmospheric pressure.
- It causes the expulsion of air from the lungs, i.e, **expiration**.
- A healthy man breathes 12-16 times/minutes.
- The volume of air involved in breathing is estimated by **spirometer**.

Respiratory Volumes and Capacities :

- **Tidal volume**: volume of air inspired or expired during a normal breathing. It is about 500 ml.
- **Inspiratory reserve volume**: Additional volume of air, a person inspire by a forceful inspiration. It is about 2500-3000 ml.
- **Expiratory reserve volume**: Additional volume of air, a person expires by a forceful expiration. It is about 1000-1100 ml.
- **Residual volume**: Volume of air remaining in the lungs even after a forceful expiration. It is about 1200 ml.
- **Inspiratory capacity**: it includes tidal volume and Inspiratory reserve volume.
- **Expiratory capacity**: it includes tidal volume and expiratory reserve volume.
- **Functional residual capacity:** This includes ERV+RV.
- **Vital capacity:** IRV + TV + ERV.
- **Total lung capacity:** RV + IRV + TV + ERV

EXCHANGE OF GASES :

- Alveoli are the primary site of exchange of respiratory gases.
- Exchange of gases also takes place between blood and tissues.
- Exchange of O_2 and CO_2 take place in the pressure gradient, by simple diffusion.
- Pressure contributed by an individual gas in a mixture of gases is called the partial pressure and is represented by pO_2 for oxygen and pCO_2 for carbon dioxide.
- **Diffusion of O_2**
    - pO_2 in alveolar air = 104 mm Hg.
    - pO_2 in venous blood = 40 mm Hg.
    - O_2 diffuses from alveoli to venous blood.

- **Diffusion of CO_2**
    - pCO_2 is venous blood = 45 mm Hg.

- pCO_2 is alveolar air = 40 mm Hg
- CO_2 diffuses from venous blood to alveoli.

- Solubility of CO_2 is 20-25 times higher than that of O_2; the amount of CO_2 that can diffuse through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O_2.
- Respiratory membrane is formed by;
  - Thin Squamous epithelium of the alveoli.
  - Endothelium of alveolar capillaries
  - Basement membrane between them.

TRANSPORT OF GASES :

- Blood is the medium of transport of O_2 and CO_2.
- About 97 per cent of O_2 is transported by RBCs in the blood.
- 3 per cent of O_2 is transported in the plasma in dissolved state.
- 20-25 per cent of CO_2 transported in the RBC in the form of carbamino-haemoglobin.
- 70 percent CO_2 carried as bicarbonate ion in plasma.
- 7 percent CO_2 transported in dissolved state in plasm.

Transport of Oxygen :

- Haemoglobin is red coloured pigment present in the RBC.
- O_2binds with hemoglobin reversibly to form **oxy-hemoglobin.**
- Each haemoglobin can binds maximum with **four O_2** molecules.
- Binding of Oxygen with haemoglobin is primarily related with partial pressure of O_2.
- Partial pressure of CO_2, hydrogen ion concentration (pH) and temperature are the factors that influence this binding.
- A sigmoid curve is obtained when percentage of saturation of hemoglobin with O_2 is plotted against the partial pressure of O_2 (pO_2). This curve is called **oxygen dissociation curve.**
- Condition favourable for binding of Hemoglobin with O_2 at alveolar level;
  - High pO_2
  - Low H^+ ion concentration.
  - Low temperature.

- Condition favourable for dissociation of HbO_2 into Hb and O_2 at tissue level;
  - Low pO_2
  - High H^+ ion concentration.
  - High temperature.

- Every 100 ml of oxygenated blood can deliver around 5 ml of O_2 to the tissues under normal physiological conditions.

Transport of Carbon dioxide:

- 20-25 percent of CO_2 is carried out in the RBC by binding with the free amino group of haemoblobin by formation of carbamino-haemoglobin.

- $CO_2 + HbNH_2 \xrightarrow{\text{Carbonic anhydrase}} HbNHCOOH$ (Carbamino haemoglobin)

- When pCO_2 is high and pO_2 is low as in the tissues, more binding of CO_2 occurs whereas, when the pCO_2 is low and pO_2 is high as in the alveoli, dissociation of CO_2 from carbamino-haemoglobin takes place.
- 70 per cent of CO_2 transported in the form of HCO_3- in the plasma.
- CO_2 from the tissue diffused into the plasma and along with the water it forms carbonic acid which dissociated into HCO_3- and H^+. This reaction is catalysed by an enzyme called **carbonic anhydrase** present in the plasma membrane of RBC and plasma.

- $CO_2 + HO_2 \xrightarrow{\text{Carbonic anhydrase}} H_2CO_3$ (Carbonic acid)

REGULATION OF RESPIRATION :

- Specialized centre present in the medulla region of the brain called respiratory rhythm centre is primarily responsible for regulation of breathing.
- Pneumotaxis centre of pons region of brain has moderate regulation.
- Neural signal from this centre can reduce the duration of inspiration and alter the rate of respiration.
- Chemosensitive area adjacent to rhythm centre is sensitive to CO_2 and H^+ ion.
- Receptors associated with aortic arch and carotid artery also can recognize changes in the CO_2 and H^+ concentration and send necessary signals to the rhythm centre for remedial actions.

DISORDERS OF REPIRATORY SYSTEM :

- **Asthma :** is a difficulty in breathing causing wheezing due to inflammation of bronchi and bronchioles.
- **Emphysema :** a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased. It caused due to smoking.

18. Body Fluids and Circulation

POINTS TO REMEMBER :

- **Blood**: A special connective tissue that circulates in principal vascular system of man and other vertebrates consisting of fluid matrix, plasma and formed elements.

Plasma :

- The liquid part of blood or lymph which is straw coloured, viscous fluid constituting nearly 55 per cent of blood.
- 90-92 percent of plasma is water and 6-8% proteins.
- **Fibrinogen**, **globulin** and **albumins** are the major protein found in plasma.
- Fibrinogen is required in blood clotting or coagulation of blood.
- Globulins involved in defense mechanism of the body.
- Albumin helps in osmotic balance of blood.
- Plasma also contains small amounts of minerals, glucose, amino acids, lipids etc.
- Plasma without the clotting factors is called **serum**.

Formed elements :

Erythrocytes :

- Also known as RBC (red blood cells) is the most abundant of all the cells of blood.
- 5 – 5.5 million RBC found per mm-3 of the blood.
- Produced from the red bone marrow in the adult.
- RBCs devoid of nucleus in most of mammals.
- Biconcave in shape
- Red in color due presence of complex conjugated protein called **haemoglobin**.
- 12-16 gm of haemoglobin present per 100 ml of blood in a healthy adult.
- RBCs have average life span of 120 days after which is destroyed in the spleen.
- Spleen is commonly known as the graveyard of RBCs.

Leukocytes :

- Also known as white blood cells (WBC).
- They are colorless due to lack of haemoglobin.
- They are nucleated and relatively lesser in number which averages 6000-8000 mm-3 of blood.
- We have two main category of WBC;
- **Granulocytes**
    - Neutrophils
    - Basophils
    - Eosinophils

- **Agranulocytes**.
    - Lymphocytes
    - Monocytes.

- Neutrophils (60-65%) of the total WBCs are phogocytic in nature.
- Basophils (0.5-1 %), secretes **histamine**, **serotonin** and **heparin** and also involved in inflammatory reactions.
- Eosinophils (2-3 %) resist infection and also associated with allergic reaction.
- Lymphocytes (T cells and B cells) constitute 20-25 percent and involved in the immune response of the body.
- Monocytes (10-15%), becomes macrophages.

Thrombocytes :

- Also known as blood platelets.
- Produced from fragmentation of **megakaryocytes**.
- Blood normally contain 1, 500, 00 – 3, 500, 00 platelets mm-3.
- Involved in releasing **thromboplastin** required to initiate blood coagulation.

BLOOD GROUPS :

- Two blood grouping mechanisms ABO and Rh system.

ABO grouping :

- ABO grouping is based on the presence or absence of two surface antigens on the RBCs namely A and B.
- Plasma of different individuals contains two natural antibodies, anti 'A' and 'B'.

Blood Groups

Blood Group	Antigen (on the Surface of R.B.Cs)	Anti body (In plasma)	Possible recipients having blood group	Prospective donors having blood group	Remarks
A	A	Anti B	A, AB	O, A	–
B	B	Anti A	B, AB	O, B,	–
AB	A and B	None	AB	O, A, B, AB	Universal recipients
O	None	Anti A and anti B	O, A, B, AB	O	Donor

- In a mismatched transfusion the antigen of the donor reacts with antibody of the recipient to cause a reaction called**clumping** of **agglutination**.
- Person with blood group 'O' has no antigen hence can donate blood anybody, called **universal donor**.
- Person with blood group 'AB' has no antibody in his plasma hence can receive blood from anybody, called **universal recipient.**

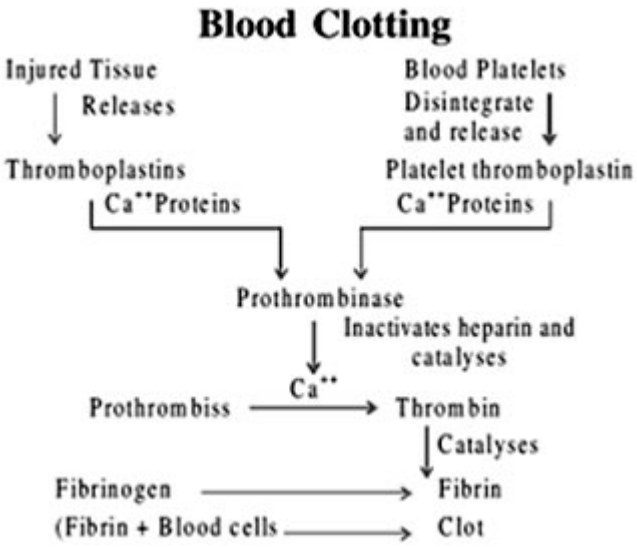
Rh grouping :

- Another antigen, the Rh antigen similar to one present in Rhesus monkeys (hence Rh), is also observed on the surface of RBCs on majority (nearly 80 %).
- Person with Rh antigen is said to be **Rh positive (Rh+).**
- Person without Rh antigen is said to be **Rh negative (Rh-).**
- Person with Rh- blood transfused with Rh+ blood, forms anti Rh antibody and destroy the Rh+ RBCs.
- A special case of Rh incompatibility (mismatching) has been observed between the Rh- bloods of pregnant mother with the Rh+ blood of the foetus.
- During parturition the Rh+ foetal blood mixed with the Rh- maternal blood, hence anti Rh antibody formed in mothers blood.
- In successive pregnancy the anti Rh antibody from mother's blood leaks into the foetal blood and destroy the Rh+ RBCs.

- This caused **HDN** (haemolytic disease in new born) or **Erythroblastosis foetalis**.
- This can be prevented by administering anti-Rh antibody to the mother immediately after the delivery of the first child.

COAGULATION OF BLOOD :

- Injury to the blood vessel leads to loss of blood called **haemorrhage**.
- There is an intrinsic mechanism to stop haemorrhage is called **haemostasis** or **coagulation of blood** or **blood clotting**.



- Clot or coagulum is formed mainly of a network of threads called fibrins in which dead and damaged formed elements of blood are trapped or entangled.
- **Fibrin** is formed by the conversion of inactive **fibrinogens** in the plasma by an enzyme called **thrombin**.
- Thrombin formed from inactive **prothrombin** of the plasma due to presence of enzyme **thrombokinase**.
- All these activation required the initial clotting factor called **thromboplastin** either released from the injured tissue or platelets.
- Calcium ions play a very important role in the coagulation of blood.

Lymph

- The colorless mobile fluid connective tissue drains into the lymphatic capillaries from the intercellular spaces.

Composition :

- It is composed of fluid matrix, plasma, white blood corpuscles or leucocytes.
- Contains less amount of protein than plasma.
- Devoid of RBCs.

Functions :

- It drains excess tissue fluid from extra cellular spaces back into the blood.
- It contains lymphocytes and antibodies.
- It transport digested fats.

CIRCULATORY PATHWAYS :

Open circulatory system :

- Found in arthropods and mollusks.
- Blood from the heart pumped into the open spaces in the body cavity called sinuses.
- The body cavity remained filled with blood (haemolymph) called haemocoel.

Closed circulatory system :

- Found in annelids, echinoderms and all chordates.
- Blood from the heart pumped into definite blood vessels.
- Blood circulated in a wide network of blood vessel throughout the body.
- Blood circulated in a regulated manner.

Heart and circulation in vertebrates :

- **Fishes**: have 2 chambered hearts with one atrium and one ventricle.
- **Amphibian** and **reptilian** (except crocodile) has three chambered heart with two atria and one ventricle.
- **Crocodiles**, **birds** and **mammals** possesses a 4-chambered heart with two atria and two ventricles
- In fishes the two chambered heart pumped deoxygenated blood to the gills for oxygenation and then circulated to the body. (**singlecirculation**)
- In amphibians and reptilians the left atrium receives oxygenated blood from the lungs and right atrium receives deoxygenated blood from the body. Blood from the atria pumped into the ventricle from which the mixed blood pumped into the body. (**Incomplete double circulation**).
- In birds and mammals oxygenated and deoxygenated blood received by left and right atria respectively passed into ventricle of their side. The ventricles pump it out without any mixing up. (**double circulation**)

HUMAN CIRCULATORY SYSTEM :

Heart :

- Originated from embryonic mesoderm.
- Situated in the thoracic cavity, in between two lungs, slightly tilted towards left.
- It has the size of the clenched fist.
- Heart is covered by a double walled bag, **pericardium**.
- Our heat is four chambered, two relatively smaller upper chamber called **atria** and two lower larger chamber called**ventricles**.
- Two atria are separated by thin muscular wall called **inter-atrial septum.**
- A thick walled **inter-ventricular septum** separates two ventricles.
- Atrium and ventricle of same side is separated by a thick fibrous tissue called the **atrio-ventricular septum.**
- Each of atrio-ventricular septa is provided with an opening through which the atrium and ventricle of same side are connected, called **atrio-ventricular opening**.
- Right atrio-ventricular opening is guarded by **tricuspid valve.**
- Left atrio-ventricular opening is guarded by **bicuspid** or **mitral valve**.
- The right ventricle opens into **systemic aorta** and left ventricle opens into **pulmonary aorta**.
- Both the aorta is guarded by **semilunar valves.**
- The valves in the heart allow unidirectional flow of blood i.e. from atria to ventricles and from ventricles to their respective aorta.

Conducting system of human heart :

- The entire heart is made of cardiac muscles.
- The wall of the ventricle is much thicker than the atria.
- A patch of nodal tissue is present in the right upper corner of the right atrium called the **Sino-atrial node(S A Node).**
- Another nodal tissue present in the posterior to the inter-ventricular septum called **A V Node (Atrio-ventricular node).**

- A bundle of nodal fibres , atrio-ventricular bundle (AV bundle) continued as A V bundle through the inter-ventricular septum and divided into right and left A V bundle, also called **bundle of His**.
- The bundle of His gives rise to profuse branches to the wall of the ventricles called **perkinji fibres.**
- S A node generates the force of contraction for auto rhythmicity of heart, hence called **pace maker** of the heart.
- Our heart normally beats 70-75 times in minutes (average of 72 beats per minutes).

Cardiac cycle :

- The cyclic events takes place in each heart beat is called one cardiac cycle.
- Lets starts with all the four chambers of heart are in a relaxed state i.e. in joint diastole.
- As the tricuspid and bicuspid valves are open, blood from the **pulmonary veins** and **vena cava** flows into the left and right ventricles respectively through left and right atria.
- Semilunar valves are closed at this stage.
- SAN generates the action potential which stimulates contraction of both atria, called **atrial systole.**
- This increases the blood flow from atria to their respective ventricles by 30 %.
- The action potential from SAN passed to AVN and then to perkinji fibres through AV bundles. This initiates ventricular systole. The atria undergo relaxation (diastole).
- During ventricular systole the intra-ventricular blood pressure increases that lead to closing of tricuspid and bicuspid valves leads to production of **first heart sound** called **lub sound**.
- Further increase in pressure leads to opening of semilunar valves.
- Oxygenated blood from the left atrium pumped into systemic aorta and deoxygenated blood from the right atrium pumped into the pulmonary aorta.
- Ventricular systole followed by ventricular diastole.
- Intra-ventricular blood pressure decreases leads to closing of semilunar valves causing **second heart sound (dub).**
- As the ventricular pressure declines further there is opening of bicuspid and tricuspid valves, blood from the atria flows into the ventricles freely.
- The ventricle and atria relaxed simultaneously called **joint diastole**.
- This sequential event in the heart which cyclically repeated called **cardiac cycle**.
- The heart beats 72 times per minutes.
- Each cardiac cycle takes 0.8 sec to complete.
- During a cardiac cycle the ventricles pumped 70 ml blood to the aorta called **stroke volume.**
- Stoke volume multiplied by heart rate (heart beat per min.) gives the **cardiac output**.
- Cardiac out put for human heart is **5000 ml.**

Electrocardiograph (ECG) :

- ECG is a graphical representation of the electrical activity of the heart during a cardiac cycle.
- Each peak in the ECG is identified with a letter from P to T that corresponds to a specific electrical activity of the heart.
- The P-wave represents the electrical **excitation (or depolarization) of the atria.**
- The QRS complex represents the **depolarization of the ventricles.**
- The ventricular contraction starts shortly after the Q and marks the beginning of the ventricular systole.
- T-wave represents the **ventricular diastole (repolarisation).**

DOUBLE CIRCULATION :

- **Pulmonary circulation**: Right ventricle (deoxygenated blood) → pulmonary artery → lungs (oxygenation) → pulmonary vein (oxygenated blood) → left atrium.
- **Systemic circulation**: left ventricle (oxygenated blood) → systemic aorta → body (deoxygenated) →vena cava (deoxygenated blood) → right atrium.
- **Portal system:** the deoxygenated blood collected from one organ by means of a vein **(portal vein)** entered into another organ before it is delivered to the systemic circulation.

- **Hepatic portal system:** the **hepatic portal vein** carries deoxygenated blood from the intestine to the liver before it is delivered to the systemic circulation by means of **hepatic vein.**
- **Coronary circulation:** A special blood vessel (coronary vessel) is present in our body exclusively for the circulation of blood to and from the cardiac musculature.

REGUALTION OF CARDIAC ACTIVITY :

- Rhythmicity of human heart is regulated by specialized (nodal tissues), hence the heart is called **myogenic**.
- A special neural centre in the medulla oblongata can regulate cardiac function moderately.
- Neural signal through sympathetic nerve can increase the heart rate and cardiac output.
- Neural signal through parasympathetic nerve can decrease the heart rate and cardiac output.
- Hormones of adrenal medulla (adrenaline) also increase the cardiac output.

DISORDERS OF CIRCULATORY SYSTEM :

Hypertension :

- Hypertension is the term for blood pressure that is higher than normal (120/80).
- 120 mm Hg is the systolic pressure and 80 mm Hg is the diastolic pressure.
- Sustained blood pressure of 140/90 or higher is said to be hypertension.
- Blood pressure is measured by sphygmomanometer.
- High blood pressure leads to heart disease and also affects vital organ like brain and kidney.

Coronary Artery Disease (CAD) :

- Often referred as atherosclerosis, affects the blood supply to the heart muscles.
- It is caused by deposition of calcium, fat, cholesterol and fibrous tissue which makes the lumen of coronary artery narrower.

Angina :

- It is also known as ‘angina pectoris’.
- Causes acute chest pain due to inadequate oxygen supply to the heart.
- It occurs due to blockade to coronary artery.

Heart failure :

- It is the state of the heart when it is not pumping blood effectively
- **Cardiac arrest**: the heart stops beating.
- **Heart attack**: heart muscle damaged suddenly by an inadequate blood supply to the heart muscles.

19. Excretory Products and Their Elimination

POINTS TO REMEMBER :

- Ammonotelic: elimination of nitrogenous waste in the form of ammonia.(fish)
- Ureotelic: elimination of nitrogenous waste in the form of urea.(Amphibia and mammalian)
- Uricotelic: elimination nitrogenous waste in the form of uric acid. (Reptilia, bird and insects)

Excretory organs :

- **Protonephridia** or **flame cells** – Platyhelminthes (Planaria), rotifers, some annelids and cephalochordates (Amphioxus)
- **Nephridia**: annelid.
- **Malpighian tubules** – insects
- **Antennal gland** or **green glands** – crustacean like prawn.

HUMAN EXCRETORY SYSTEM :

- Human excretory system consists of
  - A pair of kidney
  - A pair of ureters
  - A urinary bladder
  - A urethra

- Kidney is reddish brown, bean shaped structure situated between the levels of last thoracic vertebra close to dorsal inner wall of the abdominal cavity.
- Each kidney measures 10-12 cm in length, 5-7 cm in width, 2-3 cm in thickness.
- Towards the centre of inner concave surface is a notch, called **hilum** through which ureters, blood vessel and nerves enter into the kidney.
- Inner to hilum is a broad funnel shaped space called **renal pelvis** with projections called **calyces**.
- The outer wall of kidney is a tough **capsule**.
- Internally the kidney is differentiated into outer **cortex** and inner **medulla**.
- The medulla is divided into a few conical masses called **medullary pyramids**.
- Pyramids projected into the calyces.
- The cortex extended in-between the medullary pyramids as renal columns called **columns of Bertini**.
- Each kidney has nearly one million complex tubular structures called **nephrons**.
- Structural and functional unit of kidney is called **nephron** or **uriniferous tubule**.
- Each nephron has two parts:
  - Glomerulus
  - Renal tubule.

- Glomerulus is a tuft of capillaries formed by the **afferent renal arteriole** (a branch of renal artery).
- Blood from the Glomerulus is collected by **efferent renal arteriole**.
- The renal tubule begins with a double walled cup-like structure called **Bowman's capsule,** which encloses the Glomerulus.
- Glomerulus along with Bowman's capsule is called **Malpighian body** or **renal corpuscles.**
- Bowman's capsule followed by highly coiled **proximal convoluted tubule (PCT).**

- PCT followed by hairpin shaped **Henle's loop** with ascending and descending limb.
- The ascending limb followed by another coiled tubular region called **distal convoluted tubule (DCT).**
- DCT of many nephron opens into a straight tube called **collecting duct.**
- All the collecting duct converges and opens into renal pelvis through medullary pyramids in the calyces.
- The malpighian corpuscles, PCT and DCT of the nephron are located in the cortex but the loop of Henle dips into the upper medulla.
- In some of the nephron, the loop of the Henle is very long and runs deep into the inner medulla. These nephrons are called **juxta medullary nephrons**.
- The efferent renal 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 loop of Henle forming'U' shaped ***vasa recta***.
- Vasa recta are absent or reduced in cortical nephron.
- The juxta medullary nephron has **juxta-glomerular apparatus**, in which the DCT run close to the afferent renal arteriole.

MECHANISM OF URINE FORMATION :

- Urine formation involves three main processes –
  - **Glomerular filtration**
  - **Selective reabsorption**
  - **Tubular secretion.**

Glomerular filtration or ultra filtration :

- On an average 1120-1200 ml blood is filtered by the kidneys per minute.
- The glomerular capillary blood pressure caused filtration of through filtration membrane.
- The filtration membrane is formed by –
  - Endothelium of glomerular blood vessel.
  - The epithelium of Bowman's capsule (podocytes)
  - Basement membrane of 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 slit or slit pores.
- All constituent of plasma pass the filtration membrane except protein, hence it is called **ultra filtration**.
- The amount of filtrate formed by the kidneys per minute is called glomerular filtration rate (GFR).
- GFR is about 125 ml/min. i.e. 180 liters per day.

Selective reabsorption :

- Out of 180 liters of filtrate formed every day 178.5 liters along with useful materials reabsorbed into the blood through peritubular capillaries leaving 1.5 liters excreted in the form of urine.
- The tubular epithelial cells of different segments of nephron perform these either active or passive mechanisms.
- Substance like glucose, amino acids Na+ absorbed actively.
- Nitrogenous wastes are absorbed by passive transport.
- Reabsorption of water also occurs passively in the initial segments of the nephron.

Tubular secretion :

- The tubular cells adds substances like H^+ , K^+ and ammonia to the filtrate from the peritubular capillaries.
- Tubular secretion maintains ionic and acid base balance of the 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 absorption.
- All essential nutrients and 70-80% of the electrolytes and water are reabsorbed by this segment.
- PCT also maintain the pH and ionic balance of the body fluids by selective secretion of H^+, K^+ and ammonia into the filtrate and by absorption of HCO_3-.

Henle's Loop :

- This region plays important role in maintenance of high osmolarity of medullary interstitial fluid.
- The descending limb is permeable to water but impermeable to electrolytes. This concentrates the filtrates as it moves down.
- The ascending limb is permeable to electrolytes but impermeable to electrolytes. Therefore as the concentrated filtrate pass upward, it gets diluted due to active or passive transport of electrolytes to the medullary fluid.

Distal convoluted tubules :

- Selectable reabsorption of Na+ and water takes place in this segment.
- DCT also capable of reabsorption of HCO_3- and selective secretion of H^+, K^+, and NH_3 to maintain the pH and sodium-potassium level in blood.

Collecting duct :

- This duct extends from cortex to inner part of the medulla.
- Large amount of water could be reabsorbed from this region to produce concentrated urine.
- This segment allow small amount of urea into the medullary interstitium to keep up the osmolarity.

MECHANISM OF CONCENTRATION OF FILTRATE :

- Mammals have the ability to produce concentrated urine.
- The Henle's loop and vasa recta plays significant role in concentrating urine.
- The flow of filtrate in two limb of Henle's loop and blood flow in two limbs of vasa recta are in opposite direction hence form **counter current.**
- The proximity between the Henle's loop and vasa recta, as well as the counter current in them help in maintain 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.
- The gradient is mainly due to **NaCl** and **urea.**
- The NaCl **actively transported** from the ascending limb of Henle's loop is exchanged by the ascending portion of the **vasa recta.**
- NaCl is returned to the interstitium by the ascending portion of vasa recta.
- Small amount of urea enters the thin segment of ascending limb of Henle's loop which is transported back to the interstitium by the collecting tubule.
- This 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, that promote easy passage of water from the collecting duct, leads to formation of concentrated urine.

REGULATION OF KIDNEY FUNCTION :

Regulation by ADH :

- Osmoreceptors present in the hypothalamus are activated by the change of blood volume, body fluid volume and ionic concentration.
- An excessive loss of body fluid activates the Osmoreceptors of hypothalamus to release **antidiuretic hormone** (ADH) or**vasopressin** from the neurohypophysis.
- ADH facilitates active reabsorption of water from the DCT, preventing dieresis.
- An increase in body fluid volume can switch off the Osmoreceptors and suppress the release of ADH, promoting dilute urine formation.
- ADH also constricts the afferent renal arteriole in increase the blood pressure in the other hand to maintain the GFR.

Regulation by JGA (Juxta Glomerular Apparatus) :

- A fall in glomerular blood flow/glomerular blood pressure/GFR can activate the Juxta Glomerular cells to release**renin**.
- Renin converts angiotensinogen in blood to **angiotensin I** and further to **angiotensin II.**
- Angiotensin II constricts afferent renal arteriole to increase glomerular blood pressure and thereby GFR.
- Angiotensin II also stimulates adrenal cortex to release **aldosterone**.
- Aldosterone cause active reabsorption of Na+ and water from the distal part of the tubule, this increase in blood volume and GFR.
- This complex mechanism is called **RAAS (Renin angiotensin aldosterone system).**

Regulation by ANF :

- An increase in blood flow to the atria of the heart due RAAS cause the release of **Atrial Natriuretic Factor (ANF).**
- ANF can cause vasodilation (afferent renal arteriole) and thereby decrease the blood pressure.
- ANF also stop the release of renin hence stops RAAS.

MICTURITION :

- The expulsion of urine from the urinary bladder. It is a reflex process but can be controlled voluntarily to some extent in grown up children and adults.
- The CNS (Central Nervous System) sends the signal which causes the stretching of the urinary bladder when 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 massage to initiate the contraction of smooth muscles of the bladder and simultaneous relaxation of the urethral sphincter causing the release of urine.
- An adult human excretes on an average 1 to 1.5 liters of urine per day.
- On an average 25-30 gram of urea is excreted out per day.
- Presence of Glucose is called **Glycosuria**.
- Presence of Ketone bodies in urine called **Ketoneuria**.
- Glycosuria and Ketoneuria are the indication of **Diabetes mellitus.**

Role of other organs in excretion :

- **Lungs** - removes CO_2 (18L/day) and water.

- **Liver -** secretes bilirubin, biliverdin etc. helps to eliminate these substances along with cholesterol, vitamins, drugs and degraded steroid hormones through digestive wastes.
- **Sweat and sebaceous glands -** These glands of skin help to eliminate small amount of urea, NaCl and lactic acid etc. through sweat while sebaceous glands help to eliminate some substances like steroids, hydrocarbons and waxes through **sebum**.
- Saliva - It can help to eliminate small amount of nitrogenous wastes.

Disorders of Excretory system :

- **Uremia** - The accumulation of urea in blood due to malfunctioning of kidney.
- **Hemodialysis** - The process of removal of urea from the blood artificially. In this process the blood from an artery is passed into dialysing unit after adding an anticoagulant like heparin. The blood passes through coiled cellophane tube surrounding by dialysing fluid. The nitrogenous wastes from the concentration gradient and the blood become clear. This blood is pumped back to the body through vein after adding anti-heparin to it.
- **Renal calculi** - The formation of insoluble mass of crystallised salts (oxalates or phosphates of calcium.
- **Glomerulonephritis** - Inflammation of glomeruli of kidney.

20. Locomotion and Movement

POINTS TO REMEMBER :

Types of Movement :

- **Amoeboid movement**: This movement takes place in phagocytes where leucocytes and macrophages migrate through tissue. It is affected by pseudopodia formed by the streaming of protoplasm (as in amoeba)
- **Ciliary movement**: These movements occur in internal organs which are lined by ciliary epithelium.
- **Muscular Movement**: This movement involves the muscle fibers, which have the ability to contract and relax.

MUSCLES :

Properties of Muscle :

- Excitability
- Contractility
- Extensibility
- Elasticity

Types of Muscles :

- **Skeletal muscles or striated muscles** –
  - Closely associated with skeleton.
  - They are striped appearance under the microscope and called **Striated muscles**.
  - They are under voluntary control of nervous system, hence called voluntary muscles.
  - These involved in locomotion and change of body postures.
  - Unbranched and multinucleated.

- **Visceral muscles or smooth muscles**
  - These are located in inner wall of hollow visceral organ.
  - Spindle shaped and uni-nucleated.
  - They do not exhibit any striation and are smooth in appearance.
  - They are called smooth muscles or non-striated muscles.
  - Their activities are not under voluntary control of nervous system hence called as **involuntary muscles.**
  - They assist in transport of food through digestive tract and gametes through the genital tract.

- **Cardiac muscles –**
  - The muscles of heart, involuntary in nature.
  - Cardiac muscle cells assemble in a branching pattern to form a cardiac muscle.
  - These are uni-nucleated with characteristic **intercalated disc.**

Structure of skeletal muscle :

- Each organized skeletal muscle in our body is made of a number of muscle bundles called **fascicles** held together by common fibrous covering called **fascia**.
- Each fascicle consists of a number of muscle fibres (cell) covered by a common fibrous **perimysium.**
- Each muscle fibre is lined by the plasma membrane called **sarcolemma**, enclosing cytoplasm called **sarcoplasm**.
- The sarcoplasm contain endoplasmic reticulum, called **sarcoplasmic reticulum** is the store house of **calcium ion.**

- Muscle fibre is a **syncitium** as the sarcoplasm contain many nuclei.
- Muscle fibres contain a large number of parallelly arranged filaments in the sarcoplasm called **myofilaments** or**myofibrils**.
- There are two types of myofibrils are present in the sarcoplasm –
    - Thin filament – Actin
    - Thick filament – Myosin.

- The arrangement of thick and thin filament gives the characteristic striated appearance.
- The light bands contain only actin filaments and are called **I-band** or isotropic band.
- The dark band called **'A'** or **anisotropic band** contains both actin and myosin.
- In the centre of each 'I' band is an elastic fibre called 'Z' line which bisects it.
- The thin filaments or actin are firmly attached with the 'Z' line.
- The thick filaments or myosin in the 'A' band are also held together in the middle by a thin fibrous membrane called**'M' line.**
- The portion between two successive 'Z' lines is considered as the functional unit of the muscle called **sarcomere**.
- Each 'A' band contains two overlap zone of thick and thin filament called 'O' band.
- The central part of thick filament, not overlapped by thin filament is called 'H' band.
- 'A' band = 2(O) + H.

Structure of Contractile proteins :

Thin filament or Actin :

- Each actin filament is made of two 'F' actins helically wound to each other.
- Each 'F' actin is made of polymer of monomeric 'G' (Globular) actin.
- Each 'F' actin associated with another protein, **tropomyosin** also run throughout its length.
- Another complex protein, Troponin is distributed at regular intervals on the tropomyosin.
- Each troponin has three component –
    - Troponin-C binds with calcium.
    - Troponin-M, binds with the tropomyosin.
    - Troponin T, masks the active site on the 'G' actin (thin filament)

- In the resting state a sub-unit of Troponin (Tn-T), masks the active binding sites on the thin filaments for myosin.

Thick filament :

- Each myosin (thick) filament is consists of many monomeric protein called **Meromyosins**.
- Each meromyosin has two parts –
    - Heavy meromyosin (HMM) - A globular head with a short arm.
    - Light meromyosin (LMM) – a tail.

- 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 polymerized 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 explained by 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 via a motor neuron.
- A motor neuron along with the muscle fibres connected to it constitutes a **motor unit.**
- The junction between a motor neuron and the sarcolemma of the muscle fibre is called **neuromuscular junction** or**motor-end plate.**
- Neurotransmitter releases here which generates an action potential in sarcolemma.
- These causes release of Ca++ into sarcoplasm.
- These Ca++ binds with troponin, thereby remove masking of active site.
- Myosin head binds to exposed active site on actin to form a cross bridge, utilizing energy from ATP hydrolysis.
- This pulls the actin filament towards the centre of 'A' band.
- 'Z' lines also pulled inward thereby causing a shortening of sarcomere i.e. contraction.
- 'I' band get reduced, whereas the 'A' band retain the length.
- During relaxation, the cross bridge between the actin and myosin break.
- Ca++pumped back to sarcoplasmic cisternae.
- Actin filament slide out of 'A' band and length of 'I' band increases. This returns the muscle to its original state.
- Repeated muscle contraction causes accumulation of lactic acid, produced from anaerobic breakdown of glycogen leads to **muscle fatigue.**
- Muscle contains red coloured oxygen storing pigment called **myoglobin**.
- Muscle with myoglobin called red muscle fibres, they are also contain large number of mitochondria which can utilize large amount of oxygen stored in them for ATP production also called **aerobic muscle.**
- Some muscles possess very less quantity of myoglobin and less mitochondrion hence called **white fibres**. Amount of sarcoplasmic reticulum is high in these muscles. They depend on anaerobic process for energy.

SKELETAL SYSTEM :

- Human skeleton consists of 206 bones in adult.
    - Axial skeleton – 80 bones
    - Appendicular skeleton – 126 bones.

- **Axial skeleton :**
    - **Skull – 29 bones.**
        - **Cranium** – 8 bones forms the brain box.
        - **Facial** – 14 bones forms the front part of the face.
        - **Hyoid** – a single U-shaped bone at the base of the buccal cavity.
        - **Ear ossicles** – 6 bones- 3 on either side (Malleus, Incus and stapes)

    - The skull region articulates with the superior region of the vertebral column with the help of two occipital condyles hence called **dicondylic skull**.

    - **Vertebral column** – 26 bones
        - **Cervical** – 7 vertebrae.

        - **Thoracic** – 12 vertebrae.
        - **Lumber** – 5 vertebrae.
        - **Sacral** – 1 vertebra. (fused five bone)
        - **Caudal** – 1 vertebra (fused four bones)

    - **Sternum** or **breast bone** – 1 bone in the middle line of the thorax.

- **Ribs** – 12 pairs – (24 bones)
    - 1-7 are **true ribs** (connected to the sternum directly)
    - 8^{th}, 9^{th}, 10^{th} pairs are called **false ribs** they attached to the 7th ribs.
    - 11th and 12th not connected ventrally hence called **floating ribs.**
    - Ribs attaché dorsally to the vertebra and ventrally with the sternum by **hyaline cartilage**.
    - Thoracic vertebrae, ribs and sternum together form the rib cage.

- **Appendicular skeleton: 126 bones**
    - **Fore limb – 60 (30 in each)**
        - **Humerus** – 1 bone
        - **Radius** and **ulna** – 2 bones
        - **Carpals** (wrist bones) – 8 in numbers.
        - **Metacarpals** (palm bones) – 5 in numbers
        - **Phalanges** (digits) – 14 in number.

    - **Hind limb – 60 (30 in each)**
        - **Femur** (thigh bone- the longest and heaviest bone) – 1 number.
        - **Tibia** and **fibula** – 2 bones.
        - **Tarsals** (ankle bone) – 7 bones.
        - **Metatarsals** – 5 in numbers.
        - **Phalanges** (digits) – 14 in numbers.
        - **Patella** (knee cap) – 1 bone.

    - **Pectoral girdles**: consists of 2 bones each = 4 bones.
        - Helps in articulation of fore limb with the axial skeleton.
        - Each pectoral girdle made of two half.
        - Each half made of two bone the **clavicle** and **scapula**.
        - Scapula is a large triangular flat bone situated in the dorsal part of the thorax between the second and the seventh ribs.
        - Scapula is characterized by spine with **acromion** process.
        - Below acromion, is **glenoid cavity** to which head of humerus fits.
        - Clavicle is commonly called **collar bone.**

    - **Pelvic girdle**: 2 bones.
        - Pelvic girdle consists of two coxal bones.

- Each coxal bone is formed of fusion of three bones
  - Ilium
  - Ischium
  - Pubis.
- At the point of fusion of the three bones is a cavity called **acetabulum** to which the femur articulates.
- Two halves of the pelvic girdle meets ventrally to form the **pubic symphysis** containing fibrous cartilage.

JOINTS :

- Joints are the points of contact between bones, or between bones and cartilages.
- Force generated by the muscles is used to carry out movement through joints, where joint acts as a **fulcrum**.
- Joints are classified into three types:
  - **Fibrous joint**
  - **Cartilaginous joint**
  - **Synovial joint**

Fibrous joints :

- Do not allow any movements.
- Found in flat bones which fuse end-to-end with the help of dense fibrous connective tissues in the form of sutures.
- These types of joints are found in the bones of cranium.

Cartilaginous joints :

- The bones involved are joined together with the help of cartilages.
- Permits very little movements.
- Joint between the vertebral column are the example of such joints.

Synovial joints :

- Characterized by the presence of a fluid filled **synovial cavity** between the articulating surfaces of the two bones.
- Allow free movement between two bones.
- The fluid inside it called synovial fluid covered by synovial membrane.
  - **Ball and socket joint** - between humerus and pectoral girdle
  - **Hinge joint** – knee joint
  - **Pivot joint** – between atlas and axis.
  - **Gliding joint** – between carpals.
  - **Saddle joint** – between carpals and metacarpals of thumb.

DISORDERS OF MUSCULAR AND SKELETAL SYSTEM :

Myasthenia gravis :

- It is an auto-immuno disorder.
- Affects the neuromuscular junction leads to fatigue.
- Caused 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 characterized by decreased bone mass and increased chances of fractures. Decrease levels of oestrogen are a common cause.

Gout : inflammation of joints due to accumulation of uric acid crystals.

21. Neural Control and Coordination

POINTS TO REMEMBER :

HUMAN NEURAL SYSTEM :

- The human neural system divided into two parts –
  - **The central nervous system (CNS)**
  - **The peripheral nervous system (PNS)**

- The CNS includes the **brain** and **spinal cord** and is the site of information processing and control.
- The PNS comprises all nerves of the body associated with CNS.
  - **Cranial nerves**: nerves arises from the brain (12 pairs)
  - **Spinal nerves**: nerves arises from the spinal cord (33 pairs)

- The nerve fibres (Cranial and spinal nerves) are of two types –
  - Afferent fibres: transmits impulses from the tissues to the CNS
  - Efferent fibres: transmits impulses from the CNS to the tissues.

- The PNS is divided into two divisions –
  - **Somatic neural system.**
  - **Autonomic neural system.**
    - **Sympathetic neural system.**
    - **Parasympathetic neural system.**

- The somatic neural system relays impulses from the CNS to skeletal muscles.
- The autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body.

NEURON AS STRUCTURAL AND FUNCTUIONAL UNIT OF NERVOUS SYSTEM :

- A neuron composed of three major parts –
  - **Cell body**
  - **Dendrites**
  - **Axon**

- The cell body contains cytoplasm with typical cell organelles and specific granular body called **Nissl's granules.**
- Short fibres which profusely branched projects out of cell body called **dendrites**.
- The axon is a long fibre, branched at the end.
- Each branch terminates as a bulb-like structure called **synaptic knob.**

- Based on the number of axon and dendrites the neurons are of following types –
    - **Multipolar**: one axon and several dendrites - found in cerebral cortex.
    - **Bipolar**: one axon and one dendrite - found in retina of eye.
    - **Unipolar**: cell body with one axon only – found in embryonic stage.

- The axon may be **myelinated** or **non-myelinated**.
- The myelinated nerve fibres are enveloped with **Schwann cells**, which form myelin sheath around the axon. The gaps between two adjacent myelin sheath are called **Nodes of Ranvier.**
- Cranial and spinal nerves are myelinated.
- Autonomic and somatic neural fibres are non-myelinated.

GENERATIONA ND CONDUCTION OF NERVE IMPULSE :

Polarized membrane/Resting Potential :

- In resting phase when neuron is not conducting an impulse, the axonal membrane is called polarized. This is due to difference in concentration of ions across the axonal membrane.
- At Rest :
    - Axoplasm inside the axon contains high conc. of K^+ and low conc. of Na^+.
    - The fluid outside the axon contains low conc. of K^+ and high conc. of Na^+.

- As a result the outer surface of axonal membrane is positively charged and inner surface is negatively charged. The electric potential difference across the resting plasma membrane is called **resting potential.**

Action Potential :

- When a nerve fibre is stimulated, the permeability of membrane to Na^+ is greatly increased at the point of stimulus (rapid influx of Na^+) and hence polarity of membrane is reversed and now membrane is said to be **depolarized**.
- The electric potential difference across the plasma membrane at that site is called action potential, which in fact termed as nerve impulse.
- Depolarization is very rapid, so that conduction of nerve impulse along the entire length of axon occurs in fractions of second.
- Depolarization is followed by the increase in permeability of K^+ to the membrane leads to change in polarization i.e. +ve charge outside and –ve charge inside. It is called **repolarization**.
- Regain of resting potential takes place due to action of Na^+/K^+ ATPase enzyme which transports three Na+ inside and two K^+ inside with expense of one ATP. It continues till the resting potential becomes -70 mv.

Transmission of impulses through synapse :

- The functional junction between two neurons is called **synapse**.
- A synapse is formed by the membranes of a pre-synaptic neuron and a post-synaptic neuron, which may or may not be separated by a gap called **synaptic cleft**.
- There are two types of synapses:
    - **Electrical synapse**: pre and post synaptic membrane with close proximity without any synaptic cleft.
    - **Chemical synapse**: the pre and post synaptic membrane is separated by a fluid filled synaptic cleft.

Conduction of impulse in chemical synapse :

- The axon terminals contains vesicles filled with chemicals called**neurotransmitters**.
- When the action potential arrives at the axon terminals, it stimulates the movement of synaptic vesicles towards the membrane.
- Synaptic vesicle fused with the pre-synaptic membrane and releases the neurotransmitter into the synaptic cleft.
- The neurotransmitter binds with the receptors located on the post-synaptic membrane.
- Activation of receptors on post-synaptic membrane makes it permeable to Na+ and generates action potential as it done by stimulus.
- The new potential developed may be either excitatory or inhibitory depends on the nature of the **neurotransmitter.**

CENTRAL NERVOUS SYSTEM :

- Brain is the central control and command system in neural coordination.
- The human brain is well protected by the skull.
- Inside the skull the brain is covered by **cranial meninges**.
- **Meninges consists of following layers –**
    - **Outer layer – dura mater.**
    - **Middle layer – thin arachnoid.**
    - **Inner layer – pia mater remain close contact with the brain.**

- The human brain is divided into three major parts –
    - **Fore brain.**
        - **Cerebrum.**
        - **Thalamus.**
        - **Hypothalamus.**
    - **Mid brain.**
    - **Hind brain.**
        - **Pons.**
        - **Cerebellum**
        - **Medulla oblongata.**

Fore brain :

- Cerebrum is the major part of the fore brain.
- Deep median fissure divides the cerebrum into two equal **cerebral hemisphere.**
- The hemispheres are connected by tract of nerve fibres called **corpus callosum.**
- The thin layers of cells covers the cerebral hemispheres called cerebral cortex and are thrown into prominent folds.
- The cerebral cortex is referred as the grey matter.
- The cerebral cortex differentiated into –
    - **Motor areas** – sends information to the body
    - **Sensory areas** – receives information from the body
    - **Association area**-neither sensory nor motor (co-ordinates the information)

- Interior of the brain is called **white matter** due to myelin sheath of tract of nerve fibres.
- The cerebrum is wraps around a structure called **thalamus**, which is a major coordinating centre for sensory and motor signaling.
- At the base of the thalamus is the **hypothalamus**.
- The hypothalamus have following functions –
    - Control body temperature.
    - Urge for eating and drinking.
    - Neurosensory cells secrete different hormones.

- The inner part of the cerebral hemispheres and a group of associated deep structures like **amygdala**, **hippocampus**etc. forms 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 (excitement, pleasure, rage and fear) and motivation.

Mid brain:

- The mid brain is located between the thalamus and pons of the hind brain.
- A canal called cerebral aqueduct passes through the mid brain.
- The dorsal part of the mid brain consists of four swelling called **corpora quadrigemina**.

Hind brain:

- Comprises pons, cerebellum and 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 neuron.
- Medulla of the brain is continued as spinal cord.
- Medulla contains centers which control respiration, cardiovascular reflexes and gastric secretion.

REFLEX ACTION AND REFLEX ARC :

- Sudden spontaneous, involuntary reaction to a stimulus without involvement of brain is called **reflex action.**
- Some examples of such actions are –
    - Sudden withdrawal of the body part which comes in contact with objects that are extremely hot, cold, pointed.

- **Reflex arc**: sensory organ → sensory neuron → spinal cord → motor neuron → effector organ.

SENSORY RECEPTION AND PROCESSING :

Eye :

- Eye is the sensory organ of **vision**.
- Our paired eyes are located in sockets of the skull called **orbit**.
- Eye consists of three layer –
- **Sclera**: **tunica fibrosa.**
    - External layer composed of dense connective tissue.
    - It is the only complete layer of the eye.
    - The anterior portion of this layer is transparent and called cornea.

- **Choroid: tunica vascularis.**
    - It is the middle layer of the eye.
    - It is well vascularized and looks bluish color.
    - Posterior two third parts is thin.
    - Anterior part is thick and form **ciliary body**.
    - The ciliary body itself continues forward to form a pigmented and opaque structure called **iris** (the visible coloured portion of the eye).
    - Iris contains a central aperture called **pupil**.
    - The diameter of pupil is regulated by the muscle of iris.

- **Retina or tunica nervosa.**
    - It is the innermost layer of the eye.
    - It consists of three layer of cells – from inside to outside
        - Ganglion cells
        - Bipolar cells
        - Photoreceptor cells.

    - There are two types of **photoreceptor cells** namely **rods** and **cones.**
    - Cones contain photopigment called **iodopsin**.
    - Cones responsible for daylight (**photopic**) vision and color vision.
    - Rods contain photopigment called **rhodopsin** or visual purple, which contain a derivative of Vitamin-A.
    - Rods responsible for twilight (**scotopic**) vision.
    - The optic nerves leave the eye and the retinal blood vessel enters it at a point where rods and cones are absent hence called **blind spot**.
    - At the posterior pole of the eye lateral to blind spot there is a yellowish pigmented spot called **macula lutea**.
    - Macula lutea with highly concentrated cones, where the vision is sharpest (high resolution vision)
    - In the centre of macula lutea there is a central pit called **fovea centralis**, a tightly packed array of specialized**photosensor-receptor cells**. It prevents the entry of high intensity light by closing the eye by reflex action.

- The **lens** composed of crystalline protein, is suspended behind the pupil by a **suspensory ligament** attached to the ciliary body.
- The lens and suspensory ligament divide the cavity of the eye ball into two chambers.
- Chamber in front of lens called **aqueous chamber** filled with **aqueous humor**.
- Chamber behind the lens is called **vitreous chamber** filled with transparent gel called **vitreous humor.**

Mechanism of vision :

- The light rays in visible spectrum focused on the retina through the cornea and lens generate potentials (impulses) in rods and cones.
- Photosensitive pigments composed of **opsin** (a protein) and **retinal** (an aldehyde of vitamin-A).
- Light induces dissociation of the retinal from opsin resulting changes in structure of opsin.
- This causes change in membrane permeability. As a result, potential differences are generated in the photoreceptor cells.
- This produces a signal that generates action potential in the ganglion cells through bipolar cells.

- These action potentials transmitted by optic nerves to the visual cortex area of brain where the neural impulses are analyzed and the image formed on the retina is recognized.

THE EAR :

- The ear performs two sensory function, hearing and maintenance of body balance.
- Anatomically, the ear can be divided into three major section –
    - Outer ear or external ear.
    - Middle ear.
    - Internal ear or inner ear

External ear :

- Outer ear consists of the **pinna** and **external auditory meatus** (canal).
- Pinna collects the vibration in the air which produces sound.
- Auditory meatus extends upto the tympanic membrane (the ear drum).
- Tympanic membrane is made of connective tissue covered with skin.

Middle ear :

- Middle ear contains three ear ossicles called **Malleus** (hammer),**Incus** (anvil) and **stapes** (stirrup).
- The Malleus is attached to the tympanic membrane and the stapes is attached to the oval window of the cochlea.
- The ear ossicles amplify the sound waves comes from the tympanic membrane.
- A **Eustachian tube** connects the middle ear cavity with the pharynx.
- Eustachian tube helps in equalizing the pressures on either sides of the ear drum.

Internal ear :

- The fluid filled internal ear is called **labyrinth** consists of two parts, the bony and membranous labyrinth.
- 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 by a fluid called **endolymph**.
- The labyrinth consists of two portions –
    - The coiled portion called **cochlea**.
    - The complex above the cochlea called **vestibular apparatus**.

Cochlea:

- The coiled portion of the labyrinth is called cochlea.
- The membrane constituting cochlea are-
    - The reissner's membrane
    - The basilar membrane.

- Reissner's and basilar membrane divide the surrounding perilymph into an upper **scala vestibuli** and lower **scala tympani**.
- The space within cochlea called **scala media** is filled with **endolymph.**
- At the base of the cochlea, the scala vestibule ends at the **oval window (fenestra ovalis),** while scala tympani terminate at the **round window (fenestra rotundus**) which opens into 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 basal end of hair cells is in close contact with the afferent nerve fibres.
- Hair cells contain stereo cilia projected from the apical part of each hair cell.
- Hair cells covered by a thin elastic membrane called **tectorial membrane.**

Vestibular apparatus:

- Vestibular apparatus located above the cochlea.
- Vestibular apparatus consists of –
    - Three **semi-circular canals**
    - **Otolith organ** consisting **saccule** and **utricle**.

- Each semicircular canal lies in a different plane at right angles to each other.
- Membranous semi-circular canals are suspended in the perilymph of bony canal.
- The base of canals is swollen and is called **ampulla**, which contain a projecting ridge called **crista ampullaris** with hair cells.
- The saccule and utricle contain a projecting ridge called **macula**.
- Crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture.

Mechanism of hearing:

- The external ear receives sound waves and directs them to the ear drum.
- Sound waves are amplified by the ear ossicles and send it to the oval window in the middle ear.
- The vibration of the oval window creates waves in the perilymph of scala vestibuli.
- The waves in perilymph induce a ripple in the basilar membrane.
- Movements of the basilar membrane bend the hair cells, pressing them against the tectorial membrane.
- As a result nerve impulses are generated in the associated afferent neuron.
- These impulses are transported to the auditory cortex of the brain where the impulses are analysed and the sound is recognized.

22. Chemical Coordination and Integration

POINTS TO REMEMBER :

ENDOCRINE GLANDS AND HORMONES :

- Endocrine glands lacks ducts and are hence, called duct less glands.
- The chemicals secreted by endocrine gland is called hormone.
- Hormones are the chemical synthesized in the endocrine gland, acts as chemical messengers, transported in blood to distance place, where it acts on specific cells/tissue/organs, called target organ.
- Current specific definition of hormone is- **hormones are non-nutritional chemicals which act as intercellular messengers and are produced in trace amount.**

The hypothalamus :

- It is the basal part of the diencephalon, fore brain.
- It contains several groups of neurosecretory cells called nuclei which produce hormones.
- These hormones regulate the synthesis and secretory activity of pituitary gland.
- Hormones produced by it are two types –
    - **Releasing hormone (which stimulate secretion of pituitary hormone)**
    - **Inhibiting hormone(which inhibit secretion of pituitary hormone)**

- GnRH (gonadotrophins releasing hormone) from hypothalamus stimulate the pituitary gland to release gonadotrophins)
- Somatostatin from the hypothalamus inhibits the secretion of growth hormone from pituitary gland.
- Hormones secreted from the hypothalamus reach the pituitary gland through a portal circulation and regulate the anterior pituitary gland.
- Posterior pituitary is under the direct neural regulation of the hypothalamus.

The pituitary gland :

- Pituitary gland is located in a bony cavity called **sella tursica** and is attached to the hypothalamus by a stalk.
- Anatomically pituitary gland divided into two parts –
    - **Adenohypophysis.**
    - **Neurohypophysis.**

- Adenohypophysis consists of two portions –
    - **Pars distalis**
    - **Pars intermedia.**

- Pars distalis commonly called anterior pituitary produce following hormones –
    - **Growth hormone (GH)**
    - **Prolactin (PRL)**
    - **Thyroid stimulating hormone (TSH)**
    - **Adrenocorticotrophic hormone (ACTH)**
    - **Luteinizing hormone (LH)**

- **Follicle stimulating hormone (FSH)**

- Pars intermedia secrete one hormone called melanocyte stimulating hormone.
- **Neurohypophysis** (pars nervosa) also known as posterior pituitary store and release two hormone called **Oxytocin**and **vasopressin**, which are actually synthesized by the hypothalamus and are transported to neurohypophysis.

Growth hormone :

- Regulate normal growth of the body.
- Over secretion of GH leads to overgrowth called gigantism.
- Hypos-secretion of GH leads to dwarfism.

Prolactin :

- Regulates the growth of mammary gland.
- Stimulates formation of milk in the mammary gland.

Thyroid stimulating hormone (TSH) :

- Stimulates the synthesis and secretion of thyroid hormone from thyroid gland.

Adrenocorticotrophic hormone (ACTH) :

- Stimulates the synthesis and secretion of hormones from adrenal cortex called **glucocorticoids** and**mineralocorticoids**.

Luteinizing hormone (LH) :

- In male LH stimulate the synthesis and secretion of hormone called androgens from testes.
- In female LH induces ovulation of fully mature follicles (**Graafian follicle**).
- Maintain the **corpus luteum** formed from the remnants of Graafian follicle after ovulation.

Follicle stimulating hormone (FSH) :

- In male FSH along with androgen regulate spermatogenesis.
- FSH regulates the development of ovarian follicle.

Melanocyte stimulating hormone :

- MSH acts on the **melanocyte (**melanin containing cell)
- Regulates the pigmentation of the skin.

Oxytocin :

- Acts on smooth muscles of out body and stimulates their contraction.
- In females it stimulates a vigorous contraction of the uterus at the time of child birth.
- Stimulates contraction of smooth muscles of mammary gland causes milk ejection.

Vasopressin :

- Acts mainly on kidney and stimulates active reabsorption of water and electrolytes leads to concentration of urine and reduce loss of water. It is also known as **Anti-diuretic hormone** (ADH)

The pineal gland :

- Located on the dorsal side of the forebrain.
- Secretes one hormone called **melatonin**.
- Melatonin plays important role in sleep awakening cycle
- Regulate body metabolism.
- Control pigmentation.
- Influence on menstrual cycle.
- Influence body defense capability.

Thyroid gland :

- The thyroid gland is composed of two lobes which are located on either side of the trachea below larynx.
- Both lobes are connected by **isthmus**.
- The thyroid gland is composed of **follicles** and **stromal tissues**.
- Each thyroid follicle is lined by Cuboidal **follicular cells**, enclosing a cavity filled with a colloid called **thyrocolloid**.
- Follicular cells synthesise two hormones –
    - **Tetraiodothyronine** or **thyroxine** (T4).
    - **Triiodothyronine** (T3)

- These hormones are synthesized due to iodination of amino acid called tyrosine.
- In dietary deficiency of Iodine leads to enlargements of thyroid gland called **goitre**.
- Hypothyroidism during pregnancy causes defective development and maturation of the growing baby leading to a condition called **cretinism**.

- Cretinism is characterized by –
    - Stunted growth
    - Mental retardation.
    - Low intelligence quotient.
    - Abnormal skin.
    - Deaf mutism.
    - Pot bellied.
    - Dribbling saliva.

- In adult woman hypothyroidism may cause irregular menstrual cycle.
- Over secretion of thyroid hormone is called hyperthyroidism.

Function of thyroid hormone :

- Regulates basal metabolic rates.
- Support formation of red blood cells.

- Control metabolism of carbohydrates, protein and fat
- Maintain water and electrolyte balance.
- Hormone secreted by **parafollicular cells** called **thyrocalcitonin** (TCT).
- Thyrocalcitonin regulates blood calcium level (**hypocalcemia**).

Parathyroid gland :

- Four parathyroid glands are present on the back side of the thyroid gland.
- Parathyroid secretes a peptide hormone called **parathyroid hormone (PTH).**
- The secretion of PTH is regulated by blood calcium level by feed back regulation.
- PTH increases the blood calcium level (**hypercalcemia**).
- Stimulates resorption of bone (**demineralization**)
- Stimulates reabsorption of Ca2+ from the renal tubule.
- Increases absorption of Ca2+ from the digested food.
- Along with thyrocalcitonin it regulates blood calcium level.

Thymus gland :

- A lobular structure located on the dorsal side of the heart and the aorta.
- Plays important role in development of immune system.
- Secretes a hormone called **thymosin**.
- Thymosin play important role in differentiation of **T-lymphocytes** which provide **cell-mediated immunity**.
- Promotes production of antibodies to provide **humoral immunity**.
- It is commonly known as the throne of immunity.
- Thymus atrophies in old age decreasing body immune power.

Adrenal gland :

- One pair of adrenal glands located on the top of each kidney.
- Each adrenal gland composed of two types of tissues –
    - Centrally located tissue called **adrenal medulla.**
    - Peripheral tissue called **adrenal cortex**.

- Adrenal medulla secretes two hormones called –
    - Adrenaline or epinephrine
    - Non-adrenaline or nor epinephrine.

- Hormones of adrenal medulla are commonly known as catecholamine.
- Adrenaline and nor-adrenaline are rapidly secreted in response to stress of any kind during emergency situations and are called **emergency hormones**.
- Catecholamine are also known as **3'F'** hormone because they play a great role in manage stress full condition like**Fight, Flight** and **Fright.**

Function of adrenaline and nor-adrenaline.

- Increase alertness.

- Pupilary dilation.
- Piloerection (raising of hairs)
- Sweating.
- Increase heart rate,.
- The strength of heart contraction increased.
- Increase rate of respiration.
- Breakdown of glycogen into glucose
- Stimulate breakdown of proteins and fats.
- Adrenal cortex divided into three zones –
    - **Zona reticularis** – inner layer (mainly secretes **sex steroids**)
    - **Zona fasciculata** – middle layer (mainly secretes **glucocorticoids**)
    - **Zona glomerulosa** – outer layer (mainly secretes **mineralocorticoids**)

- Adrenal cortex secrete many steroid commonly called as **corticoids**.
- Corticoids regulate carbohydrate metabolism called **glucocorticoids**.
- Principal glucocorticoid is **cortisol**.
- Corticoids which regulate balance of water and electrolytes in our body are called **mineralocorticoids**.
- Principal mineralocorticoid is **aldosterone**.
- Sex steroids are called **androgen**.

Function of glucocorticoids :

- Stimulate gluconeogenesis (conversion of proteins and fats into glucose).
- Stimulate lipolysis (breakdown of fat)
- Promote proteolysis (conversion of protein into amino acids)
- Inhibit cellular uptake and utilization of amino acids.
- Cortisol maintains cardiovascular system as well as kidney function.
- Cortisol produces anti-inflammatory reactions and suppresses the immune response.
- Cortisol stimulates RBC production.

Function of aldosterone :

- Aldosterone acts mainly at the renal tubules.
- Stimulates the reabsorption of Na+ and water and excretion of K+ and phosphate ions.
- Aldosterone helps in maintenance of electrolytes, body fluid volume, osmotic pressure and blood pressure.

Function of androgen :

- Play a role in growth of axial hair, pubic hair and facial hair during puberty.

Pancreas :

- Pancreas is a myxocrine gland which acts as both exocrine and endocrine gland.
- The endocrine part consists of **'Islets of Langerhans'**.
- There are 1-2 millions of Islets of Langerhans in a pancreas representing only 1 – 2 percent of the pancreatic tissues.
- There are two principal cell type in Islets of Langerhans –
    - α- Cells secretes Glucagon.
    - β- Cells secrete Insulin.

Role of glucagon :

- Glucagon is a polypeptide hormone.
- Maintain normal blood glucose level.
- Stimulates **glycogenolysis** in hepatic cells, resulting increased blood sugar level called **hyperglycemia**.
- Stimulates gluconeogenesis.
- Reduce cellular glucose uptake and utilization.
- In general glucagon is a hyperglycemic hormone.

ole of Insulin :

- Insulin is a peptide hormone
- Regulate blood glucose homeostasis.
- Insulin acts mainly on **hepatocytes** and **adipocytes**.
- Enhance cellular glucose uptake and utilization.
- Stimulates rapid movement of glucose from blood to hepatocytes and adipocytes, resulting decrease in blood glucose level (**hypoglycemia**)
- Stimulates conversion of glucose into glycogen called **glycogenesis**.
- Stimulates synthesis of fat from glucose called **lipogenesis**.

Diabetes mellitus :

- Caused due to **hyposecretion** of **Insulin**.
- Prolonged hyperglycemia associated with **Glycosuria** (excretion of glucose in urine).
- Hyperglycemia leads to formation of **ketone bodies**.
- Diabetic patients are treated with insulin therapy.

Testes :

- A pair of testes is present in the scrotal sac of male.
- **Leydig cells** or **interstitial cells** are located in the intertubular spaces.
- These cells secrete a group of steroid called **androgen**, mainly**testosterone**.

Function of testosterone :

- Regulate development, maturation and functioning of male accessory sex organs like epididymis, vas deferens, seminal vesicles, prostate gland etc.
- Stimulates muscular growth.
- Plays a major role in spermatogenesis.
- Acts on central nervous system and influence the male sexual behaviour (**libido**).
- Stimulate protein anabolic effect.
- Stimulate development of **secondary sexual characters** –
    - Growth of facial and axillary hair.
    - Aggressiveness.
    - Low pitch voice

Ovary :

- Female have a pair of ovaries located in the abdomen.
- Primarily it acts as female sex organ and produce female gamete (ovum).

- It also acts as endocrine gland producing two groups of steroid hormones –
    - Oestrogen.
    - Progesterone.
- Oestrogen synthesized in the growing ovarian follicles.
- Progesterone is produced from the corpus luteum.
- Corpus luteum is formed from the remnant of ruptured Graafian follicle.

Role of oestrogen :

- Develop female secondary sexual organs.
- Development of growing ovarian follicles.
- Regulate female sexual behaviour.
- Development of female secondary sexual characters –
    - High pitch voices.
    - Development of breast or mammary glands.
    - Deposition of fat all over the body, making feminine appearance.

Role of progesterone :

- Support pregnancy.
- Control the second half of menstrual cycle.
- Maintain uterus for implantation.
- Prevents further ovulation.
- Inhibit action of Oxytocin (uterine contraction).
- Stimulate growth of mammary gland.
- Stimulates the formation of alveoli in the mammary gland.
- Stimulate milk secretion.

Hormones of heart :

- Atrial wall of heart secretes a peptide hormone called **atrial Natriuretic factor.**
- It decreases the blood pressure, by dilating the blood vessels.
- It also stops the secretion of renin; in the other hand suppress RAAS.

Hormones of Kidneys :

- Juxta glomerular cells of kidney produce a peptide hormone called **erythropoietin** which stimulates **erythropoiesis**(formation of RBC in bone marrow)

Hormones of gastro-intestinal tract :

- **Gastrin** – stimulates gastric gland to produce gastric juice.
- **Secretin** – stimulate exocrine part of pancreas to produce pancreatic juice.
- **Cholecystokinin** – contraction of gall bladder for secretion of bile juice.
- **Gastric inhibitory peptide (GIP)** – inhibits gastric secretion and motility.

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.

- There are two types of receptors –
    - Located on the cell membrane called **membrane bound receptors**.
    - Located inside the cell called **intracellular receptors.**

- On the basis of chemical nature hormones are classified into four groups –
    - **Peptide, polypeptide, protein hormone** (insulin, glucagon, pituitary and hypothalamic hormone).
    - **Steroids** (cortisol, estradiol and progesterone, testosterone).
    - **Iodothyronines** (thyroid hormone)
    - **Amino-acid derivatives** (adrenaline and nor adrenaline)

- Hormones which interacts with membrane-bound receptors normally do not enters into the cell but generates second messengers (cyclic AMP, IP_3, Ca^{++}etc).
- The second messengers in turn regulate cellular metabolism.
- The hormones which interact with intracellular receptors (steroid hormones, Iodothyronines) mostly regulate gene expression.