Chapter 1

The Living World

TOPIC-1

Living Organisms & Diversity in The Living World

Revision Notes

- **Characteristics of Living Organisms :** Growth, reproduction, metabolism, cellular organisation, consciousness (ability to sense environment), homeostasis, self-replication, and self-regulation.
- **Biodiversity** refers to the number of varieties of plants and animals on earth. The number of species that are known and described range between 1.7 – 1.8 million.
- **Need for classification :**
  - **(a)** To organise the vast number of plants and animals into categories that could be named, remembered, studied, and understood.
  - **(b)** To study the relationship among organisms.
- **ICBN :** International Code of Botanical Nomenclature. It is meant for giving scientific name to plants.
- **ICZN :** International Code of Zoological Nomenclature. It is meant for giving scientific name to animals.
- **Taxonomy :** Study of principles and procedures of classification.
- **Rules for Nomenclature :**
  - **(a)** Latinised names are used.
  - **(b)** First word represents the genus, while the second word is species name.
  - **(c)** Printed in italics; if handwritten then underlined separately.
  - **(d)** First word starts with a capital letter while species name is written in small letters.
  - **(e)** Name of scientist should be written in short form after the specific epithet Ex: Solanum tuberosum Linn. (Name of Scientist)
  - **(f)** Name of scientist witter be underlined not be Italicized.
- **Binomial Nomenclature :** It was given by Carolus Linnaeus. Each scientific name has two components namely, a generic name and a specific epithet.
- **Systematics :** It was proposed by Carolus Linnaeus who wrote the 'Systema Naturae' book. It deals with the classification of organisms based on their diversities and relationships among them.

TOPIC-2

Taxonomic Categories & Taxonomical Aids

Revision Notes

- **Taxonomic Hierarchy :** It deals with the arrangement of various steps (categories or taxa or ranks) of classification.
- Toxonomic categories :
  - Steps of classification : Toxonomic category

- Each step : unit of classification
- Taxon : group of organisation, plants and animals.

➢ Characterization, classification, identification and nomenclature are the process that are basic of taxnonomy.

➢ **Systematics :** Latin systema (Systematic arrangement of Organisms)

➢ Category is a part of overall taxonomic arrangement and all categories together Constitute the taxonomic hierarchy.

Kingdom (less specific)
↑
Phylum or Division
↑
Class
↑
Order
↑
Family
↑
Genus
↑
Species (more specific)

➢ **Species :** All the members that can interbreed among themselves and can produce fertile offsprings are the members of same species. The biological concept of species was proposed by Mayr.

➢ **Three Domains of Life :** It was proposed by Carl Woese in 1990 who also proposed the six kingdom classification for living organisms.

➢ The three domains are Archaea, Bacteria and Eukarya.
Archaea → Archaebacteria
Eubacteria → Monera
Eukaryota → Protista, Mycota, Plantae and Animalia
As we go higher from species to Kingdom the number of common characteristics goes on decreasing.

Organisms with Their Taxonomic Categories

Common Name	Biological Name	Genus	Family	Order	Class	Phylum/ Division
Man	*Homo sapiens*	*Homo*	Hominidae	Primata	Mammalia	Chordata
Housefly	*Musca domestica*	*Musca*	Muscidae	Diptera	Insecta	Arthropoda
Mango	*Mangifera indica*	*Mangifera*	Anacardiaceae	Sapindales	Dicotyledonae	Angiospermae
Wheat	*Triticum aestivum*	*Triticum*	Poaceae	Poales	Monocotyledonae	Angiospermae

Taxonomical Aids

➢ **Herbarium :** It refers to the store house of dried, pressed and preserved plant specimens on sheets.

➢ **Botanical Garden :** It is the collection of living plants for reference famous-Kew(England) India, Howrah and National Botanical Research Institute..

➢ **Museums :** Museums have collections of preserved plant and animal specimens for study and reference. Plant and animal specimens may also be preserved as dry specimens. Specimens are preserved in the containers or jars in preservative solutions. Insects are preserved in insect boxes after collecting, killing and pinning. Larger animals like birds and mammals are usually stuffed and preserved.

➢ **Zoological Parks :** These are places where wild animals are kept in protected environment to study food habits and behaviour.

➢ **Keys :** It is meant for identification of plants and animals on the basis of similarities and dissimilarities. The keys are based on the contrasting characters generally in a pair called couplet. Each statement in the key is called a lead Bracked key (Mostly used).

➢ **Flora :** It is an index to plant species found in a particular area. It contains the actual amount of habitat and distribution of plants of a given area.

➢ **Manuals :** It provides information for identification of the name of species found in an area.

➢ **Monograph :** It contain information on any one taxon.

Chapter 2

Biological Classification

TOPIC-1
Biological Classification And Kingdom Monera

Revision Notes

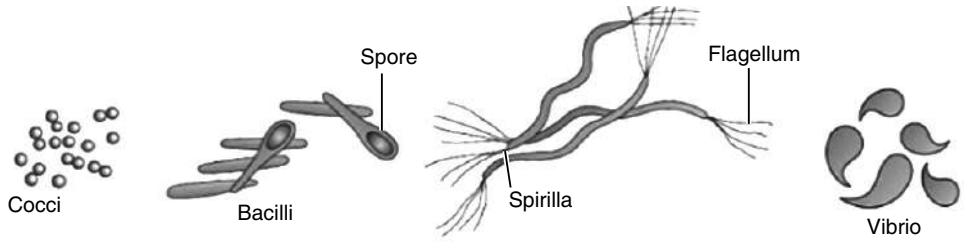
- **Systems of Classification :**
  - → Earliest classification was given by Aristotle.
  - → According to it, the plants were divided into herbs, shrubs and trees.
  - → Animals were classified based on the presence or absence of RBC's
- **Two kingdom classification :**
  - → It was given by Carolus Linnaeus.
  - → It includes Plantae kingdom and Animalia kingdom.
- **Five kingdom classification :**
  - → It was given by R. H. Whittaker.
  - → It includes Monera, Protista, Fungi, Plantae and Animalia kingdoms.

Characteristics of the Five Kingdoms

	Five Kingdoms				
Characters	**Monera**	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell well	Non-cellulosic (Polysaccharide + amino acid)	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ Loose tissue	Tissue/organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophytic/parasitic)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic/Saprophytic etc.)

Kingdom Monera

- Bacteria are the sole members of this kingdom.
- Bacteria can be grouped on the basis of their shapes : of Coccus (spherical), Bacillus (rod-shaped), Vibrio (comma shaped) and spirillum (spiral shaped).



Bacteria of different shapes

- Bacteria are found almost everywhere and can be photosynthetic autotrophs, chemosynthetic autotrophs or heterotrophs.

(a) Archaebacteria :

→ **Halophiles :** These occur in salty areas and hence are salt-loving.

→ **Thermoacidophiles :** These occur in hot springs.

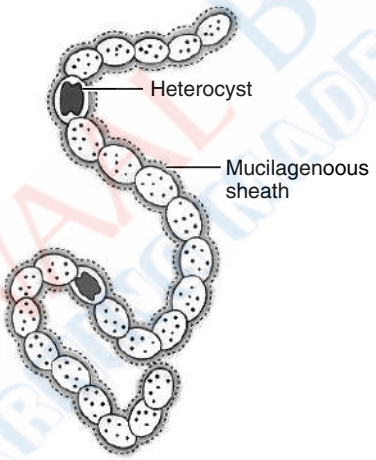
→ **Methanogens :** These occur in marsh and in the gut of ruminant animals and helps to produce methane gas.

(b) Eubacteria :

→ They are characterised by the presence of a rigid cell wall, and if motile, a flagellum.

→ These are photosynthetic autotrophic bacteria like cyanobacteria (also referred to as blue-green algae) having chlorophyll 'a' similar to green plants.

→ Some like *Anabaena* and *Nostoc* have specialised cells called heterocysts for nitrogen fixation.



A filamentous blue-green algae – *Nostoc*

- Chemosynthetic autotrophic bacteria oxidise various inorganic substances like nitrates/nitrites, ammonia and use released energy for their ATP production.
- Heterotrophic bacteria are decomposers and help in making curd, production of antibiotics, nitrogen fixation, etc. Some causes diseases like cholera and typhoid.
- **Mycoplasma :** Organisms that completely lack cell wall. They are the smallest living cells which can survive without oxygen. They are pathogenic in animals and plants.

TOPIC-2
Kingdom Protista and Kingdom Fungi

Revision Notes

Kingdom Protista

- All single celled eukaryotes are placed under this kingdom.
- It acts as a link between plants, animals and fungi.

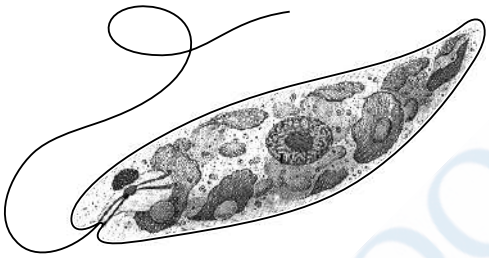
(i) Chrysophytes

→ It includes diatoms and golden algae (desmids).
→ Cell walls have silica and cell walls overlap to fit together like a soap box.
→ Their accumulation forms 'Diatomaceous Earth'.
→ These are used in polishing and filtration of oils and syrups.
→ Marine, photosynthetic, cell wall has cellulose, pleats on the outer surface.

(ii) Dinoflagellates : Diatoms are the chief producers in the oceans.

→ Most of them have two flagella – One is longitudinal and other is transverse in a furrow between wall plates.
→ Often red dinoflagellates such as *Gonyaulax* under go rapid multiplication to make the sea appear red (red tides).

(iii) Euglenoid :



Euglena

→ They have protein rich layer 'pellicle' instead of a cell wall which makes the body flexible.
→ Photosynthetic in presence of sunlight but become heterotrophs in the absence of sunlight.

(iv) Slime Moulds

→ These are saprophytic protists.
→ They form aggregates to form plasmodium which grows on decaying twigs and leaves.
→ During unfavourable conditions the plasmodium differentiates to form fruiting bodies bearing spores.
→ Spores have true walls which are extremely resistant and survive for many years.

(v) *Protozoans*

→ The protozoans are believed to be primitive relatives of animals and are categorised into four major groups.
→ **Amoeboid :** These catch prey using pseudopodia, *e.g.*, *Amoeba.*
→ **Flagellated :** These possess flagella. They cause diseases like sleeping sickness. Example - *Trypanosoma.*

Paramoecium

→ **Ciliated :** These have cilia to move food into gullet and help in locomotion. Example - *Paramoecium*.
→ **Sporozoans :** These have infective spore like stage in their life cycle. Example - *Plasmodium* which causes Malaria.

KINGDOM FUNGI

- The fungi are heterotrophic organisms. Except yeasts which are unicellular, fungi are filamentous.
- Their bodies consist of long, slender thread like structure called hyphae.
- The network of hyphae is called mycelium
- The cell wall is made up of chitin and polysaccharides
- They grow in warm and humid places
- They may be saprophytic, parasitic, and symbiotic (Lichen and as mycorrhiza).
- Examples - *Puccinia* (wheat-rust causing), *Penicillium.*

Classes of Fungi

(i) Phycomycetes :

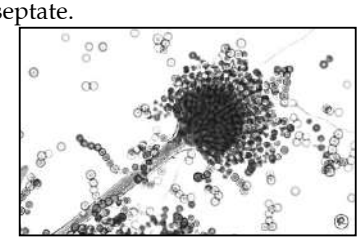
→ They grow on decaying wood or as obligate parasites on plants.
→ The mycelium is septate and coenocytic.
→ Spores are produced endogenously in sporangium.
→ Asexual reproduction takes place by zoospores (motile) or aplanospores (non-motile).

→ Examples - *Rhizopus* and *Albugo.*

(ii) Ascomycetes :

→ These are also known as 'sac fungi' and are mostly multicellular as in *Penicillium* or rarely unicellular as in yeast.

→ Mycelium is branched and septate.



Aspergillus

→ Asexual spores are called conidia produced exogenously on the conidiophores.

→ Sexual spores are called ascospores produced endogenously in ascus which are arranged in different types of fruiting bodies called ascocarps.

→ Examples - *Aspergillus, Neurospora* (used in biochemical and genetic work).

(iii) Basidiomycetes :

→ Mycelium is branched and septate.

→ Asexual spores generally are not found.

→ Vegetative reproduction by fragmentation.

Agaricus

→ Sexual reproduction by fusion of vegetative or somatic cells to form basidium produced in basidiocarp.

→ Basidium produce four basidiospores exogenously after meiosis.

→ Examples - *Agaricus, Ustilago.*

(iv) Deuteromycetes :

→ They are also called as 'Imperfect Fungi' 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.

→ They may be saprophytic, parasitic or decomposers.

→ Examples - *Alternaria, Colletotrichum* and *Trichoderma.*

TOPIC-3

Kingdom Plantae, Kingdom Animalia and Viruses, Viroids and Lichens

Revision Notes

Kingdom Plantae

- It is characterised by all eukaryotic chlorophyll-containing organisms commonly called plants.
- They may be insectivorous plants such as Bladderwort and Venus fly trap or parasites like *Cuscuta*.
- The plant cells have an eukaryotic structure with prominent chloroplasts and cell wall mainly made of cellulose.
- Plantae includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms.
- Life cycle of plants has two distinct phases – the diploid sporophytic and the haploid gametophytic – that alternate with each other.

Kingdom Animalia

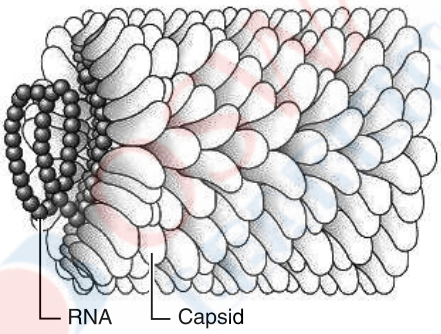
- It is characterised by heterotrophic eukaryotic organisms that are multicellular and their cells lack cell walls.
- They digest their food in an internal cavity and store food reserves as glycogen or fat.
- Their mode of nutrition is holozoic – by ingestion of food.
- Higher forms show elaborate sensory and neuromotor mechanism.
- The sexual reproduction is by copulation of male and female followed by embryological development.

Viruses

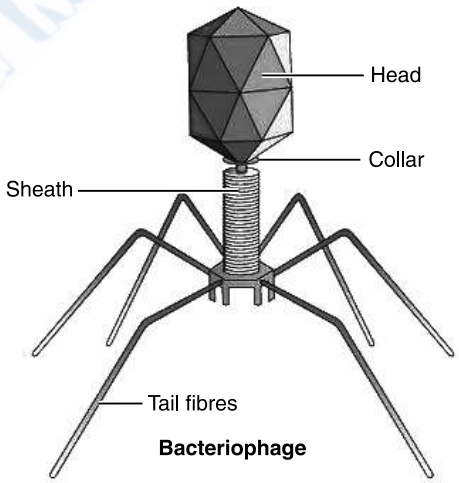
- They did not find a place in classification.
- They are characterised by having inert crystalline structure outside the living cell.
- Pasteur gave the term 'virus' *i.e.*, poisonous fluid.
- D. J. Ivanowsky (1892) found out that certain microbes caused Tobacco Mosaic Disease in tobacco plant.
- M. W. Beijerinck (1898) found that infected plants of tobacco could cause infection in healthy plants and called the fluid as 'Contagium Vivum Fluidum'.
- W. M. Stanley (1935) showed that viruses could be crystallised to form crystals of protein which are inert outside their specific host.

Structure of Virus

- It is a nucleoprotein made up of protein called Capsid and the genetic material DNA or RNA.
- Capsid is made up of capsomeres arranged in Helical or polygeometric forms.
- It has 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.
- It causes diseases such as mumps, small pox, AIDS etc.



Tobacco Mosaic Virus (TMV)



Bacteriophage

Viroids

- Viroids are infectious RNA particles which lack the protein coat.
- RNA has low molecular weight.
- It causes potato spindle tuber disease.
- It was discovered by T. O. Diener.

Lichens

- These are symbiotic association between algal component (Phycobiont) and fungal component (Mycobiont).
- Algae provide food while fungi provide shelter and absorb nutrients and water for alga.
- They are good pollution indicators as they do not grow in polluted areas.

❐❐❐

Chapter 3

Plant Kingdom

TOPIC-1

Types Of Classification And Algae

Revision Notes

Types of Classification

(a) Artificial System of Classification
- It was given by Carolous Linnaeus.
- It is based mainly on vegetative characters or on androecium structure

(b) Natural System of Classification
- It is based on natural affinities among organisms
- It included external as well as internal features
- It was given by George Bentham and J. D. Hooker

(c) Phylogenetic System of Classification
- It is based on evolutionary relationships between the various organisms
- It was given by Hutchinson

Numerical Taxonomy :
- It is carried out using computers
- It is based on all observable characteristics
- Data are processed after assigning number, codes and symbols to all the characters.
- Advantage : Each character gets equal importance and a number of characters can be considered.

Cytotaxonomy :
- It is based on cytological information.
- It gives importance to chromosome number, structure and behaviour.

Chemotaxonomy :
- It is based on chemical constituents of the plants.

Algae
- Algae are chlorophyll-bearing, simple, thalloid, autotrophic and largely aquatic (both fresh water and marine) organisms.
- Algae are unicellular like *Chlamydomonas,* colonial like *Volvox* or filamentous like *Spirogyra***.**

Importance of Algae :
- At least half of the total carbon dioxide fixation on earth is carried out by them.
- They 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.
- Algin obtained from brown algae and carrageen from red algae are used commercially.
- *Chlorella* and *Spirulina* are unicellular algae rich in protein and used even by space travellers.

Reproduction in Algae

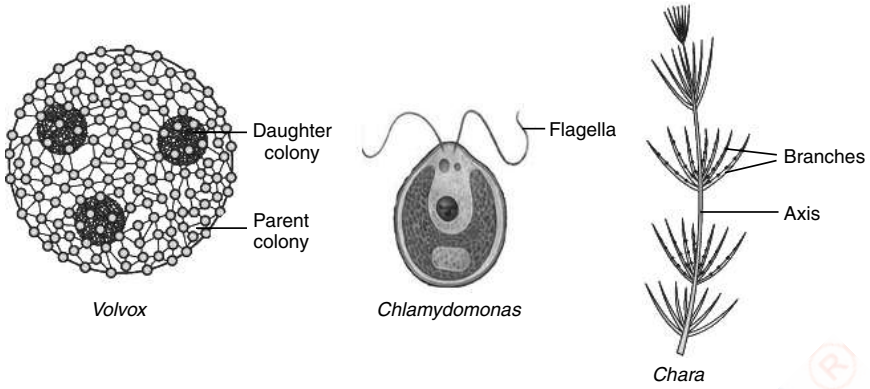
(a) Vegetative reproduction : It takes place by fragmentation

(b) Asexual Reproduction : It takes place by flagellated zoospores in Chlorophyceae, biflagellated zoospores in Phaeophyceae and by non-motile spores in Rhodophyceae.

(c) Sexual Reproduction : It may be isogamous, anisogamous or oogamous as seen in Chlorophyceae and Phaeophyceae and non-motile gametes as in Rhodophyceae.

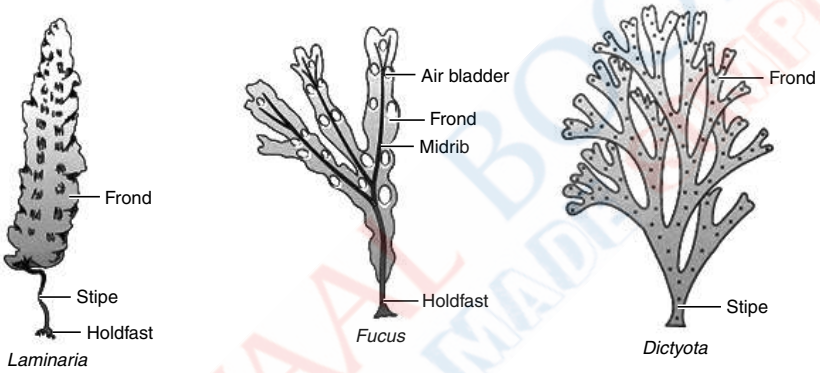
Division of Algae

(i) Class Chlorophyceae
- It is green algae due to the presence of main pigment as chlorophyll 'a' and 'b'.
- The cell wall has inner layer of cellulose and outer layer of pectose.
- It has storage bodies called pyrenoids made up of starch and proteins.
- Examples - *Chlamydomonas, Volvox, Spirogyra.*



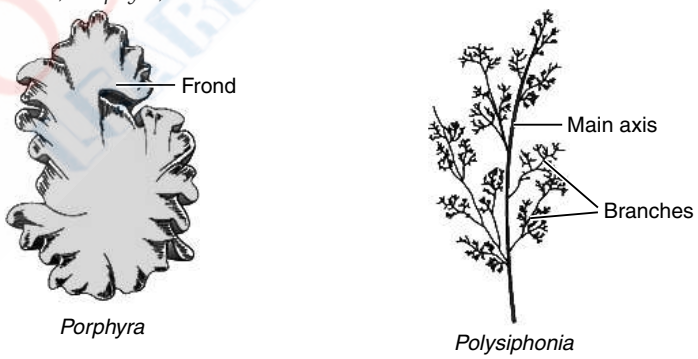
(ii) Class Phaeophyceae

- It is brown algae due to the presence of main pigments as chlorophyll 'a', 'c', carotenoids and xanthophylls.
- The cell wall has cellulose usually covered outside by a gelantinous coating of algin.
- It has mannitol and laminarin as reserve food material.
- The body is divisible into holdfast, stipe and frond.
- Examples - *Ectocarpus, Fucus, Laminaria, Dictyota and Sargassum.*



(iii) Class Rhodophyceae

- It is red algae due to the presence of main pigments as chlorophyll 'a', 'd' and r-phycoerythrin.
- It is found on surface as well as great depths in oceans.
- The cell wall is of cellulose, pectin and polysulphate esters.
- The reserve food material is floridean starch.
- Examples- *Polysiphonia, Porphyra, Gelidium.*



Divisions of Algae and their Main Characteristics

Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Geen algae	Chlorophyll *a, b*	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a, c,* carotenoids and xanthophylls	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water, brackish water, salt water

Rhodophyceae	Red algae	Chlorophyll *a*, *c*, r-phycoery thrin	Floridean starch	Cellulose	Absent	Fresh water (some), brackish water, salt water (most)

TOPIC-2
Bryophytes and Pteridophytes

Revision Notes

Bryophytes

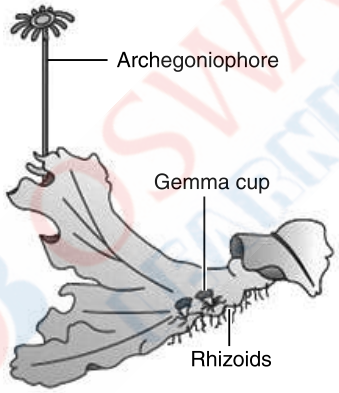
- These are called 'Amphibians of plant kingdom' because these plants can live in soil but are dependent on water for sexual reproduction.
- They occur in damp, humid and shaded places.
- They lack true roots, stem or leaves.
- The main plant body is haploid called gametophyte.

Economic Importance:

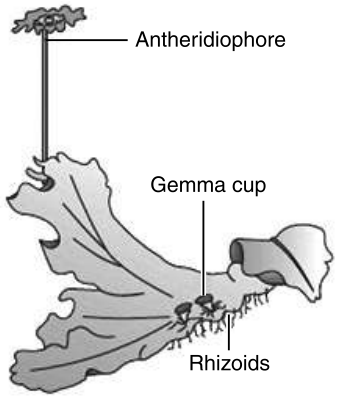
- They act as food for herbaceous animals.
- *Sphagnum* : Mosses peat is used as fuel and also as packing material used for trans-shipment of living material as it has water holding capacity, prevent soil erosion, and along with lichens are first colonizers on barren rocks.

Classes of Bryophytes

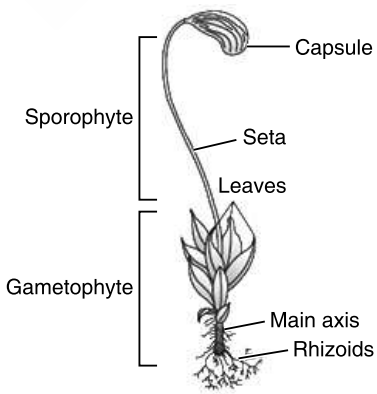
- Two classes : Liverworts and Mosses.
- Liverworts possess thalloid body, which is dorsiventral and closely appressed to the Substratum Eg - *Marchantia*
- Mosses have two stages in gametophyte creeping, green, branched, filamentous, protonema stage and the leafy stage having spirally arranged leaves. Eg - *Funaria, Polytrichum* and *Sphagnum*.



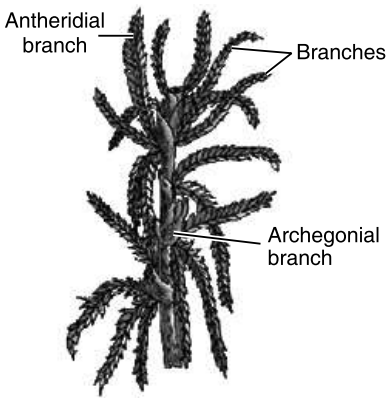
Liverworts – Female thallus of *Marchantia*



Liverworts — Male thallus of *Marchantia*



Funaria – Gametophyte and Sporophyte



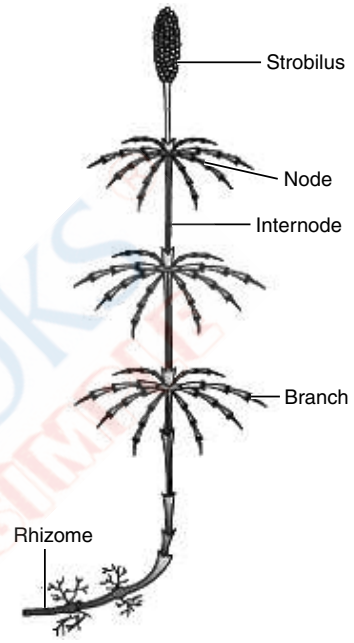
Sphagnum – Gametophyte

Reproduction in Bryophytes

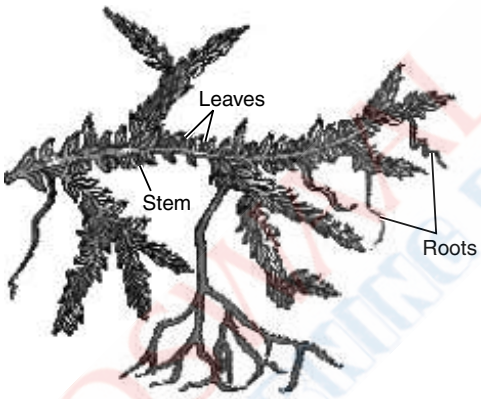
- Vegetative reproduction : It takes place by fragmentation.
- Asexual reproduction : It takes place by gemmae formed in gemma cups.
- Sexual reproduction : It takes place by fusion of antherozoids produced in antheridium and egg cell produced in archegonium. This result in formation of zygote which develops into a sporophytic structure differentiated into foot, seta and capsule. Spores produced in a capsule germinate to form free-living gametophyte.

Pteridophytes

- The main plant body is sporophyte which is differentiated into true stem and leaves.
- Leaves may be small (microsporophyll) 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 fertilisation form zygote. Zygote produces multicellular, well differentiated sporophyte.
- The four classes include Psilopsida (*Psilotum*), Lycopsida (*Selaginella*), Sphenopsida (*Equisetum*) and Pteropsida (*Pteris*).



Equisetum



Selaginella

Heterospory :

- It exhibit two kinds of spores namely, large (macro) and small (micro) spores. Examples – *Selaginella* and *Salvinia.*

Seed Habit :

- The development of zygote into young embryos takes place within the female gametophyte which is retained on parent sporophyte. This is an important step in evolution and is found in *Selaginella* and *Salvinia* among the pteridophytes.

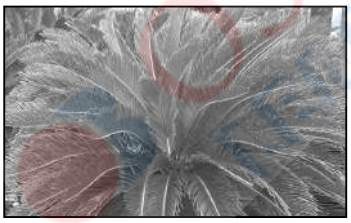

Salvinia

TOPIC-3
Gymnosperms, Angiosperms and Plant Life Cycles

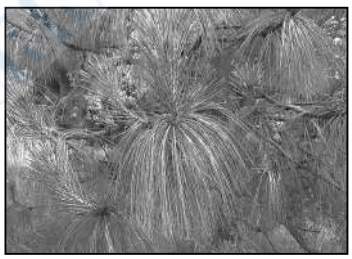
Revision Notes

Gymnosperms

- Gymnosperms are plants in which the ovules are not enclosed by an ovary wall and remain exposed before and after fertilisation.
- The stems of a gymnosperm can be branched or unbranched and bears the needle-like leaves, thick cuticle and sunken stomata on the leaves which reduce the rate of water loss.
- The roots are generally tap roots. Roots in *Pinus* have fungal association in the form of mycorrhiza while in *Cycas* have coralloid roots with N_2-fixing cyanobacteria.
- The reproductive structure of a gymnosperm is called a strobilus or a cone and gymnosperms have both male and female strobili.
- The strobili are seen on the same tree, as in *Pinus* or on different trees, as in *Cycas*.
- The male strobilus contains microsporophylls, which bear microsporangia that produce haploid microspores.
- Microspores develop into male gametes called pollen grains and the rest degenerate.
- The female strobilus is a cluster of megasporophylls, which bears ovules containing the megasporangium.
- The megasporangium, surrounded by a layer of envelopes produces haploid megaspores and a megaspore mother cell.
- The megaspore mother cell undergoes meiosis to give rise to four haploid megaspores.
- One of these mega spores develops into a multicellular female gametophyte.
- The female gametophyte further bears two or three female sex organs called archegonia, which develop inside the ovule.
- The pollen grains released from the microsporangium are carried by air to reach the micropyle.
- A pollen tube sprouts from the pollen grain and grows towards the archegonium, where it discharges the male gametes.
- These gametes fuse with the egg to form a zygote. This process is called fertilisation.
- The zygote develops into an embryo and the ovule into a seed post-fertilisation.



Cycas



Pinus

Ginkgo

Angiosperms

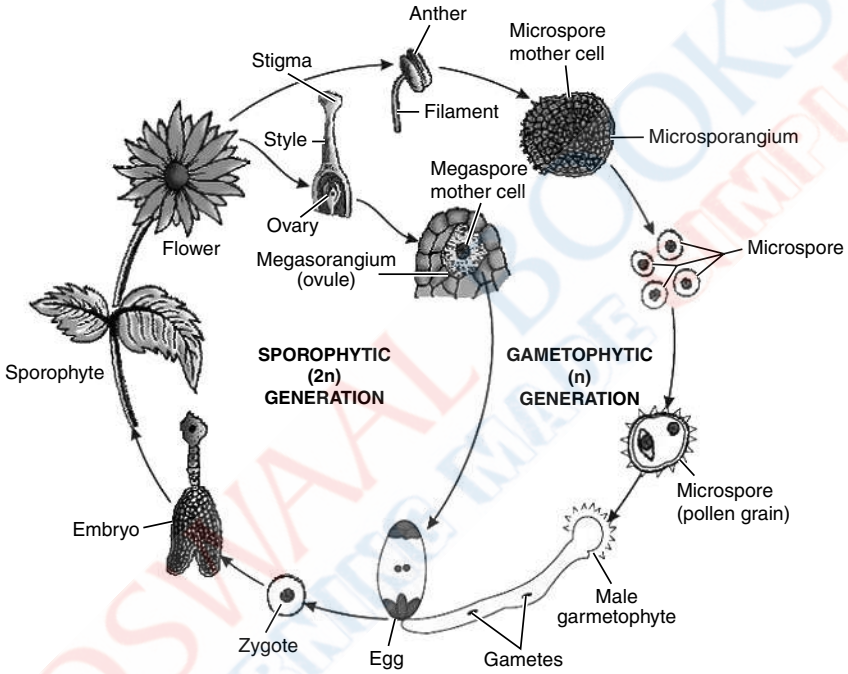
- These are called flowering plants and have seeds enclosed in fruits.
- It is divided into two classes namely, dicotyledons having two cotyledons and monocotyledons having one cotyledon.
- Smallest angiosperm : *Wolfia*
- Largest tree : *Eucalyptus*
- Stamen has filament and anther.
- Anthers bear pollen grains. Pollen grains have two male gametes.
- Pistil has stigma, style and ovary. Ovary has ovule in which female gametophyte (embryo sac) develops.
- Embryo sac has 7 cells and 8 nuclei. One egg cell, 2 synergids, 3 antipodals and two polar nuclei which fuse to form secondary nucleus.
- Pollen grain is carried by wind, water etc., and reaches to stigma to produce pollen tube which enters embryo sac.

Double Fertilisation :

- One male gamete fuses with the egg cell to form zygote which develops into embryo.
- Other male gamete fuses with secondary nucleus which forms triploid primary endosperm nucleus (PEN).
- PEN develops into endosperm which nourishes the developing embryo.
- Ovules develop into seeds and ovaries into fruits.

Plant Life Cycles and Alternation of Generations

- **Alternation of generation :** Here, haploid gametophytic and spore producing sporophytic generation alternate with each other in this process.
- **Haplontic :** Gametophytic phase dominant. Examples – *Chlamydomonas* except *Fucus* which is diplontic.
- **Diplontic :** Sporophytic phase dominant. Examples - Angiosperms and Gymnosperms.
- **Haplo-diplontic :** Intermediate like stage where gametophytic and sporophytic stages partially dominate at different stages. Examples - Bryophytes and Pteridophytes. *Ectocarpus* and *Polysiphonia* are haplo-diplontic algae.



Life cycle of an Angiosperm

❐❐❐

Chapter 4

Animal Kingdom

TOPIC-1
Basis of Classification

Revision Notes

Features used for classification :

- Arrangement of cells, body symmetry, nature of coelom, patterns of digestive, circulatory and reproductive systems.

Levels of Organisation :

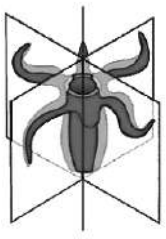
- In sponges, the cells are arranged as loose cell aggregates, i.e., they exhibit cellular level of organisation.
- In coelenterates, the arrangement of cells is more complex where the cells performing the same function are arranged into tissues, hence is called tissue level of organisation.
- Platyhelminthes exhibit organ level of organisation. In Aschelminthes, Annelids, Arthropods, Molluscs, Echinoderms and Chordates tissues are grouped together to form organs, each specialised for a particular function exhibiting organ level of organisation.

Types of Circulatory System :

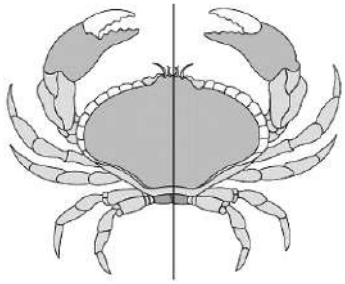
- **Open type :** Blood pumped out through heart. Cells and tissues are directly bathed in it.
- **Closed type :** Blood is circulated through vessels.

Types of Symmetry:

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



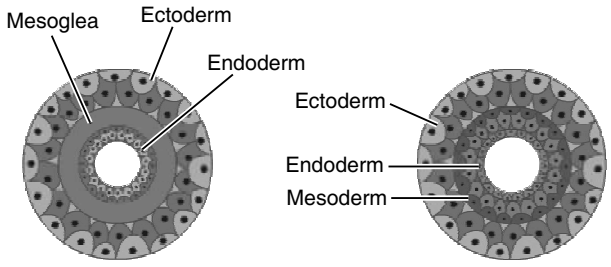
Radial symmetry



Bilateral symmetry

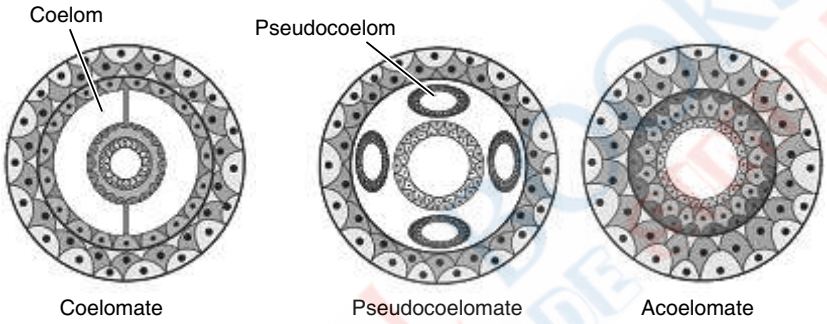
Classification on the Basis of Germinal Layers:

- **Diploblastic :** Cells arranged in two embryonic layers i.e. external ectoderm and internal endoderm. (Mesoglea may be present in between ectoderm and endoderm). Example - Coelenterates. (Cnidarians)
- **Triploblastic :** Three layers present in developing embryo i.e., ectoderm, endoderm and mesoderm. Example - Chordates.

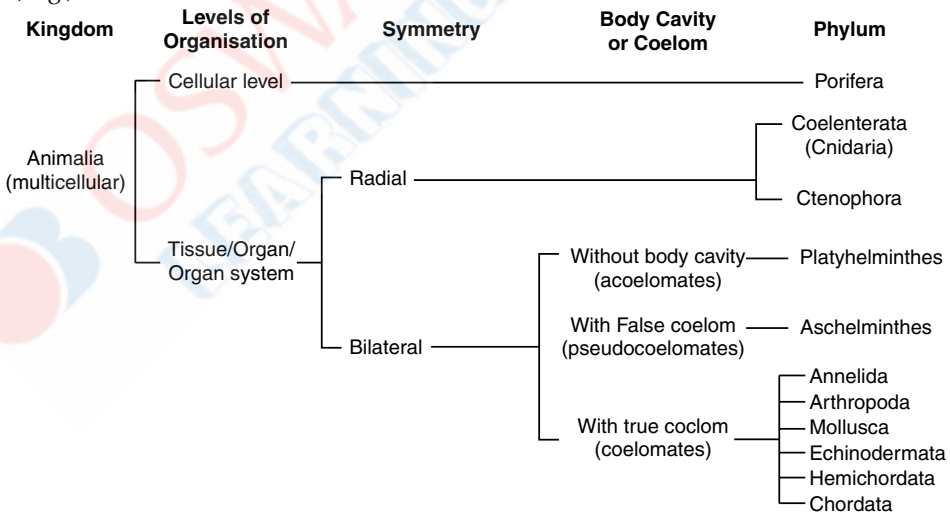


Showing germinal layers : (a) Diploblastic, (b) Triploblastic

- **Coelom :** It refers to the body cavity which is lined by mesoderm.
- **Coelomates :** Organism that possess coelom. Examples - Annelids, Chordates, etc.
- **Pseudocoelomates :** Organism in which no true Coelom as mesoderm is present in scattered pouches between ectoderm and endoderm. Example - Aschelminthes.
- **Acoelomates :** Organism in which the body cavity is absent. Example - Platyhelminthes.



- **Metamerism :** If body is externally and internally divided into segments with serial repetition of atleast some organs then phenomenon is called metamerism. Example - Earthworm.
- **Notochord :** These are rod-like structure formed during embryonic development on the dorsal side. It is mesodermally derived. Example - Chordates. Those animals which do not form notochord are called non-chordates, e.g., Porifera to Echinodermata.



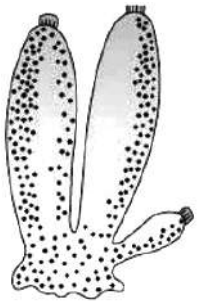
TOPIC-2

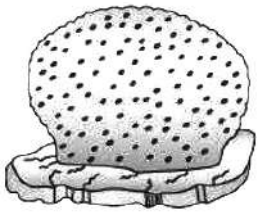
Phylum Porifera, Coelenterata, Ctenophora, Aschelminthes and Platyhelminthes

Revision Notes

- **Phylum Porifera :**

- These are also called sponges.
  - These are usually marine and asymmetrical.
  - They have cellular level of organisation.
  - Food gathering, respiratory exchange and removal of wastes occur through water canal system.
  - Digestion is 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 fibres.
  - Animals are hermaphrodite.
  - Fertilisation internal with indirect development (i.e., has a larval stage distinct from adult stage)
  - It includes *Sycon, Euspongia.* (Bath sponge is the common name for *Euspongia*.)


Sycon


Euspongia


Spongilla

Phylum Coelenterata :

- These are also called cnidarians.
- These are usually marine and radially symmetrical.
- They possess tissue level of organisation
- These are diploblastic.
- Food gathering, anchorage and defense occurs through cnidoblasts present on tentacles.
- Digestion extracellular and intracellular.
- They have gastro-vascular cavity and an opening called hypostome.
- Some of the cnidarians have a skeleton composed of calcium carbonate.
- They exhibit two body forms: polyp and medusa as seen in *Hydra, Aurelia.*
- Alternation of generation between body forms called metagenesis occurs in *Obelia* where medusa sexually produces polyp and polyp asexually produces medusa.
- It includes *Physalia, Adamsia.*


Cnidoblast


Aurelia

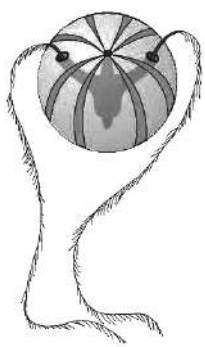

Adamsia

Phylum Ctenophora :

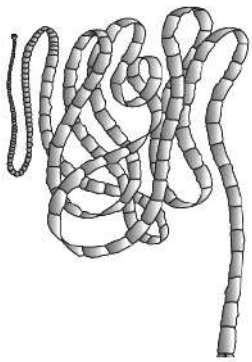
- These are also called as sea walnuts or comb jellies.
- These are exclusively marine, radially symmetrical.
- They have tissue level organisation.
- These are diploblastic.
- Digestion both extra and intracellular.
- Body has eight external rows of ciliated comb plates for locomotion.
- They exhibit bioluminescence (living organism emit light).
- Only sexual reproduction occurs.
- External fertilisation with indirect development.
- It includes *Ctenoplana* and *Pleurobrachia*.

Phylum Platyhelminthes :

- These are also called as 'flat worms'.
- They possess dorsoventrally flattened body.


Ctenophora
(*Pleurobrachia*)

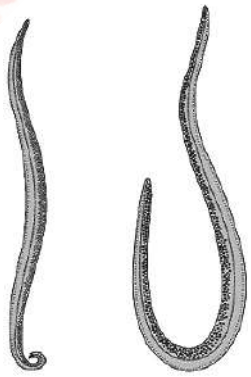
- These are endoparasites in animals.
- They are bilaterally symmetrical, triploblastic and acoelomate with organ level of organisation.
- They absorb nutrients through body surface.
- Parasite forms have hooks and suckers.
- 'Flame cells' help in osmoregulation and excretion.
- Fertilisation internal with many larval stages.
- Some members like *Planaria* has high regeneration capacity.
- It includes *Taenia* (Tapeworm), *Fasciola* (Liver fluke).


Tapeworm


Liver fluke

Phylum Aschelminthes :

- These are also called 'round worms'.
- They may be free living, parasitic, aquatic or terrestrial.
- They are bilaterally symmetrical, triploblastic and pseudocoelomate with organ-system level of organisation.
- Alimentary canal complete (has muscular pharynx), wastes removed through excretory pore.
- Sexes separate and hence show dimorphism.
- Females longer than males.
- Fertilisation internal with direct or indirect development.
- It includes *Ascaris* (Round Worm), *Wuchereria* (Filaria worm).


Male Female

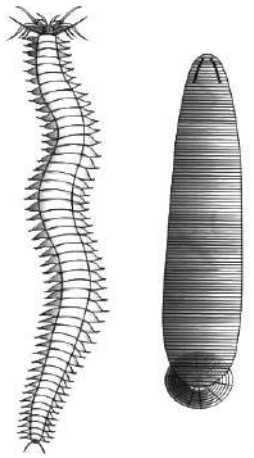
TOPIC-3

Phylum Annelida, Arthropoda, Mollusca, Echinodermata and Hemichordata

Revision Notes

Phylum Annelida :

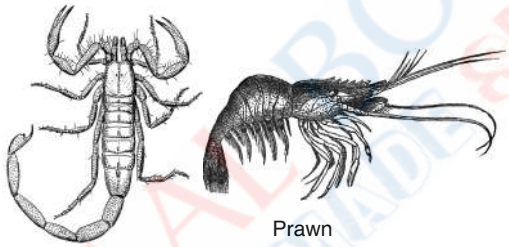
- These are aquatic or terrestrial, free-living or parasitic.
- They are bilaterally symmetrical, triploblastic, organ-system level of organisation with metamerically segmented body.
- They have longitudinal and circular muscles for locomotion.
- *Nereis* has lateral appendages called parapodia for swimming.
- They have nephridia for osmoregulation and excretion.
- Earthworm (*Pheretima*) and Leech (*Hirudinaria*) are hermaphrodites (monoecious) while *Nereis* is dioecious.
- It includes *Nereis, Pheretima* (Earthworm) and *Hirudinaria*(Blood sucking leech).



Nereis *Hirudinaria*

Phylum Arthropoda :

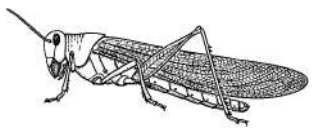
- It is the largest phylum of Animalia.
- These are bilaterally symmetrical, triploblastic with organ system level of organisation and coelomate animals.
- Body divisible into head, thorax, abdomen and has a chitinous exoskeleton.



Scorpion Prawn

- Jointed appendages are present.
- Respiration by gills, book gills, lungs or tracheal system.
- Excretion through malpighian tubules.
- Sensory organs are antennae, eyes and an organ of balance (statocysts) are present.
- Fertilisation internal with direct or indirect development.
- These are mostly oviparous.
- Examples - *Apis*, *Bombyx*, *Anopheles*, Locust, *Limulus* (living fossil-king crab).

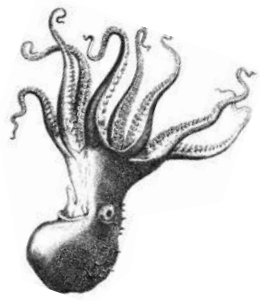
Butterfly



Locust

Phylum Mollusca :

- This is the second largest phylum of Animalia.
- These are bilaterally symmetrical, triploblastic with organ system level of organisation and coelomate animals.
- Body divisible into head, muscular foot and visceral hump and is covered by calcareous shell.
- **Mantle** is soft and spongy layer of skin over the visceral hump. Mantle cavity is the space between visceral hump and mantle.
- Respiration and excretion takes place with the help of feather like gills in mantle cavity.
- Head has sensory tentacles.



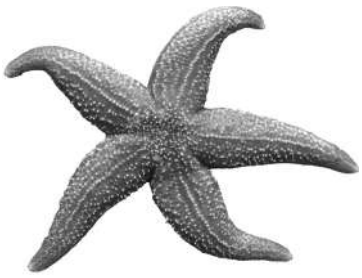
Octopus

- Radula-file like rasping organ for feeding.
- These are oviparous, dioecious, with indirect development.
- It includes *Pila, Pinctada* (Pearl Oyster), *Octopus*.

Pila

Phylum Echinodermata :

- These are spiny bodied organisms with endoskeleton of calcareous ossicles.
- These are exclusively marine, radially symmetrical in adult but bilaterally symmetrical in larval stage with organ system level of organisation.
- Digestive system complete with mouth on ventral and anus on dorsal side.
- Food gathering, respiration, locomotion carried out by water vascular system.
- Excretory system is absent.
- External fertilisation with indirect development (free swimming larva)
- It includes *Asterias, Cucumaria*.



Asterias

Ophiura

Phylum Hemichordata :

- These are small worm-like organisms with organ-system level of organisation.
- This phylum was earlier placed as sub-phylum of Phylum Chordata.
- These are bilaterally symmetrical, triploblastic and coelomate.
- Body cylindrical, has proboscis, collar and trunk.
- Respiration takes place by gills.
- Excretion takes place by proboscis gland.
- Sexes are separate.
- External fertilisation, indirect development.
- It includes *Balanoglossus* and *Saccoglossus*.

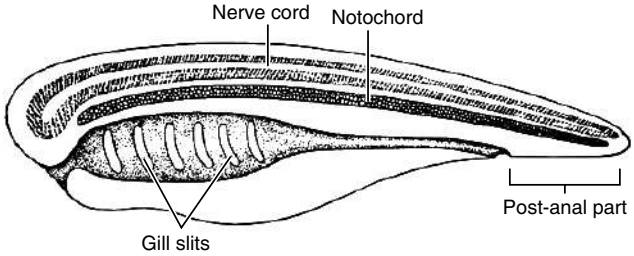
Balanaglossus

TOPIC-4
Chordata

Revision Notes

Phylum Chordata :

- These are characterised by the presence of notochord, a dorsal hollow nerve chord and paired pharyngeal gill slits.
- These are bilaterally symmetrical, triploblastic and coelomate animals with organ-system level of organisation.



Chordata characteristics

- Heart is ventral.
- Post anal tail present.

S. No.	Chordates	Non-chordates
1.	Notochord present.	Notochord absent.
2.	Central nervous system is dorsal.	Central nervous system is ventral, solid and double.
3.	Pharynx perforated by gill slits.	Gill slits are absent.
4.	Heart is ventral.	Heart is dorsal (if present).
5.	A post-anal (tail) is present.	Post-anal tail is absent.

Classification of Chordata :

(i) Sub-phyla Urochordata

- Notochord present only in larval tail.
- It includes *Ascidia*, *Salpa, Doliolum*.

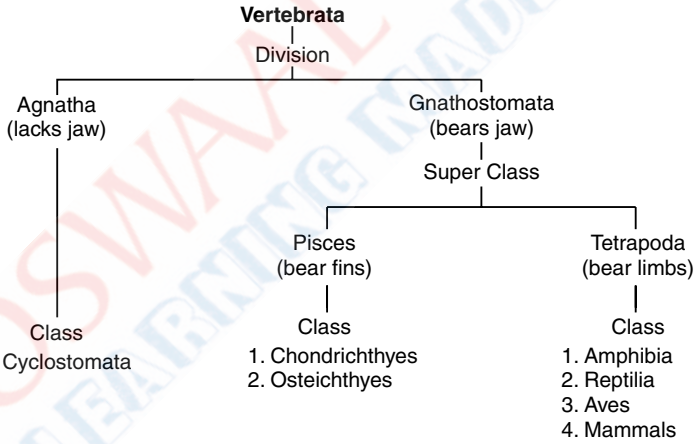
(ii) Sub-phyla Cephalochordata

- Notochord extends from head to tail.
- It includes *Amphioxus.*

(iii) Sub-phyla Vertebrata

- They have notochord only during embryonic period.
- Notochord gets replaced by bony or cartilaginous vertebral column.
- They have ventral muscular heart, paired appendages and kidneys for excretion and osmoregulation.

Ascidia



Sub-Phylum Vertebrata

(A) Agnatha (Lack Jaws)

Class : Cyclostomata

- They have sucking and circular mouth without jaws.
- They live as ectoparasites on some fishes.
- They do not possess scales and paired fins.
- Cranium and vertebral column are cartilaginous.
- They migrate to fresh water for spawning and die after spawning.
- They show metamorphism.
- It includes *Petromyzon* and *Myxine*.

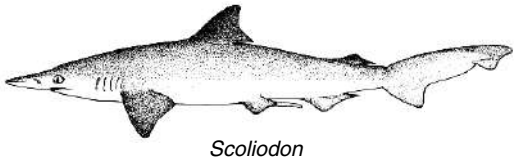
A jawless vertebrate – *Petromyzon*

(B) Gnathostomata (Bear Jaws)

A. Super Class: Pisces

1. Class : Chondrichthyes

- They have cartilaginous endoskeleton.
- The mouth is located ventrally.
- They are cold-blooded (poikilothermous) animals with two-chambered heart.
- Gill slits without operculum
- Skin has minute placoid scales.
- They are usually viviparous.
- Fertilisation is internal.
- They do not possess air bladder and so swim constantly to avoid sinking.
- Teeth are backwardly directed and are modified placoid scales.
- Notochord is persistent throughout life.
- Males have claspers on pelvic fins.
- It includes *Torpedo, Trygon, Scoliodon.*



Scoliodon

2. Class: Osteichthyes

- They have bony endoskeleton and are both marine and fresh water fishes.
- Mouth is usually terminal.
- Four pairs of gills covered by operculum.
- Skin has cycloid/ctenoid scales.
- They are usually oviparous, fertilisation external.
- They have air bladder which regulates buoyancy.
- It includes *Hippocampus, Labeo, Catla, Betta.*

Hippocampus *Catla*

B. Super Class: Tetrapoda

1. Class: Amphibia

- They can live in aquatic as well as terrestrial habitats.
- Body divisible into head and trunk.
- Their skin is moist without scales.
- Tympanum represents ear.
- Cloaca is the common chamber where alimentary, urinary and reproductive tracts open.
- Respiration takes place by gills, lungs or skin.
- Heart is three-chambered.
- Oviparous with indirect development.
- It includes *Bufo, Rana, Hyla, Salamandra, Ichthyophis* (Limbless amphibia)

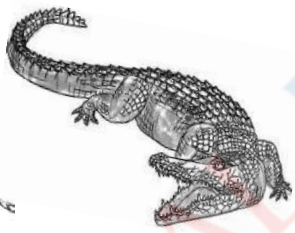
Salamandra

Rana

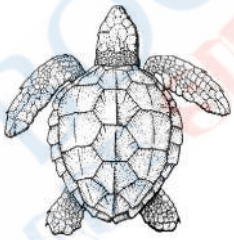
2. Class: Reptilia

- They creep or crawl to perform locomotion.
- Body has dry and cornified skin and epidermal scales or scutes.
- Tympanum represents ear.
- Limbs when present are two pairs.
- Snakes and lizards shed scales as skin cast.
- Heart is three-chambered but is four-chambered in crocodiles.
- Oviparous with direct development.
- It includes *Testudo, Naja, Vipera, Calotes.*

Chameleon



Crocodile



Chelone

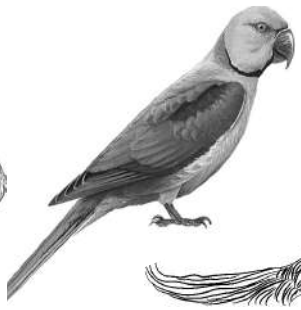
Naja

3. Class : Aves

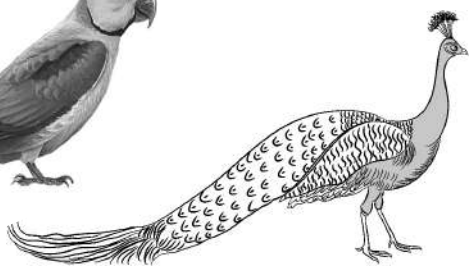
- It is characterised by the presence of feathers and beak.
- Forelimbs are modified into wings.
- Hind limbs have scales and are modified for various activities.
- There are no glands on skin except oil gland at base of tail.
- Endoskeleton bony with air cavities (pneumatic) and hollow bones to assist in flight.
- Heart is completely four chambered. They are warm blooded (homoiothermous) animal.
- Air sacs are connected to lungs to supplement respiration.
- Oviparous with direct development.
- It includes *Columba* (Pigeon), *Struthio* (Ostrich), *Neophron, Pisttacula, Pavo* (Peacock).

Neophron

Struthio



Pisttacula

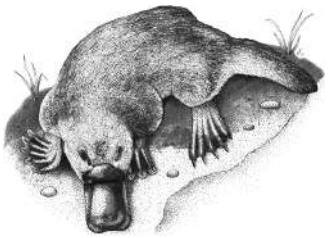


Pavo

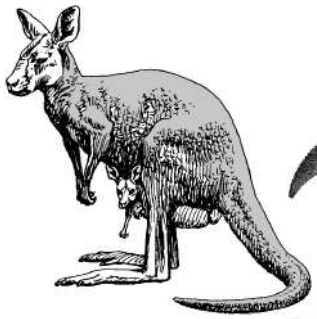
4. Class: Mammalia

- They save mammary glands to nourish young ones.
- They have two pairs of limbs.
- Skin has hairs.
- External ears or pinna is present.
- Different types of teeth are present in the jaw.
- Viviparous with direct development but *Ornithorhynchus* (Platypus) is an oviparous mammal.
- It includes *Rattus, Canis, Elephas, Equus, Pteropus, Macropus, Balaenoptera.*

Balaenoptera



Ornithorhynchus



Macropus

Pteropus

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Chapter 5

Morphology of Flowering Plants

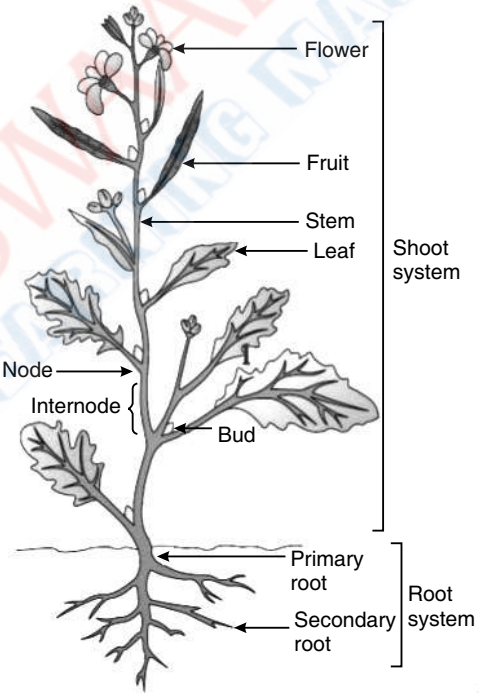
TOPIC-1

Root, Stem and Leaf

Revision Notes

Morphology and Adaptation :

- **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 the radicle of the embryo.
- Primary, secondary and tertiary roots develop due to the elongation of radicle.

Types of Root :

(a) Tap root :

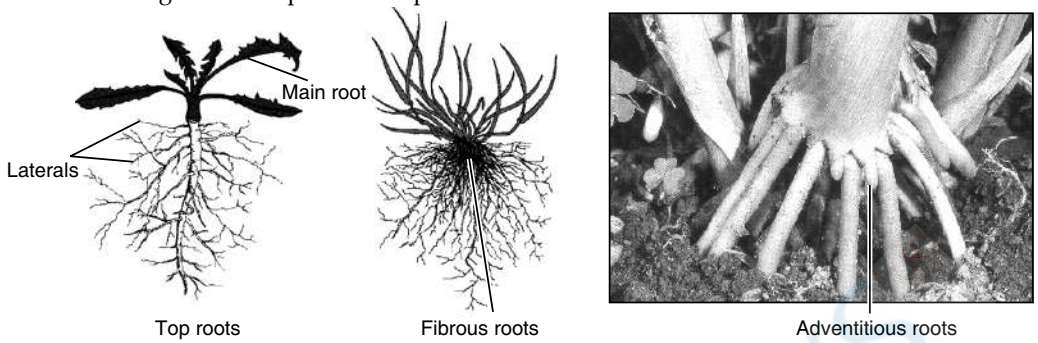
These roots originate from radicle. It is seen in dicotyledonous plants. Examples - gram, pea, mango, etc.

(b) Fibrous root :

These roots originate from base of the stem. It is seen in monocotyledonous plants. Examples - wheat, paddy, grasses, etc.

(c) Adventitious root :

These roots originate from parts of the plant other than radicle.



➢ **Root Cap :** The root is covered at the apex by a thimble-like structure which protects the tender apical part**.**

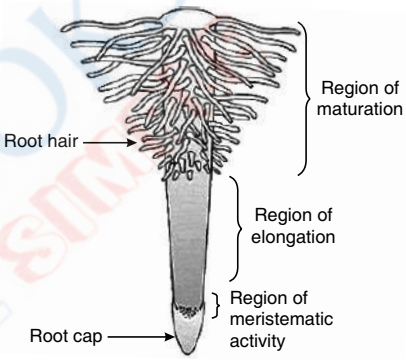
The main functions of the root system are the absorption of water and minerals from the soil, providing a proper anchorage to the plants, storing reserve food material and synthesis of plant growth regulators.

Regions of the Root :

(a) Region of meristematic activity : Cells of this region have the capability to divide.

(b) Region of elongation : Cells of this region undergo rapid elongation and enlargement.

(c) Region of maturation : This region has differentiated and mature cells. Some of the epidermal cells of this region form thread-like root hairs.

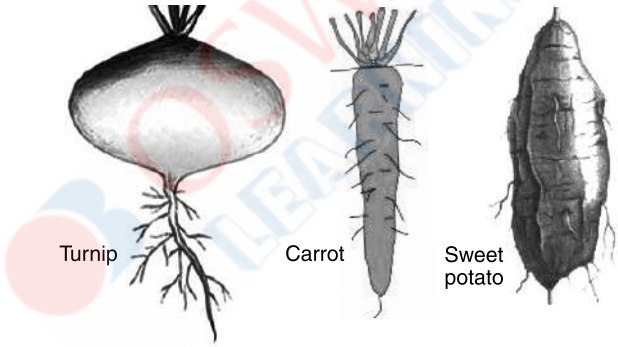


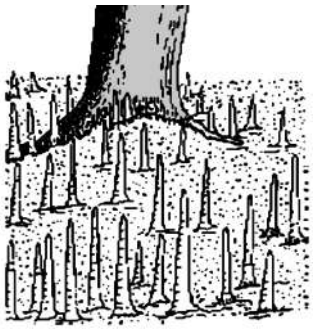
Modifications of Root :

(a) For support : Prop roots in banyan tree, stilt roots in maize and sugarcane.

(b) For respiration : Pneumatophores in *Rhizophora* (Mangrove).

(c) For storage of food : Fusiform (radish), Napiform (turnip), Conical (carrot).





Pneumatophore in *Rhizophora*

THE STEM

➢ Stem is the aerial part of the plant and develops from plumule of the embryo.

➢ It bears nodes and internodes.

Modifications of Stem :

(a) For food storage : Rhizome (ginger), Tuber (potato), Bulb (onion), Corm (*Colocasia*).

(b) For support : Stem tendrils which develop from axillary buds as in watermelon, grape vine, cucumber.

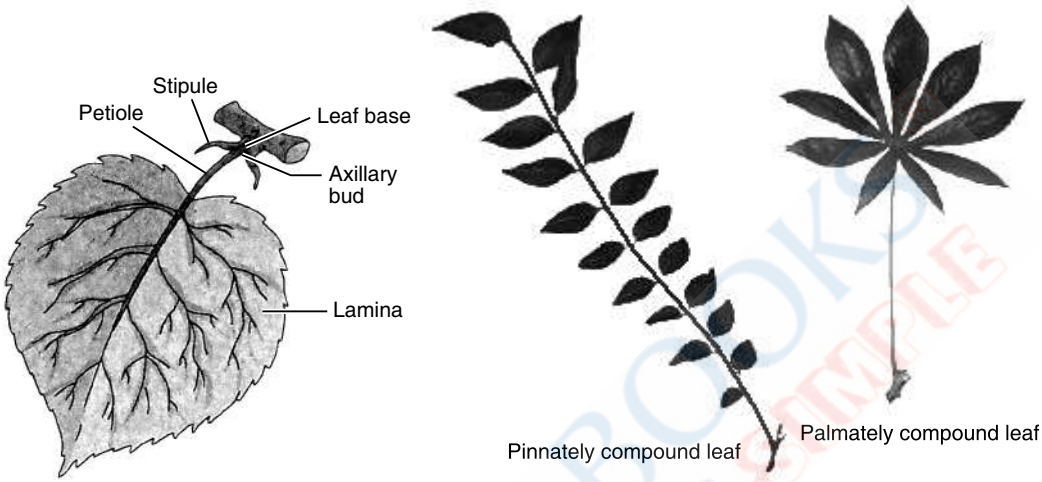
(c) For protection : Axillary buds of stem of *Citrus, Bougainvillea* get modified into pointed thorns. They protect the plants from animals.

(d) For vegetative propagation : Underground stems of grass, strawberry; lateral branches of mint and jasmine; Lateral branch with short internodes, the nodes bears tuft of roots and rosette of leaves as in *Pistia* and *Eichhornia* and in banana, pineapple and *Chrysanthemum*, the lateral branches grow below the soil which emerges out to form shoot.

(e) For assimilation of food : Flattened stem of *Opuntia* contains chlorophyll and performs photosynthesis.

THE LEAF :

- The leaf develops from shoot apical meristem.
- It is flattened, green structure that helps to manufacture the food by photosynthesis.
- It has bud in axil.
- A typical leaf has leaf base, petiole and lamina.
- In monocots, the leaf base expands into a sheath covering the stem partially whereas in some legumes it becomes swollen to form the pulvinus.



Types of Leaf :

(a) Simple leaf : It possess single leaf blade. Examples - mango, peepal.

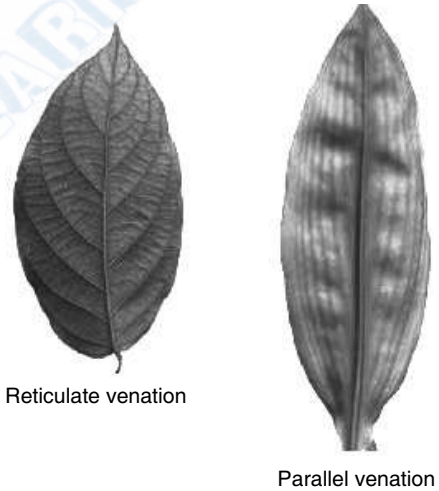
(b) Compound leaf : It has number of leaflets. It is further classified into two types namely, pinnately compound leaf such as neem, rose and palmately compound leaf such as silk, cotton.

Venation : It refers to the arrangement of veins and veinlets in the lamina of leaf.

Types of Venation :

(a) Reticulate Venation : Veinlets form a network as in leaves of dicotyledonous plants. Examples - China rose, peepal.

(b) Parallel Venation : Veins are parallel to each other as in leaves of monocotyledonous plants. Examples - grass, maize, sugarcane.



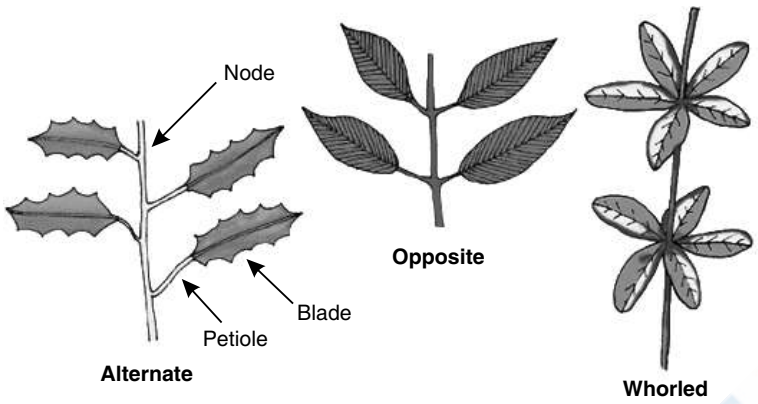
Phyllotaxy : It refers to the pattern of arrangement of leaves on the stem or branch.

Types of Phyllotaxy :

(a) Alternate phyllotaxy : It has single leaf at a node. Examples - China rose, Mustard

(b) Opposite phyllotaxy : It has two leaves at a node. Examples - *Calotropis*, guava

(c) Whorled phyllotaxy : It has more than two leaves in a whorl at a node. Examples - *Nerium, Alstonia.*



Modifications of Leaves :

(a) Tendrils : (Climbing) – Sweet wild pea

(b) Spines : (Protection) – *Aloe, Opuntia, Argemone*

(c) Pitcher : (Nutrition) – *Nepenthes,* here the leaves are modified into pitcher for trapping insect.

(d) Hook : (Support) – Cat's nail

TOPIC-2

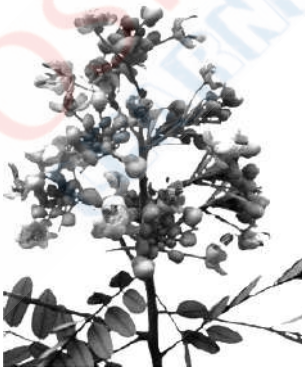
The Inflorescence And The Flower

Revision Notes

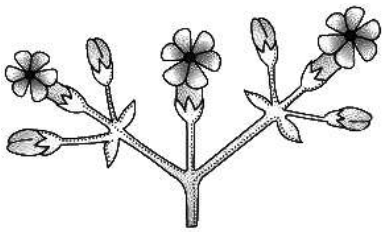
- **Inflorescence :** It refers to the arrangement of flowers on the floral axis.

Main types of Inflorescence :

1. **Racemose :** Radish, Mustard, *Amaranthus.*
2. **Cymose :** Cotton, Jasmine, *Calotropis.*
3. **Special type :** *Ficus, Salvia, Euphorbia.*



Racemose inflorescence



Cymose inflorescence

THE FLOWER

- A flower is modified shoot wherein the shoot apical meristem changes to floral meristem.
- It is a reproductive unit in angiosperms.
- Flowers may be unisexual or bisexual, bracteate or ebracteate.

Classification of Flower:

(a) Based on symmetry of flower

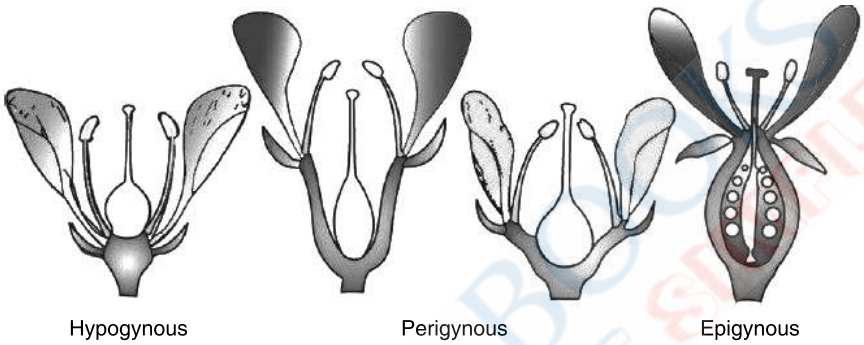
→ Actinomorphic (radial symmetry) e.g., mustard, datura, chilli

→ Zygomorphic (bilateral symmetry) e..g, pea, gulmohur, bean, *Cassia.*

→ Asymmetric (irregular), as in *Canna.*

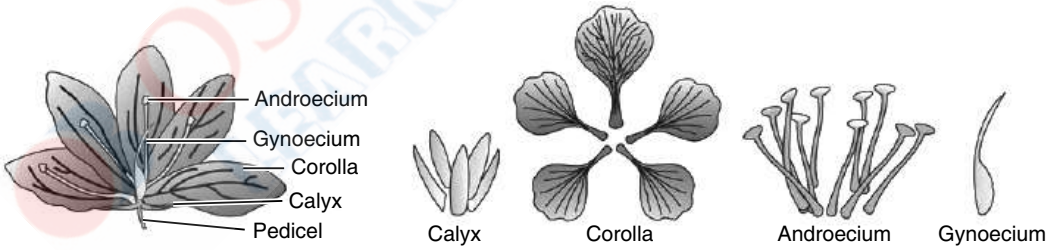
(b) Based on the number of floral appendages
- → Trimerous [3 in number]
- → Tetramerous [4 in number]
- → Pentamerous [5 in number]

(c) Based on the position of calyx, corolla and androecium with respect to gynoecium
- → Hypogynous (superior ovary), flower where gynoecium occupies the highest position, e.g., mustard, china rose and brinjal.
- → Perigynous (half inferior ovary) when the gynoecium is situated in the centre with other parts at the same level as in plum, rose, peach.
- → Epigynous (inferior ovary), when the other parts of flower arise above the ovary as in guava, cucumber and the ray florets of sunflower.



Parts of Flower :

1. **Calyx :** Sepals, green in colour, leaf like.
2. **Corolla :** Petals, usually brightly coloured to attract insects for pollination.
3. **Androecium :** Stamens (filament, anther), male organ and produce pollen grains. Stamens may be epipetalous (attached to petals) or epiphyllous (attached to perianth). Stamens may be monoadelphous (united into one bundle), diadelphous (two bundles) or polyadelphous (more than two bundles).
4. **Gynoecium :** Made up of one or more carpels, female reproductive part, consists of stigma, style and ovary. Ovary bears one or more ovules. Carpels may be apocarpous (free) or syncarpous (united). After fertilisation, ovules develop into seeds and ovary into fruit.



Classification based on the attachment of petals and sepals :

(a) Gamosepalous – (Sepals united)

(b) Polyseptalous – (Sepals free)

(c) Gamopetalous – (Petals united)

(d) Polypetalous – (Petals free)

Perianth : If calyx and corolla are not distinguishable, they are called perianth.

Aestivation : The mode of arrangement of sepals or petals in floral bud.

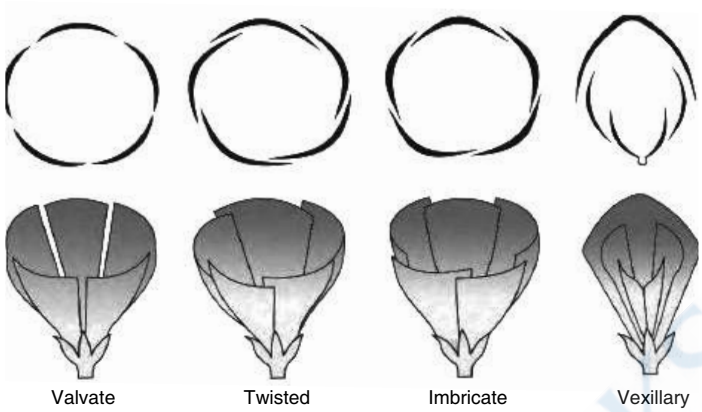
Types of aestivation :

(a) Valvate aestivation : Sepals or petals do not overlap the sepal or petal at margins as in *Calotropis.*

(b) Twisted aestivation : Sepals or petals overlap the next sepal or petal as in china rose and cotton as in *Cassia.*

(c) Imbricate aestivation : The margins of sepals or petals overlap one another but not in any definite direction. e.g. *Cassia*.

(d) Vexillary aestivation : The largest petal overlaps the two lateral petals which in turn overlap two smallest anterior petals. e.g. Pea and bean flowers.



Placentation : It refers to the arrangement of ovules within the ovary.

Types of Placentation :

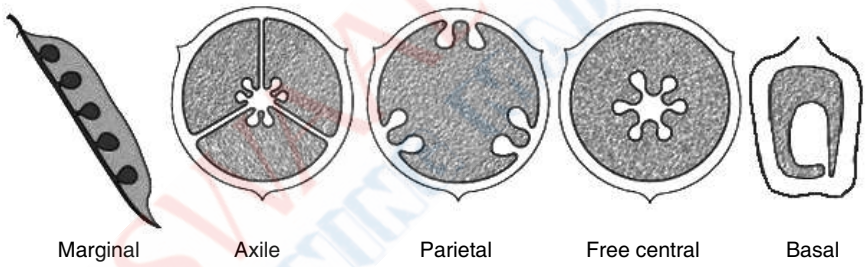
(a) Marginal Placentation : Placenta forms a ridge along the ventral suture of ovary.

(b) Axile Placentation : Margins of carpels fuse to form central axis, as in china rose, tomato and lemon.

(c) Parietal Placentation : Ovules develop on inner wall of ovary, as in mustard and *Argemone.*

(d) Free central Placentation : Ovules borne on central axis, lacking septa, in *Dianthus and Primrose.*

(e) Basal Placentation : Placenta develops at the base of ovary as in Sunflower.

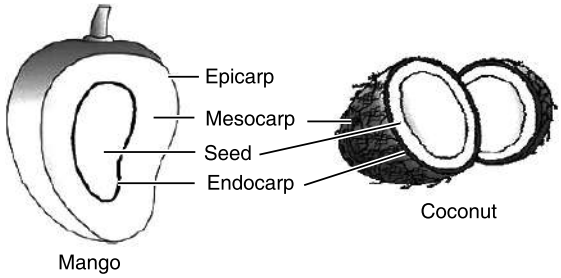


TOPIC-3

The Fruit, The Seed And The Families

Revision Notes

- After fertilisation, the mature ovary develops into fruit.
- The parthenocarpic fruits are formed from ovary without fertilisation.
- The fruit consists of a wall or pericarp and seeds.
- The pericarp may be dry or fleshy.
- When pericarp is thick and fleshy, it is differentiated into the outer epicarp, the middle mesocarp and the inner endocarp.
- In mango and coconut, the fruit is known as a drupe.
- They develop from monocarpellary superior ovaries and are one seeded.
- In mango, the pericarp is well differentiated into an outer thin epicarp, a middle fleshy edible mesocarp and an inner stony hard endocarp.
- In coconut which is also a drupe, the mesocarp is fibrous.

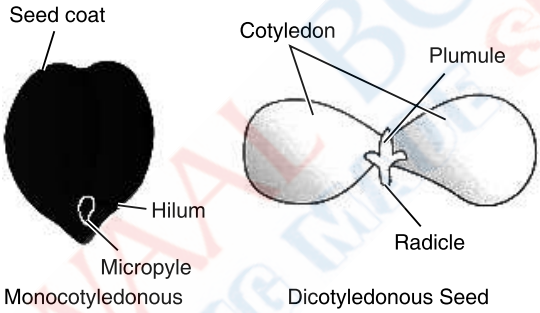


SEED

- The ovules after fertilisation develop into seeds.
- A seed is made up of a seed coat and an embryo.
- The embryo is made up of a radicle, an embryonal axis and one (as in wheat, maize) or two cotyledons (as in gram and pea).

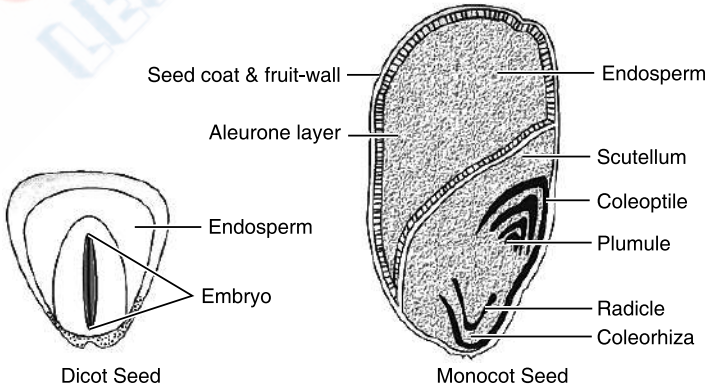
Structure of a Dicotyledonous Seed

- The seed coat has two layers, the outer testa and the inner tegmen.
- The hilum is a scar on the seed coat through which the developing seeds were attached to the fruit.
- Above the hilum is a small pore called the micropyle.
- The cotyledons are often fleshy and full of reserve food materials.
- At the two ends of the embryonal axis are present the radicle and the plumule.
- In some seeds such as castor the endosperm formed as a result of double fertilisation, is a food storing tissue.
- In plants such as bean, gram and pea, the endosperm is not present in mature seeds and such seeds are called non-endospermous.



Structure of Monocotyledonous Seed

- These seeds are endospermic except orchids.
- The endosperm is bulky and stores food.
- The outer covering of endosperm separates the embryo by a Proteinaceous layer called aleurone layer.
- The embryo consists of one large and shield shaped cotyledon known as scutellum and a short axis with a plumule and a radicle.
- The plumule and radicle are enclosed in sheaths which are called coleoptile and coleorhiza respectively.



SEMI-TECHNICAL DESCRIPTION OF A TYPICAL FLOWERING PLANT :

- The floral formula is represented by some symbols.
- In the floral formula, **Br** stands for bracteate, K stands for calyx, **C** for corolla, **P** for perianth, **A** for androecium and **G** for Gynoecium, $\underline{G}$ for superior ovary and $\overline{G}$ for inferior ovary, ♂ for male, ♀ for female, ⚥ for bisexual plants, ⊕ for actinomorphic and % for zygomorphic nature of flower.
- Fusion is indicated by enclosing the figure within bracket and adhesion by a line drawn above the symbols of the floral parts.

➢ A floral diagram provides information about the number of parts of a flower, their arrangement and the relation they have with one another.

DESCRIPTION OF SOME IMPORTANT FAMILIES

A. Family Fabaceae :

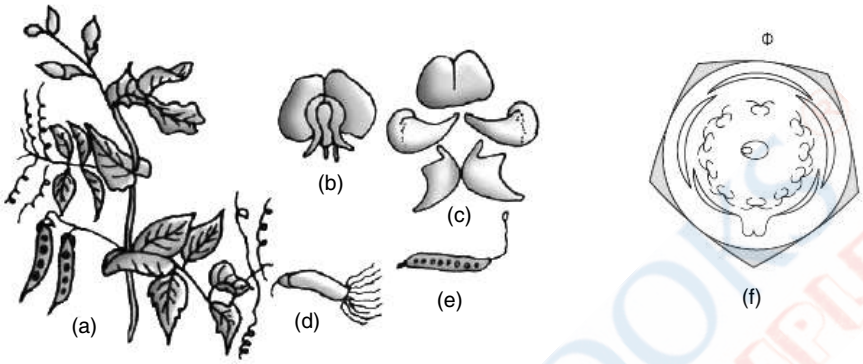
This family was earlier called Papilonoideae, a subfamily of family Leguminosae.

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

Stem : erect or climber

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

Floral characters :



Pisum sativum (pea plant) : (a) Flowering twig (b) Flower (c) Petals (d) Reproductive parts (e) L.S. carpel (f) Floral diagram

Inflorescence : racemose

Flower : bisexual, zygomorphic

Calyx : sepals five, gamosepalous; imbricate aestivation

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

Androecium : ten, diadelphous, anther dithecous

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

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

Floral Formula : $\% \, ♂ ♀ \, K_{(5)} \, C_{1+2+(2)} \, A_{(9)+1} \, \underline{G}_{1}$

Economic importance :

Sources of pulses (gram, arhar, sem, moong, soyabean), Edible oil (soyabean, groundnut), Dye (*Indigofera*), Fibres (sunhemp), Fodder (*Sesbania, Trifolium*), Ornamentals (lupin, sweet pea), Medicine Mulaithi.

B. Family Solanaceae :

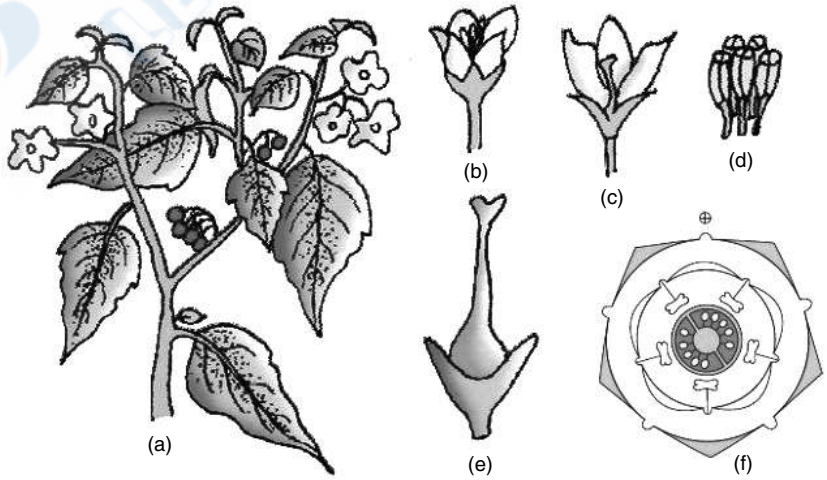
It is a large family, commonly called as the 'potato family'.

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

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

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

Floral Characters :



Solanum nigrum **(makoi plant) : (a) Flowering twig (b) Flower (c) L.S. of flower (d) Stamens (e) Carpel (f) Floral diagram.**

Inflorescence : Solitary, axillary or cymose as in *Solanum*

Flower : bisexual, actinomorphic

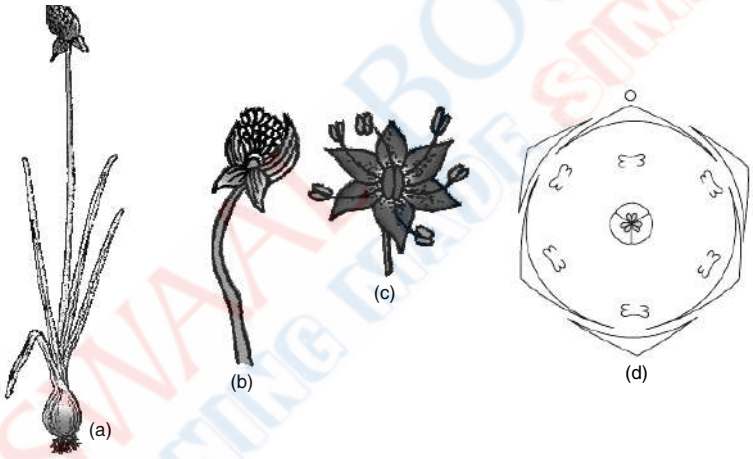
Calyx : sepals five, united, persistent, valvate aestivation
Corolla : petals five, united; valvate aestivation
Androecium : stamens five, epipetalous
Gynoecium : bicarpellary, syncarpous; ovary superior, bilocular, placenta swollen with many ovules
Fruits : berry or capsule
Seeds : many, endospermous

Floral Formula : $\oplus \, ♀♂ \, K_{(5)} \, \overset{\frown}{C_{(5)}} \, A_5 \, \underline{G}_{(1)}$

Economic Importance : Source of food (tomato, brinjal, potato), Spice (chilli), Medicine (belladonna, ashwagandha), Fumigatory (tobacco), Ornamentals (*Petunia*).

C. Family Lilaceae :

It is commonly called the 'Lily family'.
Vegetative characters : Perennial herbs with underground bulbs/corms/rhizomes
Leaves mostly basal, alternate, linear, exstipulate with parallel venation
Floral characters :
Inflorescence : solitary / cymose; often umbellate clusters
Flower : bisexual; actinomorphic
Perianth : tepal six (3+3), often united into tube; valvate aestivation
Androcium : stamen six, (3+3)
Gynoecium : tricarpellary, syncarpous, ovary superior, trilocular with many ovules; axile placentation
Fruit : capsule, rarely berry
Seed : endospermous



Allium cepa (onion) Plant : (a) Plant (b) Inflorescence (c) Flower (d) Floral diagram

Floral Formula : $Br \oplus \, ♀♂ \, P_{3+3} \, A_{3+3} \, \underline{G}_{(3)}$

Economic Importance : Ornamentals (tulip, *Gloriosa*), Medicine (*Aloe*), Vegetables (*Asparagus*), and Colchicine (*Colchicum autumnale*).

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Chapter 6

Anatomy of Flowering Plants

TOPIC-1
The Tissues

Revision Notes

Anatomy :

Anatomy is the study of internal structure of organisms.

Plant anatomy includes organisation and structure of tissues.

Tissue : A group of similar cells having a common origin which perform a specific function.

Meristematic Tissues :

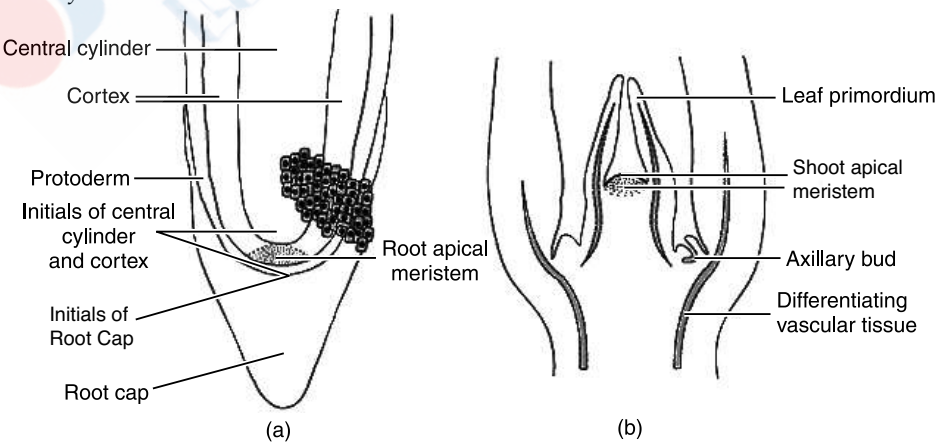
The meristematic tissue is made up of the cells which have the capability to divide.

Meristems in plants are restricted to specialised regions and responsible to the growth of plants.

Classification of Meristems :

(a) Apical meristem :

- → It occurs at the tips of roots and shoots.
- → Primary meristem as they appear early in plant.
- → It increases the length of plant.
- → Some cells left behind from shoot apical stem during the formation of leaves and elongation of stem constitute the axillary bud.



Apical Meristem (a) Root (b) Shoot

(b) Intercalary meristem :

- → It occurs between mature tissues.

→ Primary meristem.
→ It is capable of forming branch and flower

(c) Lateral meristem :

→ It occurs in the mature regions of roots and shoots.
→ Secondary meristem as they appear later than primary meristem.
Examples : Fascicular vascular cambium, interfasciular cambium and cork-cambium.
→ It is responsible for secondary growth.

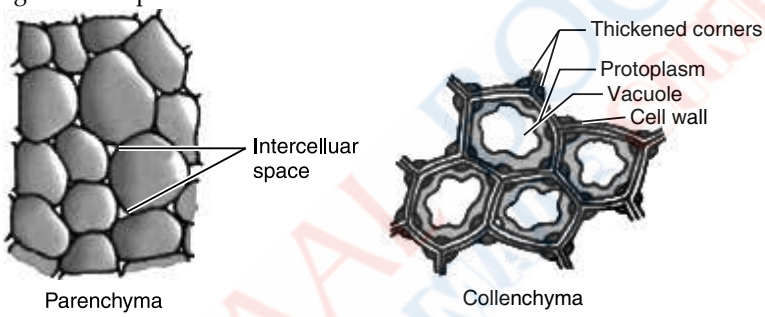
Axillary Bud : The buds which are present in the axils of leaves and are responsible for forming branches or flowers.

Permanent Tissues : The permanent tissues are derived from meristematic tissue and are composed of cells, which have lost the ability to divide.

Types of Permanent Tissue :

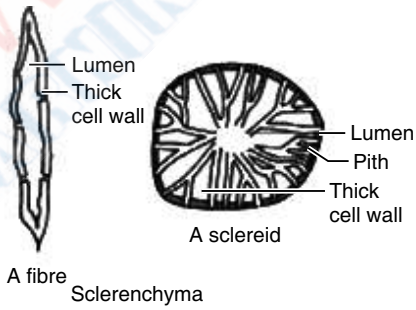
(a) Simple Permanent Tissue :

→ **Parenchyma :** Thin walled cells, with intercellular spaces, cell wall is made up of cellulose. It performs the function like photosynthesis, storage, secretion.
→ **Collenchyma :** It is formed of living, closely packed isodiametric cells. The cells are thickened at the corners due to deposition of cellulose and pectin. It provides mechanial support to the growing parts of the plant such as young stem and petiole of a leaf.



Parenchyma :

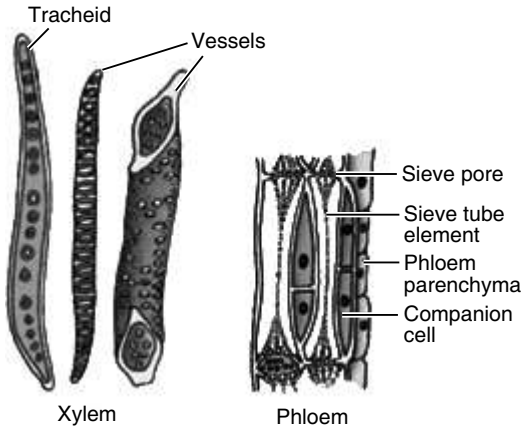
→ **Sclerenchyma :** It is formed of dead cells with thick and lignified walls. They have two types of cells namely, fibres and sclereids.



(b) Complex Permanent Tissue :

➢ **Xylem :** Xylem consists of tracheids, vessels, xylem fibres and xylem parenchyma. It conducts water and minerals from roots to other parts of plant.
- **Protoxylem :** The first formed primary xylem elements.
- **Metaxylem :** The later formed primary xylem.
- **Endarch :** Protoxylem lies towards the centre and metaxylem towards the periphery of the organ as in stem.
- **Exarch :** In roots, the protoxylem lies towards periphery and metaxylem towards the centre.

➢ **Phloem :** Phloem consists of sieve tube elements, companion cells, phloem fibres and phloem parenchyma. Phloem transports the food material from leaves to various parts of the plant.
- A mature sieve element lacks a nucleus and therefore its functions are controlled by the nucleus of companion cells.
- **Protophloem :** First formed phloem with narrow sieve tubes.
- **Metaphloem :** Later formed phloem with bigger sieve tubes.



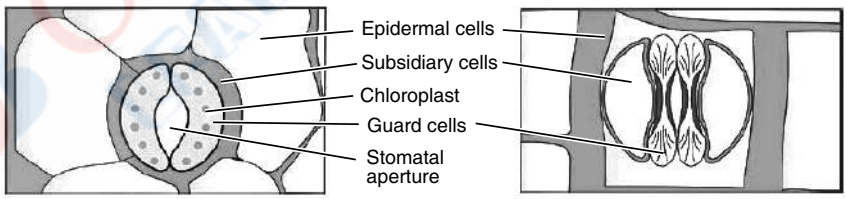
TOPIC-2
The Tissue System

Revision Notes

1. **Epidermal tissue system :** It includes cuticle, epidermis, epidermal hairs, root hairs, trichomes and stomata. This tissue forms the outermost covering of the plant body. It consists of epidermal cells, stomata and epidermal appendages including trichomes and hairs.
   Epidermis refers to the outermost layer of the primary plant body. It is a continuous layer of elongated and compactly arranged cells which are parenchymatous in nature and their cell walls are lined with a small amount of cytoplasm that has a large vacuole.
   The outer layer of the epidermis is coated with a thick and waxy layer called the 'cuticle', which prevents the loss of water.

→ Stomata are present in the epidermis of the leaves. They regulate the process of transpiration and gaseous exchange. Each stoma consists of two bean-shaped cells called 'guard cells'. Guard cells contain chloroplasts and regulate the opening and closing of a stoma. In grasses, the guard cells are dumb-bell shaped.

→ When the epidermal cells associated with the guard cells become specialised in shape and size, they are known as 'subsidiary cells'. The stomatal aperture, guard cells and the surrounding subsidiary cells are collectively called 'stomatal apparatus'.



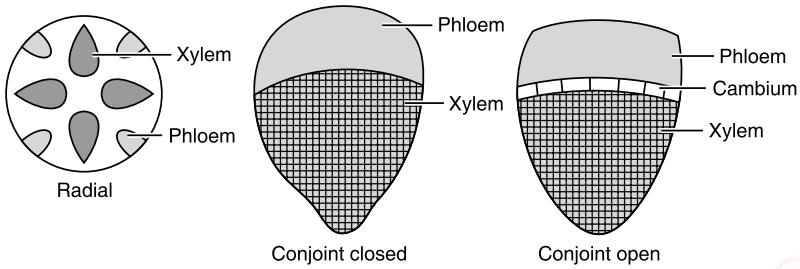
The epidermal tissue has epidermal appendages such as hair and trichomes. The root hairs are unicellular elongations of the epidermal cells and they help to absorb water and minerals from the soil. The epidermal hairs on the stem are known as trichomes. They may be branched, unbranched, soft or stiff and may also be secretory in function. Besides this, trichomes prevent loss of water due to transpiration.

2. **The ground tissue system :** All tissues except epidermis and vascular bundles constitute the ground tissue. It is made up of parenchyma, collenchyma, and sclerenchyma. In dicot stems and roots the ground tissue is divided into hypodermis cortex, endodermis, pericycle, medullary rays and pith.
   In leaves, the ground tissue is consists of thin walled chloroplast containing cells called mesophyll.
3. **The vascular tissue system :** It includes vascular bundles which are made up of xylem and phloem.

➢ **Closed vascular bundles :** In the monocotyledons, the vascular bundles have no cambium present in them. Since they do not form secondary tissues, they are referred to as closed vascular bundles.

➢ **Open vascular bundles :** In dicotyledonous stems, cambium is present between phloem and xylem. Since the cambium possess the ability to form secondary xylem and phloem tissues, these are called open vascular bundles.

- **Radial bundles :** Xylem and phloem occur on different radii of vascular bundles.
- **Conjoint bundles :** Xylem and phloem are situated at the same radius of vascular bundle.



TOPIC-3

Anatomy of Dicotyledonous And Monocotyledonous Plants

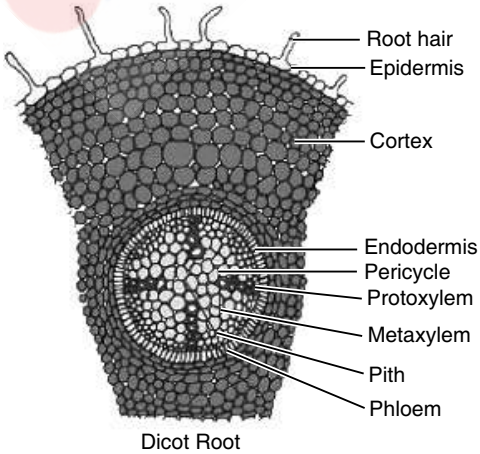
Revision Notes

Dicotyledonous Root :

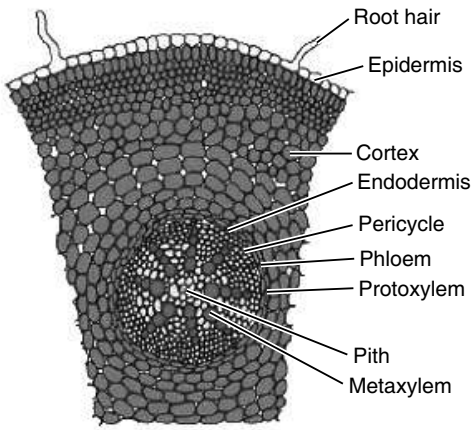
- Epidermis is the outermost layer with some protruding in the form of unicellular root hairs.
- Cortex is comparatively narrow.
- Endodermis comprises of single layer of barrel-shaped cells.
- The xylem and phloem bundles vary from 2 to 5.
- Pith is absent or very small.
- All tissues on the inner side of the endodermis such as pericycle, vascular bundles and pith constitute the stele.
- Secondary growth takes place with the help of vascular cambium and cork cambium.
- The parenchymatous cells which lie between the xylem and the phloem are called conjuctive tissue.

Monocotyledonous Root :

- Cortex is very wide.
- Endodermal cells are highly thickened.
- Casparian strips are visible only in young roots.
- Xylem and phloem are more than 6 (polyarch).
- Pith is large and well developed.
- Secondary growth is absent.



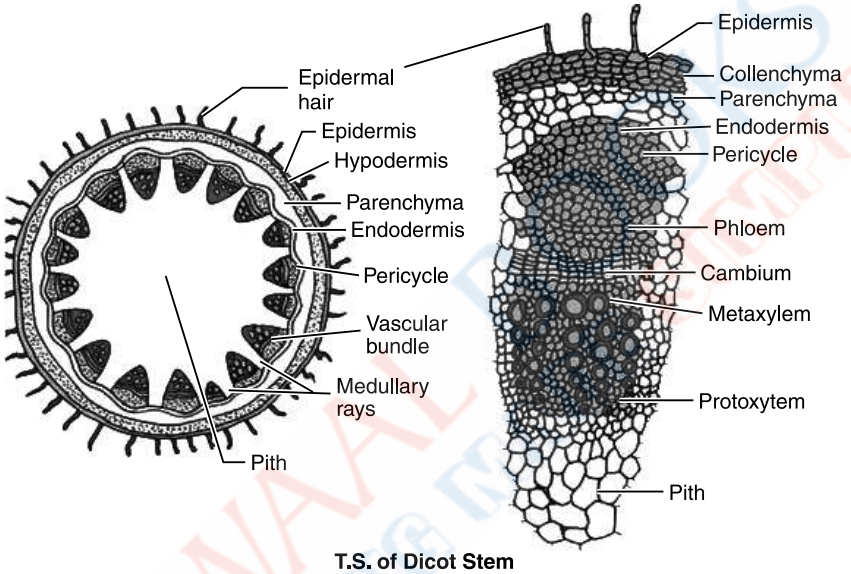
Dicot Root



Monocot Root

Dicotyledonous Stem :

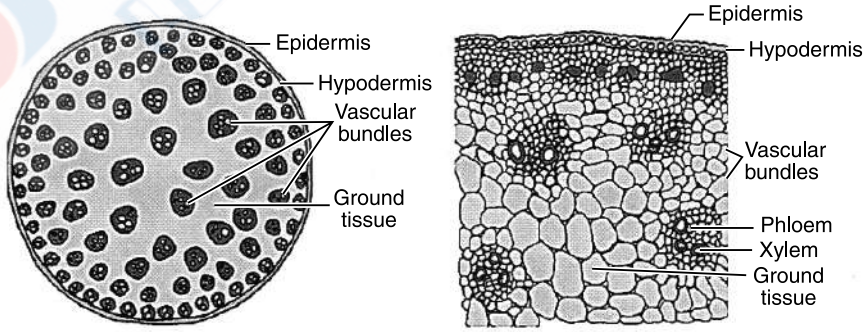
- The cells arranged in multiple layers between epidermis and pericycle constitute the cortex and consists of three sub-zones.
- The outer hypodermis consists of a few layers of collenchymatous cells which provide mechanical strength to the young stem.
- Cortical layers below hypodermis consist of rounded thin walled parenchymatous cells.
- The innermost layer of the cortex is endodermis.
- The cells of the endodermis are rich in starch grains and the layer is also referred to as the starch sheath.
- The ground tissue is differentiated into cortex, endodermis, pericycle and pith.
- The vascular bundles are arranged in a ring.
- Vascular bundles are open, conjoint and with endarch protoxylem.
- The stem shows secondary growth due to presence of cambium between xylem and phloem.



T.S. of Dicot Stem

Monocotyledonous Stem

- The monocot stem has a sclerenchymatous hypodermis.
- It has scattered vascular bundles, each surrounded by a sclerenchymatous bundle sheath.
- A large, conspicuous parenchymatous ground tissue is found.
- Vascular bundles are conjoint and closed.
- The phloem parenchyma is absent, and water-containing cavities are present within the vascular bundles.

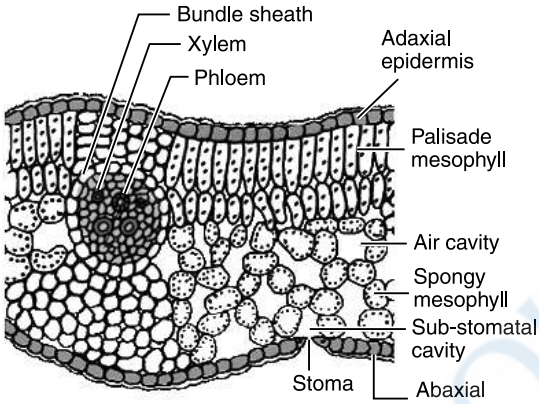


T.S. of Monocot Stem

Dorsiventral (Dicotyledonous) Leaf :

- The epidermis which covers both the upper surface (adaxial epidermis) and lower surface (abaxial epidermis) of the leaf has a conspicuous cuticle.
- Stomata are absent or less abundant on the upper side.
- The tissue between the upper and the lower epidermis is called the mesophyll.
- Mesophyll is differentiated into two parts namely, upper palisade parenchyma and lower spongy parenchyma.

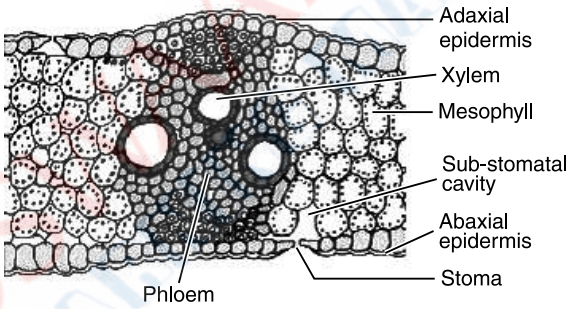
- Bundle sheath is single layered and formed of colourless cells.
- Vascular system can be seen in the veins and the midrib.
- The size of the vascular bundles depends on the size of the veins.
- The veins vary in thickness in the reticulate venation of the dicot leaves.
- The vascular bundles are surrounded by a layer of thick walled bundle sheath cells.



T.S. of Dicot Leaf

Isobilateral (Monocotyledonous) Leaf :

- The stomata are present on both the surfaces of the epidermis.
- The mesophyll is not differentiated into palisade and spongy parenchyma.
- In grasses, certain adaxial epidermal cells along the veins modify themselves into large, empty, colourless cells called bulliform cells. The bulliform cells minimise the loss of water during the condition of water stress.
- Bundle sheath may be single or double layered.



T.S. of Monocot Leaf

TOPIC-4
Secondary Growth

Revision Notes

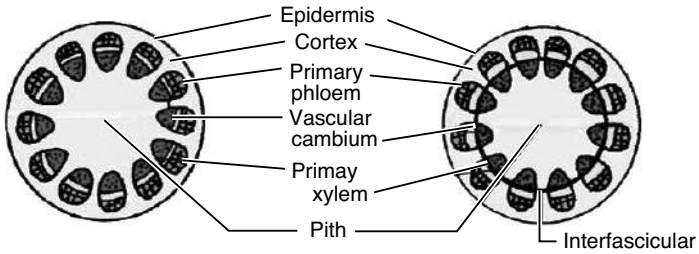
SECONDARY GROWTH :

- The growth of the roots and stems in length with the help of apical meristem is called the primary growth.
- Most of the dicotyledonous plants exhibit an increase in girth and this increase is called the secondary growth.
- The tissues involved in secondary growth are the two lateral meristems: vascular cambium and cork cambium.

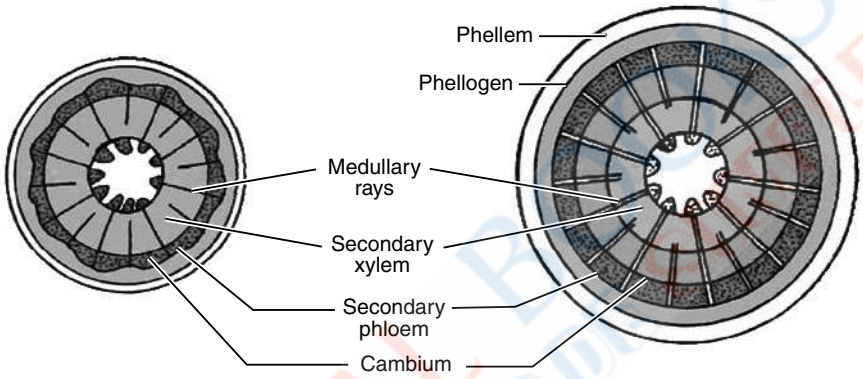
Secondary Growth in Dicot Stem :

Vascular Cambium :

- **Formation of cambial ring :** Intrafascicular cambium (the cells of cambium present between primary xylem and primary phloem) and interfascicular cambium (the cells of medullary cells, adjoining this intrafascicular cambium) become meristematic.



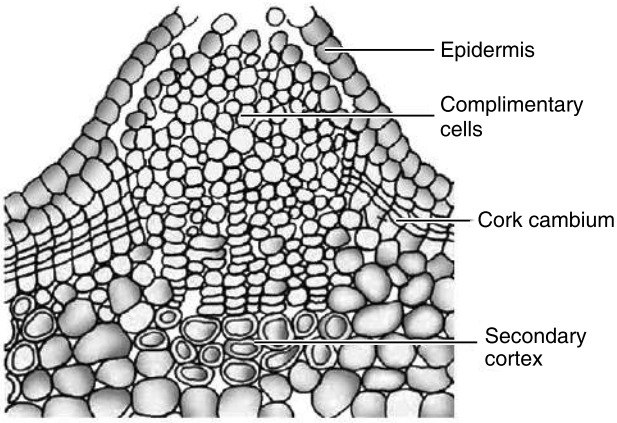
- **Formation of secondary xylem and secondary phloem from cambial ring :** The cambial ring becomes active and begins to cut off new cells, both towards the inner and the outer sides. The cells cut off towards pith, mature into secondary xylem and the cells cut off towards periphery mature into secondary phloem. At some places, the cambium forms a narrow band of parenchyma, which passes through the secondary xylem and the secondary phloem in the radial directions. These are the secondary medullary rays.



- **Formation of spring wood and autumn wood :** In the spring season, cambium is very active and produces a large number of xylem elements having vessels with wider cavities. The wood formed during this season is called spring wood or early wood. In winter, the cambium is less active and forms fewer xylem elements that have narrow vessels, and this wood is called autumn wood or late wood.
- The spring wood is lighter in colour with lower density whereas the autumn wood is darker and has a higher density the two concentric rings constitute an annual ring and in a cut stem give an estimate of the age of the tree.
- **Formation of heartwood and sapwood :** In old trees, the greater part of secondary xylem is dark brown due to deposition of organic compounds in the central or innermost layers of the stem which make it hard, durable and resistant to the attacks of microorganisms and insects. This region comprises dead elements with highly lignified walls and is called heartwood. The heartwood does not conduct water but it gives mechanical support to the stem. The peripheral region of the secondary xylem is lighter in colour and is known as the sapwood. It is involved in the conduction of water and minerals from root to leaf.

Development of Cork Cambium (Phellogen) :

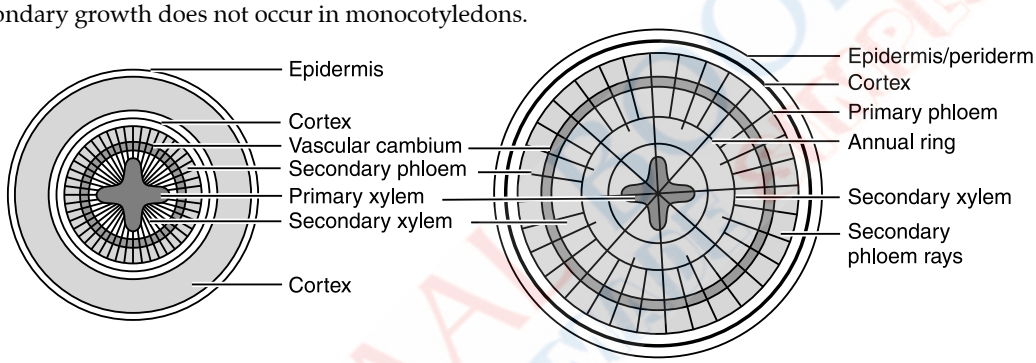
- As the stem continues to increase in girth the other cortical and epidermis layers get broken. To provide new protective cell layers the cork cambium or phellogen develops in the cortex region. Phellogen produces cork or phellem on the outside and the secondary cortex or phelloderm inside.
- Phellogen, Phellem and Phelloderm together constitute Periderm.
- Bark is a non-technical term that refers to all tissues exterior to the vascular cambium, therefore including secondary phloem.
- Bark that is formed early in the season is called early or soft bark.
- Towards the end of the season late or hard bark is formed.
- **Lenticels :** At certain regions, the phellogen cuts off closely arranged parenchymatous cells on the outer side instead of cork cells. These parenchymatous cells soon rupture the epidermis, forming a lens-shaped opening called lenticels.



Lenticel

Secondary Growth in Dicot Roots :

- Secondary growth in dicot root occurs with the activity of secondary meristems i.e., vascular cambium.
- This cambium is produced in the stele and cortex, and results in increasing the girth of dicot roots.
- Secondary growth does not occur in monocotyledons.



Different stages of the secondary growth in a typical dicot root

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Chapter 7

Structural Organisation in Animals

TOPIC-1
Animal Tissues

Revision Notes

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

Types of Animal Tissues :

(i) Epithelial Tissue

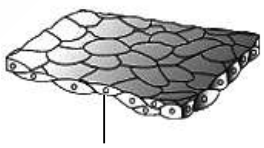
- This tissue has a free surface, which faces either a body fluid or the outside environment.
- The cells are compactly packed with little intercellular matrix.

(a) Simple Epithelium

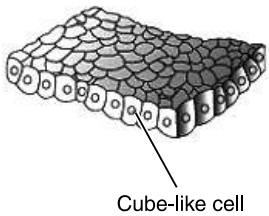
- It is composed of single layer of cells.
- It functions as lining for body cavities, ducts and tubes.

Types of Simple Epithelium

1. **Squamous**
   - It is single thin layer of flattened cells.
   - It is found in walls of blood vessels, air sacs of lungs and are involved in functions forming a diffusion boundary.
2. **Cuboidal**
   - It is single layer of cube like cells.
   - It is found in ducts of glands and tubular parts of nephron and its main functions are secretion and absorption.

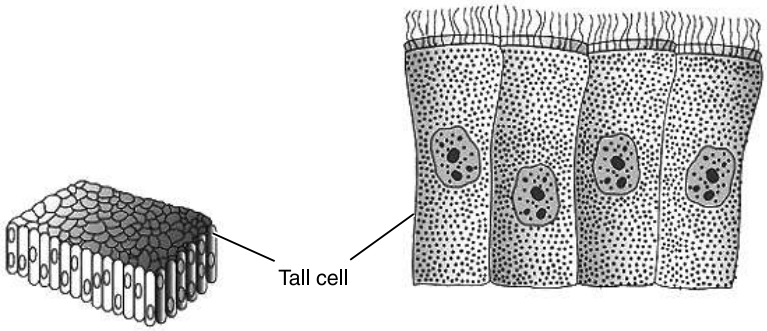


Squamous epithelium



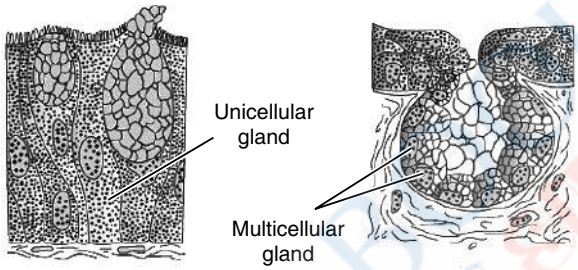
Cuboidal epithelium

3. **Columnar**
   - It is single layer of tall and slender cells.
   - It has free surface, may have microvilli.
   - It is found in stomach and intestine and help in secretion and absorption.
4. **Ciliated**
   - It is columnar or cuboidal cells with cilia.
   - It moves particles or mucus in specific direction as in bronchioles and fallopian tubes.

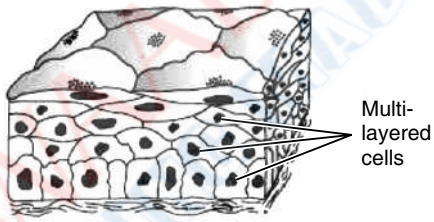


5. Glandular Epithelium

- It can be unicellular consisting of isolated glandular cells (goblet cells of the alimentary canal) and also multicellular consisting of cluster of cells (salivary gland).



- **Exocrine glands :** secrete mucus, saliva, oil, milk, digestive enzymes. Their products are released through ducts.



- **Endocrine glands:** They secrete hormones directly into the fluid bathing the gland.

(b) Compound Epithelium

- It is made up of more than one layers of cells.
- It provides protection against chemical and mechanical stresses.
- It covers dry surface of skin, moist surface of buccal cavity, pharynx, inner lining of ducts of salivary glands and pancreatic ducts. Three types of cell junctions are found in the epithelium and other tissues.
- Connective tissues are the most abundant in the animal body and are named so because they link and support other tissues/organs of the body.
- **Tight junctions:** Plasma membranes of adjacent cells are fused at intervals. They help to stop substances from leaking across a tissue.
- **Adhering junctions:** Perform cementing function to keep neighbouring cells together.
- **Gap junction:** Facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells for rapid transfer of ions, small molecules and sometimes big molecules.

(ii) Connective Tissue

- In all connective tissues except blood, the cells secrete fibres of structural proteins called collagen or elastin.
- The fibres provide strength, elasticity and flexibility to the tissue.

(a) Loose Connective Tissue

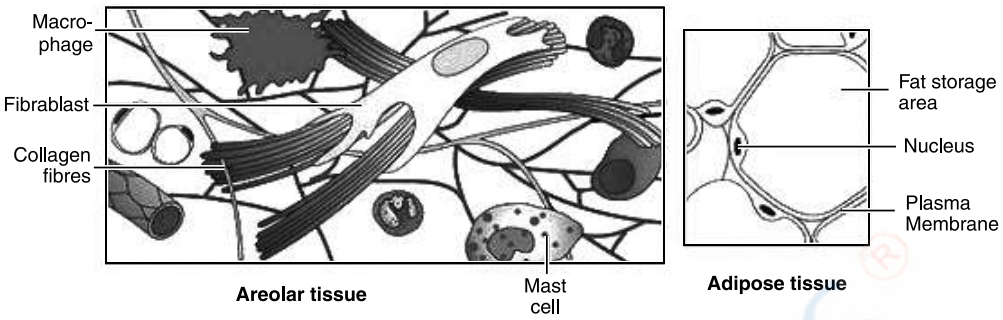
- It has cells and fibres loosely arranged in semi-fluid ground substance.

(i) Areolar Tissue :

- It is present beneath the skin.
- It contains fibroblasts, macrophages and mast cells.
- It serves as a support framework for epithelium.

(ii) Adipose Tissue :

- It is located beneath the skin.
- These cells are specialised to store fats.



(b) Dense Connective Tissue

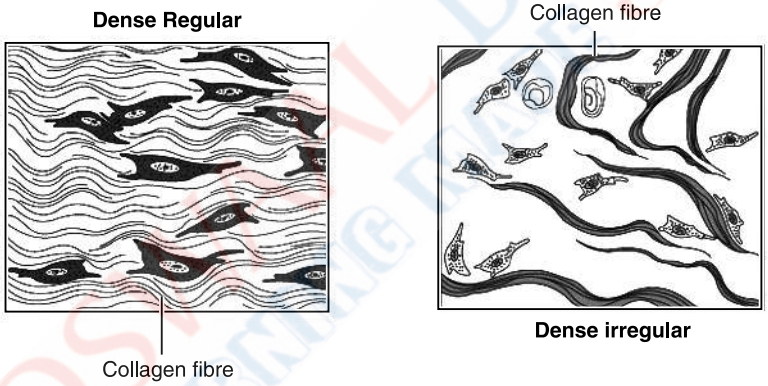
- Fibres and fibroblasts are compactly packed.

(i) Dense Regular

- Collagen fibres present in rows between many parallel bundles of fibres.
- Tendons attach skeletal muscle to bone.
- Ligaments attach bone to bone.

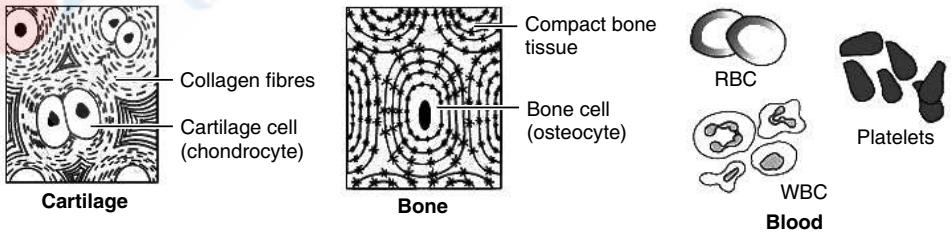
(ii)Dense Irregular

- It has collagen fibres and fibroblasts oriented differently.
- This tissue is present in the skin.



(c) Specialised Connective Tissue :

- Cartilage is made up of chondrocytes and collagen fibres.
- In bones, ground substance is rich in calcium salts and collagen fibres. Osteocytes are present in lacunae.
- Blood is a fluid connective tissue and consists of plasma and blood cells.



(iii) Muscular Tissue

- It consists of long, highly contractile cells called fibres. There fibres are composed of numerous fine fibrils, called myofibrils.
- It brings about movement and locomotion.

(a) Skeletal Muscles

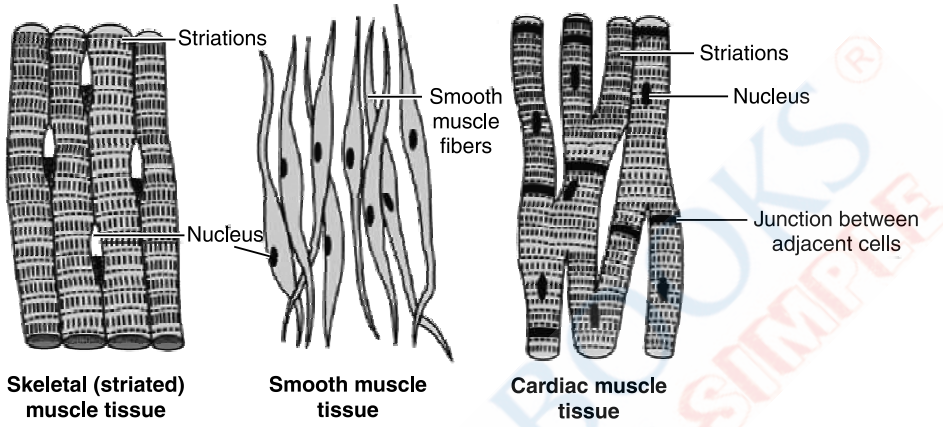
- These consist of long, cylindrical, multinucleated fibres.
- These are closely attached to skeletal bones.
- These are striated.

(b) Smooth Muscles

- These consist of spindle like, uninucleated fibres.
- These do not show striations. Smooth muscles are involuntary.
- The wall of internal organs such as blood vessels, stomach and intestine.

(c) Cardiac Muscles

- These are short, cylindrical, uninucleated fibres.
- They occur in the heart wall.
- They have intercalated discs for communication.



(iv) Neural Tissue

- Neurons are the functional unit and are excitable cells.
- Neuroglia cells make up more than half the volume of neural tissue. They protect and support neurons.

TOPIC-2

Organ and Organ System, Cockroach

Revision Notes

- The basic tissues organise to form organs which in turn associate to form organ systems in the multicellular organisms.
- Each organ in our body is made of one or more type of tissues.
- Our heart consists of all the four types of tissues, i.e., epithelial, connective, muscular and neural.

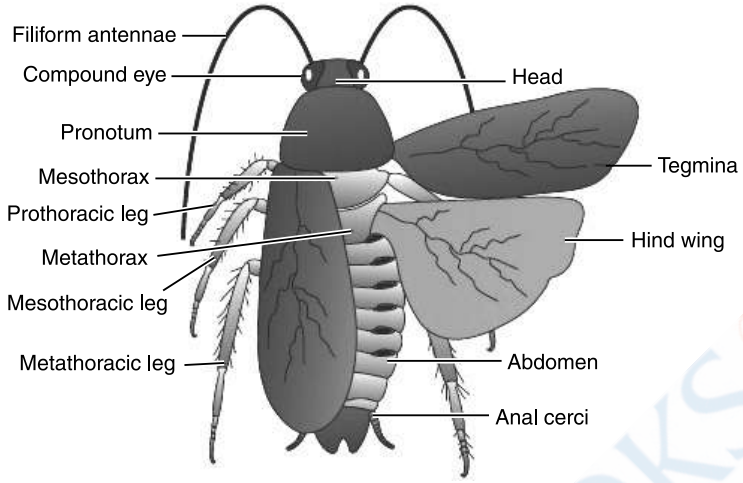
Cockroach

- It is a terrestrial, nocturnal, omnivorous, unisexual, oviparous insect.
- Body covered by a chitinous, hard exoskeleton of hard plates called sclerites.

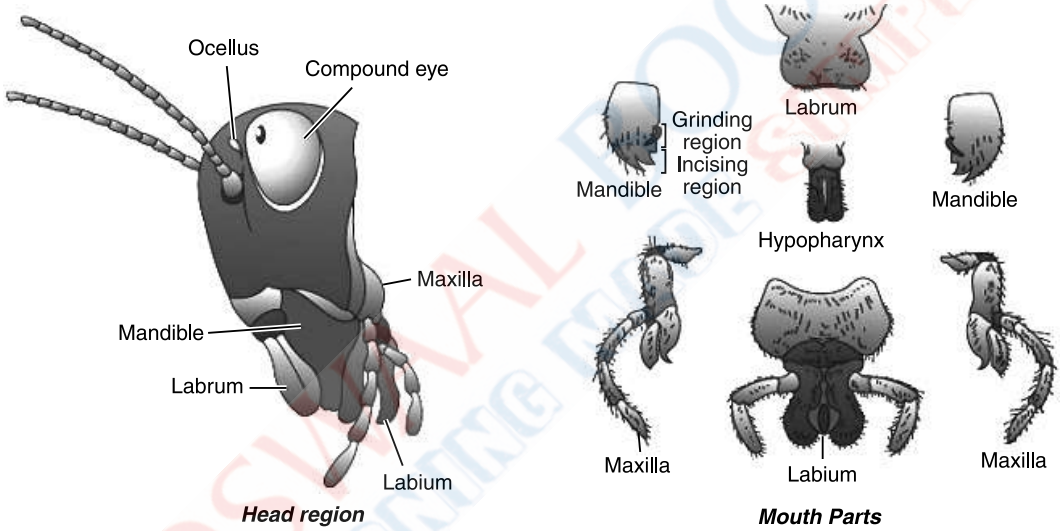
Morphology of Cockroach

- The head is triangular and formed by fusion of 6 segments.
- It bears a pair of antennae and compound eyes. Mouth parts consists of labrum (upper lip), a pair of mandibles, a pair of maxillae, labium (lower lip), and hypopharynx (acts as tongue).
- The thorax has three parts namely, prothorax, mesothorax and metathorax.
- It bears two pairs of wings namely, forewings: tegmina (mesothoracic) and hindwings: transparent, membranous (metathoracic) and three pairs of legs in each thoracic segments.
- The abdomen is made up of ten segments.
- It bears a pair of long, segmented anal cerci in both sexes and a pair of short and unjointed anal styles in males only.
- It also has anus and genital aperture at the hind end.

- Genital aperture is surrounded by external genitalia called gonapophysis or phallomere.



External Features of Cockroach



Anatomy of Cockroach

(a) Digestive system

- The alimentary canal of cockroach is divided into foregut, midgut and hindgut.
- The entire foregut consists of mouth, pharynx and oesophagus which helps in grinding the food particles.
- The oesophagus opens into crop which stores food and it is followed by a gizzard which helps in grinding the food particles.
- A ring of 6-8 blind tubules called hepatic caecae is present at the junction of forgeut and midgut which secrete digestive juice.
- The midgut is followed by the hindgut which is divided into ileum, colon and rectum.
- At the junction of midgut and hindgut are present ring of 100-150 filamentous Malpighian tublues.
- The rectum opens out through anus.

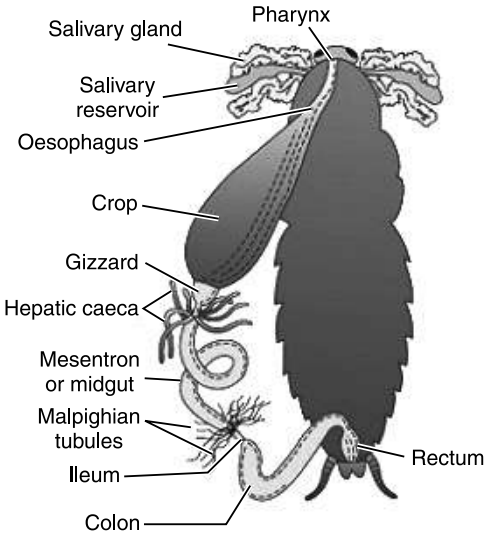
(b) Circulatory system

- Cockroaches have an open blood vascular system.
- Heart is a long muscular tube present dorsally, which is differentiated into funnel shaped chambers with ostia on either side.
- These insects also possess sinuses in their body.
- The haemolymph from these sinuses enters the heart through ostia and is pumped back into the sinuses anteriorly.

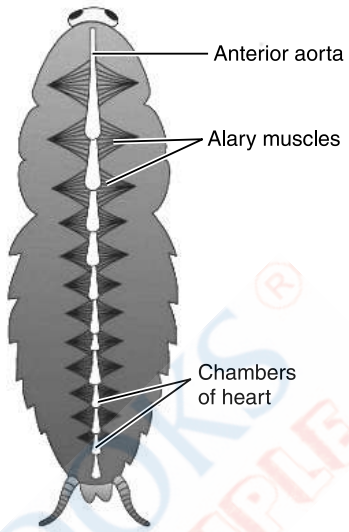
(c) Respiratory system

- The respiratory system consists of trachea that opens to exteriorly through 10 pairs of spiracles, which are located on the lateral side of the body.

- The tracheas are further divided into thin tracheoles which supply oxygen to all the parts of the body.
  - Gaseous exchange in these tracheoles takes place through diffusion.



Alimentary Canal



Open circulatory system

(d) Excretory system

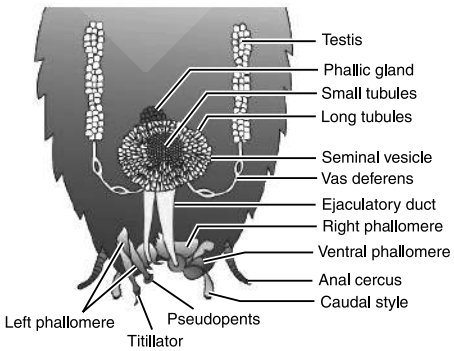
- Excretory system in cockroaches consists of malpighian tubules situated at the junction of the midgut and hindgut.
- Each tubule absorbs nitrogenous wastes from the body and converts them into uric acid.
- As cockroaches excrete uric acid, they are known as uricotelic animals.
- Apart from malpighian tubules, the fat body, nephrocytes and urecose glands also help in excretion.

(e) Nervous system

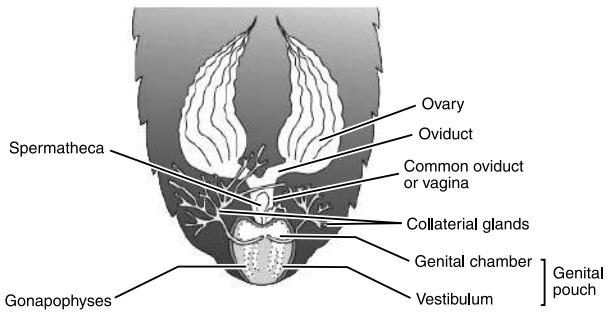
- The nervous system in cockroach consists of a series of ganglia in each segment, which is attached to a ventral nerve cord and a brain.
- There are three thoracic ganglia and six abdominal ganglia.
- In the head, the supra-oesophageal ganglion represents the brain, which supplies nerves to the antennae and the compound eyes.
- Cockroaches have many sensory organs such as antennae, eyes, maxillary and labial palps and anal cerci.
- The head bears a pair of large compound eyes; each eye consists of about 2000 hexagonal ommatidia.

(f) Reproductive system

- Cockroaches are unisexual.
- The male reproductive system consists of two testes present in the 4^{th}-6^{th} abdominal segments, from which arises vas deferens, which open into the ejaculatory duct, which further opens into the male gonopore situated ventral to anus.



Male Reproductive System



Female Reproductive System

- Sperms are stored in seminal vesicles, which are discharged during copulation.

- The female reproductive system consists of two large ovaries lying in the 2^{nd}-6^{th} abdominal segments; each ovary consists of eight ovarioles containing developing ova.
- From each ovary arises an oviduct, which joins to form a single common vagina.
- After copulation, the female cockroach secretes a capsule called an ootheca, which contains the fertilised eggs.
- In *Periplaneta americana*, the development of the insect is paurometabolous.
- Cockroach has mosaic vision with more sensitivity but less resolution, being common during night.

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Chapter 8

Cell : The Unit of Life

TOPIC-1

Cell, Cell Theory, Overview Of A Cell And Prokaryotic Cells

Revision Notes

Cell

- All organisms are composed of cells.
- Some are composed of a single cell are called unicellular organisms while some are composed of many cells called multicellular organisms.
- Unicellular organisms are capable of
  (i) Independent existence and
  (ii) Performing the essential functions of life.
- Hence, cell is the fundamental structural and functional unit of all living organisms.
- Anton Von Leeuwenhoek was first to see and describe a live cell.
- Robert Brown later discovered the nucleus.

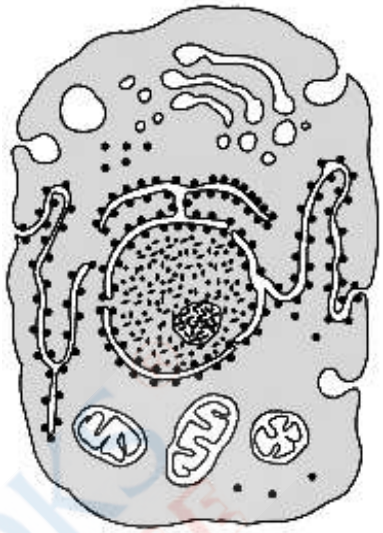
Cell Theory

- Schleiden and Schwann together formulated the Cell Theory, which states that both plants and animals are made up of cells.
- However, the cell theory did not explain the formation of new cells, which was explained by Rudolf Virchow in 1855.
- He coined the Latin phrase 'Omnis cellula-e cellula', which meant that new cells are formed from pre-existing cells.
- According to cell theory,
  (i) All living organisms are composed of cells and products of cells.
  (ii) All cells arise from pre-existing cells.

An Overview of Cell

- Prokaryotic cells: Cells which lack a well-defined nucleus and membrane bound cell organelles. Examples - bacteria, cyanobacteria, mycoplasma.
- Eukaryotic cells: Cells which have a well-defined nucleus and membrane bound cell organelles.
  Examples - all protists, plants, animals and fungi cells.

- In both prokaryotic and eukaryotic cells, a semi-fluid matrix called cytoplasm occupies the volume of the cell.
- The cytoplasm is the main arena of cellular activities in both the plant and animal cells.
- The eukaryotic cells have other membrane bound distinct structures called organelles like the endoplasmic reticulum (ER), the golgi complex, lysosomes, mitochondria, microbodies and vacuoles.
- The prokaryotic cells lack such membrane bound organelles.
- Ribosomes are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic.
- Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – chloroplasts (in plants) and mitochondria and on rough ER.
- Animal cells contain another non-membrane bound organelle called centriole which helps in cell division.
- Mycoplasmas are the smallest cells and the largest isolated single cell is the egg of an ostrich.
- Nerve cells are the longest cells.



A typical eukaryotic cell (10-20 µm)

Prokaryotic Cells

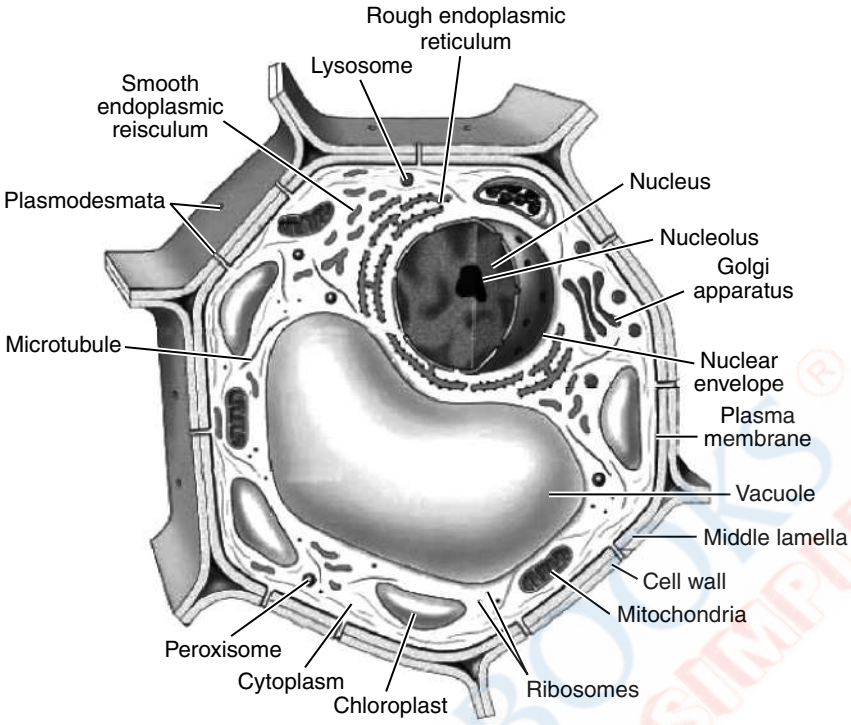
- Genetic material is not enveloped by nuclear envelope.
- Many bacteria contain extra chromosomal DNA- plasmids. The plasmid DNA confers certain unique phenotypic characters such as resistance to antibiotics. It is also used to monitor bacterial transformation with foreign DNA.
- Prokaryotic cells have a chemically complex cell envelope which consists of a tightly bound three layered structure i.e., outermost glycocalyx followed by cell wall and then plasma membrane.
- A specialised structure called mesosome is formed by the extension of plasma membrane into the cell.
- Mesosomes help in cell wall formation, DNA replication and distribution to daughter cells, respiration, secretion processes, to increase surface area of plasma-membrane and enzymatic content.
- Bacterial cells may be motile or non-motile.
- Motile bacteria have flagella composed of three parts namely, filament, hook and basal body.
- Pili and fimbriae are surface structures which do not play any role in motility.
- These structures help the bacteria to attach with rocks and the host tissues.
- 70S ribosomes are associated with plasma membrane and are made of two subunits namely, 50S and 30S.
- Ribosomes are site of protein synthesis.
- Inclusion bodies are reserve material lying freely in the cytoplasm e.g., glycogen granules and phosphate granules.

TOPIC-2

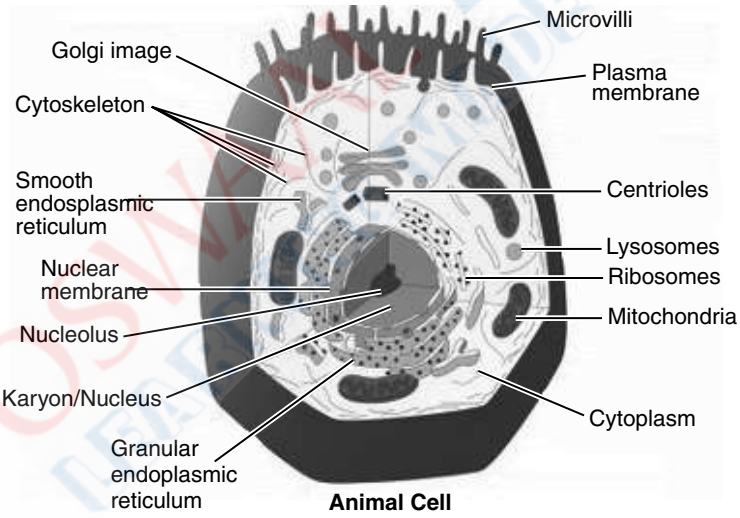
Eukaryotic Cells

Revision Notes

- It possesses an organized nucleus with nuclear envelope and has variety of complex locomotory and cytoskeletal structures.



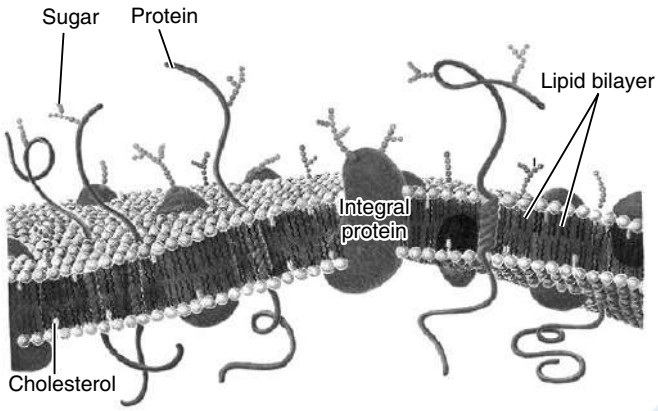
Plant Cell



Animal Cell

Cell Membrane :

- The cell membrane is composed of lipids that are arranged in a bilayer. Lipid component mainly consists of phospho-glycerides.
- The ratio of protein and lipid varies considerably in different cell types.
- In human beings, the membrane of the erythrocyte has approximately 52 per cent protein and 40 per cent lipids.
- Depending on the ease of extraction, membrane proteins can be classified as integral or peripheral.
- Peripheral proteins lie on the surface of membrane while the integral proteins are partially or totally buried in the membrane.
- Singer and Nicolson (1972) gave 'Fluid mosaic model'.
- According to this, the quasi-fluid nature of lipid enables lateral movement of proteins within the overall bilayer.



Functions :

- The main function of cell membrane is that it is selectively permeable to some molecules present on either side.
- Many molecules can move across the membrane without any requirement of energy by passive transport.
- Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient.
- Movement of water by diffusion is called osmosis. As the polar molecules cannot pass through the nonpolar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane.
- A few ions or molecules are transported across the membrane against their concentration gradient in which ATP is utilised and is called active transport. Example - Na^+/K^+ Pump.

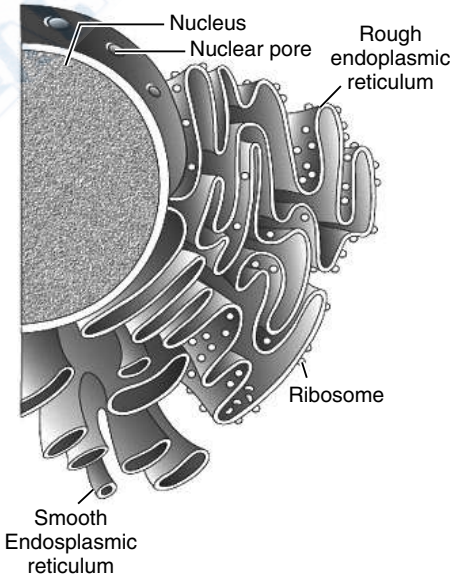
Cell Wall

- It is a non-living rigid structure which gives shape to the cell and protects cell from mechanical damage and infection, helps in cell-to-cell interaction and provides barrier to undesirable macromolecules.
- Cell wall of algae is made of cellulose, galactans, mannans and minerals like calcium carbonate.
- Plant cell wall consists of cellulose, hemicellulose, pectins and proteins.
- The cell wall of a young plant cell, the primary wall is capable of growth, which gradually diminishes as the cell matures and the secondary wall is formed on the inner (towards membrane) side of the cell.
- Middle lamella is made of calcium pectate which holds neighbouring cells together.
- Plasmodesmata connect the cytoplasm of neighbouring cells.

Endomembrane System

- Many of the membranous organelles are considered together as an endomembrane system because their functions are coordinated.

A. Endoplasmic Reticulum (ER)



- It consists of network of tiny tubular structures scattered in the cyotplasm.
- Endoplasmic reticulum divides the intracellular space into two distinct compartments namely, luminal (inside endoplasmic reticulum) and extra luminal (cytoplasm).

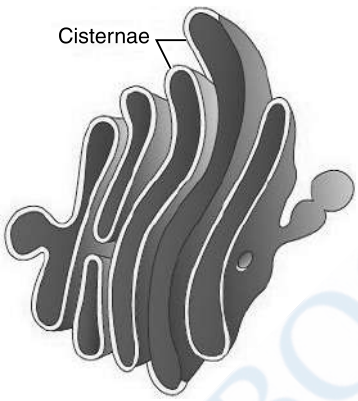
(i) Rough Endoplasmic Reticulum (RER):

- Here, the ribosomes are attached to outer surface.
- It is involved in protein synthesis and secretion.

(ii) Smooth Endoplasmic Reticulum (SER):

- It lacks ribosomes.
- It is the site for lipid synthesis.
- In animal cells lipid-like steroidal hormones are synthesised in SER.

B. Golgi apparatus:



Golgi Apparatus

- It was first observed by Camillo Golgi in 1898.
- It consists of cisternae stacked parallel to each other.
- It has two faces, the convex *cis* or the forming face and the concave *trans* or the maturing face.

Functions:

- It performs packaging of materials, to be delivered either to the intra-cellular targets or secreted outside the cell.
- Materials to be packaged in the form of vesicles from the endoplasmic reticulum fuse with the *cis* face of the Golgi apparatus and move towards the maturing face.
- A number of proteins synthesised by ribosomes on the endoplasmic reticulum are modified in the cisternae of the Golgi apparatus.
- It is an important site of formation of glycoproteins and glycolipids.
- In includes endoplasmic reticulum, golgi complex, lysosomes and vacuoles.

C. Lysosomes:

- It is a membrane bound vesicular structures formed by the process of packaging in the Golgi apparatus.
- It contains hydrolysing enzymes (lipases, proteases, carbohydrases) which are active in acidic pH.
- It is also called 'Suicidal Bag'.

Functions :

- It helps in intracellular digestion such as digesting carbohydrates, proteins, lipids and nucleic acids.

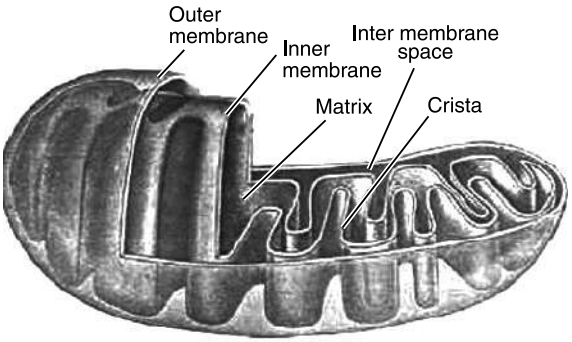
D. Vacuoles :

- It is a membrane bound space found in the cytoplasm.
- It contains water, sap, excretory product, etc.
- The vacuole is bound by a single membrane called tonoplast.

Functions:

- In plants tonoplast (single membrane of vacuole) facilitates transport of ions and other substances against concentration gradients into the vacuole.
- Contractile vacuole is important for excretion in *Amoeba* and food vacuoles are formed in protistans for engulfing of food.

Mitochondria:



Structure of Mitochondria

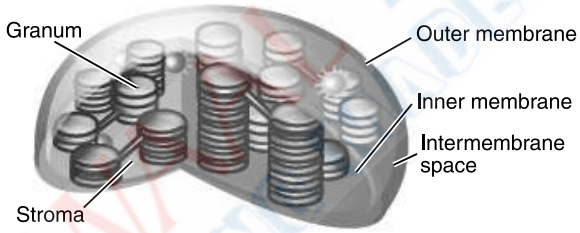
- It is a double membrane structure.
- The outer membrane is smooth while the inner membrane forms a number of infoldings called cristae.
- The mitochondria divides by fission.

Functions:

- It is the site of aerobic respiration.
- It is also called 'power houses' of cell as it produce cellular energy in the form of ATP.
- Matrix possesses single circular DNA molecule, a few RNA molecules and ribosomes (70S) required for the synthesis of proteins.

Plastids :

- It is found in plant cells and in euglenoids.



Plastid

- Chloroplasts, chromoplasts and leucoplasts are three types of plastids depending on pigments contained.

(a) Chloroplasts

- Chloroplasts are double membraned structure.
- The space limited by inner membrane is called stroma.
- There are flattened membranous sacs called thylakoids in stroma.
- Chlorophyll pigments are present in thylakoids.

(b) Chromoplasts

- The chromoplasts are coloured plastids.

(c) Leucoplasts

- The leucoplasts are the colourless plastids of varied shapes and sizes with stored nutrients.

Functions :

- The chloroplasts contain chlorophyll and carotenoid pigments which are responsible for trapping light energy essential for photosynthesis.
- In chromoplasts, the fat soluble carotenoid pigments like carotene, xanthophylls and others present gives the part of the plant a yellow, orange or red colour.
- The leucoplasts are the colourless plastids of varied shapes and sizes with stored nutrients such as amyloplasts store carbohydrates (starch), e.g., potato; elaioplasts store oils and fats whereas the aleuroplasts store proteins.

Ribosomes :

- Ribosomes are the granular structures first observed by George Palade (1953).
- It is composed of RNA and proteins; without membrane.
- The eukaryotic ribosomes are 80S while the prokaryotic ribosomes are 70S.

- Here 'S' stands for the sedimentation coefficient; It is indirectly a measure of density and size. Both 70S and 80S ribosomes are composed of two subunits.

Function :

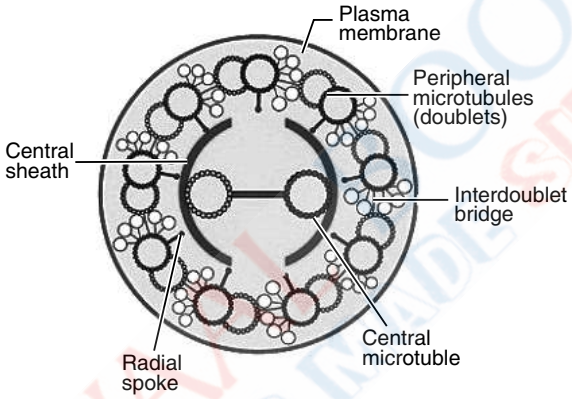
(a) It is the site of protein synthesis.

Cytoskeleton

- An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively referred to as the cytoskeleton.
- The cytoskeleton in a cell is involved in many functions such as mechanical support, motility, maintenance of the shape of the cell.

Cilia and Flagella :

- Cilia are small structures which work like oars, which help in movement.
- Flagella are longer and responsible for cell movement.
- They are covered with plasma membrane.
- Core is called axoneme which has 9 + 2 arrangement.
- Both the cilium and flagellum emerge from centriole-like structure called the basal bodies.



Centrosome and Centrioles :

- Centrosome is an organelle usually containing two cylindrical structures called centrioles.
- It is surrounded by amorphous pericentriolar material.
- It has 9 + 0 arrangement.
- The central part of the centriole is also proteinaceous and called the hub, which is connected with tubules of the peripheral triplets by radial spokes made of protein.
- Centrioles form the basal body of cilia or flagella and spindle fibres for cell division in animal cells.

Nucleus :

- Nucleus as a cell organelle was first described by Robert Brown.
- Later the material of the nucleus stained by the basic dyes was given the name chromatin by Flemming.
- It is a double membrane organelle with pores in-between called nuclear pores.
- The space between the two parallel membranes is known as perinuclear space.
- It has chromatin, nuclear matrix (nucleoplasm) and nucleoli.

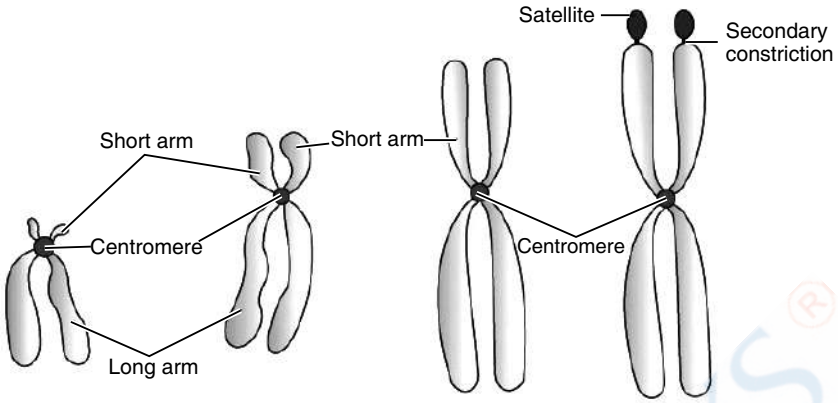
Functions :

- The perinuclear space forms a barrier between the materials present inside the nucleus and that of the cytoplasm.
- It is the site for active ribosomal RNA synthesis.
- Larger and more numerous nucleoli present in cells actively carry out protein synthesis.
- The nuclear pores help in moving RNA and protein molecules in both directions between the nucleus and the cytoplasm.

Chromatin :

- It consists of DNA and basic proteins called histones, some non-histone proteins and also RNA.
- Every chromosome essentially has a primary constriction or the centromere on the sides of which disc shaped structures called kinetochores are present.
- Chromosomes (on basis of position of centromere) :
- Metacentric - Centromere in the middle.
- Sub-metacentric - Centromere nearer to one end of chromosome.

- Acrocentric - Centromere situated close to its end.
- Telocentric - Has terminal centromere.



- **Satellite :** Some chromosomes have non-staining secondary constrictions at a constant location, which gives the appearance of small fragment called satellite.
- **Microbodies :** Many membrane bound minute vesicles called microbodies that contain various enzymes, are present in both plant and animal cells.

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Chapter 9

Biomolecules

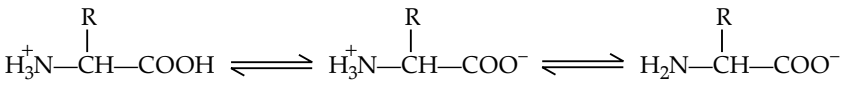
TOPIC-1

Analysing Chemical Composition, Biomacromolecules And Primary And Secondary Metabolites

Revision Notes

Analysing Chemical Composition :

- Every living organism is made of chemicals which can be either elements or compounds.
- To determine the type of organic compounds found in living organisms one has to perform chemical analysis. For e.g., A living tissue (a vegetable or a piece of liver, etc,) is grinded in a trichloroacetic acid.
- The thick slurry is then strained through a cheesecloth to obtain the filtrate- the acid soluble pool containing the organic compounds and the retentate or the acid-insoluble fraction.
- Various separation techniques are used for separating the compounds from the filtrate.
- The elemental composition of living tissues is determined through elemental analysis and the analysis for compounds gives an idea about the type of organic and inorganic constituents.
- All the carbon compounds we derive from living tissues are called biomolecules.
- Analysis of organic constituents in a living tissue identifies functional groups such as aldehydes, ketones and aromatic compounds, also known as biomolecules.
- The amino group and carboxylic group are present on the same alpha carbon atom of the amino acid. Hence, they are also known as α-amino acids.
- The four substituent groups of amino acids are hydrogen, the carboxyl group, amino group and a variable R group.
- A unique property of amino acids is the ionizable nature of the NH_2 and COOH groups.
- A particular property of amino acids is the ionizable nature of NH_2 and COOH groups. These fully ionized species known as zwitter ions have both a positive and a negative charge. Hence, in solutions of different pHs the structure of amino acids changes.



Zwitterionic form

- Lipids could be simple fatty acids or glycerol. A fatty acid have a carboxyl group attached to an R group. The R group could be a methyl, ethyl or a higher number of CH_2 groups.
- When fatty acids combine with glycerol, they form esters, also known as glycerides.
- Some lipids have phosphorous and a phosphorylated organic compound in them (phospholipids) and are found in cell membrane. Lecithin is one example.
- Living organisms also have many carbon compounds with heterocyclic rings such as adenine, guanine and thymine. These are nitrogen bases.
- When carbon compounds with heterocyclic rings are attached to a sugar, they are called nucleosides such as adenosine and thymidine.
- If a phosphate group is also found esterified to a sugar they are called nucleotides such as adenylic acid and thymidylic acid.
- Nucleotides make up the nucleic acids–DNA and RNA.

A Comparison of Elements Present in Non-living and Living Matter

Element	% Weight of	
	Earth's crust	Human body
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrogen (N)	very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	negligible

- Adapted from CNR Rao, *Understanding Chemistry*. Universities Press, Hyderabad.

A List of Representative Inorganic Constituents of Living Tissues

Component	Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{++}
Magnesium	Mg^{++}
Water	H_2O
Compounds	NaCl, $CaCO_3$, PO_4^{3-}, SO_4^{2-}

Metabolites :

- Living organisms produce thousands of organic compounds including amino acids, sugars, etc. These are required for their primary metabolic processes like photosynthesis, respiration, lipid and protein metabolism etc. These are called primary metabolites.
- Many plants, fungi and microbes synthesise a number of organic compounds (biomolecules) which are not involved in primary metabolism and seem to have no direct function in growth and development of organisms. Such compounds are called secondary metabolites.

- Compounds such as alkaloids, flavonoids, rubber, essential oils, antibiotics, coloured pigments, scents, gums and spices are secondary metabolites.

Some Secondary Metabolites

Pigments	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes, etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums, cellulose

Biomacromolecules :

- The acid insoluble fraction, has only four types of organic compounds i.e., proteins, nucleic acids, polysaccharides and lipids.
- These classes of compounds with the exception of lipids have molecular weights in the range of ten thousand daltons and above. Molecular weight of lipids do not exceed 800 Da.
- The chemical compounds found in living organisms are of two types namely, one is those which have molecular weightless than one thousand dalton and are usually referred to as micromolecules or simply biomolecules while those which are found in the acid insoluble fraction are called macromolecules or biomacromolecules.
- The macromolecules from cytoplasm and organelles become the acid insoluble fraction. Together they represent the entire chemical composition of living tissues or organisms.

Average Composition of Cells

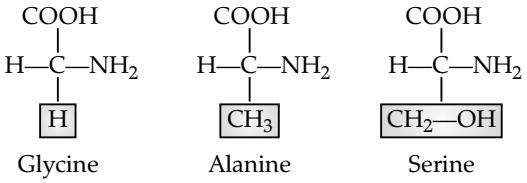
Component	% of the total cellular mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

TOPIC-2
Proteins, Polysaccharides, Nucleic Acids

Revision Notes

Proteins :

- Proteins are polypeptides. They are linear chains of amino acids linked by peptide bonds.
- Each protein is a polymer of amino acids.
- There are 20 types of amino acids and so a protein is a heteropolymer and not a homopolymer.
- A homopolymer has only one type of monomer repeating 'n' number of times.
- Amino acids can be essential or non-essential. The latter are those which our body can make, while we get essential amino acids through our diet/food.
- Collagen is the most abundant protein in animal world.
- Ribulose bisphosphate Carboxylase-Oxygenase (RuBiSCO) is the most abundant enzyme in the whole of the biosphere.



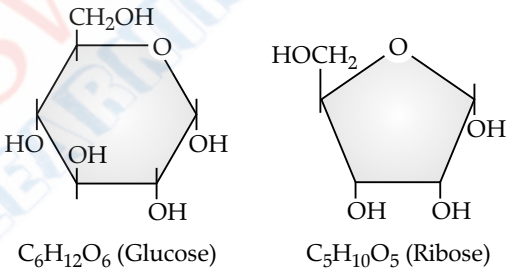
Amino acids

Functions of Proteins :

Proteins	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infection agents
Receptor	Sensory reception (smell, taste, Hormons, etc.)
GLUT -4	Enables glucose transport into cells

Polysaccharides :

- These are long chain of sugars.
- Starch is a store house of energy in plant tissues. It forms helical secondary structures and can hold I_2 molecules in the helical portion. The starch-I_2 is blue in colour.
- The properties of starch making it as storage material is that it is chemically non-reactive and osmotically inactive.
- Cellulose is a polymer of glucose. It does not contain complex helices and hence cannot hold I_2.
- Glycogen is a branched homopolymer of glucose, found as storage polysaccharide in animals.
- Inulin is a polymer of fructose.
- Chitin is chemically modified sugar (amino-sugars) N-Acetyl Glucosamine. It forms exoskeleton of arthropods.

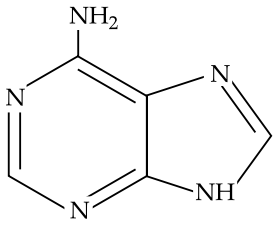


$C_6H_{12}O_6$ (Glucose) $C_5H_{10}O_5$ (Ribose)

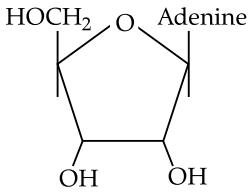
Sugars (Carbohydrates)

Nucleic Acids

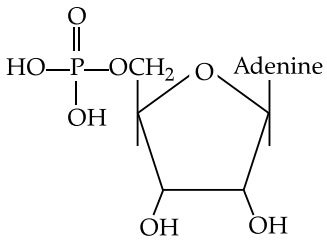
- Nucleic acids are biomacromolecules present in the acid-insoluble fraction of living tissues.
- A nucleotide acts as a building block of nucleic acid and forms a polynucleotide chain.
- A nucleotide has a heterocyclic compound, a monosaccharide and a phosphate.
- The heterocyclic compounds are nitrogenous bases, namely purines and pyrimidines.
- Purines have six-member and five-member nitrogen-containing rings fused together, while pyrimidines have only a six-member nitrogen-containing ring.
- The sugar found in nucleotides is either ribose or two-prime deoxyribose.
- The nucleic acid containing deoxyribose is deoxyribonucleic acid (DNA) while the one with ribose is ribonucleic acid (RNA).
- Both DNA and RNA carry genetic information in all the cells.



Adenine (Puine)
Nitrogen base



Adenosine
(Nucleoside)



Adenylic acid
(Nucleotide)

TOPIC-3

Structure Of Proteins, Nature Of Bond Linking Monomers In A Polymer, Concept Of Metabolism And Metabolic Basis For Living

Revision Notes

(a) Primary structure :

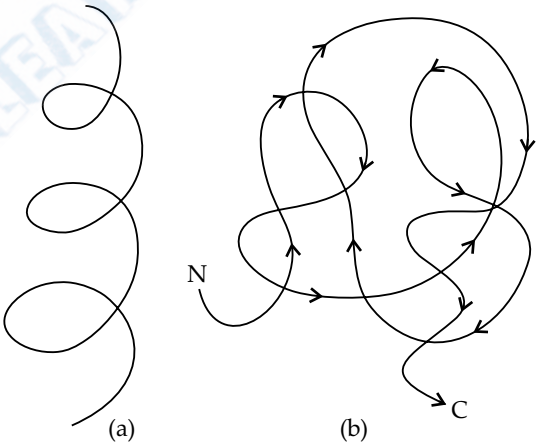
- It is found in the form of linear sequence of amino acids.
- The first amino acid is called N-terminal amino acid and last amino acid is called C-terminal amino acid.

(b) Secondary structure :

- It has a polypeptide chain which undergoes folding or coiling and stabilized by hydrogen bonding.
- Right handed helices are observed.
- Examples - fibrous protein in hair, nails, etc.

(c) Tertiary structure :

- It is a long protein chain folded upon itself like a hollow woollen ball.
- It gives a 3-dimensional view of protein.
- Example - Myoglobin.



(a) (b)

(d) Quaternary structure :

- It has two or more polypeptides with their folding and coiling are arranged with respect to each other.
- It has four helical polypeptide chains, two α-chains and two β-chains.
- Example - Human haemoglobin.

Nature of Bond linking monomer in a polymer

- In a polypeptide or protein, amino acids are linked by peptide bond which is formed between the carboxyl

(-COOH) group of one amino acid and the amino (-NH2) group of the next amino acid with the elimination of water moiety (the process is called dehydration).

- Nucleic acids are formed when a nitrogenous base, a phosphate group and a pentose sugar are linked to form a polynucleotide chain.
- Here, the three prime carbon atom of one sugar of a nucleotide are linked to the five prime carbon atom of the sugar of the succeeding nucleotide by a phosphate moiety.
- The phosphate and hydroxyl groups of sugar join to form an ester bond.
- The ester bonds formed by the phosphate group, between the third and fifth carbon atoms of adjacent pentose sugar rings, are called phosphodiester bonds.
- This bond links three prime carbon atoms of one sugar molecule with the five prime carbon atoms of an adjacent sugar molecule.
- The phosphodiester bond forms the backbone of the DNA strands.

Dynamic State of Body Constituents

- Biomolecules have a turn over *i.e.*, they are constantly being changed into some other biomolecules and also made from some other biomolecules.
- The entire set of biochemical reactions that take place in living organisms are known as metabolism.
- Each of the metabolic reactions results in the transformation of biomolecules.
- Metabolites are converted into each other in a series of linked reactions called metabolic pathways.
- These pathways are either linear or circular. These pathways criss-cross each other, i.e., there are traffic junctions.
- Flow of metabolites through metabolic pathway has a definite rate and direction called the dynamic state of body constituents.
- Every chemical reaction is a catalysed reaction.
- The catalysts which hasten the rate of a given metabolic conversation are also proteins.
- These proteins with catalytic power are named enzymes.

Metabolic Basis for Living

- **Anabolic pathways :** It leads to the formation of more complex structure from a simpler structure with the consumption of energy. Example – Formation of protein from amino acids.
- **Catabolic pathway :** It leads to the formation of simpler structure from a complex structure. Example - Glucose to lactic acid.
- The most important form of energy currency in living systems is the bond energy in a chemical called adenosine triphosphate (ATP).
- **Living State :** It is a non-equilibrium steady-state to be able to perform work; living process is a constant effort to prevent falling into equilibrium. Without metabolism there cannot be a living state.

TOPIC-4

Enzymes, Role Of Enzymes, Enzyme Activity, Classification And Nomenclature Of Enzyme And Cofactors

Revision Notes

Enzymes

- These are biocatalysts.
- Almost all enzymes are proteins.
- Ribozymes are nucleic acids that behave like enzymes.
- It has primary, secondary and tertiary structure.
- The active site of an enzyme is a crevice or pocket into which the substrate fits.
- Enzymes get damaged at high temperatures.
- Enzymes isolated from thermophilic organisms (living under high temperatures) are thermostable.

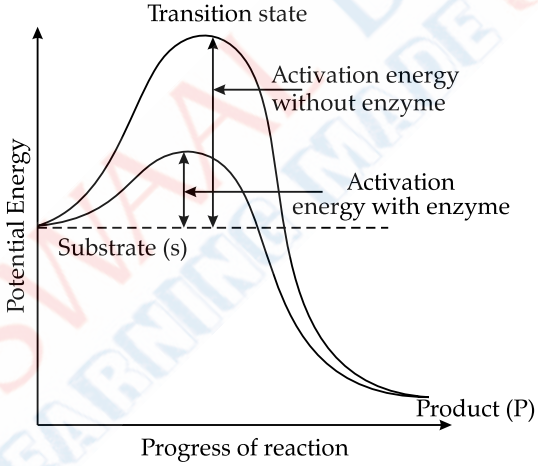
- Enzymes accelerate the reactions many folds.
- Enzymes lower the activation energy of reactions.

Chemical Reactions or Conversions

- A physical change simply refers to a change in shape without breaking of bonds.
- When bonds are broken and new bonds are formed during transformation, it is called a chemical reaction.
- Rate of a physical or chemical process refers to the amount of product formed per unit time.
- Rate can also be called velocity if the direction is specified.
- Rates of physical and chemical processes are influenced by temperature among other factors.
- A general rule of thumb is that rate doubles or decreases by half for every 10°C change in either direction.
- Catalysed reactions proceed at rates vastly higher than that of uncatalysed ones.
- When enzyme catalysed reactions are observed, the rate would be vastly higher than the same but uncatalysed reaction.
- A multistep chemical reaction, when each of the steps is catalysed by the same enzyme complex or different enzymes is called a metabolic pathway.
- In our skeletal muscle, under anaerobic conditions, lactic acid is formed. Under normal aerobic conditions, pyruvic acid is formed.
- In yeast, during fermentation, the same pathway leads to the production of ethanol (alcohol). Hence, in different conditions different products are possible.

Role of Enzymes in Chemical Conversions

- The chemical which is converted into a product is called a 'substrate'.
- The proteins with three dimensional structures including an 'active site', convert a substrate (S) into a product (P).
- The substrate 'S' has to bind the enzyme at its 'active site' within a given cleft or pocket.



Concept of activation energy

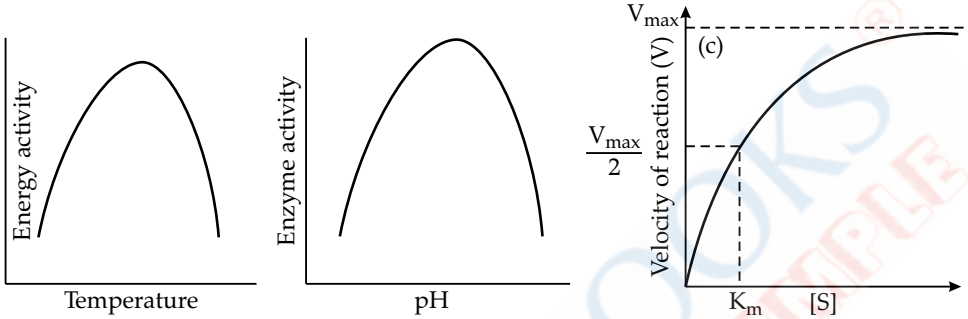
- The substrate has to diffuse towards the 'active site' to form 'ES' complex where 'E' stands for enzyme. This complex formation is a transient phenomenon.
  $E + S \rightleftharpoons ES \rightarrow EP \rightarrow E + P$
  Where E = Enzyme, S = Substrate, P = Product.
- The graph shows that the y-axis represents the potential energy content and the x-axis represents the progression of the structural transformation or states through the 'transition state'.
- If 'P' is at a lower level than 'S', the reaction is an exothermic reaction. One need not supply energy (by heating) in order to form the product.
- The difference in average energy content of 'S' from that of this transition state is called 'activation energy'.
- Enzymes bring down the energy barrier making the transition of 'S' to 'P' more easily.

Nature of Enzyme Action

- First, the substrate binds to the active site of the enzyme, fitting into the active site. So that a highly reactive enzyme-substrate complex [ES] is produced.
- The binding of the substrate induces the enzyme to alter its shape, fitting more tightly around the substrate.
- The active site of the enzyme, now in close proximity of the substrate breaks the chemical bonds of the substrate and the new enzyme- product complex is formed.
- The enzyme releases the products of the reaction and the free enzyme is ready to bind to another molecule of the substrate and run through the catalytic cycle once again.

Factors Affecting Enzyme Activity

- **Temperature :** The highest activity of enzyme occurs at optimum temperature. Activity declines above and below the optimum value.
- **pH :** Enzymes function in a narrow range of pH. The highest activity of enzyme occurs 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. Example - Inhibition of succinic dehydrogenase by malonate which closely resembles the substrate succinate in structure



Classification and Nomenclature of Enzymes :

- **Oxidoreductase/dehydrogenases :** It catalyses oxido-reduction between two substrates.
- **Transferases :** It catalyses transfer of a group between a pair of substrates.
- **Hydrolases :** It catalyses hydrolysis of ester, ether, peptide, glycosidic, C-C, P-N bonds.
- **Lyases :** It catalyses removal of groups from substrates by mechanisms other than hydrolysis.
- **Isomerases :** It catalyses inter-conversion of optical, geometric or positional isomers.
- **Ligases :** It catalyses linking together of two compounds.
- **Cofactors :** Non-protein constituents bind to the enzyme to make it catalytically active. Protein portion of enzyme is called apoenzyme.

Co-factors :

- **Prosthetic groups :** These are organic compounds tightly bound to apoenzyme. Example - Haem in peroxidase and catalase which catalyze the breakdown of H_2O_2.
- **Co-enzymes :** These are organic compounds which has transient association with enzyme. The essential chemical components of many coenzymes are vitamins, *e.g.*, coenzyme nicotinamide adenine dinucleotide (NAD) and NADP contain the vitamin niacin.
- **Metal ions :** These are required for the activity of many enzymes. They form coordination bond with side chains at active site and with substrate. Example - Zinc is a co-factor for the proteolytic enzyme carboxypeptidase.

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Chapter 10

Cell Cycle And Cell Division

TOPIC-1
Cell Cycle And Mitosis

Revision Notes

Cell cycle : The sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell and eventually divide to produce two daughter cells.

- The processes like cell division, DNA replication and cell growth have to take place in a coordinated way to ensure correct division and formation of progeny cells containing intact genome.

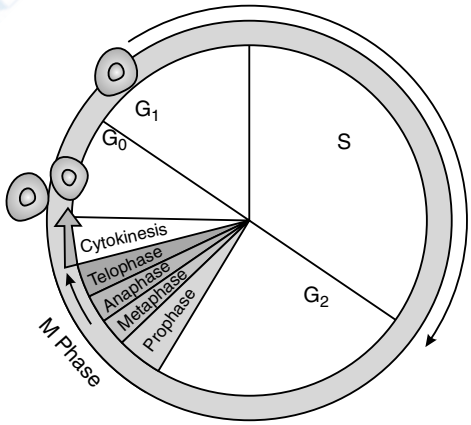
Phases of cell cycle :

Interphase :

- **G_1 Phase :** Cell is metabolically active and grows continuously.
- **S Phase :** DNA synthesis or replication occurs, DNA content increases from 2C to 4C. But the number of chromosomes remains same (2N).
- **G_2 Phase :** Proteins are synthesised in preparation for mitosis while cell growth continues.

Quiescent stage (G_0) : Cells that do not divide and exit G_1 phase to enter an inactive stage called G_0. Cells at this stage remain metabolically active but do not proliferate.

A diagrammatic view of cell cycle



M Phase (Mitosis Phase) : Starts with nuclear division, corresponding to separation of daughter chromosomes (karyokinesis) and usually ends with division of cytoplasm (cytokinesis). Mitosis is divided into the following 4 stages :

1. Prophase :

(i) Replicated chromosomes, each consisting of two chromatids, condense and become visible.

(ii) Microtubules are assembled into mitotic spindle.

(iii) Nucleolus and nuclear envelope disappear.

(iv) Centriole which has undergone duplication during S phase of interphase now move to opposite poles.

Early Prophase

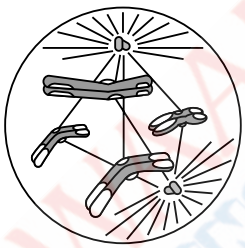
Late Prophase

2. Metaphase

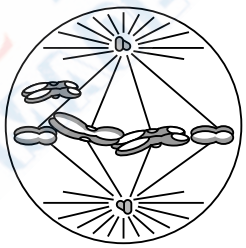
This is the stage at which morphology of chromosomes is most easily studied.

(i) Spindle fibres attaches to kinetochores (small disc-shaped structures at the surface of centromeres) of chromosomes.

(ii) Chromosomes line up at the equator of the spindle to form metaphase plate.



Transition to Metaphase



Metaphase

3. Anaphase :

(i) Centromeres split and chromatids separate.

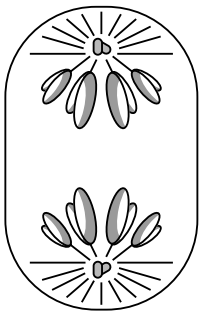
(ii) Chromatids move to opposite poles.

4. Telophase :

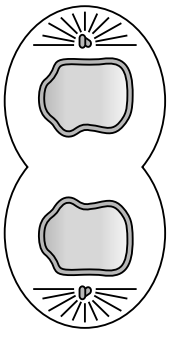
(i) Chromosomes cluster at opposite poles and their identity is lost as discrete elements.

(ii) Nuclear envelope assembles around chromosome cluster.

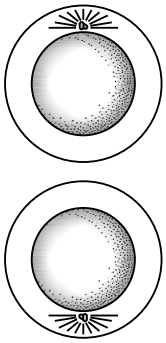
(iii) Nucleolus, Golgi complex, ER reform.



Anaphase



Telophase



Cytokinesis : It is the division of cytoplasm 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.

In some organisms karyokinesis is not followed by cytokinesis resulting into a multinucleate condition known as syncytium (e.g., liquid endosperm in coconut)

Significance of Mitosis :

1. Growth by addition of cells.
2. Maintenance of surface/volume ratio.
3. Maintenance of chromosome number.
4. Regeneration.
5. Reproduction in unicellular organism.
6. Repair and wound healing

TOPIC-2
Meiosis

Revision Notes

Meiosis

- It is a specialised kind of cell division that reduces the chromosome number by half, resulting in formation of four haploid daughter cells.
- It occurs during gametogenesis in plants and animals.
- It 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.
- Four haploid daughter cells are formed.

Meiosis I

- Prophase I : It is subdivided into five phases based on chromosomal behaviour.

Leptotene :

- Chromosomes make their appearance 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:

- Appearance of recombination nodules, the sites at which crossing over occurs.
- Crossing over occurs between non-sister chromatids of homologous chromosomes leading to recombination of genetic material on the two 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 chiasmata.

Diakinesis :

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

Metaphase I :

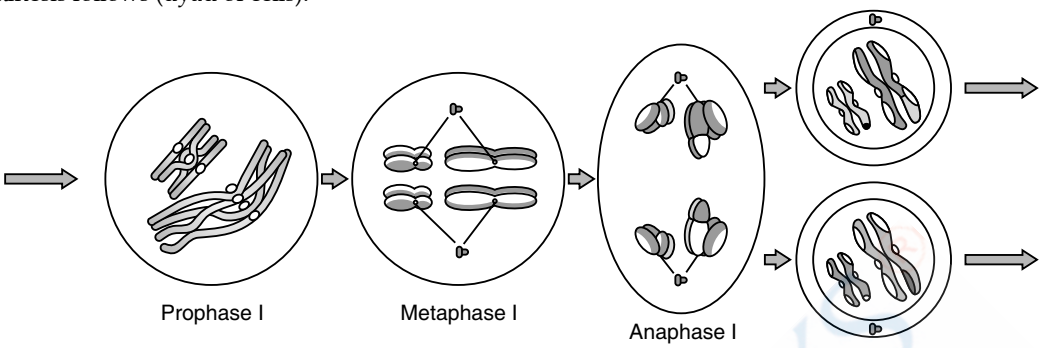
- Bivalent chromosomes align on the equatorial plate.
- Microtubules from opposite poles of the spindle attach to the pair of homologous chromosomes.

Anaphase I :

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

Telophase I :

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



Stages of metosis I

- **Interkinesis :** It is the stage between two meiotic divisions i.e., meiosis I and meiosis II.

Meiosis II

Prophase II

- Nuclear membrane disappears.
- Chromosomes become compact.

Metaphase II

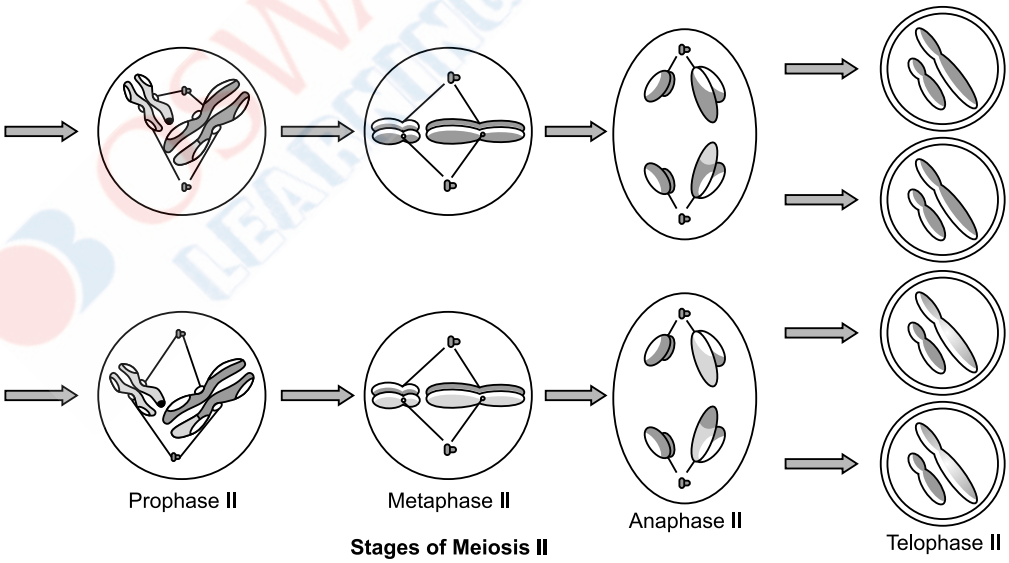
- Chromosomes align at the equator.
- Microtubules from opposite poles of spindle get attached to kinetochores of sister chromatids.

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., four haploid cells.



Stages of Meiosis II

Significance of Meiosis

1. **Formation of gametes** in sexually reproducing organisms.
2. **Genetic variability**
3. **Maintenance of chromosomal number** by reducing the chromosome number in gametes. The chromosomal number is restored by fertilisation of gametes.

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Chapter 11

Transport in Plants

TOPIC-1

Means of Transport and Plant-Water Relations

Revision Notes

- Plants do not have interstitial fluid and circulatory system.
- But they need to move various substances (water, mineral nutrients, organic nutrients, plant growth regulators, etc.) over very long distances.
- Transport over longer distances proceeds through the vascular system (the xylem and the phloem) and is called translocation.
- Unidirectional transport: Example-Transport of water and minerals in xylem (from roots to the stems, leaves, etc.).
- Multidirectional transport: Examples - Transport of photosynthates (organic compounds), transport of mineral nutrients.
- In rooted plants, transport in xylem (of water and minerals) is essentially unidirectional, from roots to the stems.
- Organic and mineral nutrients however, undergo multidirectional transport.
- Organic compounds synthesised in the photosynthetic leaves are exported to all other parts of the plant including storage organs.
- The mineral nutrients are taken up by the roots and transported upwards into the stem, leaves and the growing regions.
- When any plant part undergoes senescence, nutrients may be withdrawn from such regions and moved to the growing parts.
- Hormones or plant growth regulators and other chemical stimuli are also transported, though in very small amounts, sometimes in a strictly polarised or unidirectional manner from where they are synthesised to other parts.

Means of Transport

- The movement of food and water across short distances in plants takes place either passively by diffusion or by active transport.

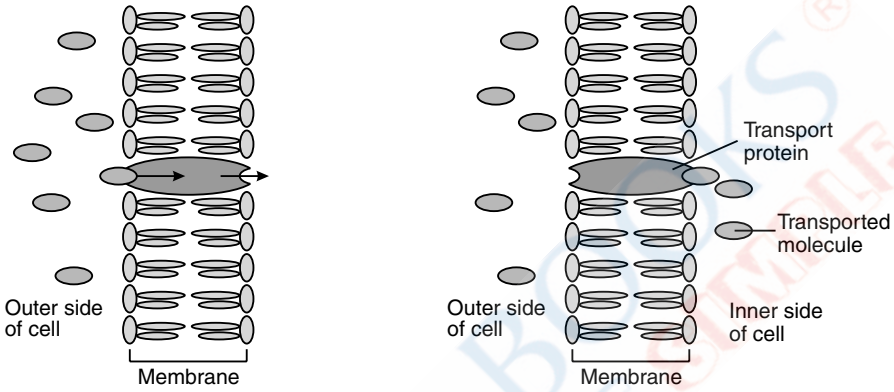
Diffusion

- Movement by diffusion is passive, and may be from one part of the cell to the other, or from cell to cell, or over short distances.
- In diffusion, no energy expenditure takes place, molecules move in a random fashion, the net result being substances moving from regions of higher concentration to regions of lower concentration.
- Diffusion is a slow process.
- Diffusion is obvious in gases and liquids, but diffusion in solids rather than of solids is more likely.
- Diffusion is very important to plants since it is the only means for gaseous movement within the plant body.
- Diffusion rates are affected by the gradient of concentration, the permeability of the membrane separating them, temperature, and pressure.

Facilitated Diffusion

- In diffusion, the molecules move from a region of high concentration to a region of lower concentration, with no expenditure of energy.

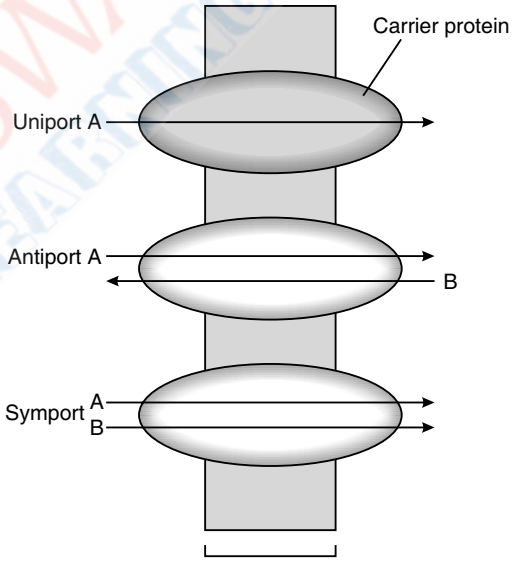
- The rate of diffusion is affected by several factors such as the size of molecules, their solubility in lipids and the concentration gradient.
- If the molecule is bigger, then rate of diffusion will be slow.
- Since all membranes are made up of lipids, lipid-soluble substances diffuse faster.
- In a concentration gradient, diffusion of hydrophilic substances is facilitated by special proteins called transport proteins, without any energy expenditure. This type of diffusion is called facilitated transport.
- Proteins are channels in the membrane, which allow molecules to pass through them.
- Some of these channels are always open while others are controlled.
- Some transport proteins, called porins, form pores in the outer membranes of cell organelles, to allow small proteins to pass through it.



Facilitated diffusion

Passive Symports and Antiports

- Based on the direction, transport of molecules can be differentiated into three types – symport, antiport and uniport.
- Both molecules cross the membrane in the same direction in a symport, while they move in opposite directions in an antiport and a single molecule diffuses across a membrane in a uniport.



Active Transport

- Active transport moves molecules against the concentration gradient with expenditure of energy.
- It is carried out by the membrane proteins called pumps that use energy and are specific to the type of substances they carry across.
- Of all the means of transport, both diffusion and facilitated diffusion always take place along a concentration gradient, without the expenditure of energy while active transport uses energy against concentration gradient.

Comparison of Different Transport Mechanisms

Property	Simple Diffusion	Facilitated Transport	Active Transport
Requires special membrane proteins	No	Yes	Yes
Highly selective	No	Yes	Yes
Transport saturates	No	Yes	Yes
Uphill transport	No	No	Yes
Requires ATP energy	No	No	Yes

Plant –Water Relations

Imbibition

- Imbibition is a special type of diffusion where, movement is along a concentration gradient.
- For any solid to imbibe a liquid, it must have an affinity for the liquid and also a water potential gradient between the solid and the liquid.

Water Potential

- The greater the concentration of water, the greater is its water potential.
- Water potential is denoted by the Greek symbol Psi, ψ.
- It is expressed in pressure units as pascal (Pa).
- The water potential of pure water at standard temperature and pressure is zero.
- Pure water has the greatest possible water potential and therefore the water potential of solutions is less than that of pure water.
- The water potential gradient comprises of two main components namely, solute potential and pressure potential.

Solute potential

- The magnitude of lowering of the water potential due to the addition of a solute is called solute potential.
- Solute potential is represented by the letter ψ_s, and it is always negative.
- Solute potential becomes increasingly negative with the addition of solutes.
- When two solutions come into contact, water molecules move from the solution with the higher water potential to the one with the lower water potential.
- For a solution at atmospheric pressure, its water potential is equal to its solute potential, $\Psi_w = \Psi_s$
- But if pressure greater than the atmospheric pressure is applied to pure water or a solution, it results in an increase in water potential.

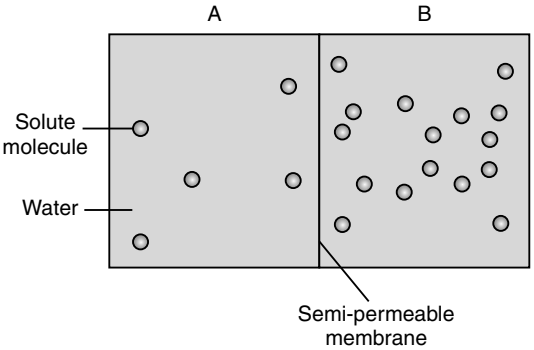
Pressure Potential

- When water enters a plant cell due to diffusion, it builds up pressure against the cell wall, causing the cell to become turgid.
- This pressure applied by the protoplasm against the cell wall is called pressure potential.
- Pressure potential, which is denoted by ψ_p, is usually positive.
- However, negative pressure potential is critical for water transport to the stem via the xylem cells.
- Water potential of cell is affected by both solute and pressure potential.

$$\Psi_w = \Psi_s + \Psi_p$$

Osmosis

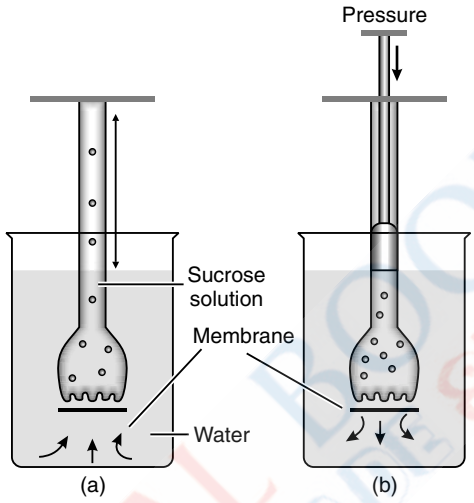
- In a plant cell, the cell wall is freely permeable to water and other smaller substances, the cell membrane is semi-permeable to oxygen, carbon dioxide, ions and water.
- The cell membrane together with the vacuolar membrane determines the movement of the molecules inside and outside the plant cell.



- The vacuolar sap in the vacuole contributes to the solute potential of the plant cell.
- The diffusion of water across a semi-permeable membrane from high concentration of water (or low solute concentration) to low concentration of water (or high solute concentration) is called osmosis.
- The net direction and rate of osmosis depends on two factors: concentration gradient and pressure gradient.
- If two solutions are put into a chamber separated by a semi-permeable membrane, water will move from the

region of the higher concentration gradient to the region of the lower concentration gradient until equilibrium is reached.

- At equilibrium, both chambers will have the same water potential.
- The potential of water molecules to move from a hypotonic solution to a hypertonic solution across a semi-permeable membrane is called **osmotic potential.**
- To demonstrate osmosis, a solution of sucrose in water is put into a funnel and separated from the pure water in the beaker by a semi-permeable membrane. The water being hypotonic will move from the beaker to the funnel containing the hypertonic sugar solution, raising the solution level in the funnel. This water movement will continue until both solutions in the funnel and beaker achieve equilibrium. Now, we can apply external pressure to the upper part of the funnel so that no water diffuses from the beaker to the funnel through the membrane. This external pressure that is required to prevent the water from diffusing is known as osmotic pressure.

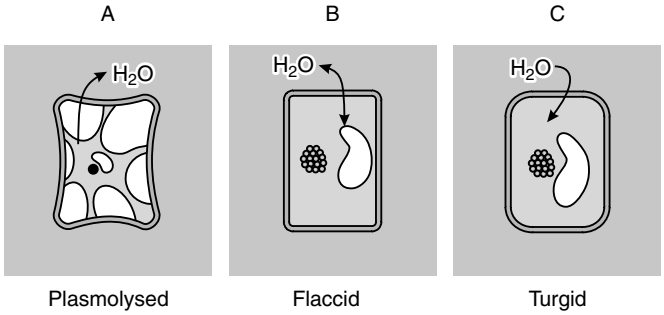


Demonstration of Osmosis

- Osmotic pressure is a function of solute concentration.
- The higher the solute concentration, the more the diffusion of water. Therefore, more osmotic pressure will be required to stop the entry of water molecules into the solution.
- The water potential is equal to its solute potential for a solution that is at atmospheric pressure.
- Unlike osmotic potential, which is negative, osmotic pressure is a positive pressure.
- However, numerically, osmotic pressure is equal to osmotic potential, only their signs differ.

Plasmolysis

- The plant cell wall can either shrink or become turgid in response to the movement of water.
- It is the surrounding isotonic, hypotonic and hypertonic solution outside the cell that decides the direction in which water flows.
- If the concentration of the external solution is more than that of the cytoplasm, that is, if it has more solutes, it is said to be hypertonic.
- If a plant cell is placed in a hypertonic solution, water moves out of the cell cytoplasm and then the vacuole due to osmosis.
- The cell membrane shrinks away from the cell wall. This phenomenon is called **plasmolysis**, while the cell is said to be plasmolysed.
- This movement of water takes place from a cell which has a higher water potential to an area outside the cell that has a lower water potential. However, plasmolysis is a reversible process.



Plant Cell Plasmolysis

- If the concentration of the external solution is lower than that of the cytoplasm, it is said to be hypotonic.
- When plasmolysed cells are placed in a hypotonic solution, i.e., in a solution with less solutes and higher water potential, water moves from the solution into the cell due to osmosis.
- This causes the cytoplasm to build a pressure against the cell wall and this pressure is called turgor pressure, which enables the plant to be erect.
- This turgor pressure exerted by the protoplast against the cell wall due to the entry of water is called pressure potential, ψ_p.
- Since plant cells have a rigid cell wall, the cell does not rupture despite the turgor pressure.
- If the concentration of the external solution is the same as that of the cell cytoplasm, the solution is said to be isotonic.
- Now if the cell is placed in an isotonic solution, there is no net flow of water either from inside or outside the cell.
- When the flow of water from and into the cell is in equilibrium, the cell is said to be in a flaccid state.
- Flaccid cells are found in a wilted plant that has not been watered for a long time.

TOPIC-2
Long Distance Transport of Water and Transpiration

Revision Notes

- When the site of the production of food or absorption of water is quite far from the plant's storage organs, diffusion and cytoplasmic streaming supplemented by active transport do not suffice.
- They can only account for short-distance movements in plants.
- Therefore, a special long-distance transport system called a mass or bulk flow system exists in plants to transport water, minerals and food, at a faster rate than diffusion.

Mass Flow system

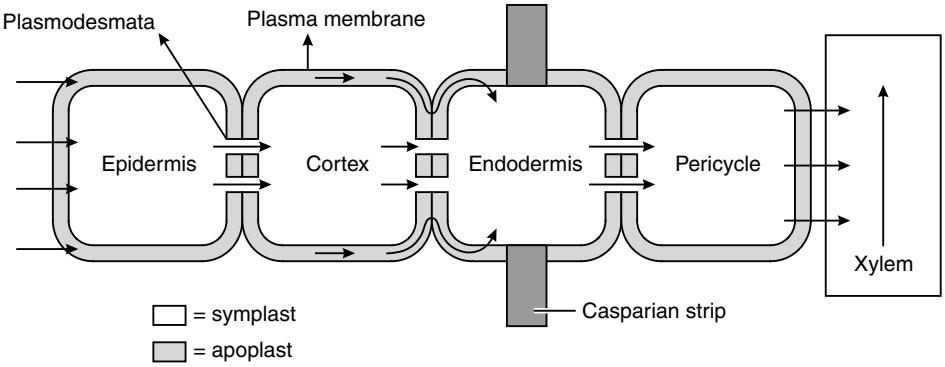
- The mass flow system moves substances in bulk, which arises out of a pressure difference between the two points.
- Bulk flow is achieved either through a positive hydrostatic gradient like the one caused by a garden hose or through a negative hydrostatic pressure like the one caused by suction through a straw.
- This bulk flow system conducted through the plant's vascular tissues, xylem and phloem, is referred to as translocation.
- Xylem transports water, minerals and hormones upwards from the plant's roots while phloem transfers organic or inorganic solutes from the leaves to the other parts of the plant.
- The bulk flow system differs from diffusion in transporting substances across long distances at the same pace and is achieved through a positive or negative hydrostatic gradient.

Plant Absorption of Water

- Root hairs in plants absorb both water and minerals from the soil through diffusion.
- After the water is absorbed, it moves deeper into the root layers by either of the two pathways – apoplast or symplast.

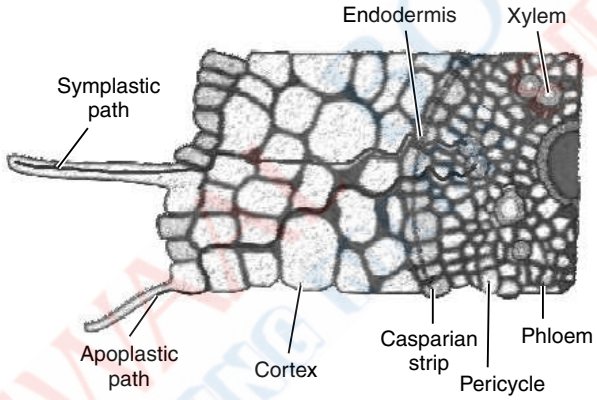
Apoplast

- In the apoplastic movement, water travels through intercellular spaces and permeable cell walls and is interrupted by waxy, suberised casparian strips in the root endodermis.



Symplast

- In the symplastic movement, water travels through the cell cytoplasm and intercellular movement is through the plasmodesmata.
- Water movement takes down the potential gradient.
- As water enters the cells through the not-so-permeable cell membrane in the symplastic pathway, water movement is slower.
- Most of the water movement in the roots occurs through the apoplast as the cortical cells are loosely packed and hence provide easy flow.
- However, the inner boundary of the cortex, that is, the endodermis, is impervious to water due to the presence of casparian strips.
- As water molecules are unable to penetrate this layer, they move to the wall regions into the cells that are not lined with casparian strips and reach the xylem cells.
- Therefore, it is the only pathway that allows water and solutes to reach the vascular tissues.
- Water moves freely once it is inside the xylem and enters the xylem vessels and tracheids.
- These xylem elements are non-living and therefore, become a part of the apoplast movement, which occurs in the non-living parts of the root.
- Some plants such as *Pinus* have additional structures called mycorrhiza associated with their roots, to help in the absorption of water and minerals.



Symplastic and apoplastic pathways of water and ion absorption and movement in roots

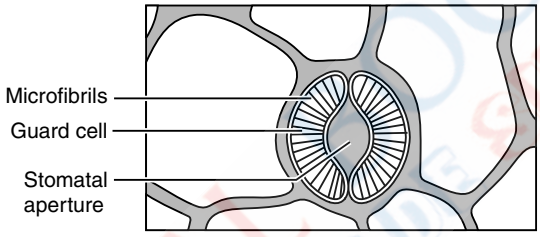
Movement of Water

- Root pressure and transpirational pull enables the upward movement of water and minerals in plants.
- The mineral ions from the soil are pushed into the root vascular tissues by diffusion and as a result, the pressure inside the xylem increases. This positive pressure is known as root pressure.
- Root pressure can be observed in a plant by a cut-stem experiment. In the early morning hours of a humid day, if a soft stem is cut horizontally near its base with a blade, drops of solution ooze from the cut stem. This oozing is caused by positive root pressure. If a rubber tube is fixed to this cut stem, we can measure the rate of exudation and the composition of exudates.
- The impact of root pressure is best witnessed during the night and early in the morning, when evaporation is slow.
- At this time, the excess water collects as droplets around the special openings of the veins called hydathodes near the tip of grass blades.
- This water loss in its liquid form is called guttation.
- However, root pressure itself does not account for the majority of water transport.
- Most of the water movement in tall trees takes place due to transpirational pull.
- The driving force behind this transpirational pull is transpiration from the leaves.
- Unlike guttation, where water is lost in liquid form, water is lost as vapour during transpiration.
- Transpiration can be witnessed by closing a healthy plant inside a polythene bag.
- The water loss due to transpiration 'pulls' the water upwards in a plant stem.

- The transpirational pull generated by transpiration is strong enough to cause water to move upwards even in tall trees by as much as 15 metres per hour.
- Water transport is also aided by cohesion and surface tension.
- Cohesion is the mutual attraction between water molecules and surface tension is the force acting on a water molecule travelling upwards in the xylem.
- Since cohesion-tension helps the transpirational pull, it is also known as the cohesion-tension-transpirational pull model of water transport.
- Less than 1 per cent of the water reaching the leaves is used in photosyntehsis.

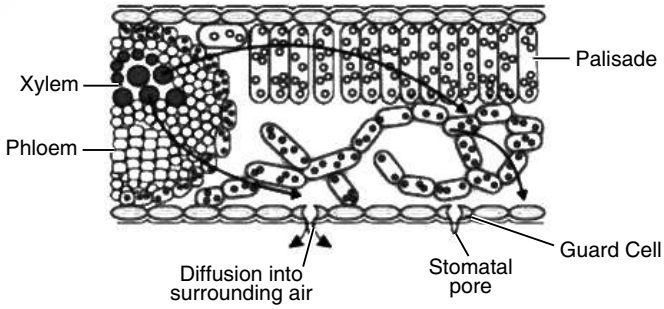
Transpiration

- Transpiration is the loss of water due to evaporation that occurs through stomata in the leaves.
- It helps in transporting water and minerals, cools leaf surfaces by evaporative cooling and maintains the shape and structure of plants by keeping cells turgid.
- Transpiration is affected by external factors, like temperature, light, humidity, etc., and plant factors like the number and distribution of stomata.
- The lower surface of a dicot leaf has a greater number of stomata, while a monocot leaf has an equal number of stomata on both surfaces.



A stomatal aperture with guard cells

- The opening and closing of the stomata is directly impacted by the turgidity of guard cells present near the stomatal aperture.
- Transpiration from the stomata causes a 'pull' that causes the upward ascent of water in xylem cells. This transpiration pull is made possible by three physical properties of water – cohesion, adhesion and surface tension.
  (a) Cohesion is the mutual attraction between water molecules.
  (b) Adhesion is the property of water to be attracted to polar surfaces like tracheids and vessel elements.
  (c) Surface tension is the property of water molecules to be extra attracted to each other.
- While water evaporates through the stomata during transpiration, a thin film of water appears over the cells, which pulls water, molecule by molecule, into the leaf from the xylem.
- The concentration of water vapour in the atmosphere is lower than that in the sub-stomatal cavity and intercellular spaces. This creates a water potential gradient, which makes the water diffuse into the surrounding air, creating a pull.



Water movement in the leaf

Evaporation from the leaf sets up a pressure gradient between the outside air and the air spaces of the leaf. The gradient is transmitted into the photosynthetic cells and on the water-filled xylem in the leaf vein.

Photosynthesis and Transpiration

- Photosynthesising plants require a lot of water. Since water swiftly depletes due to transpiration, the lack of available water may limit photosynthesis.
- The plant C_4 photosynthetic system solves this by increasing the availability of carbon dioxide and decreasing water loss.
- This system is more efficient than the C_3 system since it not only fixes carbon twice as a C_3 system, but also loses half the amount of water lost by the C_3 system while fixing the same amount of carbon dioxide.

TOPIC-3

Uptake and Transport of Mineral Nutrients and Phloem Transport

Revision Notes

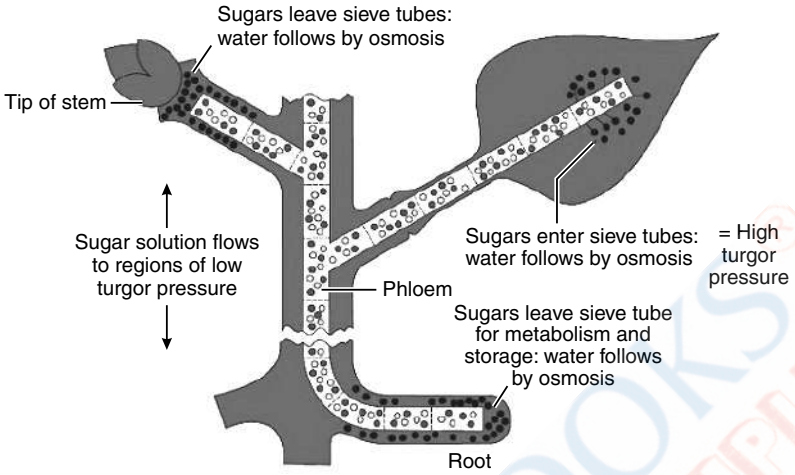
Transport of Minerals

- Plants absorb minerals from the soil through both passive and active transport.
- In passive transport, the ions just pass through the cell membrane of the root cells by osmosis or diffusion.
- On the other hand, active transport takes place when the ions move against the concentration gradient with the expense of energy to cross the cell membrane.
- The endodermal cells of the root have many transport proteins embedded in their plasma membrane.
- These transport proteins serve as control points, where they adjust the quantity and selectively allow the types of solutes to cross the membrane to reach the xylem.
- The suberin layer of the casparian strip enables the root epidermis to transport ions passively in one direction only.
- The active transport of ions causes a water potential gradient in the roots, which results in the uptake of water by osmosis.
- Once the ions reach the xylem either passively or by active absorption, they are transported up the stem to the various sinks inside the plant body by transpirational pull.
- These mineral ions are unloaded at the fine vein endings of leaves through diffusion and are taken up for active transport by mesophyll cells.
- Elements most readily mobilised are phosphorus, sulphur, nitrogen and potassium. Structrual components like calcium are not remobilised

Transport of Food

- The transport of sugars through phloem from a source to a sink is called translocation.
- The leaf is usually the source, while a sink is fruits or roots.
- However, sink and source roles can be reversed when they need energy for growth.
- Therefore, food transport by phloem is bidirectional – both upward and downward and the direction is determined by the sucrose concentration.
- Phloem tissue is made up of sieve tube cells, which are long columns with holes in their end walls. These holes are called sieve plates.
- However, most of the cellular functions of sieve tube cells inside the phloem are carried out by companion cells.
- The fluid that passes through these phloem cells is called phloem sap. It is mainly water and sucrose.
- A simple experiment called girdling can be used to illustrate the role of phloem cells in plants.
- Phloem sap translocation from source to sink takes place by a mechanism called the pressure flow hypothesis. When plant leaves prepare glucose via photosynthesis, the glucose is then converted into sucrose. Sucrose then moves into the companion cells, after which it is 'loaded' into the sieve tube cells via active transport. This process of 'loading' sucrose into the phloem causes a hypertonic condition and sets up a water potential gradient. This, in turn, results in osmosis, which causes water to move into the phloem from adjacent xylem cells.
- As osmotic pressure increases in the sieve tube, pressure flow begins and the phloem sap moves towards the sink, which has low osmotic pressure.

- This is followed by the sucrose from the phloem sap 'unloading' into the sink cells via active transport.
- The loss of sucrose produces a high water potential in phloem.
- This results in decreased osmotic pressure, which causes water to move out of the phloem cells and back into the xylem cells.



Diagrammatic presentation of mechanism of translocation

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Chapter 12

Mineral Nutrition

TOPIC-1

Methods to Study the Mineral Requirements of Plants and Essential Elements

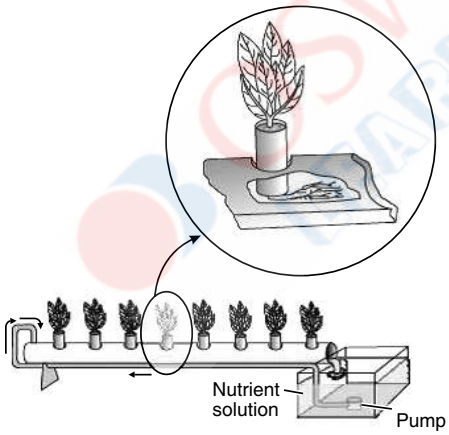
Revision Notes

Mineral Nutrition

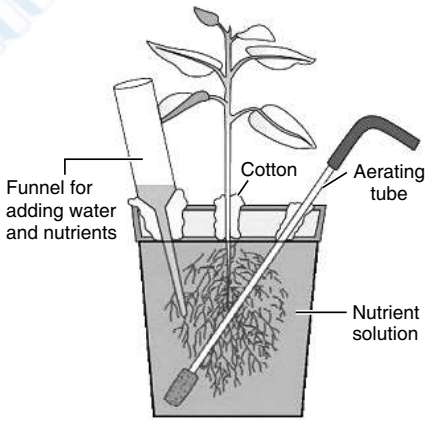
- Plants require mineral elements for their growth and development.
- The utilization of various absorbed ions by a plant for growth and development is called mineral nutrition of the plant.

Hydroponics

- Soil-less culture of plants, where roots are immersed in nutrient solution without soil is called hydroponics.
- The result obtained from hydroponics may be used to determine deficiency symptoms of essential elements.



Hydroponic Plant Production



Typical set up for nutrient solution culture

Essential Mineral Elements

- More than sixty elements of the 105 discovered so far are found in different plants.
- Some plant species accumulate selenium, some others gold, while some plants growing near nuclear test sites take up radioactive strontium.
- There are techniques that are able to detect the minerals even at a very low concentration (10^{-8} g/mL).

Criteria for Essentiality :

In 1939, Arnon and Stout proposed the characters that make an element essential to a plant.

(a) The element must be absolutely necessary for supporting normal growth and reproduction. In the absence of the element the plants do not complete their life cycle or set the seeds.

(b) The requirement of the element must be specific and not replaceable by another element. In other words, deficiency of any one element cannot be met by supplying some other element.

(c) The element must be directly involved in the metabolism of the plant.

Classification of Essential Mineral Elements

Based on their Requirements

(a) *Macronutrients*

Macronutrients are present in plant tissues in concentrations of 1 to 10 mg per gram of dry matter.

It includes carbon [C], hydrogen [H], oxygen [O], nitrogen [N], phosphorus [P], potassium [K], sulphur [S], calcium [Ca], and magnesium [Mg].

(b) *Micronutrients*

Micronutrients are needed in very low amounts of about 0.1 mg per gram of dry matter.

It includes iron [Fe], manganese [Mn], copper [Cu], molybdenum [Mo], zinc [Zn], boron [B], chlorine [Cl], and nickel [Ni].

It also include some beneficial elements required by higher plants such as sodium [Na], silicon [Si], cobalt [Co] and selenium [Se]

Based on their Diverse Functions

(i) Essential elements as components of biomolecules - carbon, hydrogen, oxygen and nitrogen.

(ii) Essential elements that are components of energy-related chemical compounds in plants - magnesium in chlorophyll and phosphorous in ATP.

(iii) Essential elements that activate or inhibit enzymes - Mg^{2+} is an activator for both ribulose bisphosphate carboxylase-oxygenase and phosphoenol pyruvate carboxylase, Zn^{2+} is an activator of alcohol dehydrogenase and Mo of nitrogenase during nitrogen metabolism.

(iv) Some essential elements can alter the osmotic potential of a cell - Potassium plays an important role in the opening and closing of stomata.

Role of Macronutrients

1. Nitrogen

- Nitrogen is an essential constituent of proteins, nucleic acids, vitamins and many other organic molecules such as chlorophyll. It is required by the plants in the greatest amount.
- Nitrogen also forms a constituent of various hormones, coenzymes and ATP.

Deficiency symptoms

(i) Stunted growth, chlorosis.

(ii) Reduction in flowering.

(iii) Excessive colouring in apple and peach.

(iv) Reduction in fruit size.

(v) Decrease in protein contents.

(vi) Change in the pigmentation pattern.

2. Phosphorus

- It is present in plasma membrane, nucleic acids, nucleotides, many co-enzymes and organic molecules.
- It plays an important role in energy metabolism.
- Phosphorus promotes healthy root growth and fruit ripening.
- It is obtained in the form of phosphate ions, $H_2PO_4^-$ or HPO_4^{2-}.
- It is required for the synthesis of nucleic acids, nucleotides, ATP, NAD and NADP and for phosphorylation reactions.

Deficiency symptoms

(i) Loss of older leaves.

(ii) Reduction in growth.

(iii) Increase in phosphatase enzyme activity.

(iv) Leaves become dull green.

(v) It causes accumulation of carbohydrates in soyabean.

3. Potassium

- Potassium is required in the meristematic regions and regions of cell differentiation.
- It accumulates in older leaves.
- Though it does not have a structural role, it is involved in stomatal opening and closing.
- It is an activator of many enzymes and has a role in protein and carbohydrate metabolism.

- It is most abundant intracellular cation obtained in the form of potassium ions, K^+.

Deficiency symptoms

(i) Leaf tips curve downward.
(ii) It causes mottled chlorosis.
(iii) Development of chlorosis at tips and margins of leaves.
(iv) Shortening of internodes leading to stunted growth.
(v) Premature deaths.

4. Calcium

- Calcium forms an important constituent of the cell wall occurring in the middle lamella as calcium pectate.
- It has an important role in the formation of plasma membrane.
- Calcium plays a role in mitotic cell division.
- It is a constituent of enzymes like phospholipase and adenyl kinase where it acts as an activator.
- It is obtained in the form of calcium ions, Ca^{2+}.

Deficiency symptoms

(i) It affects the carbohydrate metabolism.
(ii) Meristematic tissues are affected and leaf and root tips die.
(iii) Cell wall may become brittle or rigid.

5. Magnesium

- Magnesium is a constituent of chlorophyll molecule which cannot be formed without magnesium.
- It has a vital role in carbohydrate metabolism and the binding of ribosomal sub-units.
- Magnesium is the activator of many enzymes involved in DNA and RNA synthesis.
- It acts as a phosphorus carrier and activates enzymes such as PEP carboxylase and RuBP carboxylase.
- It is obtained in the form of magnesium ions,

Deficiency symptoms

(i) Interveinal chlorosis takes place.
(ii) Anthocyanin pigment deposition takes place after chlorosis.
(iii) Necrotic spots appear in acute cases.

6. Sulphur

- Sulphur is the constituent of certain vitamins such as thiamine and biotin.
- It is constituent of coenzyme.
- It plays an important role in respiration.
- It forms the sulphydryl group in many enzymes.
- It is a constituent of amino acids such as cysteine and methionine.
- It is obtained as sulphate ions.

Deficiency symptoms

(i) It causes inhibition of protein synthesis.
(ii) Younger leaves show chlorosis first

Role of Micronutrients

1. Iron

- Soil is generally not deficient in iron. Iron is a constituent of various flavoproteins and forms a part of enzymes such as catalases, peroxidases and cytochromes.
- It plays an important role in the electron transport system of photosynthesis being part of cytochrome and ferredoxin.
- It is reversibly oxidised from Fe^{2+} to Fe^{3+} during electron transfer.
- Plants obtain iron in the form of ferric ions (Fe^{3+}).

Deficiency symptoms

(i) It causes interveinal chlorosis and the leaves become yellow or white.
(ii) Impairs aerobic respiration and related processes.

2. Manganese

- Manganese is required by leaves and seeds.
- It is an activator of enzymes like carboxylases, oxidases, dehydrogenses and kinases.
- It is absorbed in the form of manganous ions (Mn^{2+}).

- The function of manganese can be seen in the splitting of water to liberate oxygen during photosynthesis.
- It activates many enzymes involved in photosynthesis, respiration and nitrogen metabolism.

Deficiency symptoms

(i) It causes grey spot disease in oat.

(ii) Poor development of root system.

3. Zinc

- Zinc is involved in the synthesis of indole acetic acid by activating the enzyme tryptophan synthetase.
- It plays a role in protein synthesis.
- It acts as an activator of many other enzymes such as carbonic anhydrase, alcohol dehydrogenase, hexokinase and so on.
- It is also needed in the synthesis of auxin. Plants obtain zinc as Zn^{2+} ions.

Deficiency symptoms

(i) It causes distortion of growth.

(ii) Leaves become very small and rosette called as little leaf disease.

(iii) Interveinal chlorosis and stunted growth of stems is seen.

4. Copper

- Copper forms a component of enzymes such as phenolases and tyrosinase.
- Copper being a constituent of plastocyanin plays a role in photophosphorylation.
- Copper maintains the carbohydrate - nitrogen balance.
- It is absorbed as cupric ions (Cu^{2+}).
- It is reversibly oxidised from Cu^{+} to Cu^{2+}.

Deficiency symptoms

(i) It causes die back of shoots especially in Citrus.

(ii) A disease called 'exanthema' causes the exudation of gums on the bark.

(iii) Reclamation disease is caused in plants growing on newly reclaimed soil where seed formation is affected.

5. Boron

- Leaves and seeds require boron.
- It is necessary for uptake and utilisation of Ca^{++} ions, pollen germination, cell differentiation and translocation of carbohydrates.
- It plays a role in nitrogen metabolism, hormone and fat metabolism.
- It is obtained by the plants in the form of BO_3^{3-} or $B_4O_7^{2-}$.

Deficiency symptoms

(i) It causes brown heart-rot disease in beetroots.

(ii) In apple internal tissues become corky.

(iii) Causes leaf to curl and become brittle.

(iv) Premature fall of fruits and flowers.

6. Molybdenum

- Molybdenum has an important role to play in the metabolism of nitrogen.
- It affects the synthesis of ascorbic acid.
- It activates the enzymes involved in nitrogen metabolism.
- Plants obtain it in the form of molybdate ions MoO_2^{2+}.

Deficiency symptoms

(i) It leads to mottling and wilting of leaves at the margins causing "yellow spot" disease of Citrus.

(ii) "Whiptail" disease in cauliflowers causing narrowing of leaf blades and their rugged appearance due to distortion.

Toxicity of Micronutrients

- The concentration of the essential elements below which plant growth is retarded is termed as critical concentration.
- Any mineral ion concentration in tissues that reduces their dry weight by about 10 per cent is considered toxic. The excess concentration of an element, affects the uptake of another element.
- The prominent symptom of manganese toxicity is the appearance of brown spots surrounded by chlorotic veins.
- Manganese competes with iron and magnesium for uptake and with magnesium for binding with enzymes.
- Manganese also inhibits calcium translocation in shoot apex.
- The excess of manganese induce deficiencies of iron, magnesium and calcium.

TOPIC-2

Mechanism of Absorption of Elements, Translocation of Solutes and Soil as Reservoir of Essential Elements

Revision Notes

Mechanism of Absorption of Elements

- In the first phase, an initial rapid uptake of ions into the 'free space' or 'outer space' of cells – the apoplast is passive.
- In the second phase of uptake, the ions are taken in slowly into the 'inner space' – the symplast of the cells. The passive movement of ions into the apoplast usually occurs through ion-channels, the trans-membrane proteins that function as selective pores.
- The entry or exit of ions to and from the symplast requires the expenditure of metabolic energy, which is an expensive process.
- The movement of ions into the cells is influx and the outward movement, efflux.

Translocation of Solutes

- Mineral salts are translocated through xylem along with the rising stream of water, which is pulled up through the plant by transpirational pull.
- Analysis of xylem sap shows the presence of mineral salts in it.
- Use of radioisotopes of mineral elements also substantiates the view that they are transported through the xylem.

Soil as Reservoir of Essential Elements

- Majority of the nutrients that are essential for the growth and development of plants become available to the roots due to weathering and breakdown of rocks.
- Soil consists of a wide variety of substances and minerals.
- It supplies air to the roots, acts as a matrix that stabilises the plant and also harbours nitrogen-fixing bacteria.
- Since deficiency of essential minerals affect the crop-yield, there is often a need for supplying them through fertilisers.

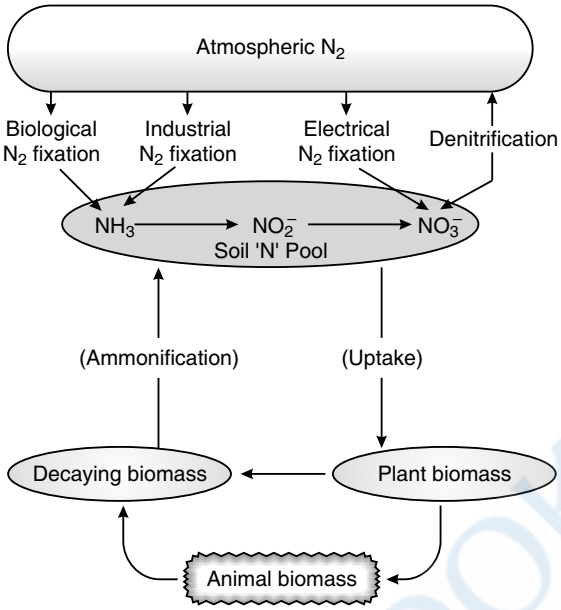
TOPIC-3

Metabolism of Nitrogen

Revision Notes

Nitrogen Cycle

- Nitrogen is one of the major constituents in the atmosphere and comprises 78% of all gases by volume.
- Atmospheric nitrogen cannot be used by plants.
- Only a small amount of nitrogen is present in soil, and plants compete with microorganisms for it. Thus, nitrogen is a limiting nutrient in both natural and agricultural ecosystems.
- Atmospheric nitrogen is in the form of elemental nitrogen which requires a large amount of energy to break it into forms suitable for living organisms to absorb.
- In nature, elemental nitrogen is converted into oxides with the help of lightning, and ultraviolet radiation.



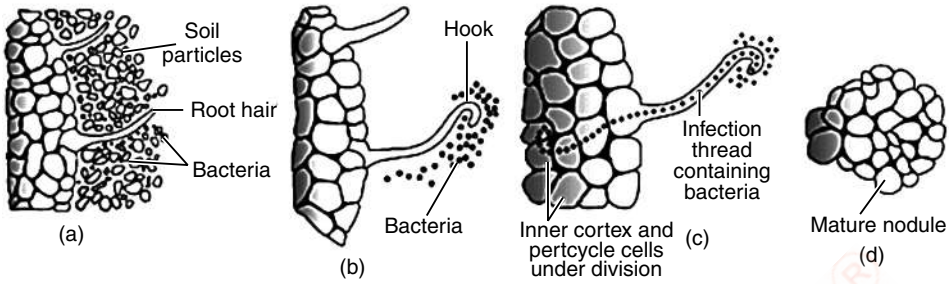
The Nitrogen cycle

- Some of these nitrogen oxides are brought to earth by precipitation as rainfall. But most of it is biochemically fixed by microorganisms. This is called biological nitrogen fixation.
- Plants absorb nitrogen in the form of nitrates through their roots, which then transport it to the leaves.
- Nitrogen in plants reaches animals through the food they eat.
- After the death of plants and animals, the organic material present in them returns to the soil.
- The nitrogen in dead plants and animals is decomposed by ammonifying bacteria to form ammonia. This process is called ammonification.
- Ammonia formed by ammonification is converted into nitrites and nitrates by nitrifying bacteria in the soil. This is called nitrification.
- During the nitrifying process, chemoautotrophic bacteria such as *Nitrosomonas* and *Nitrococcus* act on ammonia and oxidise it into nitrite.
- Nitrites are further oxidised into nitrates by the bacterium *Nitrobacter*.
- Nitrates in soil are either taken up by plants or is processed by denitrifying bacteria such as *Pseudomonas*, *Thiobacillus* and *Micrococcus*, which release it as elemental nitrogen into the atmosphere. This process is called denitrification.
- Industries, forest fires, automobile exhaust and power-generating stations also release oxides of nitrogen into the atmosphere through combustion.
- Ammonia in soil is converted into nitrites and nitrates by nitrifying bacteria, thereby enabling plants to absorb nitrates from the soil.
- Nitrogen compounds from plants are passed along the food chain to animals, which ultimately return it to the soil when they die.
- Nitrogen from the dead and decaying organic matter is converted into ammonia by ammonification.
- Denitrifying bacteria then convert the nitrates back into nitrogen.

Biological Nitrogen Fixation :

- The use of micro-organisms is one way to make atmospheric nitrogen available to the soil.
- Only a few microbes can fix this nitrogen. These microbes have a special enzyme called **nitrogenase**, which reduces nitrogen to ammonia. This is called biological nitrogen fixation.
- Microbes that possess this enzyme are called nitrogen fixers. They live independently or as symbionts, such as *Azotobacter* and blue-green algae.
- Nitrogen fixation is slow in free-living microbes due to the energy requirements.
- *Rhizobium* is known for its symbiotic association in the root nodules of leguminous plants.
- *Rhizobium* in the soil multiplies around the roots and gets attached to root hair.
- These bacteria reach the cortical cells through this root hair.

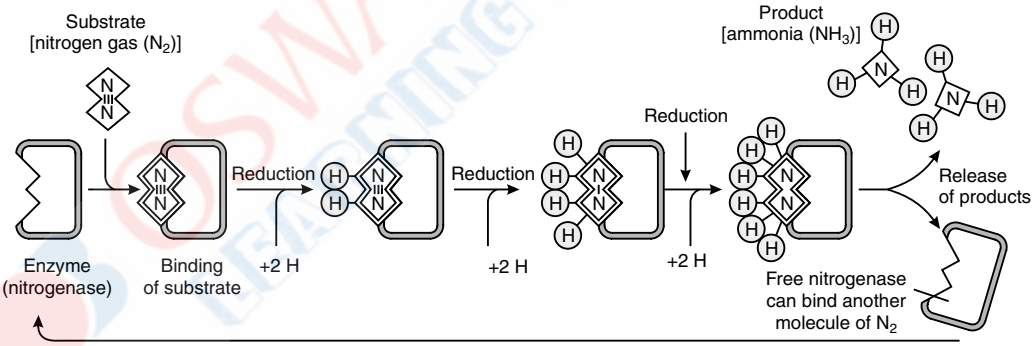
- Then the bacteria stimulate the inner cortical and pericycle cells to divide.
- These cells get differentiated as nitrogen-fixing cells and a nodule is thus formed.



Development of root nodules

- Through vascular supply, the nodule is ensured of nutrients and energy from the plant.
- The enzyme secreted by *Rhizobium*, nitrogenase, is a molybdenum-ferrous protein and acts as a catalyst in the conversion of nitrogen to ammonia.
- Leg-haemoglobin, the iron-containing protein in the root nodule, acts as an oxygen scavenger and prevents its exposure to nitrogenase.
- Nitrogen requires eight electrons, eight protons and 16 ATP molecules of energy for the formation of two molecules of ammonia.

  $N_2 + 8e^- + 8H^+ + 16ATP \longrightarrow 2NH_3 + H_2 + 16ADP + 16P_i$
- These eight ATP molecules are provided by the ATP released during respiration.
- Nitrogenase first binds with substrate nitrogen and finally forms two molecules of ammonia.
- Ammonia molecules take up protons to form ammonium (NH_4^+) ions that are used in the synthesis of amino acids.
- Amino acid synthesis in plants takes place in two ways: reductive amination and transamination.



Steps of conversion of atmospheric nitrogen to ammonia by nitrogenase enzyme complex found in nitrogen-fixing bacteria

- In reductive amination when ammonia ions react with alpha ketoglutaric acid, it forms glutamic acid and water in the presence of the enzyme glutamate dehydrogenase.
- The energy required for this reaction is obtained by the oxidation of NADPH to NADP.
- Transamination involves the transfer of one amino group from an amino acid to the keto group of a keto acid. The reaction is catalysed by a family of enzymes called transaminases.
- This results in the formation of asparagine and glutamine from asparatic acid and glutamic acid.
- This process takes place due to the replacement of the hydroxyl group of the carboxyl group of aspartic and glutamic acids with amino group.
- Amino acids are usually transported through phloem but compounds such as amides and ureides, owing to a greater nitrogen-to-carbon ratio, are easily transported through xylem.

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Chapter 13

Photosynthesis in Higher Plants

TOPIC-1

Photosynthesis, Early Experiments and Site of Photosynthesis

Revision Notes

Photosynthesis

- Experiment on Starch Formation :
- A variegated leaf or a leaf that was partially covered with black paper and one that was exposed to light.
- On testing these leaves for starch it was clear that photosynthesis occurred only in the green parts of the leaves in the presence of light.

Half-leaf Experiment :

- A part of a leaf is enclosed in a test tube containing some KOH soaked cotton (which absorbs CO_2), while the other half is exposed to air.
- The setup is then placed in light for some time.
- On testing for starch later in the two halves of the leaf, it was found that the exposed part of the leaf tested positive for starch while the portion that was in the tube, tested negative.
- This showed that CO_2 was required for photosynthesis.

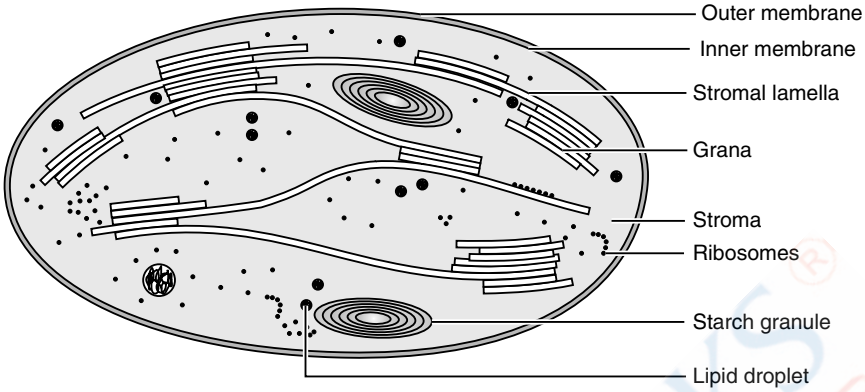
EARLY EXPERIMENTS

- **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 C_4 pathway of CO_2 fixation.

Site of 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.



Chloroplast

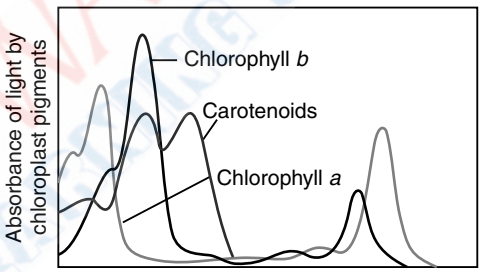
TOPIC-2

Pigments Involved in Photosynthesis, Light Reaction and The Electron Transport

Revision Notes

PIGMENTS IN PHOTOSYNTHESIS

- **Chlorophyll a :** (Bright or blue green in chromatogram). Major pigment, act as reaction centre, involved in trapping and converting light into chemical energy.



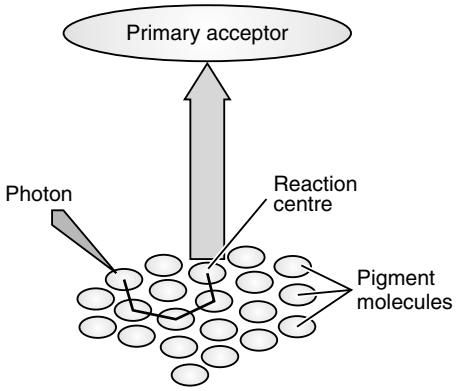
Graph showing the absorption spectrum of chlorophyll *a*, *b* and the carotenoids

- **Chlorophyll b :** (Yellow green). It is accessory pigment that collects energy and passes it on to chlorophyll *a*.
- **Xanthophyll :** (Yellow)
- **Carotenoids :** (Yellow to yellow-orange). The blue and red regions of spectrum show higher rate of photosynthesis. Action spectrum of photosynthesis corresponds closely to absorption sepctra of chlorophyll *a* showing that chlorophyll *a* is the chief pigment associated with photosynthesis. Most of the photosynthesis takes place in the blue and red regions of the spectrum.

LIGHT REACTION

Light Harvesting Complexes (LHC) :

- The light harvesting complexes are made up of hundreds of pigment molecules bound to protein within the photosystem I (PS I) and photosystem II (PS II).
- 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.
- These pigments help to make photosynthesis more efficient by absorbing different wavelengths of light.

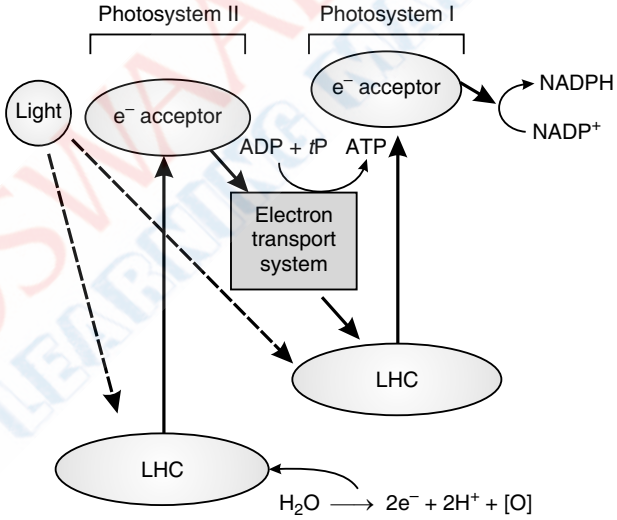


The Light harvesting complex

- The single chlorophyll a molecule forms the reaction centre.
- The reaction centre is different in both the photosystems.
- In PS I the reaction centre chlorophyll a has an absorption peak at 700 nm, hence is called P700, while in PS II it has absorption maxima at 680 nm, and is called P680.

THE ELECTRON TRANSPORT

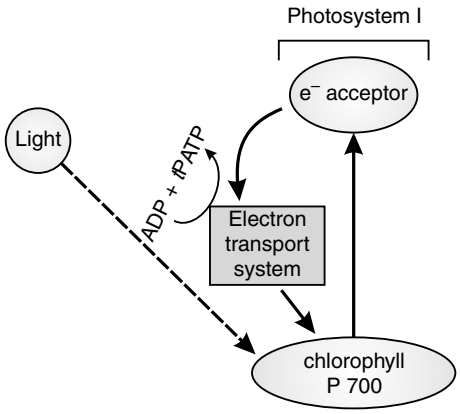
- In the light-absorption stage, the chlorophyll a in PS II absorbs the 680 nm wavelength of red light.
- The electrons from PS II are passed on to PS I through the electron transport system consisting of cytochromes.
- Simultaneously electrons of the PS I reaction centre are excited by absorbing red light of wavelength 700 nm.
- These are transferred to another acceptor molecule with greater redox potential.
- These electrons move to a molecule of energy-rich $NADP^+$, thereby reducing it to NADPH.
- This whole scheme of transfer of electrons, starting from the PS II, uphill to the accepter, down the electron transport chain to PS I, excitation of electrons, transfer to another accepter, and finally downhill to $NADP^+$ causing it to be reduced to NADPH + H^+ is called the Z scheme, due to its characteristic shape.



Z-Scheme of Light reaction

Splitting of Water

- In water-splitting, water is split into H^+, [O] and electrons. The electrons that were removed from PS II are replaced by electrons formed due to the splitting of water. The electrons needed to replace those removed from PS I are provided by the excited electrons of PS II through the electron transport system. Water splitting takes place on the inner side of the membrane, producing protons or hydrogen ions that accumulate within the lumen of the thylakoid. This creates a proton gradient across the thylakoid membrane.
- **Cyclic and Non-cyclic Photo-phosphorylation**
- The process of synthesising high-energy compounds like ATP by cells in the chloroplast and mitochondria is called phosphorylation. Photophosphorylation is the synthesis of ATP from ADP and inorganic phosphate in the presence of light.
- In cyclic photophosphorylation, two photosystems work in series first PS II and then PS I.
- These two photosystems are connected through an electron transport chain (Z-scheme).
- ATP and NADPH + H^+ are synthesised by this process.

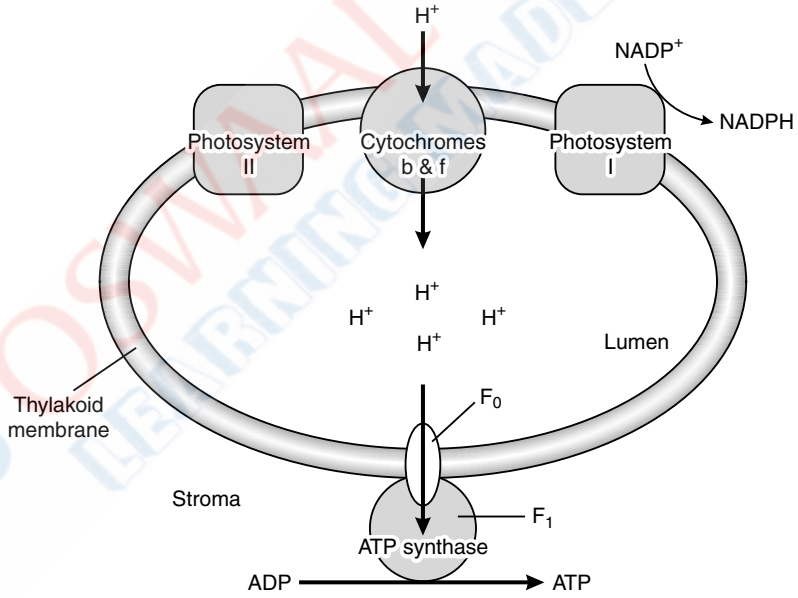


Cyclic photophosphorylation

- PS I and PS II are found in lamellae of grana; hence this process is carried here.
- In non-cyclic photophosphorylation, only PSI 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 synthesised.

Chemiosmotic Hypothesis

- The chemiosmotic hypothesis explains the mechanism of ATP synthesis.
- In photosynthesis, ATP synthesis is linked to development of a proton gradient across a membrane.
- The protons are accumulated inside of membrane of thylakoid membranes (*i.e.*, in the lumen).
- ATPase has a channel that allows diffusion of protons back across the membrane.
- This releases energy to activate ATPase enzyme that catalyses the formation of ATP.



ATP synthesis through chemiosmosis

Processes Involved in Hypothesis

- The processes that take place during the activation of electrons and their transport to determine the steps that cause a proton gradient as follows :
  (a) Since splitting of the water molecule takes place on the inner side of the membrane, the protons or hydrogen ions that are produced by the splitting of water accumulate within the lumen of the thylakoids.
  (b) As electrons move through the photosystems, protons are transported across the membrane.
  (c) The NADP reductase enzyme is located on the stroma side of the membrane. Protons are necessary for the reduction of $NADP^+$ to NADPH+ H^+. These protons are also removed from the stroma.

Proton Gradient :

- This gradient is important because it is the breakdown of this gradient that leads to release of energy.
- The gradient is broken down due to the movement of protons across the membrane to the stroma through the transmembrane channel of the F_0 of the ATPase.

- Chemiosmosis requires a membrane, a proton pump, a proton gradient and ATPase.
- Energy is used to pump protons across a membrane, to create a gradient or a high concentration of protons within the thylakoid lumen.
- ATPase has a channel that allows diffusion of protons back across the membrane; this releases enough energy to activate ATPase enzyme that catalyses the formation of ATP.

TOPIC-3
Use of ATP and NADPH

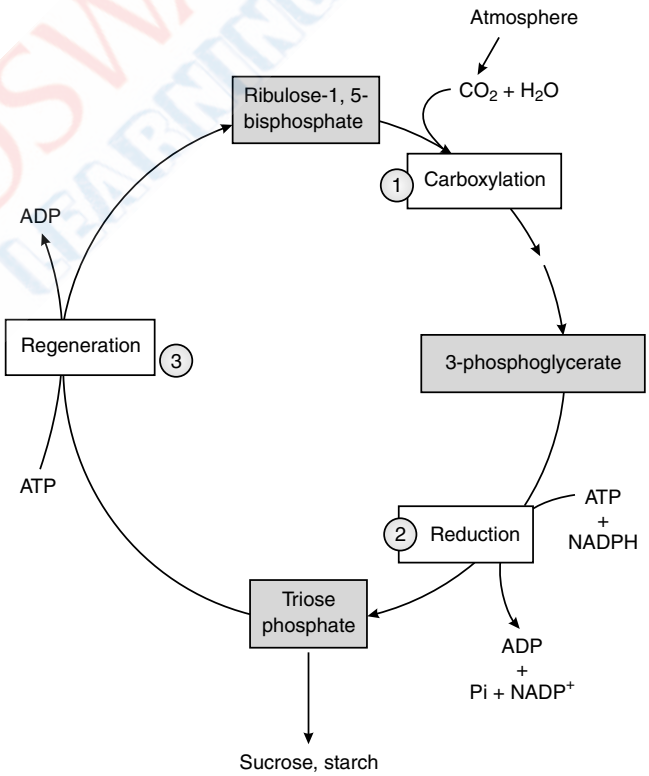
Revision Notes

Biosynthetic Phase :
- In this, ATP and NADPH are used to drive the processes leading to the synthesis of food, *i.e.*, sugars.
- This stage is also called the dark phase as it is independent of light but is dependent on the products of the light reaction, *i.e.*, ATP and $NADPH_2$.
- It takes place in the stroma of chloroplasts.
- In some plants, the first product of CO_2 fixation is a 3-carbon compound called 3-phosphoglyceric acid (PGA). These plants are said to adopt the C_3 pathway.
- In other plants, the first CO_2 fixation product is a 4-carbon compound called oxaloacetic acid. These plants are said to adopt the C4 pathway.

The Primary Acceptor of CO_2
- The accepter molecule is a 5-carbon ketose sugar – it is ribulose bisphosphate (RuBP).

The Calvin Cycle
- The path of carbon in the dark reaction was traced by Melvin Calvin using radioactive carbon (^{14}C).
- The use of radioactive ^{14}C by him in algal photosynthesis studies led to the discovery that the first CO_2 fixation product was a 3-carbon organic acid.
- The primary acceptor of CO_2 was found to be a 5-carbon ketose sugar called Ribulose bisphosphate (RuBP). RuBP is used in a cyclic manner (regenerated) and a sugar is synthesised.
- There are three phases of Calvin cycle namely, Carboxylation, Reduction and Regeneration of RuBP.

1. Carboxylation :



The Calvin cycle

- Ribulose 1, 5-bisphosphate combines with CO_2, and fixes it to a stable organic intermediate 3–C compound called 3-phosphoglycerate (2 molecules).
- 3 PGA is the first stable product of this cycle.
- Reaction is catalysed by the enzyme RuBisCO (RuBP carboxylase-oxygenase)

2. Reduction

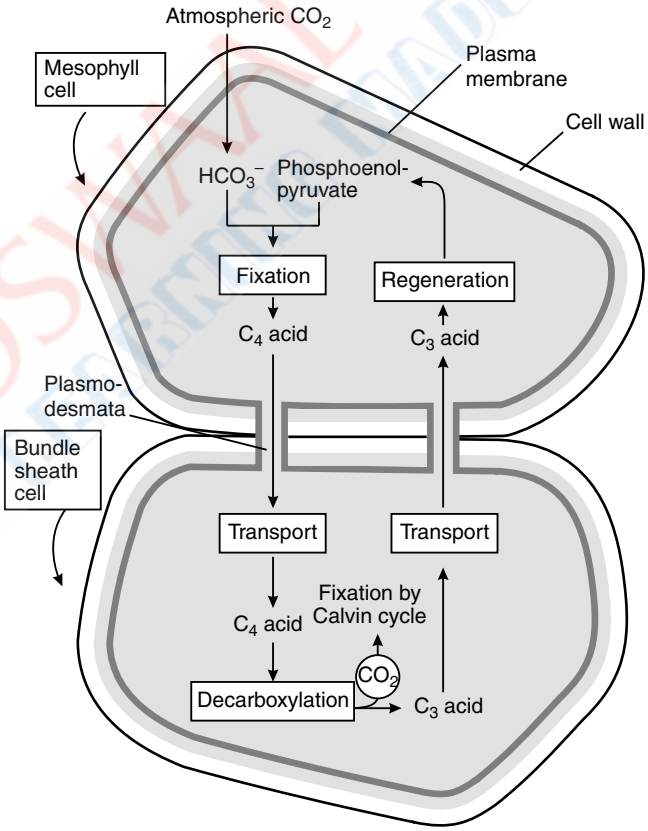
- Here, two molecules each of ATP and NADPH are required for fixing one molecule of CO_2.
- This stage involves utilisation of 2 molecules of ATP for phosphorylation and two molecules of NADPH for reduction per CO_2 molecule fixed.
- Glucose is formed as a result of this series of reactions.

3. Regeneration

- RuBP regenerates to enable the cycle to continue uninterrupted.
- 1 ATP molecule is required.
- For the formation of one molecule of glucose, six molecules of CO_2 need to be fixed; hence, six cycles are required.
- For fixing 1 molecule of CO_2 − 3 molecules of ATP is required. (2 for reduction and 1 for regeneration) For fixing 6 molecules of CO_2 − $3 \times 6 = 18$ ATP
- For fixing 1 molecule of CO_2 − 2 NADPH is required (for reduction) and for fixing 6 molecules of CO_2 − $2 \times 6 =$ 12 NADPH
- Thus, the synthesis of 1 molecule of glucose requires 18 ATP and 12 NADPH.

C_4 Pathway (Hatch and Slack Pathway)

- It occurs in plants like maize, sugarcane − plants adapted to dry tropical regions.
- The leaves of C_4 plants have Kranz anatomy.
- Chloroplasts are dimorphic i.e., those in the mesophyll cells are granal and in bundle sheath cells are agranal.



Hatch and Slack Pathway

- C_4 plants can tolerate high temperature and high light intensity, show greater productivity of biomass, and lack photorespiration.
- Primary CO_2 acceptor: Phosphoenol pyruvate (PEP) − a 3-carbon molecule.
- PEP carboxylase fixes CO_2 in the mesophyll cells to form the 4-carbon compound oxaloacetic acid (OAA), and then

other 4-carbon compounds malic acid or aspartic acid.

- These compounds are transported to the bundle sheath cells where C_4 acid breaks down to form C_3 acid and CO_2, and carbon dioxide enter the C_3 cycle).
- C_3 acid, so formed, is again transported to the mesophyll cells and regenerated back into PEP.
- C_3 cycle cannot directly occur in the mesophyll cells of C_4 plants because of the lack of the enzyme RuBisCO in these cells.
- RuBisCO is found in abundance in the bundle sheath cells of C_4 plants.

TOPIC-4

Photorespiration and Factors Affecting Photosynthesis

Revision Notes

- In C_3 plants some O_2 bind to RuBisCO, and hence CO_2 fixation is decreased. RuBP instead of being converted to 2 molecules of PGA binds to O_2 to form one molecule of phosphoglycerate and phosphoglycolate in pathway called photorespiration.
- It is a process in which there is no formation of ATP or NADPH, but there is utilization of ATP with release of CO_2. It is also considered a wasteful process.
- Photorespiration is responsible for the difference between C_3 and C_4 plants.
- In C_4 plants photorespiration does not occur as they have a mechanism that increases concentration of CO_2 at the enzyme site. C_4 acid from the mesophyll is broken down in the bundle sheath cells to release CO_2 which ensures that RuBisCO functions as carboxylase.

FACTORS AFFECTING PHOTOSYNTHESIS

Blackmans law of limiting factors:

- When a physiological process is controlled by a number of factors, the rate of reaction depends on the lowest factor, which is nearest to its minimal value; so the factor which is the least/ limiting will determine the rate of photosynthesis.

Light

- Wavelength of light between 400 nm-700 nm is called photosynthetically active radiation (PAR).
- High intensity of light breakdown the chlorophyll and decreases the photosynthesis.
- Hence, except for plants in shade or in dense forests, light is rarely a limiting factor in nature.

Carbon dioxide Concentration

- Carbon dioxide is the major limiting factor for photosynthesis.
- Increase in concentration upto 0.05 per cent can cause an increase in CO_2 fixation rates; beyond this the levels can become damaging over longer periods.
- At low light conditions neither C_3 nor C_4 plants responds to high CO_2 conditions.
- At high light intensities, both C_3 and C_4 plants show increase in the rates of photosynthesis.

Temperature

- The dark reactions being enzymatic are temperature controlled.
- The C_4 plants respond to higher temperatures and show higher rate of photosynthesis while C_3 plants have a much lower optimum temperature.

Water

- Water stress causes the stomata to close hence reducing the CO_2 availability. It also makes leaves wilt, thus, reducing the surface area of the leaves and their metabolic activity as well.

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Chapter 14

Respiration in Plants

TOPIC-1

Do Plants Breathe? Glycolysis

Revision Notes

BREATHING IN PLANTS

- All living organisms need energy for carrying out daily life activities, It can be absorption, transport, movement, reproduction or even breathing.
- All the energy required for 'life' processes is obtained by oxidation of some macromolecules that we call 'food'.
- Only green plants and cyanobacteria can prepare their own food by the process of photosynthesis by trapping light energy and converting it into chemical energy that is stored in the bonds of carbohydrates like glucose, sucrose and starch.
- Animals are heterotrophic, *i.e.*, they obtain food from plants directly (herbivores) or indirectly (carnivores).
- Saprophytes like fungi are dependent on dead and decaying matter.

Cellular Respiration

- It is the process of oxidation/breakdown of food materials within the cell to release energy. Respiratory substrate to be oxidised during respiration is usually glucose, but these can also be proteins, fats or organic acids.
- The overall cellular respiration is:

  $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$ + Energy (36 ATPs)

Respiration

- The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called respiration.

Respiratory Substrates :

- The compounds that are oxidised during this process are known as respiratory substrates.
- Plants, unlike animals have no specialised organs for gaseous exchange but they have stomata and lenticels for this purpose.

Types of Respiration :

(a) Aerobic respiration

(b) Anaerobic respiration

Aerobic Respiration

(a) It occurs in the presence of oxygen.

(b) Respiratory substrate is glucose.

(c) Glucose gets completely oxidised.

(d) The end products formed are CO_2, H_2O and 36 ATPs.

(e) Energy is released in large quantities.

(f) Cytoplasm and Mitochondria are the sites of breakdown.

Anaerobic Respiration

(a) It occurs in the absence of oxygen.

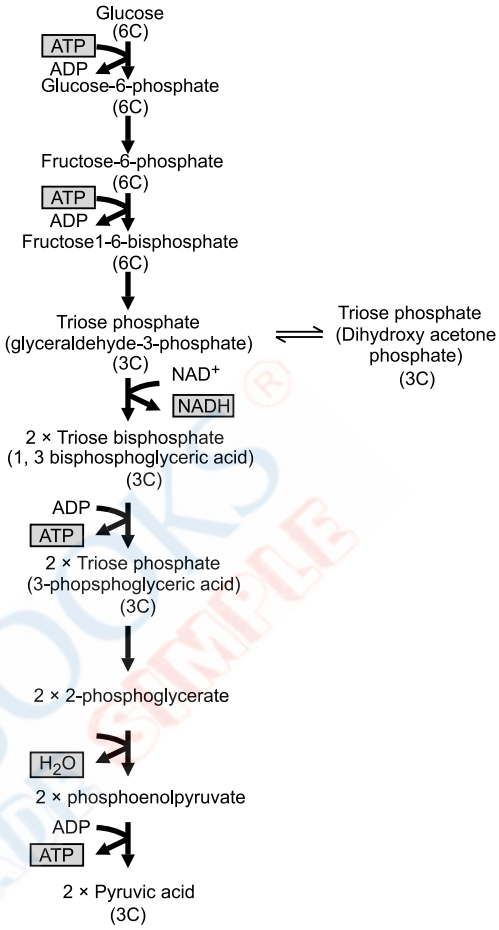
(b) Respiratory substrate is glucose.

(c) Glucose gets partially oxidised.

(d) The end products formed are ethyl alcohol / lactic acid, CO_2, 2 ATPs.

(e) Energy is released in lesser quantity.

(f) Only cytoplasm is the site of breakdown.



Steps of glycolysis

Mechanism of Respiration

- Glycolysis – it is common to both aerobic and anaerobic respiration
- Citric acid cycle/Krebs cycle - Aerobic respiration in mitochondria
- Electron transport system – in the inner membrane of mitochondria
- Both aerobic and anaerobic respiration starts with glycolysis.
- In aerobic respiration glycolysis is followed by Citric acid cycle and ETS (both occur in mitochondria).
- In anaerobic respiration glycolysis is followed by formation of ethyl alcohol / lactic acid in the cytoplasm.

GLYCOLYSIS

- It is the process of break down of glucose in to pyruvic acid.
- It was given by Embden, Meyerhof and Parnas
- A chain of 10 reactions converts glucose into pyruvate.
- Net ATPs produced = 4 (produced) − 2 (consumed) = 2 ATPs

Preparatory Phase:

- This phase starts with the phosphorylation of glucose using ATP to form glucose-6-phosphate.
- It isomerises to form fructose-6-phosphate.
- It is then phosphorylated to form fructose-1, 6-bisphosphate. It splits into two molecules of 3-carbon-3 phosphoglyceraldehyde, and DHAP.
- As DHAP cannot be utilised directly, it isomerises into PGAL.
- Thus, two molecules of PGAL are formed from one molecule of fructose-1, 6- bisphosphate.

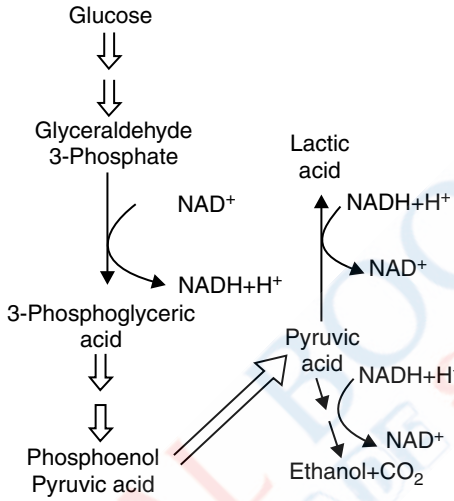
Pay-off Phase :

- This phase starts with the phosphorylation of PGAL using inorganic phosphate to form BPGA.
- The two redox-equivalents removed from PGAL are transferred to NAD^+ to form $NADH_2$.
- The BPGA thus formed undergoes dephosphorylation to form PGA. This is an energy yielding step to form ATP molecules.
- As the inorganic phosphate is directly transferred from a substrate to the ADP molecule to form ATP, it is called substrate-level phosphorylation.
- The phosphate group in 3-phosphoglycerate is relocated to form 2-phosphoglycerate, which is then converted into PEP.

- The final step is the energy yielding reaction involving dephosphorylation of PEP to form 3-carbon pyruvate.
- The phosphate released from the PEP molecule is captured by ADP to form ATP molecule. This ends the process of glycolysis.

FERMENTATION

- Incomplete oxidation of pyruvic acid, under anaerobic respiration forms lactic acid/ ethyl alcohol.
- It occurs in bacteria, yeast and striated muscles.
- Based on the end product, the process can be classified as either alcohol fermentation or lactic acid fermentation.
- The fermentation of alcohol takes place in yeast, which are facultative anaerobes.



Major pathways of anaerobic respiration

- In them, pyruvic acid is reduced to carbon dioxide and ethanol with the help of enzymes.
- During physical exercise, muscle cells undergo anaerobic respiration. The enzyme, lactate dehydrogenase, uses NADH to reduce the pyruvate molecule to lactate.
- In this process, NADH is re-oxidised to NAD^+ and used in the glycolysis pathway.
- The accumulation of lactate is the reason for the stiffness in the muscles.
- Both alcohol and lactic acid fermentation yield less energy.
- Not even 7% of the energy present in the glucose is released, and of that, only some amount of energy is trapped in the form of ATP. Also, the products formed are either alcohol or lactic acid, which is hazardous in nature.
- In fact, yeast is poisoned to death when the concentration of alcohol reaches about 13 per cent.
- Fermentation releases less energy than the process followed in the presence of oxygen.

TOPIC-2

Aerobic Respiration

Revision Notes

AEROBIC RESPIRATION

- For aerobic respiration to take place within the mitochondria, the final product of glycolysis, pyruvate is transported from the cytoplasm into the mitochondria.
- The crucial events in aerobic respiration are:

(i) The complete oxidation of pyruvate by the stepwise removal of all the hydrogen atoms, leaving three molecules of CO_2.

(ii) The passing on of the electrons removed as part of the hydrogen atoms to molecular O_2 with simultaneous synthesis of ATP.

(iii) Pyruvate, which is formed by the glycolytic catabolism of carbohydrates in the cytosol, after it enters mitochondrial matrix undergoes oxidative decarboxylation by a complex set of reactions catalysed by pyruvic dehydrogenase.

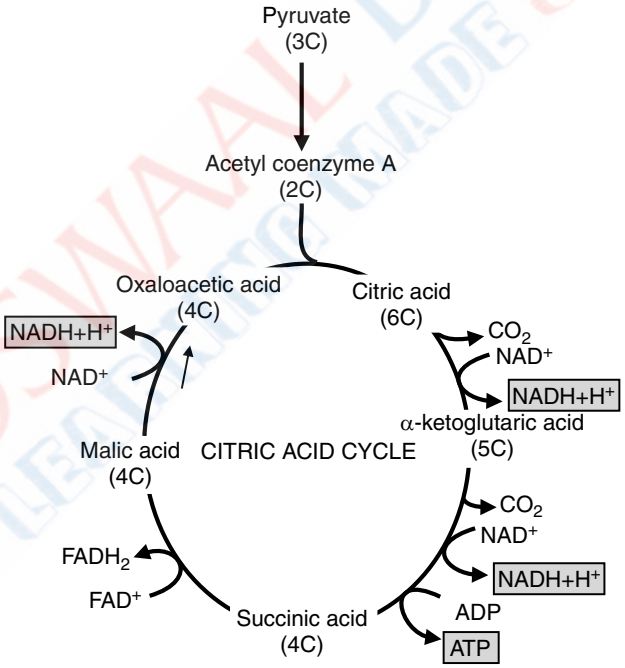
(iv) The reactions catalysed by pyruvic dehydrogenase require the participation of several coenzymes, including NAD^+ and Coenzyme A.

$$\text{Pyruvic acid} + \text{CoA} + NAD^+ \xrightarrow[\text{Pyruvate dehydrogenase}]{Mg^{2+}} \text{Acetyl CoA} + CO_2 + NADH + H^+$$

- During this process, two molecules of NADH are produced from the metabolism of two molecules of pyruvic acid (produced from one glucose molecule during glycolysis).
- The acetyl CoA then enters a cyclic pathway, tricarboxylic acid cycle, more commonly called as Krebs' cycle after the scientist Hans Krebs who first elucidated it.

Tricarboxylic Acid Cycle / Kreb's Cycle

- The TCA cycle starts with the condensation of acetyl group with oxaloacetic acid (OAA) and water to yield citric acid. The reaction is catalysed by the enzyme citrate synthase and a molecule of CoA is released.
- Citrate is then isomerised to isocitrate. It is followed by two successive steps of decarboxylation, leading to the formation of α-ketoglutaric acid and then succinyl-CoA.



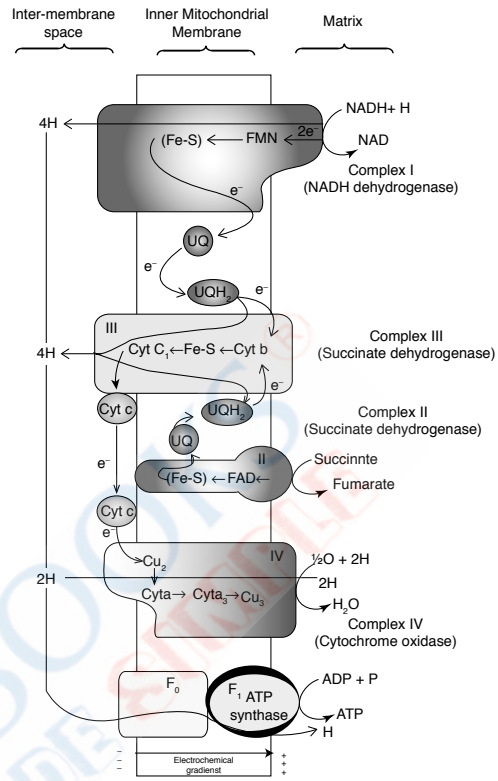
The citric acid cycle

- In the remaining steps of citric acid cycle, succinyl-CoA is oxidised to OAA allowing the cycle to continue. During the conversion of succinyl-CoA to succinic acid a molecule of GTP is synthesised. This is a substrate level phosphorylation.
- In a coupled reaction GTP is converted to GDP with the simultaneous synthesis of ATP from ADP. Also there are three points in the cycle where NAD^+ is reduced to NADH + H^+ and one point where FAD^+ is reduced to $FADH_2$.
- The continued oxidation of acetic acid via the TCA cycle requires the continued replenishment of oxaloacetic acid, the first member of the cycle. In addition it also requires regeneration of NAD^+ and FAD^+ from NADH and $FADH_2$ respectively.

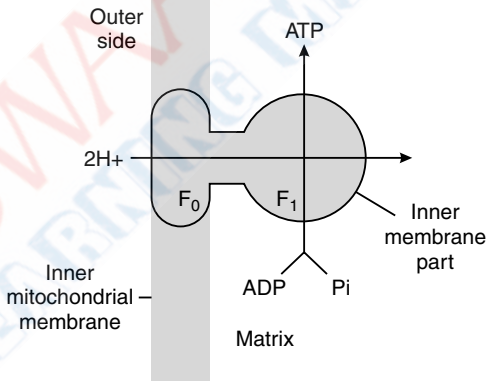
$$\text{Pyruvic acid} + 4NAD^+ + FAD^+ + 2H_2O + ADP + Pi \xrightarrow{\text{Mitochondrial Matrix}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$

Electron Transport System (ETS) and Oxidative Phosphorylation

- Glycolysis and the Krebs' Cycle together result in the formation of reduced coenzymes such as ten molecules of NADH + H^+ ions and two molecules of $FADH_2$, and four molecules of ATP.
- These reduced co-enzymes need to be oxidised to release and utilise the energy stored in them.
- This is made possible by the transport of protons and electrons from these co-enzymes to oxygen through electron carriers present in the inner mitochondrial membrane.
- This metabolic pathway of electron transport is called the Electron Transport System.
- ETS serves three important functions in aerobic respiration.
- It regenerates the oxidised form of co-enzymes to be used in glycolysis and the Krebs' Cycle.
- It transports $2H^+$ and 2 electrons to oxygen, and it utilises the energy of the co-enzymes in the production of ATP.
- ETS comprises several electron carriers that include complex I, complex Q, complex II, complex III, cytochrome c, and complex IV.
- Electrons from NADH + H^+ are transferred through complex I to ubiquinone, and protons are moved from the matrix of the mitochondria to the inter-membrane space.
- Similarly, the electrons from $FADH_2$ are transferred through complex II to complex Q, and protons are moved from the matrix of the mitochondria to the inter-membrane space, complex Q transfers the electrons to complex III, these transfers the electrons to complex IV through cytochrome c.
- Complex IV contains cytochrome *a* and cytochrome a_3. It transfers the electrons to the final electron acceptor oxygen.



Electron Transport System (ETS)



ATP Synthesis in Mitochondria

- Oxygen, on receiving the electrons, reacts with $2H^+$ ions and reduces to water and thereby drives the ETS.
- The electron transport chain is coupled to ATP synthesis.
- The electron transport and movement of protons creates a proton gradient across the mitochondrial membrane.
- The protons are pumped through a membrane protein called complex-V.
- The energy derived from the proton pumping is used for the synthesis of ATP.
- Oxidation of NADH results in 3 molecules of ATP, whereas oxidation of $FADH_2$ results in 2 molecules of ATP.
- Aerobic respiration uses energy conserved in co-enzymes during oxidation-reduction reactions to create the proton gradient required for phosphorylation.
- The net gain of ATP produced during aerobic respiration from one molecule of glucose, during glycolysis, Krebs' cycle and ETS are 38 ATP.
- Fermentation, on the other hand, results in a net gain of 2ATP molecules from the partial breakdown of the glucose molecule.
- Oxygen acts as the final hydrogen acceptor.
- In respiration it is the energy of oxidation-reduction utilised for the production of proton gradient required for phosphorylation. Hence, this process is called oxidative phosphorylation.
- The energy released during the electron transport system is utilised in synthesising ATP with the help of ATP synthase (complex V). This complex consists of two major components, F_1 and F_0.
- The F_1 headpiece is a peripheral membrane protein complex and contains the site for synthesis of ATP from ADP

and inorganic phosphate. F_0 is an integral membrane protein complex that forms the channel through which protons cross the inner membrane.

- The passage of protons through the channel is coupled to the catalytic site of the F_1 component for the production of ATP. For each ATP produced, $2H^+$ passes through F_0 from the intermembrane space to the matrix down the electrochemical proton gradient.

TOPIC-3

The Respiratory Balance Sheet, Amphibolic Pathway and Respiratory Quotient

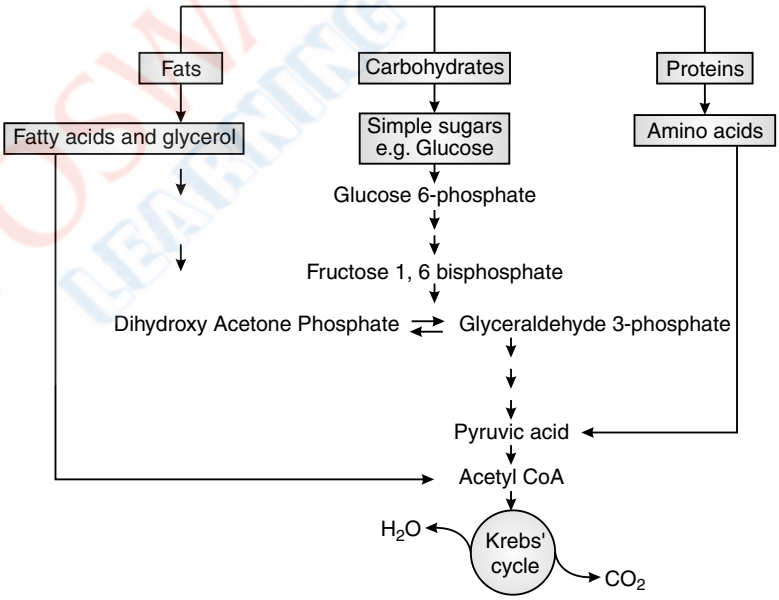
Revision Notes

THE RESPIRATORY BALANCE SHEET

- There is a sequential, orderly pathway functioning, with one substrate forming the next and with glycolysis, TCA cycle and ETS pathway following one after another.
- The NADH synthesised in glycolysis is transferred into the mitochondria and undergoes oxidative phosphorylation.
- None of the intermediates in the pathway are utilised to synthesise any other compound.
- Only glucose is being respired – no other alternative substrates are entering in the pathway at any of the intermediary stages.
- Hence, there can be a net gain of 36 ATP molecules during aerobic respiration of one molecule of glucose.
- Fermentation accounts for only a partial breakdown of glucose whereas in aerobic respiration it is completely degraded to CO_2 and H_2O.
- In fermentation there is a net gain of only two molecules of ATP for each molecule of glucose degraded to pyruvic acid whereas many more molecules of ATP are generated under aerobic conditions.
- NADH is oxidised to NAD^+ rather slowly in fermentation, however the reaction is very vigorous in case of aerobic respiration.

AMPHIBOLIC PATHWAY

- The amphibolic pathway involves both catabolism and anabolism where catabolism stands for the breakdown of complex substances to produce energy and anabolism stands for the synthesis of complex substance from simple substances.



Interrelationship among metabolic pathways showing respiration mediated breakdown of different organic molecules to CO_2 and H_2O

RESPIRATORY QUOTIENT

- It is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration.
- When carbohydrates are used as substrate and are completely oxidised, the RQ will be 1, because equal amounts of CO_2 and O_2 are evolved and consumed, respectively

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$

$$RQ = \frac{6CO_2}{6O_2} = 1.0$$

- When fats are used in respiration, the RQ is less than 1.
  $2(C_{51}H_{25}O_6) + 145O_2 \longrightarrow 102CO_2 + 98H_2O + \text{Energy}$
  Tripalmitin

$$RQ = \frac{102CO_2}{145O_2} = 0.7$$

- When proteins are respiratory substrates the ratio would be about 0.9.
- In living organisms, the respiratory substances are often more than one. Hence, pure proteins or fats are never used as respiratory substrates.

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Chapter 15

Plant Growth and Development

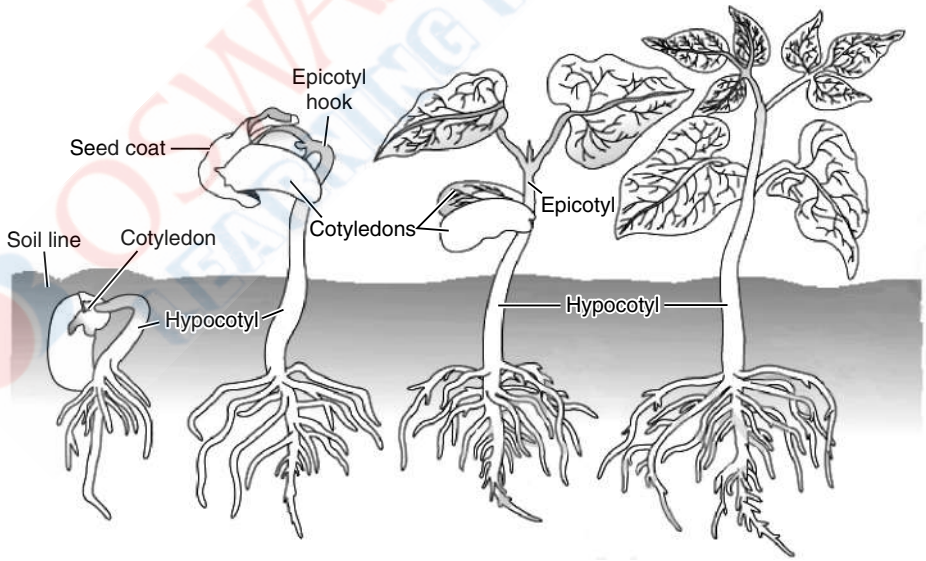
TOPIC-1

Growth, Phases of Growth, Growth Rates

Revision Notes

Growth

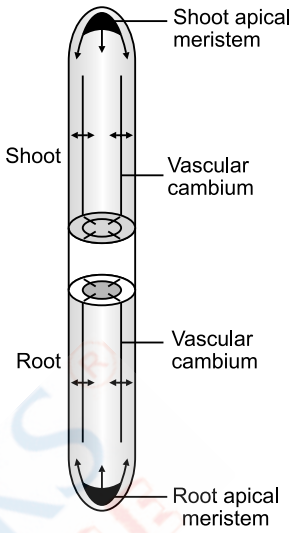
- Growth is an irreversible permanent increase in size of an organ or its parts or even of an individual.
- Growth is regarded as one of the most fundamental and conspicuous characteristics of a living being.
- Growth is accompanied by metabolic processes (both anabolic and catabolic), that occur at the expense of energy.



Germination and Seeding development in bean

- Plant growth is unique because plants retain the capacity for unlimited growth throughout their life due to the presence of meristems at certain locations in their body.
- The meristematic cells have the capacity to divide and self-perpetuate.
- The addition of new cells to the plant body by the activity of the meristem is called the open form of growth.
- The root apical meristem and the shoot apical meristem are responsible for the primary growth of the plants and contribute to the elongation of the plants along their axis.

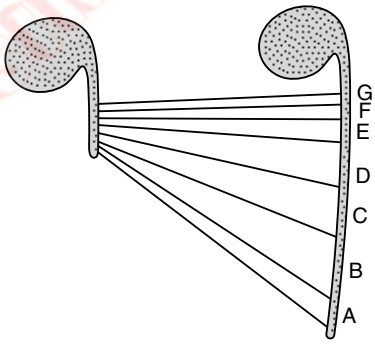
- In dicotyledonous plants and gymnosperms, the lateral meristems, vascular cambium and cork-cambium appear later in life. These are the meristems that cause the increase in the girth of the organs in which they are active. This is known as secondary growth of the plant.
- Growth is measured by a variety of parameters some of which are: increase in fresh weight, dry weight, length, area, volume and cell number.
- One single maize root apical meristem can give rise to more than 17,500 new cells per hour, whereas cells in a watermelon may increase in size by upto 3,50,000 times.
- The growth of a pollen tube is measured in terms of its length, an increase in surface area denotes the growth in a dorsi-ventral leaf.



Locations of root apical meristem. shoot apical meristem and vascular cambium.

Phases of Growth

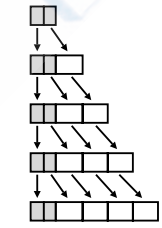
- The period of growth is generally divided into three phases, namely, meristematic, elongation and maturation.
- The constantly dividing cells, both at the root apex and the shoot apex, represent the meristematic phase of growth.
- The cells in this region are rich in protoplasm, possess large conspicuous nuclei.
- Their cell walls are primary in nature, thin and cellulosic with abundant plasmodesmatal connections.
- The cells proximal (just next, away from the tip) to the meristematic zone represent the phase of elongation. Increased vacuolation, cell enlargement and new cell wall deposition are the characteristics of the cells in this phase.
- The cells of the maturation phase zone, attain their maximal size in terms of wall thickening and protoplasmic modifications.



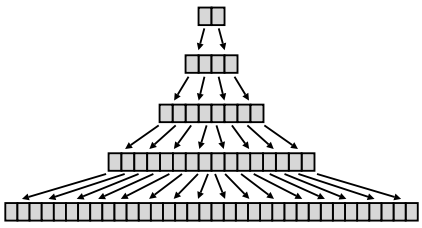
Detection of zones of elongation by the parallel line technique. Zones A, B, C, D immediately behind the apex have elongated most.

Growth Rate

- When growth is measured per unit time, it is called growth rate.
- The growth rate is due to increase in the number of cells which can be the result of arithmetic or geometric growth.
- In arithmetic growth, following mitotic cell division, only one daughter cell continues to divide while the other differentiates and matures. It gives a linear curve. Example - Elongation of root at a constant rate.
- Geometric growth, on the other hand is the division of both daughter cells obtained during mitosis. This type of growth is seen at the early stage of plant development, that is, development of the zygote to embryo.
- We can plot a graph for geometric growth by taking the length of the plant part on the Y-axis and the time taken for growth on the X-axis. An 'S' shaped sigmoidal curve is obtained.
- A sigmoid curve is a characteristic feature of living organism growing in a natural environment. Growth is slower in the initial phase and is called the lag phase. Later, growth is rapid, at an exponential rate, and is called the elongation or log phase. Finally, growth slows and it is called the stationary phase.

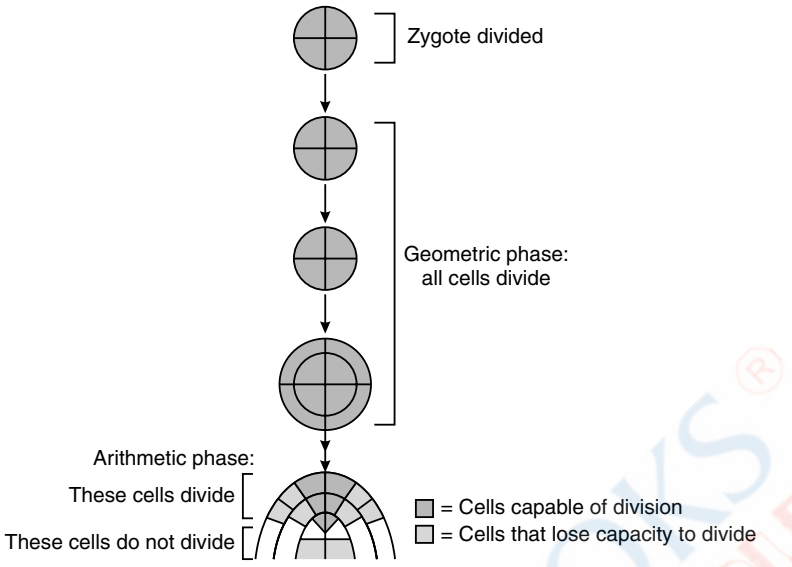


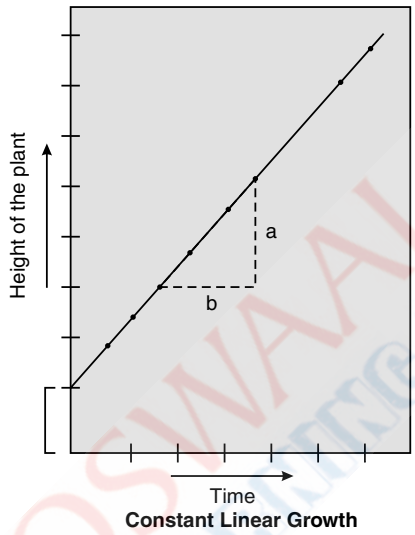
Arithmetic Growth



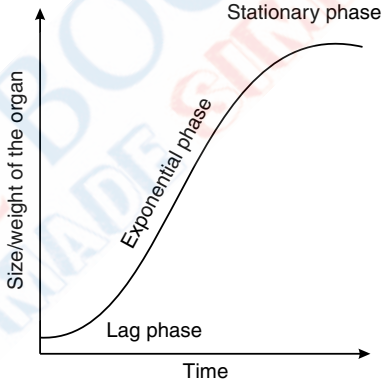
Geometric Growth

- The growth rate obtained here is called the relative growth rate.
- Geometric growth can be seen during the development of the zygote to embryo, and arithmetic growth in the later stages of development of the seed into a mature plant.
- Growth in plants can be quantitatively compared using absolute growth rate and relative growth rate.
- Absolute growth rate is the total growth of a plant part per unit time, while relative growth rate refers to the growth of a plant part per unit initial parameter.
- The difference in the relative growth rate may be due to the difference in growth conditions. Plants require specific conditions such as water, oxygen, nutrients, temperature, light and gravity for growth.





Constant Linear Growth



An idealised sigmold growth curve typical of cells in culture, and many highter plants and plant organs

TOPIC-2

Differentiation, Dedifferentiation and Redifferentiation, Development and Plant Growth Regulators

Revision Notes

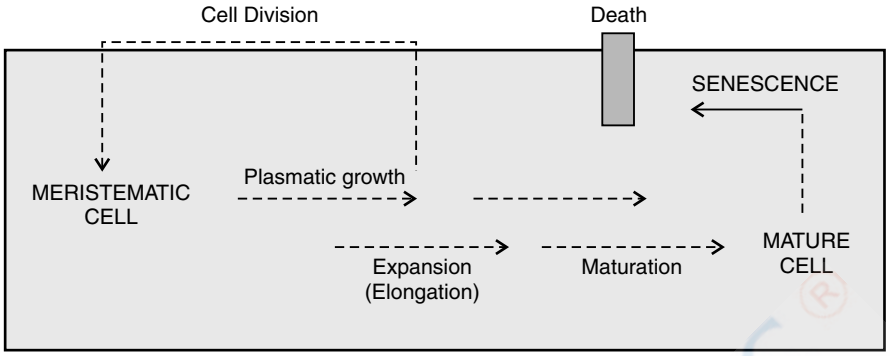
DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION

- Differentiation is a biochemical or morphological change in meristematic cell (at root apex and shoot apex) to differentiate into permanent cell.
- Dedifferentiation is the phenomenon by which the permanent tissue regain the capacity to become meristematic.
- For example, formation of interfascicular cambium and cork cambium from fully differentiated parenchyma cells.
- Redifferentiation is a process by which meristems/tissue formed by dedifferentiation is capable of producing new cells that once again lose the capacity to divide but mature to perform specific functions.

DEVELOPMENT

- Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence.

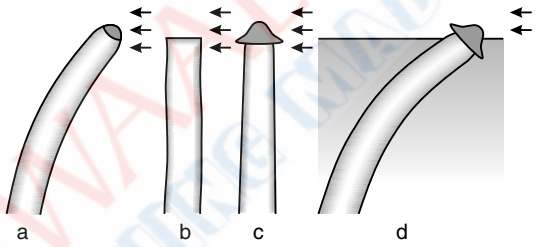
- Plasticity is the ability of the plants to follow different pathways in response to environment or phases of life to form different kinds of structures. Example–Heterophylly in cotton, coriander and larkspur.



Sequence of the developmental process in a plant cell

PLANT GROWTH REGULATORS

- Plant growth regulators are chemical compounds that include auxin, giberrellin, cytokinin, abscisic acid and ethylene.
- They are divided into two groups namely,
  (a) Plant growth promoters
  (b) Plant growth inhibitors.
- Plant growth promoters enhance growth activities like cell division, cell enlargement, flowering, fruiting and seed formation.
- Auxin, gibberellin and cytokinin act as plant growth promoters.
- Plant growth inhibitors respond to wounds and stress from biotic or abiotic factors or both by inhibiting growth.



Experiment used to demonstrate that up of the coleoptile is the source of auxin.

1. *Auxins* :

- The discovery of auxin was initiated when Charles Darwin and his son Francis Darwin observed the coleoptile of canary grass exhibiting phototropism towards blue light.
- Later, F.W. Went discovered that a substance at the tip of the plant was responsible for its growth and called it "auxin", which means 'to grow' in Greek.
- But the chemical structure of auxin was identified when it was isolated from the urine of a patient by Kogl and Thimann.

Functions and Effects :

(a) Auxins are well known to promote elongation of stem and coleoptile. It promotes the growth by cell enlargement in stems, particularly by elongation of cells behind the apical meristem.

(b) Growth in lateral bud is inhibited when the apical bud of a tall plant remains intact. However, the lateral bud grows rapidly on removal of apical bud.

(c) Suppression of growth in lateral bud by apical bud due to auxin produced by apical bud is termed as apical dominance. The reason for this is due to auxin produced in growing tip and it stimulates growth but as it moves downward, suppresses growth in the stems below.

(d) Auxin is responsible for initiation and promotion of cell division in cambium, which is responsible for the secondary growth. This property of induction of cell division has been exploited for tissue culture techniques and for the formation of callus.

(e) Auxin promotes growth of root only at extremely low concentrations. At higher concentrations, it always inhibits growth of root.

(f) When leaves and fruits mature, they shed from the stem. This is called abscission. Auxin prevents abscission.

(g) Seedless fruits are produced in tomato and apple, by external application of auxin on flowers. Such seedless fruits are called parthenocarpic fruits.

(h) 2, 4 – Dichlorophenoxy acetic acid, a synthetic auxin is used to eradicate weeds in the field.

2. *Gibberellins* :

- The discovery of gibberellin was initiated by E. Kurosawa who observed abnormal tallness in rice seedlings struck by bakane or foolish seedling disease. This disease is caused by the fungus *Gibberalla fujikuroi.*
- Later, Yabuta and Sumiki isolated the substance secreted by the fungus and called it "gibberellin".

Functions and Effects :

(a) Gibberellins produce extraordinary elongation of stem. The elongation of stem is caused by the cell division and cell elongation induced by gibberellic acid.

(b) One of the most striking effects of the gibberellins is the reversal of dwarfism in many genetically dwarf plants. For *e.g.*, 'Rosette' plant of sugar beet, when treated with GA undergoes marked longitudinal growth of axis attaining the normal size.

(c) Rosette plants usually show reduced internodal growth. These plants exhibit excessive internodal growth when they are treated with gibberellin. This sudden elongation of stem followed by flowering is called bolting.

(d) Many biennials usually flower during the second year of their growth. For flowering to take place, these plants should be exposed to cold season. Such plants could be made to flower without exposure to cold season in the first year itself, when they are treated with gibberellins.

(e) Formation of seedless fruits without fertilization can also be induced by gibberellin treatment in many plants. Examples - Tomatoes, apples, cucumbers, etc.

(f) Some of the light sensitive seeds can germinate by the treatment of gibberellic acid even in complete darkness. Example – barley.

(g) Gibberellin breaks dormancy in potato tubers.

3. *Cytokinins*

- The discovery of cytokinin was done by F. Skoog and his co-workers, who noticed that cells extracted from the internodal segment of the tobacco stem proliferated to callus when the nutrient medium is supplemented with extracts of vascular tissues, yeast and coconut milk in addition to auxin.
- Later, Skoog and Miller isolated and crystallised the substance that promoted cytokinesis in plant cells. It was then named "kinetin".

Functions and Effects :

(a) The most important function of cytokinin is the promotion of cell division.

(b) In association with IAA, cytokinin initiates bud and root formation in callus tissue.

(c) External application of cytokinin promotes the growth of lateral buds even if the apical bud is intact.

(d) Cytokinin breaks the dormancy of many seeds and also promotes germination.

(e) Application of cytokinin delays the process of ageing in plants. This is also known as Richmond Lang effect.

4. *Ethylene*

- The discovery of ethylene was identified by Cousins who observed the release of a volatile substance from ripened oranges. He also found that the volatile substance promoted ripening of other unripened oranges.
- Later, this volatile substance was identified as "ethylene", a gaseous PGR.

Functions and Effects :

(a) Ethylene prevents elongation of stem and root in longitudinal direction. Simultaneously, the tissue enlarges radially resulting in thickening of plant parts.

(b) Ethylene promotes positive geotropic growth of roots.

(c) Ethylene inhibits the growth of lateral buds in pea seedlings.

(d) Ethylene is involved in the ripening of fruits. It enhances the respiration rate during ripening of the fruits. This rise in rate of respiration is called respiratory climactic.

(e) Ethylene stimulates the formation of abscission zone in leaves, flowers and fruits. This causes leaves, flowers and fruits to shed prematurely.

(f) Flowering can be induced by application of ethylene in plants like pineapple and mango.

(g) Ethylene stimulates rooting of cuttings, initiation of lateral roots and growth of root hair.

(h) Ethylene is responsible for breaking the dormancy of buds and seeds.

(i) The most widely used compound as source of ethylene is ethephon.

5. ***Abscisic acid***

- The discovery of abscisic acid dates back to the 1960s when three independent researchers purified three different inhibitors of plant growth, namely inhibitor-B, abscission II and dormin.
- Later, they were recognised chemically identical and were called "abscisic acid".

Functions and Effects :

(a) Abscisic acid acts as growth inhibitor and induces bud dormancy in a variety of plants.

(b) Abscisic acid is a powerful growth inhibitor. It causes 50 per cent inhibition of growth of oat seedlings.

(c) As the name suggests abscisic acid is a hormone that stimulates abscission.

(d) Abscisic acid controls geotropic responses of roots. It stimulates positive geotropism in roots.

(e) Abscisic acid causes closure of stomata.

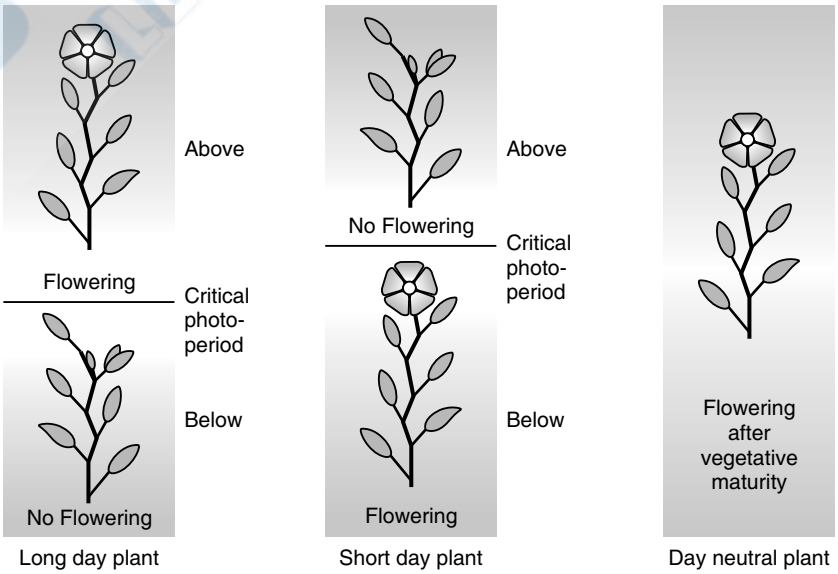
(f) Abscisic acid inhibits lateral bud growth in tomato.

TOPIC-3
Photoperiodism and Vernalisation

Revision Notes

PHOTOPERIODISM

- The response of a plant to the relative lengths of light and dark periods is known as photoperiodism.
- The most significant photoperiodic response in plants is the initiation of flowering.
- It has been first observed in Maryland Mammoth variety of tobacco (*Nicotiana tabacum*).
- From the observation of Garner and Allard all the plants do not require the same length of light and dark periods for flowering.
- Plants require specific period of light and darkness for flowering. It is known as critical period.
- The plants requiring longer exposure to light than their critical period are known as long day plants. It includes wheat and oats.
- The plants requiring light for a shorter period than their critical period are known as short day plants. It includes tobacco and *Chrysanthemum*.
- The plants in which flowering is unaffected by the photoperiod are known as day neutral plants. It includes sunflower and maize.



VERNALISATION

- The term vernalisation was first introduced by a Russian scientist T.D. Lysenko in 1920. Many species, especially biennials and perennials are induced to flower at low temperature range of 1°C to 10°C. This is known as vernalisation.
- It prevents precocious reproductive development late in the growing season, and enables the plant to have sufficient time to reach maturity.
- Some important food plants, wheat, barley, rye have two kinds of varieties: winter and spring varieties.
- The 'spring' variety are normally planted in the spring and come to flower and produce grain before the end of the growing season.
- Winter varieties, if planted in spring would normally fail to flower or produce mature grain within a span of a flowering season. Hence, they are planted in autumn.
- They germinate, and over winter come out as small seedlings, resume growth in the spring, and are harvested usually around mid-summer.
- Another example of vernalisation is seen in biennial plants where a monocarpic plants that normally flower and die in the second season.
- Sugarbeet, cabbages, carrots are some of the common biennials.
- When a biennial plant is given a cold treatment, it stimulates a subsequent photoperiodic flowering response.

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Chapter 16

Digestion and Absorption

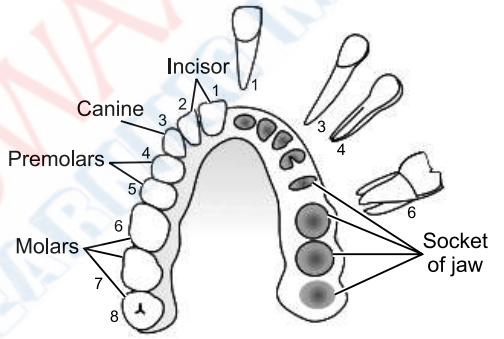
TOPIC-1
Digestive System

Revision Notes

Digestion : The process of conversion of complex food substances to simple absorbable forms is called digestion and is carried out by our digestive system by mechanical and biochemical methods.

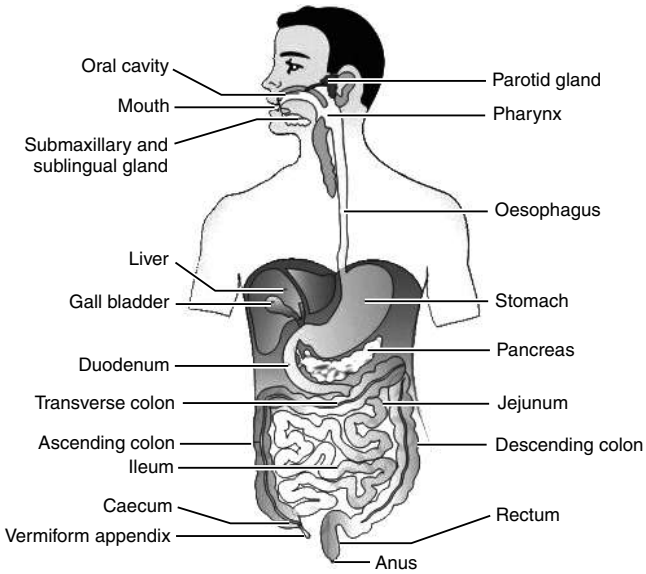
Digestive System

- The alimentary canal starts with the mouth, which contains the teeth and the tongue.

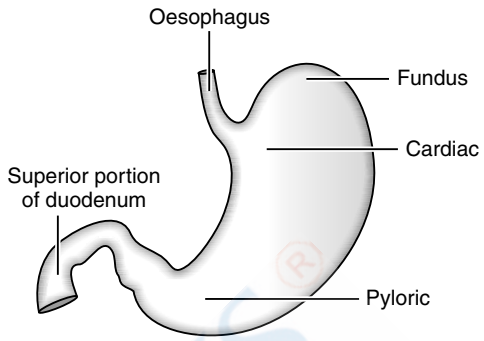


Arrangement of different types of teeth in the jaws

- The oral cavity has a number of teeth and a muscular tongue.
- Each tooth is embedded in a socket of jaw bone
- This type of attachment is called thecodont.
- Majority of mammals including human being forms two sets of teeth during their life, a set of temporary milk or deciduous teeth replaced by a set of permanent or adult teeth. This type of dentition is called diphyodont.
- An adult human has 32 permanent teeth which are of four different types *i.e.*, heterodont dentition namely, incisors (I), canine (C), premolars (PM) and molars (M).
- The arrangement of teeth in each half of the upper and lower jaw in the order I, C, PM, M is represented by a dental formula which in human is 2123/2123.
- The hard chewing surface of the teeth, made up of enamel, helps in the mastication of food.
- The tongue is a freely movable muscular organ attached to the floor of the oral cavity by the frenulum.
- The upper surface of the tongue has small projections called papillae, some of which bear taste buds.

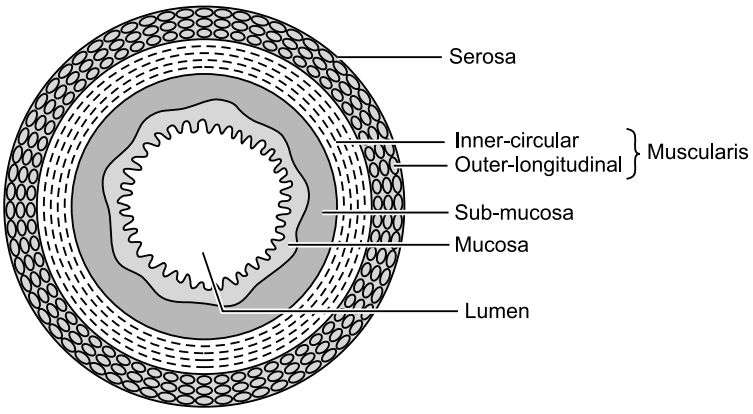


The human digestive system



Human Stomach

- The oral cavity leads into a short pharynx which serves as a common passage for food and air. The oesophagus and the trachea (wind pipe) open into the pharynx.
- A cartilaginous flap called epiglottis prevents the entry of food into the glottis – opening of the wind pipe during swallowing.
- The oesophagus is a thin, long tube which extends posteriorly passing through the neck, thorax and diaphragm and leads to a 'J' shaped bag like structure called stomach.
- A muscular sphincter (gastro-oesophageal) regulates the opening of oesophagus into the stomach.
- The stomach is made of a fundic region, a cardiac portion and a pyloric portion.
- The pyloric sphincter regulates the flow of the churned food from the stomach into the duodenum, which is followed by the jejunum and ileum that make up the rest of the small intestine.
- Ileum opens into the large intestine.
- The large intestine consists of caecum, colon and rectum.
- Caecum is a small blind sac which hosts some symbiotic micro-organisms.
- A narrow finger-like tubular projection, the vermiform appendix which is a vestigial organ, arises from the caecum.
- The walls of the anus and other organs of the alimentary canal are made of four layers of tissues, the serosa, muscularis, sub-mucosa and mucosa.
- The serosa is made up of a thin mesothelium along with some connective tissues.
- It is followed by the muscularis, a muscle layer made up of a circular inner layer and a longitudinal outer layer of smooth muscle cells.
- Adjoining the muscularis is the sub-mucosa, which is a soft connective tissue layer containing blood vessels, nerve endings and lymphatic vessels.
- The innermost layer of the alimentary canal is mucosa, which lines the lumen of the alimentary canal.



T.S. of Gut

- Mucosa forms gastric glands and rugae in stomach, whereas in the small intestine, mucosa forms villi and microvilli.
- The innermost layer forms irregular folds (rugae) in the stomach and small finger-like foldings called villi in the small intestine.

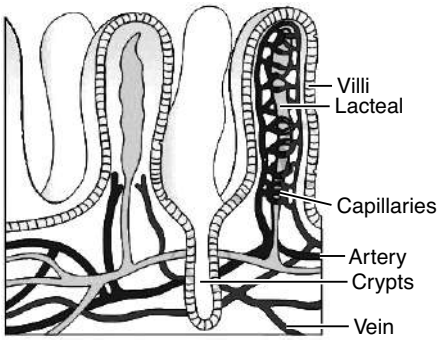
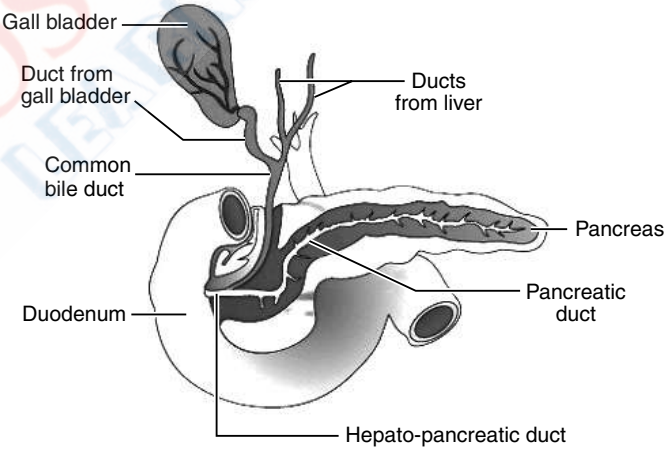


Diagram of villi in small intestine

- The cells lining the villi produces numerous microscopic projections called microvilli giving a brush border appearance.
- These modifications increase the surface area enormously.
- Villi are supplied with a network of capillaries and a large lymph vessel called the lacteal.
- Mucosal epithelium has goblet cells which secrete mucus that help in lubrication.
- Mucosa also forms glands in the stomach (gastric glands) and crypts in between the bases of villi in the intestine (crypts of Lieberkuhn).
- All the four layers show modifications in different parts of the alimentary canal.

Digestive Glands

- Apart from the alimentary canal, the digestive glands consist of the salivary glands, the liver and the pancreas.
- There are three pairs of salivary glands – the parotid gland located in the cheek, the sub-maxillary or sub-mandibular glands found in the lower jaw and the sub-lingual gland located below the tongue, which secretes saliva.
- Liver is the largest gland of the body weighing about 1.2 to 1.5 kg in an adult human.
- It is situated in the abdominal cavity, just below the diaphragm and has two lobes.
- The hepatic lobules are the structural and functional units of liver containing hepatic cells arranged in the form of cords.



The duct systems

- Each lobule is covered by a thin connective tissue sheath called the Glisson's capsule.
- The bile secreted by the hepatic cells passes through the hepatic ducts and is stored and concentrated in a thin muscular sac called the gall bladder.
- The duct of gall bladder (cystic duct) along with the hepatic duct from the liver forms the common bile duct.
- The pancreatic juices and bile pour into the duodenum through hepato-pancreatic duct, guarded by the sphincter of Oddi.
- The pancreas is a compound (both exocrine and endocrine) elongated organ situated between the limbs of the 'U' shaped duodenum.

- The exocrine portion secretes an alkaline pancreatic juice containing enzymes and the endocrine portion secretes hormones, insulin and glucagon.

TOPIC-2
Digestion of Food

Revision Notes

- Carbohydrates, fats, proteins and nucleic acids occur in food in the form of large and complex insoluble macromolecules (polymers). These macromolecules are converted into small monomers by the action of enzyme.
- In buccal cavity, teeth and tongue help in mastication and mixing of food. Mucus in saliva mixes with masticated food to form bolus. Bolus is passed to pharynx and oesophagus by swallowing or deglutition.
- Chemical digestion of food starts in oral cavity by the action of enzyme salivary amylase and lysozyme.
- Lysozyme acts as antibacterial agent in mouth to prevent infection.

$$\text{Starch} \xrightarrow{\text{Salivary anylase}} \text{Maltose}$$

- Mucosa of stomach have gastric glands having three types of cells- mucus neck cells that secrete mucus, peptic or chief cells that secretes proenzyme pepsinogen and parietal or oxyntic cells that secretes HCl.
- Food mixes with gastric juice due to churning action of muscular wall to form chyme.
- Hydrochloric acid [HCl] activates the pepsinogen to pepsin to digest protein.
- Mucus and bicarbonates present in gastric juice play important role in lubrication and protecting inner wall of stomach from the action of hydrochloric acid [HCl].
- Rennin is a proteolytic enzyme found in gastric juice of infants to digest milk protein.

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

$$\text{Milk casein} \xrightarrow{\text{Rennin}} \text{Paracasein,}$$

$$\text{Paracasein + Ca} \longrightarrow \text{Calcium paracaseinate (Curd)}$$

$$\text{Paracaseinate Curd} \xrightarrow{\text{Pepsin}} \text{Peptone paracaseinate (Curd)}$$

$$\text{Fat} \xrightarrow{\text{Lipase}} \text{Diglycerides} \longrightarrow \text{Monoglycerides}$$

- The bile, pancreatic juice and intestinal juice are released in small intestine.
- Pancreatic juice contains inactive trypsinogen, chymotrypsinogen, procarboxypeptidases, amylases, lipases and nucleases.
- Trypsinogen is activated by enzyme enterokinase into trypsin, which further activates the other enzyme of intestinal juice.
- Bile contains bile pigments (bilirubin and biliverdin), bile salts, cholesterol and phospholipids which help in emulsification of fats.

$$\text{Proteoses \& peptones} \xrightarrow{\text{Trypsin}} \text{Tri and dipeptides}$$

$$\text{Starch \& glycogen} \xrightarrow{\text{Amylase}} \text{Maltose}$$

$$\text{Emulsified fats} \xrightarrow{\text{Steapsin}} \text{Fatty acids \& glycerols}$$

$$\text{Maltose} \xrightarrow{\text{Maltase}} \text{Glucose + Glucose}$$

$$\text{Polypeptides} \xrightarrow{\text{Carboxypeptidase}} \text{Tri and dipeptides}$$

$$\text{Nucleic acids} \xrightarrow{\text{Nuclease}} \text{Nucleotides + Nucleosides}$$

- Secretion of brush border cells of mucosa and goblet cells contain enzyme succus entericus, containing variety of enzymes to complete the process of digestion.

$$\text{Dipeptides} \xrightarrow{\text{Dipeptidases}} \text{Amino acids}$$

$$\text{Maltose} \xrightarrow{\text{Maltase}} \text{Glucose + Glucose}$$

$$\text{Lactose} \xrightarrow{\text{Lactase}} \text{Glucose + Galactose}$$

$$\text{Sucrose} \xrightarrow{\text{Sucrase}} \text{Glucose} + \text{Fructose}$$

$$\text{Nucleotides} \xrightarrow{\text{Nucleotidase}} \text{Nucleosides} \xrightarrow{\text{Nucleosidase}} \text{Sugars} + \text{Bases}$$

$$\text{Di and monoglycerides} \xrightarrow{\text{Lipases}} \text{Fatty acids} + \text{Glycerol}$$

TOPIC-3

Absorption of Digested Products and Disorders of Digestive System

Revision Notes

Absorption of Digested Products

- Absorption is the process by which nutrients pass from the alimentary canal into the blood and lymph through its mucous membrane.
- Amino acids, monosaccharide, fatty acids, glycerol, salts, vitamins and water are to be absorbed.
- About 90% of absorption occurs in small intestine and rest 10% in stomach, mouth and large intestine.
- Absorption takes place in the intestinal mucosa, through passive transport and active transport.
- Small amounts of monosaccharides like glucose, amino acids and some of electrolytes like chloride ions are generally absorbed by simple diffusion.
- Some of the substances like fructose and some amino acids are absorbed with the help of the carrier ions like Na^+ mechanism is called facilitated transport.
- On the other hand, transport of water takes place from a dilute to a concentrated medium through osmosis.
- Absorption of nutrients such as sodium ions, glucose, galactose and amino acids take place against the concentration gradient through active transport which is much quicker and requires energy.
- Fatty acids and glycerol being insoluble, cannot be absorbed into the blood.
- They are first incorporated into small droplets called micelles which move into the intestinal mucosa.
- They are re-formed into very small protein coated fat globules called the chylomicrons which are transported into the lymph vessels (lacteals) in the villi.
- These lymph vessels ultimately release the absorbed substances into the blood stream.

Mouth	Stomach	Small Intestine	Large Intestine
Certain drugs coming in contact with the mucosa of mouth and lower side of the tongue are absorbed into the blood capillaries lining them.	Absorption of water, simple sugars and alcohol etc. takes place.	Principal organ for absorption of nutrients. The digestion is completed here and the final products of digestion such as glucose, fructose, fatty acids, glycerol and amino acids are absorbed through the mucosa into the blood stream and lymph.	Absorption of water, some minerals and drugs takes place.

Disorders of Digestive System

- The absorbed substances finally reach the tissues which utilise them for their activities. This process is called assimilation.
- The inflammation of intestinal tract is mainly due to bacterial and fungal infection.
- The infection causing parasites include tapeworm, hook worms, round worm, threadworm and pin worms.

(a) Jaundice- It is a disease of liver. In jaundice the skin and the eyes turn yellow due to large quantities of bilirubin pigments in the extra cellular fluid.

(b) Vomiting – it is the ejection of stomach content through the mouth. This reflex action is controlled by the vomit centre in the medulla.

(c) Diarrhoea- frequent defecation of liquid faeces is known as Diarrhoea. It reduces the absorption of food.

(d) Constipation- in constipation the faeces are retained within the rectum as the bowel movements occur irregularly.

(e) Indigestion- incomplete digestion usually accompanied by one or more of the following symptoms- pain, nausea, vomiting, heartburn, acid regurgitation, accumulation of gas and send out of gas from the stomach.

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Chapter 17

Breathing and Exchange of Gases

TOPIC-1

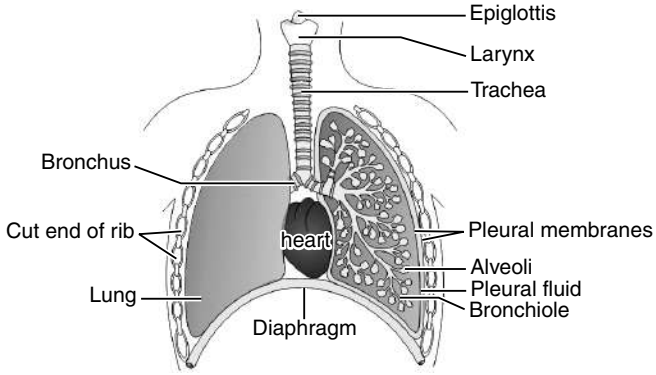
Respiratory Organs

Revision Notes

- **Breathing :** The process of exchange of oxygen from the atmosphere with carbon dioxide produced by the cells.
- **Respiratory organs in animals :**
  - **(a)** General body surface - Protozoans, sponges, coelenterates, annelids
  - **(b)** Gills - Aquatic arthropods, molluscs, Fishes, tadpole stage of frog and many other aquatic animals.
  - **(c)** Air bladder - Bony fishes (Lung fishes)
  - **(d)** Tracheae or Tracheal Tube - Insects and a few other arthropods.
  - **(e)** Lungs - All land vertebrates (Amphibians, Reptiles, Aves and Mammals)

Human Respiratory System :

- In humans, the respiratory system includes respiratory tract and lungs.
- The respiratory tract includes the nose, pharynx, larynx, trachea and bronchi.
- Air enters through the nostrils into the nasal chamber and pharynx, which opens into the trachea through the glottis of the larynx.
- The larynx, also called the sound box, helps in sound production.
- The trachea extends up to the mid-thoracic cavity, which divides at the level of 5th thoracic vertebra into a right and left primary bronchi.
- Each primary bronchus undergoes repeated division to form the secondary and tertiary bronchi ending up in very thin terminal bronchioles.
- The terminal bronchioles connect to ducts called the alveolar ducts that open into the alveoli.



- An average adult's lungs contain about 600 million alveoli.
- Each alveolus is covered by thin and fragile blood capillaries, which combine to form the pulmonary vein.

- The pulmonary vein carries purified blood to the heart and from the heart, the pulmonary artery carries impure blood to the lungs.
- Bronchi, bronchioles and alveoli form a part of a pair of lungs – the left lung and the right lung.
- The left lung has two lobes and is slightly smaller because of the location of the heart near it.
- The right lung is bigger with three lobes.
- Each lung is enclosed by the pleural membrane, which contains pleural fluid.
- The lungs are situated in the air-tight thoracic chamber.
- The thoracic chamber is formed by the vertebral column dorsally, by the sternum ventrally, by the ribs laterally and by the dome-shaped diaphragm on the lower side.
- Based on the function, the respiratory system is divided into two parts – the conducting part and the respiratory part.

Steps involved in respiration :

- Breathing or pulmonary respiration.
- Diffusion of gases (oxygen and carbon dioxide) across alveolar membrane.
- Transport of gases by the blood.
- Diffusion of oxygen and carbon dioxide between blood and tissues.
- Utilisation of oxygen by the cells for catabolic reactions and resultant release of carbon dioxide.

TOPIC-2

Mechanism of Breathing and Exchange of Gases

Revision Notes

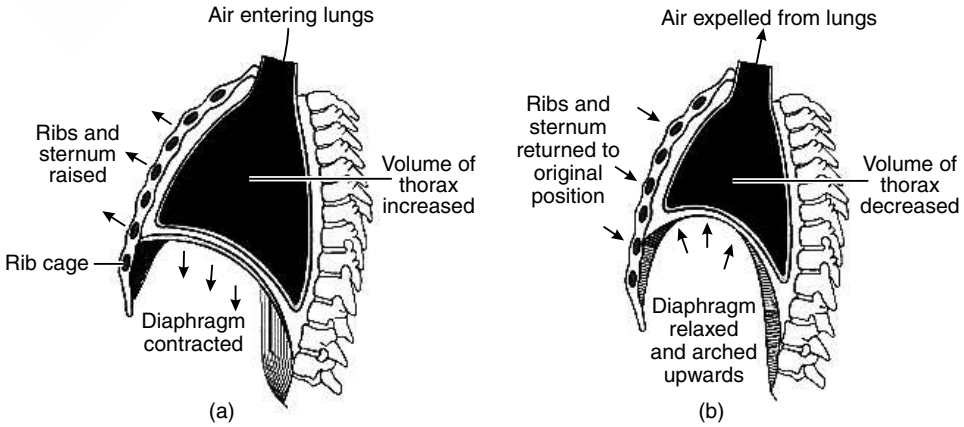
Mechanism of Breathing

Inspiration :

- Inspiration can occur if the pressure within the lungs (intra pulmonary pressure) is less than the atmospheric pressure, i.e., there is negative pressure in the lungs with respect to the atmospheric pressure.
- The contraction of diaphragm increases the volume of thoracic chamber in anterio-posterior axis.
- The contraction of external intercostal 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 which decrease the intra-pulmonary pressure to less than the atmospheric pressure.
- It forces the air outside to move into the lungs i.e., inspiration.

Expiration:

- Relaxation of diaphragm and sternum to their normal positions and reduce the thoracic and pulmonary volume.
- It increases the intrapulmonary pressure slightly above the atmospheric pressure.
- It causes the expulsion of air from the lungs i.e., expiration.



Mechanism of breathing : (a) inspiration (b) expiration

Respiratory Volumes and Capacities :

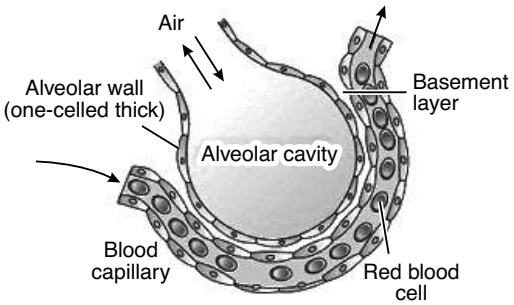
- **Tidal Volume (TV) :** Volume of air inspired or expired during normal respiration (500 mL.)
- **Inspiratory Reserve Volume (IRV) :** Additional volume of air inspired by a forcible inspiration (2500 mL to 3000 mL).
- **Expiratory Reserve Volume (ERV) :** Additional volume of air, a person can expire by a forcible expiration (1000 mL to 1100 mL).
- **Residual Volume (RV) :** Volume of air remaining in the lungs even after a forcible expiration. This averages 1100 mL to 1200 mL.
- **Inspiratory Capacity (IC) :** Total volume of air a person can inspire after a normal expiration. This includes tidal volume and inspiratory reserve volume (TV+IRV).
- **Expiratory Capacity (EC) :** Total volume of air a person can expire after a normal inspiration. This includes tidal volume and expiratory reserve volume (TV+ERV).
- **Functional Residual Capacity (FRC) :** Volume of air that will remain in the lungs after a normal expiration. This includes ERV+RV.
- **Vital Capacity (VC) :** The maximum volume of air a person can breathe in after a forced expiration. This includes ERV, TV and IRV or the maximum volume of air a person can breathe out after a forced inspiration.
- **Total Lung Capacity :** Total volume of air accommodated in the lungs at the end of a forced inspiration. This includes RV, ERV, TV and IRV or vital capacity + residual volume.

Exchange of Gases

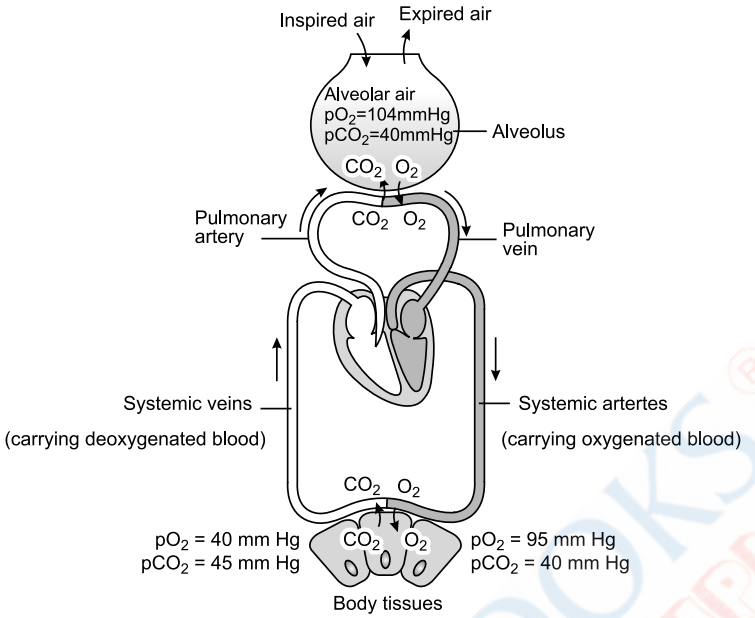
- Exchange of gases occurs primarily between the alveoli, blood and tissues.
- It takes place on the basis of pressure and concentration gradients using simple diffusion.
- Partial pressure is the pressure contributed by an individual gas in a mixture of gases.
- It is represented as pO_2 for oxygen and pCO_2 for carbon dioxide.
- The pO_2 in alveoli is higher than in tissues, so oxygen diffuses into the tissues through blood.
- The pCO_2 is higher in tissues than in alveoli, so carbon dioxide diffuses into the alveoli from where it is exhaled.
- Carbon dioxide is 25 times more soluble than oxygen, so the amount of carbon dioxide that can diffuse through the diffusion membrane is much more than that of oxygen.
- Partial pressures of these two gases in the atmospheric air and the two sites of diffusion are given in table and figure below :

Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

- The data given in the table clearly indicates a concentration gradient for oxygen from alveoli to blood and blood to tissues.



- The gradient present for CO_2 is in the opposite direction, i.e., from tissues to blood and blood to alveoli.
- The diffusion membrane is made up of three major layers namely, the thin squamous epithelium of alveoli, the endothelium of alveolar capillaries and the basement substance in between them. However, its total thickness is much less than a millimetre.
- Therefore, all the factors in our body are favourable for diffusion of O_2 from alveoli to tissues and that of CO_2 from tissues to alveoli.



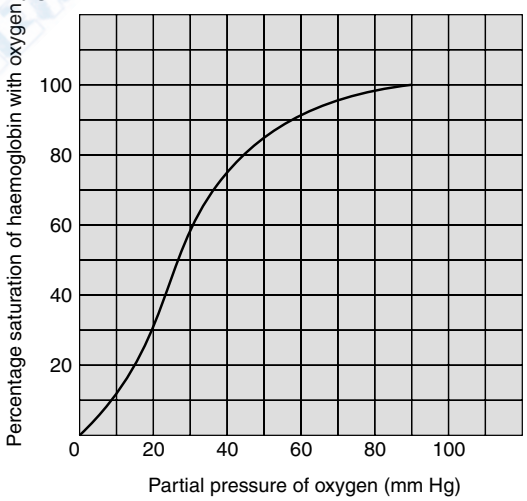
Exchange of gases

TOPIC-3

Transport of Gases and Regulation of Respiration, Disorders of Respiratory System

Revision Notes

- About 97 percent of oxygen is transported by red blood cells, whereas the remaining three per cent is carried in a dissolved state through the plasma.
- Haemoglobin is a red coloured iron containing pigment present in the RBCs.
- Oxygen combines with haemoglobin on the surface of the lungs to form oxyhaemoglobin and gets dissociated in the tissues.
- Each haemoglobin molecule can carry four molecules of oxygen.
- The percentage saturation of haemoglobin with oxygen, if plotted against the partial pressure of oxygen, results in a sigmoid curve called the oxygen dissociation curve.



Oxygen dissociation curve

- In the alveoli, where there is high pO_2, low pCO_2, lesser H^+ concentration and lower temperature, the factors are all favourable for the formation of oxyhaemoglobin.

- In the tissues where low pO_2, high pCO_2, high H^+ concentration and higher temperature exist, the conditions are favourable for dissociation of oxygen from the oxyhaemoglobin.
- This indicates that O_2 gets bound to haemoglobin in the lung surface and gets dissociated at the tissues.
- Every 100 ml of oxygenated blood can deliever around 5 ml of O_2 to the tissues under normal physiological conditions.

Transport of Carbon dioxide

- CO_2 is carried by haemoglobin as carbamino-haemoglobin (about 20-25 per cent).
- This binding is related to the partial pressure of CO_2.
- The pO_2 is a major factor which could affect this binding.
- When pCO_2 is high and pO_2 is low as in the tissues, more binding of carbon dioxide occurs.
- When the pCO_2 is low and pO_2 is high as in the alveoli, dissociation of CO_2 from carbamino-haemoglobin takes place.
- 93 per cent of carbon dioxide from tissues is transported to the alveoli through RBC's.
- A major part of it is trapped as bicarbonate ions by carbonic anhydrase in red blood cells and a minor part is transported by binding to haemoglobin in RBC as carbamino-haemoglobin.
- The rest seven per cent is carried in a dissolved state through the plasma.
- Finally, it reaches the alveoli and releases as carbon dioxide.

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3 \xrightleftharpoons{\text{Carbonic anhydrase}} HCO_3^- + H^+$$

- Every 100 mL of deoxygenated blood delivers approximately 4 mL of CO_2 to the alveoli.

Regulation of Respiration

- Human beings have ability to maintain and moderate the rate of respiration to fulfill the demand of body tissues by neural system.
- Respiratory rhythm centre is located in medulla region of hind brain. Pneumotaxic centre in pons moderate the function of respiratory rhythm centre.
- Chemo-sensitive area is highly sensitive to CO_2 and H^+ ions that ultimately control the respiratory rate. Oxygen do not play major role in controlling rate of respiration.

Functions of Respiration :

- Energy production
- Maintenance of acid-base balance.
- Maintenance of temperature
- Return of blood and lymph.

Disorder of Respiratory System

(a) Asthma- It is due to allergic reaction to foreign particles that affect the respiratory tract.

Symptoms : Coughing, wheezing and difficulty in breathing. This is due to excess of mucus in wall of respiratory tract.

(b) Emphysema- It is the inflation or abnormal distension of the bronchioles or alveolar sacs of lungs. It occurs due to destroying of septa between alveoli because of smoking and inhalation of other smokes. The exhalation becomes difficult and lung remains inflated.

- **Occupational Respiratory Disorders :** It occurs due to occupation of individual. This is caused by inhalation of gas, fumes, or dust present in surrounding of work place. This includes silicosis, asbestosis due to exposure of silica and asbestos.

  Symptoms : Proliferation of fibrous connective tissue of upper part of lung causing inflammation.

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Chapter 18

Body Fluids and Circulation

TOPIC-1

Blood, Plasma, Blood Groups and Blood Clotting

Revision Notes

Blood

- Blood is the most commonly used body fluid in most of the higher organisms.
- Lymph is also used to transports certain substances like protein and fats.
- Blood is a mobile connective tissue composed of a fluid, plasma and the cells, the blood corpuscles.
- It forms about 30-35% of the extracellular fluid. It is slightly alkaline fluid having pH 7.4
- The blood includes plasma and blood cells.

Plasma

- The blood plasma is a slightly alkaline fluid. It is straw coloured.
- The components of plasma and its functions are mentioned below :

S. No.	Components	Functions
1.	Water	As a solvent and suspending medium for blood components.
2.	Plasma proteins (a) Albumin (b) Globulins (c) Fibrinogen	 (a) Osmotic pressure balance (b) Formation of antibodies (c) Blood clotting
3.	Ions – sodium, potassium, chloride, calcium, magnesium, iron, phosphate, carbonate, bicarbonate	Osmosis, acid-base balance, buffer etc.
4.	Nutrients – amino acids, glucose, vitamins, cholesterol, triglycerides	(a) Source of energy (b) Building blocks (c) Enzyme activity
5.	Waste products Uric acid, urea, ammonia, creatinine Bilirubin Lactic acid	 Excretion Breakdown product of erythrocytes Product of anaerobic respiration.

6.	Gases (a) Oxygen (b) Carbon dioxide (c) Nitrogen	 (a) Aerobic respiration (b) Waste product of respiration (c) Inert gas
7.	Regulating substances – hormones and enzymes	Body metabolic functions

Formed Elements or Blood Cells

- There are three types of blood cells or corpuscles namely, red blood cells, white blood cells, and blood platelets.

1. Red Blood Corpuscles (RBC) or Erythrocytes

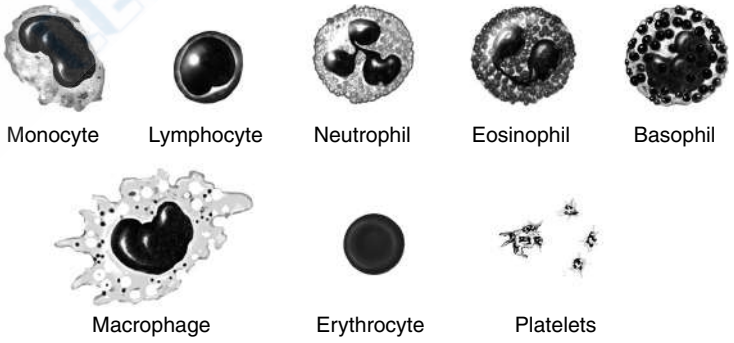
- These are circular, biconcave and non-nucleated cells. Males have about 5.2 million erythrocytes per cubic millimeter of blood (range : 4.2-5.8 million). Females have about 4.5 million/mm^3 (range 3.6-5.2 million).
- Each disc shaped RBC is about 7.5 μm in diameter.
- Their main component is a pigmented proteins is haemoglobin which gives red colour to the blood.
- The haemoglobin transports oxygen and the oxygenated form of haemoglobin is called oxyhaemoglobin.
- Erythrocytes stay in circulation for about 120 days in males and 110 days in females.
- They are manufactured in the marrow of bones such as ribs and vertebrae.
- They disintegrate in the spleen and liver. (spleen-graveyard of RBC)

2. White Blood Corpuscles (WBC) or Leucocytes

- These are clear cells lacking haemoglobin.
- They are nucleated cells exhibiting amoeboid movement.
- They protect the body against invading micro-organisms and remove dead cells from the body.
- There are five types of leucocytes namely,
  - **(a) Neutrophils** - These are the most common type of leucocytes (60-70%) in the blood. Their nuclei can occur in more than one form. Hence they are called polymorphonuclear neutrophils (PMN). Neutrophils are phagocytic which destroy foreign organisms entering the body.
  - **(b) Eosinophils** (2-3%) - They are motile cells that leave the circulation to enter the tissues during an inflammatory reaction. During allergy reaction their number increases.
  - **(c) Basophils** (0.5-1%) - They play a role in allergic and inflammatory reaction. They secrete heparin which inhibits blood clotting and histamine, serotonin, etc.
  - **(d)** Lymphocytes (20-30%) - These are smallest leucocytes. They are more common in lymphatic tissues namely the lymph nodes, spleen, tonsils and thymus. Lymphocytes, called B-cells can produce proteins called antibodies that can get attached to the bacteria and destroy them. T-cells protect us against viruses by attacking and destroying cells in which viruses are reproducing.
  - **(e)** Monocytes (6-8%) - These are largest leucocytes. They destroy bacteria, dead cells and cell fragments. During chronic infection their number increases.

3. Blood Platelets or Thrombocytes

- These are cell fragments produced from megakaryocytes (special cells in the bone marrow).
- These are minute fragments of cells that play a very important role in coagulation of blood.
- Blood normally contains 1,500,00-3,500,00 platelets mm^{-3}.



Blood Groups

- Karl Landsteiner categorised blood groups into the ABO and Rh blood groups.
- The different ABO blood groups are referred to as blood group A, B, AB and O.
- The presence of the 'Rh' antigen in blood is called 'Rh' positive and the absence of the same is called 'Rh' negative.
- Individuals with A blood group have 'A' antigen and anti-B antibody, B blood group have 'B' antigen and anti-A antibody, AB blood group have both 'A' and 'B' antigens and no antibodies, O blood group have no antigens and have both anti-A and anti-B antibodies.

- During blood transfusion, specific antigens and antibodies present in the blood may react and cause the agglutination of RBCs. Hence, blood group matching is carried out before blood transfusion.
- This table below showcases the results of ABO blood group matching between different blood groups of donors and recipients.

Blood Group	Antigens on RBCs	Antibodies in Plasma	Donor's Group
A	A	anti-B	A, O
B	B	anti-A	B, O
AB	A, B	nil	AB, A, B, O
O	nil	anti-A, B	O

- Hence, individuals with blood group 'O' type are called 'universal donors', while individuals with blood group 'AB' type are called 'universal recipients'.
- In addition to ABO blood grouping, Rh blood group matching is also carried out during blood transfusion. This is because, if Rh positive blood is transfused to a Rh negative person, it can induce the formation of 'Rh' antibodies resulting in the agglutination of RBCs.
- Such incompatibility takes place when an Rh negative woman carries an Rh positive foetus, leading to erythroblastosis foetalis.
- Erythroblastosis foetalis can be prevented by injecting anti-Rh antibodies, commercially called rhogams into the Rh negative mother, immediately after her first delivery.

Blood Clotting

- A blood clot is a network of thread like protein fibres called fibrin that traps blood cells, platelets and fluid.
- The clotting depends on several proteins in the plasma. They are called coagulation factors. Normally these factors are in an inactive state.
- After injury they are activated to produce a clot.
- The activation takes place in three steps as follows:

Step 1 : Formation of thrombokinase - Damaged tissues release a mixture of lipoproteins and phospholipids called tissue factor (TF) or thromboplastin. This factor in the presence of certain factors in the blood form a complex called prothrombinase or thrombokinase. This complex is formed by a series of enzymic reactions (Cascade process).

Step 2 : Formation of thrombin - During this stage soluble plasma protein prothrombin is converted into the enzyme thrombin by prothrombinase. Prothrombin synthesis in liver requires vitamin K.

$$\text{Prothrombin} \xrightarrow[Ca^{++}]{\text{prothrombinase}} \text{thrombin}$$

Step 3 : The soluble plasma protein fibrinogen is converted to insoluble protein, fibrin by thrombin. The fibrin forms the fibrous network of the clot.

$$\text{Fibrinogen} \xrightarrow{\text{thrombin}} \text{fibrin}$$

TOPIC-2

Lymph, Circulatory Pathways, Cardiac Cycle and ECG

Lymph (Tissue Fluid)

Revision Notes

Lymph (Tissue Fluid)

- During flow of blood through capillaries, some water soluble fluid move out in the space between cells of tissues. This fluid is called interstitial fluid or tissue fluid.
- It is similar to the blood but has fewer blood proteins, less calcium and phosphorus and high glucose concentration.
- It is a colourless fluid containing specialized lymphocytes that provide immune response to body.
- Main function of lymph is to provide immunity, carry proteins and fats molecules and transport oxygen, food materials, hormones etc.

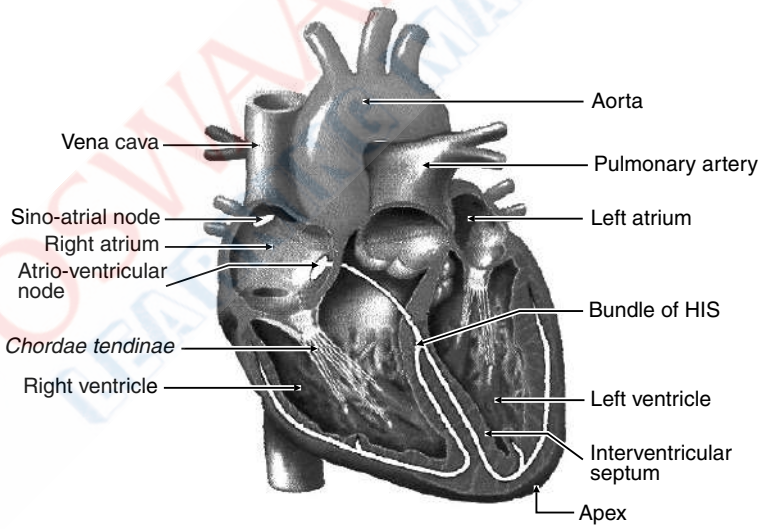
CIRCULATORY PATHWAYS

- The circulatory patterns are of two types namely, open and closed pathways.
- Open circulatory system is present in arthropods and molluscs in which blood pumped by the heart passes through large vessels into open spaces or body cavities called sinuses.

- Annelids and chordates have a closed circulatory system in which the blood pumped by the heart is always circulated through a closed network of blood vessels.
- All vertebrates possess a muscular chambered heart.
- Fishes have a two-chambered heart, all amphibians and reptiles with the exception of crocodiles have a three-chambered heart, all crocodiles, birds and mammals have four-chambered hearts.
- In fishes, blood passes through the heart only once during circulation and hence called single circulation.
- In frogs and reptiles, blood passes through the heart twice and gets mixed in the single ventricle during circulation and hence this is called incomplete double circulation.
- In birds and mammals, blood passes through the heart twice during circulation and hence this is called double circulation.

Human Circulatory System

- During blood circulation, arteries carry oxygenated blood from the heart and branch out to form small arterioles that end in capillaries to reach the tissues.
- These capillaries collect deoxygenated blood from tissues and converge to form venules, which finally converge to form veins.
- However, there are two exceptions in which the artery and vein perform different functions – the pulmonary artery and the pulmonary vein.
- The human heart is about the size of a fist and lies in the thorax between the two lungs, slightly tilted towards the left lung. It is protected by the pericardium, which encloses the pericardial fluid.
- The inter-atrial septum separates the two atria, while the inter-ventricular septum separates the two ventricles and the atrio-ventricular septum separates the atria from their respective ventricles.
- The opening between the right atrium and the right ventricle is gaurded by tricuspid valve whereas a bicuspid or mitral valve guards the opening between the left atrium and the left ventricle.
- The openings of the right and the left ventricles into the pulmonary artery and aorta respectively are provided with semilunar valves.
- With the closure of the tricuspid and bicuspid valves, the first sound, 'lub' is produced and the closure of the semilunar valves produces the second sound, 'dub'.
- Specific regions in the heart consist of specialised cardiac muscles called nodal tissues.



- The nodal tissues include Sino-atrial node (SAN) and atrio-ventricular node (AVN).
- AV bundle from the AVN branches into the right and left bundles in the ventricles to form minute Purkinje fibres.
- All these fibres together form the bundle of His.
- Here, the SAN can automatically generate around 70 to 75 action potentials or electrical impulses per minute.
- This action potential is transmitted to every other part of the heart through the AV node and bundle of His to bring about the rhythmic contraction of the heart. Hence, the SAN is called the pacemaker of the heart.
- The heart normally beats 70-75 times in a minute (average 72 beats per minute).

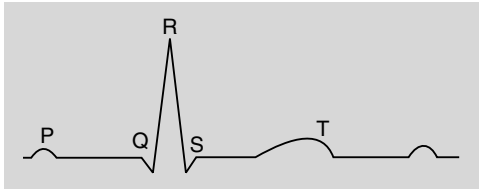
Cardiac Cycle

- To begin with, all four chambers are in relaxed state called joint diastole. The blood from pulmonary vein and vena cava flows to left and right ventricle through tricuspid and bicuspid valve. Semilunar valves are closed at this stage.
- SA node generates action potential that stimulate the contraction both atria (atrial systole). The action potential is passes to AV node and bundle of His transmit it to ventricular musculature to cause ventricular systole. At the same time atria undergoes relaxation (diastole) to close the bicuspid and tricuspid valve.

- Semilunar valves open into circulatory system that relax the ventricle and close the valves to prevent back flow of blood.
- As the pressure inside ventricles decreases the bicuspid and tricuspid valve open to repeat the process of cardiac cycle.
- During each cardiac cycle two sounds are produced. The first sound (lub) is due to closure of bicuspid and tricuspid valves and second heart sound (dub) is due to closure of semilunar valves.

Electrocardiograph (ECG)

- It is a graphical representation of electrical activity of heart during cardiac cycle. The electrocardiograph machine is used to obtain electrocardiogram. The patient is connected to three electrical leads to wrists and left ankle.



- The P-wave represents the electrical excitation of atria (depolarization) which leads to contraction of atria.
- The PRS-wave represents the depolarization of ventricles, which initiates the ventricular contraction.
- The T-wave represents the return of ventricle from excited to normal state (repolarization).
- At the end of T-wave marks the end of systole. Counting the number of QRS complex in given period of time determine the heart beat rate.

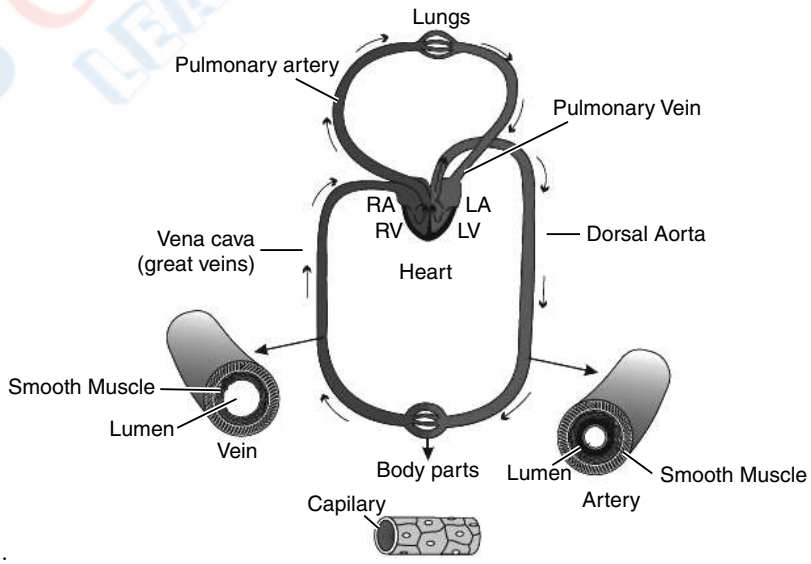
TOPIC-3

Double Circulation, Regulation of Cardiac Activity and Disorders of Circulatory System

Revision Notes

Double Circulation

- The flow of same blood twice through the heart once in oxygenated form and other in deoxygenated form is called double circulation.
- Double circulation checks the mixing of oxygenated and deoxygenated blood.
- It includes systemic and pulmonary circulation.
- Systemic circulation includes flow of oxygenated blood from the left ventricle to all parts of body and deoxygenated blood from various body parts to the right atrium.
- All systemic circulation starts form aorta and ends at superior vena cava, inferior vena cava or coronary sinus to right atrium.



- The systemic system provides oxygen, nutrients and other substance to the tissues of different body parts and takes carbon dioxide and other harmful substance from the body parts.

- Pulmonary circulation involves the flow of deoxygenated blood from the right ventricle to the lungs and the return of oxygenated blood form the lung to the left atrium.
- Two pulmonary veins from each lung transport the oxygenated blood to the left atrium.

REGULATION OF CARDIAC ACTIVITY

- Normal activities of heart are regulated by nodal tissue (SA and AV node), so the heart is myogenic.
- A special neural centre in medulla oblongata moderates the cardiac function by ANS.
- Neural signals through Sympathetic nerves can increase the rate of heart beat and parasympathetic neural signals of ANS decrease the rate of heart beat.
- Adrenal medullary hormone also increases the cardiac output.

DISORDERS OF CIRCULATORY SYSTEM

(b) Hypertension (high blood pressure) :

- ✓ Blood pressure higher than (120/80).
- ✓ 120 mm Hg is the systolic that is pumping pressure and 80 mm Hg is the diastole, resting pressure.
- ✓ It leads to heart disease and affect vital organs like brain and kidney.

(c) Coronary Artery Disease (CAD) :

- ✓ It is commonly called atherosclerosis that affects the blood vessels that supply blood to heart muscles due to deposition of fat, calcium, cholesterol that makes the arteries lumen narrower.

(d) Angina :

- ✓ It is also called angina pectoris, acute chest pain due to less supply of oxygen to heart muscles.
- ✓ It may occur in elderly male and female.
- ✓ It occurs due to restricted blood flow.

(e) Heart failure :

- ✓ In this case, heart does not pump enough blood to meet the requirement of body.
- ✓ It is also known as congestive heart failure because congestion of lung is one of its causes.
- ✓ Heart failure is different from heart attack (heart muscle is damaged by inadequate blood supply) and cardiac arrest (when heart stops beating).

(f) Coronary Thrombosis:

- ✓ It is the due to the formation of clot in the coronary artery.
- ✓ It occurs most frequently in the left anterior descending coronary artery.

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Chapter 19

Excretory Products and Their Elimination

TOPIC-1

Human Excretory System, Function of the Tubules, Urine Formation and Mechanism of Concentration of the Filtrate

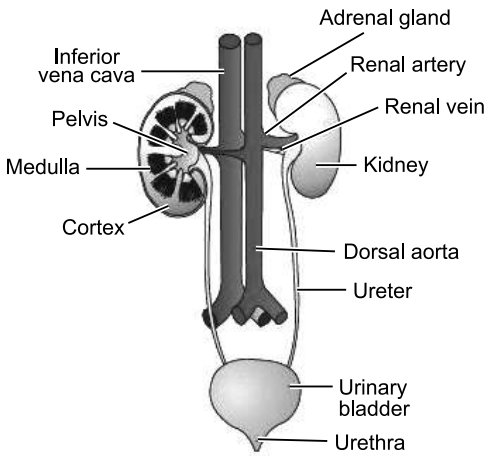
Revision Notes

Excretion

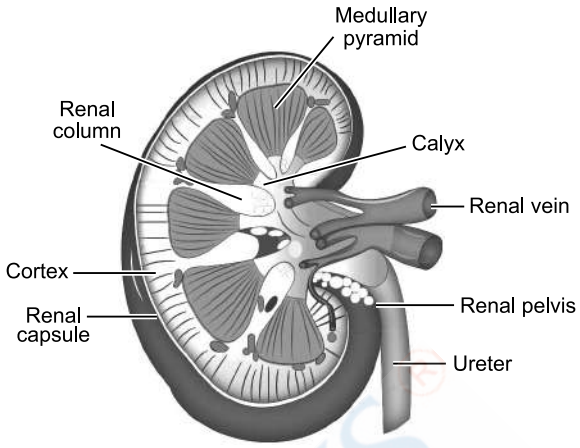
- The process by which the cellular nitrogenous wastes are eliminated is called excretion.
- Three main nitrogenous wastes are ammonia, urea and uric acid.
- Ammonia-excreting animals are called ammonotelic animals and the process is called ammonotelism.
- Excretion in the form of urea is called ureotelism and such animals are called ureotelic animals.
- Animals excreting nitrogenous wastes in the form of uric acid are called uricotelic animals and the process is called uricotelism.
- In mammals, apart from the kidneys, which are the main excretory organs, the skin, liver and lungs also help in excretion.
- Excretory products in humans - carbon dioxide, ammonia, urea, uric acid, water and excess ions like phosphate, sulphate, sodium, potassium and chloride.
- Excretory products in bony fishes, aquatic amphibians and aquatic insects – Ammonia in the form of readily soluble ammonium ions through their gills or body surface by the process of diffusion.
- Excretion in terrestrial animals – These animals converts ammonia into less toxic forms of urea and uric acid, which help conserve water.
- Excretion in mammals including humans and many marine fish and terrestrial amphibians takes place in the form of Urea.
- Protonephridia or flame cells are the excretory structures in Platyhelminthes (e.g., *Planaria*), rotifers, and the cephalochordate-*Amphioxus*. Protonephridia are primarily concerned with osmoregulation.
- Nephridia are the excretory structures of earthworms and other annelids.
- Malpighian tubules are the excretory structures of most of the insects such as cockroaches.
- Antennal glands or green glands perform the excretory function in Crustaceans like prawns.

Human Excretory System

- The human excretory system consists of a pair of kidneys, a pair of ureters, a urinary bladder and the urethra. The kidneys are compact, bean-shaped organs situated between the levels of last thoracic and third lumbar vertebra on either side of the vertebra.
- **Ureters :** These carry urine from the renal pelvis of the kidneys to the urinary bladder.
- **Urinary bladder :** It temporarily stores urine till it is released from the body. Urine leaves the urinary bladder via the urethra.

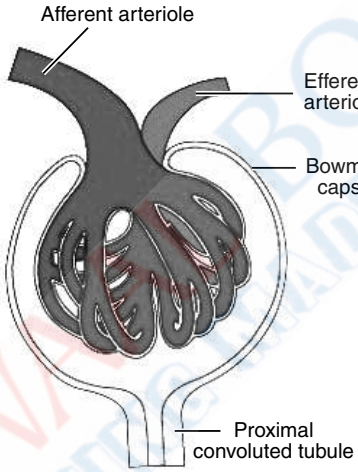


Human urinary system



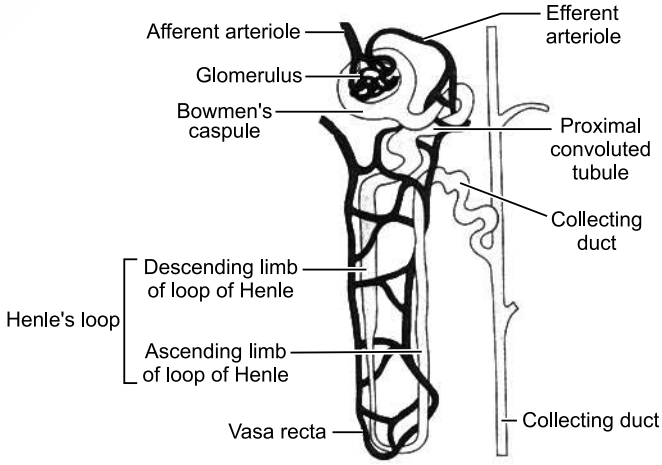
L.S. of Kidney

- **Nephron :** It is the functional unit of the kidney and consists of two parts namely,
  (a) The glomerulus
  (b) The renal tubule



Malpighian body (renal corpuscle)

- The tubule continues further to form a highly coiled network – proximal convoluted tubule [PCT], hairpin shaped Henle's loop having descending and an ascending limb. The ascending limb continues as another highly coiled tubular region called distal convoluted tubule [DCT]
- **Malpighian corpuscle :** The glomerulus along with the Bowman's capsule is termed as Malpighian corpuscle.
- **Renal papilla :** The tip of medullary pyramids in the kidney where the urine is emptied into the calyx is called renal papilla. The cortex extends in between the medullary pyramids as renal columns called Columns of Bertini.
- **Urethral sphincter :** The set of muscles which control the flow of urine from the urinary bladder to the outside.



Nephron

Types of Nephrons

- The nephron in which the loop of Henle is too short and extends only very little into the medulla. Such nephrons are called cortical nephrons. About 80–50% of the nephrons belong to this type and they lack vasa recta.
- There is a nephron in which the loop of Henle which is very long and runs deep into the medulla which is called juxta medullary nephrons. About 15–20% of the nephrons belong to this type.
- The Malpighian corpuscle, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle dips into the medulla.
- The efferent arteriole emerging from the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries. A minute vessel of this network runs parallel to the Henle's lop forming a "U" vasa recta.

Urine Formation

- The amount of filtrate formed in Bowman's capsule every minute is called the glomerular filtration rate.
- About 99% of the filtrate is absorbed during the process of reabsorption.
- Tubular secretion maintains the ionic and acid base balance of body fluids by secreting ions and ammonia back into the distal convoluted tubule and passing it to the collecting duct.
- The urine formation involves three major processes, namely glomerular filtration or ultrafiltration, reabsorption and secretion.

Glomerular Filtration :

- It is the first step in urine formation, which takes place in the glomerulus and hence the name given as glomerular filtration.
- The glomerular capillary blood pressure causes filtration of blood through 3 layers, i.e., the endothelium of glomerular blood vessels, the epithelium of Bowman's capsule and a basement membrane between these two layers.
- The epithelial cells of Bowman's capsule called podocytes are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores.
- Blood is filtered so finely through these membranes that almost all the constituents of the plasma except the proteins pass onto the lumen of the Bowman's capsule. Therefore, it is considered as a process of ultra-filtration.
- The amount of filtrate formed in the Bowman's capsule of a nephron due to glomerular filtration in the kidneys every minute is called the glomerular filtration rate or GFR, which in a healthy individual is about 125 ml per minute or 180 litres per day.
- The juxtaglomerular apparatus or JGA is one such sensitive structure that regulates the GFR.

Reabsorption :

- 180 litres of glomerular filtrate is formed per day, whereas the amount of urine released is just 1.5 litres. This is because about 99% of the filtrate is re-absorbed in the renal tubules during the process of reabsorption.
- Reabsorption is performed by the tubular epithelial cells present in the different parts of the renal tubule through active or passive mechanisms.

Secretion :

- The cells in the renal tubule also selectively secrete substances such as potassium and hydrogen ions and ammonia into the filtrate to maintain the pH and ionic balance in body fluids.

Function of the Tubules

Proximal Convoluted Tubule (PCT) :

(a) It increases the surface area for reabsorption.
(b) All of the essential nutrients and 70-80% of electrolytes and water are reabsorbed.
(c) It helps to maintain the pH and ionic balance of the body fluids by selective secretion of hydrogen ions, ammonia and potassium ions into the filtrate and by absorption of HCO_3^- from it.

Henle's Loop :

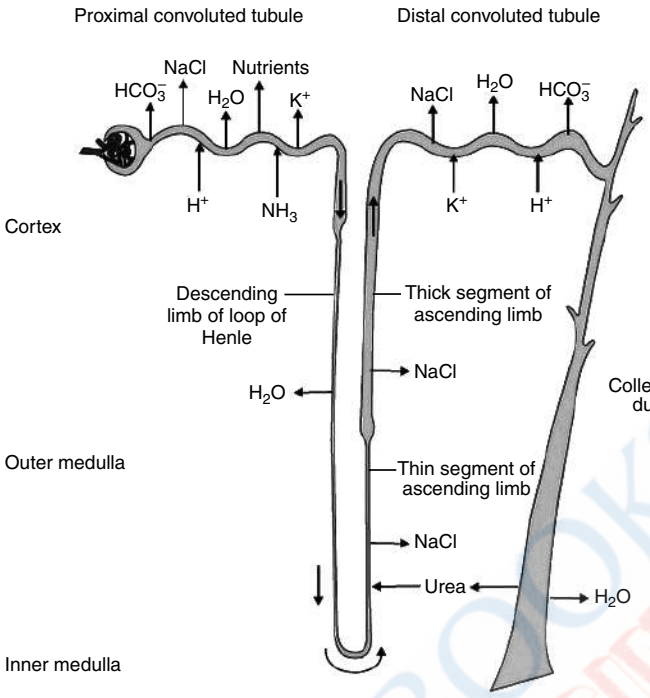
(a) It plays a significant role in the maintenance of high osmolarity of medullary interstitial fluid.
(b) The descending limb of loop of Henle is permeable to water but almost impermeable to electrolytes.
(c) The ascending limb is impermeable to water but allows transport of electrolytes actively or passively.

Distal Convoluted Tubule (DCT) :

(a) Conditional reabsorption of Na^+ ions and water takes place.
(b) It is capable of reabsorption of HCO_3^- (bicarbonate ion)
(c) Selective secretion of hydrogen and potassium ions and NH_3 to maintain the pH and sodium-potassium balance in blood.

Collecting Duct :

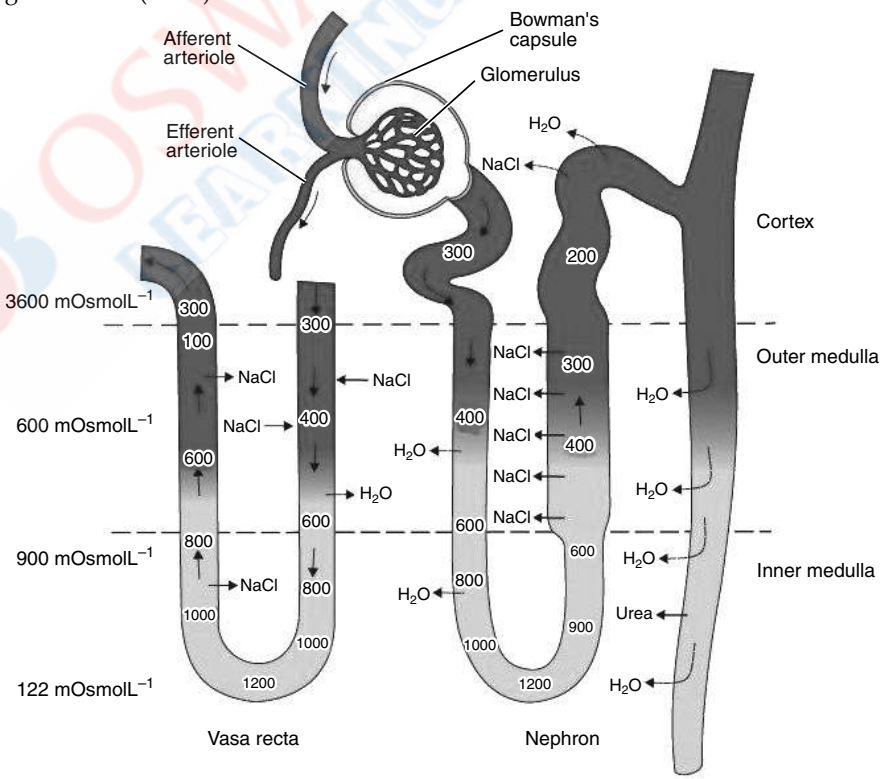
(a) Large amounts of water could be reabsorbed.
(b) It allows passage of small amounts of urea into the medullary interstitium to keep up the osmolarity.
(c) It plays a role in the maintenance of pH and ionic balance of blood by the selective secretion of H^+ and K^+ ions.



Reabsorption and secretion of major substances at different parts of the nephron

Mechanism of Concentration of the Filtrate

- The flow of filtrate in the two limbs of Henle's loop is in opposite directions and thus forms a counter current.
- The flow of blood through the two limbs of vasa recta is also in a counter current pattern.
- The proximity between the Henle's loop and vasa recta, as well as the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitium, i.e., from 300 mOsmol L^{-1} in the cortex to about 1200 mOsmo L^{-1} in the inner medulla by NaCl and urea.
- The counter current mechanism of NaCl and urea helps to maintain a concentration gradient.
- Presence of the interstitial gradient helps in an easy passage of water from the collecting tubule thereby concentrating the filtrate (urine).



A nephron and vasa recta showing counter current mechanism

TOPIC-2

Regulation of Kidney Function, Micturition, Role of Other Organs in Excretion and Disorders of the Excretory System

Revision Notes

Regulation of Kidney Function

- Kidney functions are monitored and regulated by the hormonal feedback mechanisms of the hypothalamus, juxtaglomerular apparatus or JGA and heart.
- Our body has several osmoreceptors that are activated by changes in the volume of body fluids, volume of blood and ionic concentration.
- An osmoreceptor is a sensory receptor that detects changes in osmotic pressure.
- A decrease in the level of body fluids activates the osmoreceptors, which stimulate the hypothalamus, which, in turn, neurally stimulates the neurohypophysis of the pituitary to release the antidiuretic hormone or ADH or vasopressin.
- ADH prompts the distal convoluted tubule or DCT and the collecting ducts to reabsorb more water, thereby preventing diuresis.
- On the other hand, if the fluid volume in the body increases, the osmoreceptors suppress the release of ADH, leading to increased excretion of water in urine.
- The juxtaglomerular cells detect a fall in the glomerular blood pressure or GFR and release a peptide hormone called renin.
- Renin converts angiotensinogen in the blood into angiotensin I, which is further converted into angiotensin II.
- Angiotensin II, a powerful vasoconstrictor, constricts the blood vessels thereby increasing blood pressure, which stimulates the cortex of the adrenal gland to secrete aldosterone.
- Aldosterone increases the reabsorption of sodium and water from the distal parts of the renal tubule, resulting in an increase in blood volume, which increases blood pressure and GFR. This complex mechanism is commonly known as the Renin-Angiotensin mechanism.
- An increase in blood flow to the atria of the heart can cause the release of Atrial Natriuretic Factor (ANF).
- ANF can cause vasodilation (dilation of blood vessels) and thereby decrease the blood pressure.
- ANF mechanism, therefore, acts as a check on the Renin-Angiotensin mechanism.

Micturition

- The urine passes into the urinary bladder, where it is stored until a signal is received by the central nervous system or CNS.
- The CNS, in turn, sends motor messages that make the smooth bladder muscles contract and the urethral sphincter relax, resulting in the release of urine.
- This process of disposing urine is called micturition and the neural mechanism responsible for the process is known as the micturition reflex.
- On average, an adult human releases about one to 1–1.5 L of urine every day.

Characteristics of Urine :

- The urine formed is a light yellow coloured watery fluid which is slightly acidic (pH-6.0). The acidity is because of presence of the hydrogen ions regulated by the proximal convoluted tubule in order to maintain the pH of the filtrate.
- It has a characteristic odour.
- On an average, 25-30 gm of urea is excreted out per day.
- Presence of glucose (Glycosuria) and ketone bodies (Ketonuria) in urine are indicative of diabetes mellitus.

Role of Other Organs in Excretion

- The kidneys, lungs, liver and skin also help in the elimination of excretory wastes.
- Liver, the largest gland in our body, secretes bile-containing substances like bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs.
- The sweat and sebaceous glands in the skin can eliminate certain substances through their secretions.
- Sweat produced by the sweat glands is a watery fluid containing NaCl, small amounts of urea, lactic acid, etc.

- Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum.

Disorders of the Excretory System

- The malfunctioning of the kidneys can also cause uremia, a condition where large amounts of urea accumulate in the blood.
- Uremia can even lead to kidney failure.
- A life-saving process for uremic patients is hemodialysis, wherein excess urea in the blood is removed.
- However, in cases of acute renal or kidney failure, the only option is kidney transplantation.
- In this process, a functioning kidney from a donor is transplanted in the patient.
- Usually, a close relative of the patient is the preferred donor to minimise the chances of the patient's immune system rejecting the kidney.
- Other disorders due to the malfunctioning of the kidneys include the formation of stones or insoluble masses of crystallised salts within the kidney, a condition known as renal calculi.
- These stones are usually salts of calcium, mainly calcium oxalate or calcium phosphate. Such stones are also formed in the ureter and the urinary bladder.
- An inflammation of glomeruli of kidney result in glomerulonephritis.

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Chapter 20

Locomotion and Movement

TOPIC-1
Movement and Muscles

Revision Notes

Locomotion

- Locomotion is the voluntary movement of an individual from one place to another.
- It includes walking, running, climbing, swimming etc.
- All locomotion's are movement but all movements are not locomotion.

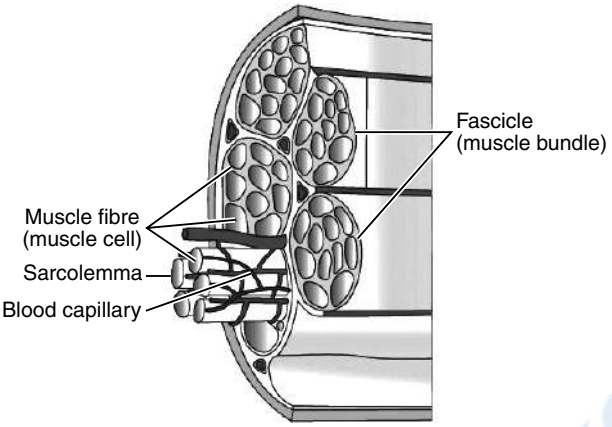
Types of Movement

- Cells of the human body show three main types of movements namely,
  - **(a) Amoeboid movement :** The movement is effected by pseudopodia. Cytoskeletal structures like microfilaments are involved in this movement. It includes movement of leucocytes and macrophages.
  - **(b) Ciliary movement :** It occurs mostly in internal tubular organs lined by ciliated epithelium. The ciliary movement in trachea removes dust and foreign particles and the movement in fallopian tube causes the ova to move to the uterus.
  - **(c) Muscular movement :** It occurs due to contractile property of muscles. This movement can be seen in jaws, limbs, eyelids, movement of food in alimentary canal and movement of urine in ureters.

Muscle

- Muscles are specialized tissues of mesodermal origin.
- They have property like excitability, contractility, extensibility and elasticity.
- Based on their location, there are three types of muscles namely,
  - **(a) Skeletal muscles :** It is associated with skeletal system, alternate light and dark bands (striated), involved in voluntary and locomotory actions and change in body posture.
  - **(b) Visceral muscles :** It form inner walls of internal visceral organs, non-striated, involuntary muscle, assists in movement of food through digestive tract and gametes.
  - **(c) Cardiac muscles :** It is the muscles of heart, having branching pattern, alternate light and dark bands, involuntary in action.

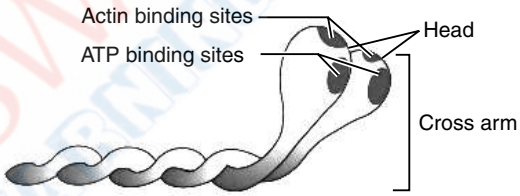
Skeletal Muscle



Muscle bundles and Muscle fibres

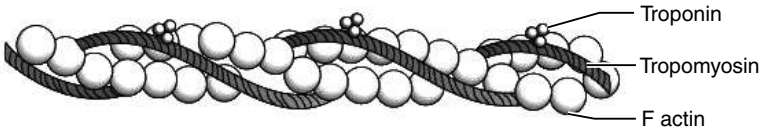
- It is made up of muscle bundles (fascicles), held together by collagenous connective tissue called fascia.
- Each muscle bundle contains a number of muscle fibres.
- Each muscle fibre is lined by plasma membrane called sarcolemma enclosing sarcoplasm.
- Partially arranged myofibrils are present in muscle bundle having alternate light and dark bands due to presence of protein- actin and myosin.
- Light bands contain actin and are called I-band (isotropic band) and dark band contains myosin, called A-band (anisotropic band).
- Both bands are present parallel to each other in longitudinal fashion.
- In centre of each I-band is elastic fibre called 'Z' line.
- In the middle of A-band is thin fibrous 'M' line.
- The portion of myofibrils between two successive 'Z' lines is the functional unit of contraction called a sarcomere.
- At resting stage thin filament overlaps the thick filament.
- The part of thick filament not overlapped is called 'H' zone.

Structure of Contractile Protein



Myosin monomer (Meromyosin)

- Each thin filament (actin) is made of two 'F' (filamentous) actins helically wounded to each other.
- Two filaments of another protein, tropomyosin runs close to it.
- A complex protein troponin is distributed at regular intervals on the tropomyosin.
- Each myosin filament is made of many monomeric proteins called meromyosins.
- Each meromyosin has globular head with short arm and tails.
- Globular head is an active ATPase enzyme and has ATP binding sites and active sites for actin.

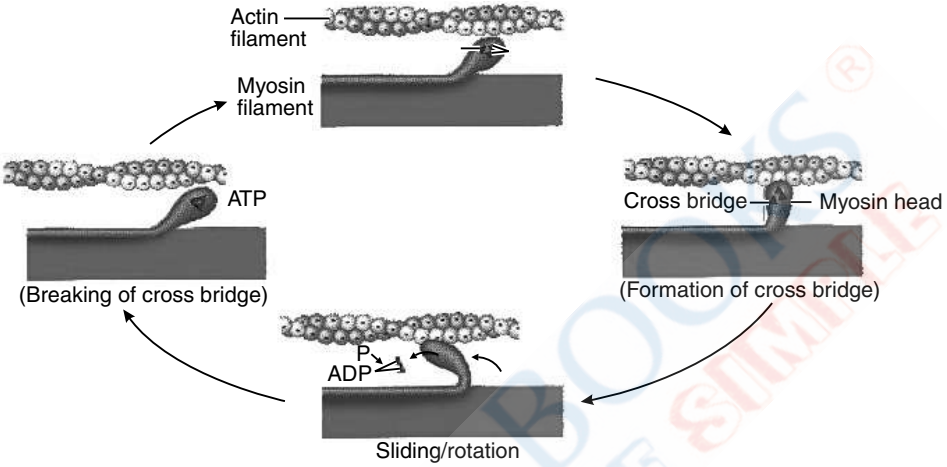


An actin (thin) filament

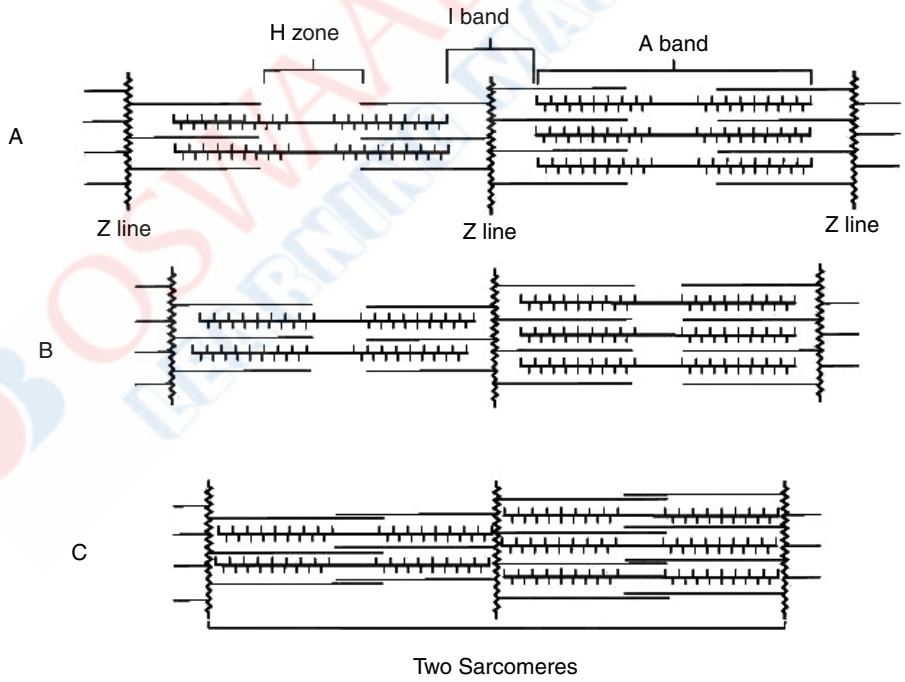
Mechanism of Muscle Contraction

- The mechanism of muscle contraction is explained by sliding mechanism theory in which thin filament slide over thick filament.
- Muscle contraction starts with signal sent by CNS via motor neuron.
- A motor neuron along with the muscle fibres connected to it constitute a motor unit.

- The junction between a motor neuron and the sarcolemma of the muscle fibre is called motor-end plate or neuromuscular junction.
- Neural signal releases neurotransmitter (Acetyl choline) to generate action potential in the sarcolemma which helps to release Ca^{++} from sarcoplasmic reticulum.
- The Ca^{++} activates actin which binds to the myosin head to form a cross bridge.
- These cross bridges pull the actin filaments causing them to slide over the myosin filaments and thereby causing contraction.
- The Ca^{++} are then returned to sarcoplasmic reticulum which inactivate the actin.
- The cross bridges are broken and the muscles relax.



Stages in cross bridge formation, rotation of head and breaking of cross bridge



Sliding-filament theory of muscle contraction (movement of the thin filaments and the relative size of the I band and H zones)

Classification of Muscles

- Red fibres are the aerobic muscles that contain myoglobin containing plenty of mitochondria to use large amount of oxygen stored in them.
- White fibres are the muscle fibres containing less number of myoglobin.

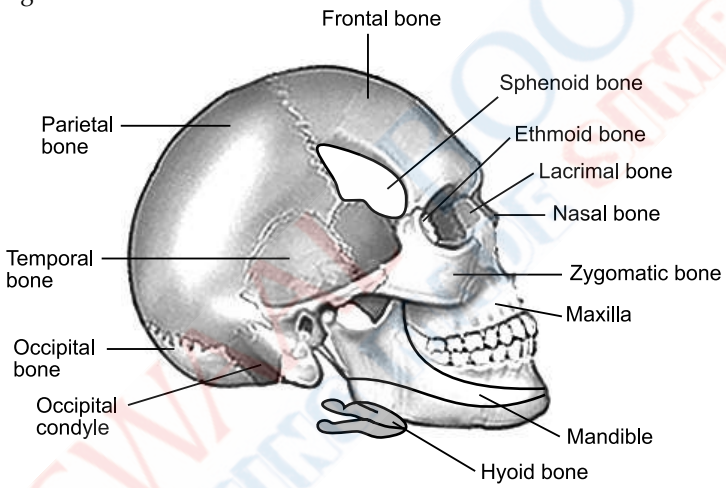
TOPIC-2

Skeletal system, Joints and Disorders of Skeletal System

Revision Notes

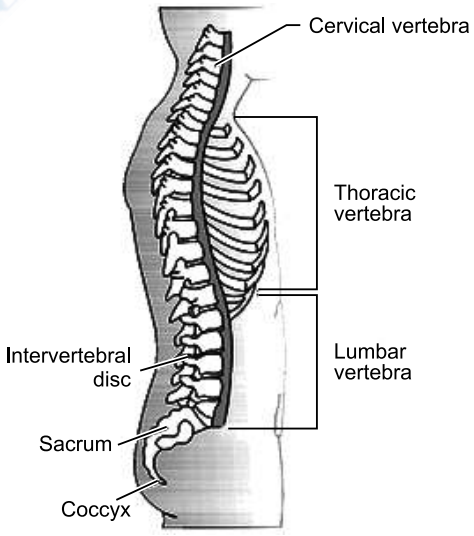
Skeletal System

- Skeletal system gives shape to our body, while muscular system helps in movement.
- A newborn baby has around 300 bones, which fuse as the baby grows, resulting in 206 bones in an adult.
- Both bone and cartilage are specialized connective tissues.
- The skeletal system has two main divisions namely, axial skeleton and the appendicular skeleton.
- A single U-shaped bone called hyoid is present at the base of the buccal cavity and is included in the Skull.
- Ear ossicles containing 3 bones-malleus, incus and stapes forms middle ear.
- The axial skeleton consists of 80 bones, which include the skull, vertebral column, ribs and sternum.
- The skull consists of eight cranial bones that form the cranium and fourteen facial bones which form the face.



Human Skull

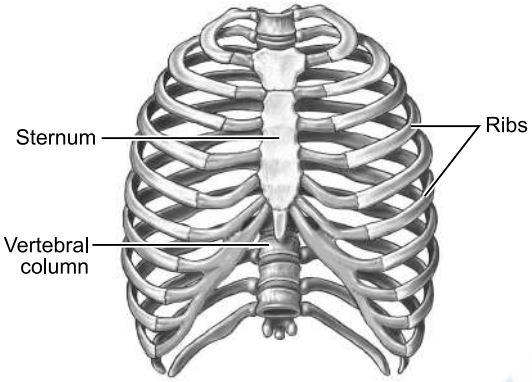
- Vertebral column consists of 26 serially arranged vertebrae.
- First vertebra is atlas that combines with occipital condyle.
- It includes seven cervical vertebrae followed by twelve thoracic, five lumbar, one sacral and one coccygeal.



Vertebral column

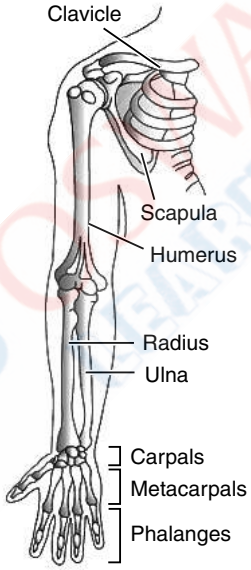
- There are twelve pairs of ribs, where each rib is a flat bone attached dorsally to the thoracic vertebrae.

- The 11th and 12th rib bones are not connected with sternum and are called floating ribs.
- The vertebral column has three main functions.
- It protects the spinal cord, supports the head and serves as the point of attachment for the ribs.

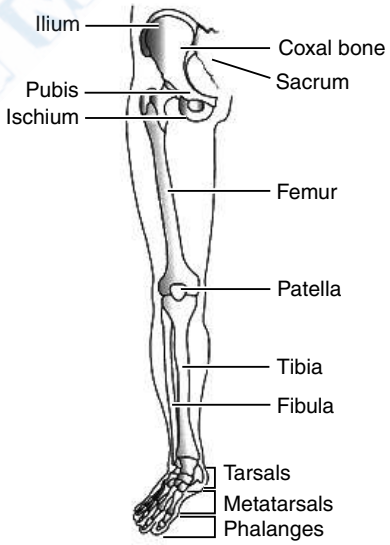


Ribs and rib cage

- The appendicular skeleton includes the bones of the limbs and their supporting girdles.
- Each limb contains 30 bones.
- The bones of the hand includes humerus, radius and ulna, eight carpals or wrist bones, five metacarpals or palm bones and fourteen phalanges.
- The bones of the leg consists of femur or thigh bone, tibia and fibula, seven tarsals or ankle bones, five metatarsals and fourteen phalanges.
- Pectoral and Pelvic girdle bones help in the articulation of the upper and the lower limbs respectively with the axial skeleton.
- Pectoral girdle consists of a clavicle and a scapula.
- Pelvic girdle consists of two coxal bones.
- Each coxal bone is formed by the fusion of three bones namely, ilium, ischium and pubis.



Right pectoral girdle and upper arm



Right pelvic girdle and lower limb bones (frontal view)

Joints

- The point at which two bones or a bone and a cartilage make contact is called a joint.
- These joints play an important role in the movement of the bony parts of our body as well as in locomotion.
- Depending on how bones are connected to each other, joints are classified into three major types namely,

(a) Fibrous joints : Fibrous joints do not allow any movement and are also referred to as immovable joints. For example, the cranial bones which fuse end-to-end with the help of fibrous connective tissues to form the cranium.

(b) Cartilaginous joints : Here, the bones are joined with the help of cartilages. This joint is found between the adjacent vertebrae in the vertebral column, which permits limited movement.

(c) Synovial joints : This joint is characterized by the presence of a lubricating fluid called synovial fluid filled in a synovial cavity between the articulating surfaces of the two bones. These joints allow a considerable degree of movement. Examples are ball-and-socket joint, pivot joint, hinge joint gliding joint and saddle joint.

DISORDERS OF MUSCULAR AND SKELETAL SYSTEM

(a) Myasthenia gravis : Auto immune disorder affecting neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscle.

(b) Muscular dystrophy : Progressive degeneration of skeletal muscle mostly due to genetic disorder.

(c) Tetany : Rapid spasms (wild contractions) in muscle due to low Ca^{++} in body fluid.

(d) Arthritis : Inflammation of joints.

(e) Osteoporosis : Age-related disorder characterised by decreased bone mass and increased chances of fractures. A common cause of this disorder is decrease in the oestrogen level.

(e) Gout : Inflammation of joints due to accumulation of uric acid crystals.

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Chapter 21

Neural Control and Coordination

TOPIC-1

Coordination, Neural System, Human Neural System, Neuron

Revision Notes

NEURON

- Coordination is the process through which two or more organs interact and complement the functions of one another.
- The neural system provides an organised network of point-to-point connections for a quick coordination.
- The endocrine system provides chemical integration through hormones.

NEURAL SYSTEM

- The neural system of all animals is composed of highly specialised cells called neurons which can detect, receive and transmit different kinds of stimuli.
- The neural organisation is very simple in lower invertebrates, it is better organised in insects with a number of ganglia and nerve tissues and very well-developed in vertebrates.

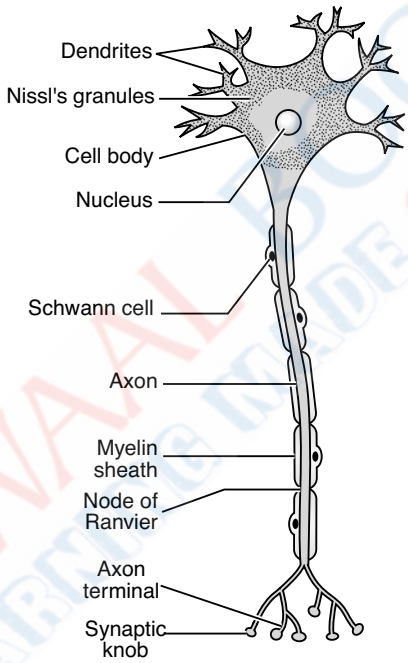
HUMAN NEURAL SYSTEM

- The human neural system is divided into two parts namely – the central neural system (CNS) and the peripheral neural system (PNS).
- The brain and the spinal cord form the central neural system.
- It is the site of information-processing and control.
- The peripheral neural system comprises of cranial and spinal nerves.
- It controls the voluntary functions of the body.
- The nerve fibres of peripheral nerves are of two types namely – afferent and efferent nerve fibres.
- Afferent fibres conduct nerve impulses from the sense organs to the central nervous system.
- Efferent fibres conduct nerve impulses from the central nervous system to the involuntary organs.
- The peripheral neural system is divided into the somatic neural system and the autonomic neural system.

- The somatic neural systems relay impulses from the central neural system to the skeletal muscles.
- The autonomic neural system controls involuntary functions.
- It is further classified into the sympathetic neural system and parasympathetic neural system.

NEURON : STRUCTURAL AND FUNCTIONAL UNIT OF NEURAL SYSTEM

- A neuron is a branched nerve cell and is the longest cell in the body consists of the cell body and nerve processes.
- The cell body has spherical nucleus, Nissl's granules which help in protein synthesis, mitochondria present in it provide high energy for the conduction of impulses.
- Nerve processes are of two types namely, dendrons and axons.
- Dendrons transmit impulses towards the cell body.
- An axon is always single, covered by plasma membrane and contains axoplasm.
- The distal end of an axon terminates in a bulb-like structure called a synaptic knob which contains neurotransmitters.

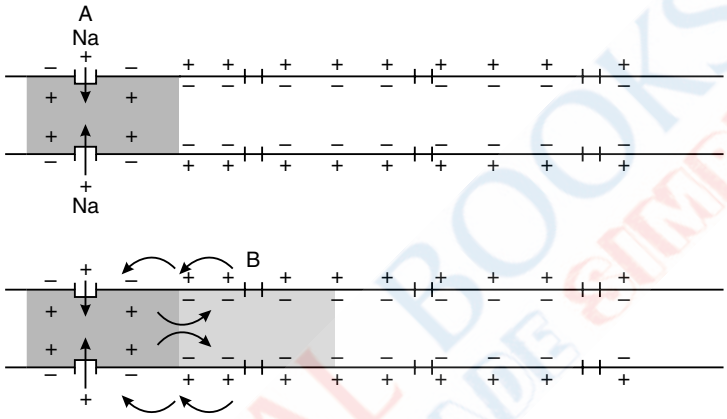


Structure of a neuron

- On the basis of the number of axons and dendrites, neurons are divided into three types namely – multipolar, bipolar and unipolar.
- Axons are of two types namely – myelinated and non-myelinated.
- Myelinated nerve fibres are enclosed by Schwann cells which form a myelin sheath around the axon.
- Unmyelinated nerve fibre is enclosed by Schwann cell that does not form a myelin sheath around the axon, and is commonly found in autonomous and the somatic neural systems.
- The gaps between two adjacent myelin sheaths are called the nodes of Ranvier.
- These fibres are found in cranial and spinal nerves.
- On the basis of the functions of neurons, they can be divided into three types namely - sensory, motor and association neurons.
- Sensory neurons are found in the sense organs, receive impulses from receptors and direct them towards the central nervous system.
- Motor neurons are found in the central nervous system, they carry impulses from the central nervous system to organs such as the muscles and glands.
- Association neurons, which are also called inter neurons or mixed neurons, are found in the central nervous system, for example, the dorsal horn of the spinal cord.

Generation and Conduction of Nerve Impulse

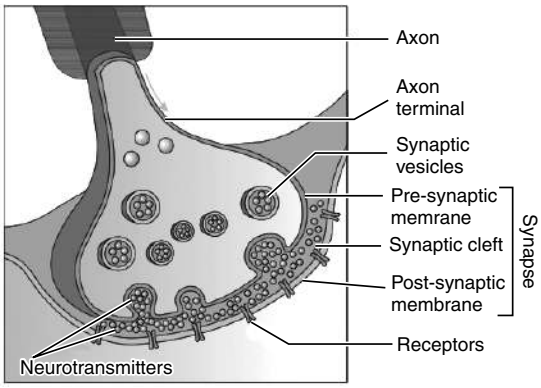
- The nerve impulse is the sum of mechanical, chemical and electrical disturbances created by a stimulus in a neuron. The conduction of the nerve impulse can be divided into two main phases – resting membrane potential and action membrane potential. Neurons are excitable cells. They may be stimulated by physical, mechanical, chemical or electrical stimuli.
- The axoplasm inside the axon contains a high concentration of potassium ions, negatively-charged proteins and a low concentration of sodium ions. On the contrary, the extracellular fluid outside the axon contains a low concentration of potassium and a high concentration of sodium. This differential permeability is maintained by a sodium-potassium pump present inside the membrane.
- The electrical potential difference across the neural membrane in an unexcited nerve fibre is called resting potential, and the neuron is called a polarised nerve fibre. The reversal of polarity across the two sides of the membrane is called depolarization. The action potential travels as a wave of depolarisation along the length of a nerve fibre in a particular direction and is called a nerve impulse.



Impulse conduction through an axon at points A and B

Transmission of Impulses

- A junction helps transmit the nerve impulse from one neuron to another. These junctions are called synapses.
- 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 the synaptic cleft.
- There are two types of synapses on the basis of nature of transfer of information.
- These are chemical synapses and electrical synapses.
- Impulse transmission across an electrical synapse is always faster than that across a chemical synapse. Electrical impulse are rare in our system.
- Chemicals called neurotransmitters are involved in the transmission of impulses in chemical synapses.
- Each synaptic vesicle contains neurotransmitter chemical molecules such as Acetyl choline.
- The neurotransmitters thus released bind to their specific chemoreceptors present on the post-synaptic membrane of the dendron.
- This binding opens sodium ion channels that allow the entry of ions to generate a new potential in the post-synaptic neuron.



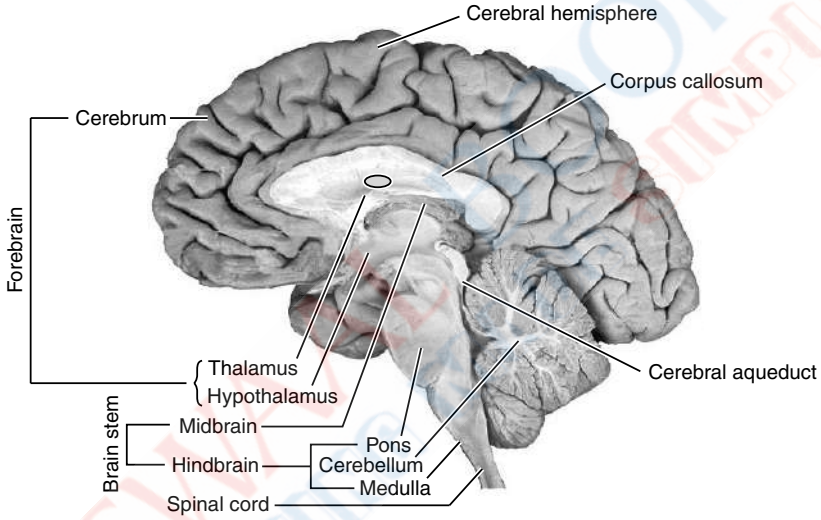
Axon terminal and Synapse

TOPIC-2
Central Neural System, Reflex Action and Reflex Arc

Revision Notes

Central Neural System

- The brain and spinal cord are collectively known as the central neural system.
- The brain is the 'command and control system' and controls voluntary and involuntary movement of organs.
- It helps to maintain the balance of our body, thermoregulation, circadian rhythms, hunger, thirst, and the activities of the endocrine glands, human behavior, vision, hearing, speech, memory, intelligence, emotions and thought.
- The brain lies inside the skull, and is protected by three meninges.
- The brain can be divided into three main parts namely – forebrain, midbrain and hindbrain.



Human Brain

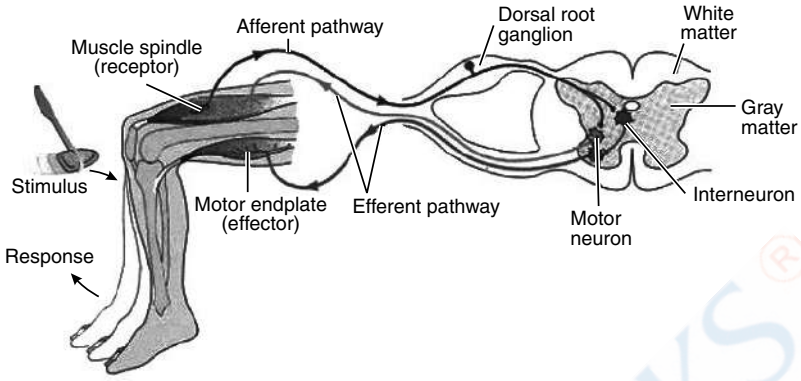
- The forebrain is the largest part and consists of **cerebrum**, **thalamus** and **hypothalamus.**
- A deep cleft divides the cerebrum into two halves – the left and right **cerebral hemispheres**.
- **Corpus callosum** connects the two hemispheres and facilitates communication between them.
- The **cerebral cortex** has prominent folds with ridges and depressions called gyri and sulci respectively.
- The neuron cell bodies concentrated in the cerebral hemispheres give grey colour to the region so **grey matter**.
- Due to the presence of myelinated axons, the inner part of the cerebral hemisphere appears white and is thus called **white matter.**
- The cerebral cortex contains **motor areas**, **sensory areas** and **association areas.**
- Association areas are responsible for complex functions.
- **The thalamus** acts as a major coordinating centre for sensory and motor signaling.
- **The hypothalamus** contains the centres that control temperature, the circadian rhythms and the urge to eat and drink.
- It secretes hormones that control the pituitary, which in turn controls the secretions of other endocrine glands.
- Forebrain includes the **amygdala** and **hippocampus** known as the **limbic system**. It controls the sexual behaviour, long-term memory, olfaction, and the expression of emotional reactions.
- **The cerebral aqueduct** connects the third ventricle to the fourth ventricle of the brain.
- The dorsal portion of the midbrain consist **corpora quadrigemina** with reflex centers.
- The midbrain and hindbrain form the brain stem which acts as a relay station for auditory and visual information and every impulse conducted between brain and spinal cord passes through the brain stem.
- The hindbrain is formed of the **pons**, **cerebellum** and **medulla oblongata**.
- Cerebellum is responsible for coordinated body movement.
- The medulla oblongata acts as a link between the brain and spinal cord and control involuntary activities.

Reflex Action and Reflex Arc

- The entire process of response to a peripheral nervous stimulation, that occurs involuntarily, i.e., without conscious effort or thought and requires the involvement of a part of the central nervous system is called a reflex action.
- The reflex pathway comprises at least one afferent neuron (receptor) and one efferent (effector or excitor) neuron

appropriately arranged in a series.

- The afferent neuron receives signal from a sensory organ and transmits the impulse via a dorsal nerve root into the CNS (at the level of spinal cord).
- The efferent neuron then carries signals from CNS to the effector.



Reflex Action showing knee jerk reflex

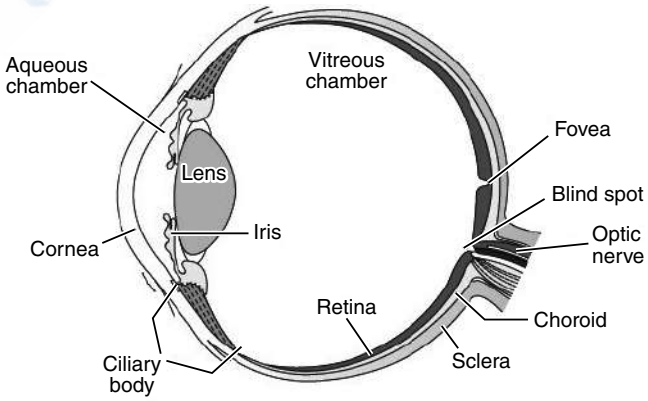
TOPIC-3

Sensory Reception and Processing

Revision Notes

Eye

- Eye is the organ of sights which detects changes and gives signals to the central neural system.
- It is located in eye sockets of the skull, and adapted for binocular vision, these are protected by the eyebrows, eyelids and lacrimal glands.
- The wall of the human eye is composed of three layers namely - sclera, choroid and retina.
- The anterior portion of the sclera is the cornea.
- Choroid forms the ciliary body which forms the iris.
- The eyeball contains a transparent crystalline lens held in place by the ligaments of the ciliary body.
- In front of the lens, the iris, which regulate the diameter of the pupil.
- The inner layer is the retina which contains three layers of cells consisting of ganglion cells, bipolar cells and the photoreceptor cells.
- Photoreceptor cells are of two types namely, rods and cones.
- Rhodopsin of rods is sensitive to dim light (scotopic) and these do not play any role in colour vision.



Parts of an Eye

- Iodopsin of cones is sensitive to bright daylight.
- Cones are of three types and contain different photo-pigments and respond to red, green and blue light radiations.

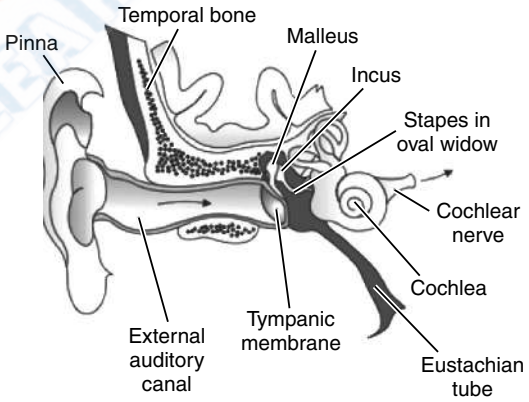
- The optical part of the retina contains two spots known as the blind spot and the fovea. The fovea is a portion of the retina where only cones are densely packed. It is the point where the resolution is the greatest.
- The aqueous chamber lies between the cornea and lens called, an aqueous humor that provides nutrition to the lens and cornea.
- The vitreous chamber lies between the lens and retina.
- It is filled with vitreous humor that gives shape to the eye, supports the retina and lens, refracts light rays and maintains intra-ocular pressure.
- The cornea, aqueous humor, lens and vitreous humor, all act as small lenses and refract light rays to focus on the retina.

Mechanism of Vision

- The light rays in the visible wavelength focus on the retina to generate impulses in the rods and cones. The photo pigments of the photoreceptors is composed of opsin and retinal. Light dissociates retinal from opsin, which results in changing the structure of opsin.
- The structural change in opsin changes membrane permeability, which in turn, results in potential differences in the photoreceptor cells. This results in the generation of action potential which is transmitted to the visual area of the cerebrum by the optic nerve. These nerve impulses are analysed in the visual area and help to recognise the image formed.

Ear

- The ear is an important organ for hearing and to maintain balance.
- It is divided into three parts namely, the outer ear, the middle ear and the inner ear.
- The outer and middle ear assist only in hearing, while the inner ear also helps in equilibrium.
- The outer ear consists of the pinna and external auditory meatus.
- Very fine hairs and wax-secreting sebaceous glands are present on the skin of the pinna and the meatus, which prevent dust and small insects.
- The pinna directs the sound into the meatus.
- The tympanic cavity is bound externally by the tympanic membrane and internally by an auditory capsule.
- The auditory capsule has two membrane bound apertures called the oval window and the round window.
- The middle ear has three ossicles called the malleus, incus and stapes.
- They increase the efficiency of transmission.
- Air pressure is maintained by the Eustachian tube.
- The inner ear consists of labyrinth, which consists of two functional parts namely, the cochlea, for hearing and the vestibular apparatus, for balance.

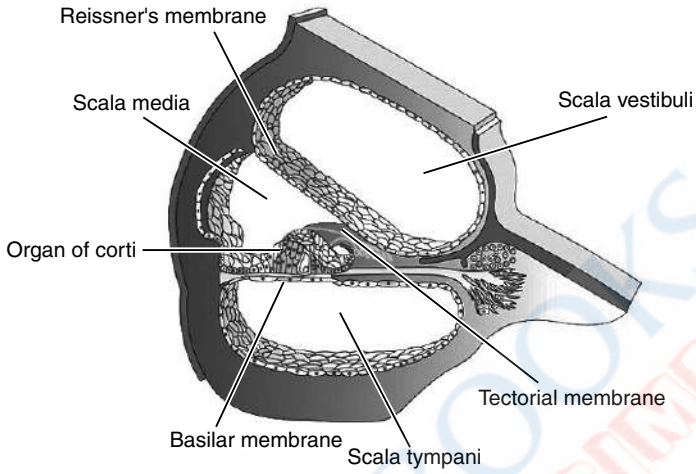


Parts of an Ear

- The labyrinth consists of two parts namely, bony and the membranous labyrinth.
- The cochlea has two membranes, namely Reissner's membrane and the basilar membrane which divide the perilymph filled bony labyrinth into scala vestibuli and scala tympani.
- The membranous labyrinth is filled with a fluid called endolymph.
- The space within cochlea called scala media is filled with endolymph.
- The fluids in the labyrinth cushion the soft structures and conduct waves from the middle ear to the organ of Corti which is the actual receptor of sound.

- It is composed of hair cells, which are in contact with tectorial membrane.
- The inner ear contains vestibular apparatus that helps maintain the body's balance.
- It consists of three semi-circular canals and the otolith organ which consists of the saccule and utricle, responsible for maintaining the body's balance and posture. The crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture.

Mechanism of Hearing



Sectional view of cochlea

- The external ear receives sound waves and directs them to the eardrum. The eardrum vibrates and transmits them through the malleus, incus and stapes and lastly to the oval window. The ossicles, in turn, amplify the sound and pass the vibrations through the oval window to the fluid of the cochlea.
- The membranous labyrinth is filled with a fluid called endolymph.
- The space within cochlea called scala media is filled with endolymph.
- This generates waves which induce a ripple in the basilar membrane, which then bend the hair cells, pressing them against the tectorial membrane. This in turn stimulates the hair cells, to generate nerve impulses, which are transmitted to the auditory cortex of the brain. The brain then interprets these nerve impulses and sound is recognised.

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Chapter 22

Chemical Coordination and Integration

TOPIC-1

Endocrine Glands, Hormones And Human Endocrine System

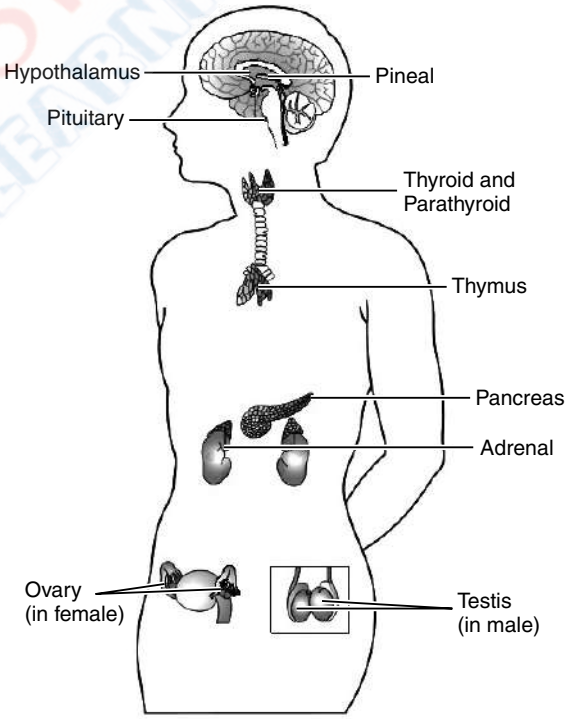
Revision Notes

Endocrine Glands and Hormones

- Endocrine glands lack ducts and hence are called ductless glands.
- The secretions of the endocrine glans are called hormones.
- Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.

Human Endocrine System

- Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus and gonads (testis in males and ovary in females) are the organised endocrine bodies in our body.



Location of endocrine glands

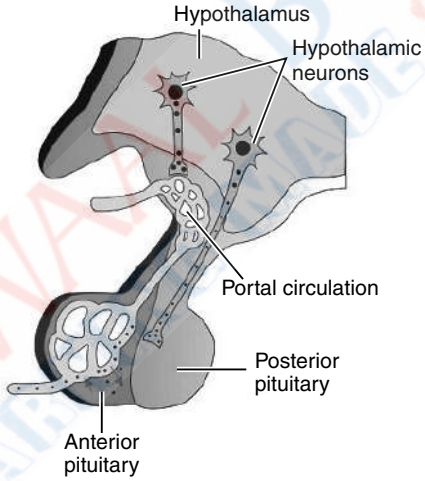
- In addition to these, some other organs, e.g., gastrointestinal tract, liver, kidney, heart also produce hormones.

(A) Hypothalamus :

- Hypothalamus contains several groups of neurosecretory cells called nuclei which produce hormones.
- Hormones released by hypothalamus regulate the synthesis and secretion of pituitary hormones.
- Hypothalamus produces two types of hormones namely, the releasing hormones-which stimulate secretion of pituitary hormones and the inhibiting hormones-which inhibit secretions of pituitary hormones. For example gonadotropin releasing hormone [GnRH] and inhibiting hormone somatostatin.
- The hormones released from hypothalamus reaches the anterior pituitary through portal circulatory system and regulate its function.
- The posterior pituitary is under the direct control of hypothalamus.

(B) Pituitary Gland :

- Pituitary gland is located in sella tursica, a bony cavity. It is attached to the hypothalamus by a stalk.
- It is divided into an adenohypophysis and a neurohypophysis.
- Adenohypophysis consists of two portions, pars distalis and pars intermedia.
- The pars distalis region of pituitary, commonly called anterior pituitary, produces growth hormone (GH), prolactin (PRL), thyroid stimulating hormone (TSH), adrenocorticotrophic hormone (ACTH), luteinizing hormone (LH) and follicle stimulating hormone (FSH).
- Pars intermedia secrete only one hormone called melanocyte stimulating hormone (MSH).

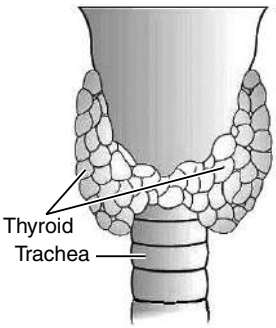


Pituitary and its relationship with hypothalamus

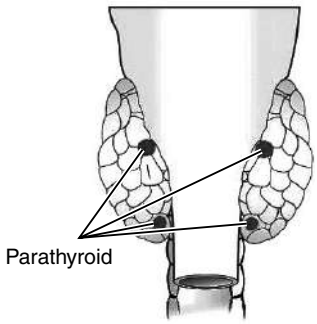
- Neurohypophysis (pars nervosa) also known as posterior pituitary, stores and releases two hormones called oxytocin and vasopressin, which are actually synthesised by the hypothalamus and are transported axonally to neurohypophysis.
- Excess secretion of growth hormone causes over growth of the body leading to gigantism and low secretion causes stunted growth called dwarfism.
- Prolactin stimulates growth of mammary gland and production of milk.
- TSH stimulates production and release of thyroid hormone.
- LH and FSH stimulate activity of the gonads.
- In male, LH stimulates synthesis and secretion of androgen hormone from testis. In female, LH induces ovulation of fully mature ovum from ovary.
- Oxytocin helps in contraction of uterus during child birth and milk ejection from mammary glands.
- Vasopressin acts mainly on the kidney and stimulates reabsorption of water and electrolytes by the distal tubules and thereby reduces loss of water through urine (diuresis). Hence, it is also called as anti-diuretic hormone (ADH).
- MSH acts on the melanocytes and regulates skin pigmentation.

(C) The Pineal Gland :

- It is located on dorsal side of forebrain and release melatonin hormone that helps to regulate diurnal rhythm of body like sleep-wake cycle and body temperature. It also influences pigmentation and menstrual cycle.



Position of Thyorid in the dorsal view



Position of Parathyroid in the ventral view

(D) Thyroid Gland :

- It is composed of two lobes on either side of trachea connected by isthmus.
- The thyroid gland is composed of follicles and stromal tissues.
- Each thyroid follicle is composed of follicular cells, enclosing a cavity which synthesise two hormones, namely tetraiodothyronine or thyroxine (T_4) and triiodothyronine (T_3).
- Iodine is essential for synthesis of thyroid hormones.
- Deficiency of iodine leads to hypothyroidism (Goitre).
- During pregnancy, hypothyroidism may cause stunted growth of baby and mental retardation (cretinism).
- Thyroid hormones regulate the basal metabolic rate.
- They support the process of red blood cell formation.
- They control the metabolism of carbohydrates, proteins and fats.
- Thyrocalcitonin hormone regulates blood calcium levels.

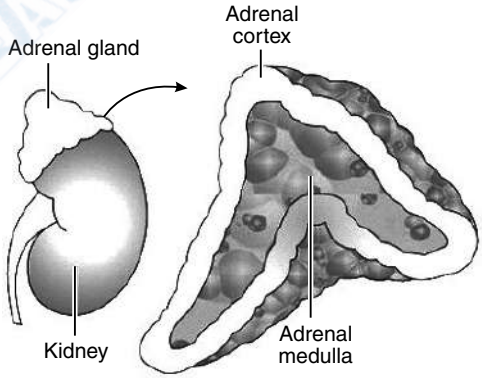
(E) Parathyroid Gland :

- It is located on the back side of thyroid gland.
- It secretes peptide hormone called parathyroid hormone (PTH).
- PTH regulates the calcium ion concentration in the blood.
- It also helps in reabsorption of calcium from renal tubules and digestive tracts.

(F) Thymus :

- It is located on the dorsal side of heart and the aorta.
- It releases peptide hormone thymosins that help in differentiation of T-lymphocytes which provide cell-mediated immunity.
- It also promotes production of antibodies to provide humoral immunity.
- Thymus is degenerated in old individuals, as a result, the immune responses of old persons become weak.

(G) Adrenal Gland :



Adrenal Gland

- It is located on anterior part of each kidney.
- It is composed of two types of tissues, central adrenal medulla and outside adrenal cortex.
- Adrenal medulla secretes adrenaline (epinephrine) and noradrenaline (norepinephrine) hormone commonly called as catecholamines. These hormones are also called as emergency hormone.
- These hormones increase alertness, pupillary dilation, sweating, heartbeat, rate of respiration, glycogenolysis.
- The adrenal cortex secretes glucocorticoids and mineralocorticoids.

- Glucocorticoids stimulate gluconeogenesis. Cortisol is the main glucocorticoid.
- Glucocorticoids, particularly cortisol, produces anti-inflammatory reactions and suppresses the immune response.
- Mineralocorticoids regulate water and electrolyte contents of the body. Aldosterone is the main mineralocorticoid in our body.

(H) Pancreas :

- It acts as both endocrine and exocrine gland, and thus is a composite gland or heterocrine gland.
- Endocrine pancreas consists of "Islets of Langerhans" which contain α-cells and β-cells.
- The α-cells secrete hormone glucagon and β-cells secrete insulin.
- Both hormones are involved in maintenance of blood sugar levels.
- Glucagon is a peptide hormone that stimulates glycogenolysis resulting in increased blood sugar (hyperglycemia). It also stimulates the process of gluconeogenises which also contributes to hyperglycemia.
- Insulin is a peptide hormone that play major role in regulation of glucose homeostasis.
- It triggers rapid movement of glucose from blood to hepatocytes and adipocytes resulting in decreased blood glucose levels (hypoglycemia).
- Prolonged hyperglycemia leads to a complex disorder called diabetes mellitus.

(I) Testis :

- It performs dual functions as a primary sex organ as well as endocrine glands.
- Testis is composed of seminiferous tubules and stromal or interstitial tissue.
- Leydig cells or interstitial cells produce androgen mainly testosterone which regulate maturation of primary sex organs and spermatogenesis. Androgens produce anabolic (synthetic) effects on protein and carbohydrate metabolism.

(J) Ovary :

- It produces two groups of steroid hormones called estrogen and progesterone.
- Estrogen is synthesized and secreted by growing ovarian follicles.
- After ovulation, ruptured follicle is converted to a structure called corpus luteum which secretes progesterone.
- Estrogen produces wide range actions like growth of female secondary sex organs, development of growing ovarian follicles, and regulation of female sexual behaviour.
- Progesterone regulates pregnancy.

TOPIC-2

Hormones of Heart, Kidney, Gastrointestinal Tract and Hormone Action

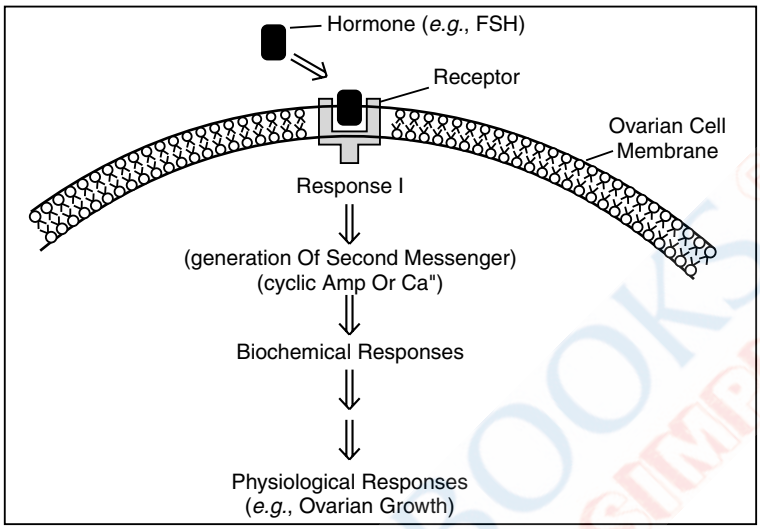
Revision Notes

Hormones of Heart, Kidney and Gastrointestinal Tract

- The tissues present in the heart, kidneys and gastrointestinal tract are not categorised as endocrine glands, but still secrete hormones.
- In the heart, the atrial wall secretes atrial natriuretic factor (ANF), which helps decrease blood pressure.
- When blood pressure increases, ANF is secreted. This dilates the blood vessels, thereby reducing blood pressure.
- The juxtaglomerular cells present in the kidneys produce erythropoietin that stimulates the formation of RBCs.
- The gastrointestinal tract secretes hormones, namely gastrin, secretin, cholecystokinin and gastric inhibitory peptide.
- Gastro-intestinal tract secrete four major peptide hormones:
  - **(a)** Gastrin stimulates the secretion of hydrochloric acid and pepsinogen.
  - **(b)** Secretin acts on the exocrine pancreas and stimulates secretion of water and bicarbonate ions.
  - **(c)** Cholecystokinin (CCK) stimulates the secretion of pancreatic enzymes and bile juice.
  - **(d)** Gastric inhibitory peptide (GIP) inhibits gastric secretion and motility.

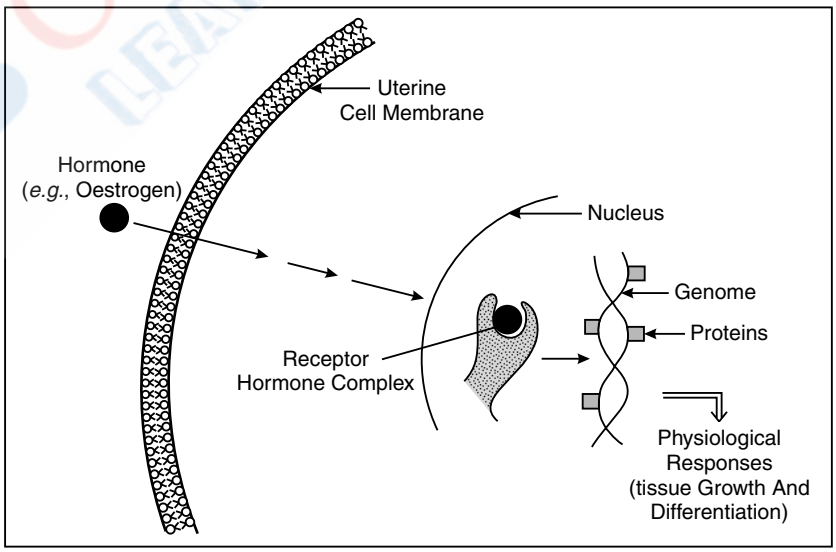
Mechanism of Hormone Action

- Hormone produce their effects on target tissues by binding to specific protein called hormone receptors located in the target tissue.
- Binding of hormones to receptor leads to the formation of hormone receptor complex. This binding leads to change in target tissue.



Mechanism of Protein Hormone Action

- On the basis of chemical nature, hormones are grouped as follows:
  - **(a)** Peptide, polypeptide and protein hormones- insulin, glucagon, pituitary hormone, hypothalamic hormones.
  - **(b)** Steroids - cortisol, testosterone, progesterone.
  - **(c)** Idothyronines - thyroid hormones.
  - **(d)** Amino acid derivatives - epinephrine.
- The hormones that bind with membrane bound receptors normally do not enter the target cells but generate second messenger which in turn regulate cellular metabolism.
- The hormones (steroid hormones) which interact with intracellular receptors mostly regulate gene expression or chromosome function by interaction with hormone-receptor complex with the genome. These biochemical actions results in physiological and developmental effects.



Mechanism of Steroid Hormone Action

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Chapter 23

Reproduction in Organisms

TOPIC-1

Life Span and Asexual Reproduction

Revision Notes

Life Span

- The period from birth to the natural death of an organism represents its life span.
- Life spans of organisms are not necessarily correlated with their sizes.
- Whatever be the life span, death of every individual organism is a certainty, i.e., no individual is immortal, except single-celled organisms.
- Life spans of some organisms are as follows: Banana tree – 25 years, Cow – 20-25 years, Parrot – 140 years, Crocodile – 60 years, **Horse** – 60 years, **Fruit fly** – 30 days, **Rice plant** – 3-4 months, **Tortoise** – 100-150 years, **Banyan tree** – 200-250 years, **Elephant** – 65 years, **Rose** – 5-7 years, **Dog** – 10-13 years, **Crow** – 15 years, **Butterfly** – 1-2 weeks, **Mango** – 150-200 years.

Reproduction

- Reproduction is defined as a biological process in which an organism gives rise to young ones (offspring) similar to itself.
- The offspring grow, mature and in turn produce new offspring.

Advantages of Reproduction

- The following are the advantages of reproduction:
  - **(a)** Reproduction enables the continuity of the species, generation after generation.
  - **(b)** Reproduction maintains life on the earth.
  - **(c)** Reproduction creates genetic variation among populations.

Factors Responsible for the Reproduction

- The following factors are responsible for the reproduction of organisms:
  - **(a)** The habitat of organisms.
  - **(b)** The internal physiology of organisms.
  - **(c)** The environmental conditions of organisms.

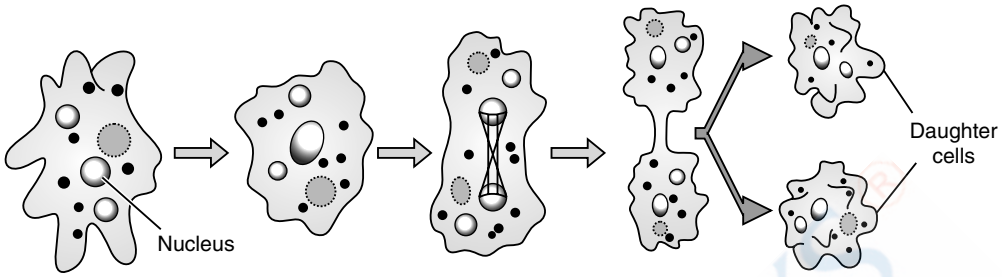
Types of Reproduction

- Based on the participation of one organism or two in the process of reproduction, it is classified into two types namely
  - **(a)** Asexual reproduction
  - **(b)** Sexual reproduction

Asexual Reproduction

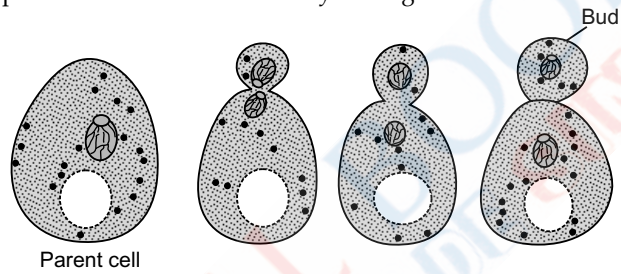
- When the offsprings are produced by single parent with or without the involvement of gamete formation, the reproduction is called asexual reproduction.
- In this method, a single individual (parent) is capable of producing offspring that are not only identical to one another but are also exact copies of their parent.

- The morphological and genetically individuals of same parents are called clone.
- Asexual reproduction is common among single-celled organisms.
- In Protists and Monerans, the organism or the parent cell divides into two to give rise to new individuals. Thus, in these organisms cell division is itself a mode of reproduction.
- In *Amoeba* and *Paramecium*, a cell divides into two halves and each rapidly grows into an adult by the process of binary fission.



Binary fission in amoeba

- In yeast, the division is unequal and small buds are produced that remain attached initially to the parent cell which, eventually gets separated and mature into new yeast organisms.

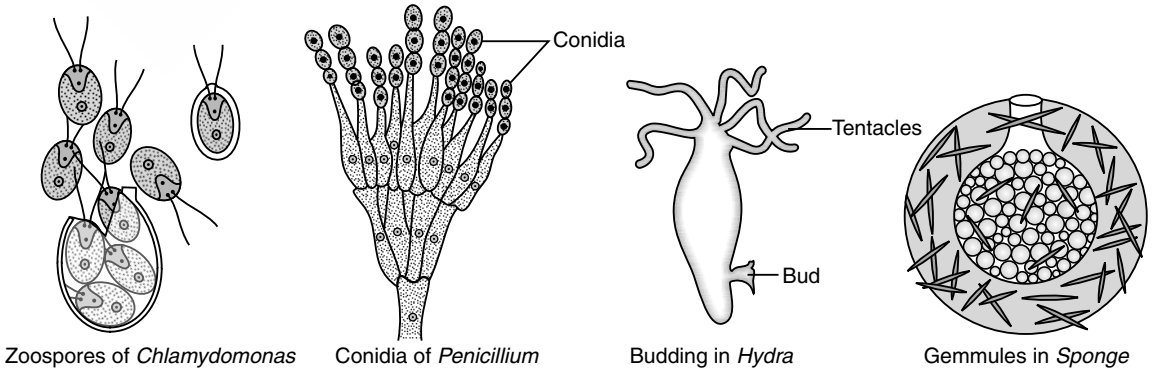


Budding in yeast

- Under unfavourable condition, the *Amoeba* withdraws its pseudopodia and secretes a three-layered hard covering or cyst around itself. This phenomenon is known as encystation.
- During favourable conditions, the encysted *Amoeba* divides by multiple fission and produces many minute pesudopodiospores.
- Later the wall of the cyst bursts and liberates these spores in the surrounding medium to grow up into individual Amoebae. This phenomenon is known as sporulation.
- Members of the Kingdom Fungi and simple plants such as algae reproduce through special asexual reproductive structures as follows:

Asexual Reproductive Structures	Examples
Zoospores	*Chlamydomonas*
Conidia	*Penicillium*
Budding	*Hydra*
Gemmules	Sponge

- Zoospores are microscopic motile structures present in the aquatic algae.



Zoospores of *Chlamydomonas* | Conidia of *Penicillium* | Budding in *Hydra* | Gemmules in *Sponge*

- Asexual reproduction is the common method of reproduction in organisms having simple organisation, as they shift to sexual method of reproduction just before the onset of adverse conditions.
- Since there is no variation, asexual reproduction does not contribute to evolution of the species.

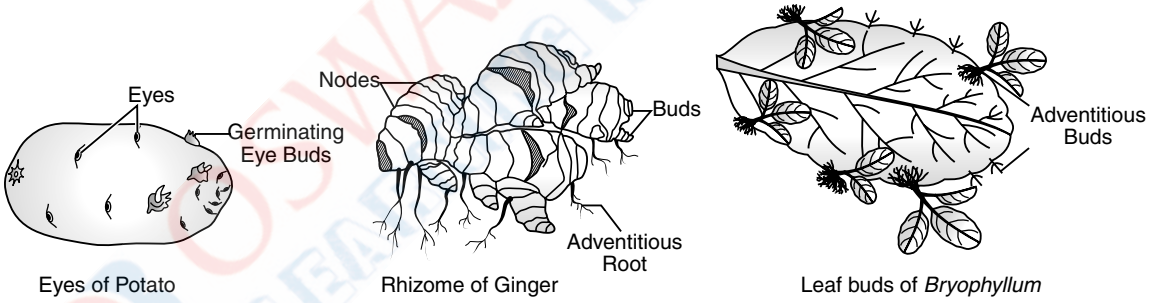
Characteristics of Asexual Reproduction

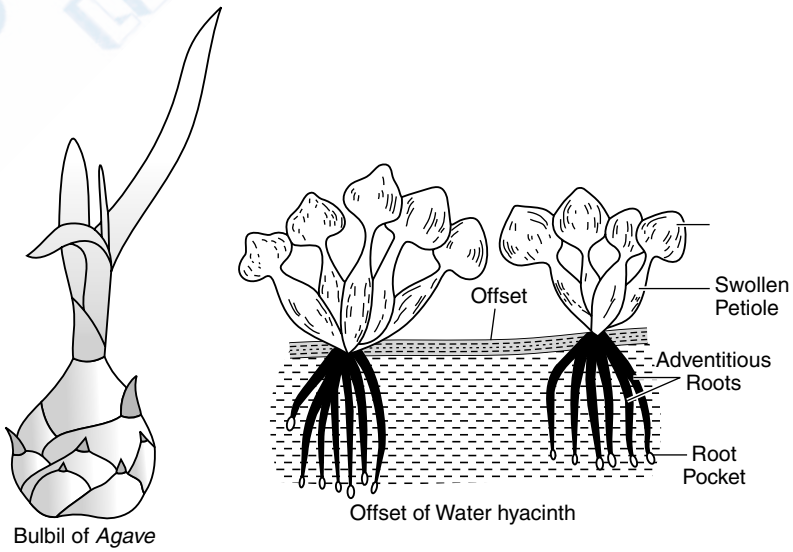
- The following are the characteristics of asexual reproduction:
- A single parent is involved.
- Gametes are not formed.
- No fertilization.
- There is only mitotic cell division.
- Daughter organisms are genetically identical to parent.
- Multiplication occurs rapidly.

Vegetative Propagation

- The process of multiplication in which fragments of the plant body function as propagule and develop into new individual is called vegetative propagation.
- In plants, the term 'asexual' is replaced by the term 'vegetative reproduction or vegetative propagation'.
- In plants, the units of vegetative propagation such as runner, rhizome, sucker, tuber, offset and bulb are all capable of giving rise to new offspring. These structures are called vegetative propagules.
- Since the formation of these structures does not involve two parents, the process involved is asexual.
- The vegetative propagules and the species involved are given as follows:

Vegetative Propagules	Parts Involved	Plants
Bulb	Stem	Onion and Garlic
Bulbil	Bulbil	Agave
Rhizome	Stem	Ginger and Banana
Runner	Stem	*Oxalis*
Tuber or eyes	Stem	Potato
Offset	Stem	Water hyacinth
Leaf buds	Leaves	*Bryophyllum*
Suckers	Stem	Mint and *Chrysanthemum*





- The site of origin of the new plantlets in the plants arises from the nodes present in the modified stems of these plants.
- When the nodes come in contact with damp soil or water, they produce roots and new plants.
- Similarly, adventitious buds arise from the notches present at margins of leaves of *Bryophyllum*.
- This ability is fully exploited by gardeners and farmers for commercial propagation.

Fragmentation

- In some organisms, the body breaks into fragments and each fragment grows into an adult has the ability to produce offspring. This mode of asexual reproduction is known as fragmentation.
- It is observed in *Hydra*.

Terror of Bengal

- The most invasive aquatic weed plant 'water hyacinth' found growing wherever there is standing water.
- It drains oxygen from the water, which leads to death of fishes.
- This plant was introduced in India because of its beautiful flowers and shape of leaves.
- Since it can propagate vegetatively at a phenomenal rate and spread all over the water body in a short period of time, it is very difficult to get rid off them.

TOPIC-2
Sexual Reproduction

Revision Notes

Sexual Reproduction

- It is an elaborate, complex and slow process.
- Sexual reproduction involves formation of the male and female gametes, either by the same individual or by different individuals of the opposite sex.
- These gametes fuse to form the zygote which develops to form the new organism.
- Because of the fusion of male and female gametes, sexual reproduction results in offspring that are not identical to the parents or amongst themselves.

Phases of Life Span

- Life span of an individual can be studied in following phases:

(a) Juvenile phase

It is the phase in which an individual achieves the ability to reproduce or prepares itself to undergo the process of reproduction.

(b) Reproductive phase

It is the phase in which an individual can reproduce offspring.

(c) Ageing and senescence phase

- During this phase, hormonal cycle begins to cease and individual loses its ability to reproduce.
- When cellular machinery begins to fails, an individual undergoes death.
- In both plants and animals, hormones are responsible for the transitions between the three phases.
- Interaction between hormones and certain environmental factors regulate the reproductive processes and the associated behavioural expressions of organisms.

Sexual Reproduction in Plants

- Both the annual and biennial plant types, show clear cut vegetative, reproductive and senescent phases whereas the perennial species does not show clearly defined phases.
- The bamboo species flower only once in their life time, generally after 50-100 years, produce large number of fruits and die.
- *Strobilanthus kunthiana* (neelakuranji), flowers once in 12 years. Last time it flowered during September-October maybe, can give the updated year - 2018. Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamil Nadu into blue stretches and attracted a large number of tourists.

Sexual Reproduction in Animals

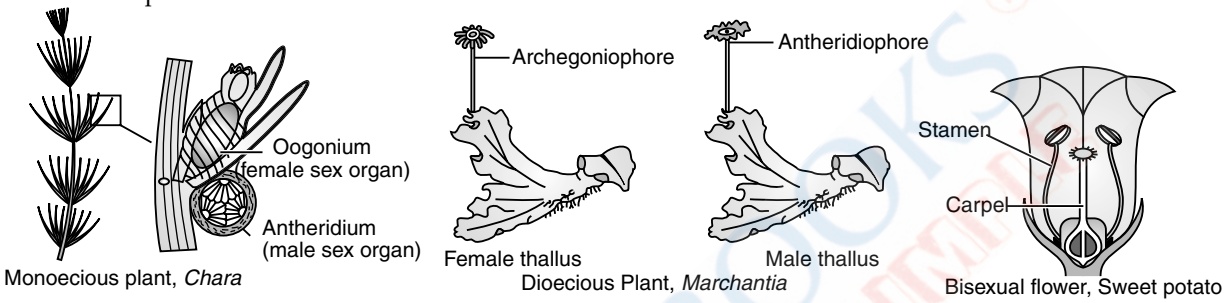
- Many mammals, especially those living in natural, wild conditions exhibit such cycles only during favourable seasons in their reproductive phase and are therefore called seasonal breeders.
- Many other mammals are reproductively active throughout their reproductive phase and hence are called continuous breeders.
- The females of placental mammals exhibit cyclical changes in the activities of ovaries and accessory ducts as well as hormones during the reproductive phase.

➢ In non-primate mammals like cows, sheeps, rats, deers, dogs, tigers, etc., such cyclical changes during reproduction are called oestrus cycle whereas in primates (monkeys, apes, and humans) it is called menstrual cycle.

Sexuality in Organisms

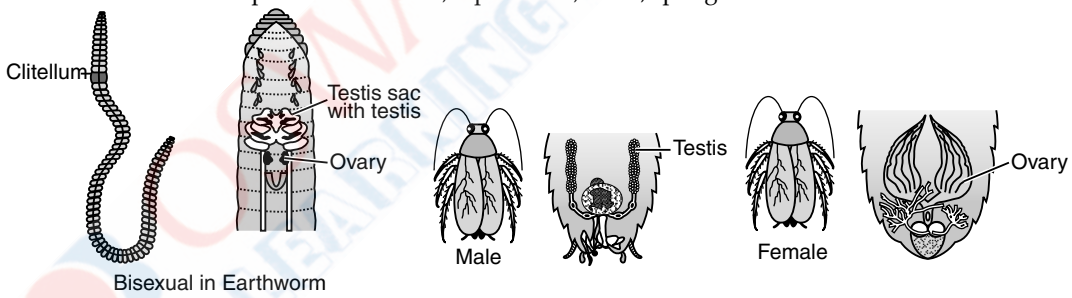
(a) Sexuality in plants

- Plants may have both male and female reproductive structures in the same plant (bisexual) or on different plants (unisexual).
- In several fungi and plants, homothallic and monoecious are used to denote the bisexual condition while heterothallic and dioecious are the terms used to describe unisexual condition.
- In flowering plants, the unisexual male flower is staminate, i.e., bearing stamens, while the female is pistillate or bearing pistils.
- In some flowering plants, both male and female flowers may be present on the same individual (monoecious) or on separate individuals (dioecious).
- Examples of monoecious plants include cucurbits and coconuts and of dioecious plants include papaya and date palm.



(b) Sexuality in animals

- Based on the sexuality, animals are classified into two categories namely,
  (a) Unisexual
  (b) Bisexual
- When an animal they are called unisexual animal possess both the sexes with clear distinct male and female individuals, they are called bisexual animal.
- These are also called as hermaphrodites. Examples – cockroaches, dogs etc.
- When an animal possess both male and female reproductive organs in the same individual, they are called bisexual animal. Examples - earthworms, tapeworms, leech, sponge etc.



Events in Sexual Reproduction

➢ The events of sexual reproduction, though elaborate and complex, follow a regular sequence.
➢ These sequential events may be grouped into three distinct stages namely,
  (a) The pre-fertilisation events
  (b) The fertilisation events
  (c) The post-fertilisation events

The Pre-fertilisation Events

➢ All the events of sexual reproduction prior to the fusion of gametes is called pre-fertilisation events.
➢ There are two main pre-fertilisation events namely,
  - Gametogenesis
  - Gamete transfer

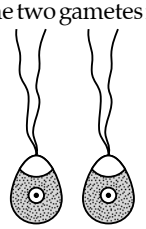
Gametogenesis

➢ The process of formation of the two types of gametes namely, male and female is known as gametogenesis.
➢ Gametes are haploid cells.

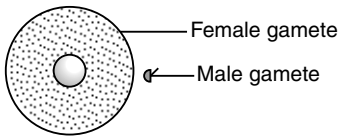
Types of Gametes

➢ Generally, the male gamete is called the antherozoid or sperm and the female gamete is called the egg or ovum.
➢ Based on the appearance of two gametes, it can be classified into two types namely,
  (a) Homogametes or Isogametes
  (b) Heterogametes

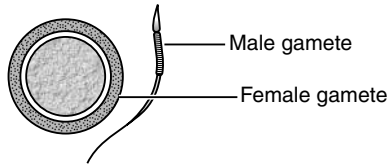
- When the two gametes i.e., male and female are similar in appearance, they are called homogametes or isogametes.
- When the two gametes i.e., male and female are morphologically dissimilar in appearance, they are called heterogametes.



Isogametes of an alga, *Cladophora*



Heterogametes of an alga, *Fucus*



Heterogametes in Human beings

Cell Division during Gamete Formation

- Gametes are haploid though the parent plant body from which they arise may be either haploid or diploid.
- A haploid parent produces gametes by mitotic division.
- Organisms of monera, fungi, algae and bryophytes have haploid plant body.
- Organisms of pteridophytes, gymnosperms, angiosperms and most of the animals including human beings, the parental body is diploid.
- The reduction division, meiosis, has to occur if a diploid body has to produce haploid gametes.
- In diploid organisms, specialized cells called meiocytes (gamete mother cell) undergo meiosis.
- At the end of meiosis, only one set of chromosomes get incorporated into each gamete.
- Chromosome numbers in meiocytes (diploid, 2n) and gametes (haploid, n) of some of the organisms are tabulated as follows :

Name of Organism	Chromosome number in meiocyte (2n)	Chromosome number in gamete (n)
Human beings	46	23
House fly	12	6
Rat	42	21
Dog	78	39
Cat	38	19
Fruit fly	8	4
Ophioglossum (a fern)	1260	630
Apple	34	17
Rice	24	12
Maize	20	10
Potato	48	24
Butterfly	380	190
Onion	32	16

Gamete Transfer

- After the formation of male and female gametes, they must be physically brought together to facilitate fusion i.e., fertilisation.
- Generally, male gamete is motile and the female gamete is stationary. However, in fungi and algae both types of gametes are motile.
- There is a need for a medium through which the male gametes move.
- In algae, bryophytes and pteridophytes, water is the medium through which this gamete transfer takes place.
- Since a large number of the male gametes fail to reach the female gametes. To compensate this loss of male gametes during transport, the number of male gametes produced is several thousand times the number of female gametes produced.

Pollination

- In seed plants, pollen grains are the carriers of male gametes and ovule has the egg. Pollen grains produced in anthers therefore, have to be transferred to the stigma before it can lead to fertilisation.
- In bisexual, self-fertilizing plants, e.g., peas, transfer of pollen grains to the stigma is easy as anthers and stigma are located close to each other.
- Pollen grains soon after they are shed, come in contact with the stigma.
- In cross pollinating plants (including dioecious plants), a specialized event called pollination facilitates transfer of pollen grains to the stigma.
- Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge male gametes near the egg.

- In dioecious animals, since male and female gametes are formed in different individuals, the organism must evolve a special mechanism for gamete transfer.
- Successful transfer and fusion of gametes (fertilisation) is essential for the most critical event in sexual reproduction.

The Fertilisation Events

Fertilisation

- The most vital event of sexual reproduction is the fusion of gametes.
- The process of fusion of gametes is known as syngamy.
- It results in the formation of a diploid zygote.
- In some organisms like rotifers, honeybees and some lizards and birds (turkey), the female gamete undergoes development to form new organisms without fertilisation. This phenomenon is called parthenogenesis.

Types of Fertilisation

Based on the occurrence of syngamy, fertilisation can be classified into two types namely :

(a) External fertilisation

(b) Internal fertilisation

External Fertilisation

- In most aquatic organisms, such as algae and fishes as well as amphibians, syngamy occurs in the external medium (water), i.e., outside the body of the organism. This type of gametic fusion is called external fertilisation.
- These organisms show great synchrony between the sexes and release a large number of gametes into the surrounding medium (water) in order to enhance the chances of syngamy.
- A major disadvantage is that the offspring are extremely vulnerable to predators threatening their survival up to adulthood.

Internal Fertilisation

- In many terrestrial organisms such as fungi, higher animals such as reptiles, birds, mammals and in bryophytes, pteridophytes, gymnosperms and angiosperms, syngamy occurs inside the body of the organism i.e., egg is formed inside the female body where they fuse with the male gamete. This type of gametic fusion is called internal fertilisation.
- In these organisms, the male gamete is motile and has to reach the egg in order to fuse with it.
- Though the number of sperms produced is very large, there is a significant reduction in the number of eggs produced.
- In seed plants, the non-motile male gametes are carried to female gamete by pollen tubes.

Post – Fertilisation Events

- All events in sexual reproduction which occur after the formation of zygote are called post-fertilisation events.
- Fertilisation results in the formation of diploid zygote.
- Zygote is the vital link that ensures continuity of species between organisms of one generation and the next.
- Every sexually reproducing organism begins life as a single cell–the zygote.
- Further development of the zygote depends on the type of life cycle and the environment.
- In fungi and algae, zygote develops a thick wall that is resistant to desiccation and damage to undergo a period of rest before germination.
- In haplontic life cycle, zygote divides by meiosis to form haploid spores that grow into haploid individuals.

Embryogenesis

- The process of development of embryo from the zygote is known as embryogenesis.
- During this process,
  (a) zygote undergoes cell division (mitosis)
  (b) cell differentiation
- The cell divisions increase the number of cells in the developing embryo while cell differentiation helps groups of cells to undergo certain modifications to form specialized tissues and organs to form an organism.
- Based on the development of zygote, the animals are classified into two types namely :
  (a) Viviparous
  (b) Oviparous

Viviparous

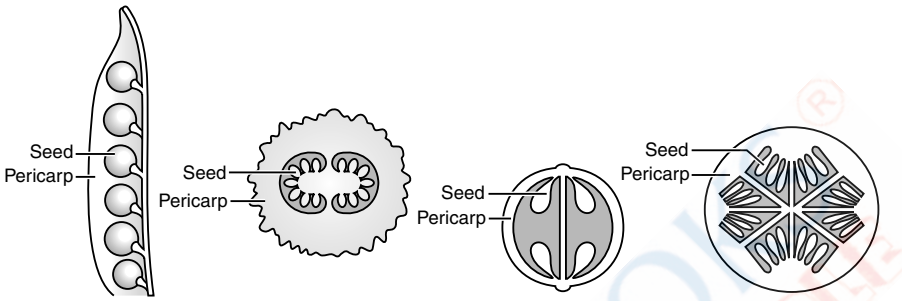
- In viviparous animals, the zygote develops into a young one inside the body of the female organism.
- After attaining a certain stage of growth, the young ones are delivered out of the body of the female organism.
- Because of proper embryonic care and protection, the chance of survival of young ones is greater in viviparous organisms.

Oviparous

- In oviparous animals, the fertilised eggs covered by hard calcareous shell are laid in a safe place in the environment.
- After a period of incubation young ones hatch out.

Development of Zygote in Plants

- In flowering plants, the zygote is formed inside the ovule.
- After fertilisation, the sepals, petals and stamens of the flower wither and fall off.
- The pistil remains attached to the plant.
- The zygote develops into the embryo and the ovules develop into the seed.
- The ovary develops into the fruit which develops a thick wall called pericarp that is protective in function. After dispersal, seeds germinate to produce new plants under favourable conditions.
- Below are certain fruit showing seeds and protective pericarp.



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Chapter 24

Sexual Reproduction in Flowering Plants

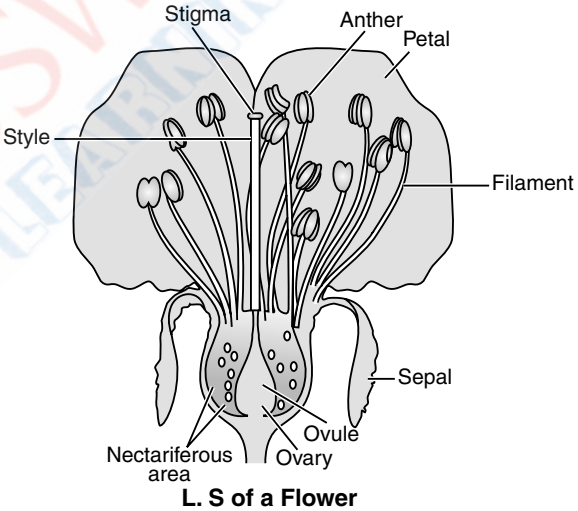
TOPIC-1

Flower, Pre-Fertilisation : Structures and Events

Revision Notes

Flower

- All flowering plants show sexual reproduction.
- Flowers are objects of aesthetic, ornamental, social, religious and cultural value.
- Flowers are morphological and embryological marvels and the sites of sexual reproduction.



L. S of a Flower

Pre-fertilisation : Structures and Events

- Several hormonal and structural changes lead to the differentiation and development of the floral primordium.
- Inflorescences are formed which bear the floral buds and then the flowers.
- In the flower the male and female reproductive structures i.e., the androecium and the gynoecium respectively get differentiated and develops.
- The androecium consists of a whorl of stamens representing the male reproductive organ and the gynoecium represents the female reproductive organ.

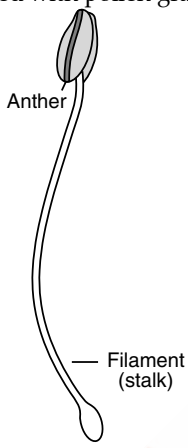
Stamen, Microsporangium and Pollen Grain

Structure of Stamen

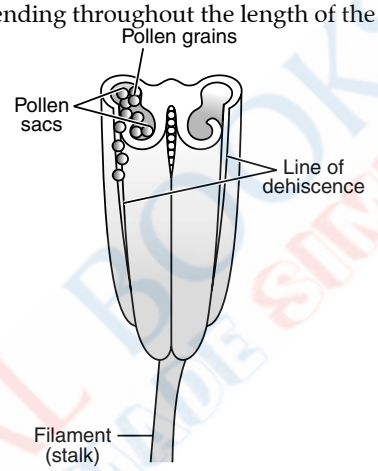
- It consists of two parts namely,
  - **(a)** The long and slender stalk called the filament.
  - **(b)** The terminal, generally bilobed, structure called the anther.
- The proximal end of the filament is attached to the thalamus or the petal of the flower.
- The number and length of stamens vary with species.

Structure of Anther

- It is bilobed with each lobe having two theca. Hence, they are dithecous.
- A longitudinal groove runs lengthwise separating the theca.
- The anther is a four-sided or tetragonal structure consisting of four microsporangia located at the corners, two in each lobe.
- The microsporangia develop to become pollen sacs.
- The pollen sacs are packed with pollen grains extending throughout the length of the anther.



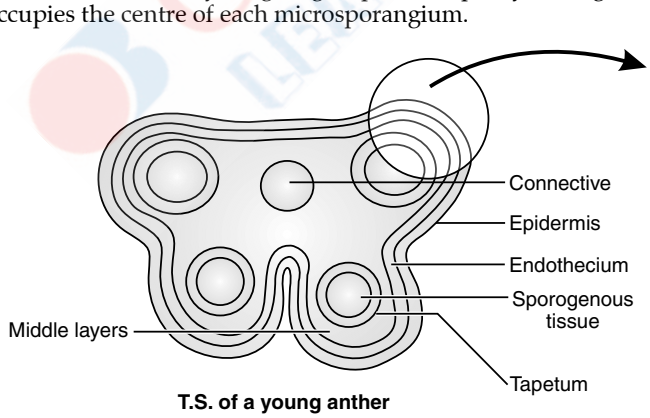
A Stamen



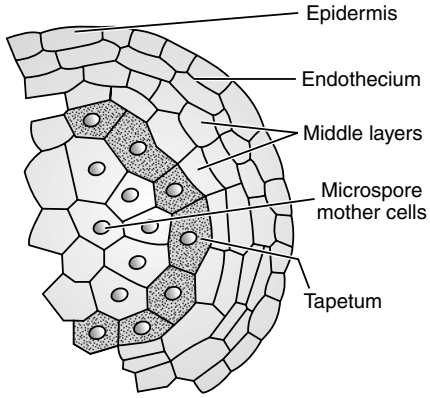
A section of an anther

Structure of Microsporangium

- It appears circular in outline, surrounded by four wall layers namely,
  - **(a)** Epidermis
  - **(b)** Endothecium
  - **(c)** Middle layers
  - **(d)** Tapetum
- The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen.
- The tapetum nourishes the developing pollen grains.
- The cells of the tapetum possess dense cytoplasm and have more than one nucleus.
- When the anther is young, a group of compactly arranged homogenous cells called the sporogenous tissue occupies the centre of each microsporangium.



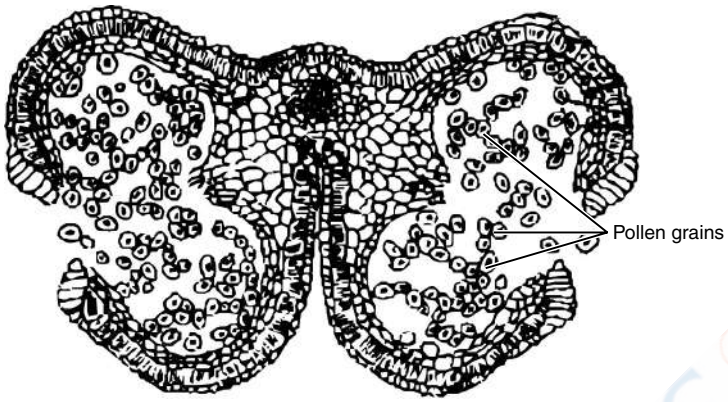
T.S. of a young anther



Microsporogenesis

- When the anther develops, the cells of the sporogenous tissue undergo meiotic divisions to form microspore tetrads.
- Each cell of the sporogenous tissue is a potential pollen or microspore mother cell (PMC).
- The process of formation of microspores from a pollen mother cell through meiosis is called microsporogenesis.
- The microspores formed are arranged in a cluster of four cells called the microspore tetrad.
- As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains.
- Inside each microsporangium several thousands of microspores or pollen grains are formed that are released with

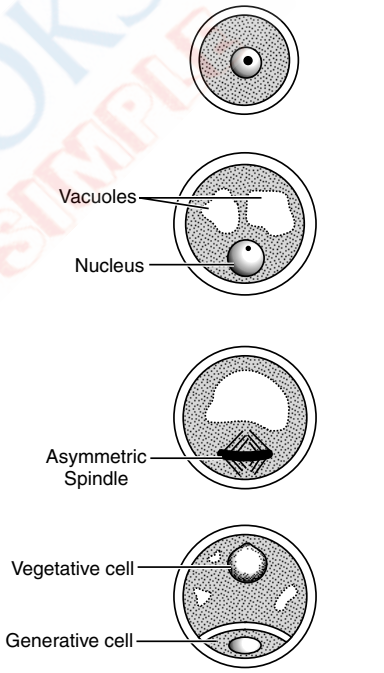
the dehiscence of anther.



Transverse section of a nature dehisced anther

Structure of Pollen Grain

- It represents the male gametophytes.
- It is spherical measuring about 25-50 micrometers in diameter.
- It has a prominent two-layered wall namely,
- The hard outer layer called the exine.
- The thin inner wall called intine.
- Exine is made up of sporopollenin, one of the most resistant organic materials known.
- It can withstand high temperatures and strong acids and alkali.
- No enzyme degrades sporopollenin.
- Intine is continuous layer made up of cellulose and pectin.
- The pollen grain has prominent apertures called germ pores where sporopollenin is absent.
- Pollen grains are well preserved as fossils because of the presence of sporopollenin.
- The cytoplasm of pollen grain is surrounded by a plasma membrane.
- When the pollen grain is matured, it contains two cells namely,
  (a) The vegetative cell
  (b) The generative cell
- The vegetative cell is bigger with abundant food reserve and a large irregularly shaped nucleus.
- The generative cell is small, spindle shaped with dense cytoplasm and a nucleus.
- The generative cell floats in the cytoplasm of the vegetative cell.
- In most of the angiosperms, the pollen grains are shed at 2-celled stage.
- In certain species, the generative cell further divides mitotically to give rise to the two male gametes before pollen grains are shed. It is a 3-celled stage.
- Once pollen grains are shed, they have to land on the stigma before they lose viability to bring about fertilization.
- The period for viability of pollen grains is highly variable and also depends on the prevailing temperature and humidity.
- For example, the pollen grains of rice and wheat lose viability within 30 minutes of their release and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months.
- It is possible to store pollen grains of a large number of species for years in liquid nitrogen (-196°C).
- This stored pollen can be used as pollen banks.



Stages of a microspore maturing into a pollen grain

Significance of Pollen Grain

(a) Pollen grains cause severe allergies and bronchial diseases leading to chronic respiratory disorders such as asthma, bronchitis, etc.

(b) *Parthenium* or carrot grass that came into India as a contaminant with imported wheat has become ubiquitous in occurrence and causes pollen allergy.

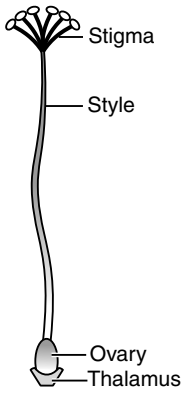
(c) Pollen grains are rich in nutrients and hence, pollen tablets act as food supplements.

(d) Pollen consumption increases the performance of athletes and race horses.

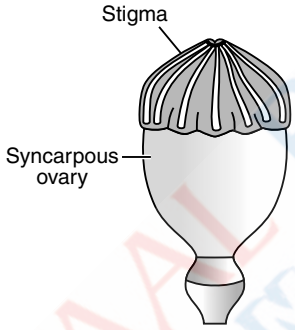
The Pistil, Megasporangium and Embryo sac

Gynoecium or Pistil

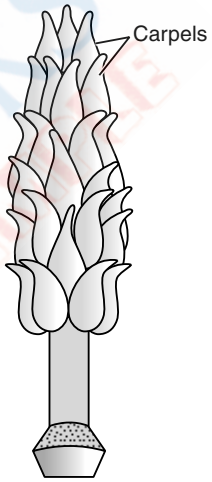
- It represents the female reproductive part of the flower.
- It may have a single pistil called monocarpellary or have more than one pistil called multicarpellary.
- When there are more than one, the pistils may be fused together called syncarpous or may be free called apocarpous.
- Each pistil has three parts namely,
  (a) Stigma **(b)** Style **(c)** Ovary
- The stigma serves as a landing platform for pollen grains.
- The style is the elongated slender part beneath the stigma.
- The basal bulged part of the pistil is the ovary.
- Inside the ovary is the ovarian cavity called locule.
- The placenta is located inside the ovarian cavity.
- The ovules or megasporangia arise from the placenta.
- The number of ovules in an ovary may be one as seen in wheat, paddy, mango etc., or many as seen in papaya, water melon, orchids etc.



Pistil of *Hibiscus* flower



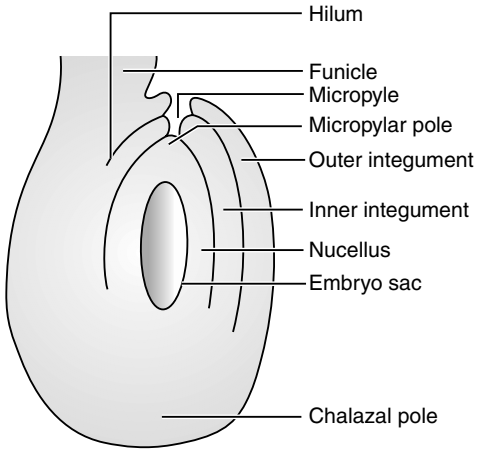
Multicarpellary, syncarpous pistil of *Papaver*



Multicarpellary, apocarpous pistil of *Michelia*

The Megasporangium or Ovule

- The ovule is a small structure attached to the placenta by means of a stalk called funicle.
- The body of the ovule fuses with funicle in the region called hilum i.e., the junction between ovule and funicle.
- Each ovule has one or two protective envelopes called integuments.
- There is a small opening in the integument called the micropyle.
- The basal part of the ovule i.e., opposite to the micropylar end, is called chalaza.
- The integuments consist of mass of cells called the nucellus which has abundant reserve food materials.
- Inside the nucellus is the embryo sac or female gametophyte.
- Thus, an ovule has a single embryo sac formed from a megaspore through reduction division.



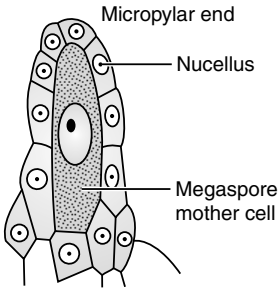
Anatropous Ovule

Megasporogenesis

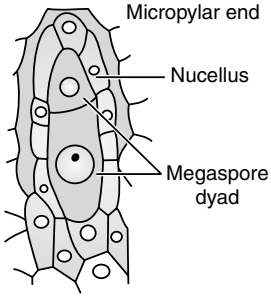
- The process of formation of megaspores from the megaspore mother cell is called megasporogenesis.
- Ovules differentiate a single megaspore mother cell (MMC) in the micropylar region of the nucellus.
- MMC is a large cell containing dense cytoplasm and a prominent nucleus.
- The MMC undergoes meiotic division resulting in the production of four megaspores.

Female Gametophyte

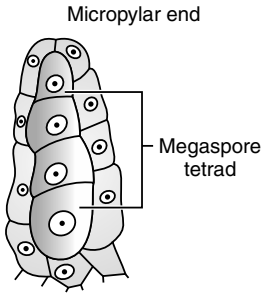
- Among the four megaspores produced, one of the megaspores becomes functional while the other three degenerates.
- Only the functional megaspore develops into the female gametophyte or embryo sac.
- This method of embryo sac formation from a single megaspore is termed monosporic development.



Megaspore Mother Cell



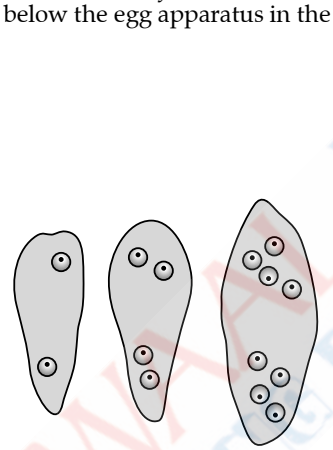
A dyad of Megaspore

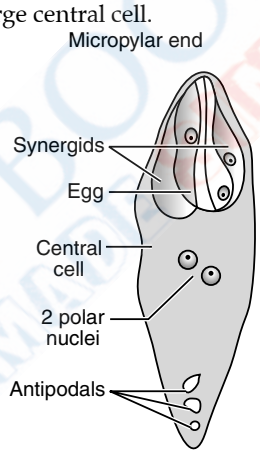


A tetrad of Megaspore

Formation of Embryo Sac

- The nucleus of the functional megaspore undergoes mitosis to form two nuclei which move to the opposite poles, forming the 2-nucleate embryo sac.
- Further, two mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac.
- Nuclear divisions are not followed immediately by cell wall formation.
- After the 8-nucleate stage, cell walls are formed resulting in female gametophyte or embryo sac.
- Six of the eight nuclei get surrounded by cell walls and organize into cells while the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell.

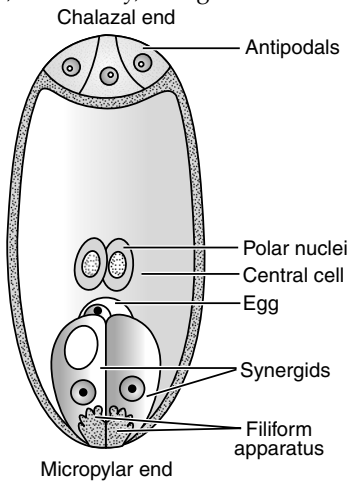

Nucleate Stages of Embryo Sac



An Embryo Sac

Characteristic Distribution of the Cells within the Embryo Sac

- There are three cells i.e., two synergids and one egg cell grouped together at the micropylar end to form the egg apparatus.
- The synergids have special cellular thickenings at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergid.
- There are three cells i.e., antipodals at the chalazal end.
- The large central cell has two polar nuclei.
- Thus, a typical angiosperm embryo sac, at maturity, though 8-nucleated is 7-celled.



A Mature Embryo Sac

Pollination

- It is the process of transferring the pollen grains to the stigma of a pistil.
- Flowering plants make use of external agents to achieve pollination.

Types of Pollination

- There are three types of pollination namely,
  - **(a)** Autogamy
  - **(b)** Geitonogamy
  - **(c)** Xenogamy

Autogamy

- It is the process of transferring the pollen grains from the anther to the stigma of the same flower.
- Complete autogamy is rare in a flower having anthers and the stigma open and exposed.
- In such flowers, the following conditions are necessary for autogamy to take place.
  - **(a)** Synchrony in pollen release
  - **(b)** Stigma receptivity
  - **(c)** Both the anthers and the stigma should lie close to each other.
- Some plants like *Viola* (common pansy), *Oxalis* and *Commelina* produce two types of flowers namely,
  - **(a)** Chasmogamous
  - **(b)** Cleistogamous
- In chasmogamous flowers, the anthers and the stigma are exposed.
- In cleistogamous flowers, the flowers do not open and hence, the anthers and stigma lie close to each other. Here, when anthers dehisce in the flower buds, the pollen grains come in contact with the stigma for the pollination.
- Thus, cleistogamous flowers are invariably autogamous as there is no chance of cross pollination while the cleistogamous flowers produce assured seed-set even in the absence of pollinators.

Geitonogamy

- It is the process of transferring the pollen grains from the anther to the stigma of another flower of the same plant.
- It is functionally cross-pollination involving a pollinating agent, but genetically similar to autogamy since the pollen grains come from the same plant.

Xenogamy

- It is the process of transferring the pollen grains from anther to the stigma of a different plant.
- This is the only type of pollination which brings genetically different types of pollen grains to the stigma.

Agents of Pollination

- There are two abiotic i.e., wind and water and one biotic i.e., animal agents to achieve pollination.
- Pollen grains coming in contact with the stigma is possible by both wind and water pollination.
- However, to compensate the loss of pollen grains, the flowers produce enormous amount of pollen for pollination to take place.

Pollination by Wind or Anemophily

- The characteristics of wind-pollinated flower are as follows:
  - **(a)** The pollen grains are light and non-sticky so that they can be transported in wind currents.
  - **(b)** They often possess well-exposed stamens, so that the pollens are easily dispersed into wind currents.
  - **(c)** They have large often-feathery stigma to easily trap air-borne pollen grains.
  - **(d)** They have a single ovule in each ovary and numerous flowers.
  - **(e)** The flowers are not colourful and do not produce any nectar.
  - **(f)** Example is the corn cob – the tassels.

Pollination by Water or Hydrophily

- Water is a regular mode of transport for the male gametes among algae, bryophytes and pteridophytes.
- In aquatic plants such as water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind.
- In *Vallisneria*, the female flower reaches the surface of water by the long stalk and the male flowers or pollen grains are released onto the surface of water. They are carried passively by water currents.
- In sea grasses, the female flowers remain submerged in water and the pollen grains are released inside the water.
- The characteristics of water-pollinated flower are as follows:
  - **(a)** Pollen grains are long, ribbon like and are carried passively inside the water and hence, only few reach the stigma and achieve pollination.
  - **(b)** Pollen grains are protected from wetting by a mucilaginous covering.

Pollination by Animals or Zoophily

- Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and humming birds) and bats are the common pollinating agents.

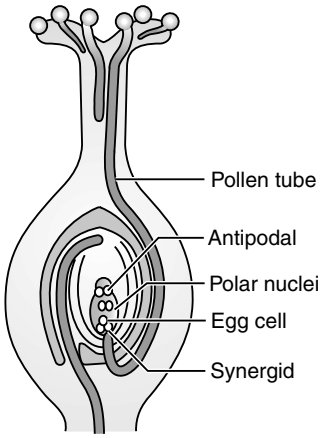
- Bees are the dominant biotic pollinating agents.
- Larger animals such as some primates (lemurs), arboreal (tree-dwelling) rodents, or even reptiles (gecko lizard and garden lizard) also act as pollinators.
- Here, animals get attracted to flowers by colour and/or fragrance.
- Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers.
- When the animal visitor comes in contact with the anthers and the stigma, the body of the animal gets a coating of sticky pollen grains and on contact with the stigma, it brings about pollination.
- The characteristics of insect-pollinated flowers are as follows:
  (a) Flowers are large, colourful, fragrant and rich in nectar.
  (b) When the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous.
  (c) The flowers pollinated by beetles and flies secrete foul odours to attract animals.
  (d) Nectar and pollen grains are the usual floral rewards.
  (e) Pollen grains are sticky.
- Floral rewards provide safe places to lay eggs.
- Example 1 – The eggs are laid at higher height as seen in the tallest flower, *Amorphophallus*.
- Example 2 – A relationship exists between a species of moth and the plant *Yucca*. Where the moth deposits its eggs in the locule of the ovary and the flower gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing.

Outbreeding Devices

- Generally, flowering plants produce hermaphrodite flowers and pollen grains come in contact with the stigma of the same flower.
- The continued self-pollination results in inbreeding depression.
- Hence, the flowering plants have developed many devices to discourage self-pollination and to encourage cross-pollination.
  (a) No synchronization of pollen release and stigma receptivity
  In some species, pollen release and stigma receptivity are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.
  (b) Position of the anther and the stigma
  In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower.
  (c) To follow a genetic mechanism i.e., self-incompatibility
  It helps to prevent self-pollination from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.
  (d) To produce unisexual flowers
  If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy. In several species such as papaya, male and female flowers are present on different plants (dioecy). This condition prevents both autogamy and geitonogamy.

Pollen-Pistil Interaction

- The pollen-pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
- Pollination does not guarantee the transfer of the right type of pollen.
- The pistil has the ability to recognize the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).
- If it is of the right type, the pistil accepts the pollen and promotes post-pollination events leading to fertilisation.
- If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
- The ability of the pistil to recognize the pollen is the result of a continuous dialogue between pollen grain and the pistil mediated by chemical components.
- After right type of pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores.
- The contents of the pollen grain move into the pollen tube.
- Pollen tube grows through the tissues of the stigma and style and reaches the ovary.
- After entering the ovary through the micropyle, it enters one of the synergids through the filiform apparatus. All these events–from pollen deposition on the stigma until pollen tubes enter the ovule–are together referred to as pollen-pistil interaction.



Longitudinal section of a flower showing growth of pollen tube

Crop Improvement Programme

- In a crop improvement programme, a breeder crosses different species and genera to combine desirable characters to produce commercially superior varieties.

- Artificial hybridisation is one of the major approaches of crop improvement programme.
- Here, only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen). This is achieved by emasculation and bagging techniques.
- If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This process is referred to as emasculation.
- Emasculated flowers have to be covered with a bag made up of butter paper of suitable size to prevent contamination of its stigma with unwanted pollen. This process is called bagging.
- When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits are developed.
- If the female parent produces unisexual flowers, there is no need for emasculation.
- The female flower buds are bagged before the flowers open.
- When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower is then rebagged.

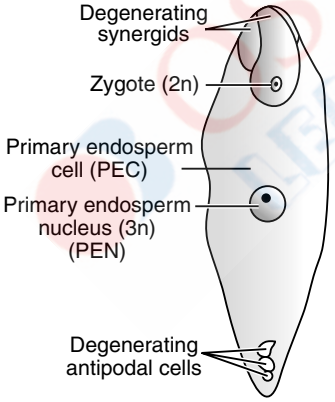
TOPIC-2

Double Fertilisation, Post-Fertilistion Structures and Events, Apomixis and Polyembryony

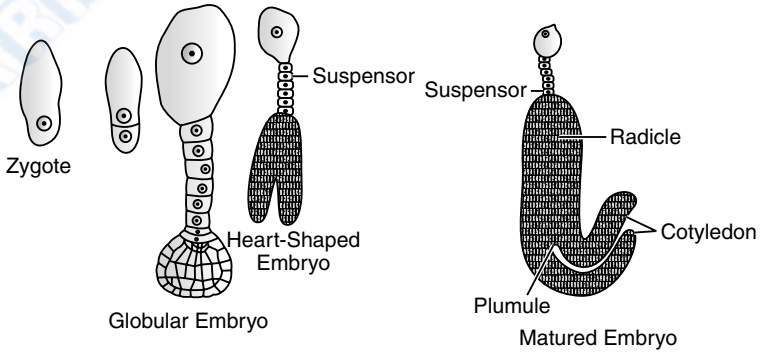
Revision Notes

Double Fertilisation

- After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid.
- One of the male gametes moves towards the egg cell and fuses with its nucleus for syngamy which results in the formation of a diploid cell, the zygote.
- The other male gamete moves towards the two polar nuclei in the central cell and fuses with them to produce a triploid primary endosperm nucleus (PEN).
- Thus, there is fusion of three haploid nuclei, it is termed triple fusion.
- Since two types of fusions i.e., syngamy and triple fusion take place in an embryo sac, the phenomenon is termed double fertilisation.
- The process of double fertilisation is an event unique to flowering plant.
- The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote develops into an embryo.



Fertilised Embryo Sac



Stages of Embryo Development

Post-Fertilisation Structures and Events

It includes development of endosperm and embryo, maturation of ovule(s) into seed(s) and ovary into fruit.

Endosperm

- Endosperm development results in embryo development. This is because the primary endosperm cell divides repeatedly to form a triploid endosperm tissue filled with reserve food materials which provides the nutrition for the developing embryo.
- The PEN undergoes successive nuclear divisions to give rise to free nuclei. This stage of endosperm development is called free-nuclear endosperm.
- Later, the cell wall formation occurs and the endosperm becomes cellular.

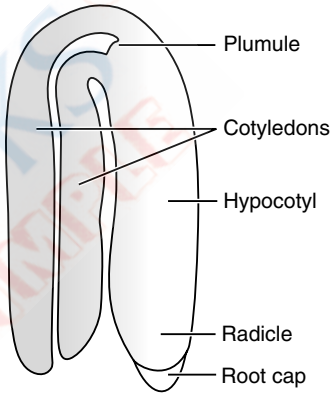
- For example, the coconut water from tender coconut is free-nuclear endosperm i.e., made up of thousands of nuclei and the surrounding white kernel is the cellular endosperm.
- Endosperm may either be completely consumed by the developing embryo as seen in pea, groundnut, beans etc before seed maturation or it may persist in the mature seed as seen in castor and coconut and be used up during seed germination.

Embryo

- Embryo develops at the micropylar end of the embryo sac where the zygote is situated.
- The zygote starts to divide only after certain amount of endosperm is formed in order to provide assured nutrition to the developing embryo.
- The early stages of embryo development are known as embryogeny is similar in both monocotyledons and dicotyledons.
- The zygote gives rise to the proembryo and then to globular, heart-shaped and mature embryo.

Dicotyledonous Embryo

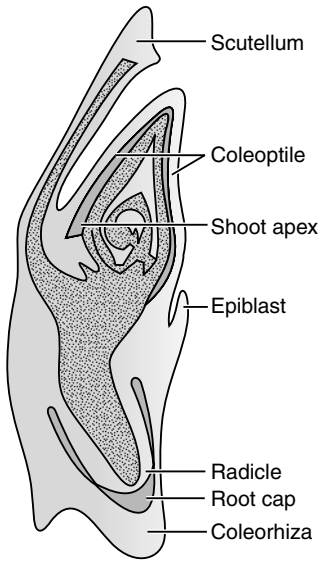
- It consists of an embryonal axis and two cotyledons.
- The portion of embryonal axis above the level of cotyledons is the epicotyl, which ends with the plumule or stem tip.
- The cylindrical portion below the level of cotyledons is hypocotyl which ends in the radicle or root tip.
- The root tip is covered with a root cap.



A Dicot Embryo

Monocotyledonous Embryo

- It has only one cotyledon.
- In grass, the large shield shaped cotyledon is called scutellum that is situated towards one side of the embryonal axis.
- At the lower end of scutellum, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorrhiza.
- The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl.
- Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.



A Monocot Embryo, Grass

Seed

- The seed is the final product of sexual reproduction.
- It is a fertilised ovule.
- Seeds are formed inside fruits.
- A seed consists of seed coat(s), cotyledon(s) and an embryo axis.
- The cotyledons of the embryo are thick and swollen due to storage of food reserves as seen in legumes.

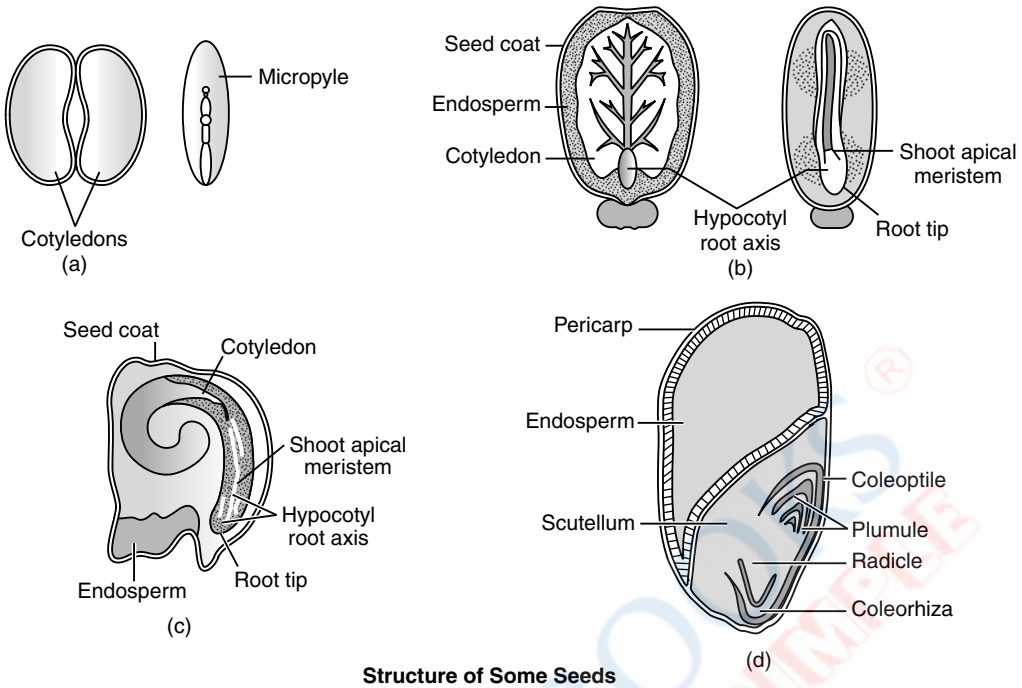
Types of Seeds

- Mature seeds may be classified into two types namely,

(a) Non-albuminous

(b) Albuminous

- Non-albuminous seeds have no residual endosperm as it is completely consumed during embryo development. It is seen in pea, groundnut, etc.
- Albuminous seeds retain a part of endosperm as it is not completely used up during embryo development. It is seen in wheat, maize, barley, castor, sunflower etc.
- In some seeds such as black pepper and beet, remnants of nucellus are persistent and are called perisperm.
- Integuments of ovules harden and become tough protective seed coats.
- The micropyle remains as a small pore in the seed coat to facilitate the entry of oxygen and water during germination.
- When the seed matures, its water content gets reduced and become relatively dry. Hence, the metabolic activity of the embryo slows down.
- The embryo then enters a state of inactivity called dormancy.
- However under favourable conditions of adequate moisture, oxygen and suitable temperature, the seeds germinate.
- As ovules mature into seeds, the ovary develops into a fruit, while the other floral parts degenerate and fall off.



Structure of Some Seeds

Advantages of Seeds

- The advantages of seeds are as follows:
  - **(a)** Seed formation is more dependable.
  - **(b)** Seeds have better adaptive strategies for dispersal to new habitats and help the species to colonise in other areas.
  - **(c)** Seeds have sufficient food reserves and hence can nourish the young seedlings until they are capable of photosynthesis.
  - **(d)** The hard seed coat provides protection to the young embryo.
  - **(e)** The seeds generate new genetic combinations leading to variations.
  - **(f)** Since, seeds are the basis of our agriculture the dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food throughout the year and also to raise crop in the next season.

Viability of Seeds

- Few species of seeds lose viability within a few months.
- However, most of the seeds of a large number of species live for several years.
- Some seeds can remain alive for hundreds of years.
- The oldest is that of a lupine, *Lupinus arcticus* excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy.
- A 2000 years old viable seed is of the date palm, *Phoenix dactylifera* discovered during the archeological excavation at King Herod's palace near the Dead Sea.

Fruits

- The fruits are the result of fertilisation.
- The wall of the ovary develops into the wall of fruit called pericarp.

Types of Fruits

- The fruits may be classified into two types namely,
- Fleshy fruits - guava, orange, mango, etc.
- Dry fruits - groundnut, and mustard, etc.
- When the fruits develop from the thalamus, it is called false fruits. Examples – Apple, strawberry, cashew etc.
- When the fruit develop only from the ovary, it is called true fruits.
- When the fruits develop without fertilisation, such fruits are called parthenocarpic or seedless fruits. Examples – Banana, grapes etc.
- Parthenocarpy can be induced through the application of growth hormones.

Apomixis and Polyembryony

- In some species of Asteraceae and grasses, there is a special mechanism to produce seeds without fertilisation, called apomixis.
- Thus, apomixis is a form of asexual reproduction that resembles sexual reproduction.

- There are several ways of development of apomictic seeds as follows:
  In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation.
  In Citrus and Mango varieties, some of the nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into the embryos.
- Occurrence of more than one embryo in a seed is referred as polyembryony.

Advantages of Apomixis and Polyembryony

- Hybrid varieties of several food and vegetable crops are being extensively cultivated to increase their productivity.
- If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny and the cost is reduced.
- The farmers can use the hybrid seeds to raise new crop year after year and does not require to buy hybrid seeds every year.

Disadvantages of Hybrids

- Hybrid seeds have to be produced every year.
- If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters.
- Production of hybrid seeds is costly.

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Chapter 25

Human Reproduction

TOPIC-1

Reproductive System and Gametogenesis

Revision Notes

Reproductive System

- The reproductive events in humans includes the following:

  (a) Formation of gametes called gametogenesis *i.e.*, formation of sperms in males and formation of ovum in females.

  (b) Transfer of sperms into the female genital tract is known as insemination.

  (c) Fusion of male and female gametes called fertilisation resulting in the formation of zygote.

  (d) Formation and development of blastocyst.

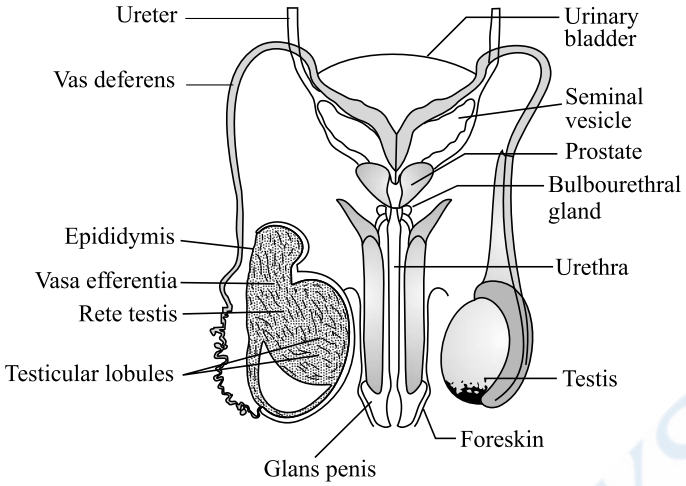
  (e) Attachment of blastocyst to the uterine wall known as implantation.

  (f) Embryonic development is called gestation.

  (g) The expelling of a fully grown fetus from the mother's uterine cavity is known as parturition.

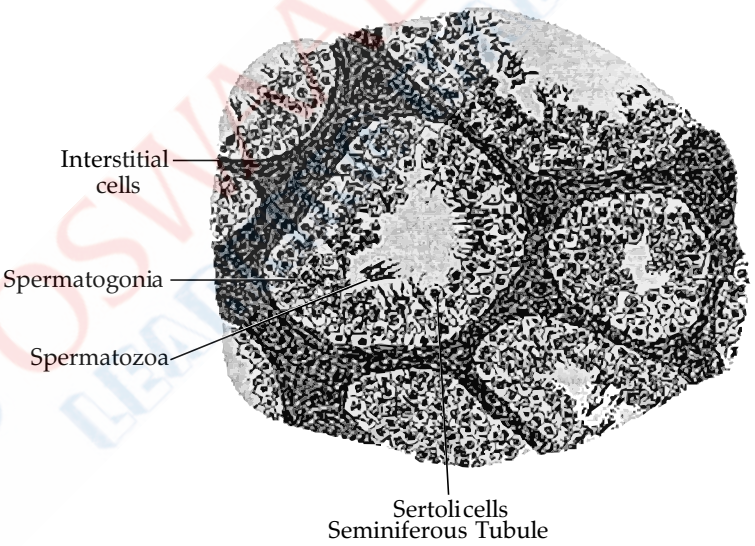
(A) The Male Reproductive System

- It is located in the pelvis region.
- It includes a pair of testis along with accessory ducts, glands and the external genitalia.
- The testes are situated outside the abdominal cavity within a pouch called scrotum.
- The scrotum helps in maintaining the low temperature of the testes about 2 – 2.5°C lower than the normal internal body temperature necessary for spermatogenesis.
- Each testis is oval in shape, with a length of about 4 to 5 cm and a width of about 2 to 3 cm.
- The testis is covered by a dense covering.
- Each testis has about 250 compartments called testicular lobules.
- Each lobule contains one to three highly coiled seminiferous tubules in which sperms are produced.
- Each seminiferous tubule is lined on its inside by two types of cells called male germ cells (*spermatogonia*) and Sertoli cells.



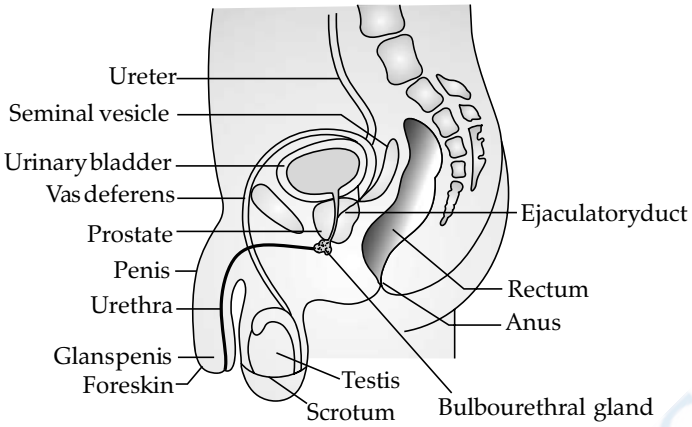
Diagrammatic view of male reproductive system

- The male germ cells undergo meiotic divisions leading to the formation of sperm while Sertoli cells provide nutrition to the germ cells.
- The regions outside the seminiferous tubules are called interstitial spaces which contain small blood vessels and interstitial cells or Leydig cells.
- Leydig cells synthesise and secrete testicular hormones called androgens.
- The male sex accessory ducts include rete testis, vasa efferentia, epididymis and vas deferens.
- The seminiferous tubules of the testis open into the vasa efferentia through rete testis.
- The vasa efferentia open into epididymis located on the posterior surface of each testis.



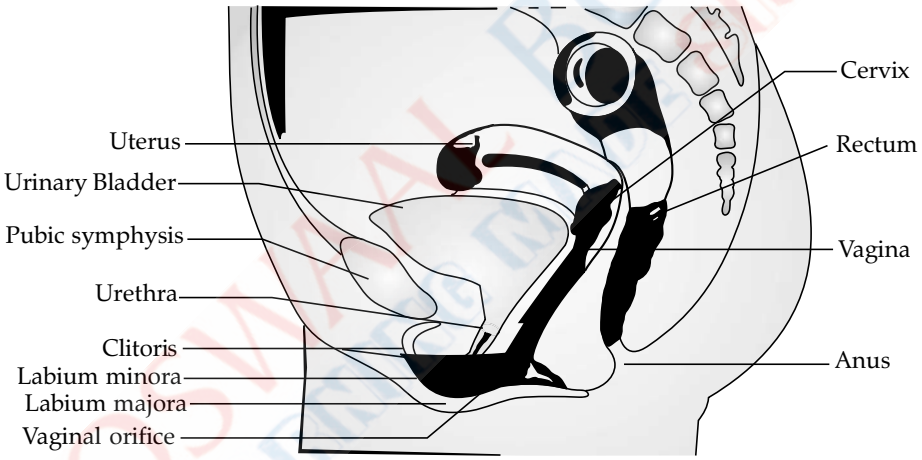
Sectional view of/Seminiferous Tubule

- The epididymis leads to vas deferens and opens into urinary bladder.
- It receives a duct from seminal vesicle and opens into urethra as the ejaculatory duct.
- These ducts store and transport the sperms from the testis to the outside through urethra.
- The urethra extends through the penis to its external opening called urethral meatus.
- The penis is the male external genitalia made up of special tissue that helps in erection of the penis to facilitate insemination.
- The enlarged end of penis called the glans penis is covered by a loose fold of skin called foreskin.
- The male accessory glands include paired seminal vesicles, prostate and paired bulbourethral glands.
- The secretions of these glands constitute the seminal plasma (semen) rich in fructose, calcium and certain enzymes which helps in the lubrication of the penis.

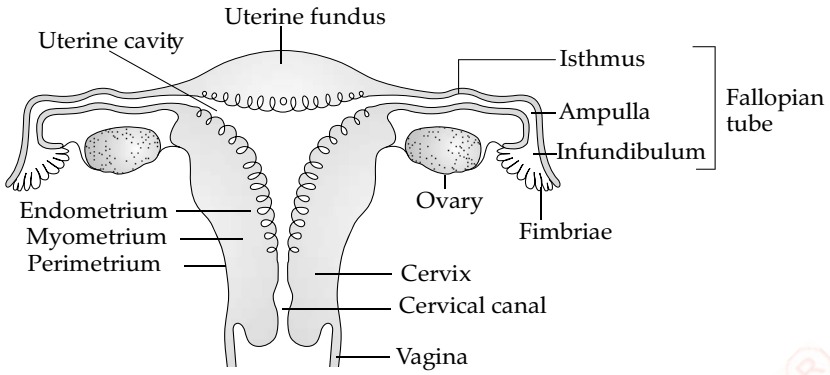


(B) The Female Reproductive System

- It is located in pelvic region.
- It consists of a pair of ovaries, a pair of oviducts or fallopian tubes, uterus, cervix, vagina and the external genitalia.
- There is a pair of the mammary glands which are integrated structurally and functionally to support the processes of ovulation, fertilisation, pregnancy, birth and child care.
- Ovaries are the primary female sex organs that produce the female gamete i.e., ovum and several steroid hormones or ovarian hormones.



- The ovaries are located one on each side of the lower abdomen connected to the pelvic wall and uterus by ligaments.
- Each ovary is covered by a thin epithelium which encloses the ovarian stroma.
- The stroma is divided into two zones namely,
  (a) A peripheral cortex
  (b) An inner medulla
- The oviducts, uterus and vagina constitute the female accessory ducts.
- Each fallopian tube is about 10-12 cm long extending from the periphery of each ovary to the uterus.
- The part closer to the ovary is the funnel-shaped infundibulum.
- The edges of the infundibulum possess finger-like projections called fimbriae, which help in collection of the ovum after ovulation.
- The infundibulum leads to a wider part of the oviduct called ampulla.
- The last part of the oviduct is the isthmus, a narrow lumen which joins the uterus.
- The uterus is single and is also called womb.
- The shape of the uterus is like an inverted pear.
- It is supported by ligaments attached to the pelvic wall.
- The uterus opens into vagina through a narrow cervix.
- The cavity of the cervix is called cervical canal which along with vagina forms the birth canal.

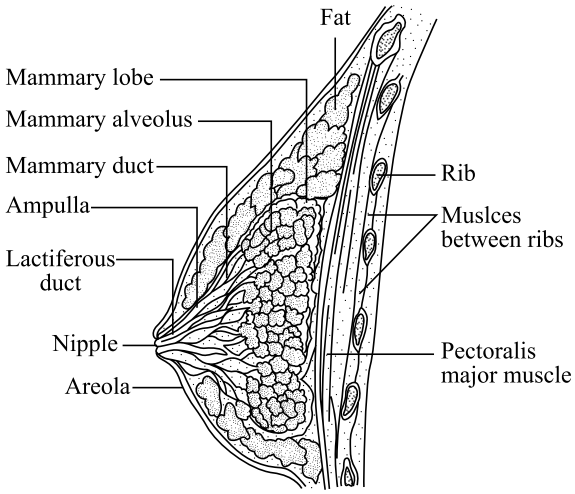


Diagrammatic Sectional view of the Female reproductive system

- The wall of the uterus has three layers of tissue namely,
  - **(a)** The external thin membranous perimetrium.
  - **(b)** The middle thick layer of smooth muscle, myometrium.
  - **(c)** The inner glandular layer lining uterine cavity called endometrium.
- The endometrium undergoes cyclical changes during menstrual cycle while the myometrium exhibits strong contractions during delivery of the baby.
- The female external genitalia include,
  - **(a)** Mons pubis
  - **(b)** Labia majora
  - **(c)** Labia minora
  - **(d)** Hymen
  - **(e)** Clitoris
- Mons pubis is a cushion of fatty tissue covered by skin and pubic hair.
- The labia majora are fleshy folds of tissue, which extend down from the mons pubis and surround the vaginal opening.
- The labia minora are paired folds of tissue.
- The opening of the vagina is covered partially by a membrane called hymen.
- The hymen is torn during the first coitus (intercourse) or by a sudden fall or jolt, insertion of a vaginal tampon, active participation in sports like horseback riding, cycling etc.
- In some women, hymen persists even after coitus.
- Thus, the presence or absence of hymen is not a reliable indicator of virginity or sexual experience.
- The clitoris is a tiny finger-like structure which lies at the upper junction of the two labia minora above the urethral opening.

Mammary Gland

- It is a characteristic of all female mammals.
- The mammary glands or breasts are paired structures that contain glandular tissue and variable amount of fat.
- The glandular tissue is divided into 15-20 mammary lobes containing clusters of cells called alveoli.
- The cells of alveoli secrete milk stored in the cavities of alveoli.
- The alveoli open into mammary tubules.
- The tubules of each lobe join to form a mammary duct.
- Several mammary ducts join to form a wider mammary ampulla connected to lactiferous duct through which milk is sucked out.



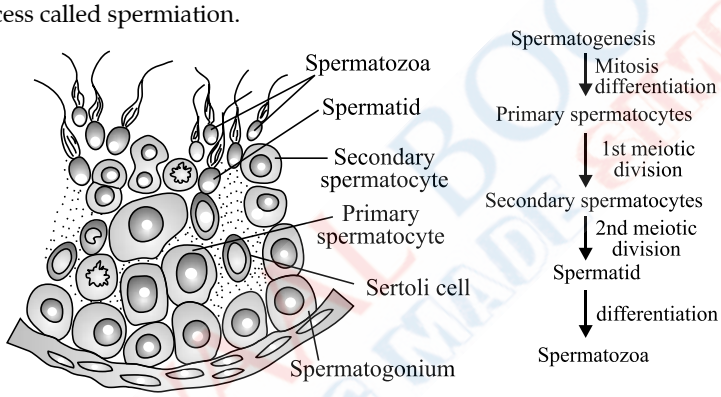
Mammary Gland

Gametogenesis

- The process by which the primary sex organs i.e., the testes in the males and the ovaries in the females produce gametes, i.e., sperms and ovum respectively is called gametogenesis.
- The gametogenesis is classified into two types, a) Spermatogenesis and b) Oogenesis

(A) Spermatogenesis

- The process of formation of a mature male gamete is called spermatogenesis.
- In testis, the immature male germ cells called spermatogonia produce sperms.
- The spermatogonia multiply mitotically and increase in numbers.
- Each spermatogonium is diploid containing 46 chromosomes.
- Some of the spermatogonia called primary spermatocytes periodically undergo meiosis.
- A primary spermatocyte completes the first meiotic division or reduction division resulting in the formation of two equal, haploid cells called secondary spermatocytes.
- The secondary spermatocytes have only 23 chromosomes each.
- The secondary spermatocytes undergo the second meiotic division to produce four equal, haploid spermatids.
- The spermatids are transformed into spermatozoa or sperms by the process called spermiogenesis.
- After spermiogenesis, sperm heads become embedded in the sertoli cells, and are released from the seminiferous tubules by the process called spermiation.



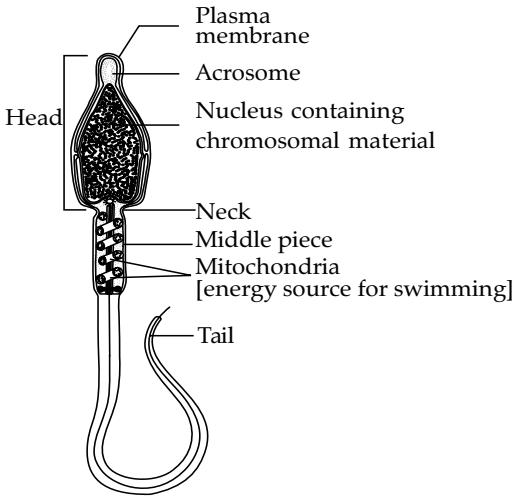
Schematic Representation : Spermatogenesis

Role of Hormones in Spermatogenesis

- Spermatogenesis starts at the age of puberty due to significant increase in the secretion of gonadotropin releasing hormone (GnRH), a hypothalamic hormone.
- The increased levels of GnRH acts at the anterior pituitary gland and stimulates the secretion of two gonadotropins namely,
  (a) Luteinising hormone (LH)
  (b) Follicle stimulating hormone (FSH)
- LH acts at the Leydig cells and stimulates the synthesis and secretion of androgens.
- Androgens stimulate the process of spermatogenesis.
- FSH acts on the Sertoli cells and stimulates the secretions which help in the process of spermiogenesis.

Structure of a Sperm

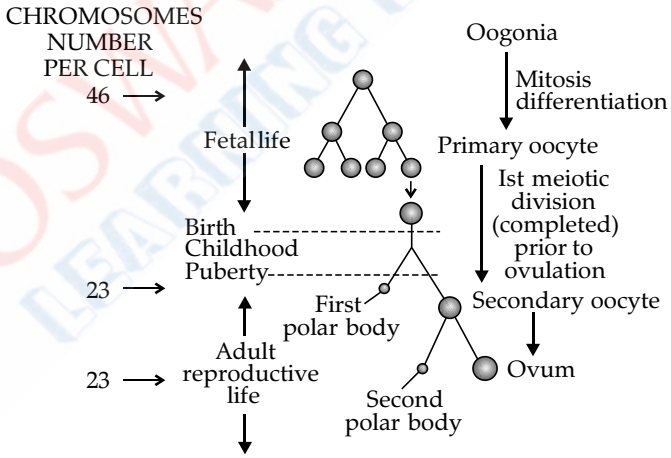
- It is a microscopic structure composed of a head, neck, a middle piece and a tail.
- A plasma membrane envelops the whole body of sperm.
- The sperm head contains an elongated haploid nucleus.
- The anterior portion is covered by a cap-like structure called acrosome.
- The acrosome is filled with enzymes that help in fertilisation of the ovum.
- The middle piece possesses numerous mitochondria, which produce energy for the movement of tail that facilitate sperm motility essential for fertilisation.
- The human male ejaculates about 200 to 300 million sperms for normal fertility.
- Sperms released from the seminiferous tubules are transported by the accessory ducts.



- The secretions of epididymis, vas deferens, seminal vesicle and prostate are essential for maturation and motility of sperms.
- The seminal plasma along with the sperms constitutes the semen.
- The functions of male sex accessory ducts and glands are maintained by the testicular hormones or androgens.

(B) Oogenesis

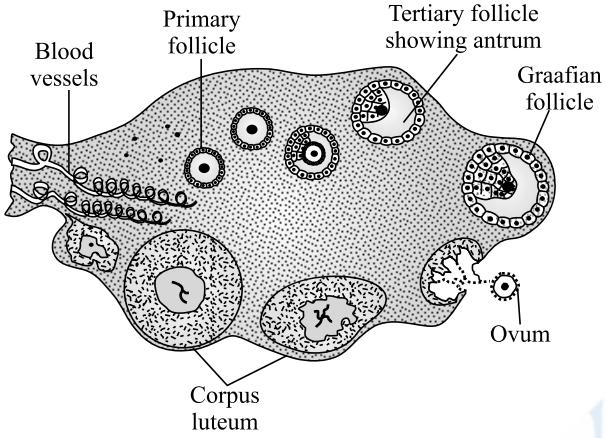
- The process of formation of a mature female gamete is called oogenesis.
- Oogenesis is initiated during the embryonic development stage when gamete mother cells (oogonia) are formed within each fetal ovary.
- No more oogonia are formed and added after birth.
- These cells start meiotic division and get temporarily arrested at Prophase-I at a stage called primary oocytes.
- Each primary oocyte then gets surrounded by a layer of granulosa cells and then called the primary follicle.
- A large number of these follicles degenerate during the phase from birth to puberty.
- Therefore, at puberty only 60,000-80,000 primary follicles are left in each ovary.
- The primary follicles get surrounded by more layers of granulosa cells and a new theca called secondary follicles.
- The secondary follicle transforms into a tertiary follicle which is characterised by a fluid filled cavity called antrum.
- The theca layer is organised into two layers namely,
  (a) An inner theca interna
  (b) An outer theca externa.
- The primary oocyte within the tertiary follicle grows in size and completes its first meiotic division (unequal division) resulting in the formation of a large haploid secondary oocyte and a tiny first polar body.
- The secondary oocyte retains bulk of the nutrient rich cytoplasm of the primary oocyte.
- The tertiary follicle further changes into the mature follicle or Graafian follicle.
- The secondary oocyte forms a new membrane called zona pellucida surrounding it.
- The Graafian follicle now ruptures to release the secondary oocyte (ovum) from the ovary by the process called ovulation.



Comparison between Spermatogenesis and Oogenesis

S. No	Spermatogenesis	Oogenesis
1.	Occurs in testis	Occurs in ovary
2.	Limited growth phase	Elaborated growth phase
3.	Each primary spermatocyte gives four sperms.	Each primary oocyte gives only one ovum. Polar bodies are formed.
4.	It begins at puberty.	It begins at embryonic stage and suspended at the time of birth. The remaining part takes place only after puberty.
5.	It occurs in seminiferous tubules of testes.	It occurs in the follicles of ovary.

Structure of Ovum or Egg



- It is spherical and non-motile.
- It is about 0.2 mm in diameter.
- Ovum has four membranes namely,
  (a) Plasma membrane (Oolemma): Innermost layer.
  (b) Vitelline membrane: Attached to plasma membrane.
  (c) Zona pellucida: Transparent non-cellular layer found outer to the vitelline membrane.
  (d) Corona radiata: Outer layer formed of follicle cells. These cells are bound together by hyaluronic acid.

TOPIC-2

Menstrual Cycle, Fertilisation and Pregnancy

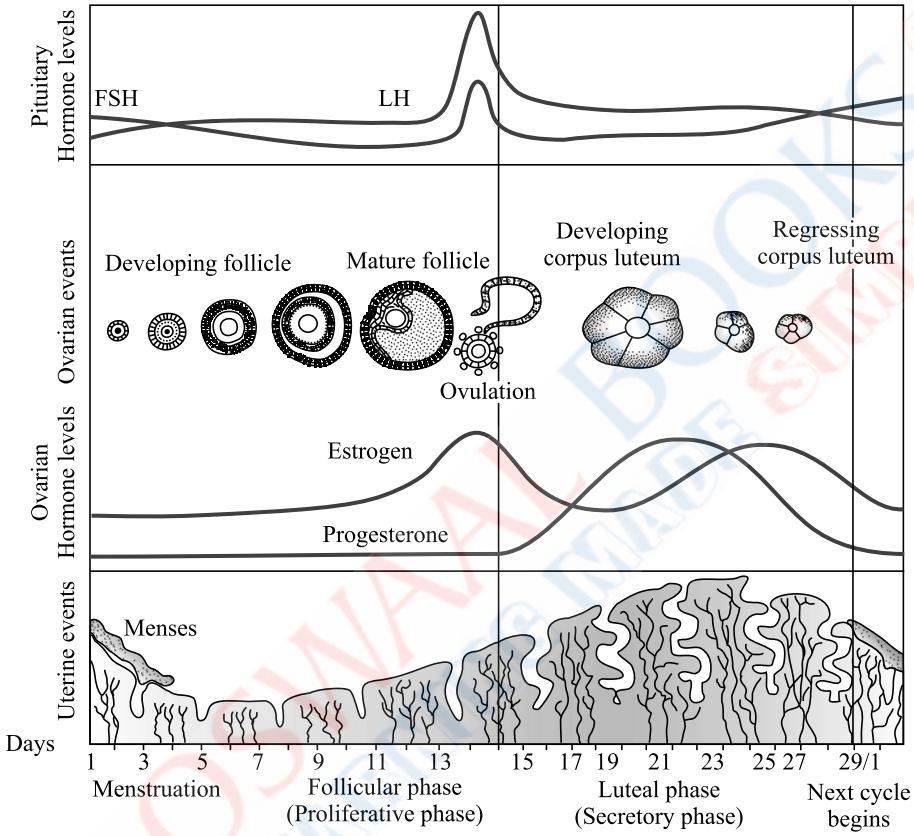
Revision Notes

Menstrual Cycle

- The reproductive cycle in the female primates (e.g. monkeys, apes and human beings) is called menstrual cycle.
- The first menstruation begins at puberty and is called menarche.
- In human females, menstruation is repeated at an average interval of about 28/29 days, and the cycle of events starting from one menstruation till the next one is called the menstrual cycle.
- One ovum is released (ovulation) during the middle of each menstrual cycle.
- The cycle starts with the menstrual phase, when menstrual flow occurs and it lasts for 3-5 days.
- Due to breakdown of endometrial lining of the uterus and its blood vessels a liquid is formed that comes out through vagina.
- Menstruation only occurs if the released ovum is not fertilised.
- Lack of menstruation may be indicative of pregnancy.
- It may also be caused due to some other underlying causes like stress, poor health etc.
- During this phase, the primary follicles in the ovary grow to become a fully mature Graafian follicle and simultaneously the endometrium of uterus regenerates through proliferation.
- These changes in the ovary and the uterus are induced by changes in the levels of pituitary and ovarian hormones.
- The secretion of gonadotropins (LH and FSH) increases and stimulates follicular development as well as secretion of estrogens by the growing follicles.
- Both LH and FSH attain a peak level in the middle of cycle (about 14th day).
- Rapid secretion of LH leading to its maximum level during the mid-cycle called LH surge induces rupture of Graafian follicle and thereby the release of ovum (ovulation).
- The ovulatory phase is followed by the luteal phase during which the remaining parts of the Graafian follicle

transform as the corpus luteum.

- It secretes large amounts of progesterone which is essential for maintenance of the endometrium a condition necessary for implantation of the fertilized ovum and pregnancy. This causes during pregnancy there is no menstruation.
- In the absence of fertilisation, the corpus luteum degenerates.
- This causes disintegration of the endometrium leading to menstruation.
- In human beings, menstrual cycles ceases around 50 years of age which is termed as menopause.
- Cyclic menstruation is an indicator of normal reproductive phase and extends between menarche and menopause.



FERTILISATION AND IMPLANTATION

Fertilisation

- During copulation (coitus) semen is released by the penis into the vagina (insemination).
- The motile sperms swim rapidly, pass through the cervix, enter into the uterus and finally reach the junction of the isthmus and ampulla (ampullary-isthmic junction) of the fallopian tube.
- The ovum released by the ovary is also transported to the ampullary-isthmic junction where fertilisation takes place.
- Fertilisation can only occur if the ovum and sperms are transported simultaneously to the ampullary-isthmic junction. Hence, not all copulations lead to fertilisation and pregnancy.
- The process of fusion of a sperm with an ovum is called fertilisation.
- During fertilisation, a sperm comes in contact with the *zona pellucida* layer of the ovum and induces changes in the membrane that block the entry of additional sperms to ensure that only one sperm can fertilise an ovum.
- The secretions of the acrosome help the sperm enter into the cytoplasm of the ovum through the zona pellucida and the plasma membrane. This induces the completion of the meiotic division of the secondary oocyte.
- The second meiotic division is also unequal and results in the formation of a second polar body and a haploid ovum (ootid).
- Soon, the haploid nucleus of the sperms and that of the ovum fuse together to form a diploid zygote.

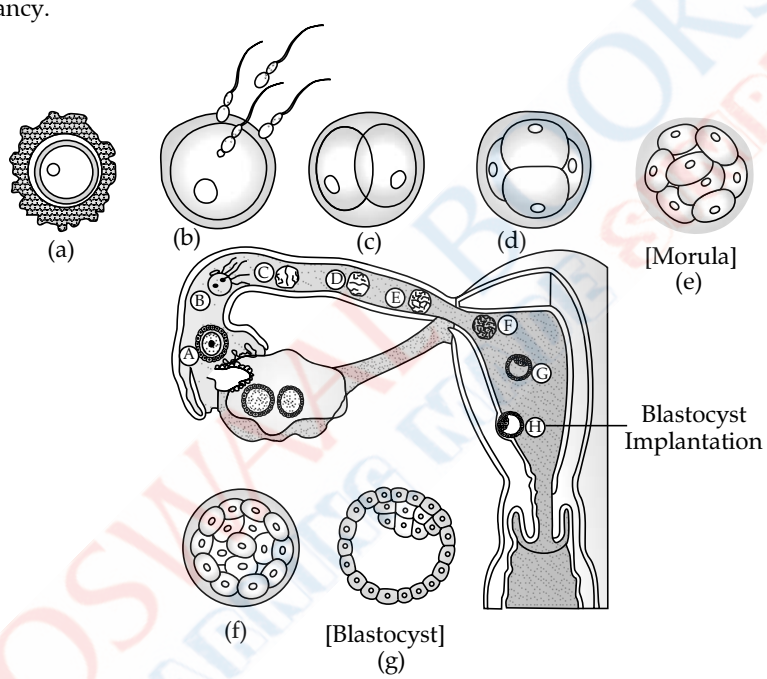
Sex Determination in Human

- The chromosome pattern in the human female is XX and that in the male is XY.

- Therefore, all the haploid gametes produced by the female (ova) have the sex chromosome X whereas in the male gametes (sperms) the sex chromosome could be either X or Y, hence, 50 per cent of sperms carry the X chromosome while the other 50 per cent carry the Y.
- After fusion of the male and female gametes the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilised the ovum.
- The zygote carrying XX would develop into a female baby and XY would form a male.

Implantation

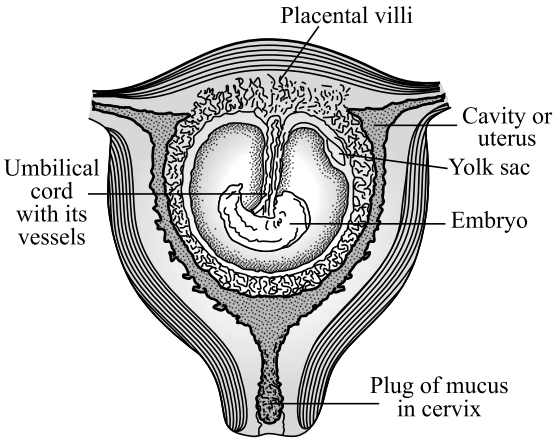
- The mitotic division starts as the zygote moves through the isthmus of the oviduct called cleavage towards the uterus and forms 2, 4, 8, 16 daughter cells called blastomeres.
- The embryo with 8 to 16 blastomeres is called a morula.
- The morula continues to divide and transforms into blastocyst as it moves further into the uterus.
- The blastomeres in the blastocyst are arranged into an outer layer called trophoblast and an inner group of cells attached to trophoblast called the inner cell mass.
- The trophoblast layer then gets attached to the endometrium and the inner cell mass gets differentiated as the embryo.
- After attachment, the uterine cells divide rapidly and cover the blastocyst.
- As a result, the blastocyst becomes embedded in the endometrium of the uterus. This is called implantation and it leads to pregnancy.



PREGNANCY AND EMBRYONIC DEVELOPMENT

Pregnancy

- After implantation, finger-like projections appear on the trophoblast called chorionic villi which are surrounded by the uterine tissue and maternal blood.
- The chorionic villi and uterine tissue become interdigitated with each other and jointly form a structural and functional unit between developing embryo (fetus) and maternal body called placenta.
- The placenta facilitate the supply of oxygen and nutrients to the embryo and also removal of carbon dioxide and excretory/waste materials produced by the embryo.
- The placenta is connected to the embryo through an umbilical cord which helps in the transport of substances to and from the embryo.
- Placenta also acts as an endocrine tissue and produces several hormones like human chorionic gonadotropin (hCG), human placental lactogen(hPL), estrogens, progestogens, etc.
- In the later phase of pregnancy, a hormone called relaxin is also secreted by the ovary. hCG, hPL and relaxin are produced in women only during pregnancy.



Human foetus within the uterus

- Levels of hormones like estrogens, progestogens, cortisol, prolactin, thyroxine, etc., are increased several folds in the maternal blood.
- Increased production of these hormones is essential for supporting the fetal growth, metabolic changes in the mother and maintenance of pregnancy.
- After implantation, (embryo) differentiates into an outer layer called ectoderm and an inner layer called endoderm.
- A mesoderm soon appears between the ectoderm and the endoderm.
- These three layers give rise to all tissues (organs) in adults.
- The inner cell mass contains certain cells called stem cells which have the potency to give rise to all the tissues and organs.
- The human pregnancy lasts 9 months.

Changes in Embryo during Pregnancy

- After one month of pregnancy, the embryo's heart is formed.
- By the end of the second month of pregnancy, the fetus develops limbs and digits.
- By the end of 12 weeks (first trimester), most of the major organ systems are formed, for example, the limbs and external genital organs are well-developed.
- The first movements of the fetus and appearance of hair on the head are observed during the fifth month.
- By the end of 24 weeks (second trimester), the body is covered with fine hair, eye-lids separate, and eyelashes are formed.
- By the end of nine months of pregnancy, the fetus is fully developed and is ready for delivery.

PARTURITION AND LACTATION

Parturition

- The average duration of human pregnancy is about 9 months which is called the gestation period.
- Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the fetus. This process of delivery of the fetus (childbirth) is called parturition.
- The parturition is induced by a complex neuroendocrine mechanism.
- The signals for parturition originate from the fully developed fetus and the placenta which induces mild uterine contractions called foetal ejection reflex. This triggers the release of oxytocin from the maternal pituitary.
- Oxytocin acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin.
- The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in stronger and stronger contractions.
- This leads to expulsion of the baby out of the uterus through the birth canal – parturition.
- Soon after the infant is delivered, the placenta is also expelled out of the uterus.

Lactation

- The mammary glands of the female undergo differentiation during pregnancy and starts producing milk towards the end of pregnancy by the process called lactation.
- This helps the mother in feeding the newborn.
- The milk produced during the initial few days of lactation is called colostrum.
- It contains several antibodies absolutely essential to develop resistance for the new-born babies.
- Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

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Chapter 26

Reproductive Health

TOPIC-1

Reproductive Health, Population and Birth Control, Medical Termination of Pregnancy

Revision Notes

REPRODUCTIVE HEALTH

- Reproductive health refers to healthy reproductive organs with normal functions.
- It also includes the emotional and social aspects of reproduction.
- According to the World Health Organisation (WHO), reproductive health means a total well-being in all aspects of reproduction, i.e., physical, emotional, behavioural and social.
- Thus, people having physically and functionally normal reproductive organs, emotional and behavioural interactions in all sex-related aspects are called reproductively healthy.

PROBLEMS AND STRATEGIES IN REPRODUCTIVE HEALTH

- India was amongst the first countries in the world to initiate action plans and programmes at a national level to attain total reproductive health as a social goal. These programmes called 'family planning' were initiated in 1951.

Reproductive and Child Health Care Programme

- Improved programmes covering wider reproduction-related areas are in operation under 'Reproductive and Child Health Care (RCH) programmes'.
- This programme :
  Create awareness among people about various reproduction related aspects.
  Provide facilities and support for building up a reproductively healthy society.
- With the help of audio-visual and the print-media governmental and non-governmental agencies have taken various steps to create awareness among the people about reproduction-related aspects.
- Introduction of sex education in schools should also be encouraged to provide right information to the young so as to discourage children from believing in myths and having misconceptions about sex-related aspects.
- Proper information about reproductive organs, adolescence and related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS, etc., would help people in the adolescent age group to lead a reproductively healthy life.
- Educating people, about birth control options, care of pregnant mothers, post-natal care of the mother and child, importance of breast feeding, equal opportunities for the male and the female child, etc., would address the importance of bringing up socially conscious healthy families of desired size.
- Awareness of problems due to uncontrolled population growth, social evils like sex-abuse and sex-related crimes, etc., need to be created to enable people to take up necessary steps to prevent them and thereby build up a socially responsible and healthy society.
- Successful implementation of various action plans to attain reproductive health requires strong infrastructural facilities, professional expertise and material support.

Factors For Improved Reproductive Health of Society

- It is essential to provide medical assistance and care to people in reproduction-related problems.
- Implementations of better techniques and new strategies from time to time are also required to provide more efficient care and assistance to people.
- Better awareness about sex related matters.
- Increased number of medically assisted deliveries and better post-natal care leading to decreased maternal and infant mortality rates.
- Increased number of couples with small families.
- Better detection and cure of STDs.
- Overall increased medical facilities for all sex-related problems.
- Statutory ban on amniocentesis for sex-determination to legally check increasing female foeticides, massive child immunisation, etc.
- Amniocentesis is a foetal sex determination test based on the chromosomal pattern in the amniotic fluid surrounding the developing embryo.
- 'Saheli'–a new oral contraceptive for the females–was developed by scientists at Central Drug Research Institute (CDRI) in Lucknow, India.

POPULATION EXPLOSION

- The development in various fields significantly improved the quality of life of the people and health facilities along with better living conditions resulting in explosive impact on the growth of population.

Reasons for Population Explosion

- A rapid decline in death rate, maternal mortality rate (MMR) and infant mortality rate (IMR).
- Increase in number of people in reproducible age.

Effect of Population Explosion

- Shortage of food.
- Unemployment.
- Difficulties in providing education.
- Poverty.

Control Measures

- The government was forced to take up serious measures to check this population growth rate.
- The most important step to overcome the population explosion problem are as follows:
  - To motivate smaller families.
  - To use various contraceptive methods.
  - Statutory raising of marriageable age of the female to 18 years and that of males to 21 years.
  - Providing incentives given to couples with small families.

BIRTH CONTROL

- The contraceptive methods are used to prevent the unwanted pregnancy.
- The contraceptive methods are the best way for birth control.
- An ideal contraceptive should be
  - User-friendly
  - Easily available
  - Effective
  - Reversible with no or least side-effects.
  - In no way interfere with the sexual drive, desire and/or the sexual act of the user.

CONTRACEPTIVE METHODS

- The contraceptive methods are broadly grouped into the following categories :

I. Natural Methods

- It works on the principle of avoiding chances of ovum and sperms meeting. It includes,

(a) Periodic abstinence

It is a method in which the couples avoid or abstain from coitus from day 10 to 17 of the menstrual cycle when ovulation could be expected. As chances of fertilization are very high during this period, it is called the fertile period. Therefore, by abstaining from coitus during this period, conception could be prevented.

(b) Withdrawal or coitus interruptus

It is another method in which the male partner withdraws his penis from the vagina just before ejaculation so as to avoid insemination.

(c) Lactational amenorrhea (absence of menstruation)

This method is based on the fact that ovulation and therefore the cycle do not occur during the period of intense lactation following parturition. Therefore, as long as the mother breast feeds, the chances of conception are almost nil.

II. Barrier Methods

- In barrier methods, ovum and sperms are prevented from physically meeting with the help of barriers.
- These methods are available for both males and females.
- It includes,

(a) Condoms

- These are barriers made of thin rubber or latex sheath that are used to cover the penis in the male or vagina and cervix in the female, just before coitus so that the ejaculated semen would not enter into the female reproductive tract, thereby preventing conception.
- Using of condoms also protect the user from contracting STDs and AIDS.
- Both the male and the female condoms are disposable, can be self-inserted and thereby gives privacy to the user.
- One common condom is 'Nirodh'.

(b) Diaphragms, Cervical caps and Vaults

- These are also barriers made of rubber that are inserted into the female reproductive tract to cover the cervix during coitus. They prevent conception by blocking the entry of sperms through the cervix. They are reusable. Spermicidal creams, jellies and foams are usually used along with these barriers to increase their contraceptive efficiency.

III. IUDs

- Another effective and popular method is the use of Intra Uterine Devices (IUDs).
- These devices are inserted by doctors or expert nurses in the uterus through vagina.
- These are available as the non-medicated IUDs such as Lippes loop, copper releasing IUDs such as CuT, Cu7, Multiload 375 and the hormone releasing IUDs like Progestasert, LNG-20.
- IUDs increase phagocytosis of sperms within the uterus and the Cu ions released suppress sperm motility and the fertilising capacity of sperms.
- The hormone releasing IUDs make the uterus unsuitable for implantation and the cervix hostile to the sperms. IUDs are ideal contraceptives for the females to delay pregnancy and/or space children.
- It is one of the most widely accepted methods of contraception in India.

IV. Oral Contraceptives

(a) Pills

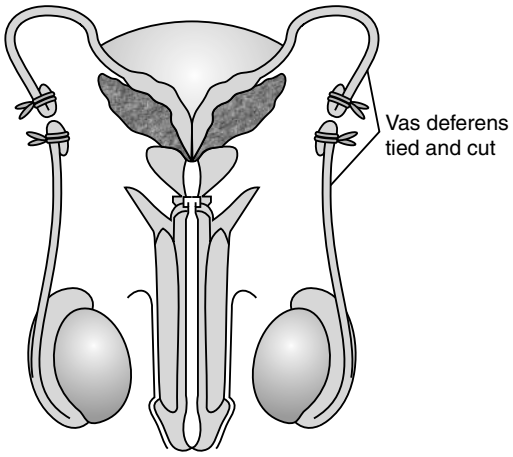
- Oral administration of small doses of either progestogens or progestogen–estrogen combinations is another contraceptive method used by the females.
- They are used in the form of tablets and hence are popularly called the pills.
- Pills have to be taken daily for a period of 21 days preferably within the first five days of menstrual cycle.
- After a gap of 7 days, (during which menstruation occurs) it has to be repeated in the same pattern till the female desires to prevent conception.
- The oral contraceptives inhibit ovulation and implantation as well as alter the quality of cervical mucus to prevent or retard entry of sperms.
- Pills are very effective with lesser side effects.
- Saheli, the new oral contraceptive for the females contains a non-steroidal preparation.
- It is a 'once a week' pill with very few side effects and high contraceptive value.

(b) Injections and Implants

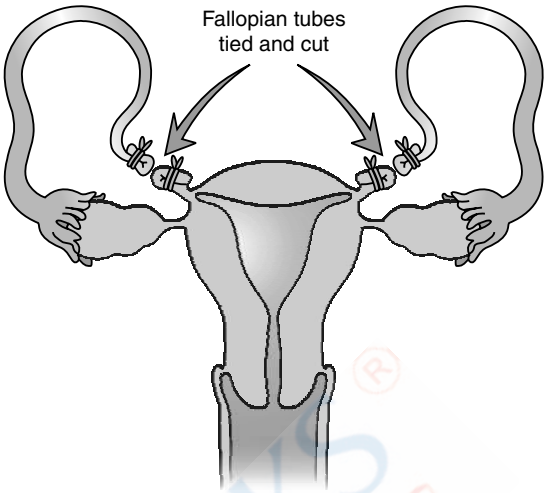
- Progestogens alone or in combination with estrogen can be used by females as injections or implants under the skin.
- Their mode of action is similar to that of pills and their effective periods are much longer.
- Administration of progestogens or progestogen-estrogen combinations or IUDs within 72 hours of coitus is very effective as emergency contraceptives as they could be used to avoid possible pregnancy due to rape or casual unprotected intercourse.

V. Surgical Methods

- Surgical methods are also called sterlization.
- This is a terminal method advised for the male/female partner to prevent any more pregnancies.
- Surgical intervention blocks gamete transport and thereby preventing conception.
- Sterlization procedure in the male is called 'vasectomy' while that in the female is called 'tubectomy'.
- In vasectomy, a small part of the vas deferens is removed or tied up through a small incision on the scrotum whereas in tubectomy, a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina.
- These techniques are highly effective but their reversibility is very poor.



Vasectomy in Male



Tubectomy in Female

Disadvantages of Contraceptive Methods

- The selection of a suitable contraceptive method should always be undertaken in consultation with qualified medical professionals.
- The contraceptives are not regular requirements for the maintenance of reproductive health.
- They are practiced against a natural reproductive event.
- It may cause ill-effects like nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding or even breast cancer.

MEDICAL TERMINATION OF PREGNANCY (MTP)

- Intentional or voluntary termination of pregnancy before full term is called medical termination of pregnancy (MTP) or induced abortion.
- MTP has a significant role in decreasing the population.
- Accepting or legalizing MTP is in debate due to emotional, ethical, religious and social issues.
- Government of India legalized MTP in 1971 with some strict conditions to avoid its misuse such as to check indiscriminate and illegal female foeticides.
- MTPs are safe during the first trimester, up to 12 weeks of pregnancy.
- Majority of the MTPs are performed illegally by unqualified quacks which are not only unsafe but could be fatal too.
- It is being misused to determine the sex of the unborn child.

Factors Leading to MTP

(a) It helps to get rid of unwanted pregnancies either due to casual unprotected intercourse or failure of the contraceptive.

(b) It is also essential in cases where continuation of the pregnancy could be harmful or even fatal either to the mother or to the fetus or both.

TOPIC-2

Sexually Transmitted Diseases (STDs) and Infertility

Revision Notes

Sexually Transmitted Diseases (STDs)

- Diseases or infections which are transmitted through sexual intercourse are called sexually transmitted diseases (STD) or venereal diseases (VD) or reproductive tract infections (RTI).
- It includes gonorrhoea, syphilis, genital herpes, chlamydiasis, genital warts, trichomoniasis, hepatitis-B and HIV leading to AIDS.
- HIV infection is most dangerous.

- Hepatitis–B and HIV infections are transmitted by sharing of injection needles, surgical instruments, etc., with infected persons, transfusion of blood, or from an infected mother to the fetus too.
- Except for hepatitis-B, genital herpes and HIV infections, other diseases are completely curable if detected early and treated properly.

Symptoms of Sexually Transmitted Diseases

- The symptoms of these diseases include :
  - Itching, fluid discharge, slight pain, swellings, etc., in the genital region.
  - Infected females may often be asymptomatic and hence, may remain undetected for long.
  - Absence or less significant symptoms in the early stages of infection and the social stigma attached to the STDs deter the infected persons from going for timely detection and proper treatment leading to pelvic inflammatory diseases (PID), abortions, still births, ectopic pregnancies, infertility or even cancer of the reproductive tract.

Prevention of STDs

- STDs are a major threat to a healthy society and therefore one could prevent by following the simple principles :
  - Avoid sex with unknown partners/multiple partners.
  - Always use condoms during coitus.
  - Go to a qualified doctor for early detection and get complete treatment if diagnosed with disease.
  - Awareness about STDs.
  - Using sterilised needles and syringes.

Infertility

- A large number of couples are unable to produce children inspite of unprotected sexual co-habitation.
- The reasons could be many–physical, congenital, diseases, drugs, immunological or even psychological.
- Often the female is blamed for the couple being childless, but more often the problem lies in the male partner.
- Specialised health care units such as infertility clinics enable these couples to have children.

Causes of Infertility in Males and Females

In males,

(a) Low semen quality.
(b) Low sperm count called oligospermia.
(c) Absence of sperms called azoospermia.
(d) Sexual dysfunction.

In females,

(a) Polycystic ovarian syndrome.
(b) Age-related factors.
(c) Uterine problem.
(d) Blockage or damage in fallopian tube.
(e) Previous tubal ligation.

Assisted Reproductive Technologies [ART]

- The couples could be assisted to have children through certain special techniques commonly known as assisted reproductive technologies (ART).
- This technology includes IVF, IUT, ICSI, ZIFT, GIFT, AI, etc.
- Legal adoption is one of the best methods for couples looking for parenthood.

(a) IVF [In vitro Fertilisation]

- Here, the fertilisation takes place outside the body followed by embryo transfer (ET).
- This method is popularly known as test tube baby programme in which ova from the wife/donor (female) and sperms from the husband/donor (male) are collected and induced to form zygote under simulated conditions in the laboratory.
- The embryos formed by fusion of gametes within the female also could be used for transfer to those females who cannot conceive.

(b) ZIFT [Zygote Intra Fallopian Transfer] and IUT [Intra Uterine Transfer]

- When the zygote or early embryos develop to 8 blastomeres, it is transferred into the fallopian tube. This method is called ZIFT.
- When the zygote or embryos is more than 8 blastomeres, it is directly placed into the uterus for its further complete development. This method is called IUT.

(c) GIFT [Gamete Intra Fallopian Transfer]

- In this method, the ovum collected from a donor is transferred into the fallopian tube of another female who cannot produce one, but can provide suitable environment for fertilisation and for its further development.

(d) ICSI [Intra Cytoplasmic Sperm Injection]

- In this method, a single sperm collected is directly injected into the ovum using microneedle.
- This method is used in case of male infertility where the sperm count is low.

(e) AI [Artificial Insemination]

- In this technique, the semen collected either from the husband or a healthy donor is artificially introduced either into the vagina or into the uterus (IUI – intra-uterine insemination) of the female.
- This method is used in infertility cases either due to inability of the male partner to inseminate the female or due to very low sperm counts.

Disadvantages in ART

(a) It requires extremely high precision handling by specialised professionals and expensive instrumentation.

(b) It is affordable to only a limited number of people.

(c) Emotional, religious and social factors are also deterrents in the adopting of these methods.

❐❐❐

Chapter 27

Principle of Inheritance and Variation

TOPIC-1

Mendel's Laws of Inheritance and chromosomal theory

Revision Notes

- Hybridization experiments on garden peas (*Pisum sativum*).
- Mendel selected 7 pairs of true breeding pea varieties as given below

S.No.	Characters	Dominant	Recessive
1.	Height of Stem	Tall	Dwarf
2.	Colour of the Flower	Violet	White
3.	Position of the Flower	Axial	Terminal
4.	Shape of Pod	Inflated	Constricted
5.	Colour of Pod	Green	Yellow
6.	Shape of Seed	Round	Wrinkled
7.	Colour of Seed	Yellow	Green

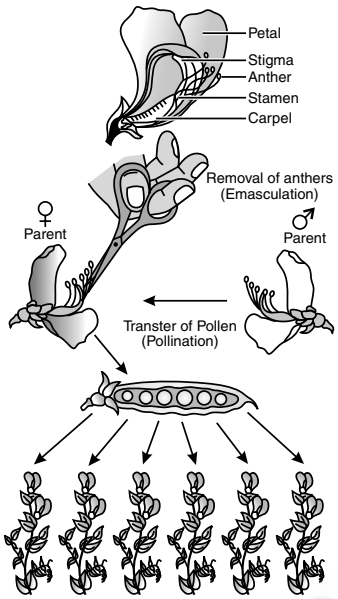
INHERITANCE OF ONE GENE

Steps in Making a Cross in Pea

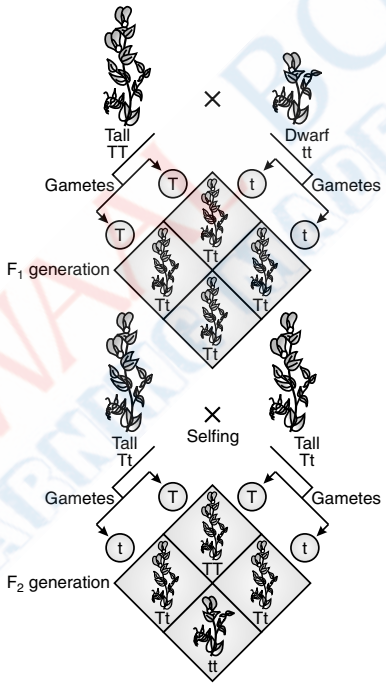
- Selection of two pea plants with contrasting characters.
- Removal of anthers (emasculation) of one plant to avoid self-pollination. This is female parent.
- Collection of pollen grains from the other plant (male parent) and transferred to female parent (pollination).
- Collection of seeds and production of offspring.

Monohybrid Cross

- A cross involving two plants differing in one character pair is known as monohybrid cross.
- e.g., Mendel crossed tall and dwarf pea plants to study the inheritance of one gene.



Steps in making a cross in pea



Parents : TT (Homozygous tall) × tt (Homozygous dwarf)

Gametes : T, t

F_1 : Tt

Selfing : Tt × Tt

Gametes : T t T t

F_2 :

	T	t
T	TT (tall)	Tt (tall)
t	Tt (tall)	tt (dwarf)

Phenotypic ratio : tall : Dwarf
3 : 1

Genotypic ratio : TT : Tt : tt
1 : 2 : 1

- Mendel made similar observations for other pairs of traits and proposed that some factors were inherited from parent to offspring. Now it is called as genes.
- The F_1 (T*t*) when self-pollinated, produces gametes T and t in equal proportion.
- During fertilization, pollen grains of T have 50% chance to pollinate eggs of T & *t*.
- Also, pollen grains of t have 50% chance to pollinate eggs of T and t.
  1/4th of the random fertilization leads to TT (1/4 TT)
  1/2 of the random fertilization leads to Tt (1/2 Tt)
  1/4th of the random fertilization leads to tt (1/4 tt)
  Thus, it leads to a phenotypic ration of 3/4 Tall : (1/4 TT + 1/2 Tt) and 1/4 tt, i.e.,, a 3 : 1 ratio. This ratio, 1/4:1/2:1/4 of TT : Tt : Tt is mathematically condensed to the
  binomial expression = $(ax + by)^2$
  Hence,
  $(1/2\ T + 1/2\ t)^2 = (1/2\ T + 1/2\ t)\ (1/2\ T + 1/2\ t)$
  $= 1/4\ TT + 1/4\ Tt + 1/4\ Tt + 1/4\ tt$
  $= 1/4\ TT + 1/2\ Tt + 1/4\ tt$
- Mendel self-pollinated the F_2 plants.
- He found that dwarf F_2 plants continued to generate dwarf plants in F_3 and F_4.
- He concluded that genotype of the dwarfs was homozygous- tt.

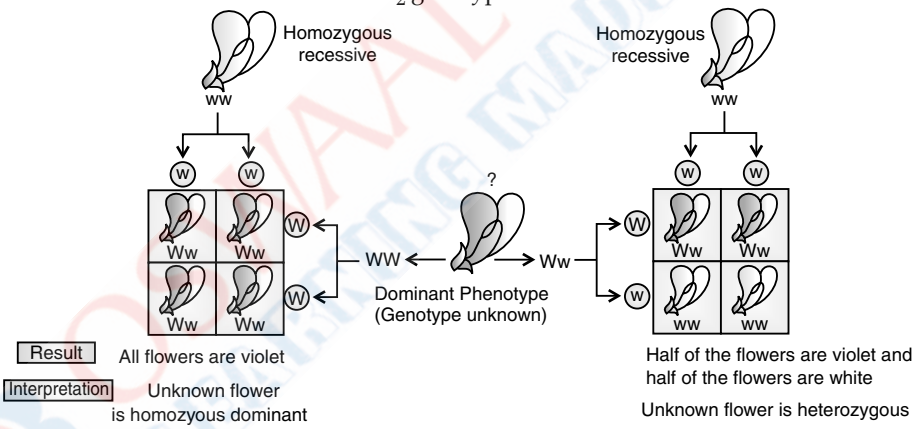
Back cross and Test cross

Back cross :

- When crossing takes place between F_1 hybrid with its any of parent, it is known as back cross.

Test cross :

- When crossing takes place between F_1 hybrid with its recessive parent, it is known as test cross.
- The ratio of test cross = 1:1.
- It is used to find out the unknown genotype.
- Mendel conducted test cross to determine the F_2 genotype.



Mendel's Principles or Laws of Inheritance

First Law (Law of Dominance)

- Characters are controlled by discrete units called factors.
- Factors occur in pairs.
- In a dissimilar pair of factors one member of the pair dominates (dominant) the other (recessive).

Second Law (Law of Segregation)

- During gamete formation, the factors (alleles) of a character pair present in parents segregate from each other such that a gamete receives only one of the two factors".
- Homozygous parent produces similar gametes.
- Heterozygous parent produces two kinds of gametes each having one allele with equal proportion.

The Concept of Dominance

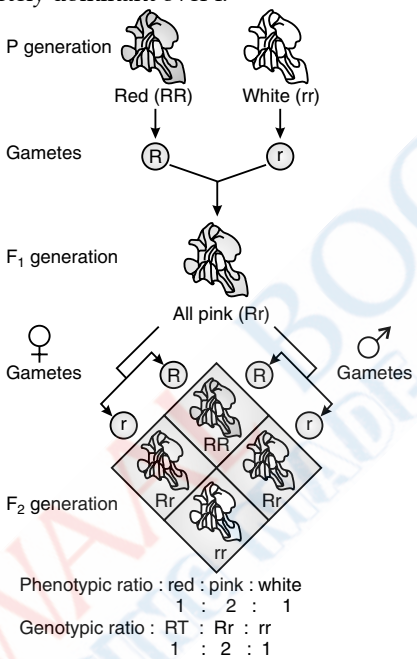
- In heterozygotes, there are dominant and recessive alleles.
- The normal (unmodified or functioning) allele of a gene produces a normal enzyme that is needed for the transformation of a substrate.
- The modified allele is responsible for production of
  (i) The normal/less efficient enzyme - The modified allele will produce the same phenotype like unmodified allele. It becomes dominant.
  (ii) A non-functional enzyme
  (iii) No enzyme at all

- In (ii) and (iii), the phenotype will dependent only on the functioning of the unmodified allele. Here, the modified allele becomes recessive.

NON-MENDELIAN INHERITANCE

Incomplete Dominance

- It is an inheritance in which heterozygous offspring shows intermediate character between two parental characteristics.
- E.g., Flower colour in snapdragon (dog flower or *Antirrhinum* sp.) and *Mirabilis jalapa* (4'O clock plant).
- Here, phenotypic and genotypic ratios are same.
- Phenotypic ratio
  1 Red: 2 Pink: 1 White
- Genotypic ratio
  1 (RR):2 (Rr):1(rr)
- This means that R was not completely dominant over r.



- Pea plants also show incomplete dominance in other traits.

Co-dominance

- It is the inheritance in which both alleles of a gene are expressed in a hybrid. E.g., ABO blood grouping in human.
- ABO blood groups are controlled by the gene I.
- The plasma membrane of the RBC has sugar polymers that protrude from its surface and is controlled by the gene.
- The gene (I) has three alleles I^A, I^B and *i*.
- The alleles I^A and I^B produce a slightly different form of the sugar while allele *i* does not produce any sugar.
- When I^A and I^B are present together they both express their own types of sugars. This is due to co-dominance.

Allele from Parent 1	Allele form Parent 2	Genotype of offspring	Blood types of offspring
I^A	I^A	I^AI^A	A
I^A	I^B	I^AI^B	AB
I^A	*i*	I^Ai	A
I^B	I^A	I^AI^B	AB
I^B	I^B	I^BI^B	B
I^B	*i*	I^Bi	B
i	*i*	*ii*	O

Multiple Allelism

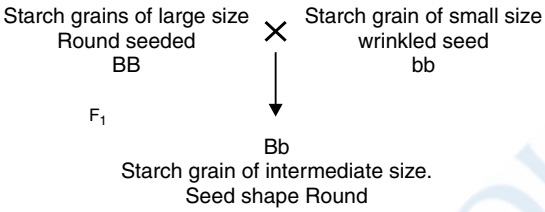
- Here more than two alleles govern the same character.
- E.g., ABO blood grouping *i.e.*, three alleles: I^A, I^B and *i*.

Pleiotropy

- Here, a single gene produces more than one effect.
- E.g., starch synthesis in pea seeds, sickle cell anaemia etc.

Starch synthesis in pea plant:

- Starch synthesis in pea seeds is controlled by one gene.
- It has two alleles (B and b).
- Starch is synthesized effectively by BB homozygotes and therefore, large starch grains are produced while bb homozygotes have lesser efficiency in starch synthesis and produce smaller starch grains.
- After maturation of the seeds, BB seeds are round and the bb seeds are wrinkled.
- Heterozygotes produce round seeds and so B seems to be the dominant allele.
- But, the starch grains produced are of intermediate size in Bb seeds.

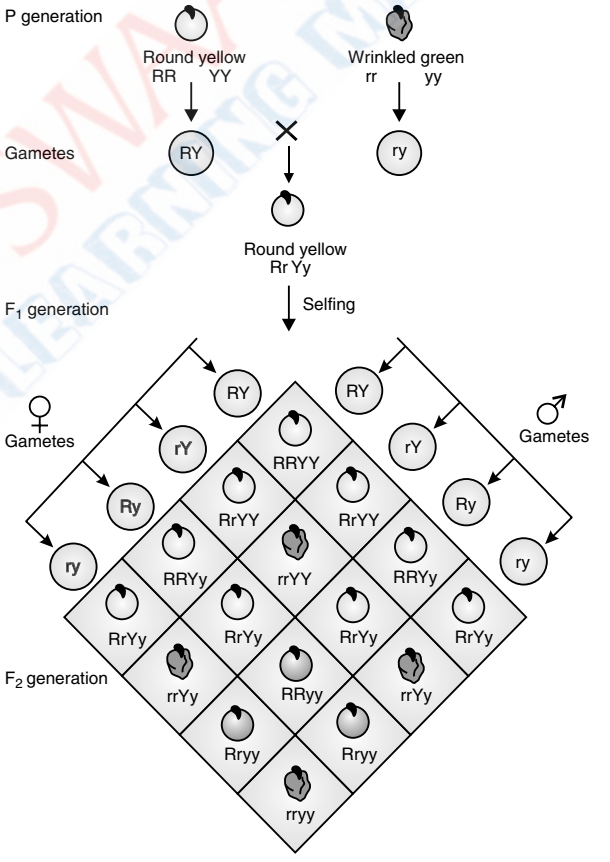


- So, if starch grain size is considered as the phenotype, then the alleles show incomplete dominance.
- Therefore, dominance is not an autonomous feature of a gene or the product information.
- It depends on the gene product and the production of a particular phenotype when more than one phenotype is influenced by the same gene.

INHERITANCE OF TWO GENES (Dihybrid cross)

Dihybrid Cross

- A cross between two parents differing in two pairs of contrasting characters is known as dihybrid cross.
- Mendel crossed pea plant with round shaped and yellow coloured seeds (RRYY) and wrinkled shaped and green coloured seeds (rryy).
- On observing the F_2, Mendel found that the yellow and green colour segregated in a 3:1 ratio. Round and wrinkled seed shape also segregated in a 3:1 ratio.



Phenotypic ratio : round yellow : round green : wrinkled yellow : wrinkled green
9 3 3 1

- Dihybrid Phenotypic ratio
- Round yellow 9: Round green 3: Wrinkled yellow 3: Wrinkled green 1, *i.e.*, 9:3:3:1
- The ratio of 9:3:3:1 can be derived as a combination series of 3 yellow: 1 green, with 3 round: 1 wrinkled.
- Dihybrid genotypic ratio
  1:2:1:2:4:2:1:2:1
- 1 RRYY =1 RRYy =2 RrYY =2 RrYy =4 RRyy =1 Rryy =2 rrYY =1 rrYy =2 rryy =1 *i.e.*, (3: 1) (3: 1) = 9: 3: 3: 1

Third Law (Mendel's Law of Independent Assortment)

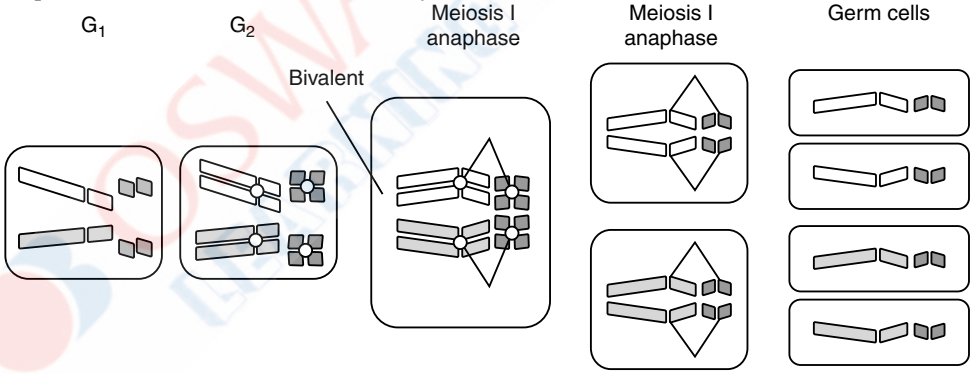
- It states that 'when more than one pair of characters is involved in a cross, factor pairs independently segregate from the other pair of characters'.

CHROMOSOMAL THEORY OF INHERITANCE

- In 1900, de Vries, Correns and von Tschermak independently rediscovered Mendel's results.
- Mendel's work remained unrecognized till 1900 because,
  1. Communication was not easy.
  2. His mathematical approach was new and unacceptable.
  3. The concept of genes (factors) as stable and discrete units was not accepted. (Mendel could not explain the continuous variation seen in nature).
  4. Mendel could not provide any physical proof for the existence of factors.

Chromosomal Theory (1902): Walter Sutton and Theodore Boveri

- According to them, the pairing and separation of a pair of chromosomes lead to segregation of a pair of factors they carried.
- Sutton united chromosomal segregation with Mendelian principles and called it the chromosomal theory of inheritance.
- It states that,
  (a) Chromosomes are vehicles of heredity that are transmitted from parents to offspring, i.e., they are immortal.
  (b) Two identical chromosomes form a pair.
  (c) They segregate at the time of gamete formation.
  (d) Independent pairs segregate independently of each other.
  (e) Chromosomes are mutable.
- Genes are present on chromosomes. Hence they show similar behaviours.



Chromosomal Theory of Inheritance in Fruit Flies

- Thomas Hunt Morgan proved chromosomal theory of inheritance using fruit flies (*Drosophila melanogaster*).
- It is the suitable material because,
  a. It breeds very quickly
  b. It has shorter generation time (life cycle: 12-14 days)
  c. Breeding can be done throughout the year.
  d. Hundreds of progenies per mating.
  e. They can grow on simple synthetic medium.
  f. Male and female flies are easily distinguishable.
  g. It has many types of hereditary variations that can be seen with low power microscopes.

Recombination

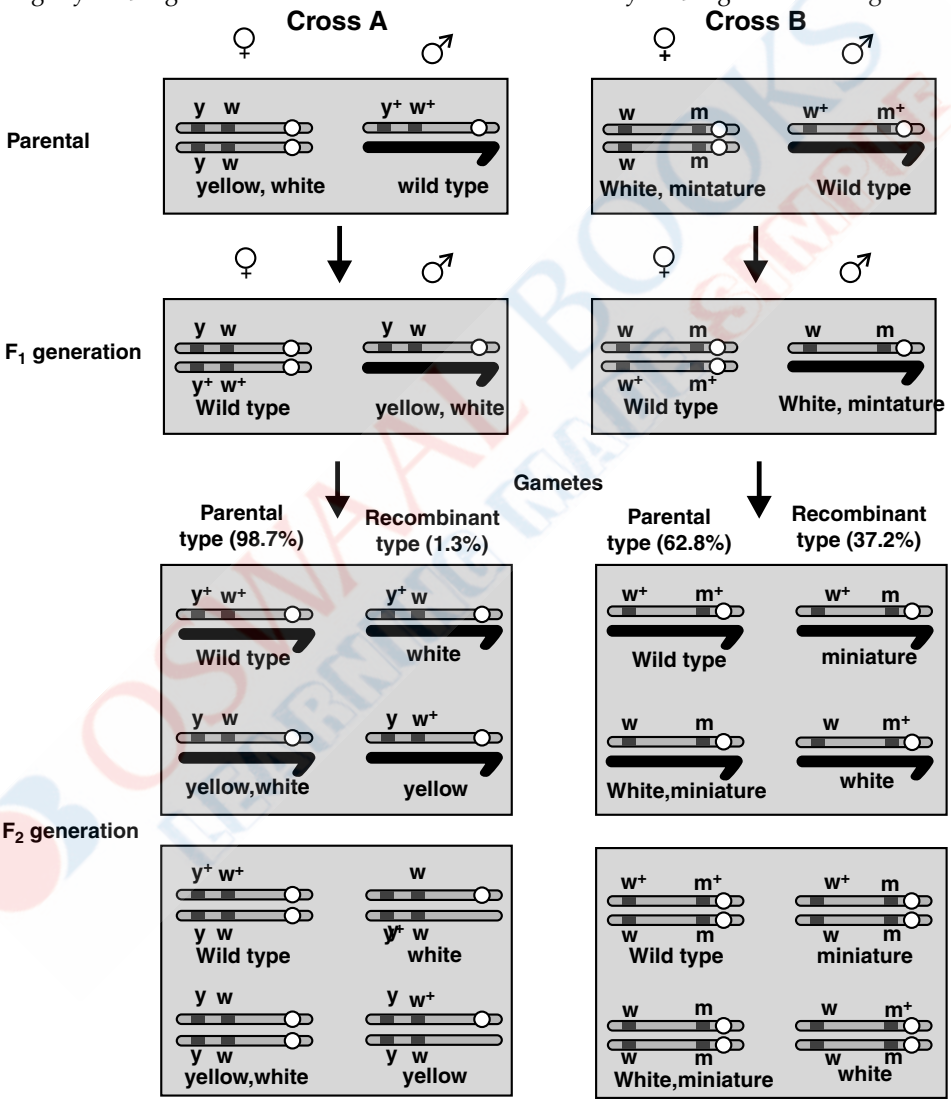
- It is the generation of non-parental gene combinations.

Linkage:

- The physical association of two or more genes on a chromosome is known as linkage.
- They do not show independent assortment.

Sex – Linked Genes

- Morgan carried out several dihybrid crosses in *Drosophila* to study sex-linked genes.
- Cross 1: Yellow-bodied, white-eyed females X Brown-bodied, red-eyed males (wild type)
- Cross 2: White-eyed, miniature winged X Red eyed, large winged (wild type)
- Morgan intercrossed their F_1 progeny and found that
  - **(a)** The two genes did not segregate independently of each other.
  - **(b)** The F_2 ratio deviated from the 9:3:3:1 ratio.
  - **(c)** Genes were located on the X chromosome
  - **(d)** When two genes were situated on the same chromosome, the proportion of parental gene combinations was much higher than the non-parental type. This is due linkage.
  - **(e)** Genes white and yellow were very tightly linked and showed only 1.3% recombination while white and miniature wing showed 37.2% recombination (loosely linked).
- Thus, the tightly linked genes show low recombination while loosely linked genes show high recombination.



Mapping

- Alfred Sturtevant used the recombination frequency between gene pairs as a measure of the distance between genes and 'mapped' their position on the chromosome.
- Genetic maps are used as a starting point in the sequencing of genomes as was done in Human Genome Project.

Polygenic Inheritance

- When two or more genes control the traits having distinct alternate forms, it is called polygenic inheritance.
- The polygenic inheritance is influenced by the environment.
- Eg – Human skin colour.

Explanation

- The skin colour in humans is caused due to the pigment called melanin.
- The quantity of melanin is due to three pairs of genes namely, A, B and C.
- The genotype of offspring of F_1 generation will have three dominant alleles and three recessive alleles with intermediate skin colour.
- Thus, the number of each type of alleles in the genotype would determine the darkness or lightness of the skin in an individual.

TOPIC-2

Sex Determination and Genetic Disorders

Revision Notes

Sex Determination

- Henking (1891) studied spermatogenesis in some insects and observed that 50% of sperm received a nuclear structure after spermatogenesis, whereas other 50% sperm did not receive it.
- Henking called this structure as the X-body (later is called as X-chromosome).
- Later it was observed that the ovum that receive the sperms with X-body become female and that do not have an X-body becomes males, so this X-body was called as sex chromosome and other chromosomes are called autosomes.
- Autosomes are chromosomes other than sex chromosomes.
- Number of autosomes is same in males and females.
- Sex chromosomes i.e., allosomes (X and Y) are the chromosomes which are involved in sex determination.

Mechanism of Sex Determination

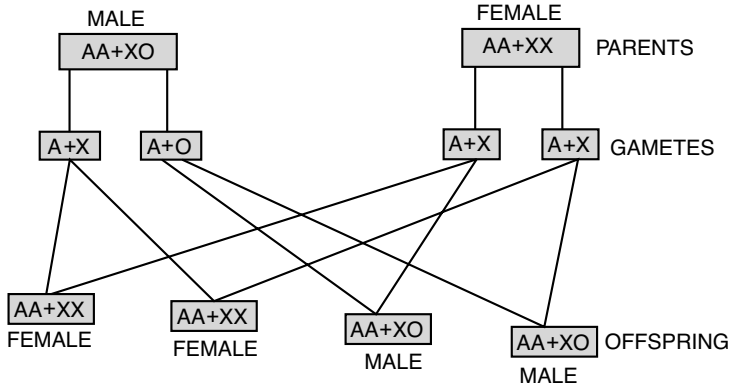
- The mechanism of sex determination can be classified into two types namely,

  (a) Male heterogamety **(b)** Female heterogamety

The Male Heterogamety

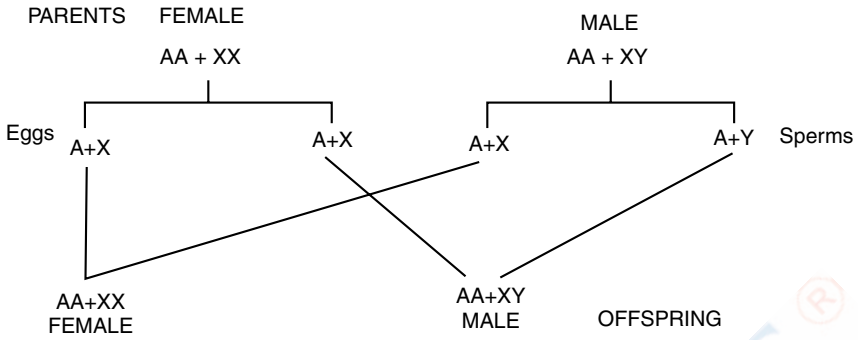
- In this mechanism, the male produces two different types of gametes.
- It includes,

  (a) XX – XO Mechanism
- Here, male is heterogametic, i.e., XO (Gametes with X and gametes without X) and female is homogametic, i.e. XX (all gametes are with X-chromosomes).
- Eggs fertilised by sperms having an X-chromosome become females and those fertilised by sperms that do not have X-chromosome become males.
- e.g., Many insects such as grasshopper, cockroach.



(b) XX – XY Mechanism:

- Here, male is heterogametic (X and Y) and female is homogametic (X only).
- e.g., Human and *Drosophila*.

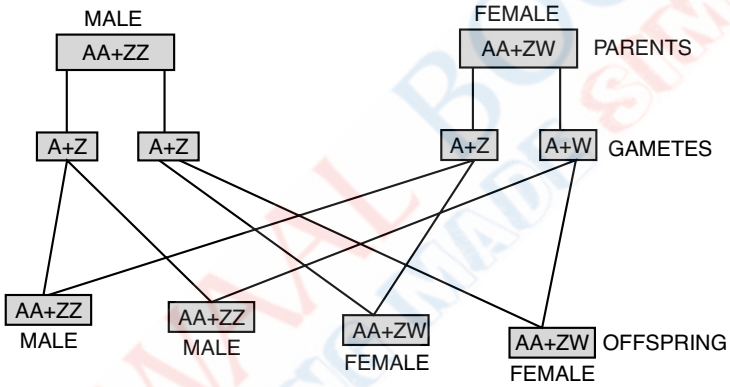


The Female Heterogamety

- In this mechanism, the total number of chromosomes is same in both males and females.
- Here, the female produces two different types of gametes.

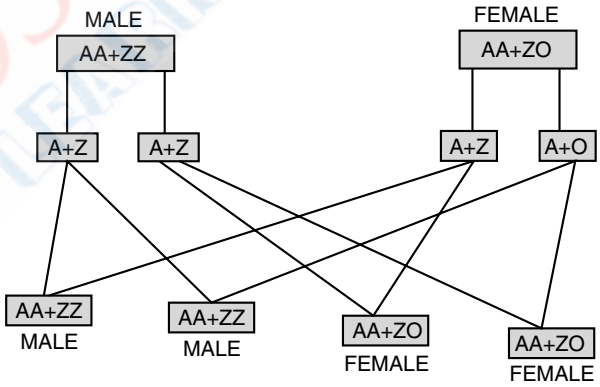
(a) ZZ – ZW Mechanism:

- Here, male is homogametic (ZZ) and female is heterogametic (Z and W).
- e.g., Birds.



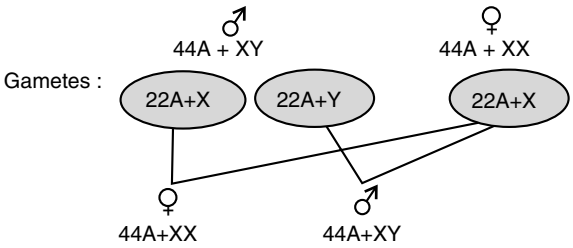
(b) ZZ – ZO Mechanism:

- In this mechanism, the female is heterogametic (Z and O) and male is homogametic (ZZ).



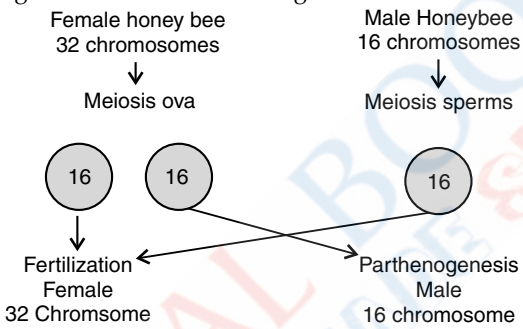
Sex Determination in Humans (XX-XY type)

- Human has 23 pairs of chromosomes in which 22 pairs are autosomes and 1 pair is sex chromosomes.
- A pair of X-chromosomes (XX) is present in the female whereas X and Y chromosomes are present in male.
- During spermatogenesis, the males produce two types of gametes, 50% with X-chromosome and 50% with Y-chromosome.
- Females produce only ovum with an X-chromosome.
- There is an equal probability of fertilization of the ovum with the sperm carrying either X or Y chromosome.
- The sperm determines whether the offspring is male or female.



Sex Determination in Honey Bee

- The sex determination in honey bee is based on the number of chromosomes an individual receives.
- An offspring formed from the fusion of a sperm and an egg develops as a female queen or worker and an unfertilized egg develops as a male drone by parthenogenesis.
- This shows that the males have half the number of chromosomes than that of female.
- The females are diploid having 32 chromosomes and males are haploid having 16 chromosomes.
- This is called haplodiploid sex determination system.
- The special characteristic feature is that the males produce sperms by mitosis, hence do not have father and cannot have sons. But have a grandfather and can have grandsons.



Pleiotropy

- A single gene which shows multiple phenotypic expressions is called pleiotropy.
- The mechanism of pleiotropy is the effect of a gene on metabolic pathways which contribute to different phenotypes.
- Eg – Phenylketonuria in humans.

Explanation

- The disease is caused by mutation in the gene that code for the enzyme phenylalanine hydroxylase (single gene mutation).
- It is characterized by mental retardation and a reduction in hair and skin pigmentation.

Mutation

- It is a sudden heritable change in DNA sequences resulting in changes in the genotype and the phenotype of an organism.
- It leads to variation in DNA.
- The loss (deletions) or gain (insertion/duplication) of a segment of DNA, result in alteration in chromosomes. Since genes are known to be located on chromosomes, alteration in chromosomes results in abnormalities or aberrations.
- Chromosomal aberrations are seen in cancer cells.

Causes of Mutation

(a) Frame-shift mutation: Loss (deletions) or gain (insertion/ duplication) of a DNA segment.

(b) Point mutation: Mutation due to change in a single base pair of DNA. E.g., sickle cell anaemia.

- Mutation results in chromosomal abnormalities (aberrations).
- The physical and chemical factors that induce mutations are referred to as mutagens.
- Mutagens (agents which induce mutation) include,

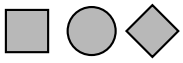
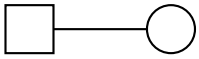
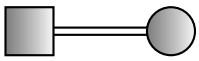
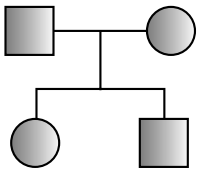
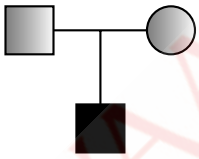
(a) Physical mutagens: UV radiation, α, β, γ rays, X-ray etc.

(b) Chemical mutagens: Mustard gas, phenol, formalin etc.

Pedigree Analysis

- The practice of analyzing inheritance pattern of traits in several of generations of a family is called the pedigree analysis.
- The representation or chart showing family history is called family tree (pedigree).

- In human genetics, pedigree study provides a strong tool, which is utilized to trace the inheritance of a specific trait, abnormality or disease.
- Some of the important standard symbols used in the pedigree analysis are as follows:

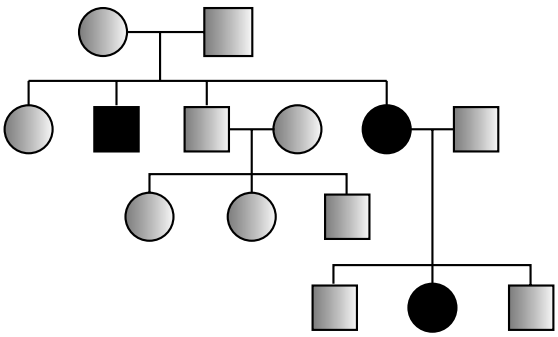
Symbols	Pedigree Analysis
	Normal Male
	Normal Female
	Sex unspecified
	Affected individuals (Male or Female)
	Mating
	Mating between relatives (consanguineous mating)
	Parents above and children below in order of birth from left to right
	Parents with male child affected with disease
	Five unaffected offspring

GENETIC DISORDERS

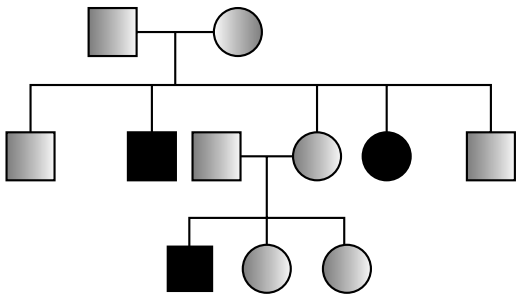
- It is classified into two types namely,
  - **(a)** Mendelian disorders
  - **(b)** Chromosomal disorders

Mendelian Disorders

- It is caused by alteration or mutation in the single gene.
- The pattern of inheritance of Mendelian disorders can be traced in a family by the pedigree analysis.
- Eg. Haemophilia, Cystic fibrosis, Sickle-cell anaemia, Colour blindness, Phenylketonuria, Thalassemia, etc.
- Mendelian disorders may be dominant or recessive.
- By pedigree analysis one can easily understand whether the trait is dominant or recessive.
- A pedigree representation for dominant and recessive traits or characters linked to both autosomes and sex chromosome.



Autosomal Dominant Trait, Myotonic dystrophy



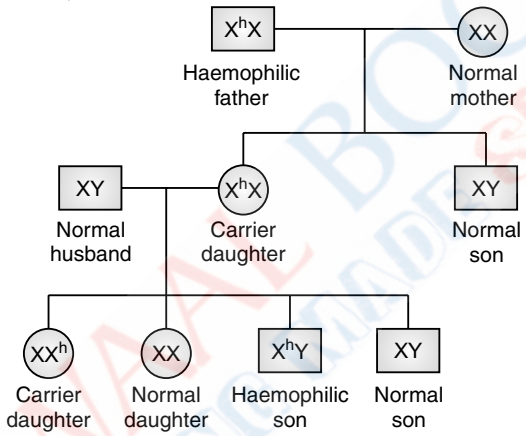
Autosomal Recessive Trait, Sickle cell anaemia

Haemophilia

- It is a sex linked recessive disease.
- In this, a protein involved in the blood clotting is affected.
- A simple cut results in non-stop bleeding.
- The heterozygous female (carrier) for haemophilia may transmit the disease to sons.
- The possibility of a female becoming a haemophilic is very rare because mother has to be at least carrier and father should be haemophilic (unviable in the later stage of life).
- Queen Victoria was a carrier of the disease. So her family pedigree shows a number of haemophilic descendents.
- Haemophilia B is also called as Christmas disease.

Colour Blindness

- It is a sex-linked recessive disorder.
- It is caused due to the defect in either red or green cone of eye resulting in the failure of discrimination between red and green colour.
- This defect is due to mutation in certain genes present in the X chromosome.
- It occurs about 8% in males and about 0.4% in females.
- The son of a woman who carries the gene has 50% chance of being colour blind.
- The mother is not herself colour blind because the gene is recessive.
- A daughter will not be colour blind, unless her mother is a carrier and her father is colour blind.



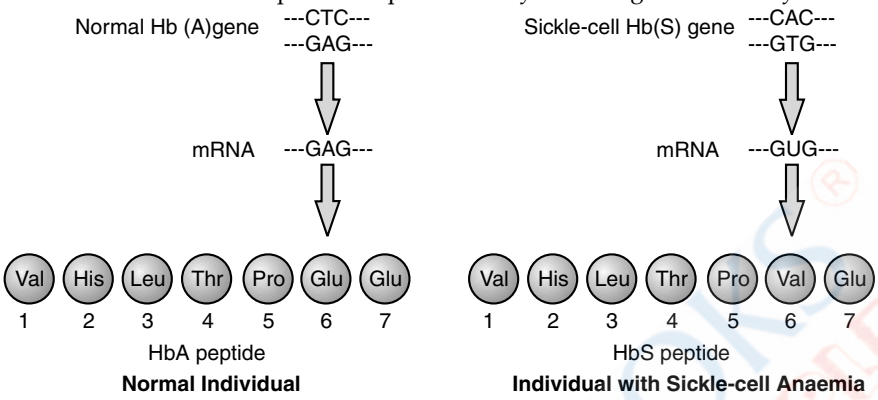
Thalassemia

- It is an autosome-linked recessive blood disease transmitted from parents to offspring when both the partners are unaffected carrier for the gene.
- This is due to either mutation or deletion which results in the reduction of synthesis of one of the globin chains that make up haemoglobin.
- Thus, an abnormal haemoglobin molecules resulting in anaemia is formed.
- Thalassemia is classified into three types as follows:
  - **(a)** α-Thalassemia
    It is controlled by two closely linked genes HbA1 and HbA2 on chromosome 16 of each parent.
    The production of α-globin chain is affected due to mutation or deletion of one or more of the four genes.
  - **(b)** β-Thalassemia
    It is controlled by a single gene HbB on chromosome 11.
    The production of β-globin chain is reduced due to mutation of one or both the alleles of the gene.
  - **(c)** δ-Thalassemia
    It is controlled by a single gene HbD on chromosome 11.
    This disease is minor as adults have 3% haemoglobin consisting of α and δ chains.

Sickle-cell Anaemia

- This is an autosome linked recessive trait.
- It can be transmitted from parents to the offspring when both the partners are carrier for the gene (or heterozygous).
- The disease is controlled by a pair of allele, Hb^A and Hb^S.
  - **(a)** Homozygous dominant (Hb^AHb^A): Normal
  - **(b)** Heterozygous (Hb^AHb^S): Sickle cell trait
  - **(c)** Homozygous recessive (Hb^SHb^S): Affected
- The defect is caused by the substitution of Glutamic acid (Glu) by Valine (Val) at the sixth position of the β-globin chain of the haemoglobin (Hb).

- The substitution of amino acid in the globin protein results due to the single base substitution at the sixth codon of the beta globin gene from GAG to GUG.
- The mutant haemoglobin molecule undergoes polymerisation under low oxygen tension causing the change in the shape of the RBC from biconcave disc to elongated sickle like structure.
- Thalassemia differs from Sickle-cell anaemia in that the former is a quantitative problem of synthesizing too few globin molecules while the latter is a qualitative problem of synthesizing an incorrectly functioning globin.



Phenylketonuria

- It is an inborn error of metabolism.
- It is an autosomal recessive trait.
- The affected individual lacks an enzyme (phenylalanine hydroxylase) that converts the amino acid phenylalanine into tyrosine.
- As a result, phenylalanine accumulates and converts into phenyl pyruvic acid and other derivatives.
- They accumulate in brain resulting in mental retardation.
- These are also excreted through urine because of poor absorption by kidney.

Chromosomal Disorders

- They are caused due to absence or excess or abnormal arrangement of one or more chromosomes.
- These are of two types namely,
  (a) Aneuploidy
  (b) Polyploidy

Aneuploidy

- The gain or loss of chromosomes due to failure of segregation of chromatids during cell division is known as aneuploidy.
- Eg - Down's syndrome results in the gain of extra copy of chromosome 21. Similarly, Turner's syndrome results due to loss of an X chromosome in human females.
- It includes,
  (a) Nullisomy (2n-2): A chromosome pair is lost from diploid set.
  (b) Monosomy (2n-1): One chromosome is lost from diploid set.
  (c) Trisomy (2n+1): One chromosome is added to diploid set.
  (d) Tetrasomy (2n+2): 2 chromosomes are added to diploid set.

Down's Syndrome

- It is a genetic disorder caused due to the presence of an additional copy of the chromosome number 21 (trisomy of 21).
- This disorder was first described by Langdon Down (1866).
- Genetic Constitution: 45 A + XX or 45 A + XY (i.e., 47 chromosomes).
- Characteristics
  (a) The affected individual is short statured with small round head, furrowed tongue and partially open mouth.
  (b) Palm is broad with characteristic palm crease.
  (c) Physical, psychomotor and mental development is retarded.

Klinefelter's Syndrome

- It is the genetic disorder caused due to the presence of an additional copy of X-chromosome.
- Genetic Constitution: 44 A + XXY (i.e., 47 chromosomes).

- Characteristics
  - **(a)** Overall masculine development, however, the feminine development such as development of breast, i.e., Gynaecomastia is also expressed.
  - **(b)** Sterile.
  - **(c)** Mentally retarded.

Turner's Syndrome

- It is a genetic disorder caused due to the absence of one of the X chromosomes.
- Genetic Constitution: 44 A + X0 (i.e. 45 chromosomes).
- Females are sterile as ovaries are rudimentary.
- Lack of secondary sexual characters.

Polyploidy (Euploidy)

- It is an increase in a whole set of chromosomes due to failure of cytokinesis after telophase stage of cell division. This is often seen in plants.
- Aneuploidy differs from polyploidy in the addition of one or more complete sets of chromosome in the genome.

❐❐❐

Chapter 28

Molecular Basis of Inheritance

TOPIC-1

The DNA, The Search For Genetic Material RNA World

Revision Notes

Introduction

- Nucleic acids are the building blocks of genetic material.
- Nucleic acids are polymers of nucleotides.
- Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two types of nucleic acids found in living systems.
- DNA acts as the genetic material in most of the organisms. RNA acts as a genetic material in some viruses, mostly functions as a messenger.
- RNA also functions as adapter, structural, and in some cases as a catalytic molecule.

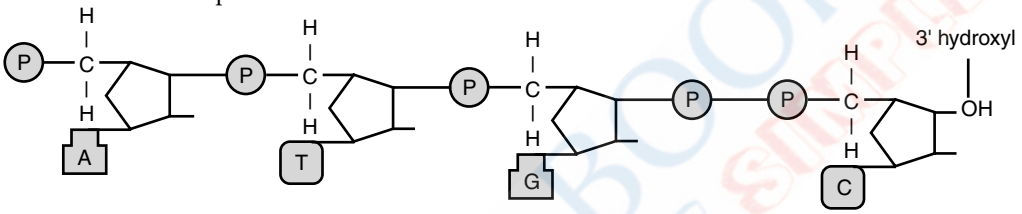
The DNA

- DNA is a long polymer of deoxyribonucleotides.
- The length of DNA is defined as number of nucleotides (or a pair of nucleotide referred to as base pairs) present in it. It is the characteristic of an organism.
- For example, a bacteriophage $\phi \times 174$ has 5386 nucleotides, bacteriophage lambda has 48502 base pairs (bp), *Escherichia coli* has 4.6×10^6bp, and haploid content of human DNA is 3.3×10^9bp.

Structure of Polynucleotide Chain

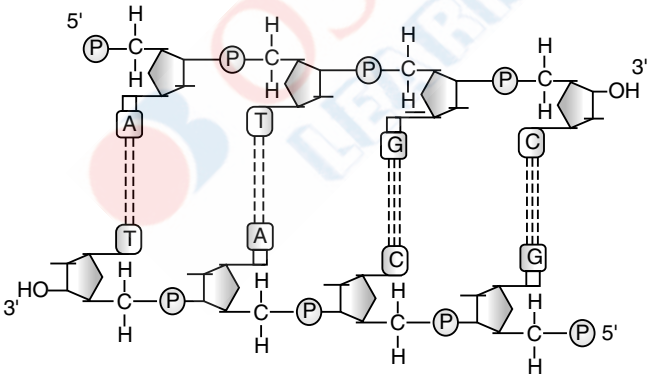
- A nucleotide has three components namely,
  - **(a)** A nitrogenous base
  - **(b)** A pentose sugar (ribose in case of RNA, and deoxyribose for DNA)
  - **(c)** A phosphate group.
- There are two types of nitrogenous bases namely,
  - **(a)** Purines (Adenine and Guanine)
  - **(b)** Pyrimidines (Cytosine, Uracil and Thymine).
- Cytosine is common for both DNA and RNA whereas Thymine is present in DNA and Uracil is present in RNA.
- A nitrogenous base is linked to the pentose sugar through an N-glycosidic linkage to form a nucleoside, such as adenosine or deoxyadenosine, guanosine or deoxyguanosine, cytidine or deoxycytidine and uridine or deoxythymidine.
- When a phosphate group is linked to 5'-OH of a nucleoside through phosphoester linkage, a nucleotide or deoxynucleotide is formed.
- Two nucleotides are linked through 3'-5' phosphodiester linkage to form a dinucleotide.
- More nucleotides can be joined to form a polynucleotide chain.

- A polymer formed has at one end a free phosphate moiety at 5'-end of ribose sugar, which is referred to as 5′-end of polynucleotide chain.
- At the other end of the polymer the ribose has a free 3'-OH group which is referred to as 3' -end of the polynucleotide chain.
- The backbone in a polynucleotide chain is formed due to sugar and phosphates.
- In RNA, every nucleotide residue has an additional –OH group present at 2' -position in the ribose.
- DNA as an acidic substance present in nucleus was first identified by Friedrich Meischer in 1869. He named it as 'Nuclein'.
- In 1953 James Watson and Francis Crick, based on the X-ray diffraction data produced by Maurice Wilkins and Rosalind Franklin, proposed double helix model for the structure of DNA.
- Base pairing between the two strands of polynucleotide chains was based on the observation of Erwin Chargaff.
- According to him, the ratios between Adenine and Thymine and Guanine and Cytosine are constant and equal one.
- A unique property of base pairing is that they are said to be complementary to each other and therefore if the sequence of bases in one strand is known, then the sequence in other strand can be predicted.
- If each strand from a DNA acts as a template for synthesis of a new strand, the two double stranded DNA produced would be identical to the parental DNA molecule.

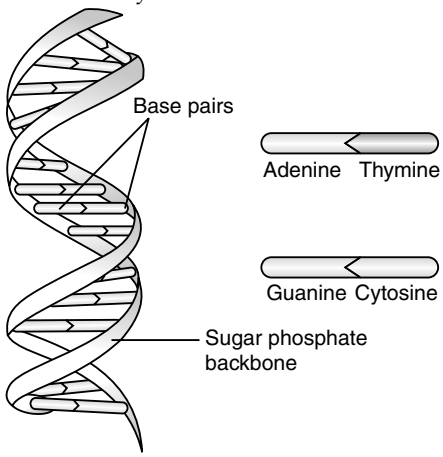


Salient Features of Double Helix Model for the Structure of DNA

1. It is made of two polynucleotide chains.
2. The two chains have anti-parallel polarity.
3. The bases in two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). Adenine forms two hydrogen bonds with Thymine from opposite strand similarly Guanine is bonded with Cytosine with three H-bonds. As a result, uniform distance between the two strands of the helix is formed.
4. The two chains are coiled in a right-handed fashion. The pitch of the helix is 3.4 nm. There are roughly 10 bp in each turn. The distance between a bp in a helix is approximately equal to 0.34 nm.
5. The plane of one base pair stacks over the other in double helix for the stability of the helical structure.



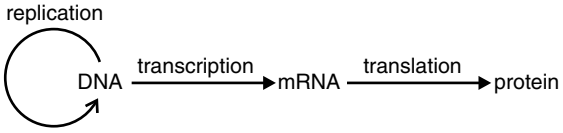
Double stranded polynucleotide chain



DNA double helix

Central Dogma

- Francis Crick proposed the Central dogma in molecular biology, which states that the genetic information flows from DNA → RNA → Protein.

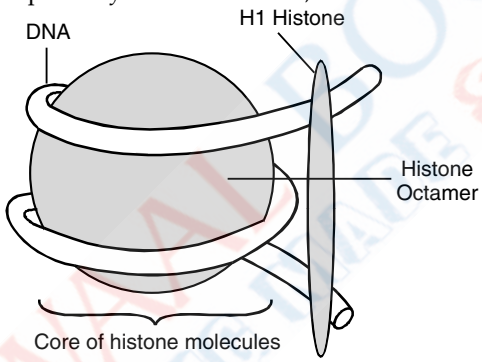


Central dogma

- In some viruses the flow of information is in reverse direction *i.e.*, from RNA to DNA.

Packaging of DNA Helix

- In prokaryotes, such as, *E. coli*, the DNA is not scattered throughout the cell.
- DNA being negatively charged is held with some proteins having positive charges in a region termed as 'nucleoid'.
- In eukaryotes, there is a set of positively charged, basic proteins called histones.
- A protein acquires charge depending upon the abundance of amino acids residues with charged side chains.
- Histones are rich in the basic amino acid residues lysines and arginines.
- Both the amino acid residues carry positive charges in their side chains.
- Histones are organised to form a unit of eight molecules called as histone octamer.
- The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called nucleosome.
- A nucleosome contains 200 bp of DNA helix.
- Nucleosomes constitute the repeating unit of a structure in nucleus called chromatin, thread-like stained (coloured) bodies seen in nucleus.
- The nucleosomes in chromatin are seen as 'beads-on-string' structure to form chromatin fibers that further coils and condense at metaphase stage of cell division to form chromosomes.
- The packaging of chromatin requires additional set of proteins referred to as Non-histone Chromosomal (NHC) proteins.
- In a nucleus, some region of chromatin are loosely packed with light stains are referred to as euchromatin.
- The chromatin that is more densely packed with dark stains is called as heterochromatin.
- Euchromatin is said to be transcriptionally active chromatin, whereas heterochromatin is inactive.



Nucleosome

TRANSFORMING PRINCIPLE

- In 1928, Frederick Griffith, in a series of experiments with *Streptococcus pneumoniae* (bacterium responsible for pneumonia), found a transformation in the bacteria in physical form.
- When *Streptococcus pneumoniae* (pneumococcus) bacteria are grown on a culture plate, some produce smooth shiny colonies (S) while others produce rough colonies (R).
- This is because the S strain bacteria have a mucous (polysaccharide) coat, while R strain does not.
- Mice infected with the S strain (virulent) die from pneumonia infection but mice infected with the R strain do not develop pneumonia.

S strain ⟶ Inject into mice ⟶ Mice die
R strain ⟶ Inject into mice ⟶ Mice live

- Griffith was able to kill bacteria by heating them.
- He observed that heat-killed S strain bacteria injected into mice did not kill them.
- When he injected a mixture of heat-killed S and live R bacteria, the mice died.
- He recovered living S bacteria from the dead mice.

S strain ⟶ Inject into mice ⟶ Mice live
(heat-killed)
R strain
(heat-killed)
\+ ⟶ Inject into mice ⟶ Mice die
R strain
(live)

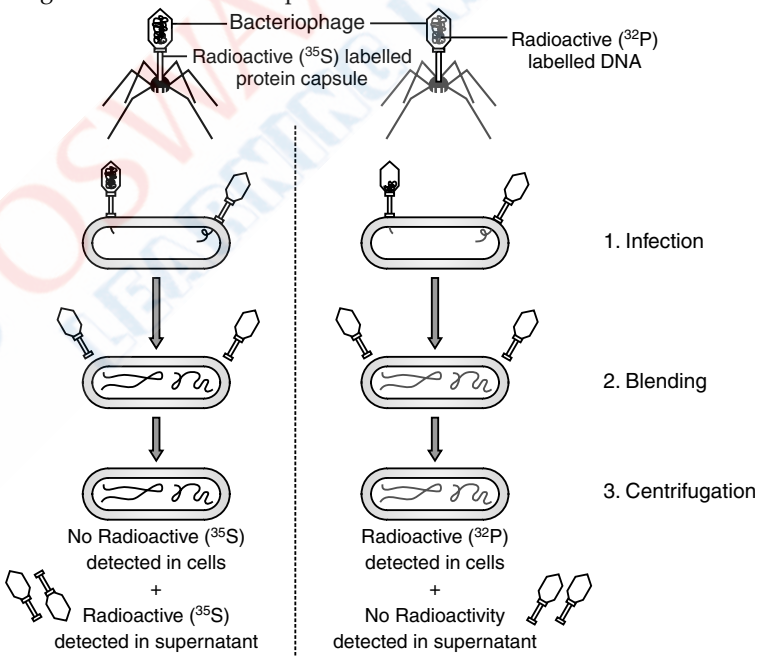
- Thus, he concluded that the R strain bacteria had been transformed by the heat-killed S strain bacteria. Some transforming principle transferred from the heat-killed S strain had enabled the R strain to become virulent. This must be due to the transfer of the genetic material.
- However, the biochemical nature of genetic material was not defined from his experiments.

Biochemical Characterisation of Transforming Principle

- According to Oswald Avery, Colin MacLeod and Maclyn McCarty (1933-44), the genetic material was a protein.
- They worked to determine the biochemical nature of 'transforming principle' in Griffith's experiment.
- They purified biochemicals such as proteins, DNA, RNA, etc., from the heat-killed S cells to see which could transform live R cells into S cells and found that DNA from S bacteria caused R bacteria to become transformed.
- They also discovered that protein-digesting enzymes (proteases) and RNA-digesting enzymes (RNases) did not affect transformation.
- DNase did inhibit transformation suggesting that the DNA caused the transformation.
- Hence, they concluded that DNA is the hereditary material.

The Genetic Material is DNA

- The unequivocal proof that DNA is the genetic material came from the experiments of Alfred Hershey and Martha Chase (1952).
- They worked with viruses that infect bacteria called bacteriophages.
- The bacteriophage attaches to the bacteria and its genetic material enters the bacterial cell.
- The bacterial cell manufactures more viral genetic particles.
- Hershey and Chase worked to discover whether it was protein or DNA from the viruses that entered the bacteria.
- They grew some viruses on a medium that contained radioactive phosphorus and some others on medium that contained radioactive sulphur.
- Viruses grown in the presence of radioactive phosphorus contained radioactive DNA but not radioactive protein because DNA contains phosphorus but protein does not.
- On the other hand, viruses grown on radioactive sulphur contained radioactive protein but not radioactive DNA because DNA does not contain sulphur.
- Radioactive phages were allowed to attach to *E. coli* bacteria.
- As the infection proceeded, the viral coats were removed from the bacteria by agitating them in a blender.
- The virus particles were separated from the bacteria by spinning them in a centrifuge.
- Virus infected bacteria had radioactive DNA were radioactive, indicating that DNA was the material that passed from the virus to the bacteria.
- Virus infected bacteria that had radioactive proteins were not radioactive.
- This indicated that proteins did not enter the bacteria from the viruses.
- DNA is therefore the genetic material that is passed from virus to bacteria.



Properties of Genetic Material (DNA versus RNA)

- RNA is the genetic material in Tobacco Mosaic Viruses, QB bacteriophage, etc.
- DNA is the predominant genetic material whereas RNA performs dynamic functions of messenger and adapter.
- A molecule that can act as a genetic material must fulfill the following criteria :

1. It should be able to generate its replica (Replication).

Due to rule of base pairing and complementarity, both the nucleic acids (DNA and RNA) have the ability to direct their duplications.

However, proteins fail to fulfill first criteria itself.

2. It should chemically and structurally be stable.

   The genetic material should not change with different stages of life cycle, age or with change in physiology of the organism.

   Stability as one of the properties of genetic material was evident in Griffith's 'transforming principle' which showed that the two strands of DNA being complementary if separated by heating come together under appropriate conditions.

   Further, 2'-OH group present at every nucleotide in RNA is a reactive group and makes RNA labile and easily degradable.

   RNA is also now known to be catalytic, hence reactive.

   Therefore, DNA chemically is less reactive and structurally more stable when compared to RNA. DNA is a better genetic material.

   The presence of thymine at the place of uracil provides additional stability to DNA.

3. It should provide the scope for slow changes (mutation) that are required for evolution.

   Both DNA and RNA are able to mutate.

   RNA being unstable, mutate at a faster rate.

   Thus, viruses having RNA genome and having shorter life span will mutate and evolve faster.

4. It should be able to express itself in the form of 'Mendelian Characters'.

   RNA can directly code for the synthesis of proteins and hence can easily express the characters.

   DNA is dependent on RNA for synthesis of proteins.

   Both RNA and DNA can function as genetic material.

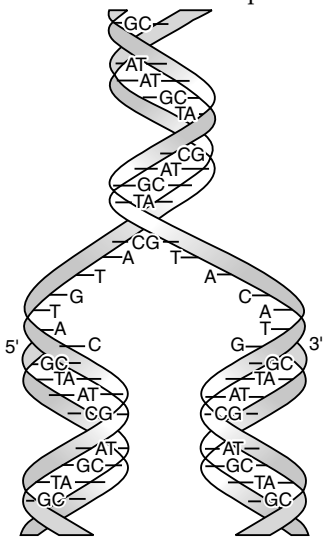
   However, DNA being more stable is preferred for storage of genetic information while RNA is preferred for the transmission of genetic information.

RNA WORLD

- RNA was the first genetic material.
- RNA used to act as a genetic material as well as a catalyst.
- Since RNA being a catalyst is reactive and hence unstable.
- DNA has evolved from RNA with chemical modifications that make it more stable.
- Further, DNA being double and complementary stranded resists changes by repair.

REPLICATION

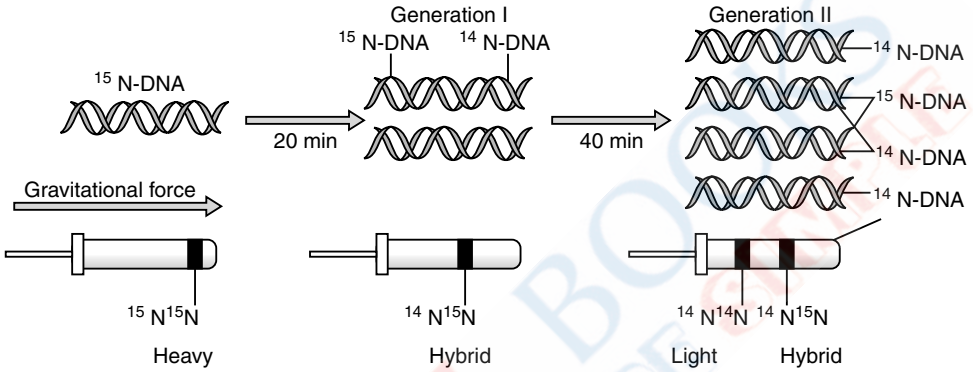
- After proposing the double helical structure for DNA, Watson and Crick proposed a scheme for replication of DNA.
- The scheme suggested that the two strands would separate and act as a template for the synthesis of new complementary strands.
- After the completion of replication, each DNA molecule would have one parental and one newly synthesized strand. This scheme was termed as semiconservative DNA replication.



Watson-Crick model for Semiconservative DNA replication

The Experimental Proof

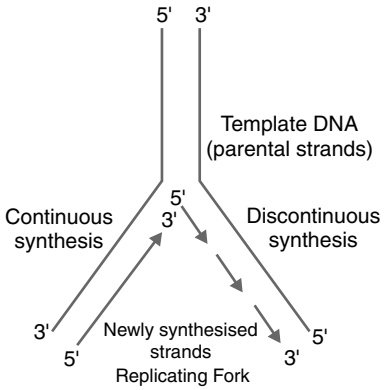
- DNA replicates semi-conservatively was shown first in *Escherichia coli*.
- Matthew Meselson and Franklin Stahl performed the following experiment in 1958:
  - **(a)** They grew *E. coli* in a medium containing $^{15}NH_4Cl$ in which ^{15}N is the heavy isotope of nitrogen. This resulted ^{15}N to synthesize new DNA. This heavy DNA molecule could be distinguished from the normal DNA by centrifugation in a cesium chloride (CsCl) density gradient.
  - **(b)** Then they transferred the cells into a medium with normal $^{14}NH_4Cl$ and took samples at various definite time intervals as the cells multiplied, and extracted the DNA that remained as double-stranded helices. The various samples were separated independently on CsCl gradients to measure the densities of DNA.
  - **(c)** The DNA extracted from the culture one generation after the transfer from ^{15}N to ^{14}N medium had a hybrid or intermediate density. DNA extracted from the culture after another generation was composed of equal amounts of the hybrid DNA and of 'light' DNA.



- Experiments involving use of radioactive thymidine to detect distribution of newly synthesised DNA in the chromosomes was performed on *Vicia faba* (faba beans) by Taylor and colleagues in 1958.

The Machinery and the Enzymes

- In *E. coli*, the process of replication requires a set of catalysts (enzymes).
- The main enzyme is referred to as DNA-dependent DNA polymerase, since it uses a DNA template to catalyse the polymerisation of deoxynucleotides.
- These enzymes are highly efficient in a very short time. *E. coli* that has only 4.6×10^6 bp completes the process of replication within 38 minutes *i.e.*, the average rate of polymerisation is approximately 2000 bp per second.
- These polymerases have to be fast and catalyse the reaction with high degree of accuracy.
- Any mistake during replication would result into mutations.
- Energetically replication is a very expensive process.
- Deoxyribonucleoside triphosphates serve dual purposes as follows:
  - **(a)** Act as substrates
  - **(b)** They provide energy for polymerization reaction
- There are many additional enzymes required to complete the process of replication with high degree of accuracy.
- In long DNA molecules, the two strands of DNA cannot be separated in its entire length as it requires high energy.
- Thus, the replication occurs within a small opening of the DNA helix, referred to as replication fork.
- The DNA-dependent DNA polymerases catalyse polymerisation only in one direction ($5' \rightarrow 3'$).
- So, on the template with polarity $3' \rightarrow 5'$, the replication is continuous, while on the other $5' \rightarrow 3'$, it is discontinuous.
- The discontinuously synthesized fragments are joined by the enzyme DNA ligase.
- The DNA polymerases cannot initiate the process of replication and does not initiate randomly at any place in DNA on their own.
- Therefore, there is a definite region called origin of replication in *E. coli* DNA where the replication originates.
- If a piece of DNA is needed to be propagated during recombinant DNA procedures, it requires a vector which provides the origin of replication.
- In eukaryotes, the replication of DNA takes place at S-phase of the cell-cycle.
- The replication of DNA and cell division cycle should be highly coordinated.
- A failure in cell division after DNA replication results into polyploidy.

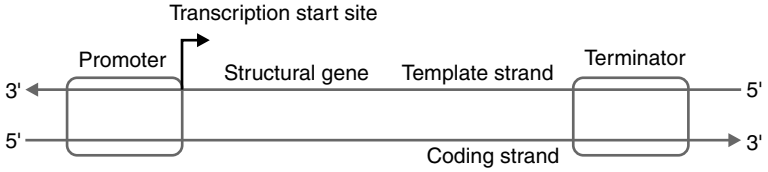


TRANSCRIPTION

- The process of copying genetic information from one strand of the DNA into RNA is termed as transcription.
- The principle of complementarity governs the process of transcription, except the adenosine which forms base pair with uracil.
- In transcription, only a segment of DNA and only one of the strands is copied into RNA.
- This would demarcate the region and the strand of DNA that would be transcribed.
- Both the strands are not copied during transcription. This is because
  - **(a)** The code for proteins is different in both strands. This complicates the translation.
  - **(b)** The two RNA molecules if produced simultaneously, it would be complementary to each other and hence would form a double stranded RNA. This would prevent RNA from being translated into protein.

Transcription Unit

- A transcription unit in DNA is differentiated into three regions namely,
  - **(a)** A Promoter
  - **(b)** The Structural gene
  - **(c)** A Terminator
- Since the two strands of DNA have opposite polarity and the DNA-dependent RNA polymerase catalyse the polymerisation in only one direction (5' → 3'), the strand that has the polarity 3' → 5' acts as a template, and is referred to as template strand.
- The other strand which has the polarity (5' → 3') is referred to as coding strand.
- For example – a hypothetical sequence from a transcription unit is represented below :
  3'-ATGCATGCATGCATGCATGCATGC-5' Template Strand
  5'-TACGTACGTACGTACGTACGTACG-3' Coding Strand
- The promoter and terminator play an important role in transcription unit.
- The promoter is located towards 5'-end in the upstream of the structural gene.
- It is a DNA sequence that provides binding site for RNA polymerase.
- The promoter defines the template and coding strands.
- By switching its position with terminator, the coding and template strands could be reversed.
- The terminator is located towards 3'-end in the downstream of the coding strand and defines the end of the process of transcription.
- Inheritance of a character is also affected by promoter and regulatory sequences of a structural gene.
- Hence, regulatory sequences are loosely defined as regulatory genes, though these do not code for any RNA or protein.



Transcription Unit and the Gene

- A gene is defined as the functional unit of inheritance.
- It is the DNA sequence coding for tRNA or rRNA molecule.

- Cistron : A segment of DNA coding for a polypeptide.
- Structural gene in a transcription unit are of two types:
  (a) Monocistronic structural genes (split genes): It is seen in eukaryotes. Here, the coding sequences (expressed sequences or exons) are interrupted by introns (intervening sequences).
  (b) Polycistronic structural genes: It is seen in prokaryotes. Here, there are no split genes.

Steps of Transcription in Prokaryotes

- It includes three steps namely,
  (a) Initiation
  (b) Elongation
  (c) Termination

Initiation :

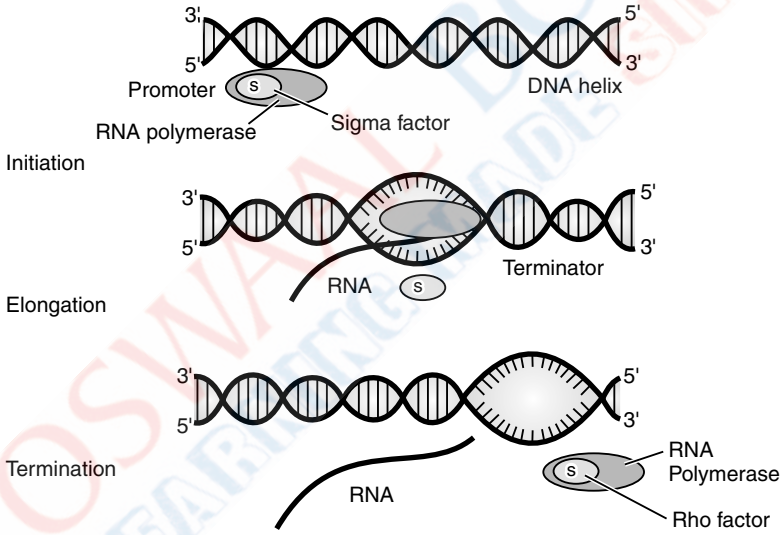
- Here, the enzyme RNA *polymerase* binds at the promoter site of DNA. This causes the local unwinding of the DNA double helix. An *initiation factor* (σ *factor*) present in RNA polymerase initiates the RNA synthesis.

Elongation :

- The RNA chain is synthesized in the 5′-3′ direction. In this process, activated ribonucleoside triphosphates (ATP, GTP, UTP & CTP) are added. This is complementary to the base sequence in the DNA template.

Termination :

- A *termination factor* (ρ *factor*) binds to the RNA polymerase and terminates the transcription.
- In bacteria, translation can begin much before the mRNA is fully transcribed since the mRNA does not require any processing to become active, and transcription and translation take place in the same compartment due to absence of a well defined nucleus.

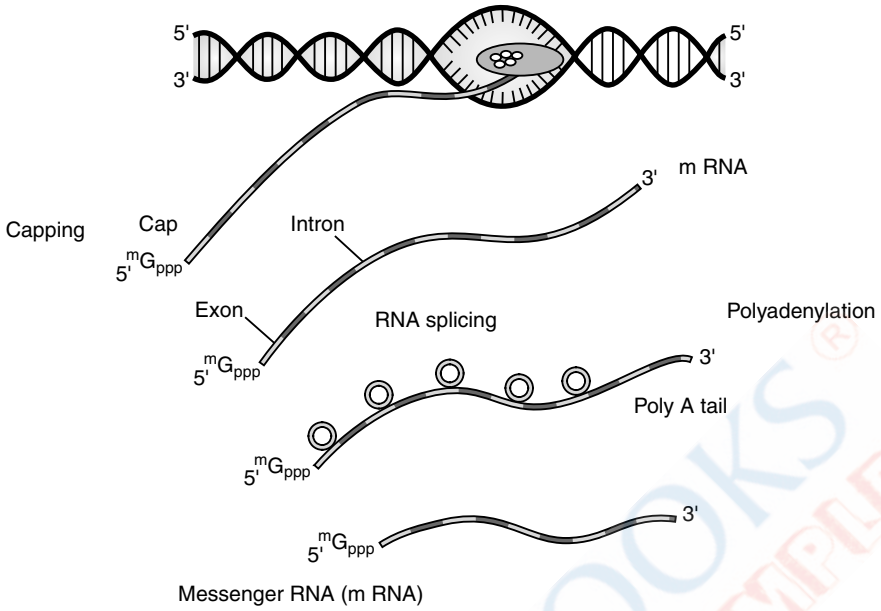


Process of Transcription in Bacteria

Steps of Transcription in Eukaryotes

- In eukaryotes, the monocistronic structural genes have interrupted coding sequences – the genes in eukaryotes are split.
- The coding sequences or expressed sequences are defined as exons.
- Exons are said to be those sequence that appear in mature or processed RNA.
- The exons are interrupted by introns.
- Introns or intervening sequences do not appear in mature or processed RNA.
- In eukaryotes, there are two additional complexities :
  (a) There are three RNA polymerases in the nucleus in addition to the RNA polymerase found in the organelles.
    (i) The RNA polymerase I: It transcribes rRNAs (28S, 18S, and 5.8S)
    (ii) The RNA polymerase II: It is the precursor of mRNA, the heterogeneous nuclear RNA (hnRNA).
    (iii) The RNA polymerase III: It is responsible for transcription of tRNA, 5srRNA, and snRNAs(small nuclear RNAs).
  (b) The primary transcripts (hnRNA) contain both the exons and the introns and are non-functional. In order to remove the introns, it undergoes the following processes:
    (i) Splicing :
    The introns are removed from hnRNA and exons are joined together.
    (ii) Capping :
    Here, a nucleotide methyl guanosine triphosphate is added to the 5′ end of hnRNA.

(iii) Tailing (Polyadenylation): Here, adenylate residues (200-300) are added at 3'-end.



Process of Transcription in Eukaryotes

- The fully processed hnRNA is now called mRNA that is transported for translation.

Significance of the Split-gene Arrangements in Eukaryotes

(a) It represents an ancient feature of the genome.

(b) The presence of introns is reminiscent of antiquity, and the process of splicing represents the dominance of RNA-world.

TOPIC-2

Genetic Code, Gene Expression And DNA Fingerprinting

Revision Notes

- The process of translation requires transfer of genetic information from a polymer of nucleotides to a polymer of amino acids. This led to the proposition of genetic code.
- Genetic code is the sequence of nucleotides (nitrogen bases) in mRNA that contains information for protein synthesis (translation).
- There are 20 amino acids involved in translation as follows :

Alanine (Ala)	Leucine (Leu)
Arginine (Arg)	Lysine (Lys)
Asparagine (Asn)	Methionine (Met)
Aspartic acid (Asp)	Phenyl alanine (Phe)
Cystein (Cys)	Proline (Pro)
Glutamine (Gln)	Serine (Ser)
Glutamic acid (Glu)	Threonine (Thr)
Glycine (Gly)	Tryptophan (Trp)
Histidine (His)	Tyrosine (Tyr)
Isoleucine (Ile)	Valine (Val)

Scientists Involved in Genetic Code

George Gamow:

- He suggested that for coding 20 amino acids, the code should be made up of 3 nucleotides.

Har Gobind Khorana :

- He developed the chemical method of synthesizing RNA molecules with defined combinations of bases (homopolymers & copolymers).

Marshall Nirenberg :

- He developed cell-free system for protein synthesis.

Severo Ochoa

- He used polynucleotide phosphorylase enzyme to polymerize RNA with defined sequences in a template independent manner.

Codons for Amino Acids

- The checker board below shows the codons for the various amino acids.

	U		C		A		G		
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC	Phe	UCC	Ser	UAC	Tyr	UGC	Cys	C
	UUA	Leu	UCA	Ser	UAA	Stop	UGA	Stop	A
	UUG	Leu	UCG	Ser	UAG	Stop	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC	Leu	CCC	Pro	CAC	His	CGC	Arg	C
	CUA	Leu	CCA	Pro	CAA	Gln	CGA	Arg	A
	CUG	Leu	CCG	Pro	CAG	Gln	CGG	Arg	G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC	Ile	ACC	Thr	AAC	Asn	AGC	Ser	C
	AUA	Ile	ACA	Thr	AAA	Lys	AGA	Arg	A
	AUG	Met	ACG	Thr	AAG	Lys	AGG	Arg	G
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC	Val	GCC	Ala	GAC	Asp	GGC	Gly	C
	GUA	Val	GCA	Ala	GAA	Glu	GGA	Gly	A
	GUG	Val	GCG	Ala	GAG	Glu	GGG	Gly	G

Salient Features of Genetic Code

1. The codon is triplet.
2. 61 codons code for amino acids while 3 codons *i.e.*, UAA, UAG & UGA do not code for any amino acids, hence they function as stop codons or non-sense codons.
3. Genetic code is unambiguous and specific. *i.e.*, one codon specifies only one amino acid.
4. A single amino acid is represented by many codons (except AUG for methionine & UGG for tryptophan). Such codons are called degenerate codons.
5. No punctuations between adjacent codons (comma less code). The codon is read in mRNA in a contiguous fashion.
6. Genetic code is universal. E.g., From bacteria to human UUU codes for Phenylalanine. Some exceptions are found in mitochondrial codons, and in some protozoans.
7. AUG has dual functions. It codes for Methionine (Met), and also acts as initiator codon. In eukaryotes, methionine is the first amino acid and *formyl methionine* in prokaryotes.

Mutation and Genetic Code

- The effect of large deletions, addition and rearrangements in a segment of DNA results in loss or gain of a gene that can be easily comprehended.
- Eg – A point mutation is a change of single base pair in the gene for beta globin chain that changes amino acid residue glutamate to valine resulting in a diseased condition called as sickle cell anaemia.
- Insertion or deletion of one or two bases changes the reading frame from the point of insertion or deletion.
- Eg – Insertion or deletion of three or its multiple bases insert or delete one or multiple codon hence one or multiple amino acids, and reading frame remains unaltered from that point onwards. Such mutations are referred to as frame-shift insertion or deletion mutations. This forms the genetic basis of proof that codon is a triplet and it is read in a contiguous manner.

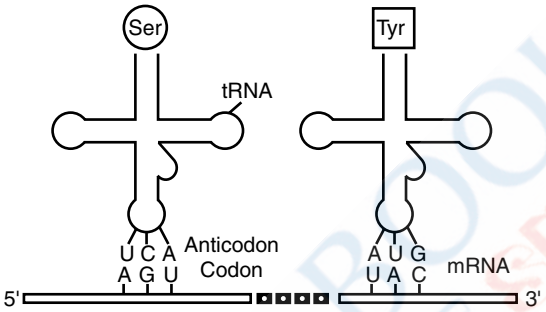
Types of RNA

- In prokaryotes such as bacteria, there are three major types of RNAs namely,
  - **(a)** mRNA (messenger RNA)
  - **(b)** tRNA (transfer RNA)
  - **(c)** rRNA (ribosomal RNA).
- All three RNAs are needed to synthesise a protein in a cell.

- The mRNA provides the template, tRNA brings amino acids and reads the genetic code, and rRNAs play structural and catalytic role during translation.
- There is single DNA-dependent RNA polymerase that catalyses transcription of all types of RNA.

The tRNA, the Adapter Molecule

- Francis Crick postulated the presence of an adapter molecule that would on one hand read the code and on other hand would bind to specific amino acids as amino acids have no structural specialities to read the code.
- The tRNA, then called sRNA (soluble RNA) play the role as an adapter molecule.
- The tRNAs are specific for each amino acid.
- The tRNA is a compact molecule having the following:
  - **(a)** An anticodon loop that has bases complementary to the code.
  - **(b)** An amino acid acceptor end to which amino acid binds.
  - **(c)** Initiator tRNA for initiation and no tRNAs for stop codons.
  - **(d)** Secondary (2-D) structure of tRNA looks like a clover-leaf while 3-D structure looks like inverted 'L'.



t-RNA the adapter molecule

TRANSLATION

- It is the process of polymerisation of amino acids to form a polypeptide.
- The order and sequence of amino acids are defined by the sequence of bases in the mRNA.
- The amino acids are joined by a bond which is known as a peptide bond.

Steps Involved in Translation

- The translation involves the following steps:
  - **(a)** Charging of tRNA
  - **(b)** Initiation
  - **(c)** Elongation
  - **(d)** Termination

Charging of tRNA or Aminoacylation of tRNA

- **(a)** Formation of peptide bond requires energy obtained from ATP.
- **(b)** So, amino acids are activated (amino acid + ATP) and linked to their cognate tRNA in the presence of *aminoacyl* tRNA *synthetase*.
- **(c)** Hence, the tRNA becomes charged.
- **(d)** The presence of a catalyst would enhance the rate of peptide bond formation.

Initiation

- **(a)** It begins at the 5′-end of mRNA in the presence of an *initiation factor.*
- **(b)** The mRNA binds to the small subunit of ribosome.
- **(c)** Later the large subunit binds to the small subunit to complete the initiation complex.
- **(d)** The large subunit has 2 binding sites for tRNA- aminoacyl tRNA binding site (A site) and peptidyl site (P site).
- **(e)** Initiation codon and the codon for methionine is AUG. So methionyl tRNAcomplex would have UAC at the Anticodon site.

Elongation

- **(a)** At the P site the first codon of mRNA binds with anticodon of methionyl-tRNA complex.
- **(b)** Another aminoacyl-tRNA complex with an appropriate amino acid enters the ribosome and attaches to A site. Its anticodon binds to the second codon on the mRNA and a peptide bond is formed between first and second amino acids in presence of an enzyme, peptidyl transferase.
- **(c)** First amino acid and its tRNA are broken and the tRNA is removed from P site.
- **(d)** The second tRNA from A site is pulled to P site along with mRNA. This is called translocation.
- **(e)** Now, the third codon comes into A site and a suitable tRNA with third amino acid binds at the A site. This process is repeated.

(f) A group of ribosomes associated with a single mRNA for translation is called a polyribosome (polysomes).

Termination

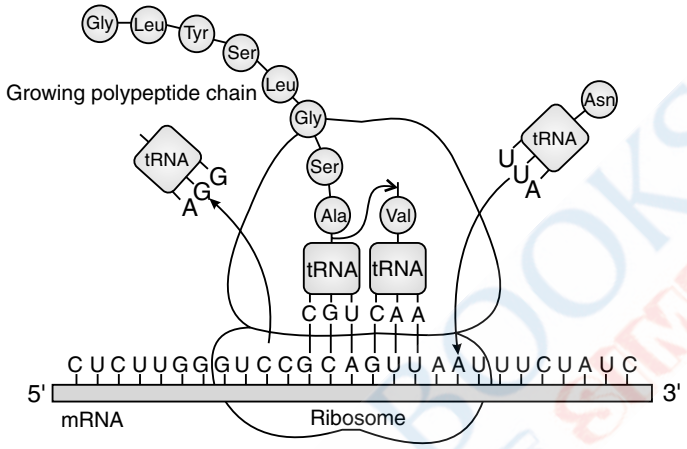
(a) When aminoacyl-tRNA reaches the termination codon like UAA, UAG & UGA, the termination of translation occurs.

(b) The ribosome dissociates into large and small subunits at the end of protein synthesis.

(c) An mRNA has additional sequences that are not translated (untranslated regions or UTR).

(d) UTRs are present at both 5′-end (before start codon) and 3′-end (after stop codon) and are required for efficient translation process.

(e) At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome.



Translation

Regulation of Gene Expression

- Gene expression results in the formation of a polypeptide.

Eukaryotes

- In eukaryotes, the regulation includes the following levels:
  1. Transcriptional level (formation of primary transcript)
  2. Processing level (regulation of splicing)
  3. Transport of mRNA from nucleus to the cytoplasm
  4. Translational level.
- The genes are expressed to perform a particular function or a set of functions. Eg – In bacteria like *E. coli*, the enzyme *beta-galactosidase* hydrolyses lactose into galactose and glucose.
- In the absence of lactose, the synthesis of beta-galactosidase stops. Eg 2 – The development and differentiation of embryo into adult are a result of the expression of several set of genes.
- The metabolic, physiological and environmental conditions regulate expression of genes.

Prokaryotes

- In prokaryotes, the expression of gene is done at transcriptional level.
- Here, the activity of RNA polymerase at a given promoter is regulated by interaction with accessory proteins, which affect its ability to recognize start sites.
- These regulatory proteins can act both positively (activators) and negatively (repressors).
- The accessibility of promoter regions of prokaryotic DNA is regulated by the interaction of proteins with sequences termed operators.
- The operator region is adjacent to the promoter elements and the sequences of the operator bind a repressor protein.
- Each operon has its specific operator and specific repressor.
- For example, *lac* operator is present only in the *lac* operon and it interacts only with *lac* repressor.

OPERON CONCEPT

- "Each metabolic reaction is controlled by a set of genes"
- All the genes regulating a metabolic reaction constitute an Operon. E.g., *lac* operon, *trp* operon, *ara* operon, *his* operon, *val* operon etc.
- When a substrate is added to growth medium of bacteria, a set of genes is switched on to metabolize it. This is called induction.
- When a metabolite (product) is added, the genes to produce it are turned off. This is called repression.

Lac* Operon in *E. coli

- The operon controls lactose metabolism. It consists of two genes namely,
  - **(a)** A regulatory or inhibitory gene (i)
  - **(b)** Three structural genes
    - i. *z* gene
    - ii. *y* gene
    - iii. *a* gene
- The inhibitory gene (*i* gene) codes for the repressor.
- The '*z*' gene codes for β *galactosidase* and helps in hydrolyzing lactose to galactose and glucose.
- The '*y*' gene codes for *permease* and helps to increase the permeability of the cell to lactose.
- The '*a*' gene codes for a *transacetylase*.
- In most other operons, the genes present in the operon function together in the same or related metabolic pathway.
- There is an operator region for each operon.
- If there is no lactose (inducer), *lac* operon remains switched off.
- The regulator gene synthesizes mRNA to produce the repressor protein.
- This protein binds to the operator genes and blocks RNA polymerase movement. So, the structural genes are not expressed.
- If lactose is provided in the growth medium, the lactose is transported into the *E. coli* cells by the action of permease.
- The repressor protein binds to the operator region of the operon and prevents RNA polymerase from transcribing the operon.
- In the presence of an inducer, such as lactose, the repressor is inactivated. This allows RNA polymerase access to the promoter and transcription proceeds.
- Regulation of *lac* operon by repressor is called negative regulation.

HUMAN GENOME PROJECT

- The entire DNA in the haploid set of chromosome of an organism is called a genome.
- In Human genome, DNA is packed in 23 chromosomes.
- Human Genome Project (1990-2003) is the first effort in identifying the sequence of nucleotides and mapping of all the genes in human genome.
- Human genome contains about 3×10^9bp.
- HGP was closely associated with bioinformatics.

Bioinformatics

- It is the application of computer science and information technology to the field of biology and medicine.
- It helps to analyze DNA sequence data.

Goals of HGP

- **a.** Identify all the estimated genes in human DNA
- **b.** Determine the sequences of the 3 billion chemical base pairs that make up human DNA.
- **c.** Store this information in databases.
- **d.** Improve tools for data analysis.
- **e.** Transfer related technologies to other sectors.
- **f.** Address the ethical, legal and social issues (ELSI) that may arise from the project.

Methodologies of HGP

- The methods of HGP involve two major approaches namely,
  - **(a)** Expressed sequence tags (ESTs)
  - **(b)** Sequence annotation

Expressed Sequence Tags [ESTs]

- It focusses on identifying all the genes that expressed as RNA (referred to as Expressed Sequence Tags (ESTs).

Sequence Annotation

- It sequences the whole set of genome containing all the coding and non-coding sequence, and assigning different regions in the sequence with functions (a term referred to as Sequence Annotation).

Procedure

- For sequencing, the total DNA from a cell is isolated and converted into random fragments.
- These fragments are then cloned in suitable host using specialised vectors.
- This results in the amplification of each piece of DNA fragment so that it could be sequenced with ease.

- The fragments were sequenced using automated DNA sequencers using Frederick Sanger method.
- These sequences were then arranged based on some overlapping regions present in them.
- Alignment of these sequences is done using specialized computer based programs.
- Genetic and physical maps on the genome were generated using information on polymorphism of restriction endonuclease recognition sites and some repetitive DNA sequences (microsatellites).
- The commonly used hosts were bacteria and yeast, and the vectors were called as BAC (bacterial artificial chromosomes), and YAC (yeast artificial chromosomes).

Salient Features of Human Genome

(a) The human genome contains 3164.7 million nucleotide bases.
(b) The average gene consists of 3000 bases, but sizes vary greatly, with the largest known human gene being dystrophin at 2.4 million bases.
(c) The total number of genes is estimated at 30,000.
(d) Almost all (99.9%) nucleotide bases are exactly the same in all people.
(e) The functions of 50% of discovered genes are unknown.
(f) Less than 2% of the genome codes for proteins.
(g) Repeated sequences make up very large portion of the human genome.
(h) Repetitive sequences are stretches of DNA sequences that are repeated many times, sometimes hundred to thousand times. They have no direct coding functions, but help in understanding chromosome structure, dynamics and evolution.
(i) Chromosome 1 has most genes (2968), and the Y has the fewest (231).
(j) About 1.4 million locations where single-base DNA differences (SNPs- Single nucleotide polymorphism or 'snips') occur in humans.

DNA FINGERPRINTING OR DNA PROFILING

- It is the technique to identify the similarities of the DNA fragments of 2 individuals.
- It was developed by Alec Jeffreys (1985).
- DNA carries some non-coding sequences called repetitive sequence [variable number tandem repeats (VNTR) The VNTR belongs to a class of satellite DNA referred to as mini-satellite. A small DNA sequence is arranged tandemly in many copy numbers.
- Number of repeats is specific from person to person.
- The size of VNTR varies from 0.1 to 20 kb.
- Repetitive DNA are separated from bulk genomic DNA as different peaks during density gradient centrifugation.
- The bulk DNA forms a major peak and the other small peaks are called as satellite DNA.
- Satellite DNA is classified into many categories, (micro-satellites, mini-satellites etc) based on base composition (A:T rich or G:C rich), length of segment and number of repetitive units.
- An inheritable mutation observed in a population at high frequency is called DNA polymorphism (variation at genetic level).
- Polymorphism is higher in non-coding DNA sequence. This is because, the mutations in these sequences may not have any immediate effect in an individual's reproductive ability.
- These mutations accumulate generation after generation and cause polymorphism.
- Polymorphism plays an important role in evolution and speciation.

Southern Blot Hybridisation

- It is the technique used earlier which involves radiolabeled VNTR as a probe.
- The steps included in Southern blot hybridisation are as follows:

(a) Isolate DNA (from any cells like blood stains, semen stains or hair roots).
(b) Digestion of DNA by restriction endonucleases,
(c) Separation of DNA fragments by electrophoresis,
(d) Transferring (blotting) of separated DNA fragments to synthetic membranes, such as nitrocellulose or nylon,
(e) Hybridisation using labelled VNTR probe, and
(f) Detection of hybridised DNA fragments by autoradiography.
(g) The image obtained in the form of dark and light bands is called DNA fingerprint.

Application of DNA Fingerprinting

(a) Forensic tool to solve paternity, rape, murder etc.
(b) For the diagnosis of genetic diseases.
(c) To determine phylogenetic status of animals.

❐❐❐

Chapter 29

Evolution

TOPIC-1

Origin of Life on Earth and Related Evidences

Revision Notes

Introduction

- Evolution is an orderly change from one form to another.
- Evolutionary Biology : Study of history of life forms.

ORIGIN OF LIFE

- Big Bang Theory states that universe originated about 20 billion years ago, by a thermonuclear explosion (big bang) of a dense entity.
- The earth was formed about 4.5 billion years ago.
- There was no atmosphere on early earth.
- Water vapour, CH_4, CO_2 and NH_3 released from molten mass covered the surface.
- Then the ozone layer was formed.
- As it cooled, the water vapour fell as rain to form oceans.

Theories of Origin of Life

1. Theory of spontaneous generation (Abiogenesis)

- It states that, life came out of decaying and rotting matter like straw, mud etc.
- Louis Pasteur demonstrated that life comes only from pre-existing life and disproved this theory.
- He showed that in pre-sterilized flasks, life did not come from killed yeast while in another flask open to air, new living organisms arose from killed yeast.

2. Biogenesis

- It was proposed by Francisco Redi, Spallanzani and Louis Pasteur.
- It states that, life originates from pre-existing life.

3. Cosmic theory (Theory of Panspermia)

- It states that the units of life (spores) were transferred to different planets including earth.

4. Theory of special creation

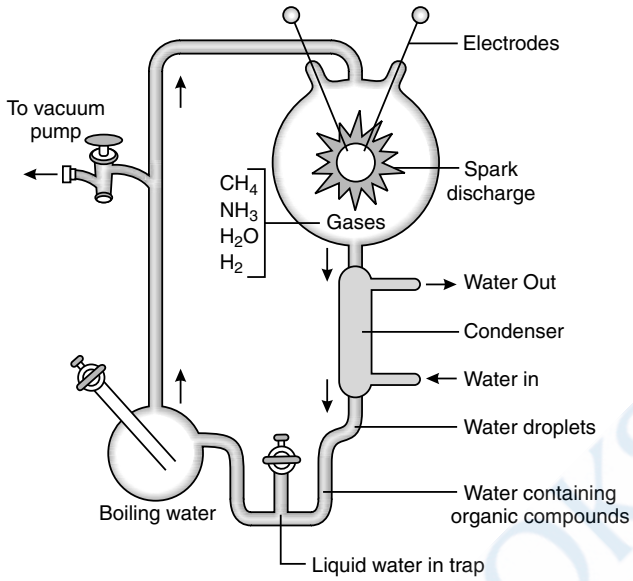
- It states that, living and nonliving was created by some supernatural power (God).

5. Theory of chemical evolution

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

UREY-MILLER EXPERIMENT

- Harold Urey and Stanley Miller conducted an experiment to prove theory of chemical evolution.



Diagrammatic Representative of Miller's Experiment

- They created a condition similar to that of primitive earth (*i.e.*, high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, H_2O, H_2 etc).
- They made electric discharge in a closed flask containing CH_4, NH_3, H_2 and water vapour at 800°C. As a result, some amino acids were formed.
- In similar experiments, others observed formation of sugars, nitrogen bases, pigment and fats.
- First non-cellular form of life originated 3 billion years ago. They were RNA, proteins, polysaccharides, etc.

Evolution of Life Forms – A Theory

- Based on observations made during a sea voyage in a sail ship called H.M.S. Beagle round the world, Charles Darwin concluded that existing living forms share similarities to varying degrees not only among themselves but also with life forms that existed millions of years ago.
- There had been extinctions of different life forms in the years gone by just as new forms of life arose at different periods of history of earth.
- There has been gradual evolution of life forms due to variation in characteristics.
- Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors etc.) would outbreed others that are less-endowed to survive under such natural conditions or fitness of the individual or population.
- The fitness, according to Darwin, refers ultimately and only to reproductive fitness.
- Hence, those who are better fit in an environment, leave more progeny than others.
- These, therefore, will survive more and hence are selected by nature.
- He called it natural selection and implied it as a mechanism of evolution.
- Alfred Wallace, a naturalist who worked in Malay Archepelago also came to similar conclusions around the same time.
- All the existing life forms share similarities and share common ancestors.
- However, these ancestors were present at different periods in the history of earth.
- The geological history of earth closely correlates with the biological history of earth.

EVIDENCES OF EVOLUTION

1. Embryological Evidences

- Embryological support for evolution was also proposed by Ernst Heckel based upon the observation of certain features during embryonic stage common to all vertebrates that are absent in adult.
- Example – The embryos of all vertebrates including human develop a row of vestigial gill slit just behind the head but it is a functional organ only in fish and not found in any other adult vertebrates. But, this proposal was disapproved on careful study performed by Karl Ernst von Baer.
- He noted that embryos never pass through the adult stages of other animals.

2. Paleontological Evidences

Paleontology

- The study of fossils is known as paleontology.

Fossils

- Fossils are remains of hard parts of life-forms found in rocks.
- Rocks form sediments and a cross-section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth.
- Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment.

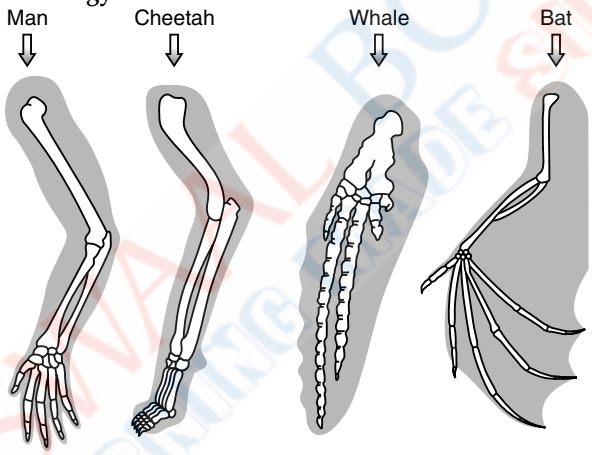
Significance of Fossils

- To study phylogeny (evolutionary history or race history). E.g. Horse evolution.
- To study the connecting link between two groups of organisms. E.g. Archaeopteryx.
- To study about extinct animals. E.g. Dinosaurs
- To study about geological period by analyzing fossils in different sedimentary rock layers. The study showed that life forms varied over time and certain life forms are restricted to certain geological time spans.

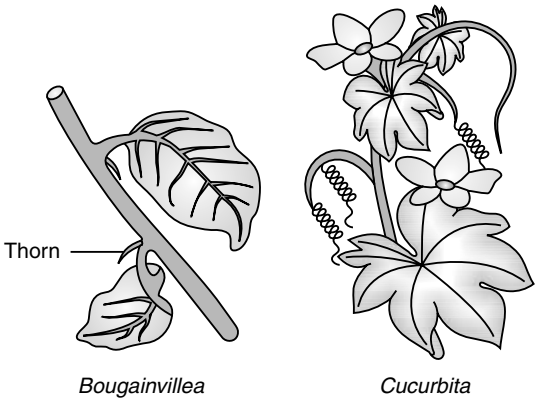
3. Morphological and Anatomical evidences

- Comparative anatomy and morphology shows that different forms of animals have some common structural features.
- This can be explained as follows:

(a) Homologous Organs and Homology



- Homologous organs are the organs having fundamental similarity in structure and origin but different functions. This phenomenon is called homology.
- E.g. Human hand, Whale's flippers, Bat's wing, and Cheetah's foot.
- All these perform different functions, but are constructed on the same plan.
- Homology can be seen in skeleton (e.g., humerus, radius, ulna, carpals, metacarpals & phalanges), heart, blood vessels, excretory system, brain, etc.



Homology in Plants

- The thorns of *Bougainvillea* and tendrils of *Cucurbita*.
- The origin of homologous organs is due to divergent evolution.
- The divergent evolution is the process by which related species become less similar in order to survive and adapt in different environmental condition.
- Homology indicates common ancestry.

(b) Analogous Organs and Analogy

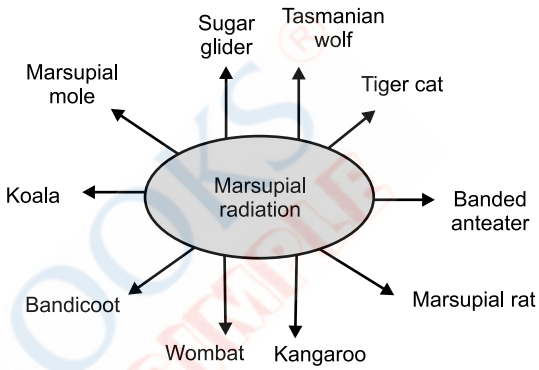
- Analogous organs are the organs having similar function but different structure and origin. This phenomenon is called analogy.
- Examples

(i) Wings of insects (formed of a thin flap of chitin) and wings of birds (modified forelimbs).
(ii) Eyes of Octopus (retina from skin) and mammals (retina from embryonic brain).
(iii) Flipper of Penguins and Dolphins.
(iv) Sweet potato (modified root) and Potato (modified stem).
(v) Trachea of insects (from ectoderm) and lungs of vertebrates (from endoderm).

- The origin of analogous organs is due to convergent evolution.
- The convergent evolution is the process by which unrelated species become more similar in order to survive and adapt in similar environmental condition.

4. Adaptive Radiation (Biogeographical Evidences)

- Adaptive radiation (evolution by adaptation) is the evolution of closely related species in a given geographical area starting from a point.
- E.g.
  (a) Darwin's finches (seen in Galapagos Islands).
  (b) Australian marsupials.
  (c) Placental mammals in Australia.



Convergent Evolution

- When more than one adaptive radiation appeared to have occurred in an isolated geographical area, it leads to convergent evolution.
- E.g. Australian Marsupials and Placental mammals converged towards similarity.

Placental mammals	Australian Marsupials
Mole	Marsupial mole
Ant eater	Numbat (Ant eater)
Mouse	Marsupial mouse
Lemur	Spotted cuscus
Flying squirrel	Flying phalanger
Bobcat	Tasmanian tiger cat
Wolf	Tasmanian wolf

5. Biochemical Evidences

- Similarities in proteins and genes.
- Similarities in other biomolecules and metabolism.

6. Evidences for Evolution by Natural Selection

- Natural selection is the process by which the organisms that are best suited for their environment survive and reproduce.
- Some evidences are given below :

Industrial Melanism (In England)

Before industrialization (1850s) :

- There were more white winged moths (*Biston betularia*) on trees than dark winged or melanised moths (*Biston carbonaria*).
- Reason : There was white colored lichen that covered the trees. In that background the white winged moths survived but the dark colored moths were picked out by predators.

After industrialization (1920) :

- More dark winged moths and less white winged moths.
- Reason: The tree trunks became dark due to industrial smoke and soot. No growth of lichens. Under this condition the white winged moth did not survive because the predators identified them easily. Dark winged moth survived because of suitable dark background.
- Excess use of herbicides, pesticides, antibiotics or drugs etc., resulted in selection of resistant varieties (Natural selection by anthropogenic action).

TOPIC-2

Evolutionary Theories, Its Mechanism and Evolution of Man

Revision Notes

Theories of Biological Evolution

1. Lamarckism (Theory of Inheritance of Acquired Characters)

- It was proposed by Lamarck.
- It states that evolution of life forms occurred by use and disuse of organs.
- E.g.

(a) Evolution by use of organs :
Long neck of giraffe is due to continuous elongation to forage leaves on tall trees. This acquired character was inherited to succeeding generations.

(b) Evolution by disuse :
Disappearance of limbs in snakes. This theory was eliminated out because, it is proved that the characters are inherited only through genes.

2. Darwinism (Theory of Natural Selection)

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

(a) Branching descent
(b) Natural selection

Branching Descent

- It explains that all organisms are modified descendants of previous life forms.

Natural Selection

- Consider a bacterial colony (say A) growing on a given medium.
- If the medium composition is changed, only a part of the population (say B) can survive under new condition. This variant population outgrows the others and appears as new species, i.e., B is better than A under new condition.
- Nature selects for fitness.
- The work of Thomas Malthus on populations influenced Darwin.
- Natural selection is based on the following facts:

(a) Heritable minor variations
(b) Overproduction by organisms
(c) Limited natural resources
(d) Struggle for existence
(e) Survival of the fittest

- Population size grows exponentially if everybody reproduces maximally (E.g., bacterial population).
- In fact, population size is limited due to competition for resources (Struggle for existence).
- Only some survives (Survival of the fittest).
- Darwin said that the organisms with heritable variations make resource utilization better.
- They reproduce and leave more progeny.
- It leads to a change in population characteristics and new forms appear.

MECHANISM OF EVOLUTION

Mutation Theory

- Hugo de Vries proposed Mutation Theory of evolution.
- He conducted some experiments on *Oenothera lamarckiana* (evening primrose) and believed that evolution takes place through mutation and not by minor variation.
- Evolution for Darwin was gradual while deVries believed mutation caused speciation and hence called it saltation (single step large mutation).

Differences between Darwinian Variation and Mutation

Darwinian Variation	Mutation
It shows minor variation	It shows large variation
It is slow and directional	It is random, sudden and directionless
It shows gradual evolution	It shows speciation by saltation

Hardy- Weinberg Principle

- It says that allele frequencies in a population are stable and constant from generation to generation.
- The gene pool (total genes and their alleles in a population) remains a constant. This is called genetic equilibrium (Hardy-Weinberg equilibrium).
- Sum total of all the allelic frequencies = 1
- E.g. In a diploid, p and q are the frequencies of alleles A and a respectively.
- The frequency of AA = p^2 (i.e., the probability of an allele A with frequency p is the product of the probabilities, *i.e.* p^2)
- The frequency of aa = q^2
- The frequency of Aa = 2pq
- Hence $p^2 + 2pq + q^2 = 1$ [binomial expansion of $(p+q)^2$]
- Change of frequency of alleles in a population causes disturbance in genetic equilibrium. This results in evolution.

Factors affecting Hardy-Weinberg Equilibrium

(a) Gene Migration

- Gene flow from one population to another.
- Here, gene frequencies change in both populations.
- There would be a gene flow if migration happens multiple times.

(b) Genetic Drift

- The accidental gene flow causing change in frequency.
- Sometimes, the change in frequency is so different in the new sample of population that they become a different species.
- The original drifted population becomes founders and the effect is called founder effect.

(c) Mutation

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

(d) Genetic Recombination

- It is the reshuffling of gene combinations during crossing over resulting in genetic variation.

(e) Natural Selection

- These of three types namely,
  - **(a)** stabilizing selection
  - **(b)** directional selection
  - **(c)** disruptive selection

(i) Stabilizing selection

(i) Stabilizing selection – in which more individuals acquire value mean character value.
(ii) Directional selection – in which more individuals acquire value other than the mean character value.
(iii) Disruptive selection – in which more individuals acquire peripheral characters value at both ends of the distribution curve.

ACCOUNT ON EVOLUTION

Proterozoic Era - 2000 Million Years Ago (mya)

(a) First cellular forms of life.
(b) Some of the cells had the ability to release O_2 similar to that of the light reaction in photosynthesis.
(c) Single celled organisms to multicellular organisms

Paleozoic Era

(a) 500 mya: Invertebrates were formed.
(b) 400-600 mya: First land organisms (plants).
(c) 400 mya: Arthropods invaded the land.
(d) 350 mya: Jawless fish. Fish with stout and strong fins could move on land and go back to water.
(e) 320 mya: Sea weeds and few plants.
(f) Amphibians to reptiles. They lay thick-shelled eggs which do not dry up in sun unlike those of amphibians.
(g) In the next 200 million years reptiles dominated on earth. Giant ferns (Pteridophytes) were present but they all fell to form coal deposits slowly.

Mesozoic Era

(a) 200 mya: Some of the land reptiles went back into water to evolve into fish-like reptiles (E.g. *Ichthyosaurs*).
(b) The land reptiles were dinosaurs.
(c) They include
  - **(i)** *Tyrannosaurus rex*: Largest dinosaur (20 feet in height, huge fearsome dagger-like teeth).
  - **(ii)** *Triceratops*
  - **(iii)** *Pteranodon*
  - **(iv)** *Stegosaurus*
  - **(v)** *Brachiosaurus*

Coenozoic Era

(a) 65 mya: Dinosaurs suddenly disappeared

(b) First mammals (shrew-like). Their fossils are small sized.

(c) In South America, there were mammals resembling horse, hippopotamus, bear, rabbit etc.

(d) Due to continental drift, when South America joined North America, these animals were overridden by North American fauna.

(e) Due to continental drift, Australian marsupials survived because of lack of competition from any other mammals.

ORIGIN AND EVOLUTION OF MAN

***Dryopithecus and Ramapithecus* (15 mya)**

(a) Hairy.

(b) Walked like gorillas and chimpanzee.

(c) *Dryopithecus*: ape-like.

(d) *Ramapithecus*: man-like.

(e) Fossils of man-like bones found in Ethiopia and Tanzania.

Man-like primates (3-4 mya)

(a) Height up to 4 feet.

***Australopithecus* (2 mya)**

(a) Probably lived in East African grass lands.

(b) Hunted with stone weapons.

(c) Ate fruits.

Homo habilis

(a) First human-like being (hominid).

(b) Brain capacity: 650-800 cc.

(c) Did not eat meat.

***Homo erectus* (1.5 mya)**

(a) Large brain (900 cc). Ate meat.

Neanderthal man (1 lakh – 40,000 years ago):

(a) Brain size of 1400 cc.

(b) Lived in East and Central Asia.

(c) Used hides to protect their body.

(d) Buried their dead.

***Homo sapiens* (Modern man): 10,000 to 75,000 yrs ago.**

(a) Pre-historic cave art developed about 18,000 years ago.

(b) Agriculture and settlements: 10,000 years ago.

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Chapter 30

Human Health and Disease

TOPIC-1

Human Health, Diseases and Immunity

Revision Notes

- Health is a state of complete physical, mental and social well-being.
- Health does not simply means disease free condition or physical fitness. Health is affected by-
  (a) Genetic disorders – the defect which child inherits from its parents.
  (b) Infection from microbes or other organisms.
  (c) Life style- including food and water we take, exercise and rest.
- When people are healthy, they are more efficient at work. This increases productivity and brings prosperity. It also increases longevity of people and reduces infant and maternal mortality.
- Good health can be maintained by–
  - Balanced diet.
  - Personal hygiene
  - Regular exercise
  - Awareness about the disease and their effect
  - Immunization against the infectious disease
  - Proper disposal of wastage
  - Control of vectors
  - Maintenance of hygienic food and water.

TYPES OF DISEASES

- Diseases may be of two types namely,
  (a) Infectious disease
  (b) Non-infectious disease
- The diseases which are easily transmitted from infected person to healthy persons are called infectious disease and diseases which cannot be transmitted from one person to another are called non-infectious disease.

COMMON INFECTIOUS DISEASES IN MAN

- The disease causing microorganisms like bacteria, virus, fungus, protozoa, helminthes are called pathogens.
- The pathogens can enter the body by various means and multiply and interfere with normal vital activities resulting in morphological and functional damage.

BACTERIAL DISEASES

A. Typhoid

Pathogen : *Salmonella typhi*

Mode of Transmission :

It enters the small intestine through food and water and migrates to other organs through blood.

Symptoms :

(a) Sustained high fever (39°C to 40°C), weakness, stomach pain, constipation, headache and loss of appetite.

(b) Intestinal perforation and death may occur.

(c) Widal test is used for confirmation of the disease.

B. Pneumonia

Pathogen : *Streptococcus pneumonia and Haemophilus influenza*

Mode of Transmission :

Inhaling the droplets/aerosols released by an infected person, sharing glasses and utensils with an infected person.

Symptoms :

(a) Infects lung alveoli as a result the alveoli get filled with fluid leading to respiratory problems.

(b) Fever, chills, cough, headache.

(c) Severe cases: Lips and finger nails turn gray to bluish colour.

OTHER BACTERIAL DISEASES

Diseases	Pathogens	Transmission
Dysentery	*Shigella*	Contact, contaminated food and water
Plague	*Pasteurella pestis*	Rat fleas
Diphtheria	*Corynebacterium diphtheriae*	Contaminated food, direct contact
Cholera	*Vibrio cholerae*	Food & water contaminated with faeces
Tuberculosis	*Mycobacterium tuberculosis*	Droplets from patient / carrier
Tetanus	*Clostridium tetani*	Contamination of wound by bacteria
Whooping cough	*Bordetella pertussis*	Contact, Droplets
Leprosy	*Mycobacterium leprae*	Direct contact
Anthrax	*Bacillus anthracis*	Contact with cattle
Weil's disease	*Leptospira*	Contact with rodents, dogs etc.

VIRAL DISEASES

A. Common cold

Pathogen : *Rhinoviruses*

Mode of Transmission :

Inhaling droplets resulting from cough or sneezes, through contaminated objects.

Symptoms :

(a) Infects nose and respiratory passage.

(b) Nasal congestion and discharge, sore throat, hoarseness, cough, headache, tiredness, etc.

(c) Last for 3-7 days.

OTHER VIRAL DISEASES

Diseases	Pathogen	Transmission
Rabies	Rabies virus	Rabid dogs
Dengue	Dengue virus	*Aedes* mosquito
Influenza	Influenza virus	Coughing and sneezing
Measles	Rubeloa virus	Droplets
German measles	Rubella virus	Close contact
Mumps	Mumps virus	Air borne droplets
Chicken pox	*Varicella zoster*	Air borne droplets
Small pox	Variola virus	Direct contact
Polio	Polio virus	Faeces and Air
Chikungunya	CHIK virus	*Aedes* mosquito
Avian flu	H5N1 virus	Contact with infected poultry. Air borne spread
H1N1 (Swine flu)	H1N1 virus	Contact with pigs, cough & sneeze of infected person

PROTOZOAN DISEASES

A. Malaria

Pathogen : *Plasmodium sp. (P. vivax, P. malariae, and P. falciparum).*

Mode of Transmission :

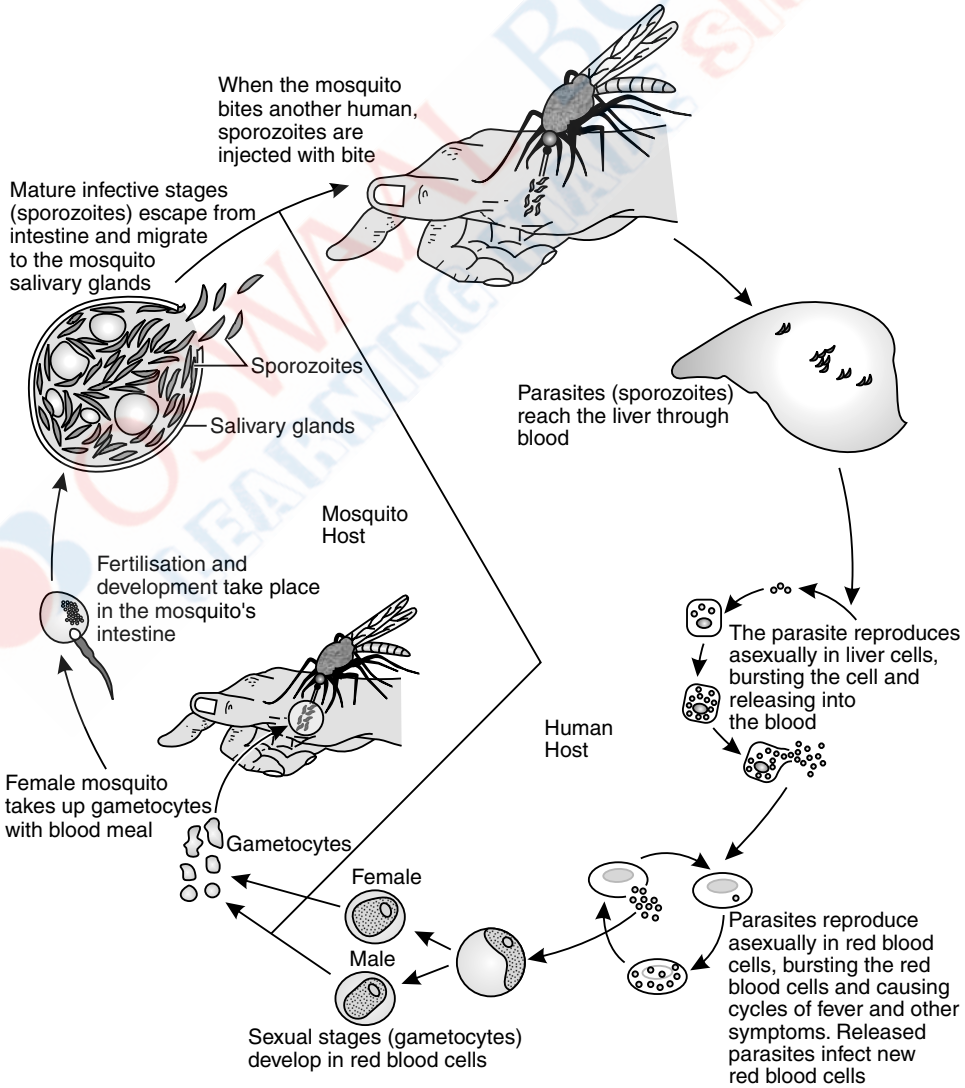
Anopheles mosquito biting.

Symptoms :

Haemozoin causes chill and high fever recurring every 3-4 days.

Life Cycle of *Plasmodium*

- *Plasmodium* enters the human body as sporozoites (infectious form) through the bite of infected female *Anopheles* mosquito.
- The parasites initially multiply within the liver cells and then attack the red blood cells (RBCs) resulting in their rupture.
- The rupture of RBCs is associated with release of a toxic substance, haemozoin, which is responsible for the chills and high fever recurring every three to four days.
- When a female *Anopheles* mosquito bites an infected person, these parasites enter the mosquito's body and undergo further development.
- The parasites multiply within them to form sporozoites that are stored in their salivary glands.
- When these mosquitoes bite a human, the sporozoites are introduced into his/her body.
- The malarial parasite requires two hosts to complete its life cycle namely,
  (a) Human
  (b) Mosquitoes
- The female *Anopheles* mosquito is the vector (transmitting agent).



Stages in the life cycle of *Plasmodium*

B. Amoebiasis (Amoebic dysentery)

Pathogen : *Entamoeba histolytica.*

Mode of Transmission :

Houseflies (mechanical carriers) transmit parasites from faeces to food and water.

Symptoms :

(a) Constipation, abdominal pain and cramps.

(b) Stools with excess mucous and blood clots.

HELMINTH DISEASES

A. Ascariasis

Pathogen : *Ascaris* (Intestinal parasite).

Mode of Transmission :

Soil, water, vegetables, fruits etc., contaminated with faeces containing eggs of parasites.

Symptoms :

(a) Internal bleeding, muscular pain, fever, anaemia.

(b) Blockage of intestinal passage.

Filariasis (Elephantiasis)

Pathogen : Filarial worms or *Wuchereria* (*W. bancrofti and W. malayi*).

Mode of transmission :

Bite of female *Culex* mosquito.

Symptoms :

(a) Filarial worms live in lymphatic vessels (usually of lower limbs) causing chronic inflammation of the organs in which they live for many years.

(b) Limbs and genital organs may be deformed.

FUNGAL DISEASES

A. Ring worms

Pathogens : *Microsporum, Trichophyton and Epidermophyton.*

Mode of Transmission :

(a) From soil or by using infected person's towels, cloths, comb, etc.

(b) Heat and moisture help fungi to grow.

Symptoms :

(a) Appearance of dry, scaly lesions on various body parts such as skin, nails and scalp.

(b) Intense itching.

(c) They are seen in groin, between the toes, etc.

PREVENTION AND CONTROL OF DISEASES

1. Personal hygiene

(a) Keep the body clean.

(b) Use clean drinking water, food etc.

2. Public hygiene

(a) Proper disposal of wastes and excreta.

(b) Periodic cleaning and disinfection of water reservoirs, pools, cesspools and tanks.

(c) Avoid contact with infected persons or their belongings (to control air-borne diseases).

(d) Standard practices of hygiene in public catering.

(e) Control or eliminate the vectors (*e.g.* mosquitoes) and their breeding places.

Methods to Control Breeding Places

- Avoid stagnation of water.
- Regular cleaning of household coolers.
- Use of mosquito nets.
- Introduce larvivorous fishes like *Gambusia* in ponds.
- Spraying insecticides in ditches, drainage and swamps.
- Doors and windows should be provided with wire mesh to prevent entry of mosquitoes.
- These precautions can avoid vector borne diseases like Malaria, Filariasis, Dengue and Chikungunya.

IMMUNITY

- It is the ability of the immune system to fight the disease-causing organisms.
- It is of two types namely,

(a) Innate immunity

(b) Acquired immunity.

Innate immunity

- It is the non-specific defense present at the time of birth.
- It provides different types of barriers to the entry of foreign agents into our body.

- It is of four types :

(a) Physical barriers :

It includes

(i) Skin (prevent entry of foreign bodies)

(ii) Mucus coating of epithelium lining the respiratory, gastro-intestinal and urino-genital tracts to trap microbes.

(b) Physiological barriers:

It includes

(i) Acid in the stomach, saliva in the mouth, tears from eyes–all prevent microbial growth.

(c) Cellular barriers:

It includes,

(i) Leucocytes like WBC such as neutrophils or polymorpho-nuclear leucocytes (PMNL neutrophils), monocytes and natural killer lymphocytes, macrophages, etc.

(d) Cytokine barriers :

It includes,

Virus infected cells secrete proteins called interferon which protect non-infected cells from further viral infection.

Acquired immunity

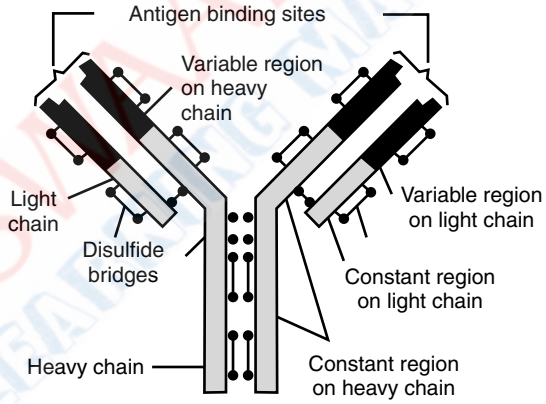
- It is pathogen specific immunity.
- It is characterized by memory, i.e., during first encounter of a pathogen, our body produces primary response in low intensity. Second encounter with the same pathogen produces a secondary (anamnestic) response in high intensity.
- The primary and secondary immune responses are carried out with two special types of lymphocytes namely,
  (a) B-lymphocytes
  (b) T-lymphocytes

B-lymphocytes (B-cells)

- It produces proteins in response to pathogens into our blood to fight with them.
- These proteins are called antibodies.

T-lymphocytes (T-cells)

- It helps B-cells to produce antibodies.



Structrue of an Antibody Molecule

- Each antibody has four peptide chains namely,
  (a) Two small chains called light chains
  (b) Two longer chains called heavy chains
- Hence an antibody is represented as H_2L_2.
- Types of antibodies produced in our body: IgG, IgA, IgM, IgE and IgD.

Acquired Immune Response

- There are two types namely,
  (a) Antibody mediated response
  (b) Cell mediated response

Humoral or Antibody mediated response / Antibody mediated immunity (AMI)

Because these antibodies are found in the blood, the response is also called as **humoral immune response.**

Cell-mediated response / cell-mediated immunity (CMI)

- T-lymphocytes (T-cells) mediate CMI.
- CMI is responsible for graft rejection.
- The body is able to differentiate 'self' and 'non-self'.

- Tissue matching and blood group matching are essential before undertaking any graft/transplant. After this, the patient has to take immune-suppressants all his life.

Types of Immunity

There are two types of immunity namely,

(a) Active immunity

(b) Passive immunity

Active Immunity

- When a host is exposed to antigens, which may be in the form of living or dead microbes or other proteins, antibodies are produced in the host body. This type of immunity is called active immunity.
- Active immunity is slow and takes time to give its full effective response.
- Injecting the microbes deliberately during immunisation or infectious organisms gaining access into body during natural infection induce active immunity.

Passive Immunity

- When ready-made antibodies are directly given to protect the body against foreign agents, it is called passive immunity.
- The yellowish fluid colostrum secreted by mother during the initial days of lactation has abundant antibodies (IgA) to protect the infant. The foetus also receives some antibodies from their mother, through the placenta during pregnancy.

Vaccination and Immunization

- Immunization is based on the memory of the immune system.
- There are two types namely,
  (a) Active immunisation
  (b) Passive immunisation

Active Immunisation

- A preparation of vaccine (antigenic proteins of pathogen or inactivated pathogen) is introduced into the body.
- The antibodies produced in the body against the antigens neutralize the pathogenic agents during actual infection.
- The vaccines also generate memory B and T-cells that recognize the pathogen quickly.
- E.g., Polio vaccine, Hepatitis B vaccine, DPT vaccine, etc.
- Vaccines are produced using DNA recombinant technology (E.g. Hepatitis B vaccine produced from Yeast).

Passive Immunisation

- It is the direct injection of pre-formed antibodies or antitoxin. It is required for quick immune response.
- E.g. Immunisation against Tetanus, snake venom etc.

Allergies

- It is the exaggerated response of the immune system to certain antigens present in the environment.
- The substances causing allergy are called allergens.
- E.g., mites in dust, pollens, animal dander, fur etc.
- Antibodies produced against the allergens are of IgE type.
- Allergy is due to the release of chemicals like histamine and serotonin from the mast cells.
- Modern-day life style results lowering of immunity and more sensitivity to allergens.
- More children in India suffer from allergies and asthma due to sensitivity to the environment due to protected environment provided early in life.

Symptoms of Allergy

(a) Sneezing

(b) Watery eyes

(c) Running nose

(d) Difficulty in breathing

Determination of Cause of Allergy

- The patient is exposed to or injected with very small doses of possible allergens, and the reactions studied.

Treatment for Allergy

- Drugs like anti-histamine, adrenaline and steroids quickly reduce the symptoms of allergy.

AUTOIMMUNITY

- Due to genetic and other unknown reasons, body attacks self-cells resulting in auto-immune disease. E.g., Rheumatoid arthritis.

IMMUNE SYSTEM

- It is the system that gives immunity to the body by recognizing, responding and remembering foreign antigens.
- It plays a role in allergic reaction, auto-immune disease and organ transplantation.
- It includes lymphoid organs, tissues, cells and soluble molecules like antibodies.

Lymphoid Organs

- These are the organs where origin, maturation and proliferation of lymphocytes occur.
- It is are of two types namely,
  (a) Primary lymphoid organs
  (b) Secondary lymphoid organs

Primary Lymphoid Organs

- The primary lymphoid organs are bone marrow and thymus where immature lymphocytes differentiate into antigen-sensitive lymphocytes.

Bone Marrow and Thymus

- The bone marrow is the main lymphoid organ where all blood cells including lymphocytes are produced.
- The thymus is a lobed organ located near the heart and beneath the breastbone.
- The thymus is large at the time of birth but keeps reducing in size with age and by the time puberty is attained it reduces to a very small size.
- Both bone-marrow and thymus provide micro-environments for the development and maturation of T-lymphocytes.

Secondary Lymphoid Organs

- After maturation the lymphocytes migrate to secondary lymphoid organs like spleen, lymph nodes, tonsils, Peyer's patches of small intestine and appendix.
- The secondary lymphoid organs provide the sites for interaction of lymphocytes with the antigen, which then proliferate to become effector cells.

Spleen

- The spleen is a large bean shaped organ.
- It mainly contains lymphocytes and phagocytes.
- It acts as a filter of the blood by trapping blood-borne microorganisms.
- Spleen also has a large reservoir of erythrocytes.

Lymph Nodes

- The lymph nodes are small solid structures located at different points along the lymphatic system.
- Lymph nodes serve to trap the micro-organisms or other antigens, which happen to get into the lymph and tissue fluid.
- Antigens trapped in the lymph nodes are responsible for the activation of lymphocytes present there and cause the immune response.

MALT [Mucosal Associated Lymphoid Tissue]

- There is lymphoid tissue also located within the lining of the major tracts (respiratory, digestive and urogenital tracts) called mucosal associated lymphoid tissue (MALT).
- It constitutes about 50 per cent of the lymphoid tissue in human body.

TOPIC-2
AIDS, Cancer, Drug Abuse and Adolescence

Revision Notes

AIDS [Acquired Immuno Deficiency Syndrome]

- It means deficiency of immune system acquired during the lifetime of an individual indicating that it is not a congenital disease.
- The word 'syndrome' refers to a group of symptoms.
- It was first reported in 1981.
- It has spread all over the world killing more than 25 million peoples.
- There is a time-lag between the infection and appearance of AIDS symptoms.
- It varies from months to years [5 – 10 yrs].
- Causes of AIDS
- It is caused by the Human Immuno deficiency Virus [HIV], a member of a group of viruses called retrovirus which have an envelope enclosing the RNA genome.
- It is transferred
  (a) By sexual contact with infected person

(b) By transfusion of contaminated blood and blood products
(c) By sharing infected needles
(d) From infected mother to her child through placenta
(e) Through body fluids

- So people having multiple sexual partners, drug addicts, blood transfusion and children born to an infected mother have high risk of getting this disease.
- It does not spread by touching, physical contact and hence it is imperative for the physical and psychological well-being, so that the infected persons are not isolated from family and society.

Symptoms of AIDS

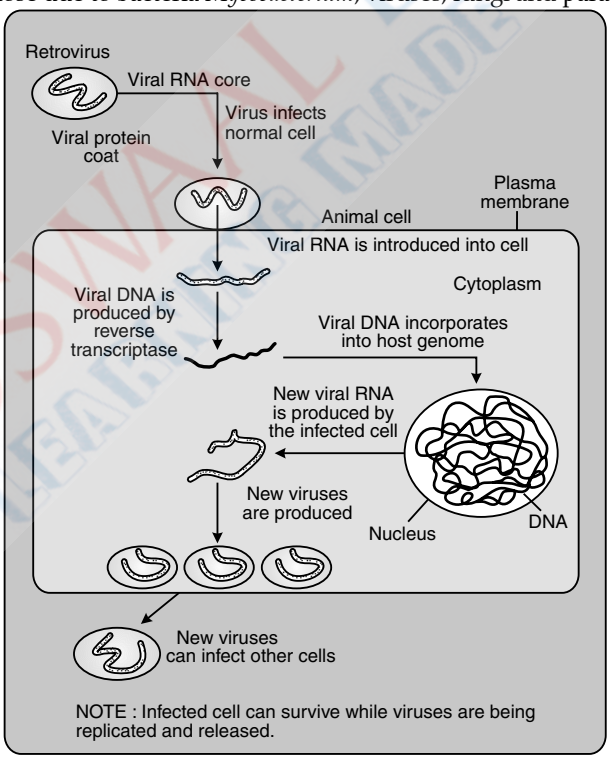
- The person suffers from bouts of fever, diarrhoea and weight loss.
- The patient becomes so immuno-deficient that he/she is unable to protect against these infections.

Test or Identification for AIDS

- It can be identified by ELISA [Enzyme Linked Immuno-Sorbent Assay] test.
- Treatment of AIDS
- The anti-retroviral drugs gives partial effect and can prolong the life of the patient but cannot prevent death, which is inevitable.

Process of AIDS

- After getting into the body of the person, the virus enters into macrophages where RNA genome of the virus replicates to form viral DNA with the help of enzyme reverse transcriptase.
- The viral DNA enters host cell's DNA and directs the infected cells to produce viral particles.
- The macrophages produce more and more virus and act as a HIV factory.
- Simultaneously HIV enters into helper T – lymphocytes (T_H), replicates and produce progeny viruses.
- The progeny viruses released in the blood attack other helper T – lymphocytes resulting in the decrease of number of helper T – lymphocytes in the body and the person starts suffering from infections that could have been overcome such as those due to bacteria *Mycobacterium*, viruses, fungi and parasites like *Toxoplasma*.



Replication of retrovirus

Prevention of AIDS

- AIDS has no cure but can be prevented.
- The only excuse may be ignorance and it has been rightly said "don't die of ignorance".
- NACO [National AIDS Control Organisation] and NGOs [Non-governmental Organisation] are educating people about AIDS.
- WHO [World Health Organisation] has started a number of programmes to prevent the spreading of HIV infection.

Steps to Prevent AIDS

- Using of disposable syringes and needles in private and public hospitals.
- Free distribution of condoms.

- Controlling drug abuse.
- Advocating safe sex.
- Promoting regular check-up
- HIV/AIDS – infected people need help and sympathy instead of being shunned by society.
- Unless society recognizes it as a problem, the chances of spreading of disease increases manifold.
- It is difficult to be tackled, unless the society and medical fraternity act together, to prevent the spread of the disease.

CANCER

- It is one of the most dreaded diseases of human beings.
- It is a major cause of death all over the world.
- The development of cancer, its transformation, treatment and control have been some of the most intense areas of research in biology and medicine.
- Normal cells show a property called contact inhibition by virtue of which contact with other cells inhibits their uncontrolled growth.
- Cancer cells lose this property and continue to divide giving rise to mass of cells called tumors.
- Tumors are of two types namely, a) Benign and b) Malignant.
- Benign tumors remain in their original position and do not spread to other parts of the body causing little damage.
- Malignant tumors are a mass of proliferating cells called neoplastic or tumor cells which grow rapidly, invading and damaging the surrounding normal tissues.
- These cells starve the normal cells by competing for vital nutrients.
- These cells reach distant sites through blood and get lodged in the body starting a new tumor. This property is called metastasis.
- This property is the most feared property of malignant tumors.

Causes of Cancer

- Normal cells can be transformed into cancerous cells induced by physical, chemical or biological agents which are called carcinogens.
- Ionizing radiations such as X-rays and gamma rays and non-ionizing radiations such as UV rays cause DNA damage.
- The chemical carcinogens in tobacco smoke are the major cause of lung cancer.
- The viruses causing cancer is called oncogenic viruses which have genes called viral oncogenes.
- Several genes called cellular oncogenes (*c-onc*) or proto oncogenes in normal cells under certain conditions gets activated leading to cancer.

Detection and Diagnosis of Cancer

- It is based on biopsy and histopathological studies of the tissue, blood and bone marrow tests for increased cell counts as in the case of leukemias.
- In biopsy, a piece of the suspected tissue cut into thin part is stained and examined under microscope by a pathologist.
- Techniques such as CT [Computed Tomography], radiography and MRI [Magnetic Resonance Imaging] are useful in detecting cancer in internal organs.
- CT uses X-rays to produce 3-D image of the internal organs, MRI uses strong magnetic fields and non-ionising radiations to detect the changes in tissues.
- Antibodies against cancer-specific antigens are also used for detecting cancers.
- Molecular biology helps to detect genes in individuals with inherited susceptibility to certain cancers. Such individuals are advised to avoid exposure to particular carcinogens to which they are susceptible. Eg – tobacco smoke in case of lung cancer.

Treatment of Cancer

- The common approaches are surgery, radiation therapy and immunotherapy.
- In radiation therapy, the tumor cells are irradiated lethally, taking care of the normal tissues.
- Chemotherapeutic drugs are used to kill cancerous cells.
- Majority of the drugs has side effects like hair loss, anemia etc.
- Some cancers are treated by combination of surgery, radiotherapy and chemotherapy.
- Tumor cells avoid detection and destruction by immune system and therefore the patients are given substances called biological response modifiers such as α-interferon which activates their immune system and destroys the tumor.

DRUG ABUSE

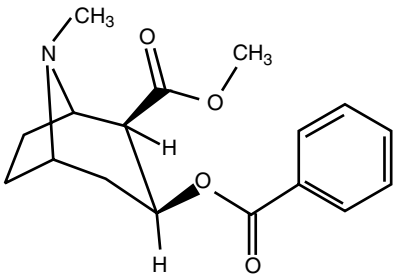
- The surveys and statistics show that the use of drugs has been increased among youths.
- Proper education and guidance would enable youth to safeguard themselves against the drug abuse by following healthy life styles.
- The drugs commonly abused are opioids, cannabinoids and coca alkaloids.
- These drugs are obtained from flowering plants and fungi.

Opioids

- These drugs bind specific opioids receptors in the central nervous system and gastrointestinal tract. Examples : morphine and heroin.

(a) Morphine

- It is obtained from the latex of poppy plant [*Papaver somniferum*].
- It is sedative and pain killer.
- It is used to reduce pain after surgery.



Chemical structure of Morphine

Opium Poppy plant

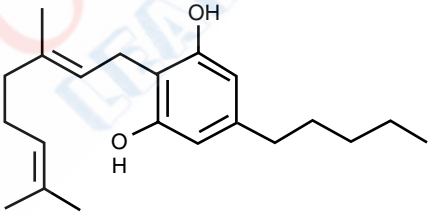
(b) Heroin

- It is commonly called smack and chemically diacetylmorphine.
- It is bitter, white, odourless and crystalline compound obtained by acetylation of morphine which is extracted from the latex of poppy plant.
- It is generally taken by snorting and injection.
- It is a depressant and slows down the body functions.

Cannabinoids

- These are a group of chemicals which interact with cannabinoids receptors present mainly in the brain.
- Natural cannabinoids are obtained from the inflorescences of *Cannabis sativa*.
- Marijuana, hashish, ganja and charas are produced by the tops, leaves and resins of *Cannabis* plant.
- These are taken by inhalation and oral ingestion.
- These affect cardiovascular system of the body.

Flowering branch of *Datura*



Skeletal structure of cannabinoid molecule

Leaves of *Cannabis sativa*

Coca Alkaloid or Cocaine

- It is obtained from *Erythroxylon coca* found in South America.
- It interferes with the transport of the neuro-transmitter dopamine.
- It is commonly called coke or crack.
- It is generally taken by snorting.
- It has a potential stimulating action on central nervous system producing a sense of euphoria and increased energy.
- Excessive dosage of cocaine causes hallucinations.
- These are abused by sportspersons.
- The plants having hallucinogenic properties are *Atropa belladonna* and *Datura*.

- Drugs like barbiturates, amphetamines, benzodiazepines, lysergic acid diethyl amides [LSD] are used medicines to help patients cope with mental illness like depression and insomnia are abused.
- When these are taken for a purpose other than medicinal use or in high amounts impair one's physical, physiological or psychological functions, it constitutes drug abuse.
- Smoking paves the way to hard drugs.

Tobacco

- Tobacco used for more than 400 years is smoked, chewed or used as a snuff.
- It contains a large number of chemical substances including nicotine, an alkaloid.
- Nicotine stimulates adrenal gland to release adrenaline and nor-adrenaline into blood circulation, both of which raise blood pressure and increase heart rate.
- Smoking increases cancer in lungs, urinary bladder and throat, bronchitis, emphysema, coronary heart diseases, gastric ulcer etc.
- Tobacco chewing increases the risk of cancer of the oral cavity.
- Smoking increases CO content in blood and reduces the concentration of haem-bound oxygen. This causes oxygen deficiency in the body.
- Smoking is prevalent in society, both among young and old. Knowing the dangers of smoking and chewing tobacco and its addictive nature, the youth and old need to avoid these habits.
- Any addict requires counselling and medical help to get rid of the habit.

ADOLESCENCE and DRUG/ALCOHOL ABUSE

- Adolescence means both 'a period' and 'a process' during which a child becomes mature in terms of his/her attitudes and beliefs for effective participation in society.
- The period between 12 – 18 years of age is said to be adolescence period.
- The term adolescence is a bridge linking childhood and adulthood.
- It is accompanied by biological and behavioural changes.
- Thus adolescence is a vulnerable phase of mental and psychological development of an individual.
- Curiosity, excitement, experimentation and the adventure motivate youngsters towards drug and alcohol.
- Later the youngster starts using to escape facing problems, stress, pressure to excel in academics etc.
- The perception among youth that it is 'cool' to smoke or use drugs or alcohol is also one of the major causes for youth to start this habit.
- Television, movies, newspapers and internet helps to promote this perception.
- Other factors includes unsupportive family structures and peer pressure.

Addiction

- Addiction is a psychological attachment to certain effects such as euphoria and a temporary felling of well-being associated with drugs and alcohol.
- It makes people to use it even when not required.
- With repeated use of drugs, the tolerance level of the receptors increases and the receptors respond to higher doses of drugs or alcohols leading to greater intake addiction.
- Thus the addictive potential of drugs and alcohol pull the user leading to regular use from which the person may be unable to get out.
- In absence of guidance and counselling the person gets addicted and becomes dependent on them.

Dependence

- It is the tendency of the body to manifest a characteristic and unpleasant withdrawal syndrome if regular dose of drugs or alcohol is abruptly discontinued.
- It is characterized by anxiety, shakiness, nausea and sweating which may be relieved when use is resumed again.
- Sometimes withdrawal symptoms becomes severe and even life threatening, the person need medical supervision.
- Dependence leads the patient to ignore all social norms in order to get sufficient funds to satisfy his or her needs.
- It results in many social adjustment problems.

Effects of Drug/Alcohol Abuse

- The immediate adverse effects of drug and alcohol abuse leads to reckless behaviour, vandalism and violence.
- Excessive doses of drug leads to coma and death due to respiratory failure, heart failure or cerebral haemorrhage.
- A combination of drugs and alcohol result in overdosing and even death.
- The most common warning signs of drugs and alcohol abuse among youth are drop in academic performance, absence of school/college, lack of interest in personal hygiene, withdrawal, isolation, depression, fatigue, aggressiveness, rebellious behaviour, deteriorating relationships with family and friends, loss of interest in hobbies, change in sleeping and eating habits, fluctuations in weight, appetite etc.
- The persons affected, in absence of money, steal to buy drugs or alcohol.
- Sometimes, a drug/alcohol addict becomes the cause of mental and financial distress to his/her entire family and friends.

- Those who take drugs intravenously i.e., by directly injecting into the vein using a needle or syringe acquire serious infections like AIDS and Hepatitis B.
- Both AIDS and Hepatitis B are chronic infections and leads to death.
- AIDS can be transmitted to one's life partner through sexual contact while Hepatitis B is transmitted through infected blood.
- The uses of alcohol during adolescence have long term effects such as leading to heavy drinking in adulthood.
- The chronic use of drugs and alcohol damages nervous system and liver (cirrhosis).
- The use of drugs and alcohol during pregnancy affect the foetus.
- The narcotic analgesic drugs and steroids are misused by sportsperson to improve the performance, increase muscle strength, to promote aggressiveness and increase athletic performance.
- The side-effects of the use of anabolic steroids in females include masculinisation, increased aggressiveness, mood swings, depression, abnormal menstrual cycle, excessive hair growth on the face and body, enlargement of clitoris and deepening of voice.
- In males it includes acne, increased aggressiveness, mood swings, depression, reduction of size of testicles, decreased sperm production, potential for kidney and liver dysfunction, breast enlargement, premature baldness, enlargement of prostrate gland.
- In adolescent males and females, severe facial and body acne and premature closure of growth centres of the long bones may result in stunted growth.

Prevention and Control of Drug/Alcohol Abuse

- The habits such as smoking, taking drug or alcohol are more likely to be taken up at a young age, more during adolescence. So, parents and the teachers have a special responsibility.
- Parenting with high levels of nurturance and consistent discipline reduces the risk of drug/alcohol abuse.
- Some of the measures useful for prevention and control of alcohol and drug abuse are as follows: -

1. **Avoid undue peer pressure**
   Every child should be respected for her/his personality and choice. He/she should not be pushed to perform beyond his/her threshold limits in studies, sport and other activities.
2. **Education and counseling**
   Education and counseling helps him/her to face problems and stress and to accept disappointments and failures as a part of their life. Make them involve in other extra-curricular activities.
3. **Seeking help from parents and peers**
   Parents and peers should help them immediately to give proper guidance and solution to sort out the problems to escape from anxiety and guilty.
4. **Looking for danger signs**
   Teachers and friends should not hesitate to bring the habit to the notice of parents and the parents should take appropriate measures to diagnose the underlying cause to initiate proper remedial steps or treatment.
5. **Seeking professional and medical help**
   Highly qualified psychiatrist, psychologists conduct de-addiction and rehabilitation programmes to help individuals to overcome from drug/alcohol abuse and lead a normal and healthy life.

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Chapter 31

Strategies for Enhancement in Food Production

TOPIC-1

Animal Husbandry

Revision Notes

Animal Husbandry

- Biological principles such as animal husbandry and plant breeding have a major role in increasing the food production.
- Animal husbandry is the agricultural practice of breeding and raising livestock.
- It deals with the care & breeding of livestock such as buffaloes, cows, pigs, horses, cattle, sheep, camels, goats, bees, silkworms, etc, and also poultry farming and fisheries.
- Fisheries include rearing, catching, selling, etc., of fish, molluscs like shell-fish and crustaceans like prawns, crabs, etc.
- Animals like bees, silk-worm, prawns, crabs, fishes, birds, pigs, cattle, sheep and camels have been used by humans for products like milk, eggs, meat, wool, silk, honey, etc.
- More than 70% of the world livestock population is in India and China.
- The contribution of farm produce to the world is only 25%, i.e., the productivity per unit is very low.
- Hence new technologies have to be applied to achieve improvement in quality and productivity.

Management of Farms and Farm Animals

- Management of farm and farm animals include traditional practices, procedures employed in various animal farm systems.

1. Dairy Farm Management (Dairying)

- Dairying is the management of animals for milk and its products for human consumption.
- It deals with the processes and systems that increase yield and improve quality of milk.
- The yield of milk depends on the quality of breeds in the farm.
- Good breeds having high yielding potential and resistance to diseases are selected.
- For the yield potential:
  - **(a)** The cattle have to be looked after well.
  - **(b)** They have to be housed well.
  - **(c)** They should have adequate water.
  - **(d)** They should be maintained disease free.
  - **(e)** The feeding of cattle should be carried out in a scientific manner and with special emphasis on the quality and quantity of fodder.

(f) Stringent cleanliness and hygiene (of cattle and handlers) while milking, storage and transport of the milk.

- However, these processes have been mechanised and so it has reduced the chance of direct contact of the produce with the handler.
- To ensure these stringent measures there should be

(a) Regular inspections, with proper record keeping. It also helps to identify and rectify the problems.

(b) Regular visits by a veterinary doctor.

2. Poultry Farm Management

- Poultry is the class of domesticated birds used for food or for their eggs.
- It includes chicken, ducks, turkey and geese.

Components of Poultry Farm Management

(a) Selection of disease free and suitable breeds.

(b) Proper and safe farm conditions.

(c) Proper feed and water.

(d) Hygiene and health care.

Animal Breeding

- A group of animals related by descent and similar in most characters like general appearance, features, size, configuration, etc., are said to belong to a breed.
- Breeding is the modification of genotype of an organism to make that organism more useful to humans.
- Animal breeding aims at increasing the yield of animals and improving the desirable qualities of the produce.

Types of Breeding

- There are two types of breeding namely,

(a) Inbreeding

- It is the process of mating more closely related individuals within the same breed for 4-6 generations.

Process :

- Superior males and superior females of the same breed are identified and mated in pairs.
- The progeny obtained are evaluated and superior males and females among them are identified for further mating.
- In cattle, a superior female produces more milk per lactation whereas a superior male (bull) gives rise to superior progeny.

Advantages of Inbreeding

(a) It increases homozygosity to evolve a pureline animal.

(b) It exposes harmful recessive genes that are eliminated by selection.

(c) It helps in accumulation of superior genes and elimination of less desirable genes. This approach increases the productivity of inbred population.

Disadvantage of Inbreeding

- Continued inbreeding, especially close inbreeding, may reduce fertility and productivity. This is called inbreeding depression.
- To solve this problem, selected animals of the breeding population should be mated with unrelated superior animals of the same breed which helps to restore fertility and yield.

(b) Out-breeding

- It is the breeding of the unrelated animals which may be between individuals of the same breed (but having no common ancestors), or between different breeds (cross-breeding) or different species (inter-specific hybridisation).
- It includes outcrossing, cross-breeding and inter-specific hybridization.

Out-crossing

- It is the practice of mating of animals within the same breed having no common ancestors on either side of their pedigree up to 4-6 generations.
- The offspring formed is known as an out-cross.
- It is the best breeding method for animals having low productivity in milk production, growth rate in beef cattle, etc.
- It helps to overcome inbreeding depression.

Cross-breeding

- In this method, superior males of one breed are mated with superior females of another breed.
- It allows the desirable qualities of two different breeds to combine to form the progeny hybrid animals that may be used for commercial production or may be subjected to inbreeding and selection to develop new stable superior breeds.
- Eg. Hisardale (sheep) developed in Punjab by crossing Bikaneri ewes and Marino rams.

Interspecific hybridization

- It is the mating of male and female animals of two different species.
- The progeny formed may combine desirable features of both the parents, and may be of considerable economic value.
- Eg. Mule (male ass X female horse).

Controlled Breeding Experiments

- It includes,

(a) Artificial insemination

- The controlled breeding experiments are carried out using artificial insemination.
- In this process, the semen collected from male parent is injected into the reproductive tract of selected female by the breeder.
- The semen may be used immediately or can be frozen and used later.
- It can also be transported in a frozen form to where the female is housed to obtain desirable hybrid.
- Success rate of crossing mature male and female animals is low even though artificial insemination is carried out.

(b) Multiple Ovulation Embryo Transfer Technology (MOET)

- It is a programme for herd improvement i.e., to improve the chances of successful production of hybrids.
- In this process, a cow is administered with hormones like FSH to induce follicular maturation and super ovulation to produce 6-8 eggs per cycle instead of one egg.
- The animal is either mated with an elite bull or artificially inseminated.
- Then the fertilised eggs at 8–32 cells stages are recovered and transferred to surrogate mothers.
- This technology has been demonstrated for cattle, sheep, rabbits, buffaloes, mares, etc.
- High milk yielding breeds of females and high quality (lean meat with less lipid) meat-yielding bulls have been bred successfully to increase herd size in a short time.

Bee-keeping (Apiculture)

- It is the practice of maintenance of hives of honeybees for the production of honey and beeswax.
- Honey is a food of high nutritive and medicinal value.
- Honeybee produces beeswax which is used in the preparation of cosmetics, polishes etc.
- The increased demand of honey has led to large-scale beekeeping practices as income generating industry.
- Bee-keeping can be practiced in an area where there are sufficient bee pastures of some wild shrubs, fruit orchards and cultivated crops.
- Most common species that can be reared is *Apis indica*.

Important Features for Successful Bee-keeping

- Bee-keeping though relatively easy does require some specialized knowledge as follows:

(i) Knowledge of the nature and habits of bees.
(ii) Selection of suitable location for keeping beehives.
(iii) Catching and hiving of swarms (group of bees).
(iv) Management of beehives during different seasons
(v) Handling and collection of honey and of beeswax.

- Bees are the pollinators of many of our crop species such as sunflower, *Brassica*, apple and pear.
- Keeping beehives in crop fields during flowering period increases pollination which thereby improves crop and honey yield.

Fisheries

- It deals with catching, processing or selling of fish, shellfish or other aquatic animals (prawn, crab, lobster, edible oyster etc).
- The development and flourishing of the fishery industry is known as blue revolution.
- It includes,

(a) Freshwater fishes: *Catla, Rohu*, common carp, etc.
(b) Marine fishes : *Hilsa*, Sardines, Mackerel, Pomfrets, etc.

- Fisheries provide income and employment to fishermen and farmers.
- Techniques to Increase the Production of Aquatic Plants and Animals

There are two main techniques namely :

(a) Aquaculture
(b) Pisciculture

The culturing of all aquatic organisms in fresh water, brackish and marine environment is called aquaculture. Pisciculture is growing of only fishes and related food animals in water bodies.

TOPIC-2

Plant Breeding, Single Cell Protein and Tissue Culture

Revision Notes

- Plant breading is the method where manipulation of plant species helps to create desired plant types that are better suited for cultivation, give better yields and are disease resistant.
- Plant breeding as a technology has helped to increase yield in food production resulting in green revolution.

Green Revolution

- The development and flourishing of the agriculture is known as green revolution.
- Green revolution was dependent to a large extent on plant breeding techniques for development of high-yielding and disease resistant varieties in wheat, rice, maize, etc.

Types of Plant Breeding

- There are two main methods of plant breeding namely,
  (a) Conventional plant breeding
  (b) Classical plant breeding
- Conventional plant breeding has been practiced for thousands of years, since the beginning of human civilization.
- Classical plant breeding involves hybridization of pure lines followed by artificial selection to produce desirable traits of higher yield, nutrition and resistance to diseases.
- Nowadays, plant breeding is carried out by using molecular genetic tools.

Desirable Traits Breeders Need to Incorporate

- The following are the traits or characters that the breeders have tried to incorporate into crop plants:
  (a) Increased crop yield.
  (b) Improved quality.
  (c) Increased tolerance to environmental stresses (salinity, extreme temperatures and drought), resistance to pathogens.
  (d) Increased tolerance to insect pests.

Steps in Breeding

(i) Collection of Variability

- Genetic variability is the root of any breeding programme.
- The pre-existing genetic variability is available from wild relatives of many crops.
- The collection and preservation of all different wild varieties, species and relatives of the cultivated species is a pre-requisite for effective exploitation of natural genes.
- The entire collection of plants or seeds having all the alleles for all genes in a given crop is called germplasm collection.

(ii) Evaluation and selection of parents

- The germplasm is evaluated to identify plants with desirable combination of characters.
- Selected plants are multiplied and used for hybridization.
- Pure lines are created wherever desirable and possible.

(iii) Cross hybridisation among the selected parents

- The desired characters are combined from two different plants (parents) to produce hybrids having the combined desired characters in a single plant.
- Eg – High protein quality of one parent is combined with disease resistance from another parent, on cross hybridizing produces hybrids that genetically combine the desired characters in one plant.

Limitations of Cross Hybridisation

(a) This is a very time-consuming and tedious process
Since the pollen grains from the desirable male plant have to be collected and placed on the stigma of the flowers selected as female parent.

(b) The hybrids may not combine the desirable characters
Usually only one in few hundred to a thousand crosses shows the desirable combination.

(iv) Selection and Testing of Superior Recombinants

- It includes the process of selecting among the progeny of the hybrids of those plants that have the desired character combination.
- The selection process is crucial to the success of the breeding objective and requires careful scientific evaluation of the progeny.
- It yields plants that are superior to both of the parents.
- These are self-pollinated for several generations till they reach a state of uniformity (homozygosity), so that the characters will not segregate in the progeny.

(v) Testing, release and commercialization

- The newly selected lines are evaluated for their yield and agronomic traits of quality, disease resistance, etc., by growing them in the research fields and recording their performance under ideal fertilizer application, irrigation and other crop management practices.
- The materials are then tested in farmers' fields for at least three growing seasons at several locations in the country, representing all the agroclimatic zones.
- The material is then evaluated in comparison to the best available local crop cultivar a check or reference cultivar.

Indian Hybrid Crops

Wheat and Rice

- During the period 1960-2000, wheat and rice production increased due to the development of semi-dwarf varieties of wheat and rice.
- Nobel laureate Norman E. Borlaug, at International Centre for Wheat and Maize Improvement in Mexico, developed semi-dwarf wheat.
- Later, high yielding and disease resistant varieties such as *Sonalika* and *Kalyan Sona* were introduced all over the wheat-growing belt of India.
- Semi-dwarf rice varieties were derived from IR-8, (developed at International Rice Research Institute (IRRI), Philippines) and Taichung Native-1 (from Taiwan).
- Better-yielding semi dwarf varieties *Jaya* and *Ratna* were also developed in India.

Sugarcane

- *Saccharum barberi*, grown in North India having poor sugar content and yield was crossed with *Saccharum officinarum*, grown in South India having thicker stems and higher sugar content, but do not grow in North India to get a hybrid sugar cane having desirable qualities like high yield, thick stems, high sugar and ability to grow in north India.

Millets

- Hybrid maize, jowar and bajra were also developed in India.
- It includes high yielding varieties resistant to water stress.

Plant Breeding for Disease Resistance

- A wide range of fungal, bacterial and viral pathogens, affect the yield of cultivated crop species.
- Hence, breeding and development of cultivars resistant to disease helps to
  - **(a)** Enhance the food production
  - **(b)** Reduce the use of fungicides and bacteriocides
- Resistance of the host plant is the genetic ability to prevent the pathogens from causing disease.
- For this, before breeding, the causative organism and the mode of transmission is to be known.

Plant Diseases

- Some plant diseases are as follows:
  - **(a)** Fungi : Rusts (E.g., brown rust of wheat) red rot of sugarcane and late blight of potato.
  - **(b)** Bacteria: Black rot of crucifers.
  - **(c)** Virus : Tobacco mosaic, turnip mosaic, etc.

Methods of Breeding for Disease Resistance

- It includes two types :

(a) Conventional Method of breeding

- The steps are:
  - **(a)** Screening germplasm for resistance sources.
  - **(b)** Hybridization of selected parents.
  - **(c)** Selection and evaluation of the hybrids.
  - **(d)** Testing and release of new varieties.

The following tabular column shows the crop varieties bred by conventional method :

Crop	Variety	Resistance to diseases
Wheat	Himgiri	Leaf and stripe rust, hill bunt
Brassica	Pusa swarnim (Karan rai)	White rust
Cauliflower	Pusa Shubhra, Pusa Snowball K–1	Black rot and curl Blight black rot
Cowpea	Pusa Komal	Bacterial blight
Chilli	Pusa Sadabahar	Chilly mosaic virus, Tobacco mosaic virus, and leaf curl

- Conventional breeding is constrained by the availability of limited number of disease resistance genes in the crop varieties.
- Inducing mutations in plants and then screening the plant materials for resistance help to identify the desirable genes.
- Plants having these desirable characters can then be either multiplied directly or can be used in breeding.

(a) Mutation Breeding

- Mutation is the process by which genetic variations are created through changes in the base sequence within genes resulting in the creation of a new character or trait not found in the parental type.
- Mutation is induced by using chemicals or radiations (like gamma radiations) and selecting the plants that have desirable character as a source in breeding.
- Eg – In mung bean, the resistance to yellow mosaic virus and powdery mildew were induced by mutations.
- Since wild relatives of different cultivated species show certain resistant characters with low yield, hence resistant genes from wild species are introduced into the high-yielding cultivated varieties.
- Eg. Resistance to yellow mosaic virus in bhindi (*Abelmoschus esculentus*) was transferred from a wild species and resulted in a new variety called *Parbhani kranti*.
- Transfer of resistance genes is achieved by sexual hybridization between the target and the source plant.

Plant Breeding for Developing Resistance to Insect Pests

- Insect resistance in host crop plants may be due to morphological, biochemical or physiological characteristics.
  (a) Hairy leaves: e.g., resistance to jassids in cotton and cereal leaf beetle in wheat.
  (b) Solid stems in wheat: lead to non-preference by the stem sawfly.
  (c) Smooth leaved and Nectar-less cotton varieties do not attract bollworms.
  (d) High aspartic acid, low nitrogen and sugar content in maize leads to resistance to maize stem borers.
- Sources of resistance genes for breeding are cultivated varieties, germplasm collections of crop or wild relatives.
- The tabular column below shows some crop varieties bred for insect pest resistance :

Crop	Variety	Inspect pests
Brassica (rapeseed mustard)	Pusa Gaurav	Aphids
Flat bean	Pusa Sem 2, Pusa Sem 3	Jassids, aphids & fruit borer.
Okra (Bhindi)	Pusa Sawani, Pusa A–4	Shoot and Fruit borer

Plant Breeding for Improved Food Quality

- Those people who suffer from micronutrient, protein and vitamin deficiencies are called 'hidden hunger' because they cannot afford to buy enough fruits, vegetables, legumes, fish and meat.

Biofortification

- It refers to breeding crops with higher levels of nutrients that help to improve public health.

Objectives of breeding for improved nutritional quality:

(a) To improve protein content and quality.
(b) To improve oil content and quality.
(c) To improve vitamin content.
(d) To improve micronutrient and mineral content.

Examples for hybrids with improved nutritional quality

- Maize hybrids having twice the amount of amino acids, lysine and tryptophan compared to existing maize hybrids.
- Wheat variety, Atlas 66, having high protein content.
- Iron-fortified rice variety containing over five times as much iron as in common varieties.
- Vegetable crops rich in vitamins and minerals are also released by Indian Agricultural Research Institute, New Delhi.
- Eg. – vitamin A enriched carrots, spinach, pumpkin; vitamin C enriched bitter gourd, bathua, mustard, tomato; iron & calcium enriched spinach & bathua; and protein enriched beans (broad, lablab, French and garden peas).

SINGLE CELL PROTEIN (SCP)

- It is an alternate source of proteins for animal and human nutrition.
- Eg., microbes like *Spirulina*.
- *Spirulina* is rich in protein, minerals, fats, carbohydrate and vitamins.
- It is grown on materials like waste water from potato processing plants, straw, molasses, animal manure and sewage. This also reduces environmental pollution.
- A 250 Kg cow produces 200 g of protein/day. In the same period, 250g of a micro-organism like *Methylophilus methylotrophus* produce 25 tonnes of protein.

TISSUE CULTURE

- It is a technique of growing plant cells/tissues/organs in sterile culture medium under controlled aseptic conditions.
- The ability to generate a whole plant from any cell/explant is called totipotency.
- An explant is any part of a plant that is grown in a test tube under sterile nutrient media.
- The nutrient medium must provide a carbon source (such as sucrose), inorganic salts, vitamins, amino acids and growth regulators like auxins, cytokinins etc.
- The method of producing thousands of plants in very short time through tissue culture is called micropropagation.
- These plants will be genetically identical to original plant, from which they were grown, i.e., they are somaclones.
- Tomato, banana, apple etc. are produced using this method.
- Tissue culture is also used for recovering healthy plants from diseased plants.
- The meristem which is free of virus from infected plant is removed and grown *in vitro* to obtain virus-free plants.
- Scientists have cultured meristems of banana, sugarcane, potato, etc.

Somatic Hybridisation

- Protoplasts from two different varieties of plants (with desirable characters) are fused to get hybrid protoplasts.
- It can be grown to form a new plant called somatic hybrids. This process is called somatic hybridization.
- Protoplasts can be isolated after digesting the cell walls of single cells of plants.
- A protoplast of tomato has been fused with that of potato, to form new hybrid plants with the characteristics of tomato and potato.
- But it did not have all the desired characteristics for its commercial utilization.

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Chapter 32

Microbes in Human Welfare

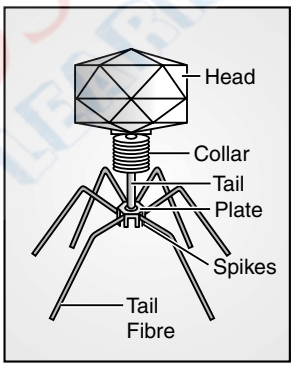
TOPIC-1

Microbes in Household and Industrial Products, In Sewage Treatment and Production of Biogas

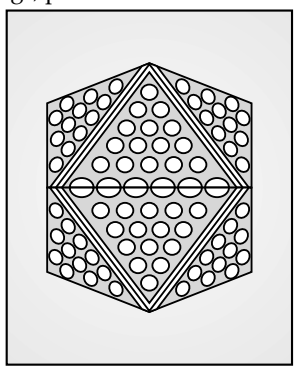
Revision Notes

Introduction

- Microbes are the major components of biological systems on this earth.
- Microbes are present everywhere such as in soil, water, air, inside our bodies and that of other animals and plants.
- They are also found at sites such as deep inside the geysers (thermal vents) where the temperature may be as high as 1000C, deep in the soil, under the layers of snow several metres thick, and in highly acidic environments.
- Microbes are diverse protozoa, bacteria, fungi and microscopic plants viruses, viroid and prions that are proteinaceous infectious agents.
- Microbes like bacteria and many fungi can be grown on nutritive media to form colonies that can be seen with the naked eyes.
- Microbes cause a large number of diseases in human beings, plants and animals.



A Bacteriophage


Adenovirus

Microbes in Household Products

(a) *Lactobacillus* or Lactic Acid Bacteria (LAB)

- Micro-organisms such as *Lactobacillus* called lactic acid bacteria (LAB) grow in milk and convert it to curd.
- LAB produces acid that coagulate and partially digest the milk proteins.
- A small amount of curd added to the fresh milk as inoculum or starter at suitable temperature convert milk to curd.
- This improves the nutritional quality of curd by increasing vitamin B_{12}.
- In stomach, LAB plays a beneficial role by checking pathogens.

(b) Bacterial Fermentation

- It is an anaerobic respiration taking place in dough to make foods such as dosa, idli, etc.
- The puffed up appearance of dough is due to the production of carbon dioxide gas.

(c) Baker's Yeast (*Saccharomyces cerevisiae*)

- It is used to make bread by fermenting dough.

(d) Microbes in Cheese

- Microbes are used to produce cheeses differing in flavour, taste and texture.
- Eg 1 - Large holes in 'Swiss cheese' are due to production of carbon dioxide by *Propionibacterium sharmanii* (a bacterium).
- Eg 2 - 'Roquefort cheese' is ripened by growing a specific fungus on them that gives them a particular flavour.

(e) Other Uses of Microbes

- Toddy is made by fermenting sap from palms.
- Microbes are used to ferment fish, soya bean and bamboo-shoots to make foods.

Microbes in Industrial Products

- Microbes are used to synthesize a number of products such as beverages, antibiotics etc., to human beings.
- Production of beverages, antibiotics etc., on an industrial scale require growing microbes in very large vessels called fermentors.

(a) Fermented Beverages

- *Saccharomyces cerevisiae* (Brewer's yeast) is used in the production of beverages by fermenting malted cereals and fruit juices to produce ethanol.
- Wine and Beer are produced without distillation.
- Whisky, brandy and rum are produced by distillation of fermented broth.

(b) Antibiotics

- Anti is a Greek word that means 'against', and bio means 'life', together they mean 'against life' with respect to disease causing organisms whereas with reference to human beings, they are 'pro life' and not against.
- These are the chemical substances produced by microbes that can kill or retard the growth of other disease-causing microbes.
- They are used to treat plague, whooping cough, diphtheria, leprosy, etc.

(i) Antibiotic Penicillin :

- First antibiotic discovered by Alexander Fleming.
- He observed that a mould (*Penicillium notatum*) growing in unwashed culture plates around which *Staphylococci* could not grow. He extracted penicillin from it.
- Later, Earnest Chain and Howard Florey established its full potential as an effective antibiotic.
- This antibiotic was used to treat American soldiers wounded in World War II.
- Fleming, Chain and Florey were awarded Nobel Prize (1945) for this discovery.

(c) Chemicals, Enzymes and Other Bioactive Molecules

1. Production of organic acids :

(i) *Aspergillus niger* (a fungus) : Citric acid
(ii) *Acetobacter aceti* (a bacterium) : Acetic acid
(iii) *Clostridium butylicum* (a bacterium) : Butyric acid
(iv) *Lactobacillus* (a bacterium) : Lactic acid

2. Alcohol :

(i) *Saccharomyces cerevisiae* (yeast): Used to produce ethanol.

3. Enzymes :

(a) Lipases :

(i) Used in detergent formulations.
(ii) Help to remove oily stains from the laundry.

(b) Pectinases & Proteases :

(i) To clarify bottled juices.

(c) Streptokinase :

(i) *Streptococcus* : Used as a 'clot buster' to remove clots from the blood vessels of patients who have myocardial infarction.

4. Cyclosporine A :

(i) *Trichoderma polysporum* (fungus) : Used as an immunosuppressive agent in organ transplant patients.

5. Statins :

(i) ***Monascus purpureus*** **(yeast) :**

(a) Used as blood-cholesterol lowering agents.

(b) It inhibits the enzymes responsible for synthesis of cholesterol.

Microbes in Sewage Treatment

- A major component of the waste water is human excreta. This municipal waste-water is also called sewage.
- It contains large amounts of organic matter and microbes.
- This cannot be discharged into natural water bodies like rivers and streams directly.
- Hence, sewage is treated in sewage treatment plants (STPs) to make it less polluting.
- Treatment of waste water is done by the heterotrophic microbes naturally present in the sewage.
- This treatment is carried out in two stages namely,
  (a) Primary treatment
  (b) Secondary treatment

Primary Treatment

- It involves the physical removal of small and large particles from the sewage through sedimentation and filtration.
- It includes
  (a) Removal of floating debris by sequential filtration.
  (b) Removal of the grit (soil and pebbles) by sedimentation.
- All solids that settle form the primary sludge and the supernatant form the primary effluent.

Secondary Treatment or Biological Treatment

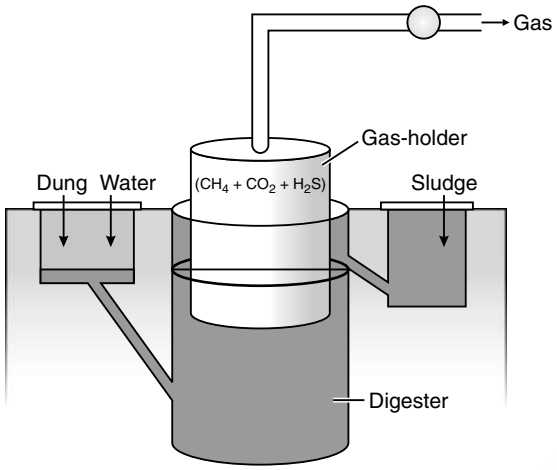
- Primary effluent is passed into large aeration tanks and constantly agitated for allowing vigorous growth of useful aerobic microbes into flocs.
- Flocs refer to masses of bacteria associated with fungal filaments to form mesh-like structures.
- These microbes consume the major part of the organic matter in the effluent.
- This reduces the BOD (Biochemical Oxygen Demand) of the effluent.
- BOD refers to the amount of the oxygen that would be consumed if all the organic matter in one liter of water were oxidised by bacteria.
- The sewage water is treated till the BOD is reduced.
- The BOD test measures the rate of uptake of oxygen by micro-organisms in a sample of water.
- Indirectly, BOD is a measure of the organic matter present in the water.
- Greater the BOD of waste water, more is its polluting potential.
- The effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment.
- This sediment is called 'activated sludge'.
- A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum.
- The remaining major part of the sludge is pumped into large tanks called anaerobic sludge digesters. Here, some anaerobic bacteria digest the bacteria and fungi in the sludge by producing gases like methane, hydrogen sulphide and carbon dioxide.
- These gases form the biogas.
- The effluent from secondary treatment plant is then released into natural water bodies like rivers and streams.
- The Ministry of Environment & Forests has initiated Ganga Action Plan and Yamuna Action Plan to save these major rivers from water pollution.

Microbes in the Production of Biogas

- Biogas is a mixture of gases, containing predominantly methane produced by the microbial activity.
- Biogas is used for cooking and lighting.
- Microbes produce different types of gaseous end-products during growth and metabolism.
- The type of the gas produced depends upon the microbes and the organic substrates they use.
- In fermentation of dough, cheese making and production of beverages, the main gas produced was carbon dioxide.
- Certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with carbon dioxide and hydrogen sulphide are collectively called methanogens. Eg - *Methanobacterium*.
- *Methanobacterium* is found in the anaerobic sludge and in the rumen of cattle (for cellulose digestion).
- The dung of cattle called gobar is rich in these bacteria.
- Dung can be used for generation of biogas called gobar gas.

The Biogas Plant

- It consists of four parts namely,
  (a) A concrete tank (digester)
  (b) A floating cover
  (c) Two outlets
  (d) Gas holder



A Biogas Plant

- A concrete tank (10-15 feet deep) is used to collect bio-wastes and slurry of dung.
- A floating cover is placed over the slurry, which keeps on rising as the biogas is produced.
- An outlet connected to a pipe to supply biogas.
- Another outlet to remove spent slurry that can be used as fertilizer.
- The technology of biogas production in India was developed by Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC).

TOPIC-2

Microbes As Biocontrol Agents And As Biofertilizers

Revision Notes

Microbes as Biocontrol Agents

- Biocontrol refers to the use of biological methods for controlling plant diseases and pests.
- Chemical pesticides and insecticides are harmful to all organisms and causes pollution.
- Chemical pesticide kills both useful and harmful life forms.
- The use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides. An important part of the biological farming is to become familiar with the various life forms that inhabit the field, predators as well as pests, and also their life cycles, patterns of feeding and the habitats that they prefer.
- These help to develop appropriate biocontrol.
- Eg - The very familiar beetle with red and black markings – the Ladybird and Dragonflies are useful to get rid of aphids and mosquitoes respectively.

Microbial Biocontrol Agents

(a) Biocontrol agents in controlling butterfly caterpillars
- The microbial biocontrol agent is the bacteria *Bacillus thuringiensis* (Bt).
- These are available in sachets as dried spores which are mixed with water and sprayed on to vulnerable plants such as brassicas and fruit trees, where these are eaten by the insect larvae.
- In the gut of the larvae, the toxin is released and the larvae get killed.
- The bacterial disease will kill the caterpillars, but leave other insects unharmed.
- By the development of genetic engineering, the scientists have introduced *B. thuringiensis* toxin genes into plants.
- Eg. Bt cotton.

(b) *Trichoderma* species as biocontrol agents in the treatment of plant disease
- The microbial agent is the fungus *Trichoderma sp*.
- These are free living species seen in the root ecosystems.
- They are effective biocontrol agents of several plant pathogens.

(c) Baculoviruses as biocontrol agent

- The microbial agent is the fungus *Trichoderma* sp.
- Baculoviruses belonging to genus *Nucleopolyhedrovirus* attacks insects and other arthropods.
- These viruses are suitable for species-specific, narrow spectrum insecticidal applications.
- This is desirable in IPM [Integrated Pest Management] program to conserve beneficial insects.

Microbes as Biofertilisers

- The use of the chemical fertilizers to meet the ever-increasing demand of agricultural products has contributed significantly to environmental pollution.
- There are problems associated with the overuse of chemical fertilizers, hence there was compulsion in using biofertilizers.
- Biofertilizers are organisms that enrich nutrient quality of the soil.
- The main sources of biofertilisers are bacteria, fungi, cyanobacteria etc.
- The nodules on the roots of leguminous plants formed by the symbiotic association of *Rhizobium*, a bacterium fixes atmospheric nitrogen into organic forms, which is used by the plant as nutrient.
- Other free-living bacteria such as *Azospirillum* and *Azotobacter* enrich the nitrogen content of the soil.
- Fungi also form symbiotic associations with plants, mycorrhiza belonging to the genus of *Glomus*.
- The fungus gets food from the plant whereas the fungal symbiont obtains the following :
  (a) Absorb phosphorous from soil and passes it to the plant.
  (b) Give resistance to root-borne pathogens and tolerance to salinity and draught.
  (c) Give an overall increase in plant growth and development.
- Cyanobacteria (Blue green algae) such as *Anabaena*, *Nostoc*, *Oscillatoria,* etc., are autotrophic microbes which fixes atmospheric nitrogen.
- In paddy fields, cyanobacteria serve as an important biofertilizers, add organic matter to the soil and increase its fertility.

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Chapter 33

Biotechnology: Principles & Processes

TOPIC-1

Principles of Biotechnology and Tools of Recombinant DNA Technology

Revision Notes

Introduction

- Biotechnology deals with techniques of using live organisms or their enzymes for products and processes useful to humans.
- Processes/Techniques included under Biotechnology.
  - **(a)** Microbe-mediated processes (making curd, bread, wine, etc).
  - **(b)** *In vitro* fertilisation ('test-tube' baby programme)
  - **(c)** Synthesis and using of a gene
  - **(d)** Preparation of a DNA vaccine
  - **(e)** Correcting a defective gene
- The European Federation of Biotechnology (EFB) defines biotechnology as 'the integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services'.

PRINCIPLES OF BIOTECHNOLOGY

- Modern biotechnology is based on the two core techniques namely,
  - **(a)** Genetic engineering
  - **(b)** Maintenance of sterile ambience

Genetic Engineering

- It is the technique in which the genetic material *i.e.*, DNA and RNA is chemically altered and introduced into host organisms to change the phenotype.

Maintenance of Sterile Ambience

- It is necessary in chemical engineering processes for growing only the desired microbe/eukaryotic cell in large quantities for the manufacture of antibiotics, vaccines, enzymes, etc.

Conceptual Development of the Principles of Genetic Engineering

- The advantage of sexual reproduction is that it provides opportunities for variations and formulation of unique combinations of genetic setup, some of which may be beneficial to the organism as well as the population.
- The advantage of asexual reproduction is that it preserves the genetic information.
- Traditional hybridization techniques lead to inclusion and multiplication of undesirable genes along with desired genes.
- The techniques of genetic engineering include creation of recombinant DNA, use of gene cloning and gene transfer, overcome this limitation and allow us to introduce only desirable genes into the target organism.
- A piece of DNA is not able to multiply itself in the progeny cells of the organism.
- But, when it gets integrated into the recipient genome, it multiplies and is inherited along with the host DNA.
- This is because the alien piece of DNA has become part of a chromosome, which has the ability to replicate.
- In chromosome there is a specific DNA sequence called the origin of replication, which is responsible for initiating replication. In genetic engineering the foreign DNA is linked with the origin of replication, so the foreign DNA

can replicate and multiply itself in the host organism, which is also known as cloning or making multiple identical copies of any template DNA.

Formation of First Recombinant DNA

- First recombinant DNA emerged from the possibility of linking a gene of antibiotic resistance with a native plasmid of *Salmonella typhimurium*.
- Stanley Cohen and Herbert Boyer (1972) isolated the antibiotic resistance gene by cutting out a piece of DNA from a plasmid which was responsible for conferring antibiotic resistance DNA.
- The cutting of DNA at specific locations became possible with the discovery of 'molecular scissors" called the restriction enzymes.
- The cut piece of DNA was then linked with the plasmid DNA.
- These plasmid DNA act as vectors to transfer the piece of DNA attached to it.
- The linking of antibiotic gene with the plasmid vector become possible with the enzyme ligase, which acts on cut DNA molecules and joins their ends. This makes a new combination of autonomously replicating DNA created *in vitro* and known as recombinant DNA.
- When this DNA is transferred into *Escherichia coli*, a bacterium closely related to *Salmonella*, it could replicate using the new host's DNA polymerase enzyme and make multiple copies.
- The ability to multiply copies of antibiotic resistance gene in *E. coli* was called cloning of antibiotic resistance gene in *E. coli.*

Steps Involved in Genetically Modifying an Organism

(a) Identification of DNA with desirable genes

(b) Introduction of the identified DNA into the host

(c) Maintenance of introduced DNA in the host and transfer of the DNA to its progeny

TOOLS OF RECOMBINANT DNA TECHNOLOGY

- The tools of recombinant DNA technology includes,
  - **(a)** Restriction enzymes
  - **(b)** Polymerase enzymes
  - **(c)** Ligases
  - **(d)** Vector
  - **(e)** host organisms

A. Restriction Enzymes (Molecular Scissors)

- In 1963, two enzymes responsible for restricting the growth of bacteriophage in *E. coli* were isolated.
- One of these added methyl groups to DNA while the other (restriction endonuclease) cut DNA.
- The first restriction endonuclease is *Hind* II.
- It always cuts DNA molecules at a particular point by recognizing a specific sequence of six base pairs known as the recognition sequence for *Hind* II.
- Today more than 900 restriction enzymes have been isolated from over 230 strains of bacteria.

Naming of the restriction enzymes

- First letter indicates genus and the second two letters indicate species of the prokaryotic cell from which they were isolated.
- Eg - *EcoRI* comes from *E. coli* RY 13 (R = the strain while the Roman numbers indicate the order in which the enzymes were isolated from that strain of bacteria).
- Restriction enzymes belong to a class of enzymes called nucleases.

Types of Nucleases

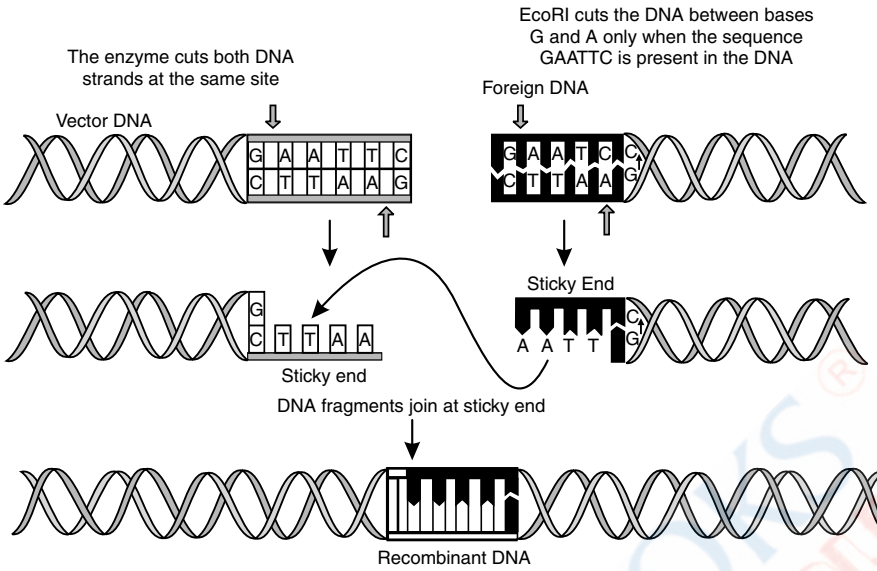
- Nucleases can be classified into two types namely,
  - **(a)** Exonucleases
  - **(b)** Endonucleases

Exonucleases

- They remove nucleotides from the ends of the DNA.

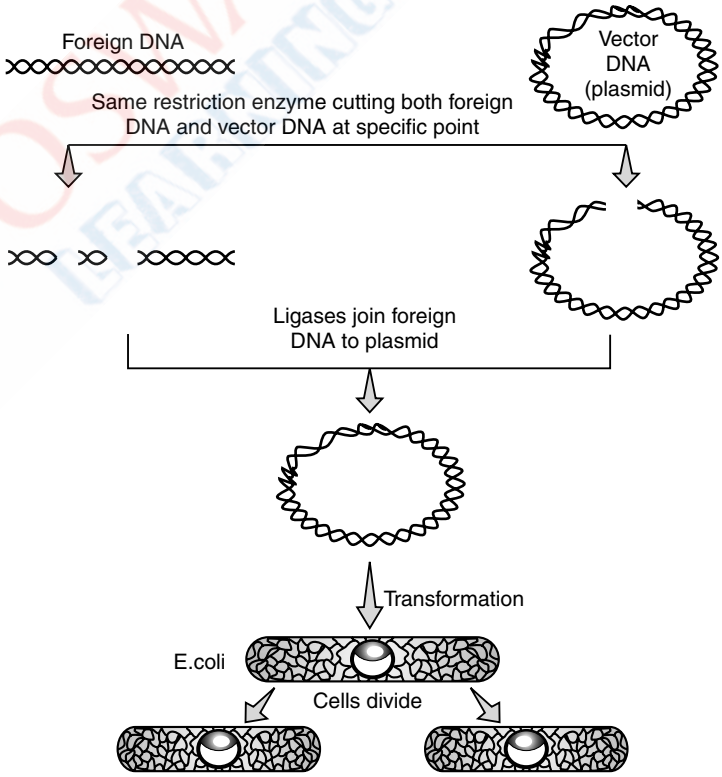
Endonucleases

- They cut at specific positions within the DNA.
- Each restriction endonuclease can bind to specific recognition sequence of the DNA and cut each of the two strands at specific points in their sugar-phosphate backbones.
- Each restriction endonuclease recognizes a specific palindromic nucleotide sequences in the DNA.



Action of Restriction Endonuclease Enzyme to form Recombinant DNA

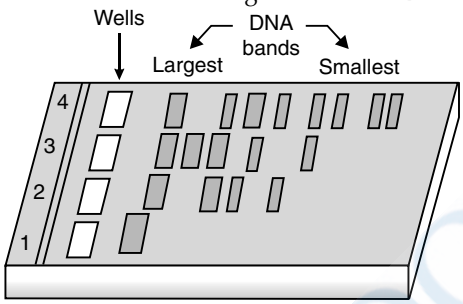
- The palindrome in DNA is a sequence of base pairs that read the same on the two strands in 5' → 3' direction and in 3' → 5' direction. e.g.
- 5' —— GAATTC —— 3'
- 3' —— CTTAAG —— 5'
- Restriction enzymes cut the strand a little away from the centre of the palindrome sites, but between the same two bases on the opposite strands.
- This leaves single stranded overhanging stretches at the ends called sticky ends.
- They form H-bonds with their complementary cut counterparts with the help of the enzyme DNA ligase.
- When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of sticky-ends and these are joined together by DNA ligases.
- It is important to note that unless one cuts the vector and the source DNA with the same restriction enzyme, the recombinant vector molecule cannot be created.



Diagrammatic Representation of Recombinant DNA Technology

Separation and Isolation of DNA Fragments

1. DNA fragments formed by restriction endonucleases can be separated by a technique called gel electrophoresis.
2. DNA fragments are negatively charged and hence can be separated by moving them towards the anode under an electric field through a medium/matrix such as agarose, a natural polymer extracted from sea weeds.
3. The DNA fragments separate (resolve) according to their size through sieving effect provided by the agarose gel.
4. The smaller sized fragment move farther.
5. The separated DNA fragments can be visualized after staining the DNA with ethidium bromide followed by exposure to UV radiation. Bright orange coloured DNA bands can be seen.
6. The separated DNA bands are cut out from agarose gel and extracted from gel piece. This step is called elution.
7. These purified DNA fragments are used in constructing recombinant DNA by joining them with cloning vectors.



Agarose Gel Electrophoresis

B. Cloning Vectors

- These are the DNA molecules that can carry a foreign DNA segment and replicate inside the host cells.
- Eg – Plasmids (a circular extra-chromosomal DNA of bacteria) and bacteriophages.
- Bacteriophages have very high copy numbers of their genome within the bacterial cells.
- Some plasmids have only 1-2 copies per cell.
- Others may have 15-100 copies per cell.
- When the cloning vectors are multiplied in the host the linked piece of DNA is also multiplied to the numbers equal to the copy number of the vectors.

Features Requred to facilitate cloning into a vector.

(a) Origin of replication
(b) Selectable marker or Marker gene
(c) Cloning sites
(d) Vectors for cloning genes in plants and animals

Origin of Replication (ori)

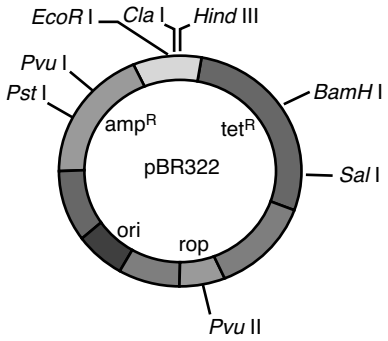
- This is a sequence from where replication starts.
- A piece of DNA linked to ori can replicate within the host cells and also controls the copy number of the linked DNA.
- In order to get many copies of the target DNA, it should be cloned in a vector whose origin supports high copy number.

Selectable Marker (Marker Gene)

- It helps to select the transformants and eliminate the non-transformants.
- Transformation is a procedure in which a piece of DNA is introduced in a host bacterium.
- Selectable markers of *E. coli* include the genes encoding resistance to antibiotics like ampicillin, chloramphenicol, tetracycline or kanamycin, etc.
- The normal *E. coli* cells do not carry resistance against any of these antibiotics.

Cloning Sites

- To link the alien DNA, the vector needs very few recognition sites for restriction enzymes.
- Presence of more than one recognition sites generates several fragments, which complicates the gene cloning.
- The ligation of alien DNA is carried out at a restriction site present in one of the two antibiotic resistance genes.
- Eg - Ligation of a foreign DNA at the *Bam* H I site of tetracycline resistance gene in the vector pBR322.
- The recombinant plasmids lose tetracycline resistance due to insertion of foreign DNA.
- But they can be selected out from non-recombinant ones by plating the transformants on ampicillin containing medium.
- Then, these transformants are transferred on tetracycline medium.



- The recombinants grow in ampicillin medium but not on tetracycline medium.
- But, non-recombinants will grow on the medium containing both the antibiotics.
- In this case, one antibiotic resistance gene helps to select the transformants whereas the other antibiotic resistance gene gets inactivated due to insertion of alien DNA and helps in selection of recombinants.
- Selection of recombinants due to inactivation of antibiotics requires simultaneous plating on 2 plates having different antibiotics.
- Therefore, alternative selectable markers have developed to differentiate recombinants from non-recombinants on the basis of their ability to produce colour in the presence of a chromogenic substrate.
- A recombinant DNA is inserted within the coding sequence of an enzyme, β-galactosidase and so the enzyme become inactivated which is called insertional inactivation.
- The presence of a chromogenic substrate gives blue colored colonies if the plasmid in the bacteria does not have an insert.

Vectors for Cloning Genes in Plants and Animals

- Genetic tools of some pathogens can be transformed into useful vectors for delivering genes to plants and animals.

Example 1

- *Agrobacterium tumifaciens*, a pathogen of many dicot plants can deliver a piece of DNA (T-DNA) to transform normal plant cells into a tumor.
- These tumor cells produce the chemicals required by the pathogen.
- The tumor inducing (Ti) plasmid of *A. tumifaciens* modified into a cloning vector which is not pathogenic to the plants but is able to use the mechanisms to deliver genes of interest into plants.

Example 2

- Retroviruses in animals can transform normal cells into cancerous cells and are used to deliver desirable genes into animal cells.
- So, once a gene or a DNA fragment has been ligated into a suitable vector it is transferred into a bacterial, plant or animal host (where it multiplies).

C. Competent Host (For Transformation with Recombinant DNA)

- DNA is a hydrophilic molecule and hence it cannot pass through cell membranes.
- Due to this, the bacterial cells are treated with a specific concentration of a divalent cation such as calcium to allow DNA to pass through pores in cell wall of bacterium.
- Such cells are incubated with recombinant DNA on ice.
- Then they are placed at 42°C (heat shock) and put back on ice to enable the bacteria to take up the recombinant DNA.

Different Methods to Introduce Alien / Foreign DNA into Host Cells

- There are three methods to introduce alien DNA into host cells namely,
  - **(a)** Micro-injection
  - **(b)** Biolistics or Gene gun
  - **(c)** Disarmed pathogen

Micro-injection

- In this method, the recombinant DNA is directly injected into the nucleus of an animal cell.

Biolistics (Gene Gun)

- In this method, the cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA. This method is suitable for plants.

'Disarmed Pathogen' Vectors

➢ When these vectors infect the cell, it transfers the recombinant DNA into the host.

TOPIC-2
Process of Recombinant DNA Technology

Revision Notes

Process of Recombinant DNA Technology

➢ Recombinant DNA technology involves several steps in specific sequence as follows:
- **(a)** Isolation of DNA
- **(b)** Fragmentation of DNA by restriction endonucleases
- **(c)** Isolation of a desired DNA fragment
- **(d)** Ligation of the DNA fragment into a vector
- **(e)** Transferring the recombinant DNA into the host
- **(f)** Culturing the host cells in a medium at large scale and extraction of the desired product.

A. Isolation of the Genetic Material (DNA)

➢ In order to obtain DNA free from other macro-molecules such as RNA, proteins, polysaccharides and lipids, the bacterial cells/plant or animal tissue are treated with enzymes such as lysozyme (bacteria), cellulase (plant cells), chitinase (fungus) etc.
➢ The cell is broken to release DNA along with other macromolecules.
➢ Genes on the DNA are interwined with proteins such as histones.
➢ RNA is removed by treating with ribonuclease.
➢ Proteins are removed by treatment with protease.
➢ Other molecules are removed by appropriate treatments.
➢ The purified DNA precipitates out as a collection of fine threads in the suspension when chilled ethanol is added.

B. Cutting of DNA at Specific Locations

➢ Restriction enzyme digestions are performed by incubating purified DNA with the restriction enzyme, at optimal conditions for that specific enzyme.
➢ Agarose gel electrophoresis is employed to check the progression of a restriction enzyme digestion.
➢ Since DNA is negatively charged, it moves towards the anode.
➢ The process is repeated with the vector DNA also.
➢ After cutting the source DNA and the vector DNA, the cut out gene (DNA segment) of interest from the source DNA and the cut vector are mixed and ligase is added.
➢ This creates recombinant DNA.

C. Amplification of Gene of Interest using PCR

➢ Polymerase Chain Reaction (PCR) is the synthesis of multiple copies of the gene of interest *in vitro* using two sets of primers and the enzyme DNA polymerase.
➢ Primers are small chemically synthesized oligonucleotides that are complementary to the regions of DNA.
➢ The enzyme extends the primers using the nucleotides and the genomic DNA (template).
➢ By continuous DNA replication, the DNA segment is amplified up to 1 billion copies.
➢ For repeated amplification, a thermostable DNA polymerase isolated from a bacterium, *Thermus aquaticus* is used which remains active in high temperature during the denaturation of double stranded DNA.
➢ The amplified fragment can be used to ligate with a vector for further cloning.

Steps in PCR Technique

➢ There are three main steps involved in PCR technique namely,
- **(a)** Denaturation
- **(b)** Annealing of primers
- **(c)** Extension of primers

Denaturation

✓ Here, the double stranded DNA is denatured using high temperature to form single strand to act as a template for DNA synthesis.

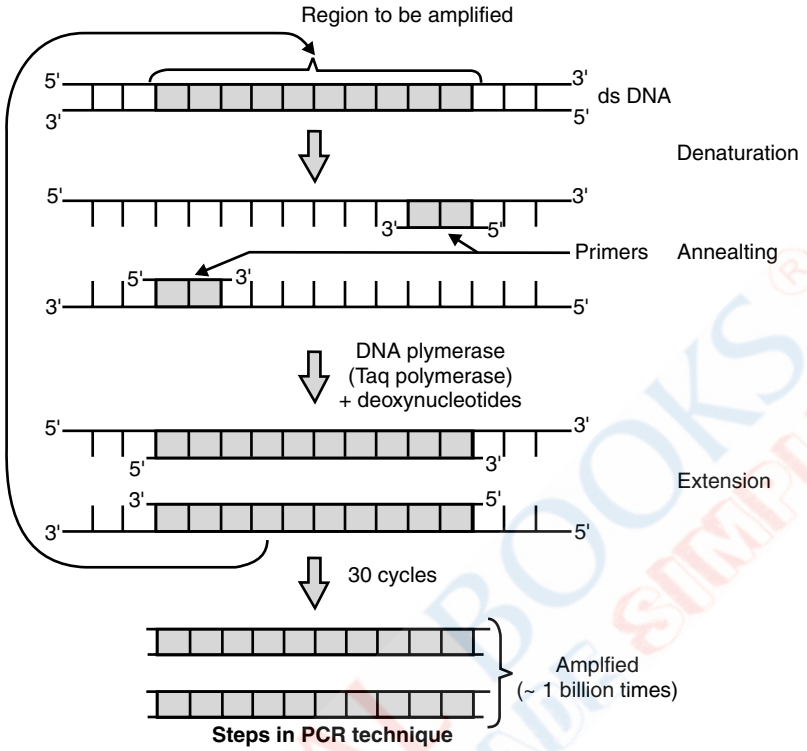
Annealing of Primers

✓ Two sets of primers are annealed or hybridized at low temperature using suitable enzymes based on the length

and the sequence of the primers.

Extension of Primers

✓ The primers are extended by adding nucleotides complementary to the template by *Taq* DNA polymerase.



Steps in PCR technique

D. Insertion of Recombinant DNA into the Host Cell/Organism

- There are several methods of introducing the ligated DNA into recipient cells.
- Recipient cells take up DNA present in its surrounding.
- If a recombinant DNA bearing ampicillin resistant gene, a selectable marker gene is transferred into *E. coli* cells, then the host cells become ampicillin-resistant cells.
- If the transformed cells are spread on agar plates containing ampicillin, only transformants will grow while the untransformed recipient cells will die.

E. Obtaining the Foreign Gene Product

- The ultimate aim of recombinant DNA technology is to produce a desirable protein.
- For this, there is a need for the recombinant DNA to be expressed.
- The foreign gene gets expressed under appropriate conditions.
- If a protein encoding gene is expressed in a heterologous host, it is called a recombinant protein.
- The cells with foreign genes may be grown on a small scale in the laboratory.
- The cultures may be used to extract the desired protein and purify it by using different separation techniques.
- The cells can also be multiplied in a continuous culture system.

Continuous Culture System

- In this system, the used medium is drained out from one side while fresh medium is added from the other.
- It maintains the cells more physiologically active and so produces a larger biomass leading to higher yields of desired protein.
- This type of culturing method produces a larger biomass leading to higher yields of desired protein.

Bioreactors

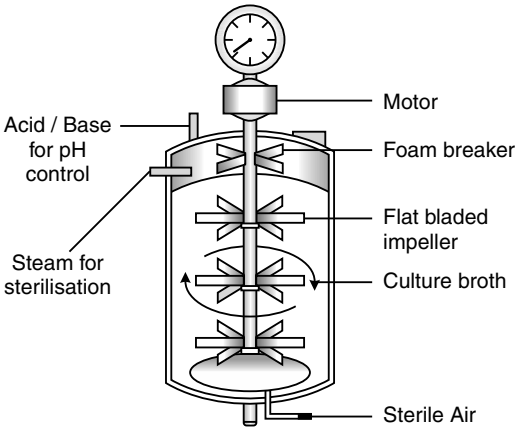
- To produce large quantities of desired products, the bioreactors are used.
- Bioreactors are the vessels in which raw materials are biologically converted into specific products, enzymes etc., using microbial, plant, animal or human cells.
- A bioreactor provides the optimal growth conditions such as temperature, pH, substrate, salts, vitamins, oxygen to obtain the desired product.
- The most commonly used bioreactors are of stirring type.

Stirred Tank Reactor

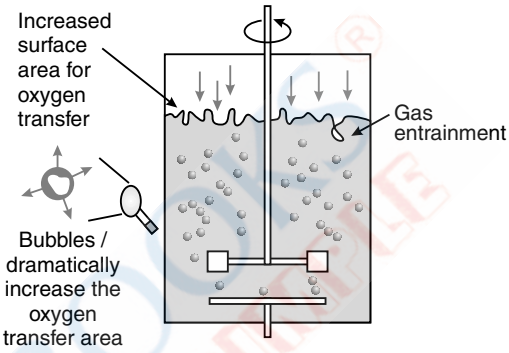
✓ A stirred-tank reactor is cylindrical or with a curved base to facilitate the mixing of the reactor contents with

available oxygen.

- ✓ Alternatively, air can be bubbled through the reactor.
- ✓ The bioreactor has
  - **(a)** An agitator system
  - **(b)** An oxygen delivery system
  - **(c)** A foam control system
  - **(d)** A temperature control system
  - **(e)** pH control system
  - **(f)** Sampling ports, for periodic withdrawal of the culture.



Simple stirred-tank bioreactor



Sparged stirred tank bioreactor

F. Downstream Processing

- ➢ It is a series of processes such as separation and purification of products after the biosynthetic stage.
- ➢ The product is formulated with suitable preservatives.
- ➢ Such formulation undergoes thorough clinical trials as in case of drugs.
- ➢ Strict quality control testing for each product is also required.
- ➢ The downstream processing and quality control testing vary from product to product.

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Chapter 34

Biotechnology And Its Applications

TOPIC-1

Application of Biotechnology in The Field of Agriculture and Medicine

Revision Notes

Critical Areas of Research

- Biotechnology has three critical research areas:
  - **(a)** Providing the best catalyst in the form of improved organism usually a microbe or pure enzyme.
  - **(b)** Creating optimal conditions through engineering for a catalyst to act.
  - **(c)** Downstream processing technologies to purify the protein/organic compound.

APPLICATIONS OF BIOTECHNOLOGY IN AGRICULTURE

Methods to Increase Food Production

- There are three options for increasing food production
  - **(a)** Agro-chemical based agriculture
  - **(b)** Organic agriculture
  - **(c)** Genetically engineered crop-based agriculture
- The Green Revolution has increased the yield of crops due to
  - **(a)** Use of improved crop varieties
  - **(b)** Use of agrochemicals such as fertilizers and pesticides
- However, further increase in the yield with existing varieties of crops is not possible using conventional methods of breeding.
- Also, the agrochemicals cause soil and water pollution and are expensive for the farmers.
- In order to overcome these problems, genetically modified organisms were used.

Genetically Modified Organisms (GMO) or Transgenic Organisms

- These are the plants, bacteria, fungi and animals whose genes are altered by manipulation.

Advantages of Genetic Modification in Plants

(a) It makes crops more tolerant to abiotic stresses (cold, drought, salt, heat etc).

(b) Pest-resistant crops reduce the use of chemical pesticides.

(c) It helps to reduce post-harvest losses.

(d) It increases efficiency of mineral usage by plants, thereby preventing early exhaustion of fertility of soil.

(e) It enhances nutritional value of food. E.g., Vitamin 'A' enriched rice.

(f) GM is used to create tailor-made plants to supply alternative resources to industries, in the form of starches, fuels and pharmaceuticals.

Application of Biotechnology in the Production of Pest Resistant Plants

Pest Resistant Plants

- Pest resistant plants decrease the amount of pesticides used.
- Bt toxin is produced by a bacterium called *Bacillus thuringiensis*.
- Bt toxin gene has been cloned from bacteria in plants to provide resistance to insects to produce bio-pesticide without the need for insecticides.
- Examples - *Bt* cotton, *Bt* corn, rice, tomato, potato and soyabeans, etc.

(a) *Bt* Cotton

- Some strains of *Bacillus thuringiensis* have proteins that kill insects like coleopterans (beetles), lepidopterans (tobacco budworm, armyworm) and dipterans (flies, mosquitoes).
- *B. thuringiensis* forms a toxic insecticidal protein (*Bt* toxin) crystal during a particular phase of their growth.
- It does not kill the *Bacillus* as it exists as inactive protoxins.
- When an insect ingest the inactive toxin, it is converted into active toxin due to the alkaline pH of the gut which solubilise the crystals.
- The toxin binds to the surface of midgut epithelial cells and creates pores.
- It causes cell swelling, lysis and ultimately the death of the insect.
- *Bt* toxin genes were isolated from *B. thuringiensis* and incorporated into crop plants such as cotton.
- Most Bt toxins are insect-group specific.
- The toxin is coded by a gene named cry.
- Eg - The proteins encoded by the genes cryIAc and cryIIAb control the cotton bollworms, that of cryIAb controls corn borer.

(b) Nematode Resistance in Tobacco Plants

- A nematode *Meloidegyne incognitia* infects the roots of tobacco plants and causes a great reduction in yield.
- RNA interference (RNAi) strategy is used to prevent this infestation.
- RNAi is a method of cellular defense in all eukaryotic organisms.
- It prevents translation of a specific mRNA (silencing) due to a complementary dsRNA molecule.
- The source of this complementary RNA is from an infection by RNA viruses or mobile genetic elements (transposons) that replicate via an RNA intermediate.
- Using *Agrobacterium* vectors, nematode-specific genes (DNA) were introduced into the host plant.
- It produced both sense and anti-sense RNA in host cells.
- These two RNA's being complementary to each other form a double stranded (dsRNA) that initiates RNAi, thereby silenced the specific mRNA of nematode.
- The parasite cannot survive in a transgenic host expressing specific interfering RNA.
- The transgenic plant therefore got itself protected from the parasite

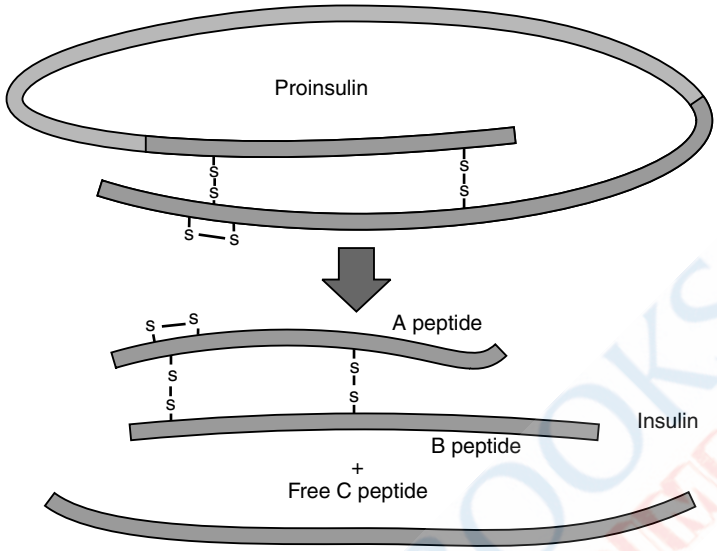
APPLICATIONS IN MEDICINE

- The recombinant DNA technology helps for the mass production of safe and more effective therapeutic drugs.
- The recombinant therapeutics does not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.
- At present, there are about 30 recombinant therapeutics that have been approved for human-use.
- In India, 12 of these are being marketed.

Genetically Engineered Insulin

- Management of adult-onset diabetes is possible by taking insulin at regular time intervals.
- Now, it is possible to produce human insulin using bacteria.
- Insulin from the pancreas of animals such as cattle and pigs causes allergy or other types of reactions to the foreign protein.
- Insulin consists of two short polypeptide chains namely, chain A and chain B that are linked together by disulphide bridges.
- In mammals, insulin is synthesized as a pro-hormone.
- The pro-hormone needs processing before it becomes a fully mature and functional hormone.
- The pro-hormone contains an extra stretch called the C-peptide, which is removed during maturation into insulin.

- In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B chains of human insulin and introduced them in plasmids of *E. coli* to produce insulin chains.
- These chains were produced separately, extracted and combined by creating disulfide bonds to form human insulin.



Maturation of proinsulin into insulin

Gene Therapy

- Gene therapy is a collection of methods that allows correction of a gene defect that has been diagnosed in a child/ embryo.
- Here, genes are inserted into a person's cells and tissues to treat a hereditary disease.
- Correction of a genetic defect involves compensation for the non-functional gene.
- First clinical gene therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency.
- The disorder is caused due to the deletion of the gene for adenosine deaminase, the enzyme crucial for the immune system to function.
- This can be cured by bone marrow transplantation or by enzyme replacement therapy where injection of functional ADA is done.
- However, these approaches are not completely curative.
- In gene therapy, lymphocytes from the patient's blood are grown in a culture.
- A functional ADA cDNA, using a retroviral vector is introduced into these lymphocytes.
- Then, they are returned to the patient.
- This should be periodically repeated as these cells are not immortal.
- However, if the ADA gene from marrow cells is introduced into cells at early embryonic stages, it could be a permanent cure.

Molecular Diagnosis

- Recombinant DNA technology, PCR and Enzyme Linked Immuno-sorbent Assay (ELISA) are some techniques for early diagnosis of a disease.
- Presence of a pathogen is suspected only when the pathogen produces a symptom.
- By this time, the concentration of pathogen becomes very high in the body.
- However, very low concentration of a bacteria or virus can be detected by amplification of their nucleic acid by PCR.
- PCR is used to detect HIV in suspected AIDS patients.
- It is also used to detect mutations in genes in suspected cancer patients.
- It is a powerful technique to identify many genetic disorders.
- A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is allowed to hybridise to its complementary DNA in a clone of cells followed by detection using autoradiography.
- The clone having the mutated gene will hence not appear on the photographic film, because the probe will not have complementarity with the mutated gene.
- ELISA is based on the principle of antigen-antibody interaction.
- Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins, etc.) or by detecting the antibodies synthesized against the pathogen.

TOPIC-2

Transgenic Animals And Ethical Issues, Biopiracy and Patents

Revision Notes

TRANSGENIC ANIMALS

- These are the animals whose genome has been altered by introduction of an extra (foreign) gene by manipulation.
- In other words, animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as transgenic animals
- Examples - Transgenic rats, rabbits, pigs, sheep, cows and fish.
- Over 95% of all existing transgenic animals are mice.
- Advantages of Transgenic Animals
  - **(a)** To study normal physiology and development
  - **(b)** To study the contribution of genes in the development of a disease
  - **(c)** Biological products
  - **(d)** Vaccine safety
  - **(e)** Chemical safety testing

Normal Physiology and Development:

- Transgenic animals are used to study regulation of genes and their effect in normal body functions and its development.
- Eg - study of complex factors such as insulin-like growth factor.
- Genes from other species that alter the formation of this factor are introduced and the biological effects are studied.
- This gives information about the biological role of the factor in the body.

Study of Disease :

- Transgenic models help investigate new treatments for human diseases.
- Examples - Transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

Biological Products :

- Some medicines contain biological products, but they are often expensive.
- Transgenic animals are used to produce useful biological products by introducing genes which codes for a particular product.
- Egs - Human protein (α-1-antitrypsin) used to treat emphysema. Attempts are being made for treatment of phenylketonuria (PKU) and cystic fibrosis etc.

Transgenic Cow

- In 1997, Rosie (first transgenic cow) produced human protein-enriched milk (2.4 gm per litre).
- It contains the human α-lact albumin, which is nutritionally more balanced product for human babies than natural cow-milk.

Vaccine Safety :

- Transgenic mice are used in testing the safety of the polio vaccine used on humans.
- If it is found to be reliable, they can replace the use of monkeys to test the safety of batches of the vaccine.

Chemical Safety Testing (Toxicity Testing) :

- Transgenic animals are made to carry genes which make them more sensitive to toxic substances than non-transgenic animals.
- Then they are exposed to the toxic substances and the effects studied.
- It gives immediate results.

ETHICAL ISSUES

- Genetic modification may cause unpredictable results when such organisms are introduced into the ecosystem.
- Therefore, Indian Government has set up organizations like GEAC (Genetic Engineering Approval Committee), which make decisions about the validity of GM research and the safety of GM-organisms for public services.
- Certain companies have got patents for products and technologies that make use of the genetic materials, plants etc that have been identified, developed and used by farmers.

- Eg. Basmati rice, herbal medicines like turmeric, neem etc.

Basmati Rice

- It has unique aroma and flavor.
- India has 27 documented varieties of Basmati.
- In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati.
- This had actually been derived from Indian farmer's varieties.
- Indian Basmati was crossed with semi-dwarf varieties and claimed as a novelty.
- Other people selling Basmati rice could be restricted by the patent.

Biopiracy

- It refers to the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned.
- Most of the industrialized nations are poor in biodiversity and traditional knowledge.
- The developing and the underdeveloped world have rich biodiversity and traditional knowledge related to bio-resources.
- It has to develop laws to prevent unauthorized exploitation of bio-resources and traditional knowledge.
- Indian Parliament has cleared the second amendment of the Indian Patents Bill that takes such issues into consideration, including patent terms emergency provisions and research and development initiative.

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Chapter 35

Organisms and populations

TOPIC-1

Organisms and Its Environment

Revision Notes

INTRODUCTION

- Levels of biological organizations– macromolecules ⇨ cells ⇨ tissues ⇨ organs ⇨ organism ⇨ population ⇨ communities ⇨ ecosystem ⇨ biomes.
- Ecology refers to the interactions among organisms and its physical or abiotic environment.
- Ecology is basically concerned with four levels of biological organisation.
  Organisms ⇨ Populations ⇨ Communities ⇨ Biomes

ORGANISMS AND ITS ENVIRONMENT

- At organism level, ecology makes us understand about the adaptations of different organisms to their environment in terms of survival and reproduction.
- The annual variation in the intensity and duration of temperature lead to different seasons.
- These variations in seasons together with annual variation in precipitation form different types of biomes such as desert, rain forest and tundra.
- Regional and local variations within each biome result in the formation of variety of habitats.
- Major biomes of India are classified as follows:
  (a) Desert
  (b) Tropical Rain forest
  (c) Tundra
  (d) Sea coast
- Life also exists in extreme and harsh habitats such as scorching Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, permafrost Polar Regions, high mountain tops, boiling thermal springs and stinking compost pits.
- Our intestine is a unique habitat for hundreds of species of microbes.
- The key elements for the variation in the different habitats are:- water, temperature, light and soil.
- The habitat includes both biotic and abiotic components.
- An abiotic component includes water, temperature, light, soil, etc.
- A biotic component includes pathogens, parasites, predators and competitors.
- The organisms interact with these components constantly.
- The organism through natural selection, adaptations optimizes its survival and reproduction in its habitat.
- Each organism has an invariably defined range of conditions that it can tolerate, diversity in the resources it utilises and a distinct functional role in the ecological system, all these together comprise its niche.

MAJOR ABIOTIC FACTORS

- The major abiotic factors are as follows:
  - **(a)** Temperature
  - **(b)** Soil
  - **(c)** Water
  - **(d)** Light

Temperature

- The average temperature on the land varies seasonally, decreases from the equator towards the poles and from plains to the mountain tops.
- There are unique habitats such as thermal springs and deep-sea hydrothermal vents where the average temperature exceeds 100°C.
- Examples – Mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in Kerala forests and tuna fish are not seen beyond tropical latitudes in the ocean.
- The temperature affects the kinetics of enzymes, basal metabolism, activity and other physiological functions.
- Organisms that can tolerate and survive in a wide range of temperature are called Eurythermal organisms.
- Organisms that cannot tolerate and survive in a wide range of temperature are called Stenothermal organisms.
- The thermal tolerance of different species varies with their geographical distribution.

Water

- The productivity and distribution of plants depend on the water.
- For aquatic organisms the quality (chemical composition, pH) of water, the salt concentration (salinity in parts per thousand) are important.
- The salt concentration in less than 5% in inland waters, 30 – 35% in the sea and is >100% in hyper saline lagoons.
- Organisms that can tolerate a wide range of salinity are called Euryhaline.
- Organisms that cannot tolerate a wide range of salinity are called Stenohaline.
- Many freshwater animals cannot live for long in sea water and vice versa because of osmotic pressure problems.

Light

- Plants prepare their own food with the help of sunlight, carbon dioxide, water, and chlorophyll by the process called photosynthesis.
- Sunlight is available as a source of energy.
- Small plants such as herbs and shrubs growing in forests are adapted to photosynthesise optimally under very low light conditions because they are shadowed by tall trees.
- Plants depend on sunlight for flowering.
- It ranges from subzero levels in polar areas and high altitudes to > 50°C in tropical deserts in summer.
- Many animals use the diurnals and seasonal variations in light intensity and duration for timing their foraging, reproductive and migratory activities.
- Deep in the oceans (>500m) the environment is perpetually dark and its inhabitants are not aware of the existence of sun, a celestial source of energy.
- The UV component of the spectrum is harmful to many organisms while not all the colour components of the visible spectrum are available for marine plants living at different depths of the ocean.

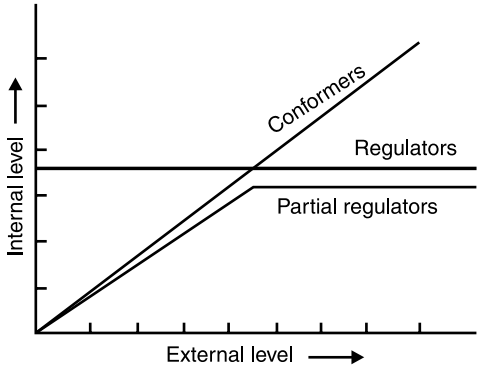
Soil

- The nature and the properties of soil in different places depend on the climate, weathering process and the development of the soil.
- The characteristics of soil such as composition, size and aggregation determine the percolation and water holding capacity of the soil.
- The characteristics of the soil along with pH, mineral composition and topography determine the vegetation in an area.
- In the aquatic environment, the soil characteristics determine the type of benthic animals that can live there.

RESPONSES TO ABIOTIC FACTORS

- Many species would have evolved at a constant internal environment that allows all biochemical reactions and physiological functions to have maximum efficiency and enhance the overall fitness of the species.
- The organisms should try to maintain the constancy of its internal environment (homeostasis) though faces different external environmental conditions.
- The living organisms cope with external environment differently. The possibilities are as follows :
  - **(a)** Regulate
  - **(b)** Conform
  - **(c)** Migrate

(d) Suspend



Diagrammatic representation of organismic response.

Regulate

- ✓ Some organisms maintain homeostasis by physiological or behavioural means ensuring constant osmotic concentrations, body temperature (osmo-and thermoregulation), etc.
- ✓ Birds, mammals and few lower vertebrates and invertebrates regulate osmo-and thermoregulation.
- ✓ According to evolutionary biologists, the success of mammals is largely due to their ability to maintain a constant body temperature
- ✓ A constant body temperature is 37°C.

Conform

- ✓ Nearly 99% animals and almost all plants have their body temperature changes with the ambient temperature.
- ✓ In aquatic animals and plants the osmotic concentration of the body fluids changes with that of ambient water osmotic concentration. These animals and plants are called conformers.
- ✓ Thermoregulation is energetically expensive for many organisms, even for small animals like humming birds and shrews, heat loss or gain depends on the surface area.
- ✓ Larger the area, the body lose heat very fast when it is cold outside; they tend to spend more energy to produce heat in their body. So small animals are rarely found in Polar Regions.
- ✓ Some species have evolved the ability to regulate a limited range of environmental conditions beyond which they are conformers.
- ✓ If stressful external conditions are seen for a short duration, the organisms undergo migration or get suspended.

Migration

- ✓ The organism move away temporarily to more hospitable habitat and return after the stressful period is over.
- ✓ Particularly birds, during winter undergo long distance migrations.
- ✓ Examples – Keolado National Park at Bharatpur in Rajasthan host thousands of migratory birds from Siberia.

Suspend

- ✓ In bacteria, fungi and other lower plants during unfavorable conditions forms thick walled spores to survive which later during favourable conditions germinate to form new plants.
- ✓ In higher plants, seeds and other vegetative reproductive structures help to overcome the period of stress by reducing their metabolic activity and undergo a period of 'dormancy'.
- ✓ Examples – Bears undergo hibernation during winter, Snails and Fish undergo aestivation to avoid summer, heat and desiccation.
- ✓ Zooplankton species in lakes and ponds undergo diapause, a stage of suspended development.

ADAPTATIONS

Adaptations of Kangaroo Rat in North American Deserts

- ➢ Adaptation is any attribute of an organism's morphological, physiological and behavioral that enable them to survive and reproduce in its habitat.
- ➢ Example – in the absence of an external source of water, the Kangaroo rat in North American Deserts meet their water requirement through internal fat oxidation in which the water is the by product and also through concentrating its urine to minimal volume of water as excretory products.

Adaptations of Desert Plants

- ➢ Many desert plants have thick cuticle on their leaf surfaces and stomata to minimize water loss through transpiration.
- ➢ CAM, a special photosynthetic pathway enables their stomata to remain closed during day time.
- ➢ Some plants like *Opuntia* have spines which are modified leaves and the function of the leaf is taken by the flattened stem which is green in colour.

Adaptations of Mammals

- Allen's Rule – Mammals from colder region have shorter ears and limbs to reduce the heat loss.
- In polar areas, aquatic mammals have a thick layer of fat or blubber seen below the skin that acts as an insulator to reduce the heat loss. Example – seal.

Physiological and Biochemical Adaptations

- Some organisms adapt physiologically to respond to a stressful situation.
- Example – humans at high altitudes > 3500m near Rohtang Pass, Manali and Mansarovar, in China occupied Tibet experiences altitude sickness due to low atmospheric pressure which results in nausea, fatigue and heart palpitations. But soon get acclimatized and stop experiencing altitude sickness.
- The process of adaptation is that the body compensates low oxygen by increasing RBC production and decreasing the binding affinity of Hb and by increasing breathing rate.
- Tribes living in high altitude of Himalayas have higher RBC count than the people living in the plains.
- Microbes like archaebacteria can live in hot springs and deep sea hydrothermal vents.
- Many fish live in Antarctic waters where the temperature is always zero.
- Many marine invertebrates and fishes live at great depths in the ocean where the pressure is >100 times the normal atmospheric pressure.

Behavioral Adaptations

- Desert lizards lack the physiological ability to deal with the high temperatures but manage to keep their body temperature constant by absorbing heat from the sun upto comfort zone and then come to shade when the ambient temperature starts increasing.
- Some species burrow into the soil and hide from the above ground heat.

TOPIC-2

Populations And Its Attributes

Revision Notes

Populations

- A population is a group of individuals of same species that live in a given geographical area, share or compete for similar resources and potentially reproduce.
- Example - All the cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus plants in a pond ,etc.
- Population ecology is an important area of ecology as it links ecology to population genetics and evolution.

Population Attributes

Birth Rate and Death Rate

- An individual may have deaths and births, but a population has birth and death rates.
- In a population these rates refer to per capita births and deaths respectively.

Calculation of Birth Rate

- Consider in a pond there are 20 lotus plants last year and through reproduction 8 new plants are added.
- Hence, the current population = 28
- The birth rate = 8/20 = 0.4 offspring per lotus per year.

Calculation of Death Rate

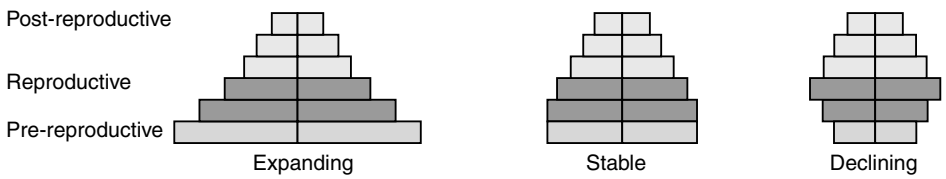
- Consider 4 individuals in a laboratory population of 40 fruit flies died during a week.
- Hence, the death rate = 4/40 = 0.1 individuals per fruit fly per week.

Sex Ratio

- Another characteristic of a population is sex ratio where an individual is either a male or female but a population has a sex ratio of 60% females and 40% males.

Age Pyramid

- When a population at any given time is plotted against the age distribution, the resulting structure is called an age pyramid.
- For human population, the age pyramids show status age distribution of males and females in a combined diagram.
- The shape of the pyramids shows the growth status of the population whether it is growing, stable or declining.



Population Size or Population Density (N)

- It is the number of individuals of a species per unit area or volume.
- The size of the population inform us about its status in the habitat, ecological processes in a population, outcome of competition with another species, the impact of predator or the effect of a pesticide.
- The size could be as low as <10 (Siberian cranes at Bharatpur wetlands) or into millions (*Chlamydomonas* in a pond).
- Population size is technically called as population density (N).
- In some cases, population size is measured in percentage cover or biomass.
- Example - Consider in an area, 200 *Parthenium* plants and a single huge banyan tree are seen where the percentage cover or biomass is a measure of the population size to show the importance of banyan tree.
- Total number is a difficult measure for a huge population.
- For ecological investigations, relative density is taken than the absolute population density.
- Example – The number of fish caught per trap indicates its total population density in the lake.
- Example – The tiger census in our national parks and tiger reserves is based on pug marks and fecal pellets. In this case population size is estimated indirectly.

POPULATION GROWTH

- The population size changes in time, depending on various factors like food availability, predation pressure and weather.
- Changes in population density give some idea about the population whether it is flourishing or declining.

Factors Affecting Population Density

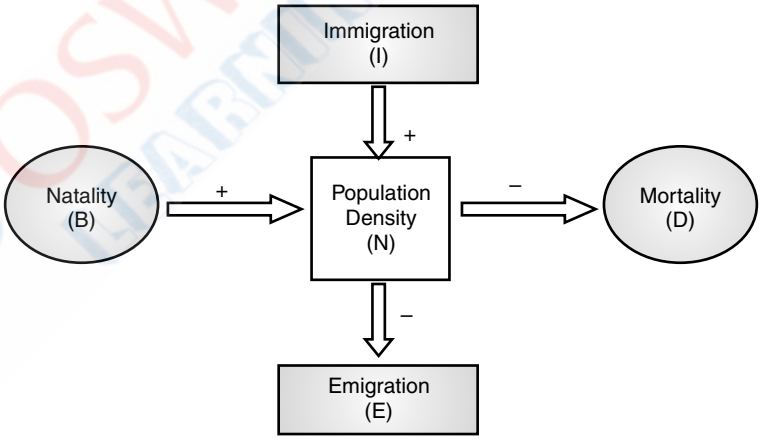
- There are four basic processes that fluctuates the population density namely,
  (a) Natality
  (b) Mortality
  (c) Immigration
  (d) Emigration

  Natality (B):
- It is the number of births in a population during a given period.

  Mortality (D):
- It is the number of deaths in a population during a given period.

  Immigration (I):
- It is the number of individuals of the same species that have come into the habitat from elsewhere during a given time period.

  Emigration (E):
- It is the number of individuals of the population who left the habitat and gone elsewhere during a given time period.



- If N is the population density at time t, then its density at time t +1 will be
  $N_{t+1} = N_t + [(B + I) – (D + E)]$
- This equation indicates that population density increases if B + I is more than D + E or it will decrease.
- Under normal conditions, births and deaths are important factors influencing population density.
- The other two factors have importance only under special conditions.
- For example, if a new habitat is just being colonized, immigration may be more significant to population growth than birth rates.

GROWTH MODELS

- There are two growth models namely,
  (a) Exponential growth
  (b) Logistic growth

Exponential Growth

- Resource availability (food and space) is essential for the unimpeded population growth.
- If resources are unlimited, each species shows its full innate potential to grow in number.
- Then, the population grows in an exponential or geometric fashion.
- If in a population of size N, the birth rates (per capita births) are represented as b and death rates (per capita deaths) as d, then the increase or decrease in N during a unit time period t (dN/dt) will be
  $dN/dt = (b - d) \times N$
  Let (b–d) = r, then
  $dN/dt = rN$
  The *r* ('intrinsic rate of natural increase') is an important parameter for assessing impacts of any biotic or abiotic factor on population growth.
  The *r* value for the Norway rat = 0.015
  The *r* value for the flour beetle = 0.12
  The *r* value for human population in India (1981) = 0.0205
- The integral form of the exponential growth equation is
  $N_t = N_0 e^{rt}$
  Where,
  N_t = Population density after time t, N_0 = Population density at time zero, r = intrinsic rate of natural increase, e = the base of natural logarithms (2.71828)

Logistic Growth

- There is no population in nature having unlimited resources for exponential growth.
- This leads to competition between individuals for limited resources.
- Eventually, the 'fittest' individuals survive and reproduce.
- In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. It is called carrying capacity (K).
- A population with limited resources show initially a lag phase, followed by phases of acceleration and deceleration and finally an asymptote, when the population density reaches the carrying capacity. This type of population growth is called Verhulst-Pearl Logistic Growth.

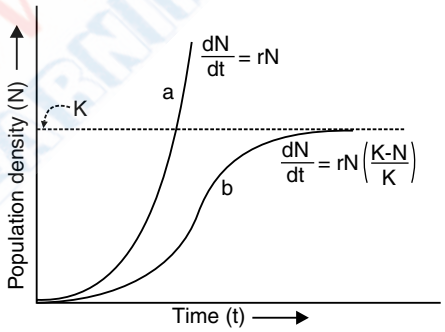
Verhulst-Pearl Logistic Growth

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

Where, N is the population density at time t, r is the intrinsic rate of natural increase, K is the carrying capacity

- Since resources for growth for most animal populations are finite the logistic growth model is more realistic one.

Population Growth Curves



- The curve 'a' indicates exponential growth (J-shaped curve) while the curve 'b' indicates logistic growth (Sigmoid curve).

Life History Variation

- Populations evolve to maximize their reproductive fitness or Darwinian fitness (high r value). Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy.
- Some organisms breed only once in their lifetime (Pacific salmon fish, bamboo) while others breed many times (most birds and mammals).
- Some produce a large number of small-sized offspring (Oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals).
- The above facts indicate that life history traits of organisms have evolved due to limited abiotic and biotic components of the habitat.

Population Interactions

- In nature, animals, plants and microbes interact in various ways to form a biological community.
- Interspecific interactions arise from the interaction of populations of two different species.

- The interspecific interactions include,
  - **(a) Mutualism :** Both the species are benefitted (+).
  - **(b) Competition :** Both the species are harmed (–).
  - **(c) Parasitism :** One species (parasite) is benefitted and other species (host) is harmed.
  - **(d) Predation :** One species (predator) is benefitted and other species (prey) is harmed.
  - **(e) Commensalism :** One species is benefitted and the other is neither benefitted nor harmed
  - **(f) Amensalism :** One species is harmed and the other is unaffected.

Species A	Species B	Name of interaction
+	+	Mutualism
–	–	Competition
+	–	Predation
+	–	Parasitism
+	0	Commensalism
–	0	Amensalism

- In predation, parasitism and commensalisms, the interacting species live closely together.

A. Predation

- In a broad ecological context, all carnivores, herbivores etc., are predators.
- About 25% of all insects are phytophagous.
- If a predator overexploits its prey, then the prey might become extinct.
- It results in the extinction of predator and so, predators in nature are 'prudent'.

Importance of Predators

- Predators act as conduits for energy transfer across trophic levels. Predators keep prey populations under control.
- When certain exotic species are introduced into a geographical area, they spread fast due to the absence of its natural predators in the invaded land.
- Example - The prickly pear cactus introduced into Australia in the early 1920's caused havoc by spreading. Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) was introduced into the country.
- Biological control methods are based on the ability of the predator to regulate prey population.
- Predators maintain species diversity in a community, by reducing the intensity of competition among competing prey species.
- Example - The starfish *Pisaster* is a predator in the rocky intertidal communities of the American Pacific Coast.
- In an experiment, when all the starfishes were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year, due to interspecific competition.

Defenses of prey species to lessen impact of predation :

- Some insects and frogs are camouflaged (cryptically colored) to avoid being detected by the predator.
- Some are poisonous and so avoided by the predators.
- The Monarch butterfly is highly distasteful to its predator (bird) due to a special chemical in its body.
- This chemical is acquired during its caterpillar stage by feeding on a poisonous weed.
- Thorns (*Acacia, Cactus* etc) are the most common morphological means of defence of plants.
- Many plants produce chemicals that make the herbivore sick, inhibit feeding or digestion, disrupt its reproduction or kill it.
- Example - Calotropis (a weed growing in abandoned fields) produce highly poisonous cardiac glycosides. Therefore cattle or goats do not eat it. Nicotine, caffeine, quinine, strychnine, opium, etc., are defences against grazers and browsers.

B. Competition

- Interspecific competition is a potent force in organic evolution.
- Competition is a process in which fitness of one species (measured as 'r' value) is significantly lower in presence of another species.
- Competition occurs when closely related species compete for the same limited resources.
- Unrelated species can also compete for the resource.

  Example - Flamingoes and fishes in some shallow South American lakes compete for zooplankton.
- Competition occurs in abundant resources also.
- Example – In interference competition, the feeding efficiency of one species is reduced due to the interfering and inhibitory presence of other species, even if resources are abundant.

Evidences for competition :

- The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, due to greater browsing efficiency of the goats.

'Competitive release' :

- A species, restricted to a small geographical area (due to the presence of competitively superior species), expands its distributional range when the competing species is experimentally removed.
- Connell's field experiments showed that on the rocky sea coasts of Scotland, the larger and competitively superior barnacle *Balanus* dominates intertidal area, and excludes the smaller barnacle *Chathamalus* from that zone.

Gause's 'Competitive Exclusion Principle' :

- It states that
  "Two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually"
- This may be true in limited resources, but not otherwise.
- Species facing competition may evolve mechanisms that promote co-existence rather than exclusion.
- Example - 'resource partitioning'.

Resource partitioning

If two species compete for the same resource, they could avoid competition by choosing different times for feeding or different foraging patterns.

Example - MacArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

C. Parasitism

Many parasites have evolved to be host-specific i.e., they can parasitize only a single species of host in such a way that both host and the parasite tend to co-evolve.

If the host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to counteract and neutralize them, in order to be successful with the same host species.

Adaptations of parasites :

(a) Loss of sense organs
(b) Presence of adhesive organs or suckers to cling on to the host
(c) Loss of digestive system, high reproductive capacity etc.

- Majority of the parasites harm the host.
- They may reduce the survival, population density, growth and reproduction of the host.
- They might render the host more vulnerable to predation by making it physically weak.
- Life cycles of parasites are often complex.
  Examples
  (a) Human liver fluke depends on two intermediate hosts i.e., a snail and a fish) to complete its life cycle.
  (b) Malarial parasite needs mosquito to spread to other hosts.

Types of Parasites

- The parasites are classified into two types namely,
  (a) Ectoparasites
  (b) Endoparasites

Ectoparasites :

- Parasites that feed on the external surface of the host organism is known as ectoparasites.
- Example - Lice on humans and ticks on dogs. Many marine fish are infested with ectoparasitic copepods. *Cuscuta*, a parasitic plant that is commonly found growing on hedge plants, has lost its chlorophyll and leaves in the course of evolution.
- It derives its nutrition from the host plant which it parasitizes.
- The female mosquito is not considered a parasite, although it needs our blood for reproduction.

Endoparasites :

- Parasites that live inside the host body at different sites (liver, kidney, lungs, RBC, etc) are known as endoparasites.
- The life cycles of endoparasites are more complex.
- Their morphological and anatomical features are simplified while emphasizing their reproductive potential.

Brood Parasitism in Birds

- Here, the parasitic birds lay eggs in the nest of its host and lets the host incubate them.
- During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest.
- Example - Brood parasitism between cuckoo and crow.

D. Commensalism

Examples :

- Orchid (+) growing as epiphyte on a mango branch.
- Barnacles (+) growing on the back of a whale.
- Cattle egret (+) and grazing cattle (0). The egrets forage close to where the cattle are grazing. As the cattle move, the vegetation insects come out. Otherwise it is difficult for the egrets to find and catch the insects.
- Sea anemone (0) & clown fish (+). The fish gets protection from predators with the help of stinging tentacles of sea anemone. The anemone has no any benefit.

E. Mutualism

Examples:

(a) Lichen
It is an intimate mutualistic relationship between a fungus and photosynthesizing algae or cyanobacteria.

(b) Mycorrhizae
These are associations between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant provides the fungi with carbohydrates.

Mutualism between plant and animal through pollination and seed dispersion

Examples :

1. Many fig trees and wasps. The fig species is pollinated only by its 'partner' wasp species and no other species. The female wasp pollinates the fig inflorescence while searching for suitable egg-laying sites in fruits. The fig offers the wasp some developing seeds, as food for the wasp larvae.
2. Orchids show diversity of floral patterns. They can attract the right pollinator insect (bees and bumblebees) to ensure pollination. Not all orchids offer rewards.
3. 'Sexual deceit' of *Ophrys*(the Mediterranean orchid). One petal of its flower resembles female bee in size, colour and markings. So, the male bee 'pseudocopulates' with another flower. The bee is dusted with pollen from the flower. When the same bee 'pseudocopulates' with another flower, it transfers the pollen. If the female bee's colour patterns change slightly during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee.

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Chapter 36

Ecosystem

TOPIC-1

Ecosystem - Structure And Function, Productivity And Decomposition

Revision Notes

INTRODUCTION

- An ecosystem is a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.
- Ecosystem varies greatly in size from a small pond to a large forest or a sea.
- Many ecologists regard the entire biosphere as a global ecosystem, as a composite of all local ecosystems on Earth.

ECOSYSTEM: TYPES, STRUCTURE AND FUNCTION

- The various components of ecosystem include biotic and abiotic.
- In an ecosystem, interaction of biotic and abiotic components takes place in a more integrated manner resulting in a physical structure that is characteristic for each type of ecosystem.
- Identification and enumeration of plant and animal species of an ecosystem gives its species composition.
- Vertical distribution of different species occupying different levels is called stratification.
- Example - Trees occupy top vertical strata (layer) of a forest, shrubs the second and herbs and grasses occupy the bottom layers.

COMPONENTS OF ECOSYSTEM

- There are four basic components that function as a unit. These include,
  - **(a)** Productivity
  - **(b)** Decomposition
  - **(c)** Energy flow
  - **(d)** Nutrient cycling

TYPES OF ECOSYSTEMS

(a) Terrestrial ecosystem: Forest, grassland, desert etc

(b) Aquatic ecosystem: Pond, lake, wetland, river and estuary

(c) Man-made ecosystem: Crop fields and aquarium

Aquatic Ecosystem

Pond

- A pond is a shallow, simple, self-sustainable water body that exhibits all basic components of an ecosystem.
- Abiotic components in pond: water and the rich soil deposit at the bottom.
- Climatic conditions: The solar input, the cycle of temperature, day-length etc.
- Autotrophic components: phytoplankton, some algae and the floating, submerged and marginal plants.
- Consumers (heterotrophs): zooplankton, free swimming and bottom dwelling forms.
- Decomposers: fungi, bacteria and flagellates.
- Pond performs all the functions of an ecosystem such as

(a) Conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs.
(b) Consumption of the autotrophs by heterotrophs.
(c) Decomposition and mineralization of the dead matter to release them back for reuse by the autotrophs.

- There is unidirectional movement of energy towards the higher trophic levels and its dissipation and loss as heat to the environment.

PRODUCTIVITY

- A constant input of solar energy is the basic requirement for any ecosystem to function and sustain.

Primary Production

- The amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis is called primary production.
- It is expressed in terms of weight (gm^{-2}) or energy (kcal m^{-2}).

Productivity

- The rate of biomass production is called productivity. It is expressed in terms of $gm^{-2}yr^{-1}$ or (kcal m^{-2}) yr^{-1}.

TYPES OF PRODUCTIVITY

- It includes,
  (a) Primary productivity
  (b) Secondary productivity

Primary Productivity

- It can be divided into gross primary productivity (GPP) and net primary productivity (NPP).
- Gross primary productivity: It is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilized by plants in respiration.
- NPP is the available biomass for the consumption to heterotrophs (herbivores and decomposers).
- Gross primary productivity minus respiration losses (R) is the net primary productivity (NPP), *i.e.* NPP = GPP – R
- The primary productivity varies with different types of ecosystems.
- The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter.
- Of this, despite occupying about 70% of the surface, the productivity of the oceans is only 55 billion tons.

Factors Influencing Primary Productivity

- Primary productivity depends on the following:
  (a) The plant species inhabiting a particular area
  (b) Environmental factors
  (c) Availability of nutrients
  (d) Photosynthetic capacity of plants

Secondary Productivity

- It is the rate of formation of new organic matter by consumers.

DECOMPOSITION

- It is the breakdown of complex organic matter by decomposers into inorganic substances like carbon dioxide, water and nutrients.
- Detritus is dead plant remains such as leaves, bark, flowers and dead remains of animals, including faecal matter.
- The detritus is the raw material for decomposition.
- The earthworm is referred to as the farmer's 'friend'. This is so because they help in the breakdown of complex organic matter as well as in loosening of the soil.

STEPS INVOLVED IN DECOMPOSITION

- The steps involved in the decomposition process are:
  (a) Fragmentation
  (b) Leaching
  (c) Catabolism
  (d) Humification
  (e) Mineralization

  Fragmentation, leaching and catabolism operate simultaneously on the detritus.

  Fragmentation: It is the breakdown of detritus into smaller particles by detritivores like earthworm.

  Leaching: Here, the water soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.

  Catabolism: It is the degradation of detritus into simpler inorganic substances by bacterial and fungal enzymes.

  Humification: The degradation of detritus leads to accumulation of humus, a dark amorphous substance in soil. Humus is resistant to microbial action and so decomposes very slowly. Being colloidal in nature it serves as a reservoir of nutrients.

Mineralization: The humus gets degraded by some microbes and release inorganic nutrients. This process is called mineralization.

FACTORS INFLUENCING DECOMPOSITION

(a) It is largely an oxygen-requiring process.

(b) It is controlled by chemical composition of detritus.
Decomposition rate is slower if detritus is rich in lignin and chitin and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.

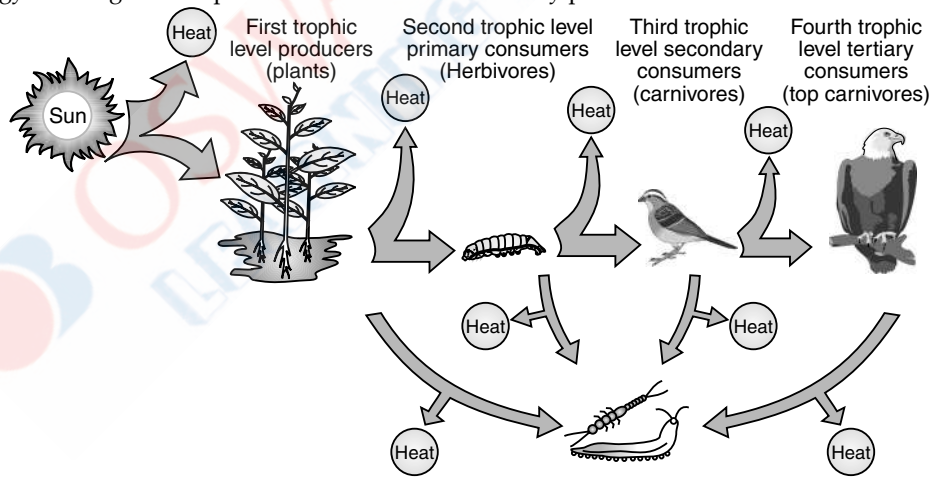
(c) Climatic factors like temperature and soil moisture:
Warm and moist environment favours decomposition whereas low temperature and anaerobiosis inhibit decomposition resulting in build up of organic materials.

TOPIC-2
Energy Flow And Ecological Pyramids

Revision Notes

ENERGY FLOW

- Sun is the only source of energy for all ecosystems except deep sea hydro-thermal ecosystem.
- Of the incident solar radiation less than 50% of it is photosynthetically active radiation (PAR).
- Plants, photosynthetic and chemosynthetic bacteria (autotrophs), fix solar radiant energy to prepare food.
- Plants capture only 2-10% of the PAR to sustain the entire living world.
- Hence, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem.
- Ecosystems obey second law of thermodynamics.
- They need a constant supply of energy to synthesize the molecules they require, to counteract the universal tendency toward increasing disorderliness.
- The energy flow begins with producers and ends with tertiary producers.



Energy Flow Through Different Trophic Level

Producers (Autotrophs) :

- All organisms are dependent for their food on producers (green plants), either directly or indirectly. In a terrestrial ecosystem, major producers are herbaceous and woody plants.
- Primary producers in an aquatic ecosystem are phytoplankton, algae and higher plants.
- The energy trapped by the producer is either passed on to a consumer or the organism dies.
- Death of organism is the beginning of the detritus food chain/web.

Consumers (Heterotrophs) :

- These are all animals that depend on plants (directly or indirectly) for their food.
- They include:
  (a) Primary consumers are herbivores which feed on plants.
  (b) It includes insects, birds and mammals in terrestrial ecosystem and molluscs in aquatic ecosystem.

(c) Secondary consumers are primary carnivores which feed on herbivores.
(d) It includes frog, fox, man etc.
(e) Tertiary consumers are secondary carnivores which feed on primary carnivores.

Simple Grazing Food Chain

- A simple grazing food chain (GFC) is depicted below :

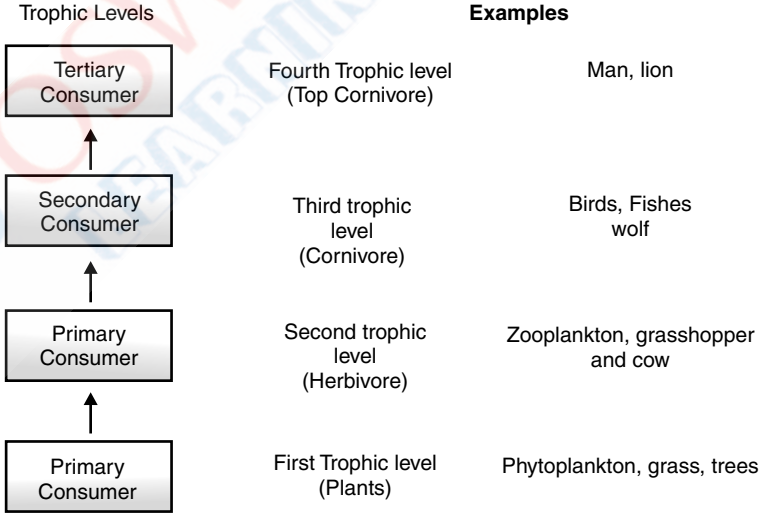
Grass ----------→ Goat ----------→ Man ----------→
(Producer) (Primary Consumer) (Secondary Consumer)

Detritus Food Chain

- It begins with dead organic matter.
- It is made up of decomposers i.e., saprotrophs which are heterotrophic organisms. It includes fungi and bacteria.
- They meet their energy and nutrient requirements by degrading dead organic matter or detritus.
- Decomposers secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them.
- In an aquatic ecosystem, GFC is the major conduit for energy flow.
- In a terrestrial ecosystem, a much larger fraction of energy flows through the DFC than through the GFC.
- DFC may be connected with GFC at some levels: some of the organisms of DFC are prey to the GFC animals.
- Some omnivorous animals like cockroaches, crows etc., are also involved in the food chain.
- These interconnections of food chains make a food web.

Trophic Levels

- Based on their feeding relationship, organisms occupy a place in the natural surroundings or in a community.
- A specific place of organisms in the food chain is known as their trophic level.
- Producers belong to the first trophic level, herbivores to the second and carnivores to the third.
- The amount of energy decreases at successive trophic levels.
- When an organism dies it becomes dead biomass (detritus) that serves as an energy source for decomposers.
- Organisms at each trophic level depend on those at the lower trophic level for their energy demands.
- Each trophic level has a certain mass of living material at a particular time called as the standing crop.
- It is measured as the mass of living organisms (biomass) or the number in a unit area.
- Biomass of a species is expressed in terms of fresh or dry weight.
- Measurement of biomass in terms of dry weight is more accurate.
- The number of trophic levels in the grazing food chain is restricted as the transfer of energy follows 10% law *i.e.*, only 10% of the energy is transferred to each trophic level from the lower trophic level.
- It is possible to have so many levels such as producer, herbivore, primary carnivore, secondary carnivore in the grazing food chain.



Different Trophic Levels in an Ecosystem

ECOLOGICAL PYRAMIDS

- The representation of a food chain in the form of a pyramid is called ecological pyramid.
- The base of a pyramid is broad and it narrows down at the apex.
- The base of each pyramid represents the producers (first trophic level) while the apex represents tertiary or top level consumer.

Types of Ecological Pyramids

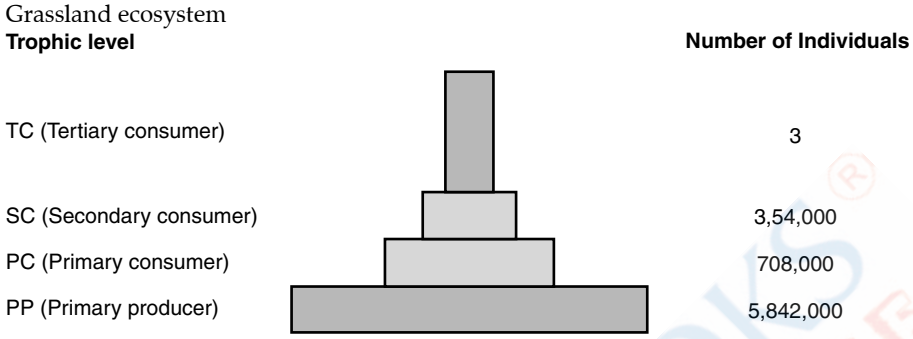
- There are three ecological pyramids, namely

(a) Pyramid of number
(b) Pyramid of biomass
(c) Pyramid of energy

- In most ecosystems, all the pyramids are upright, i.e., producers are more in number than the carnivores.
- Also energy at a lower trophic level is always more than at a higher level.

Pyramid of Number :

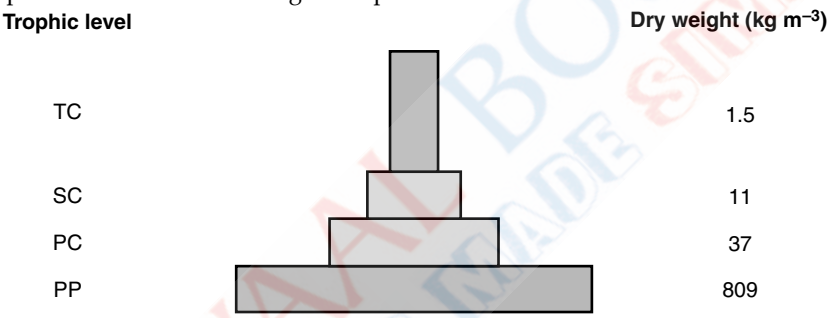
- Example - Grassland ecosystem



Pyramid of Numbers in a Grassland Ecosystem

Pyramid of Biomass :

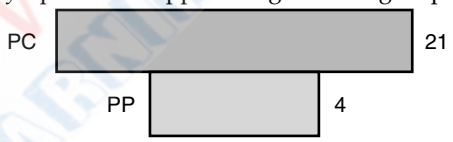
- It shows a sharp decrease in biomass at higher trophic levels.



Pyramid of Biomass

Inverted Pyramid of Biomass

Here, the small standing crop of phytoplankton supports large standing crop of zooplankton.



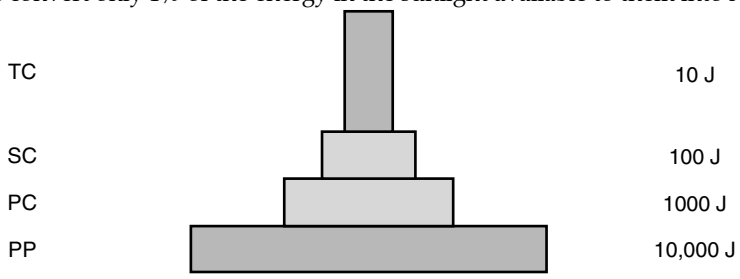
Inverted Pyramid of Biomass

It includes,

(a) Insects feeding on a big tree
(b) Pyramid of biomass in sea is generally inverted because the biomass of fishes far exceeds than that of phytoplankton.

Pyramid of Energy :

- Primary producers convert only 1% of the energy in the sunlight available to them into NPP.



1,000,000 J of Sunlight
An Ideal Pyramid of Energy

- Pyramid of energy is always upright, because when energy flows from a trophic level to the next trophic level, some energy is always lost as heat at each step.

- Each bar in the energy pyramid indicates the amount of energy present at each trophic level in a given time or annually per unit area.
- Any calculations of energy content, biomass or numbers has to include all organisms at that trophic level.
- The trophic level represents a functional level.
- A given species may occupy more than one trophic level in the same ecosystem at the same time.
- For eg, a sparrow is a primary consumer when it eats seeds, fruits, peas and it becomes a secondary consumer when it eats insects and worms.

Limitations of Ecological Pyramids

(a) It does not take into account the same species belonging to two or more trophic levels.
(b) It assumes a simple food chain that almost never exists in nature; it does not accommodate a food web.
(c) Saprophytes are not included in ecological pyramids even though they play a vital role in the ecosystem.

TOPIC-3
Ecological Succession And Nutrient Cycling

Revision Notes

ECOLOGICAL SUCCESSION

- An important characteristic of all communities is that composition and structure constantly change in response to the changing environmental conditions in an orderly and sequential manner resulting in a community that is in near equilibrium with the environment and that is called a **climax community.**
- The gradual and fairly predictable change in the species composition of a given area is called **ecological succession.**
- During succession, some species colonize an area and become more numerous, whereas populations of other species decline and disappear.
- The entire sequences of communities that successively change in a given area are called sere.
- The individual transitional communities are termed seral stages (seral communities).
- In the successive seral stages, there is a change in the diversity of species, increase in the number of species and organisms and an increase in the total biomass.
- The present day communities are the results of succession that occurred over millions of years.
- Succession and evolution would have been parallel processes at that time.

Types of Succession

- There are two types of succession namely,
  (a) Primary succession
  (b) Secondary succession

Primary Succession

- The succession taking place in areas where no living organisms ever existed is known as primary succession.
- It includes newly cooled lava, bare rock, newly created pond or reservoir.
- Before a biotic community is established, there must be formation of fertile soil through natural processes. Hence, the primary succession is a very slow process.

Secondary Succession

- The succession taking place in an area after the existed organisms are lost, it is known as secondary succession.
- It includes abandoned farm lands, burned or cut forests, lands that have been flooded.
- Since some soil or sediment is present, succession is faster than primary succession.
- Description of ecological succession usually focuses on changes in vegetation.
- However, these vegetational changes in turn affect food and shelter for various types of animals.
- Thus, as succession proceeds, the numbers and types of animals and decomposers also change.
- At any time during primary or secondary succession, natural or human induced disturbances such as fire, deforestation, etc., can convert a particular seral stage of succession to an earlier stage.
- Such disturbances create new conditions that encourage some species and discourage or eliminate other species.

Succession of Plants

- Based on the nature of the habitat, succession of plants may be of two types namely,
  (a) Hydrarch
  (b) Xerarch

Hydrarch succession :

- It takes place in wetter areas.
- The successional series progress from hydric to the mesic conditions.

Xerarch succession :

- It takes place in dry areas.
- The series progress from xeric to mesic conditions.
- Hence, both the successions lead to medium water conditions i.e., mesic, neither too dry (xeric) nor too wet (hydric).
- The species invading a bare area are called pioneer species.
- Primary succession on rocks (xerophytic habitat):

(a) Lichens (pioneer species on rocks) → secrete acids to dissolve rock, helping in weathering and soil formation → small plants like bryophytes (they need only small amount of soil) → bigger plants → stable climax forest community (mesophytic).

(b) The climax community remains stable as long as the environment remains unchanged.

- Primary succession in water:
  - **(a)** Phytoplankton (pioneer species in water) → free-floating angiosperms → rooted hydrophytes → sedges, grasses → trees (climax community is a forest).
  - **(b)** With time the water body is converted into land.
- In secondary succession, the species that invade depends on the condition of the soil, availability of water, the environment as also the seeds or other propagules present.
- Since soil is already there, the rate of succession is much faster and hence, climax is also reached more quickly.

NUTRIENT CYCLING

- Organisms need a constant supply of nutrients to grow, reproduce and regulate various body functions.
- The amount of nutrients like carbon, nitrogen, phosphorus, calcium etc., present in the soil at any given time, is referred to as the standing state.
- It varies in different kinds of ecosystems and also on a seasonal basis.
- Nutrients are never lost from the ecosystems, but are recycled again and again.
- The movement of nutrient elements through various components of an ecosystem is called nutrient cycling (biogeochemical cycles).

Types of Nutrient Cycles

- There are two types of nutrient cycles namely,
  - **(a)** Gaseous cycle
  - **(b)** Sedimentary cycle

Gaseous Cycle :

(a) The reservoir exists in the atmosphere.

(b) It includes nitrogen, carbon cycle, etc.

Sedimentary Cycle :

(a) The reservoir is located in Earth's crust.

(b) It includes sulphur and phosphorus cycle.

- Environmental factors (soil, moisture, pH, temperature, etc.) regulate the rate of release of nutrients into the atmosphere.
- The reservoir meets with the deficit of nutrients due to imbalance in the rate of influx and efflux.

Carbon Cycle

Reservoir of carbon :

- Atmosphere (about 1%), organisms (49% of dry weight), oceans (71% dissolved carbon).

Importance:

- It regulates the amount of atmospheric carbon dioxide, fossil fuel etc.

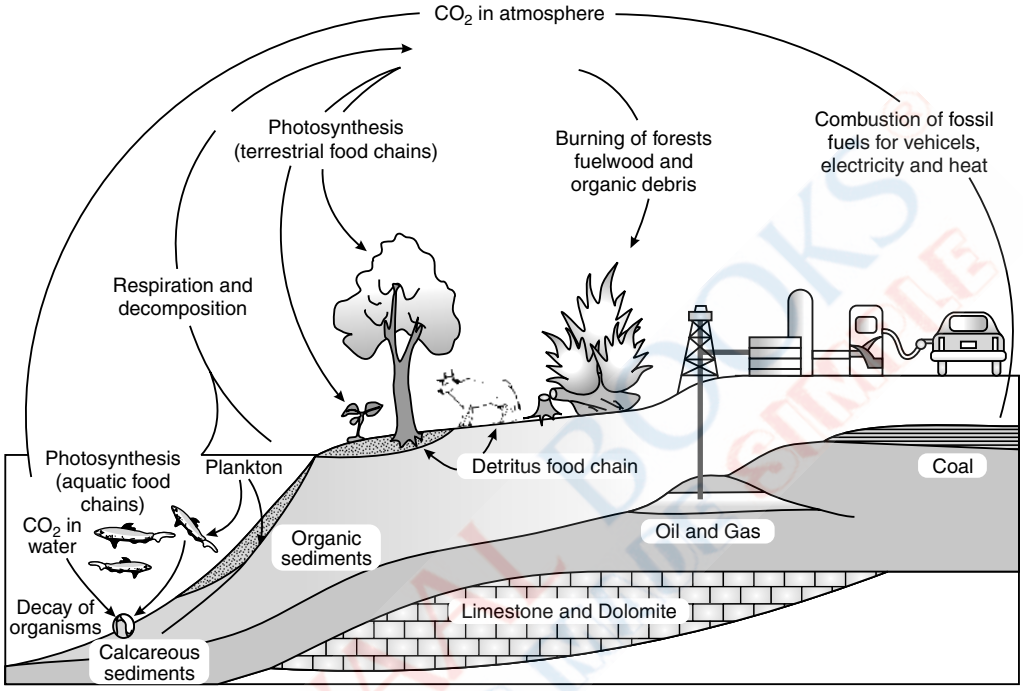
Source:

- Carbon cycling occurs through atmosphere, ocean and through living and dead organisms.
- 4×10^{13} kg of carbon is fixed in the biosphere through photosynthesis annually.
- A major amount of carbon returns to the atmosphere as carbon dioxide through respiration.

- Decomposers also contribute to carbon dioxide pool by their processing of waste materials and dead organic matter.
- Some amount of the fixed carbon is lost to sediments and removed from circulation.
- Burning of wood, forest fire and combustion of organic matter, fossil fuel and volcanic activity are other sources for releasing carbon dioxide in the atmosphere.

Role of human activities in carbon cycle:

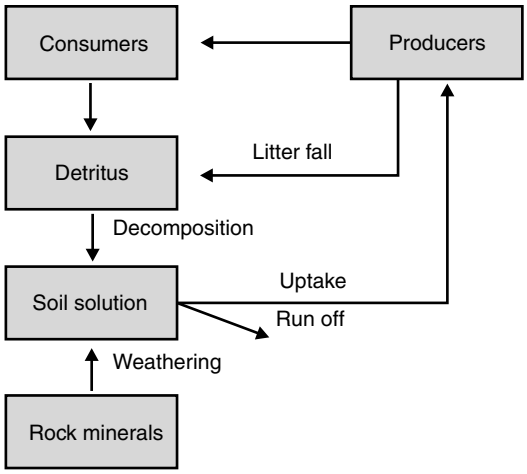
- Deforestation, burning of fossil fuel etc., has increased the rate of release of carbon dioxide into the atmosphere.



Model of Carbon Cycle

Phosphorus Cycle

- Phosphorus is a constituent of biological membranes, nucleic acids and cellular energy transfer systems.
- Many animals use phosphorus to make shells, bones and teeth.
- The natural reservoir of phosphorus is rock (in the form of phosphates).
- When rocks are weathered, minute amounts of phosphates dissolve in soil solution and are absorbed by the plants.
- Herbivores and other animals obtain this element from plants.
- The waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus.



Model of Phosphorus Cycle in a Terrestrial Ecosystem

Differences between Carbon and Phosphorous Cycle

Carbon Cycle	Phosphorus Cycle
Atmospheric input is higher.	Atmospheric input is much smaller.
There is gaseous exchange between organism and environment.	Gaseous exchange is negligible.

ECOSYSTEM SERVICES

- The products of ecosystem processes are called ecosystem services.
- It includes healthy forest ecosystems, purify air and water, mitigate droughts and floods, cycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, provide storage site for carbon and provide aesthetic, cultural and spiritual values.
- Robert Constanza and his colleagues have tried to put price tags on nature's life-support services.
- Researchers have put an average price tag of US $ 33 trillion a year on these fundamental ecosystems services.
- This is nearly twice the value of the global gross national product GNP which is (US $ 18 trillion).
- Out of the total cost of various ecosystem services, the soil formation accounts for about 50%.
- Contributions of other services like recreation and nutrient cycling are less than 10% each.
- The cost of climate regulation and habitat for wildlife are about 6% each.

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Chapter 37

Biodiversity And Conservation

TOPIC-1

Biodiversity And Its Patterns

Revision Notes

BIODIVERSITY

- The term 'biodiversity' refers to the diversity of biological organisation ranging from cellular macromolecules to biomes.
- The term 'biodiversity' was popularized by Edward Wilson.

LEVELS OF BIODIVERSITY

There are three levels of biodiversity namely,

(a) Genetic diversity

(b) Species diversity

(c) Ecological diversity

Genetic Diversity

- It is the diversity shown by a single species at genetic level.
- Eg - *Rauwolfia vomitoria* grown in Himalayan ranges shows genetic variation in the potency and concentration of the chemical called reserpine.
- India has more than 50,000 different strains of rice and 1000 varieties of mango.

Species Diversity

- It is the diversity at species level.
- Eg - Western Ghats have greater amphibian species than Eastern Ghats.

Ecological Diversity

- It is the diversity at ecosystem level.
- Eg - India with its deserts, rain forests, mangroves, coral, reefs, mangroves, wetlands, estuaries, and alpine meadows has greater ecosystem diversity.

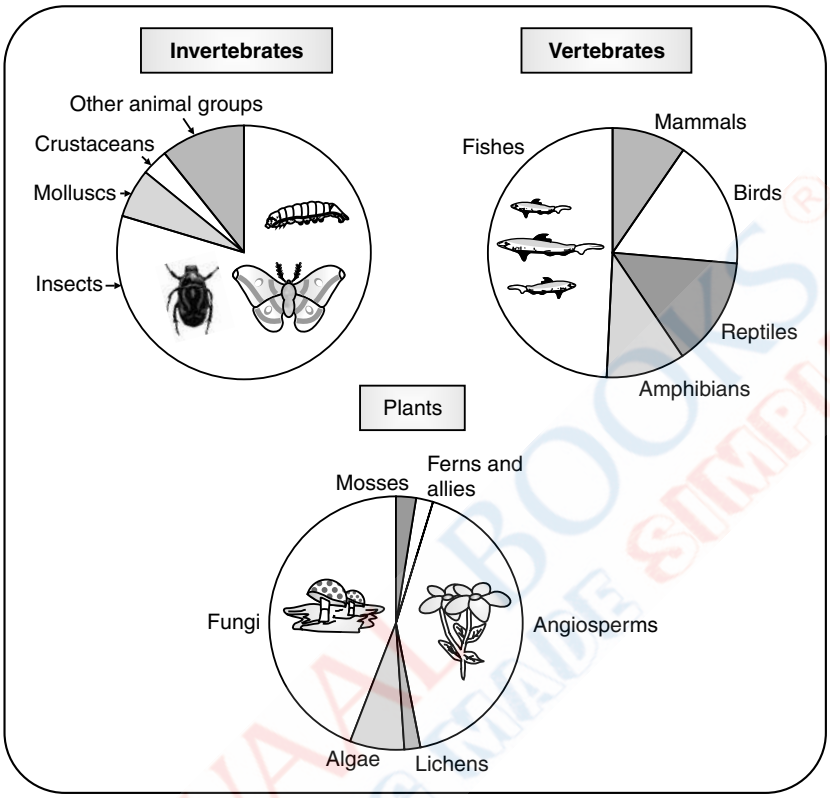
NUMBER OF SPECIES ON EARTH AND IN INDIA (GLOBAL SPECIES DIVERSITY)

Species on Earth

- According to IUCN (2004) : More than 1.5 million species described so far.
- According to Robert May's Global estimate: About 7 million species. He considered the species to be discovered in the tropics. *i.e.* only 22% of the total species have been recorded so far.
- Animals are more diverse (above 70%) than plants including Plantae and Fungi (22%).
- Most species rich taxonomic group among animals: Insects, 70% i.e. out of every 10 animals, 7 are insects).
- Number of fungi species is more than the combined total of the species of fishes, amphibians, reptiles and mammals.
- Biologists are not sure about total number of prokaryotic species because
  - **(a)** Conventional taxonomic methods are not suitable for identifying microbial species.
  - **(b)** Many species are not culturable under laboratory conditions.

Species in India

- India has only 2.4% of world's land area, but has 8.1% of the species diversity.
- India is one of the 12 mega diversity countries of the world.
- Nearly 45,000 species of plants and twice as many of animals have been recorded from India.
- India would have more than 1 lakh plant species and 3 lakh animal species.



PATTERNS OF BIODIVERSITY

There are two patterns of biodiversity namely,

(a) Latitudinal gradients

(b) Species-Area relationship

Latitudinal Gradients

- Species diversity decreases from the equator to the poles.
- Tropics (latitudinal range of 23·5° N to 23·5° S) have more species than temperate or polar areas. Colombia (near equator) has about 1400 species of birds.
- New York (41° N): 105 species of birds.
- Greenland (71° N): 56 species of birds.
- India (tropical latitudes): more than 1200 species - Tropical forest region like Equador has up to 10 times species of vascular plants as compared to a forest of equal area in a temperate region like the Midwest of USA. Tropical Amazonian rain forest (South America) is the greatest biodiversity on earth.
- It contains more than 40000 species of plants, 3000 species of fishes, 1300 species of birds, 427 species of mammals, 427 species of amphibians, 378 species of reptiles and more than 1,25,000 species of invertebrates.
- Biodiversity (species richness) is highest in tropics because
  - **(a)** Tropics had more evolutionary time.
  - **(b)** Relatively constant environment (less seasonal).
  - **(c)** They receive more solar energy which contributes to greater productivity.

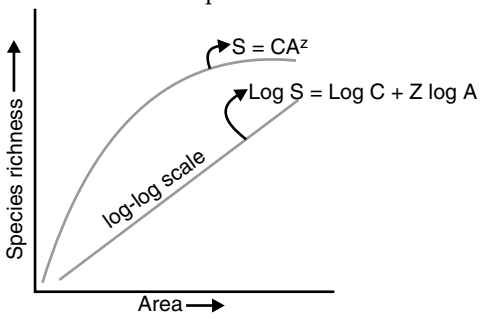
Species- Area Relationship

- According to the study of Alexander von Humboldt within a region, species richness increases with increasing explored area, but only up to a limit.
- Relation between species richness and area for a wide variety of taxa gives a rectangular hyperbola.
- On a logarithmic scale, the relationship is a straight line described the equation

$$\log S = \log C + Z \log A$$

Where, S = Species richness, A= Area, C= Y-intercept, Z= slope of the line (regression co-efficient).

- The value of Z lies in the range of 0.1 to 0.2
- In species-area relationship among the large areas like entire continents, slope of the line is steeper (Z value: 0.6 to 1.2).
- Eg - for frugivorous birds and mammals in the tropical forests of different continents, the slope is 1.15.



IMPORTANCE OF SPECIES DIVERSITY TO THE ECOSYSTEM

- The communities with more species are generally more stable than those with less species. A stable community should not show too much variation in productivity from year to year. A stable community must be resistant to invasions by alien species.
- Rich biodiversity is essential for ecosystem health and imperative for the very survival of human race on this planet.
- According to Tilman, increased diversity contributed to higher productivity.
- Rich biodiversity is not only essential for ecosystem health but crucial for the very survival of human race on this plant.
- The effect of reduction in biodiversity has been explained by Paul Ehrlich through rivet popper hypothesis . Loss of key species that drive major ecosystem functions is a more serious threat to the biodiversity.

LOSS OF BIODIVERSITY

- The biological wealth of our planets has been declining rapidly due to human activities.
- In last 20 years, 27 species have been disappeared.
- IUCN Red List (2004) says that 784 species (338 vertebrates, 359 invertebrates and 87 plants) were extinct in the last 500 years.
- Eg. - Dodo (Mauritius), Quagga (Africa), Thylacine (Australia), Stellar's sea cow (Russia) and 3 subspecies (Bali, Javan, Caspian) of tiger.
- 27 species have been disappeared in the last 20 years.
- More than 15,500 species are facing threat of extinction.
- 12% birds, 23% mammals, 32% amphibians, 31% gymnosperm species face the threat of extinction.
- The current extinction rate is 100 - 1000 times faster than in the pre-human times.
- If this trend continues, nearly 50% species might be extinct within next 100 years.

Impacts of Loss of biodiversity

(a) Decline in plant production

(b) Environmental perturbations such as drought.

(c) Increased variability in ecosystem processes such as plant productivity, water use and pest and disease cycles.

CAUSES OF BIODIVERSITY LOSSES ('The Evil Quartet')

- The main causes of biodiversity losses are follows:
  - **(a)** Habitat loss and Fragmentation
  - **(b)** Over-exploitation
  - **(c)** Alien species invasions
  - **(d)** Co-extinction

Habitat Loss and Fragmentation:

- ✓ It is the most important cause.
- ✓ Eg - Tropical rain forests (loss from 14% to 6%).
- ✓ Thousands hectares of rain forests is being lost within hours.
- ✓ The Amazon rain forest is being cut for cultivating soya beans or for conversion of grass lands for cattle. Due to fragmentation, animals requiring large territories and migratory animals are badly affected.

Over-exploitation:

- ✓ Human obtain food and shelter from nature but due to over exploitation many marine fish population are over harvested, endangering the continued existence of some important species.

✓Many species like Stellar's Sea cow, Passenger pigeon etc., are extinct due to over-exploitation by humans.

Alien Species Invasions :

- ✓ Alien species cause decline or extinction of indigenous species.
- ✓ Eg - The Nile Perch introduced in Lake Victoria (East Africa) caused extinction of more than 200 species of cichlid fish.
- ✓ Invasive weed species like carrot grass (*Parthenium*), *Lantana* and water hyacinth (*Eicchornia*) caused damage to our native species.
- ✓ The illegal introduction of the African Catfish (*Clarias gariepinus*) for aquaculture is posing a threat to the indigenous catfishes in our rivers.

Co-extinction :

- ✓ When a species becomes extinct, the plant and animal species associated with it also extinct.
- ✓ Eg - Extinction of the parasites when the host is extinct.
- ✓ Co-evolved plant-pollinator mutualism where extinction of one leads to the extinction of the other.

TOPIC-2

Biodiversity Conservation

Revision Notes

CONSERVATION OF BIODIVERSITY

- ➢ There are three categories for conservation namely,
  - **(a)** Narrowly Utilitarian Arguments
  - **(b)** Broadly Utilitarian Arguments
  - **(c)** Ethical Arguments

Narrowly Utilitarian Arguments

- ✓ Human derive economic benefits from nature such as food, firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and medicines.
- ✓ More than 25% of the drugs are derived from plants.
- ✓ 25,000 species of plants have medicinal value.

Broadly Utilitarian Arguments

- ✓ Biodiversity plays a major role in many ecosystem services that nature provides.
- ✓ Biodiversity has many ecosystem services.
  - **(a)** Amazon forest ('lung of the planet') produces 20% of total O_2 in the earth's atmosphere.
  - **(b)** Pollination through bees, bumblebees, birds and bats.
  - **(c)** Aesthetic pleasures.

Ethical Arguments

- ✓ Every species has an intrinsic value.
- ✓ We have a moral duty to care for their well-being.

Types of Conservation

- ➢ There are two types of conservation namely,
  - **(a)** *In-situ* conservation
  - **(b)** *Ex-situ* conservation

***In-situ* Conservation (on site)**

Hotspots :

- ✓ These are the richest and the most threatened reservoirs of plant and animal life on earth.
- ✓ There are 34 hotspots in the world.
- ✓ The three hotspots such as Western Ghats and Sri Lanka, Indo-Burma and Himalaya cover India's biodiversity regions.

- ➢ These hotspots are with very high levels of species richness and high degree of endemics (species unfined to that region and not found anywhere else).
- ➢ It is the conservation of genetic resources within natural or human-made ecosystems in which they occur.
- ➢ Eg - Protected areas such as National Parks, Sanctuaries, Biosphere reserves, cultural landscapes, natural monuments.
- ➢ National Park :
  - ✓ Strictly reserved for the welfare of the wildlife where private ownership, cultivation, grazing etc are prohibited. Eg - Eravikulam National Park in Kerala.

Sanctuary :
- ✓ Here, protection is given only to the animals.
- ✓ Collection of timbers, minor forest products and private ownership are allowed so long as they do not harm the animals. Eg - Periyar wildlife sanctuary in Kerala.

➢ Biosphere Reserves:
- ✓ Areas of land or coastal environments to conserve ecosystem and genetic resources contained therein.

Sacred forests (Sacred groves) :
- ✓ Eg - Sacred groves in Khasi and Jaintia Hills in Meghalaya, Aravalli Hills of Rajasthan, Western Ghat regions of Karnataka and Maharashtra, Sarguja, Chanda and Bastar areas (Madhya Pradesh).

➢ India has 14 Biosphere Reserves, 90 National Parks and 448 wildlife sanctuaries.

***Ex situ* conservation (off site)**
- ➢ It is the conservation of organisms outside their habitats.
- ➢ Eg - genetic resource centres, zoological parks, botanical gardens, gene banks, etc.
- ➢ These hot spots are with very high levels of species richness and high degree of endemism (species confined to that region and not found anywhere else).
- ➢ In recent years *ex situ* conservation has advanced beyond keeping threatened species in enclosures.
- ➢ Now gametes of threatened species can be preserved in viable and fertile condition for long periods using cryopreservation techniques, eggs can be fertilized *in vitro*, and plants can be propagated using tissue culture methods.
- ➢ Seeds of different genetic strains of commercially important plants can be kept for long periods in seed banks.

International Efforts for Conserving Biodiversity
- ➢ The historic Convention on Biological Diversity ('The Earth Summit') held in Rio de Janeiro in 1992.
- ➢ Its aim is to
  - **(a)** To conserve the biodiversity
  - **(b)** Sustainable use of biodiversity
  - **(c)** Sharing of benefits in the utilization of genetic resources
- ➢ In the World Summit on Sustainable Development held at Johannesburg, South Africa 2002, 190 countries pledged to reduce the current rate of biodiversity loss.

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Chapter 38

Environmental Issues

TOPIC-1

Pollution And Its Types

Revision Notes

Pollution

- Human population explosion increases the demand for food, water, home, electricity, roads, automobiles, etc.
- It leads to pollution of air, water and soil.
- Pollution is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil.
- Agents that cause pollution are called as pollutants.
- The Government of India has passed the Environment (Protection) Act, 1986 to control environmental pollution and protect and improve the quality of our environment.

Types of Pollution

- There are four types of pollution namely,
  - **(a)** Air pollution
  - **(b)** Water pollution
  - **(c)** Noise pollution
  - **(d)** Soil pollution

Air Pollution and Its Control

- The air pollution is caused due to undesirable change in the physical, chemical and biological characteristics of air.

Factors Involved in Air Pollution

(a) Concentration of pollutants
(b) Duration of exposure to the pollutants
(c) Type of organism it affects

Causes of Air Pollution

- Particulate and gaseous air pollutants from smokestacks of thermal power plants, smelters, etc.
- Pollutants from automobiles.
- Uses of leaded petrol.
- Garbage decomposition.

Effects of Air Pollution

(a) Humans and Animals
- ✓ According to Central Pollution Control Board (CPCB), particulate size of less than 2.5 micrometer (μm) in diameter (PM 2.5) causes greatest harm such as respiratory problems, irritation, inflammations and damage to lungs and premature deaths.
- ✓ It also causes cancer and genetic mutations.

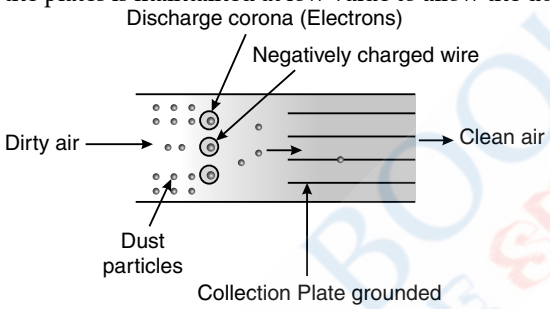
(b) Plants
- ✓ It causes fruit damage and various leaf diseases like necrosis, chlorosis, etc.
- ✓ It decreases the crop yield resulting in premature death of plants.
- ✓ It increases infestation by pests

Control of Air Pollution

- In order to control the air pollution, the particulate matters must be separated/filtered out before releasing the harmless gases into the atmosphere.
- There are several ways for controlling the air pollution. Some are as follows:
  - **(a)** Electrostatic precipitator
  - **(b)** Scrubber
  - **(c)** Catalytic converter

Electrostatic Precipitator

- It is the device widely used to remove particulate matter.
- It can remove over 99% particulate matter present in the exhaust from a thermal power plant.
- It has electrode wires maintained at high voltage which produces electrons.
- These electrons get attached to the dust particles, giving them negative charge.
- The collecting plate grounded being positive charge attracts the negatively charged dust particles.
- When the air passes through the collecting plate, it gets cleaned.
- The velocity of air between the plates is maintained at low value to allow the dust to fall on the collecting plate.



Scrubber

- It is a device used to remove harmful gases from the industrial exhausts.
- The exhausts are passed through a spray of lime or water.
- The water dissolves the gases and lime (CaO) reacts with sulphur dioxide to form a precipitate of calcium sulphate and sulphide.
- There are two types of scrubber namely,
  - **(a)** Wet scrubber
  - **(b)** Dry scrubber

Catalytic Converters

- It is made up of expensive metals like platinum-palladium and rhodium.
- These are fitted into the automobiles for reducing emission of poisonous gases such as carbon monoxide, nitrogen dioxide etc.
- When the exhaust emission passes through the catalytic converter
  - **(a)** Nitric oxide splits into nitrogen and oxygen.
  - **(b)** Carbon monoxide gets oxidized into carbon dioxide.
  - **(c)** Unburnt hydrocarbons get burnt completely into carbon dioxide and water.

Impact of Air Pollution on Environment

(a) Higher energy efficient

(b) Greater fuel economy

(c) Hybrid vehicles reduce emissions even lower than recommended level set by the Environment Protection Agency.

Measures Taken by the Government to Control Air Pollution

(a) Use of catalytic converters

(b) Use of lead-free petrol or diesel

(c) Phasing out of old vehicles

(d) Using low-sulphur petrol and diesel

(e) Application of pollution-level norms for vehicles, etc.

- ✓ Application of Euro II norms in vehicles. According to this, sulphur must be controlled at 350 ppm in diesel and 150 ppm in petrol.
- ✓ Application of Bharat Stage II for all automobiles throughout the country from 1 April, 2005.
- ✓ All automobiles in eleven Indian cities had to meet Euro III emission specification by 1 April, 2005 and Euro IV by 1 April, 2010.
- ✓ Bharat stage IV norms are applicable to 13 cities along with NCR passenger cars and diesel vehicles.
- ✓ Bharat Stage IV is expected to be applied for two and three wheelers by 2016.

Case Study 1

Controlling Vehicular Air Pollution: Delhi

With its very large population of vehicular traffic, Delhi leads the country in its levels of air-pollution. In the 1990s, Delhi ranked fourth among the 41 most polluted cities of the world. Air pollution problems in Delhi became so serious that a public interest litigation (PIL) was filed in the Supreme Court of India. After being censured very strongly by the Supreme Court, under its directives, the government was asked to take appropriate measures, including switching over the entire fleet of public transport, i.e., buses, from diesel to compressed natural gas (CNG). All the buses of Delhi were converted to run on CNG by the end of 2002.

Advantages of CNG:

CNG is better than petrol and diesel because

(a) CNG burns most efficiently leaving no unburnt remain behind.

(b) CNG is cheaper than petrol or diesel, cannot be siphoned off by thieves and adulterated like petrol or diesel.

Disadvantage of CNG:

(a) CNG is the difficulty of laying down pipelines to deliver CNG through distribution points/pumps and ensuring uninterrupted supply.

NOISE POLLUTION AND ITS CONTROL

- In India, the **Air (Prevention and Control of Pollution) Act** (1981) was amended in 1987 to include noise as an air pollutant.
- The sound level above 150 dB, generated by takeoff of a jet plane or rocket may damage ear drums.
- Chronic exposure to relatively lower noise may damage hearing abilities of humans.

Definition :

- Noise is undesired high level of sound.

Causes of Noise Pollution

(a) Use of music instruments, loudspeaker, crackers, etc.

(b) Jet plane or rocket take-off.

(c) Industrial, factory and traffic noises.

Harmful Effects of Noise Pollution

(a) Noise causes psychological and physiological disorders.

(b) Sleeplessness and increased heart beat.

(c) Altered breathing pattern, stress, etc.

(d) Hearing disability.

Control of Noise Pollution

(a) Using sound absorbent materials in industries and buildings.

(b) Creating horn-free zones around hospitals and schools.

(c) Sticking to permissible sound-levels of crackers and loudspeakers.

(d) Delimit the timings of using loudspeakers by framing laws.

(e) Silencers for automobiles, industries, etc.

WATER POLLUTION AND ITS CONTROL

- Water bodies are lifeline of all living organisms.
- Water pollution refers to the contamination of water bodies due to changes in physical, chemical and biological properties of water that affect the living beings.
- Due to human activities, the ponds, lakes, stream, rivers, estuaries and oceans are becoming polluted.
- The Government of India has passed the Water (Prevention and Control of Pollution) Act, 1974 to safeguard our water resources.

Sources of Water Pollution

- The sources of water pollution may be classified into two types namely,
  - **(a)** Natural sources such as clay and slit from soil erosion, leaching of minerals, falling of organic matter from the banks.
  - **(b)** Anthropogenic or man-made sources such as human activities including domestic sewage, industrial wastes, agricultural run-off.

Domestic Sewage and Industrial Effluents

- Domestic sewage contains biodegradable organic matter.
- It is decomposed by microorganisms, which can multiply using these organic substances as substrates and hence utilize some of the components of sewage.

- A mere 0.1% impurities make domestic sewage unfit for human use.
- They include suspended solids such as sand, silt, clay, colloidal materials such as faecal matter, bacteria, cloth, paper fibres and dissolved materials like nitrate, ammonia, phosphate, sodium, calcium, etc.
- Solids are easy to remove while removal of dissolved materials, organic compounds and toxic metal ions are most difficult.
- Domestic sewage from home and hospitals contain pathogen and cause diseases like typhoid, dysentery, etc.

Industrial Wastes

- The industrial effluents from petroleum, paper and chemical manufacturing industries contain toxic heavy metals like mercury and organic compounds leading to biomagnification (biological magnification).
- Heated (thermal) waste water from electricity-generating units (e.g. thermal power plants) eliminates organisms sensitive to high temperature.
- It may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

Agricultural Run-off

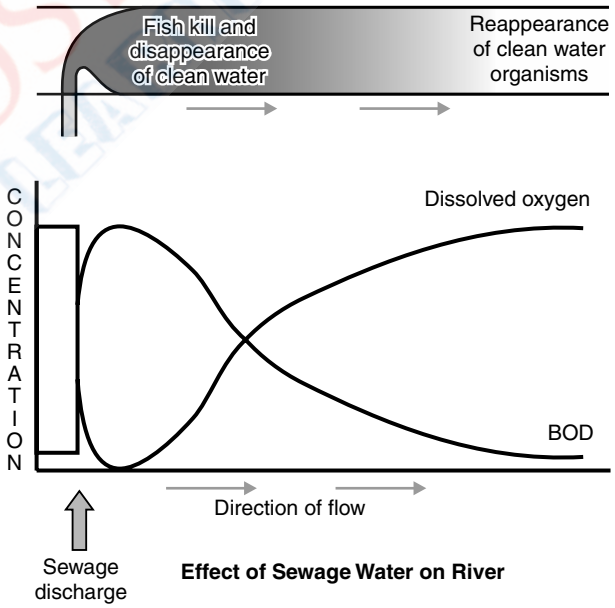
- The run-off from agricultural land is polluted with pesticides and fertilizers.
- It enters water sources by seeping into ground water or streams.

Effects of Water Pollution

- The various effects of water pollution include –
  (a) Biological oxygen demand [BOD]
  (b) Eutrophication
  (c) Algal bloom

Biological Oxygen Demand

- The amount of biodegradable organic matter in sewage water is estimated by measuring Biochemical Oxygen Demand (BOD).
- During biodegradation, microorganisms consume a lot of oxygen.
- It results in a sharp decline in dissolved oxygen causing death of aquatic organisms.
- The prime contaminants are nitrates and phosphates, which act as plant nutrients.
- They overstimulate the growth of algae, causing unsightly scum and unpleasant odours, and robbing the water of dissolved oxygen vital to other aquatic life.
- At the same time, other pollutants flowing into a lake may poison whole populations of fish; whose decomposing remains further deplete the water's dissolved oxygen content.



Effect of Sewage Water on River

Eutrophication

- It is the natural aging of a lake by nutrient enrichment.
- In a young lake, the water is cold and clear.

- With time, due to introduction of nutrients such as nitrogen, phosphorus etc., there arise the growth of aquatic organisms.
- As the lake's fertility increases, plants and animals grow rapidly, and organic remains are deposited on the lake bottom.
- Slowly, the slit and organic debris pile up and the lake grows shallower and warmer, with warm-water organisms.
- Marsh plants take root in the shallows and fill in the original lake basin and eventually, the lake gets converted into land.

Cultural or Accelerated Eutrophication

- The acceleration of ageing process due to heavy discharge of pollutants from the industries and home is known as cultural or accelerated eutrophication.

Algal Bloom

- The presence of large amounts of nutrients in waters causes excessive growth of planktonic algae or algal bloom.
- It imparts a distinct colour to the water bodies and deteriorates the water quality resulting in death of fishes. Some bloom-forming algae are extremely toxic to human beings and animals.
- For example, the water hyacinth (*Eichhornia crassipes*) is the most problematic aquatic weed (Terror of Bengal).
- They grow faster than our ability to remove them.
- It leads to an imbalance in the ecosystem dynamics of the water body.

Control of Water Pollution

(a) Treating of sewage in sewage treatment plant.
Sewage contains a large quantity of human excreta, organic matter and microbes which should be treated first in sewage treatment plant before discharging into water bodies.

(b) Judicious use of small doses of fertilizers and manure.
Biomagnification of toxic chemicals can be controlled by using the fertilizers, pesticides and manure in small doses.

Case Study 2

Integrated Waste Water Treatment

It includes artificial and natural processes. An example is the town of Arcata, situated along the northern coast of California. Collaborating with biologists from the Humboldt State University, the townspeople created an integrated waste water treatment process within a natural system. The cleaning occurs in two stages as follows:

(a) Sedimentation, filtering and chlorine treatments. After this stage, lots of dangerous pollutants like dissolved heavy metals still remain. To combat this, an innovative approach was taken.

(b) The biologists developed a series of six connected marshes over 60 hectares of marshland. Appropriate plants, algae, fungi and bacteria were seeded into this area, which neutralize, absorb and assimilate the pollutants. Hence, as the water flows through the marshes, it gets purified naturally. The marshes also constitute a sanctuary, with a high level of biodiversity in the form of fishes, animals and birds that now reside there. A citizens group called Friends of the Arcata Marsh (FOAM) is responsible for the upkeep and safeguarding of this wonderful project.

Ecological Sanitation [EcoSan]

- It is a sustainable system for handling human excreta, using dry composting toilets.
- There are 'EcoSan' toilets in many areas of Kerala and Sri Lanka.

Advantages of EcoSan

(a) This is a practical, hygienic, efficient and cost-effective solution to human waste disposal.

(b) Human excreta can be recycled into a resource (as natural fertilizer), which reduces the need for chemical fertilizers.

SOLID WASTES

- Solid wastes refer to everything that goes out in trash.

Sources of Solid Wastes

- The various sources of solid wastes are as follows:
  - **(a)** Municipal solid wastes
  - **(b)** Industrial wastes
  - **(c)** Hospital wastes
  - **(d)** Electronic or e-wastes

Municipal Solid Wastes

- These are wastes from homes, offices, stores, schools, hospitals, etc., that are collected and disposed by the municipality.
- It includes paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc.

Industrial Wastes

- These are wastes from industries.
- It includes scraps, toxic heavy metals and oxides of iron, silica and aluminium.

Hospital Wastes

- These are the wastes from hospitals.
- It includes disinfectants and other harmful chemicals.

E-Wastes

- These are the wastes from electronic goods.
- It includes damaged electronic goods and irreparable computers.
- Over half of the e-wastes generated in the developed world are exported to developing countries, mainly to China, India and Pakistan, where metals like copper, iron, silicon, nickel and gold are recovered during recycling process.

Methods of Solid Wastes Disposal

- There are various methods of solid waste disposal. These are as follows:

(a) Open Burning
- ✓ Open burning reduces the volume of the wastes, although it is generally not burnt to completion and open dumps often serve as the breeding ground for rats and flies.

(b) Sanitary landfills
- ✓ This method was adopted as the substitute for open-burning dumps.
- ✓ In this method, wastes are dumped in a depression or trench after compaction, and covered with dirt every day.

(c) Incineration
- ✓ It is a method of e-wastes disposal.
- ✓ The incinerators are used to dispose hospital wastes.

(d) Recycling
- ✓ It is the only way to manage e-wastes.
- ✓ It is done in an eco-friendly way.
- ✓ It can be done specifically and manually.

(e) Rag-pickers and Kabadiwallas
- ✓ It helps to collect and separate out wastes into reusable or recyclable.

Case Study 3

Polyblend: A Remedy for Plastic Waste

Ahmed Khan (A plastic sack manufacturer in Bangalore) developed Polyblend. It is a fine powder of recycled modified plastic. Polyblend is mixed with the bitumen and is used to lay roads. Blend of Polyblend and bitumen enhances the bitumen's water repellant properties and helps to increase road life. The raw material for creating Polyblend is any plastic film waste.

CLASSIFICATION OF WASTES

- All wastes can be categorized into three types namely,
  - **(a)** Bio-degradable
  - **(b)** Recyclable
  - **(c)** Non-biodegradable
- The biodegradable materials can be put into deep pits in the ground and be left for natural breakdown. That leaves only the non-biodegradable to be disposed-off.
- Examples : compost, sewage, livestock waste etc.
- The non-biodegradable materials cannot be decomposed or degraded by microbes and hence becomes complex and toxic. Examples : DDT, BHC, polythene bags
- State Governments are trying to push for reduction in use of plastics and use of eco-friendly packaging.
- We can use carrying cloth or other natural fibre carry-bags instead of polythene bags for shopping.

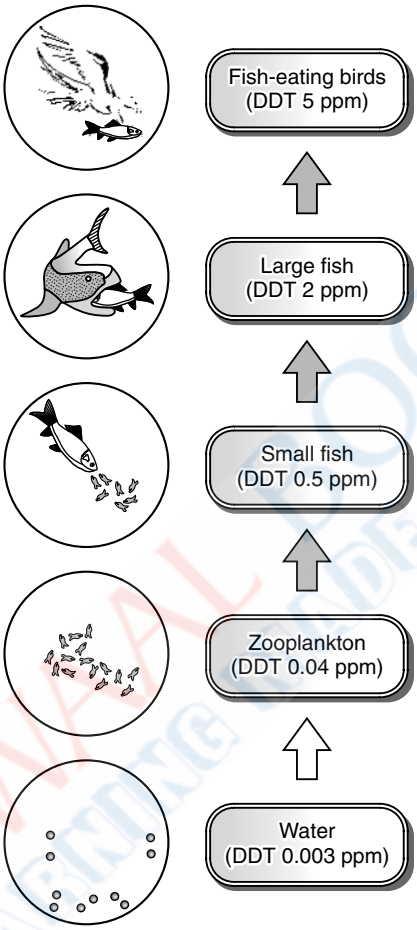
AGRO-CHEMICALS AND THEIR EFFECTS

- The use of inorganic fertilizers, pesticides, herbicides, fungicides, etc., has increased manifold for enhancing crop production.
- These are toxic to non-target organisms that are important components of the soil ecosystem.
- These can be biomagnified in the terrestrial ecosystems.
- Chemical fertilizers cause eutrophication, biomagnification and soil pollution.

Biomagnification

- ✓ Biomagnification is the accumulation of concentration of toxicant at successive trophic levels.
- ✓ The organism in each trophic level cannot metabolize or excrete the toxicant, and is thus passed on to the next trophic level.
- ✓ The toxic substances include mercury and DDT.
- ✓ DDT disturbs calcium metabolism in birds, which causes thinning of eggshell and their premature breaking. It causes decline in bird populations.

Biomagnification of DDT in an Aquatic Food Chain



Control of Agrochemicals

- ➢ One of the major preventive measures from harmful effect of agrochemicals is using organic farming.

Organic Farming

- ✓ It is a zero-waste procedure where waste from a process is cycled as nutrients to the next process.
- ✓ It results in maximum using of resources and higher efficiency.

Case Study 4

Integrated Organic Farming

It is a cyclical, zero-waste procedure, where waste products from one process are cycled in as nutrients for other processes. This allows the maximum utilization of resource and increases the efficiency of production.

Ramesh Chandra Dagar, a farmer in Sonipat, Haryana includes bee-keeping, dairy management, water harvesting, composting and agriculture in a chain of processes, which support each other and allow an extremely economical and sustainable venture. There is no need of chemical fertilisers, as cattle excreta are used as manure. Crop waste is used to create compost, which can be used as a natural fertilizers or can be used to generate natural gas for satisfying the energy needs of the farm. Dagar has created the Haryana Kisan Welfare Club, with a membership of 5000 farmers to spread information on the practice of integrated organic farming.

RADIOACTIVE WASTES

- ➢ Nuclear energy was thought to be a non-polluting way of producing energy.
- ➢ But, the use of nuclear energy was found to have two serious problems namely,
  - **(a)** Accidental leakage
    Eg -Incident in the Three Mile Island and Chernobyl incidents
  - **(b)** Safe-disposal

Effects of Radioactive Wastes

- Radiation from nuclear waste is extremely damaging to organisms, because it causes mutations at a very high rate.
- At high doses, nuclear radiation is lethal but at lower doses, it creates various disorders, such as cancer.

Disposal Method

- It has been recommended that storage of nuclear waste, after sufficient pre-treatment, should be done in suitably shielded containers buried within the rocks, about 500 m deep below the earth's surface.
- However, this method of disposal is meeting stiff opposition from the public.

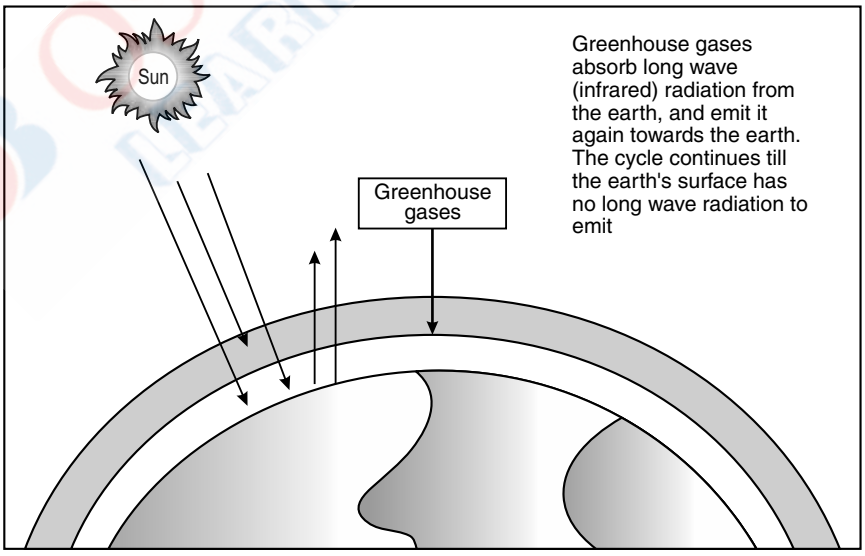
TOPIC-2

Greenhouse Effect, Global Warming, Ozone Depletion and Deforestation

Revision Notes

GREENHOUSE EFFECT

- The Greenhouse is a small glass house used for growing plants during winter.
- The glass panel lets the light in, but does not allow heat to escape.
- Therefore, the greenhouse warms up.
- Greenhouse effect is a natural phenomenon responsible for heating of Earth's surface and atmosphere.
- It maintains the present average temperature (15°C).
- Without greenhouse effect, the average temperature at Earth surface would have been a chilly (–18°C).
- Clouds and gases reflect about 1/4th of the incoming solar radiation, and absorb some of it.
- But almost half of incoming solar radiation falls on Earth's surface heating it, while a small proportion is reflected back.
- Earth's surface re-emits heat as infrared radiation, but a part of infrared is absorbed by atmospheric gases such as carbon dioxide, methane, N_2O, CFCs etc., cannot escape into space.
- These greenhouse gases radiate heat energy, and a major part of which again comes to Earth's surface, thus heating it up again.
- These gases cause the greenhouse effect.
- Increase in the level of greenhouse gases has led to global warming (overheating of Earth).



Green House Effect

GLOBAL WARMING

- It is the result of gradual and continuous increase in average temperature of surface of the earth.

Causes of Global Warming

- There are three main reasons for global warming:

(a) Increase in the level of greenhouse gases.

Since the greenhouse gases are prevented from escaping into the space, there is increase in the level of greenhouse gases on the earth.

(b) Deforestation.

When plants are destroyed, the amount of carbon dioxide is reduced which lead to global warming.

(c) Increase in population.

Increase in population lead to deforestation which ultimately results in global warming.

Effects of Global Warming

The major effects of global warming include:

- During the past century, the temperature of Earth has increased by 0.60C, most of it during the last 3 decades.
- Deleterious changes in the environment resulting in odd climatic changes (e.g. El Nino effect). This melts polar ice caps, Himalayan snow caps etc.
- Rise in sea level that submerges many coastal areas.

Control of Global Warming

The global warming can be controlled by

(a) Reducing the use of fossil fuel

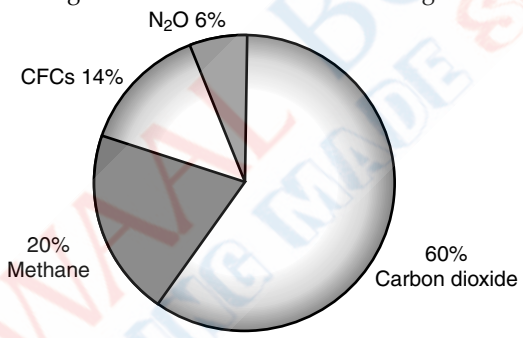
(b) Improving efficiency of energy usage

(c) Reducing deforestation

(d) Afforestation

(e) Slowing down the growth of human population

(f) International initiatives are also being taken to reduce the emission of greenhouse gases into the atmosphere.



Contribution of Greenhouse Gases to Global Warming

OZONE DEPLETION IN THE STRATOSPHERE

- It is the 'Bad' ozone formed in the lower atmosphere (troposphere).
- It harms plants and animals.
- The 'good' ozone is found in the stratosphere.
- It acts as a shield absorbing ultraviolet radiation from the sun.
- UV rays are highly injurious since they cause mutation.
- The thickness of the ozone (O_3) in a column of air from the ground to the top of the atmosphere is measured in terms of Dobson units (DU).

Formation of Ozone

- Ozone is continuously formed by the action of UV rays on molecular oxygen, and also degraded into molecular oxygen in the stratosphere.
- Production and degradation of ozone in the stratosphere should be balanced.

Ozone Hole

- It is thinned area of ozone layer found over the Antarctic region.

Reasons for Ozone Depletion

- The balance is disrupted due to ozone degradation by chlorofluorocarbons (CFCs).
  - **(a)** CFCs used as refrigerants move upward and reach stratosphere.
  - **(b)** UV rays act on them releasing Cl atoms.
  - **(c)** In presence of Cl (catalyst), ozone degrades releasing molecular oxygen (O_2) causing ozone depletion.

Harmful Effects of UV Rays

(a) UV-B causes mutation of DNA.

(b) It causes aging of skin, damage to skin cells and skin cancers.

(c) A high dose of UV-B causes inflammation of cornea (snow-blindness), cataract, etc.

(d) It permanently damages the cornea.

Control of Ozone Depletion

- The Montreal Protocol (an international treaty in Canada, 1987) was signed to control the emission of ozone depleting substances.
- Many more efforts have been made and protocols have laid down definite roadmaps, separately for developed and developing countries, for reducing the emission of CFCs and other ozone depleting chemicals.

DEGRADATION BY IMPROPER RESOURCE UTILISATION AND MAINTENANCE

- The degradation of natural resources can occur by the action of pollutants as well as by improper resource utilization practices.

Soil Erosion and Desertification

- Human activities like over-cultivation, deforestation, grazing and poor irrigation practices, leads to soil erosion.
- It results in arid patches of land and desertification.
- Increased urbanization also creates desertification.

Water Logging and Soil Salinity

- These are the problems as a part of Green Revolution.
- Irrigation without proper drainage of water leads to water logging in the soil.
- It draws salt to the surface of the soil.
- The salt is deposited on the land surface or collects at the plant roots damaging the agriculture.

DEFORESTATION

- It is the conversion of forested areas to non-forested ones.
- Almost 40% forests have been lost in the tropics, compared to only 1% in the temperate region.
- National Forest Policy (1988) of India has recommended 33% forest cover for the plains and 67% for the hills.

Slash and Burn Agriculture (Jhum Cultivation)

- It is practiced in the north-eastern states of India.
- In this method, the farmers cut down the trees of the forest and burn the plant remains.
- The ash is used as a fertilizer and the land is then used for farming or cattle grazing.
- After cultivation, the area is left for several years so as to allow its recovery.
- In earlier days, enough time-gap was given for recovery.
- With increasing population and repeated cultivation, this recovery phase is done away with, resulting in deforestation.

Reasons of Deforestation

(a) Forest fires

(b) Demand for forest products such as timber, wood, etc.

(c) Overgrazing of animals

(d) Urbanization

Effects of Deforestation

(a) Increase in the concentration of carbon dioxide in atmosphere.

(b) Loss of biodiversity due to habitat destruction.

(c) Disturbs hydrological cycle

(d) Soil erosion and Desertification

Reforestation

- The process of restoring a forest that once existed in the past is known as reforestation.
- It may occur naturally or can be planted in a deforested area.

Case Study 5

People's Participation in Conservation of Forests

(a) Bishnoi Movement

In 1731, the king of Jodhpur in Rajasthan asked to arrange wood for constructing a new palace. The minister and workers went to a forest near a village, inhabited by Bishnois. The Bishnois thwarted them from cutting down the trees. A Bishnoi woman Amrita Devi hugged a tree. Sadly, the king's men cut down the tree along with Amrita Devi. Her three daughters and hundreds of other Bishnois followed her, and thus lost their lives for saving trees.

(b) Wildlife Protection Award

Government of India has instituted the Amrita Devi Bishnoi Wildlife Protection Award for individuals or communities from rural areas for extraordinary courage and dedication in protecting wildlife.

(c) Chipko Movement of Garhwal Himalayas

In 1974, local women participated to protect trees from the axe of contractors by hugging them.

Realizing the significance of participation by local communities, the Government of India in 1980s has introduced the concept of Joint Forest Management (JFM) so as to work closely with the local communities for protecting and managing forests. In return for their services to the forest, the communities get benefit of various forest products (*e.g.*, fruits, gum, rubber, medicine, etc.), and thus the forest can be conserved in a sustainable manner.

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