BIOLOGY

NEET NCERT NOTES

CLASS 11 QUICK REVISION

Biology Simplified Tamil

BIOLOGY SIMPLIFIED TAMIL

NCERT EXTRACTED NOTES

Living World

Characteristics of Living Beings

1) Growth: Increase in mass and no. of cells in body.
- Fundamental characteristic, intrinsic property.
- Continuous in plants but upto certain age in animals.
- Non living organisms also grow → **extrinsic growth.**
  E.g: Mountains grow by addition of snow.
- Unicellular organism grow by cell division.
- It can't be taken as defining property of living organism.

2) Reproduction: Production of new individuals of same kind by grown up individuals.
- Fundamental characteristic, it can be sexual or asexual.
- Some organism like **mule, worker bee, sterile human** can't reproduce.
- In unicellular, reproduction is synonymous with growth.
- It is characteristic of living organisms but not an exclusive feature.
- It can't be taken as defining property of living organism.

3) Metabolism: Sum total of all chemical reactions occuring inside living organism during processes like photosynthesis, respiration etc.
- Isolated reaction outside body (in-vitro) are neither living nor non living.
- It can be considered as defining features of all life forms.

4) Consciousness: Ability to detect changes in environment and respond accordingly.
- Plants respond to external factors - light, water, temperature.
- Photoperiod affect reproduction in both plants and animals.
- Human beings have self consciousness too.
- Patient in coma virtually supported by machine which replace heart and lungs are neither living nor dead.
- It is regarded as defining features of all life forms.

Diversity in Living World

Biodiversity: No. and various kind of organisms found on earth.
- No. of species that are known and described in the range between **1.7-1.8 million.**

Nomenclature: Standardised naming of living organism such that a particular organism is known by the same name all over the world.
Identification: Determining the features of organism correctly.
ICBN: International Code for Botanical Nomenclature.
ICZN: International Code for Zoological Nomenclature.
ICVN: International Code for Virus Nomenclature.
ICNCP: International Code of nomenclature for cultivated plants.
Binomial Nomenclature: Universally accepted name with 2 parts.
- by Carolus Linnaeus.

Rules:
i) In Latin, written in Italics, if handwritten then underlined.
ii) First word starts with capital letter, second word with small letter. First name represent Genus and second species.
iii) Author's name after second word i.e. specific epithet.

E.g: Mangifera Indica Linn
↓ ↓ ↓
Generic Name Specific epithet Author Name

• Carolus Linnaeus used **'Systema Naturae'** for animals and **'Species Plantarum'** for plants.

Classification: Grouping organisms in categories, according to similarities and dissimilarities.

• To make study simple and easier.

Systematics: Systematic arrangement of organisms on the basis of evolutionary relationships.

• From latin word - 'Systema'.

Taxonomic Categories

Taxonomy: Branch of science which deals with principles and procedure of classification.

• **Characterisation, identification, classification and nomenclature are basis to taxonomy.**

Taxa: Specific characteristic shown by specific organism help to assign a category to it. Specific term for these categories - taxa.

Taxon: Level of grouping of organism based on certain easily observable common characteristic or each category or unit of classification.

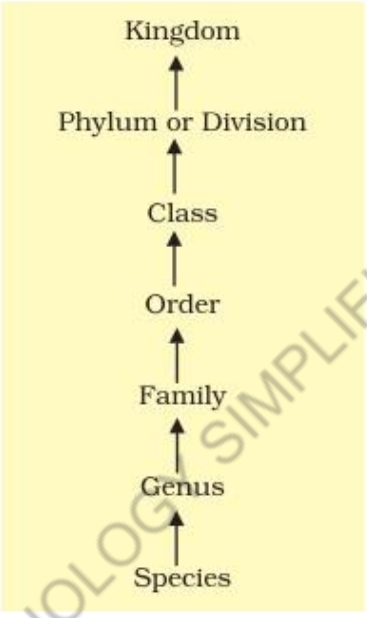


Figure 1.1 Taxonomic categories showing hierarchial arrangement in ascending order

• All categories constitute heirarchy.

i) **Species:** Organisms with fundamental similarities.
E.g: Indica, tuberosum, leo, tigris, nigrum, melongena.

ii) **Genus:** Group of related species.
E.g: Solanum, Panthera, Felis.

iii) **Family:** Group of related genera.
E.g: Felidae, Canidae, Solanaceae (Genera Solanum, Petunia, Datura).
iv) **Order:** Assemblage of families with similar characters.
E.g: Polymoniales (Convolvulaceae, Solanaceae), Primata, Carnivora (Felidae, Canidae).
v) **Class:** Related orders.
E.g: Mammalia (order Primata), Insecta.
vi) **Phylum:** Related class.
E.g: Chordata, Arthropoda.
vii) **Kingdom:** Related phylum.
E.g: Animalia, Plantae.
Lower taxa, more characteristics members.

Tippy Top (Taxonomical category)

King Philip Came Over For Good Soup.
Common Name Biological Name Genus Family Order class Phylum/Division.

TABLE 1.1 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 aid: Procedures and technique to store and preserve information and specimens.
Herbarium - store house of collected plant specimens that are dried, pressed and preserved on sheet.

Figure 1.2 Herbarium showing stored specimens

- Sheet carry information like date and place of collection, local and botanical name, family, collector's name etc.
- Allow morphological study.

Botanical garden: Collection of living plants.

- Grown for indentification, morphological and anatomical study.
- Each plant is labelled indicating botanical/scientific name and family.

E.g: **Indian Botanical garden (Howrah), National Botanical Garden (Lucknow), Royal Botanical Garden (Kew, England).**

Museum: Collection of preserved plant and animal specimen.

- Preserved in containers or jar in preservative solution (formalin), preserved as dry specimen, collect skeletons of animals also, keep extinct and endangered animals.
- Insects are preserved in insect boxes after collecting, killing and pinning.
- Larger animals (bird, mammals) are stuffed and preserved.

Zoological park: Wild animals are kept in protected environment under human care which enable us to learn their food habits, behaviour, gestation period.

E.g: Jim Corbett National Park, Gir Forest.

Figure 1.3 Pictures showing animals in different zoological parks of India

- Conditions similar to natural habitat are provided.

Key: Identification of plants and animals based on similarities and dissimilarities.

- Based on contrasting characters, generally in pair → couplet which represent choice between two opposite options.
- Each statement in key – **lead.**
- Analytical in nature

i) Flora: Information about plants in particular area, actual account of habitat and distribution of plants in given area.

ii) Manual: Information for identification of names of various species in an area.
iii) Monograph: Information of any one taxon.
iv) Catalogue: Alphabetical arrangement of species of particular place describing their features.

Biological Classification

Classification

Aristotle: Enaime (have RBCs) and Anaime (absence of RBCs).

Linnaeus: Plantae and Animalia.

- Aristotle used simple morphological characters.
- But 2 system classification didn't distinguish between eukaryote and prokaryote, unicellular and multicelluar, photosynthetic (green algae) and non-photosynthetic (fungi).

3 Kingdom classification (Haeckel):

Protista (aquatic unicellular eukaryote), Animalia, Plantae.

4 Kingdom classification (Copeland):

Monera (prokaryote), Protista, Animalia, Plantae.

5 Kingdom classification (R.H. Whittaker) [1969]:

Monera, Protista, Fungi (heterotrophs), Animalia, Plantae.

- Used cell structure, body organisation, mode of nutrition, reproduction and phylogenetic relationship.

Overcome: Didn't grouped together unicellular (chlamydomonas) and multicellular (spirogyra), differentiate between heterotrophic (fungi), autotrophic (green plants) as they showed difference in wall compositition – fungi (chitin), plants(cellulosic wall).

6 kingdom classification or 3 domain (carl Woese):

Monera was divided into archaebacteria and eubacteria.

Table 2.1 Characteristics of the Five Kingdoms

Characters	Five Kingdoms				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic (Polysaccharide + amino acid)	Present in some	Present with chitin	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.)

1) Kingdom Monera:

- Sole members are bacteria (most abundant).

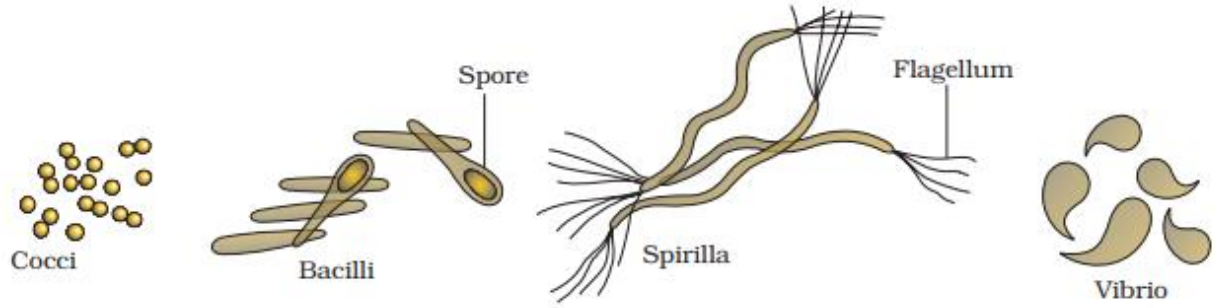


Figure 2.1 Bacteria of different shapes

• Some bacteria are autotrophic (synthesise own food from inorganic substrates), majority are heterotrophs (depend on other organism for food). They can be photosynthetic autotroph or chemosynthetic autotroph.

i) Archaebacteria: Live in most harsh habitats due to cell wall structure.

→ Salty area (halophiles).
→ Hot spring (thermoacidophiles)
→ Marshy areas (methanogens) -present in gut of ruminant animals like cow, buffaloes and are responsible for production of methane (biogas) from dung.

ii) Eubacteria: True bacteria, rigid cell wall, if motile a flagellum present. **Photosynthetic autotrophs** – **E.g:** Cyanobacteria (blue green algae).

- Have chlorophyll a (similar to plants).
- Unicellular, colonial or filamentous, fresh water/ marine or terrestrial.
- Colonies are surrounded by gelatinous sheath, often form blooms in polluted water.
- Some fix atmospheric nitrogen in specialised cell – **heterocysts.**

E.g: Nostoc and anabaena

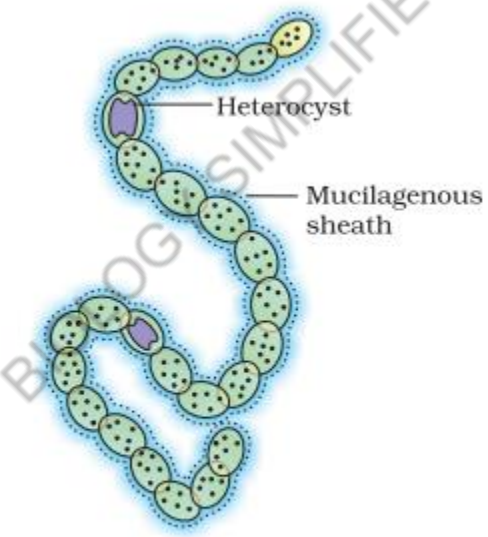


Figure 2.2 A filamentous blue-green algae – *Nostoc*

Chemosynthetic autotrophs: Oxidise inorganic substances like nitrate, nitrite, ammonia and use released energy for ATP production, play role in recycling nutrients like N_2, phosphorous,Fe, sulphur.

Heterotrophic bacteria: Mostly decomposers, help in making curd from milk, production of antibiotic, fixing N_2, in legume, some cause damage to humans, crop, farm, pets, cause diseases like **cholera, typhoid, citrus cancer, tetanus.**
Reproduction: Mainly by fission.

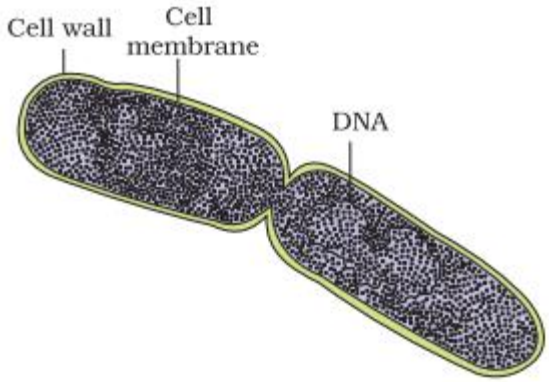


Figure 2.3 A dividing bacterium

- Under unfavourable condition produce spores.
- Sexual reproduction - by adopting primitive type DNA transfer from 1 bacterium to other called Genetic Recombination.

Mycoplasma: Lack cell wall, smallest living cell, survive without oxygen, many are pathogenic in plants and animals.

2) Kingdom Protista: Single celled eukaryote (aquatic).

- Reproduce sexually and asexually with process of cell fusion and zygote formation.

i) Chrysophytes: Diatoms and golden algae (desmids).

- Fresh water and marine, float passively in water current **(plankton).**
- In diatoms, cell walls form 2 thin overlapping shells which fit as in soap box, walls have silica so indestructible.
- They have left behind large deposit in their habitat, this accumulation is **diatomaceous earth.**Used in filtration, polishing, syrup.
- Chief producer in ocean.

ii) Dinoflagellates: Mostly marine and photosynthetic.

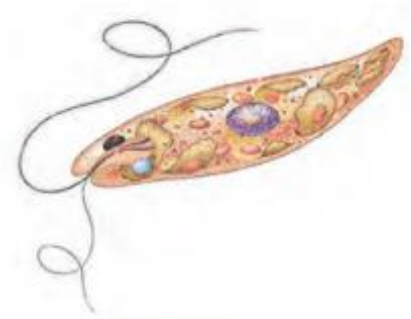
- Yellow, green, brown, blue red depending on pigment.
- Cell wall has stiff cellulosic plate on outside.
- Have 2 flagella - one longitudinal other transverse in furrow.
- Red ones undergo multiplication, make sea red (red tide), release toxins also.

E.g: Gonyaulax.

iii) Euglenoids: Mostly in stagnant fresh water.

- Protein rich layer - **pellicle** makes it flexible.
- Pigment is identical to higher plants.

  E.g: Euglenoid.
- Have 2 flagella - a short and a long one.
- Photosynthetic in presence of sunlight, heterotroph in its absence.
- Undergo longitudinal binary fission.



Euglena

iv) Slime mould: Saprophytic protists.

- Move along decaying twigs to engulf organic material.
- In suitable condition - form aggregation **(plasmodium).**
- In unfavourable condition - plasmodium differentiate and form fruiting bodies bearing spores at tips. Spores possess true walls, resistant, survive in adverse condition, dispersed by air current.

v) Protozoans: Heterotroph, live as predator/parasite.

→ **Amoeboid:** Fresh water, sea, soil, move and capture prey by pseudopodia, marine form have silica shell.

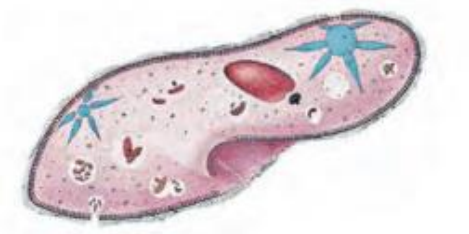
E.g: Entamoeba (parasite).

→ **Flagellated:** Free living or parasitic, have flagella.

E.g: Trypanosoma (cause sleeping sickness).

→**Ciliated:** Aquatic, 1000s cilia, have cavity (gullet) that open to outside cell surface, cilia cause water laden food to be steered into gullet.

E.g: Paramoecium.



→ **Sporozoans:** Have infectious spore like stage called sporozoite.
E.g: Plasmodium (malarial parasite) cause malaria.

3) Kingdom Fungi: Heterotrophic.

- Cosmopolitan, occur in air, water, soil etc., grow in warm and humid places, cell wall – chitin and polysachharide.
- Filamentous except yeast **(unicellular).**
- Have long, slender thread like structures – **hyphae.**
- Network of hyphae - **myecilium.** Some are continuous tubes filled with multinucleated cytoplasm (coenocytic), other have septae or cross wall in their hyphae.
- Yeast - bread and beer, Puccinia - cause wheat rust Penicillium forms antibiotic penicillin.
- Most of them absorb organic matter from dead substrates - **saprophyte**.
- Some depend on living plants and animals - **parasites.** They also live as **symbionts** - with algae **(lichens)**, with roots of higher plants **(mycorhiza).**

Reproduction -

- Vegetative - fragmentation, fission, budding.
- Asexual - spores called **conidia or sporangiospores or zoospores.**
- Sexual - oospores, ascospores, basidiospores.
  Various spores are produced in fruiting bodies.

→ **Plasmogamy:** Fusion of protoplasm.
→ **Karyogamy:** Fusion of 2 nuclei.
Meiosis in zygote produce haploid spores.
In ascomycetes and basidiomycetes an intervening dikaryotic stage occur- **dikaryon** and **phase – dikaryophase.**

i) Phycomycetes: Aseptate and coenocytic myecilium.

- Aquatic and on decaying wood in moist and damp places.
- Asexual by zoospores or aplanospores (non - motile) → **endogenous.**
- Sexual by isogamous or anisogamous or oogamous gametes.

E.g: Rhizopus (bread mould), Mucor, Albugo (Parasitic fungi).

Mucor

ii) Ascomycetes: Sac fungi, branched and septate myecilium.

- Mostly **multicelluar** - **E.g: Penicillium,** rarely unicellular - **E.g: Yeast.**
- Saprophytic, decomposers, parasitic or coprophilous (grow on dung).
- **Exogenous conidia** - conidiophores, **sexual spores - endogenous ascospores** in sac like asci arranged in fruiting bodies – **ascocarp**.
  E.g: Claviceps, Aspergillus, Neurospora (biochemical and genetic work), **Morels and truffels** (edible).

Aspergillus

iii) Basidiomycetes: Mushrooms, bracket fungi, puffballs.

- Branched and septate mycelium.
- Grow in soil, logs, tree stumps, live as parasite. **E.g:** Rust, smut.
- Asexual spores aren't found, vegetative reproduction is common.
- **Sex organs are absent,** dikaryotic phase gives rise to basidium.
- Karyogamy and meiosis results in 4 basidiospores **(exogenous).**
- Basidia are arranged in **basidiocarp**.

E.g: Agaricus (mushroom), Ustilago (smut), Puccinia (rust fungus).

Agaricus

iv) Deuteromycetes: Imperfect fungi, septate and branched mycelium.

- Only asexual or vegetative phases are known.
- When sexual phase were known they were moved to ascomycetes and basidiomycetes.
- Reproduce only by asexual spore-conidia.
- Help in mineral cycling and decomposers of litter.

E.g: Alternaria, Colletotrichum, Trichoderma.

4) Kingdom Plantae: Eukaryotic chlorophyll containing organism.

- Some are **insectivorous**. **E.g: Bladderwort and Venus fly trap Cuscutta (parasitic).**
- Have 2 phases - diploid sporophytic and haploid gametophytic.
- Show alternation of generation.

5) Kingdom Animalia: Heterotrophic eukaryotic organism, lack cell wall.

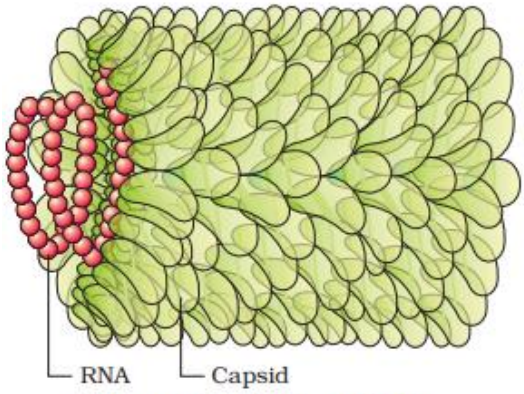
- Food reserve as glycogen, holozoic mode of nutrition.
- Capable of locomotion.

6) Viruses, Viroids, Prions and Lichens:

i) Virus: Non cellular organisms that have inert crystalline structure outside cell. once they infect cell they take over machinery of host cells to replicate themselves killing host.

Biological Classification

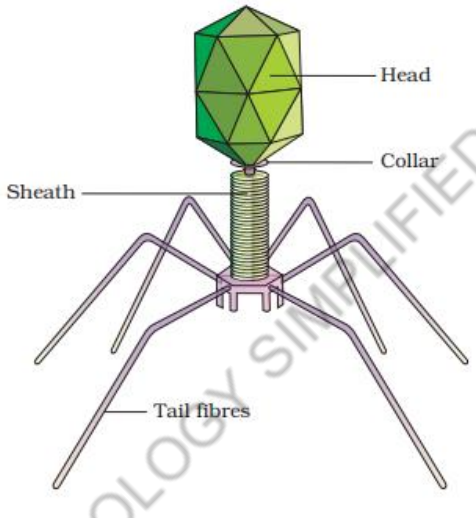
Pasteur: Virus means venom.
DJ. Ivanowsky (1892): Recognised microbes as casual organism of mosaic disease of tobacco, smaller than bacteria as passed through bacteria proof filters.



Tobacco Mosaic Virus (TMV)

M.W. Beijerinek (1898): Extract of infected plant of tobacco cause infection called **Contagium Vivum Fluidum.**
W. M Stanley (1935): Virus could be crystallised, crystals consist of protein.

- Virus are obligate parasites, no virus contain both RNA and DNA.
- Virus is nucleoprotein and has infectious genetic material.
- Virus that infect plants have singly stranded RNA, that infect animals have single or double stranded RNA or double stranded DNA.



Bacteriophage

- Bacteriophage (virus infecting bacteria) have double stranded DNA.
- Protein coat - **capsid,** has small subunits - **capsomere** (protect nucleic acid). They are arranged in helical or polyhedral form.
- **Disease:** Mumps, small pox, herpes, influenza, AIDS, Covid-19.
- Mosaic formation, leaf rolling, yellowing, vein clearing, stunted growth are symptoms.

ii) Viroids: T.O. Diener (1971) - Smaller than virus, cause **potato spindle tuber disease,** have **free RNA** (low molecular weight).

iii) Prions: Abnormally folded protein, similar size of virus, cause **Bovine Spongiform Encephalopathy (BCE)** commonly mad cow disease in cattle analogous to Cr Jacob in humans.

Biological Classification

iv) Lichens: Symbiotic association between algae and fungi. Algae prepare food and fungi provide shelter and absorb mineral and nutrients. Algal component - **phycobiont**, fungal component - **mycobiont**. Lichen don't grow in polluted area i.e. pollution indicators, mainly SO_2 pollution indicator.

Plant Kingdom

Classification systems

1) Artificial system: Earliest, given by Linnaeus.
- Used only superficial morphological characters - habit, colour, number.
- Based on vegetative characters or on androecium structure.
- Separated closely related species as based on few characteristics.
- Equal weightage to vegetative and sexual characteristics but vegetative characters are easily affected by environment.

2) Natural system: By George Bentham and Joseph Dalton Hooker.
- Based on natural affinities among organisms.
- Not only external features but also internal features like ultra structure, anatomy, embryology and phytochemistry.

3) Phylogenetic system:
- Based on evolutionary relationship of organisms.
- Assume organisms belonging to same taxa have common ancestor.

4) Phenetic classification:
- Based on affinities, similarities or dissimiliarities of organism. Some evidences are:

a) Numerical taxonomy: Using computers.
- Based on observable characters.
- No. and codes are assigned to all characters.
- Each character is given equal importance.
- 100s of characters can be considered at same time.

b) Cytotaxonomy:
- Based on cytological information - chromosome no., structure, behaviour.

c) Chemotaxonomy: Use chemical constituent of plant/organism like aminoacids, proteins, DNA sequence.

ALGAE: Chlorophyll bearing, simple, thalloid, autotrophic, largely aquatic, occur in moist stones, soil, wood, occur in association with fungi **(Lichen)** and with animals **(E.g: sloth bear)**.
- Can be colonial **(Volvox)** or filamentous **(Ulothrix and spirogyra).**

Reproduction

i) Vegetative - fragmentation (each fragment develops into thallus).
ii) Asexual - by spores, mostly flagellated zoospores (motile).
iii) Sexual - fusion of 2 gametes.

a) Isogamous: Flagellated & similar - Ulothrix; non flagellated & similar – Spirogyra.
b) Anisogamous: Fusion of 2 gametes dissimilar in size. **E.g: Udorina.**
c) Oogamous: Fusion between 1 large, non motile female gamete and smaller, motile male gamete. **E.g: Volvox, Fucus.**

Economic importance
- Half carbon dioxide on earth is fixed by algae.
- Being photosynthetic, increase level of dissolved oxygen.
- Primary producers of energy rich compounds. **E.g: Porphyra, Laminaria & Sargassum** are used as food.
- Produce hydrocolloids (water holding substances). **E.g: Algin (brown algae & Carageen (red algae).**

• **Agar** from Gelidium & Gracilaria are used in icecream & jellies.
• **Chlorella** (unicellular algae) rich in protein is used as food supplement by space travellers.

1) Chlorophyceae : Green algae.

• May be **unicellular,** colonial, filamentous.
Pigment: Chlorophyll a, chlorophyll b.
Chloroplast: May be discoid, plate like, reticulate, cup shape (chlamydomonas), spiral, ribbon shape.
Pyrenoids: One or more storage bodies, have protein & starch, store food in form of oil droplets also.
Cell wall: Inner cellulosic outer pectose.
Habitat: Fresh water, brackish water, salt water.
Flagella: 2, 8 equal, apical position.

Reproduction

→ Vegetative - fragmentation.
→ Asexual - flagellated zoospores in zoosporangia.
→ Sexual - isogamous, anisogamous, oogamous.
E.g: Chlamydomonas, Volvox, Ulothrix, Spirogyra, Chara.

2) Phaeophyceae: Brown algae.

• Mostly marine.
• Range from simple branched, filamentous **(Ectocarpus)** to profusely branched **(Kelps)** – 100 metres tall.

Pigment: Chlorophyll a, chlorophyll c, carotenoid, xanthophyll, **fucoxanthin** (responsible for colour from green to brown).
Food storage: Laminarin or mannitol.
Cell wall: Cellulose + gelatinous coating of algin (non sulphated).
Protoplast: Plastids + vacuole + nucleus.
Plant body: Attached to substratum by holdfast, has stalk, stipe and leaf like photosynthetic organ – **frond.**
Habitat: Fresh water (rare), brackish water, salt water.
Flagella: 2, unequal, lateral.

Reproduction

→ Vegetative: Fragmentation.
→ Asexual: Biflagellated zoospores (pear shape with 2 unequal flagella).
→ Sexual: Isogamous, anisogamous, oogamous (pear shaped gamete).
E.g: Ectocarpus, Dictyota, Laminaria, sargassum, fucus.

3) Rhodophyceae: Red algae, **multicellular.**

• Majority marine with higher concentration in warmer areas.
• Occur in well lighted region close to water surface & at great depth.

Pigment: r - phycoerythrin, chlorophyll a, chlorophyll d.
Food storage: Floridean starch similar to amylopectin & glycogen.
Cell wall: Cellulose, pectin, polysulphate esters.
Habitat: Fresh water (some), brackish water, salt water (most).
Flagella: Absent.

Reproduction

→ Vegetative: Fragmentation.
→ Asexually: Non motile spores.

Plant Kingdom

→ Sexually: Non motile gametes, oogamous.
E.g: **polysiphonia, Porphyra, Gracilaria, Gelidium.**

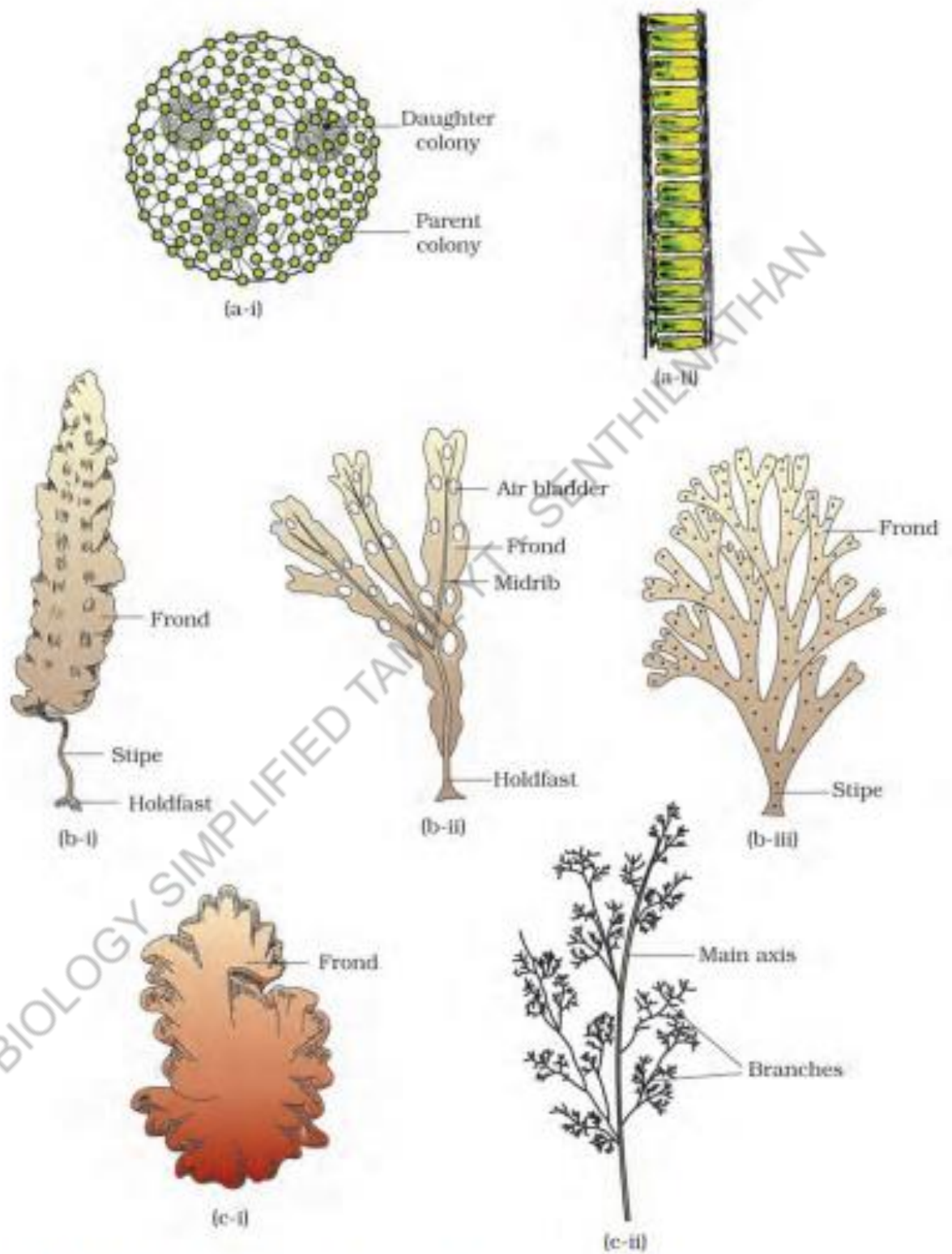


Figure 3.1 Algae : (a) Green algae (i) *Volvox* (ii) *Ulothrix*
(b) Brown algae (i) *Laminaria* (ii) *Fucus* (iii) *Dictyota*
(c) Red algae (i) *Porphyra* (ii) *Polysiphonia*

TABLE 3.1 Divisions of Algae and their Main Characteristics

Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Green algae	Chlorophyll *a, b*	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a, c,* fucoxanthin	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll *a, d,* phycoerythrin	Floridean starch	Cellulose, pectin and poly sulphate esters	Absent	Fresh water (some), brackish water, salt water (most)

BRYOPHYTES: Amphibian of plant kingdom.

- Moist shaded areas in hills, damp, humid, shaded areas.
- Dependent on water for sexual reproduction.
- Important role in plant succession on bare rocks.
- Thallus like, prostrate or erect.
- Attached to sustratum by unicellular or multicellular rhizoids.
- Lack true roots, stem or leaves because vascular bundles are absent.
- **Haploid,** sex organs - multicellular (Jacketed).
- Produces gamete – **Gametophyte.**
- Male sex organs - **antheridium,** produce biflagellated antherozoids.
- Female sex organs - **archegonium** (flask shaped, produce single egg).
- Antherozoids are released in water, fused with egg when come in contact with archegonium and produce zygote.
- Zygote don't undergo reduction division immediately & produce multicellular body – **sporophyte** which is not free - living & attached to photosynthetic gametophyte & derive nourishment (semiparasite). Some of its cell undergo meiosis & produce haploid spores which germinate to give gametophyte.

Economic Importance:

- Some mosses provide food for herbaceous mammals, birds.
- Sphagnum **(moss)** provide peat which is used as fuel and as packing material for trans – shipment of living material due to good water holding capacity so called **Peat Moss.**
- Mosses & lichens are first to colonise rocks.
- Mosses reduce impact of falling rain & soil erosion as they form dense mats on the soil.

1) LIVERWORT: E.g: Marchantia.

- Grow in moist, shady, marshy habitat, bark of trees, woods.
- Thalloid plant body, dorsiventral thallus closely appressed to substrate.
- Tiny leaf like appendages in 2 rows on thallus called scales.

Reproduction:

→ **Asexual:** Fragmentation or by specialised structure – **gemmae.**

Gemmae: Green, multicellular, asexual bud, develop in small receptacle - gemma cups on thalli. Gemmae detach and germinate to form new individual, one gammae produced two new thallus.

→ **Sexual:** Male and female sex organs either on same or different thalli. Sporophyte is differentiated into foot, seta & capsule. After meiosis spores are produced within capsule which germinate to form free living gametophytes.

2) MOSSES: E.g: Funaria, Polytrichum, Sphagnum.

- First stage is protonema which develop directly from spore. Its a creeping, green, branched & frequently filamentous stage.
- Second stage is leafy stage called **Gametophore** which develop from secondary protonema as lateral bud. It has upright, slender axes bearing spirally arranged leaves. It bears sex organs and attached to soil through multicellular & branched rhizoids.

Reproduction:

→ Vegetative - fragmentation & budding in secondary protonema.

→ Sexual - after fertilisation antherozoids and egg cell, produced diploid oospore which develops into sporophyte (foot, seta, capsule) where capsule contains spores which are produced after meiosis.

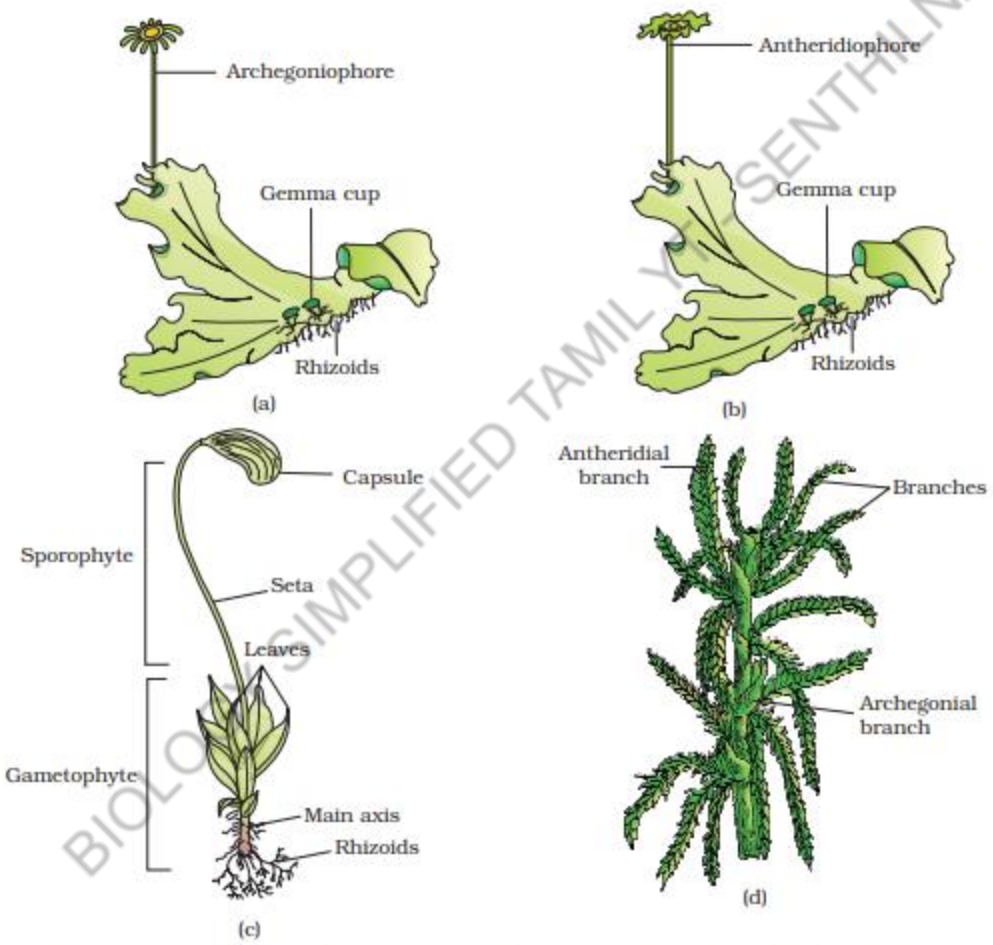


Figure 3.2 Bryophytes: A liverwort – *Marchantia* (a) Female thallus (b) Male thallus Mosses – (c) *Funaria*, gametophyte and sporophyte (d) *Sphagnum* gametophyte

PTERIDOPHYTES:

- Horsetails & ferns.
- Usually for medicinal purpose & soil binders, ornamentals.
- **First terrestrial plants with vascular tissues.**
- Found in cool, damp, shady places.

Plant Kingdom

Figure 3.3 Pteridophytes : (a) *Selaginella* (b) *Equisetum* (c) Fern (d) *Salvinia*

- Main plant body is sporophyte, differentiated into true roots, stem & leaves.
- Leaves can be small **(microphyll) - Selaginella** or large **(macrophyll) – Ferns.**
- Sporophyte bear sporangia subtended by leaf like appendages **sporophylls** which form **strobili or cones (Selaginella, Equisetum).**
- Sporangia produce spores by meiosis which give rise to small, multicellular, free living, photosynthetic thalloid gametophyte - **prothallus** which require specific habitat.
- Water is required for transfer of antherozoids to mouth of archegonium. Fusion results in zygote which produce multicellular sporophyte.
  Homosporous: Same kind of spores. **E.g: Majority.**
  Heterosporous: 2 kinds of spores (micro & macro). **E.g: Selaginella, Salvinia.**
- **Development of zygote into embryo occur within female gametophyte.**
  It is a precursor to seed habit.

Plant Kingdom

GYMNOSPERMS:

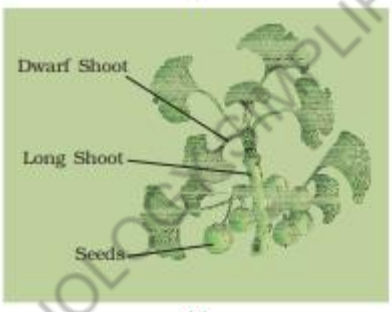
- Naked Seeded Plant.
- Ovules are not enclosed by ovary wall, remain exposed both before & after fertilisation.
- **Sequoia:** Tallest redwood tree (gymnosperm).
- Generally tap root.
- Roots in some species have fungal association (mycorrhiza). **E.g: Pinus** and in some coralloid roots are associated with N_2 fixing cyanobacteria. **E.g: Cycas.**
- Stems are **unbranched in cycas** and **branched in Pinus, Cedrus.**
- Leaves may be simple or compound.
- Pinnate leaves persist for few years in cycas.
- Leaves are adapted to extreme temperature, humidity & wind.
- In conifers, needle like leaf reduce surface area, thick cuticle & sunken stomata reduce water loss.
- **Heterosporous - haploid microspores & megaspores.**
- 2 kinds of spores are produced within sporangia born on sporophyll which are spirally arranged on axis to form strobili or cones.
- Strobili bearing microsporophylls & microsporangia - **male strobili or microsporangiate.** Microspore develop to **male gametophyte (pollen grain)** which is highly reduced & has limited no. of cells.
- Cones bearing megasporophyll or megasporangia – **female strobili or macrosporangiate.**
- Male & female cones may be borne on same tree in **Pinus** & on different trees in **Cycas.**
- Megaspore mother cell is differentiated from one of the cells of nucellus, protected by envelopes & composite structure – ovule.
- Megaspore mother cell divide meiotically to form 4 megaspores.
- One of the megaspore enclosed in megasporangium develops into multicellular female gametophyte that bears 2 or more archegonia.

- **Unlike bryophytes & pteridophytes, male & female gametophytes don't have independent existence in gymnosperms.**
- They remain within sporangia (short lived gametophyte stage).
- Pollen grains are carried by air current & come in contact with ovule on megasporophyll. Pollen tube with male gametes grow towards archegonia & discharge their contents. After fertilisation, zygote develops into embryo & ovules into seeds.

  E.g: **Cycas, Pinus, Ginkgo, Cedrus.**

(a)

(b)



(c)

Figure 3.4 Gymnosperms: (a) *Cycas* (b) *Pinus* (c) *Ginkgo*

ANGIOSPERMS

- Pollen grains & ovules are developed in flowers. Seeds are enclosed in fruits.
- Range from **smallest Wolfia** to **tall trees of Eucalyptus (100 m).**
- Provide food, fodder, fuel, medicines.
- **Dicotyledons** - 2 cotyledons, reticulate venation, tetramerous or pentamerous flowers i.e. 4 or 5 members in each floral whorl.
- **Monocotyledons** - 1 cotyledon, parallel venation, trimerous flowers.
- Male sex organ is stamen, which has slender filament with anther at tip.

(a) (b)

Figure 3.5 Angiosperms : (a) A dicotyledon (b) A monocotyledon

- Within anther, pollen mother cell divide by meiosis to produce microspores which mature to form pollen grains.
- Female sex organ is pistil, consist of ovary base, long slender style, stigma. Inside ovary, ovule is present. Each ovule has megaspore mother cell that undergo meiosis to form 4 haploid megaspores. 3 degenerate & 1 divide to form embryo sac which has 3 celled egg apparatus – **1 egg cell, 2 synergid, 3 antipodals, 2 polar nuclei.**
- Polar nuclei fuse to produce **diploid secondary nucleus.**
- **Pollination -** transfer of pollen grains by wind or other agencies to stigma of pistil.
- Pollen grains germinate & pollen tube grow through tissues of stigma & style & reach ovule & discharge 2 male gamates.
- One fuses with egg cell $\xrightarrow{Syngamy}$ zygote; other fuses with diploid secondary nucleus $\xrightarrow{triple\ fusion}$ triploid primary endosperm nucleus (PEN).
- This is double fertilisation. Zygote develops to embryo & PEN develops into endosperm.

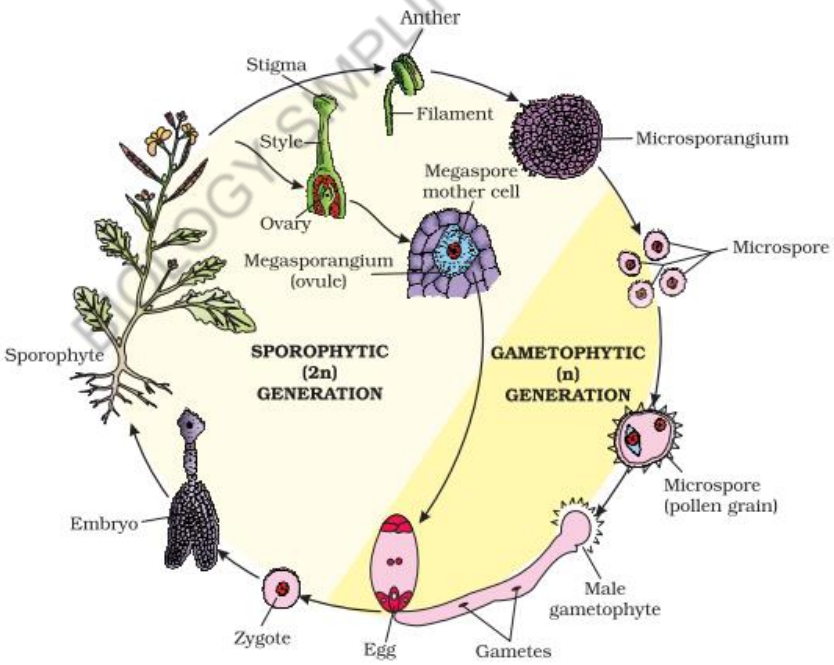


Figure 3.6 Life cycle of an angiosperm

- **Synergids and antipodals degenerate after fertilisation.**
- ovules develop to seeds & ovaries into fruit.

Plant Life Cycle & Alternation of Generations

- In plants, both haploid & diploid cells can divide by mitosis.
- Haploid plant produce gamete be mitosis, following fertilisation. Zygote also divide by mitosis to produce diploid sporophytic plant body. Haploid spores are produced by meiosis, which inturn divide by mitosis to form haploid plant body.
- So there is alternation of generation between gamete producing haploid gametophyte & spore producing diploid sporophyte.

1) Haplontic – E.g: Volvox, Spirogyra, Chlamydomonas.

- Sporophytic generation is represented by 1 celled zygote, no free living sporophyte.
- Dominant phase is free living gametophyte.

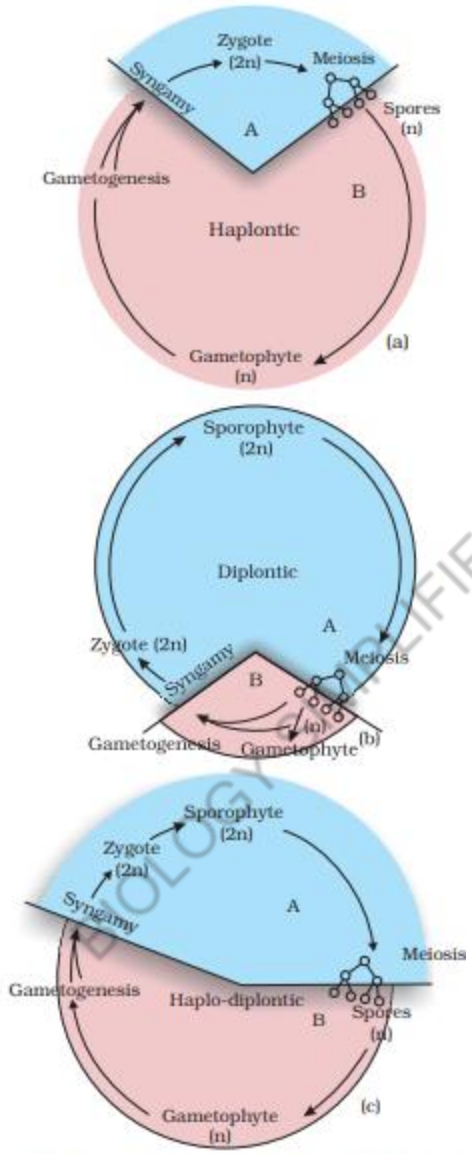


Figure 3.7 Life cycle patterns : (a) Haplontic (b) Diplontic (c) Haplo-diplontic

2) Diplontic – E.g: Fucus, Gymnosperm, Angiosperm.

- Diploid sporophyte is dominant, photosynthetic, independent phase of plant.
- Gametophyte is represented by few celled stage.

3) Haplo – diplontic – E.g: Bryophyte, Pteridophyte.

• Both phases are multicelleluar.

Bryophyte: Dominant, independent, photosynthetic phase is haploid gametophyte, sporophyte is dependent on it for anchorage & nutrition.

Pteridophyte: Dominant is diploid sporophyte, alternate with multicellular, independent but short lived haploid gametophyte.

E.g: Some algae like Ectocarpus, Polysiphonia, Kelps.

Animal Kingdom

Basic of Classification

1) Levels of Organisation:

→ **Cellular:** Loose cell aggregate. **E.g: Sponges.**

→ **Tissue level:** Cell performing same function are arranged. **E.g: Cnidaria and Ctenophora.**

→ **Organ level:** Tissues group to form organ. **E.g: Platyhelminthes.**

→ **Organ system level:** Associated organ. **E.g: Annelida, Arthropoda and all vertebrates.**

Digestive system:

→ **Complete:** 2 openings mouth & anus. **E.g: Aschelminthes to chordata.**

→ **Incomplete:** Single opening acts as both mouth and anus. **E.g: Platyhelminthes, Coelentrata/Cnidaria, Ctenophora.**

Circulatory system: From Annelida to chordata.

→ **Open:** Blood is pumped out & cells are directly bathed in it. **E.g: Arthropoda.**

→ **Closed:** Blood is circulated through vessels of different diameter. **E.g: Annelida and all chordates.**

2) Symmetry:

→ **Assymmetrical:** No plane through centre divides into 2 halves. **E.g: Sponges.**

→ **Radial:** Any plane through centre divides into 2 half. **E.g: Coelentrate, Ctenophore, Echinoderm.**

→ **Bilateral:** Only one plane divides into 2 equal half. **E.g: Annelids, arthropoda etc.**

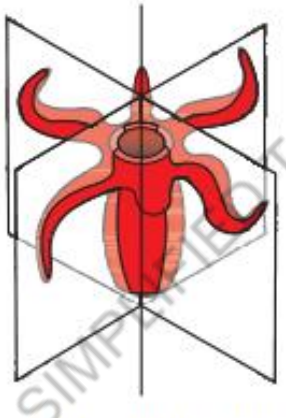


Figure 4.1 (a) Radial symmetry

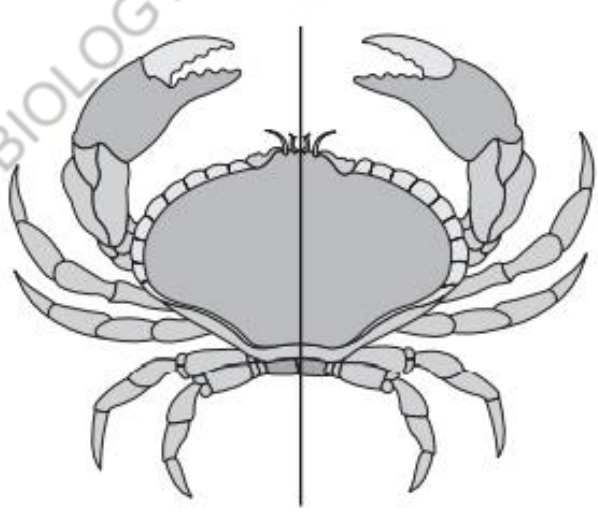


Figure 4.1 (b) Bilateral symmetry

Animal Kingdom

3) Diploblastic & Triploblastic:

→ **Diploblastic:** Cells are arranged in 2 embryonic layers, external ectoderm & internal endoderm. Undifferentiated **mesoglea** is present between them. **E.g: Coelentrates.**

→ **Triploblastic:** Developing embryo has third germinal layer - **mesoderm** in between ectoderm & endoderm. **E.g: Platyhelminthes to Chordates.**

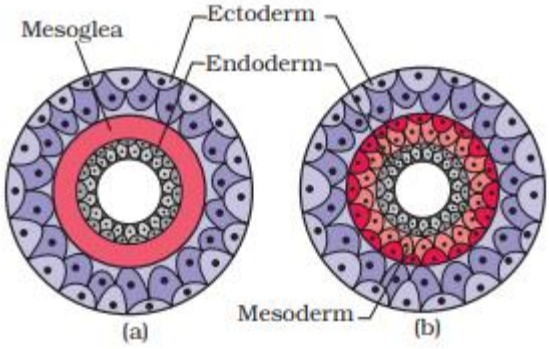


Figure 4.2 Showing germinal layers : (a) Diploblastic (b) Triploblastic

4) Coelom: Body cavity lined by mesoderm on both sides.

→ **Coelomates:** Possess coelom. **E.g: Annelids, Molluscs to Chordates.**

→ **Pseudocoelomates:** Mesoderm as scattered pouch. **E.g: Aschelminthes.**

→ **Acoelomates:** Body cavity is absent. **E.g: Platyhelminthes.**

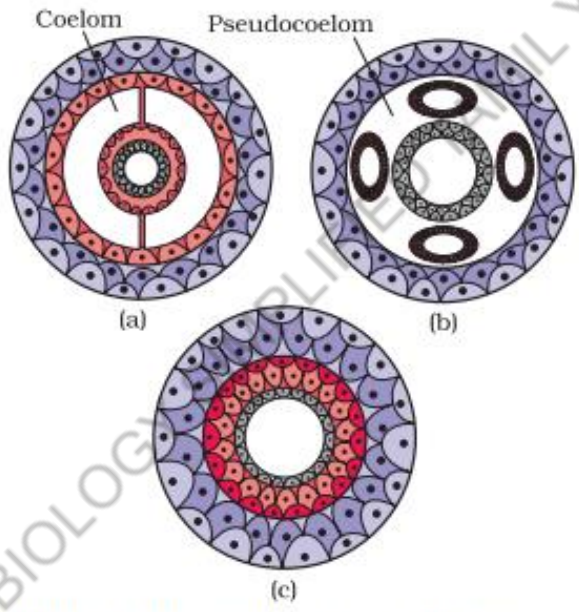


Figure 4.3 Diagrammatic sectional view of : (a) Coelomate (b) Pseudocoelomate (c) Acoelomate

5) Segmentation:

→ External & internal division in segments with serial repetition.
E.g: Earthworm show metamerism (metameric segmentation)/**true segmentation** and **false segmentation** found in tapeworm.

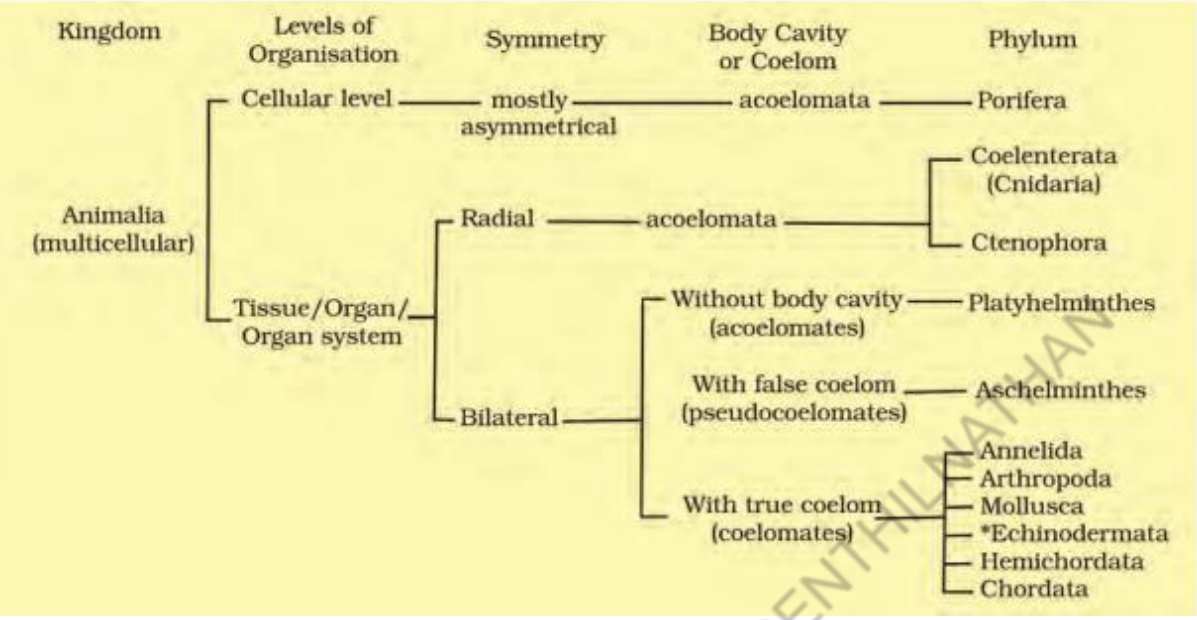
6) Notochord: Mesodermally derived rod like structure on dorsal side.

→ **Animals with notochord:** Chordates.

→ **Animals without notochord:** Non chordate. **E.g: Porifera to Echinoderms.**

Animal Kingdom

Classification of Animals:



1) Phylum – Porifera: (Sponges)

- Generally marine, assymmetric, cellular level organisation.
- Multicellular with **water transport or canal system.**
- Water enters through minute pores **(ostia)** in body wall into **spongocoel,** where it goes out through **osculum.**
- It helps in food gathering, respiration & excretion.
- **Choanocyte (collar cell)** line spongocoel, helps in **intracellular digestion.**
- Skeleton is made up of spicules or spongin fibres.
- Sexes aren't separate **(hermaphrodite)**, digestive system absent.
- Internal fertilisation & indirect development (larval stage).

E.g: Sycon (scypha), Spongilla (fresh water sponge), Euspongia (Bath sponge).

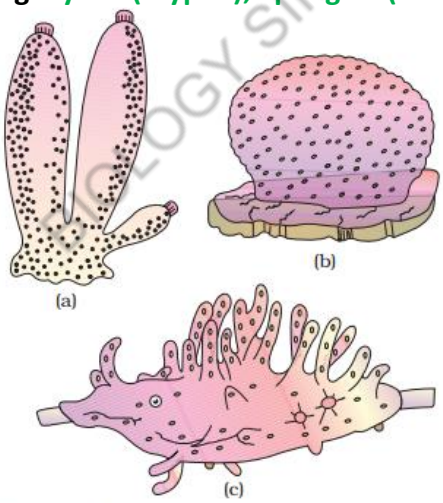


Figure 4.5 Examples of Porifera : (a) *Sycon* (b) *Euspongia* (c) *Spongilla*

Animal Kingdom

2) Phylum – Coelentrata: (Cnidaria)

- Aquatic, mostly marine, radial symmetry, diploblastic, tissue level of organisation.
- **Cnidoblast/cnidocytes -** Contain stinging capsules or nematocysts on tentacles, used for anchorage, defense & capturing prey.
- Have central gastro vascular cavity with single opening mouth on **hypostome,** extracellular & intracellular digestion takes place.
- Corals have $CaCO_3$ skeleton.
- **Exhibit 2 forms –**
  Polyp - Sessile, cylindrical. **E.g: Hydra, Adamsia** etc.
  Medusa - Umbrella shaped, free living. **E.g: Aurelia, Jelly Fish** etc.
- **Species existing in both forms - Metagenesis .i.e.** Polyp produce medusae asexually & medusae form polyp sexually. **E.g: Obelia.**
  E.g: Physalia (Portuguese man of war), Adamsia (Sea anemone), Pennatula (Sea pen), Gorgonia (Sea fan), Meandrina (Brain coral).

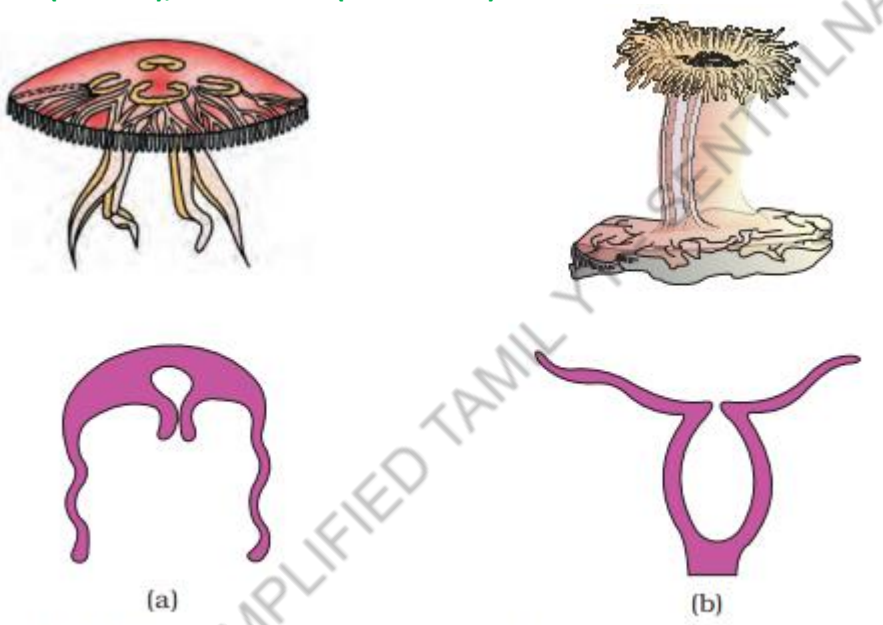


Figure 4.6 Examples of Coelenterata indicating outline of their body form : (a) *Aurelia* (Medusa) (b) *Adamsia* (Polyp)

Figure 4.7
Diagrammatic view of Cnidoblast

3) Phylum – Ctenophora: (sea walnuts/comb jellies)

- Exclusively marine, radial symmetry, diploblastic, tissue level of organisation.
- 8 external rows of ciliated comb plates (locomotion).

- Intracellular & extracellular digestion.
- Bioluminescence (property of living organism to emit light).
- Sexual reproduction, hermaphrodite, external fertilisation with indirect development.

E.g: **Pleurobrachia & Ctenoplana.**

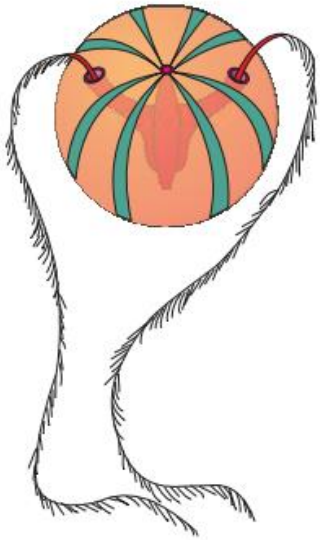


Figure 4.8 Example of Ctenophora (*Pleurobrachia*)

4) Phylum – Platyhelminthes:

- Dorso ventrally flattened → flatworms.
- **Endoparasites & free living,** bilateral symmetry, triploblastic, acelomate, organ level.
- Hooks & suckers to absorb nutrient from host & for attachment.
- Flame cells help in osmoregulation & excretion.
- Hermaphrodite, internal fertilisation, indirect development.
- **Planaria -** High regeneration capacity.

E.g: **Taenia (Tapeworm), Fasciola (Liver Fluke).**

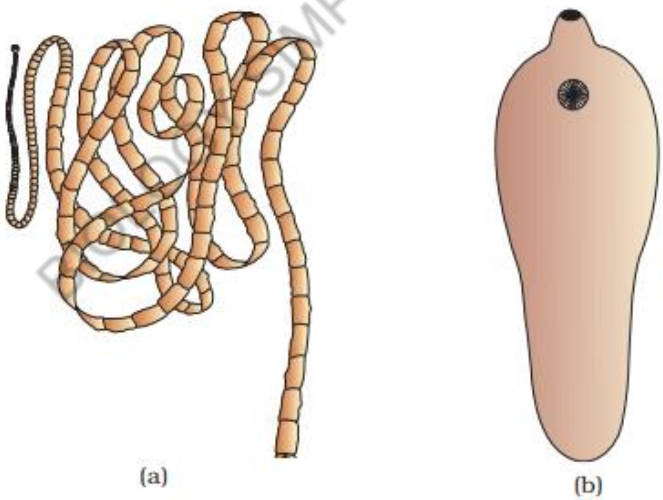


Figure 4.9 Examples of Platyhelminthes : (a) Tape worm (b) Liver fluke

5) Phylum – Aschelminthes:

- Circular body in cross section → Roundworm.
- May be free living, aquatic or terrestrial or parasitic.

Animal Kingdom

- Organ system level, bilateral symmetry, triploblastic, pseudocoelomate, dioecious **(separate sex).**
- Complete digestive system with well developed muscular pharynx.
- **Often females are longer than males, sexual dimorphism is clearly seen.**
- Internal fertilisation, direct development or indirect.

E.g: Ascaris (Round worm), Wuchereria (Filarial worm), Ancylostoma (Hookworm).

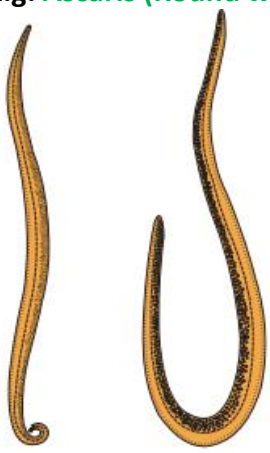


Figure 4.10 Example of Aschelminthes: Roundworm

6) Phylum – Annelida:

- May be aquatic or terrestrial, free living or parasitic.
- Organ system level, bilateral symmetry, triploblastic, coelomate, metamerically segmented, has **metameres (segment).**
- Possess longitudinal & circular muscles for locomotion.
- **Aquatic annelids** like **Nereis** possess lateral appendages, **parapodia** which help in swimming, dioecious (unisexual).
- Closed circulatory system, earthworm & leech - **monoecious (Hermaphrodite).**
- **Nephridia** for osmoregulation & excretion.
- Paired ganglia connected by lateral nerves to double ventral nerve cord.

E.g: Nereis, Pheretima (Earthworm), Hirudinaria (Blood sucking leech).

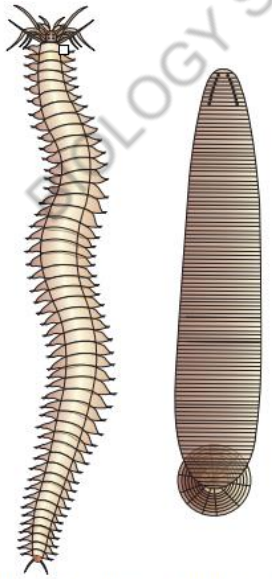


Figure 4.11 Examples of Annelida : (a) *Nereis* (b) *Hirudinaria*

Animal Kingdom

7) Phylum - Arthropoda (Insects)

- **Largest phylum** (2 – 3rd of all species on earth).
- Organ system level, bilateral symmetry, triploblastic, coelomate.
- **Segmented, chitinous exoskeleton,** open circulatory system.
- Body consist of head, thorax & abdomen, have jointed appendages.
- Respiratory organs - gills, book gills, book lungs or tracheal system.
- Sensory organs - **antennae, eyes (compound & simple), statocysts or balancing organ.**
- Excretion through **malpighian tubules,** dioecious, oviparous.
- Internal fertilisation, direct or indirect development.

E.g: **Economically important - Apis (Honey bee), Bombyx (silkworm), Laccifer (lac insect),**
Vectors - Anopheles, culex & Aedes (Mosquito),
Gregarious pest - Locusta (Locust),
Living fossil - Limulus (King crab).

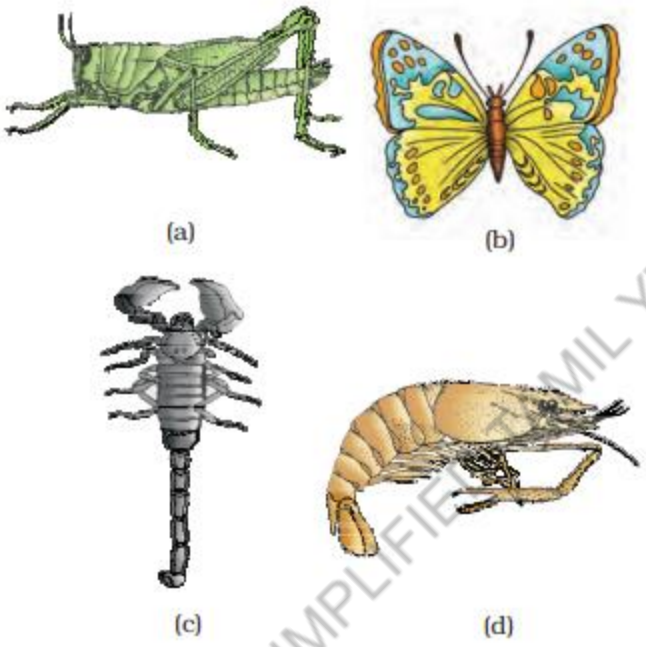


Figure 4.12 Examples of Arthropoda :
(a) Locust (b) Butterfly
(c) Scorpion (d) Prawn

8) Phylum – Mollusca:

- Second largest animal phylum.
- Terrestrial or aquatic, organ system level, bilateral symmetry.
- Triploblastic, coelomate, dioecious, oviparous, indirect development.
- **Calcareous shell, unsegmented** with **head, muscular foot, visceral hump .**
- Soft & spongy layer of skin forms mantle over hump.
- **Mantle cavity** - space between hump & mantle, gills are present.
- Anterior head has sensory tentacles.
- **Radula** – file like rasping organ for feeding in mouth .

E.g: **Pila (Apple Snail), Pinctada (Pearl Oyster), Sepia (cuttle fish), Loligo (Squid), Octopus (Devil fish), Aplysia (Sea hare), Dentalium (Tusk shell), Chaetopleura (Chiton).**

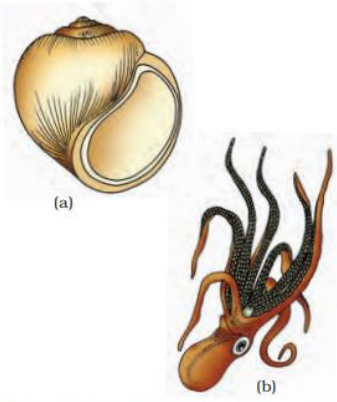


Figure 4.13 Examples of Mollusca : (a) *Pila* (b) *Octopus*

9) Phylum – Echinodermata:

- Exclusively marine, organ system level, triploblastic, coelomate, dioecious.
- **Calcareous endoskeleton,** excretory system absent.
- Adult - **radial symmetry,** larva - **bilateral symmetry.**
- Complete digestive system with mouth on ventral (lower) & anus on dorsal.
- Distinctive feature - **water vascular system** (locomotion, respiration, capture & transport of food).
- External fertilisation, indirect development.

E.g: Asterias (Star fish), Echinus (Sea urchin), Antedon (Sea lily), Cucumaria (Sea cucumber), Ophiura (Brittle star).

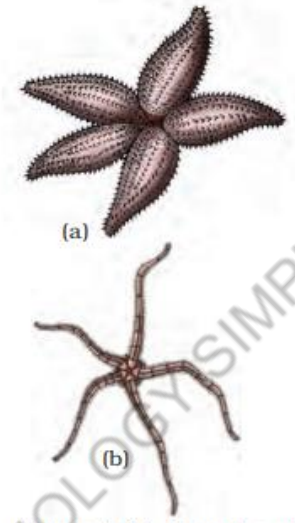


Figure 4.14 Examples of Echinodermata : (a) *Asterias* (b) *Ophiura*

10) Phylum – Hemichordata: (Worm like marine animals)

- Organ system level, bilateral symmetry, triploblastic, coelomate.
- **Stomochord -** Rudimentary structure in collar region, similar to notochord.
- Cylindrical body with proboscis, collar & trunk.
- Open circulatory system, **excretion - proboscis gland.**
- Gills for repriration, dioecious, external fertilisation, indirect development.

E.g: Balanoglossus & Saccoglossus.

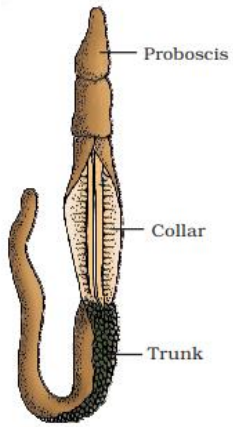


Figure 4.15 *Balanoglossus*

11) Phylum – Chordata: Segmented

• Bilateral symmetry, triploblastic, coelomate, organ system level.

TABLE 4.1 Comparison of Chordates and Non-chordates

S.No.	Chordates	Non-chordates
1.	Notochord present.	Notochord absent.
2.	Central nervous system is dorsal, hollow and single.	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 part (tail) is present.	Post-anal tail is absent.

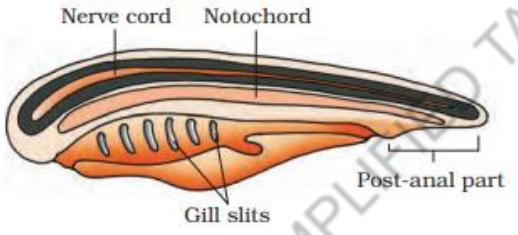


Figure 4.16 Chordata characteristics

• **Chordata is divided into three subphyla: Urochordata or Tunicata, Cephalochordata and Vertebrata.**

• Subphyla Urochordata and Cephalochordata are often referred to as **protochordates** and are **exclusively marine.**

i) Urochordata – Notochord only in larval tail. **E.g: Ascidia, salpa, Doliolum.**

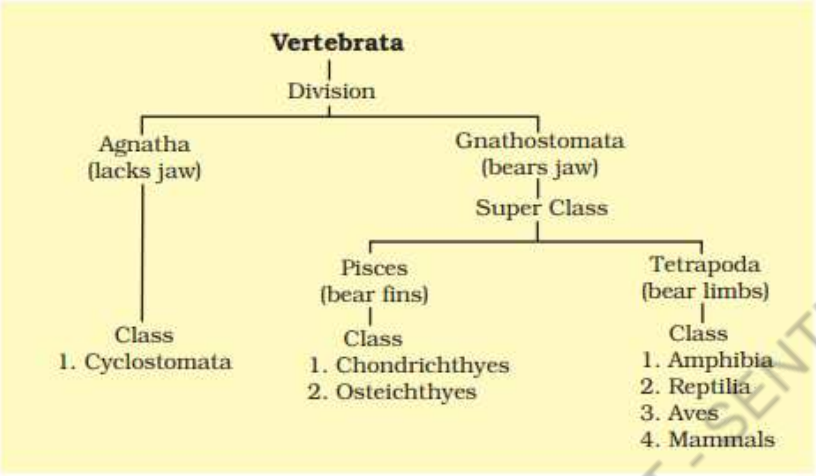
Figure 4.17 *Ascidia*

ii) Cephalochordata – Persistent notochord from head to tail. **E.g: Branchiostoma** (Amphioxous or Lancelet)**.**

iii) Vertebrata – Notochord during embryonic period.

- **Notochord is replaced by cartilagenous or bony vertebral column in adult.**
- **All vertebrates are chordates but all chordates are not – vertebrate.**
- Vertebrates have 2, 3 or 4 chamber ventral muscular heart, kidney for excretion & osmoregulation, paired appendages.

The subphylum Vertebrata is further divided as follows:



a) Class – Cyclostomata:

- Some are endoparasite on fish, elongated body.
- 6 - 15 pairs of gill slits, sucking & circular mouth without jaws.
- No scales, paired fins, closed circulation.
- **Cartilagenous cranium & vertebral column.**
- Marine but migrate to fresh water for spawning, then die.
- Larva after metamorphosis return to ocean.

E.g: Petromyzon (Lamprey) & Myxine (Hag fish)

Figure 4.18 A jawless vertebrate - *Petromyzon*

b) Class – Chondrichthyes:

- Marine with stream lined body, **cartilagenous endoskeleton,** dioecious.
- Persistent notochord, **ventral mouth**, tough skin, **placoid scales.**
- Separate gill slits **without operculum, powerful jaws.**
- Teeth are modified scales, predaceous, 2 chamber heart (one auricle & one ventricle).
- **Air bladder absent,** poikilothermous (cold blooded).
- Some have **electric organ (E.g: Torpedo)** & some posess **poison sting (E.g: Trygon).**
- **Pelvic fins bear claspers in males.**
- Internal fertilisation, **viviparous**.

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

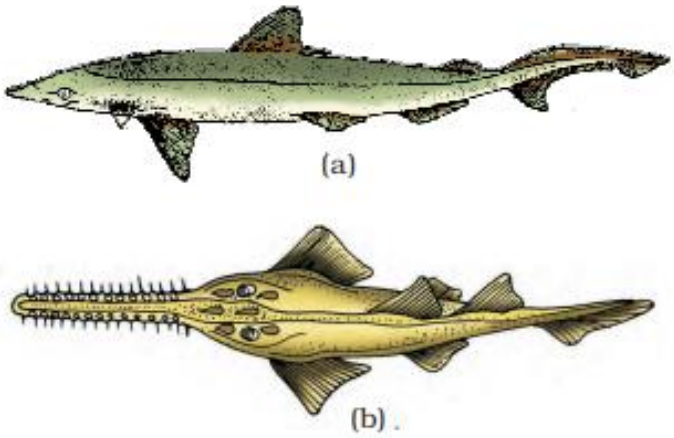


Figure 4.19 Example of Cartilaginous fishes : (a) *Scoliodon* (b) *Pristis*

c) Class – Osteichthyes:

- Marine & fresh water, **bony endoskeleton,** streamlined body.
- **Terminal mouth,** 4 pair gills **with operculum, cycloid scales.**
- **Air bladder present** (buoyancy), 2 chamber heart, cold blooded (Poikilothermic).
- Dioecious, external fertilisation, direct development, oviparous.

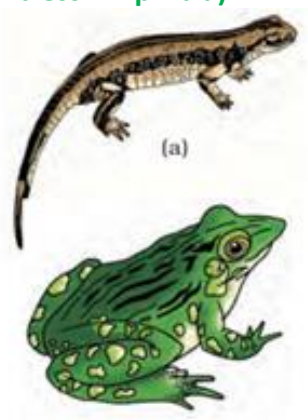
E.g: **Marine - Exocoetus (Flying fish), Hippocampus (Sea horse).**
Freshwater - Labeo (Rohu), Catla (Katla), Clarias (Magur).
Aquarium - Betta (Fighting Fish), Pterophyllum (Angel Fish).

Figure 4.20 Examples of Bony fishes : (a) *Hippocampus* (b) *Catla*

d) Class – Amphibia: Aquatic + terrestrial.

- 2 pair limbs, body - head + trunk, tail may be present, neck absent.
- **Moist skin without scales,** eyelids present, tympanum represent ear.
- Respiration by gills, lungs, skin, 3 chamber heart, dioecious.
- External fertilisation, indirect development, oviparous.

- **Cloaca –** common chamber for alimentary canal, urinary & reproductive tract which opens to exterior.
  E.g: Bufo (Toad), Rana (Frog), Hyla (Tree frog), Salamandra (Salamander), Ichthyophis (Limbless Amphibia).



a) Salamandra & b) Rana

e) Class – Reptilia: Creeping or crawling locomotion .

- **Terrestrial, dry cornified skin with epidermal scales or scutes.**
- Tympanum represent ear, 2 pair of limb if present.
- 3 chambered heart but 4 chambered in crocodiles.
- Poikilothermous, dioecious, internal fertilisation, oviparous.
- Direct development, snakes & lizard shed their scales.

  E.g: Chelone (Turtle), Testudo (Tortoise), Chameleon (Tree Lizard), Calotes (Garden Lizard), Crocodilus (crocodile), Alligator (Alligator), Hemidactylus (Wall Lizard).
  Poisonous – Naja (Cobra), Bangarus (Krait), Vipera (Viper).

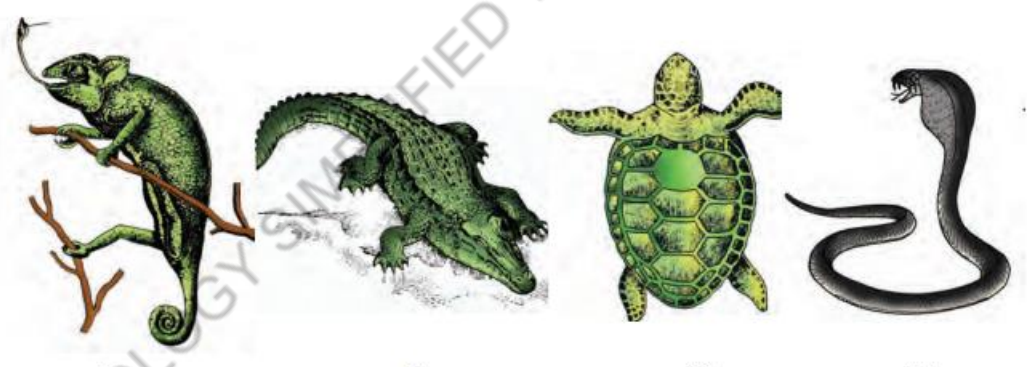


Figure 4.22 Reptiles: (a) *Chameleon* (b) *Crocodilus* (c) *Chelone* (d) *Naja*

f) Class – Aves:

- Feathers present, beak present, forelimbs modified to wings.
- Hind limbs have scales, help in walking, swimming etc.
- Flightless bird, **E.g: Ostrich,** 4 chambered heart.
- **Dry skin without glands** (except oil gland at tail base).
- Bony endoskeleton, hollow with air cavity **(pneumatic)**.
- Digestive tract have **crop & gizzard,** dioecious.
- Warm blooded (homoiothermous) - maintain constant body temperature.
- Respiration by lungs, supplemented by air sacs.
- Internal fertilisation, direct development, **oviparous**.

E.g: **Corvus (Crow), Columba (Pigeon), Psittacula (Parrot), Pavo (Peacock), Struthio (Ostritch) , Aptenodytes (Penguin), Neophron (Vulture).**

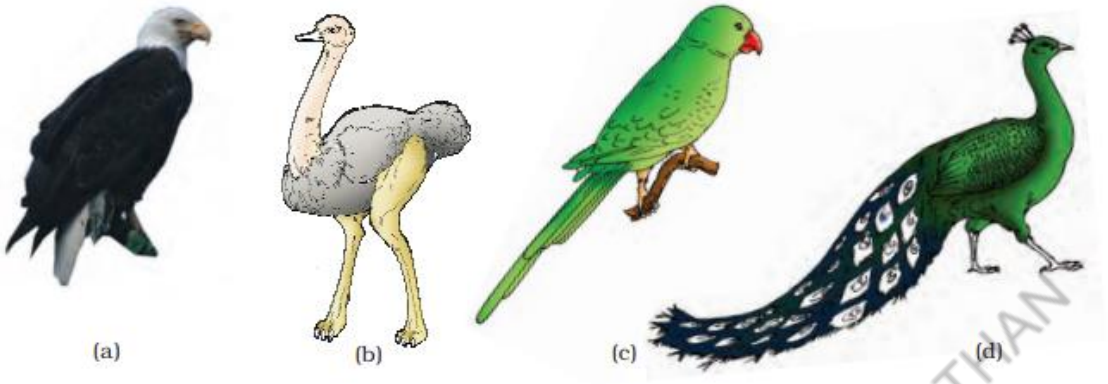


Figure 4.23 Some birds : (a) *Neophron* (b) *Struthio* (c) *Psittacula* (d) *Pavo*

g) Class – Mammalia:

- Found in ice caps, desert, mountain, forest, caves, grassland.
- Milk producing glands (mammary gland) to nourish young ones.
- 2 pair of limbs for walking, running, burrowing, flying etc.
- Hair on skin, external ear **(Pinnae)** present.
- 4 chambered heart, warm blooded, different types of teeth.
- Respiration by lungs, dioecious, internal fertilisation.
- Direct development, **viviparous with exception.**

E.g: **Oviparous** - **Ornithorhynchus (Platypus)**,
Viviparous - **Macropus (Kangaroo), Pteropus (Flying fox), Camelus (Camel), Macaca (Monkey), Rattus (Rat), Canis (Dog), Felis (Cat), Elephas (Elephant), Equus (Horse), Delphinus (Dolphin), Balaenoptera (Blue Whale), Panthera tigris (Tiger), Panthera Leo (Lion).**

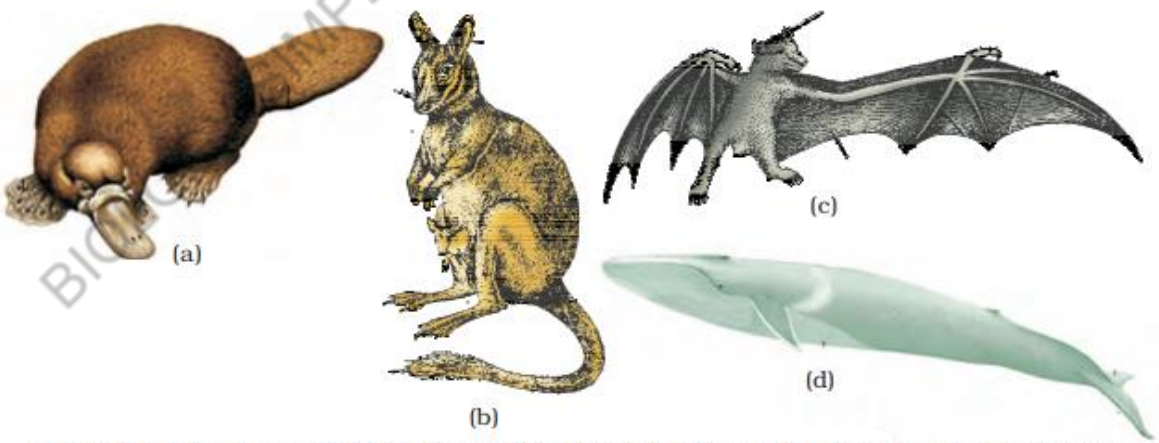


Figure 4.24 Some mammals : (a) *Ornithorhynchus* (b) *Macropus* (c) *Pteropus* (d) *Balaenoptera*

Some Features:

Segmentation: Annelida, Arthropoda & Chordata.
Digestive system: Aschelminthes to Chordata.
Circulatory system: Annelida to Chordata.
Respiratory system: Arthropoda to Chordata.

Animal Kingdom

TABLE 4.2 Salient Features of Different Phyla in the Animal Kingdom

Phylum	Level of Organisation	Symmetry	Coelom	Segmentation	Digestive System	Circulatory System	Respiratory System	Distinctive Features
Porifera	Cellular	Various	Absent	Absent	Absent	Absent	Absent	Body with pores and canals in walls.
Coelenterata (Cnidaria)	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Cnidoblasts present.
Ctenophora	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Comb plates for locomotion.
Platyhelminthes	Organ & Organsystem	Bilateral	Absent	Absent	Incomplete	Absent	Absent	Flat body, suckers.
Aschelminthes	Organsystem	Bilateral	Pseudo coelomate	Absent	Complete	Absent	Absent	Often worm-shaped, elongated.
Annelida	Organsystem	Bilateral	Coelomate	Present	Complete	Present	Absent	Body segmentation like rings.
Arthropoda	Organsystem	Bilateral	Coelomate	Present	Complete	Present	Present	Exoskeleton of cuticle, jointed appendages.
Mollusca	Organsystem	Bilateral	Coelomate	Absent	Complete	Present	Present	External skeleton of shell usually present.
Echinodermata	Organsystem	Radial	Coelomate	Absent	Complete	Present	Present	Water vascular system, radial symmetry.
Hemichordata	Organsystem	Bilateral	Coelomate	Absent	Complete	Present	Present	Worm-like with proboscis, collar and trunk.
Chordata	Organsystem	Bilateral	Coelomate	Present	Complete	Present	Present	Notochord, dorsal hollow nerve cord, gill slits with limbs or fins.

Morphology of Flowering Plants

Morphology:

• External structure study.

The Root:

• Direct elongation of radicle - primary root which grow inside soil, **positively geotropic.**
• Lateral roots of primary root - secondary, tertiary etc. roots.
• Water absorption, proper anchorage to plant parts, storing reserve food material, synthesis of plant growth regulator, mineral absorption.

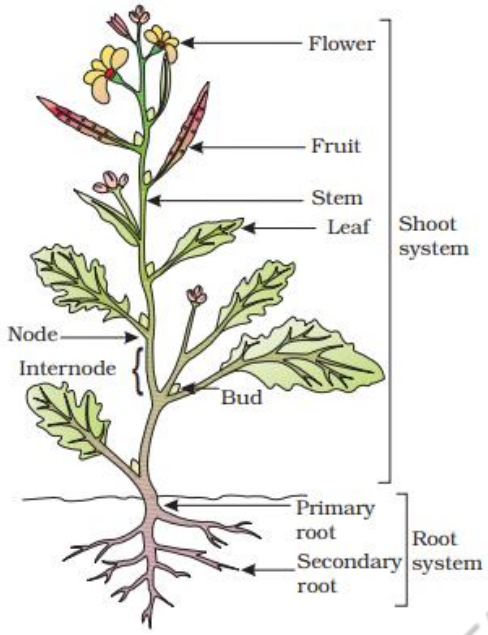


Figure 5.1 Parts of a flowering plant

1) Tap root system: Primary roots & its branches. **E.g: Mustard.**
2) Fibrous root system: Roots originating from base of stem. **E.g: Wheat.**
3) Adventitious roots: Roots arising from parts other than radicle. **E.g: Grass, monstera, banyan.**

• **In monocots, primary root is short lived & replaced by large number of fibrous roots.**

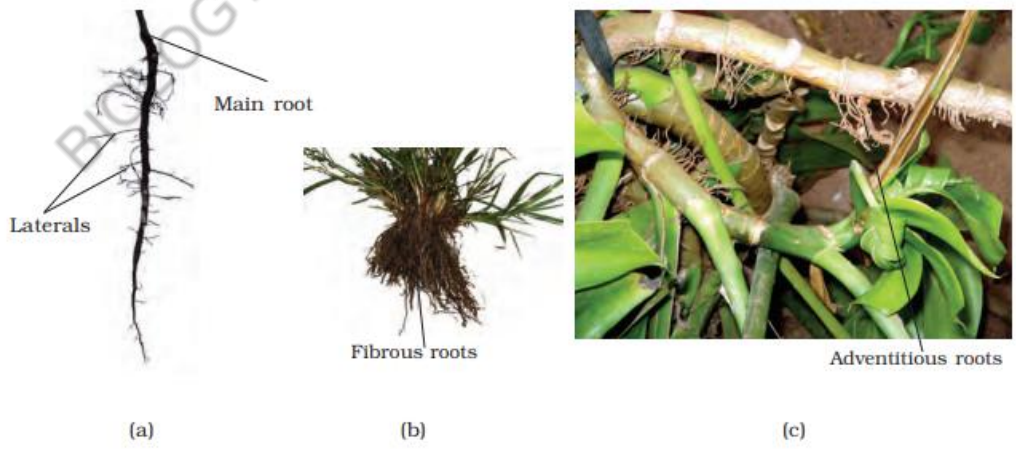


Figure 5.2 Different types of roots : (a) Tap (b) Fibrous (c) Adventitious

Morphology of Flowering Plants

Regions of the Root:

• Root is covered by thimble like structure at apex - root cap. (Protects tender apex of roots)

1) Meristematic region: Few millimetre above root cap, divide rapidly, small, thin walled cell with dense protoplasm.

2) Elongation region: Cells undergo rapid elongation & enlargement, help in growth of root in length.

3) Maturation region: Epidermal cells form fine, delicate, thread like structure - root hairs (absorb water & minerals).

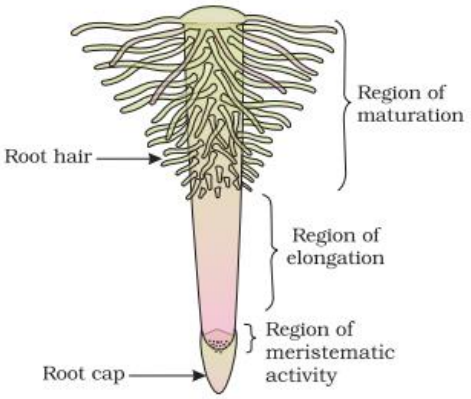


Figure 5.3 The regions of the root-tip

Modification of Root –

• To perform more functions.

1) Storage: **Tap root of carrot, turnip; adventitious roots of sweet potato; asparagus.**

2) Prop: Roots become hanging structure to support tree. **E.g: Banyan**

3) Stilt: Supporting roots come out of lower nodes of stem. **E.g: Sugarcane, maize.**

4) Pneumatophores: Roots come out of ground & grow vertically upwards, swampy areas, help to get O_2 for respiration. They are positively phototropic and also called **respiratory roots.** **E.g: Rhizophora.**

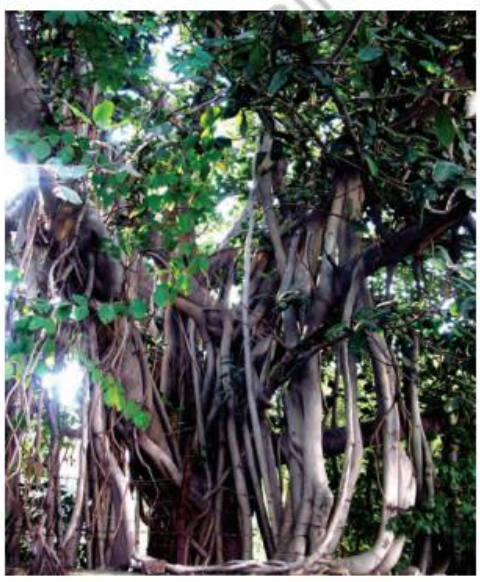


Figure 5.4 Modification of root for support: Banyan tree

Morphology of Flowering Plants

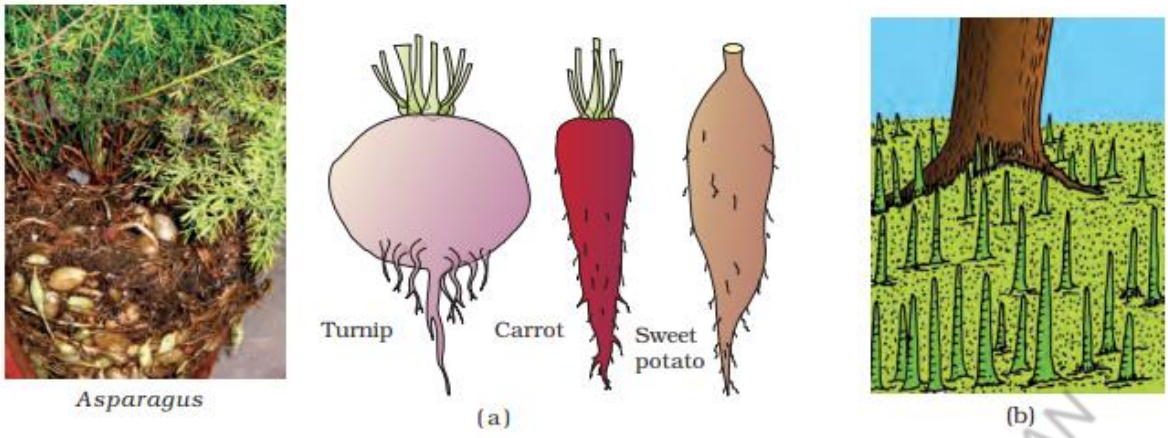


Figure 5.5 Modification of root for: (a) storage (b) respiration: pneumatophore in *Rhizophora*

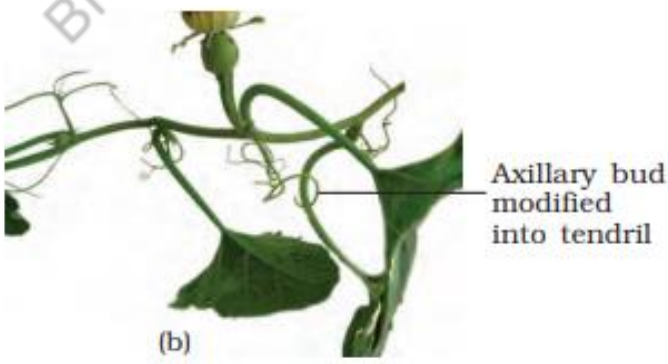
The Stem:

- Positively phototropic.
- Ascending part of axis bearing branches, leaves, flowers & fruits.
- Develops from plumule of embryo of germinating seed.
- Region of stem where leaves are born – nodes.
- Space between 2 nodes – internode.
- Green when young & later become woody & dark brown.
- Conducts water, mineral & photosynthates (when green).

Modifications of Stem:

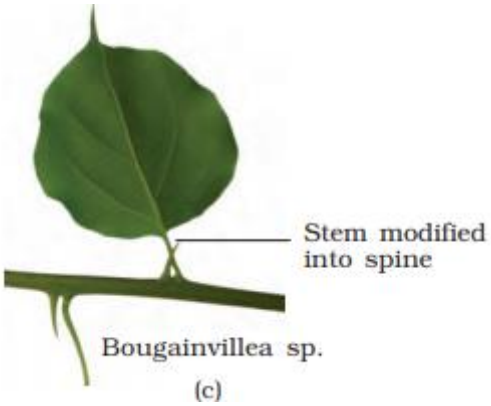
1) Storage: Underground stem of **potato, ginger, turmeric, zaminkand, colocasia;** organ of perennation in unfavourable condition.

2) Tendrils: Develop from axillary buds, spiral, slender, help plants to climb. **E.g: Gourds (cucumber, pumpkin, watermelon), grapevine.**

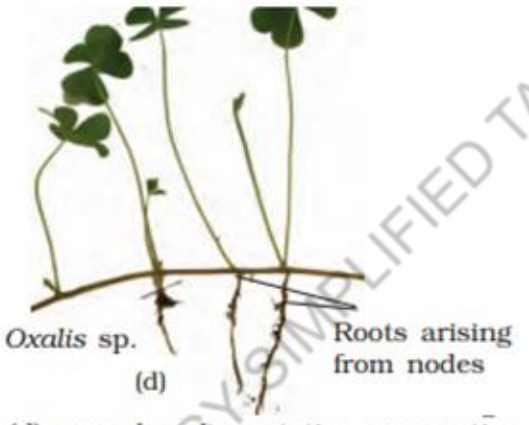


3) Thorns: Axillary buds modify into woody, straight, pointed structure. **E.g: Citrus & Bougainvillea; protect from browsing animals.**

Morphology of Flowering Plants



4) **Runner:** Lateral branches originate from basal & underground portion of main stem, grow horizontally beneath soil, come out obliquely upward. **E.g: Banana, Chrysanthemum, pineapple.**
5) In arid region, stems are modified to flattened (**E.g: Opuntia** called **phylloclade**) or fleshy. (**E.g: Euphorbia**) structure which contain chlorophyll.
6) Underground stem spread to new niches & when older die, new arise. **E.g: Grass, strawberry.**
7) Lateral branch arise from base of main axis, arch downward after growing aerially to touch the ground. **E.g: Mint, jasmine.**
8) Lateral branch with short internode & each node bearing rosette of leaves & tuft of roots are found in aquatic plants. **E.g: Pistia & Eichhornia (water hyacinth).**



(d) spread and vegetative propagation

The leaf:

- Lateral, flattened, develops at node, bears bud in axil.
- Axillary bud develops into branch.
- Originate from shoot apical meristem as lateral outgrowth, acropetal order.

Parts of Leaf:

→ **Lamina/Leaf blade:** Green expanded part with vein & veinlets.
→ **Petiole:** Hold blade to light, allow leaf blade to flutter, cools leaf, brings fresh air to surface.
→ **Leaf base:** Attached to stem, may bear 2 small leaf like structure **(Stipules)**. In legumes, its swollen **(Pulvinus).** In monocots, it expands into sheath covering stem.

Midrib: Middle prominent vein.
Veins: Provide rigidity to leaf, transport water, minerals.
Venation: Arrangement of veins & veinlets in lamina.

Morphology of Flowering Plants

1) Reticulate: Veinlets form network. **E.g: Dicots.**
2) Parallel: Veinlets run parallel within lamina. **E.g: Monocots.**

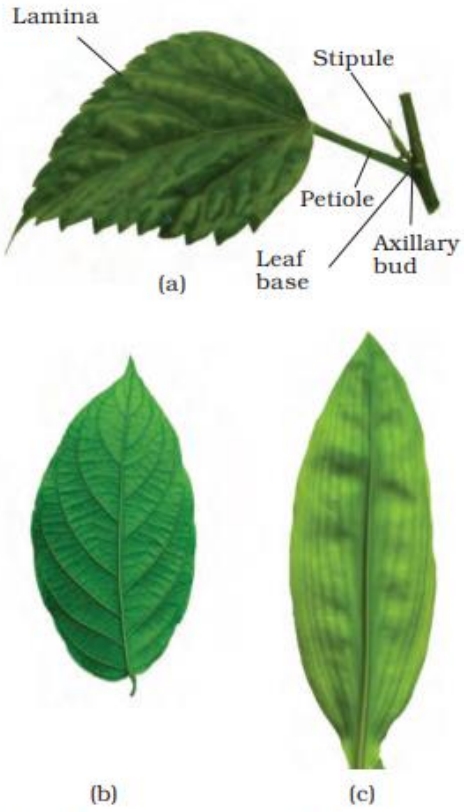


Figure 5.7 Structure of a leaf :
(a) Parts of a leaf
(b) Reticulate venation
(c) Parallel venation

Types of Leaves:

→ **Simple:** Incisions don't touch the midrib.
→ **Compound:** Incisions reach midrib breaking into no. of leaflets.
Pinnately - No. of leaflets on common axis **(rachis)**. **E.g: Neem.**
Palmately - leaflets attached to common point (tip of petiole). **E.g: Silk cotton.**
* **Bud is present in axil of petiole in both simple & compound leaf but not in axil of leaflets of compound leaf.**

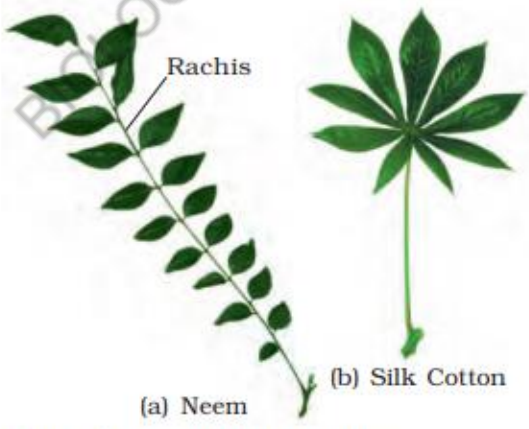


Figure 5.8 Compound leaves :
(a) pinnately compound leaf
(b) palmately compound leaf

Morphology of Flowering Plants

Phyllotaxy: Pattern of arrangement of leaves on stem.

1) Alternate: Single leaf at each node in alternate manner.
E.g: China Rose, mustard, sunflower.

2) Opposite: Pair of leaves at each node & opposite to each other.
E.g: Calotropis, guava.

3) Whorled: More than 2 leaves at node, form whorl. **E.g: Alstonia.**

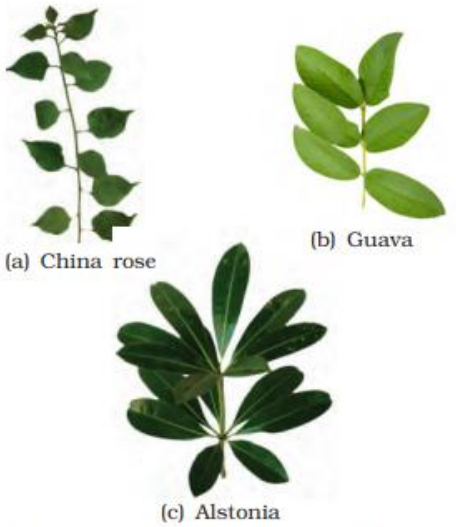


Figure 5.9 Different types of phyllotaxy : (a) Alternate (b) Opposite (c) Whorled

Modification of Leaves:

1) Tendril: Climbing. **E.g: Peas.**

2) Spines: Defense. **E.g: Cacti, Bougainvillea.**

3) Bulb: Fleshy leaves of **onion & garlic.**

4) Insectivorous: Pitcher plant, venus fly trap.

*** Australian Acacia - small & short lived leaves & petiole is modified into leaf called phyllode.**

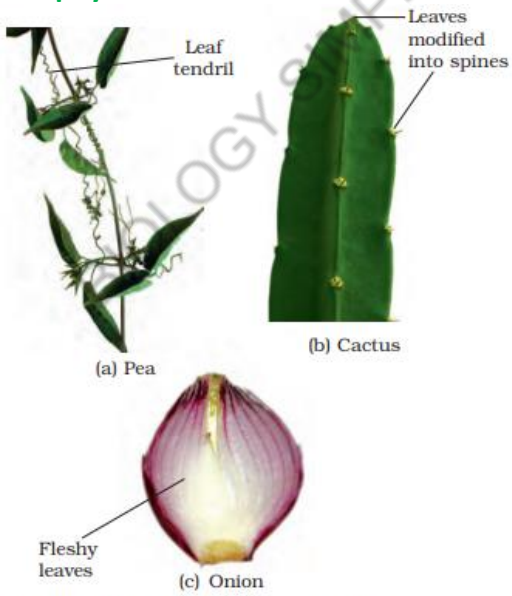


Figure 5.10 Modifications of leaf for : (a) support: tendril (b) protection: spines (c) storage: fleshy leaves

Morphology of Flowering Plants

The Inflorescence:

• Arrangement of flowers on floral axis.

*** When shoot tip transforms into flower its solitary.**

1) Racemose: Main axis continue to grow, flowers in **acropetal** succession.

2) Cymose: Main axis terminates in flower, limited growth, **basipetal** order.

Figure 5.11 Racemose inflorescence

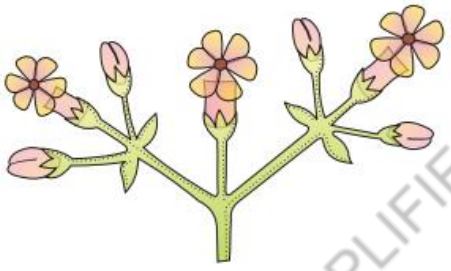


Figure 5.12 Cymose inflorescence

The flower:

• Reproductive unit in angiosperms.

• 4 whorls on swollen end of stalk **(pedicel)** called **thalamus or receptacle.**

• **Accessory organ -** calyx & corolla.

• **Reproductive organ -** Androecium & gynoecium.

• If calyx & corolla aren't distinct - **Perianth. E.g: lily.**

1) Sex :

• **Bisexual -** Both androecium & gynoecium in 1 flower.

• **Unisexual -** Either stamen or only carpel.

2) Symmetry:

• **Actinomorphic -** 2 equal half from any plane → through centre. **E.g: Mustard, chilli, datura.**

• **Zygomorphic -** 2 similar half from 1 plane. **E.g: Gulmohar, Pea, bean, cassia.**

• **Assymmetric -** Can't be divided into 2 equal half. **E.g: Canna.**

3) Floral appendages:

• Trimerous - multiple of 3

• Tetramerous - multiple of 4
• Pentamerous - multiple of 5

4) Bracts:

• Reduced leaf at base of pedicel (floral axis).
• With Bracts - Bracteate, without Bracts – ebracteate.

5) Position of calyx, corolla & androecium with respect to ovary:

i) **Hypogynous:** Highest position of gynoecium, other parts below it, **superior ovary**.
E.g: China rose, brinjal, mustard.

ii) **Perigynous:** Gynoecium in centre & other parts on rim of thalamus, **half inferior ovary.**
E.g: Plum, rose, peach.

iii) **Epigynous:** Thalamus grows upward enclosing ovary, other parts above ovary, **inferior ovary. E.g: Guava, cucumber, ray floret of sunflower.**

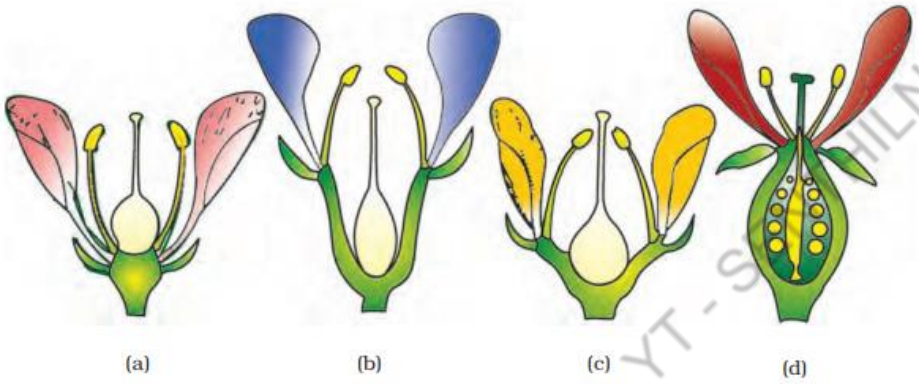


Figure 5.13 Position of floral parts on thalamus : (a) Hypogynous (b) and (c) Perigynous (d) Epigynous

Parts of flower

A) Calyx - Outermost whorl, members - sepals.
• Green, leaf like, protect flower in bud stage.
• Gamosepalous (united) or polysepalous (free).

B) Corolla - Petals, bright coloured to attract insects.
• Gamopetalous (united) polypetalous (free).
• May be tubular, bell shape, funnel shape, wheel shape.

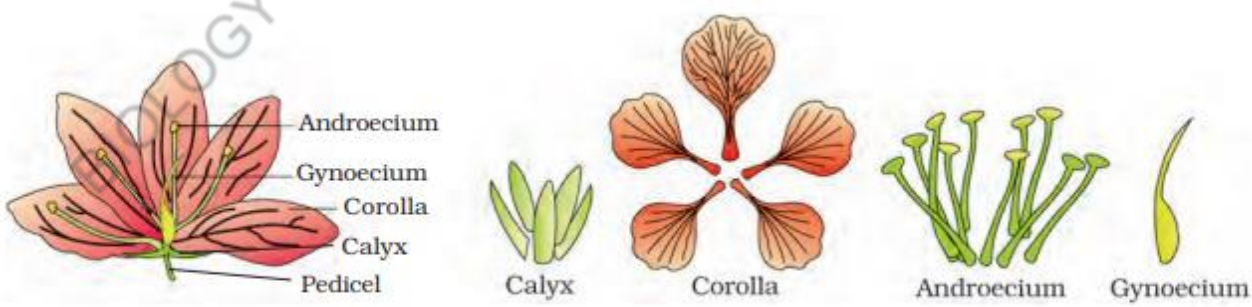


Figure 5.14 Parts of a flower

Aestivation - Arrangement of sepals & petals in floral bud with respect to other members of same whorl.

1) **Valvate -** Sepals and petals just touch each other. **E.g: Calotropis.**
2) **Twisted -** One margin of appendage overlaps the next & so on.
E.g: China rose, lady finger, cotton.

3) Imbricate - Margins overlap one another but not in particular direction (1 out, 1 in, 3 out in). **E.g: Cassia, gulmohar**.

4) Vexillary - Large (vexillum or standard) overlaps 2 lateral petals **(wings)** which overlap 2 smallest petals **(Keels)**.
E.g: Peas & bean (Papilionaceous).

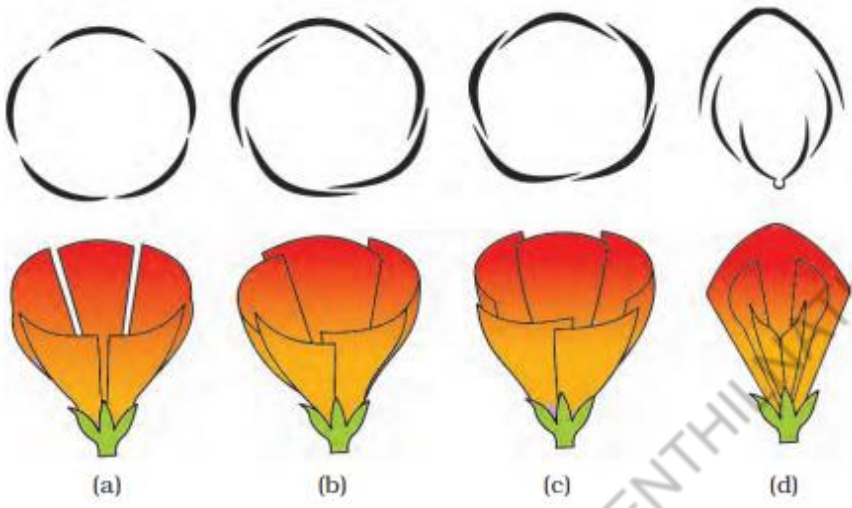


Figure 5.15 Types of aestivation in corolla : (a) Valvate (b) Twisted (c) Imbricate (d) Vexillary

C) Androecium - Composed of stamen. (Male reproductive organ).

- Consist of stalk/filament & anther.
- Anther- bilobed, each with 2 chamber, pollen sacs.
  Sterile stamen - Staminode.
- Stamens attached to petals - **epipetalous. E.g: Brinjal**.
- Stamens attached to perianth - **epiphyllous.E.g: Lily**.
- May be united or free.
- United into 1 bunch - **monoadelphous**. **E.g: China rose.**
- United into 2 bunch - **E.g: Diadelphous, pea.**
- United into more than 2 bunch - **Polyadelphous. E.g: Citrus.**
- Variation in length of filament. **E.g: Salvia, mustard.**

D) Gynoecium - Female reproductive part, 1 or more carpels.

- **Stigma -** Recepts pollen grain.
- **Style -** Connects to ovary, elongated tube.
- **Ovary -** Enlarged basal part.
- Each ovary has 1 or more ovules attached to **placenta**.
- Carpels may be free - **apocarpous. E.g: Lotus & rose.**
- Carpels may be fused **- syncarpous. E.g: Mustard & tomato.**

Placentation - Arrangement of ovules within ovary.

1) Marginal - Placenta forms ridge along ventral suture of ovary & ovules form 2 rows.
E.g: Pea.

2) Axile - Axial placenta & ovules attached to multilocular ovary.
E.g: China rose, lemon, tomato.

3) Parietal - Ovules on inner wall of ovary, (1 chambered but becomes 2 due to false septum). **E.g: Mustard & Argemone.**

4) Free central - Ovules on central axis & septa is absent. **E.g: Dianthus & Primrose.**

5) Basal - Placenta at base of ovary & single ovule is attached to it. **E.g: Sunflower, marigold.**

Figure 5.16 Types of placentation : (a) Marginal (b) Axile (c) Parietal (d) Free central (e) Basal

The Fruit :

- Mature ripened ovary developed after fertilisation.

Parthenocarpic –

- Fruit developed without fertilisation. They are seedless fruits. **E.g: Banana.**
- Fruit wall/pericarp - Dry or fleshy.
  → Outer epicarp, middle mesocarp & inner endocarp.
- **Mango & Coconut -** Fruit is drupe (develop from monocarpellary superior ovaries & 1 seeded).
- **Mango -** thin epicarp & fleshy mesocarp, stony endocarp.
- **Coconut -** fibrous mesocarp, hard endocarp.

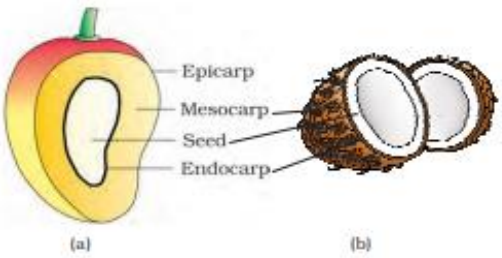


Figure 5.17 Parts of a fruit : (a) Mango (b) Coconut

- Edible part of mango is fleshy mesocarp.
- Edible part of coconut is endosperm.

The Seed:

- Ovules after fertilisation, seed coat + embryo.
- **Embryo -** Radicle, embryonal axis, 1 or 2 cotyledons.

1) Dicot seed – E.g: Gram, pea, bean.

- Seed coat - **Outer testa, inner tegmen.**
- **Hilum -** Scar on seed coat through which developing seeds attached to fruit. Small pore above it – **micropyle**.
- 2 fleshy, full of reserve food cotyledons.
- Non - endospermic seed - endosperm absent in mature seed.
- At 2 ends of embryonal axis are radicle & plumule.

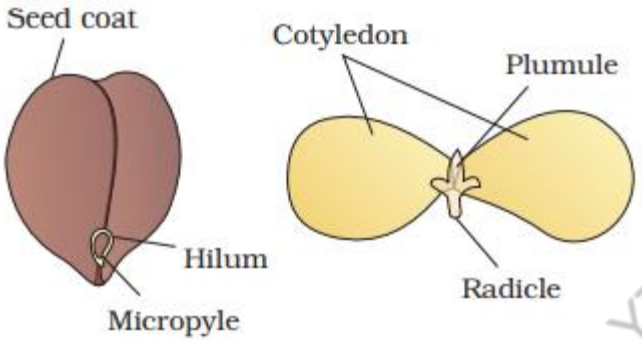


Figure 5.18 Structure of dicotyledonous seed

2) Monocot seed - E.g: Wheat, maize, castor.

- Endospermic, **orchid – non - endospermic (Exception).**
- In maize - membranous seat coat fused with fruit wall.
- **Aleurone layer -** Proteinaceous layer.
- Small embryo in a groove at one end.
- Large, shield shaped cotyledon – **scutellum.**
- Short axis with plumule & radicle enclosed in coleoptile & coleorhiza.

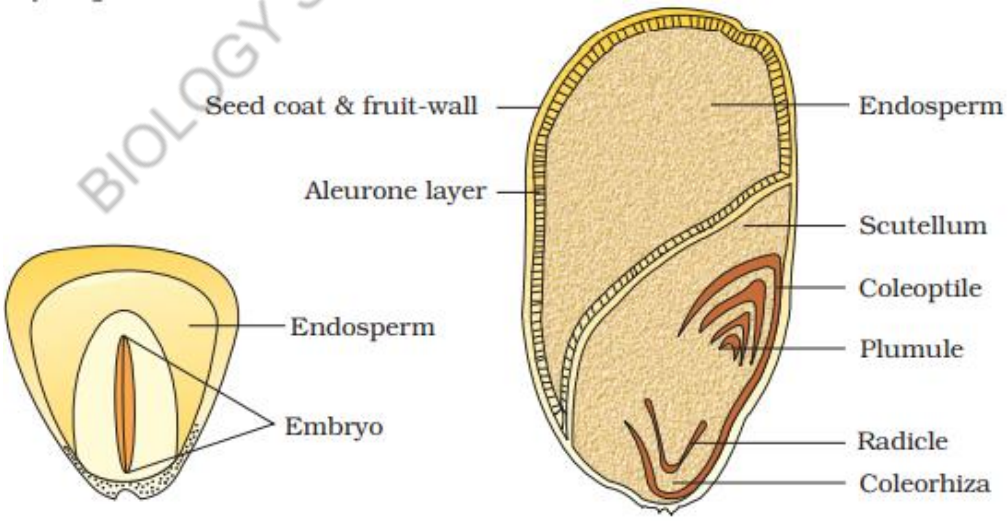


Figure 5.19 Structure of a monocotyledonous seed

Morphology of Flowering Plants

Semi Technical Description of a typical flowering plant:

- K - Calyx, C - Corolla, P - Perianth, A - Androecium.
- G - Gynoecium, G - Superior ovary, Ḡ - Inferior ovary.
- ♂ - Male, ♀ - Female, ⚥ - Bisexual, ⊕ - Actinomophic,
- % - Zygomorphic, (--) - Fusion, ⌒ Adhesion.

*** Position of mother axis with respect to flower - dot on top.**

Figure 5.20 Floral diagram with floral formula

1) Fabaceae - Papilionoideae (sub family of Leguminosae) tree, shrubs, herbs, root.

- **Stem -** Erect/climber.
- **Leaves -** Alternate, pinnately, pulvinate leaf base, reticulate.

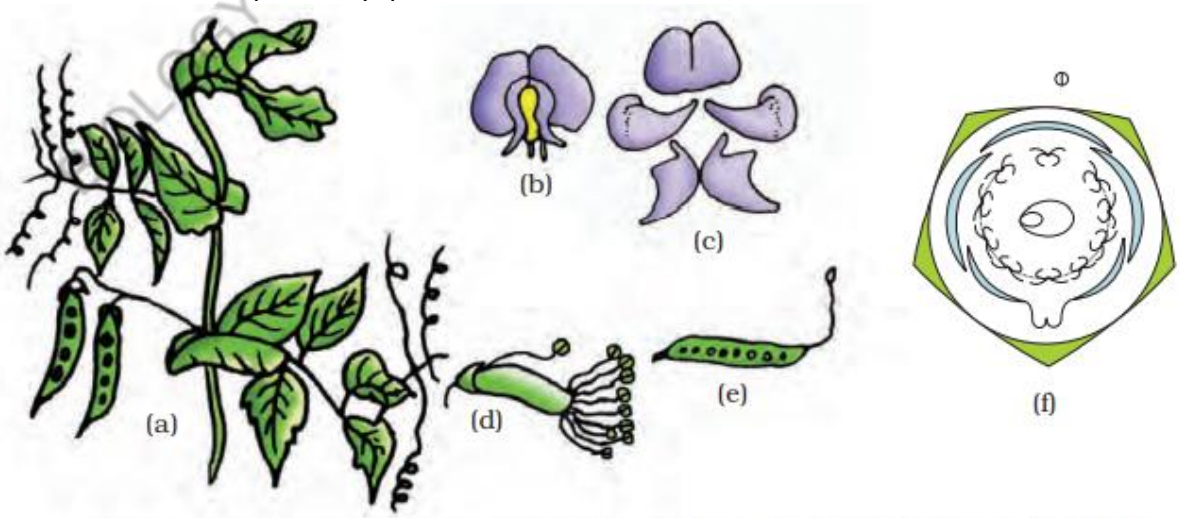


Figure 5.21 *Pisum sativum* (pea) plant : (a) Flowering twig (b) Flower (c) Petals (d) Reproductive parts (e) L.S.carpel (f) Floral diagram

- **Inflorescence –** Racemose.
- **Flower -** Bisexual, zygomorphic.
- **Calyx -** 5, gamosepalous, valvate/imbricate.
- **Corolla -** 5, polypetalous, vexillary .
- **Androecium -** 10, diadelphous, dithecous anther.
- **Gynoecium -** Ovary superior, monocapellary, unilocular.
- **Fruit -** Legume, seed, non- endospermic.
- **Floral Formula -** $\% \, ♀♂ \, K_{(5)} \, C_{1+2+(2)} \, A_{(9)+1} \, \underline{G}_1$
- **Economic Importance -** Pulses (gram, arhar, sem, moong, soyabean), dye **(indigofera)**, oil (soyabean, groundnut), **fibres (sunhemp)**, medicine (muliathi), fodder **(Sesbania, Trifolium),** ornamental **(lupin, sweet Pea)**.

2) Solanaceae - Potato family.

- Herbs, shrubs, small trees.
- **Stem -** Aerial, erect, branched, cylindrical, solid/hollow/hairy.
- **Leaves -** Alternate, simple, reticulate.
- **Inflorescence -** Cymose, solitary.
- **Flower -** Bisexual, actinomorphic.
- **Calyx -** 5, united, valvate.
- **Corolla -** 5, united, valvate.
- **Androecium -** 5, epipetalous.
- **Gynoecium -** Bicarpellary, ovary superior, axile, bilocular, syncarpous.
- **Fruit -** Berry/capsule.
- **Seeds -** Many endospermous.
- **Floral formula –**

$$\oplus \, ♀♂ \, K_{(5)} \, \widehat{C_{(5)} \, A_5} \, \underline{G}_{(2)}$$

- **Economic Importance -** Source of food (tomato, brinjal, potato), spice (chilli), **fumigatory (tobacco), ornamental (petunia),** medicine (Ashwagandha, **Belladonna**).

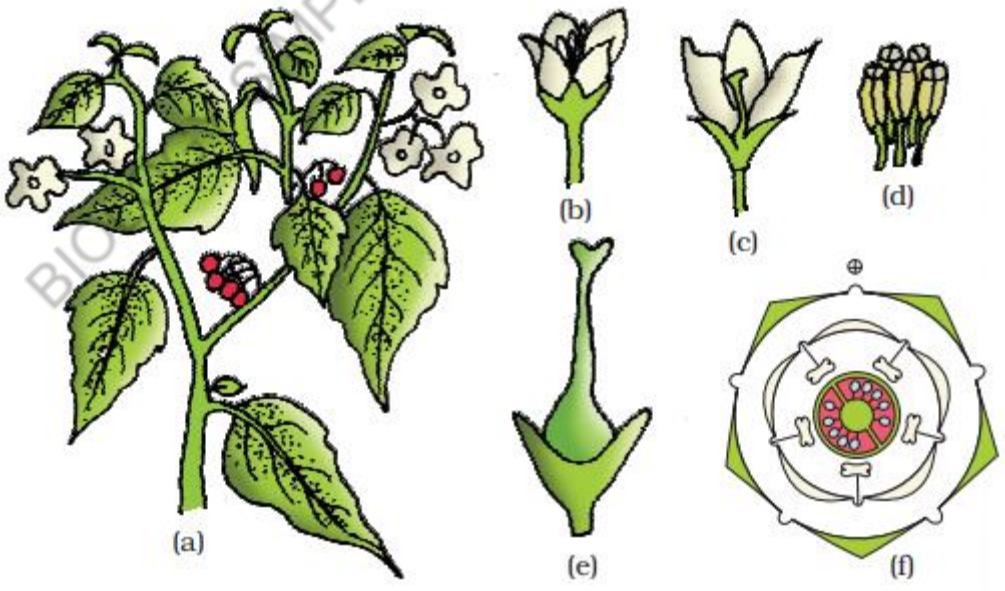


Figure 5.22 *Solanum nigrum* (makoi) plant : (a) Flowering twig (b) Flower (c) L.S. of flower (d) Stamens (e) Carpel (f) Floral diagram

Morphology of Flowering Plants

3) Liliaceae- lily family.

- Herbs with underground bulbs/rhizomes.
- **Leaves -** Alternate, parallel.
- **Inflorescence -** Solitary, cymose.
- **Flower -** Bisexual, actinomorphic.
- **Perianth -** 6 tepals (3+3), valvate.
- **Androecium -** 6, (3+3), epitepalous/epiphyllous.
- **Gynoecium -** Tricarpellary, syncarpous, ovary superior, axile trilocular.
- **Fruit -** Capsule, rarely berry.
- **Seed -** Endospermous.
- **Floral formula -**

$$Br \oplus \varphi \overset{\frown}{P}_{(3+3)} A_{3+3} G_{(3)}$$

- **Economic importance -** Ornamentals (tulip, **gloriosa**), medicine (Aloe), **vegetables (Asparagus, bulb of onion and garlic is also edible), colchicine** (causes polyploidy).

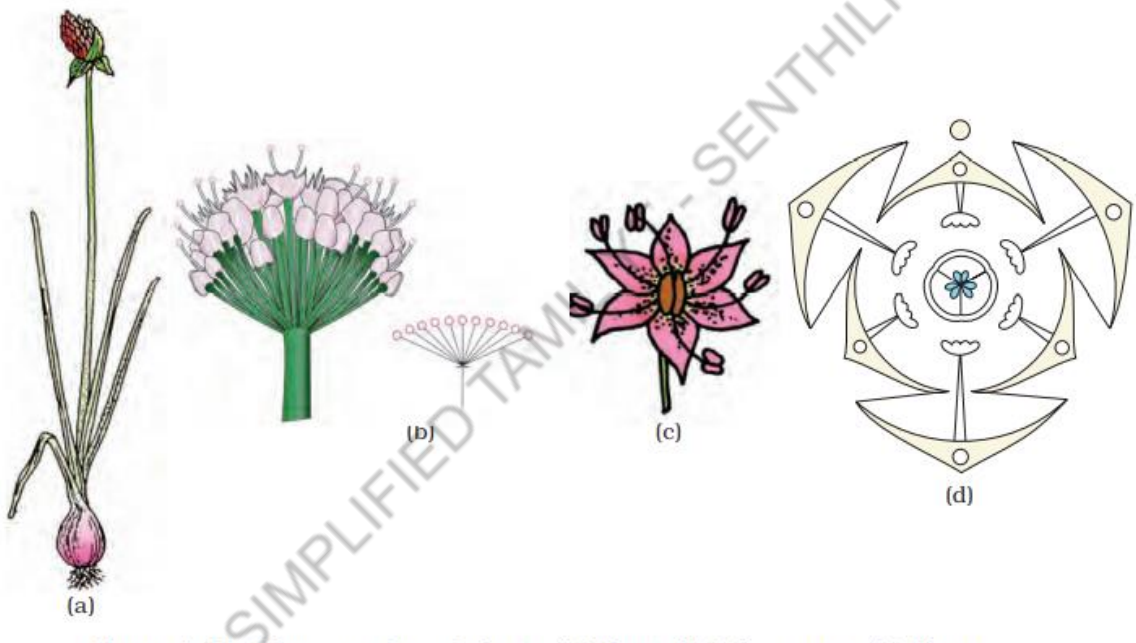


Figure 5.23 *Allium cepa* (onion) plant : (a) Plant (b) Inflorescence (c) Flower (d) Floral diagram

Anatomy of Flowering Plants

Anatomy –

• Study of internal structure.

The tissues –

• Group of cells having common origin performing common function.

Meristematic tissues:

• **Meristems** - Region of active cell division.

A) Apical meristems - Tip of roots & shoots, produce primary tissues.

B) Intercalary meristems - Between mature tissues.

• Occur in **grass & regenerate parts** removed by grazing herbivores.

• Apical & intercalary meristem constitute primary meristem as appear in early life.

• **Axillary bud** - Cell left behind from **shoot apical meristem** during formation of leaves & elongation of stem, present in axils of leaves & form branch or flower.

C) Lateral meristem - It constitute secondary meristem.

• Mature regions of roots & shoots. **E.g: Woody axis.**

• Cylindrical, produce secondary tissues.
E.g: Fascicular vascular cambium, interfascicular Cambium & cork cambium.

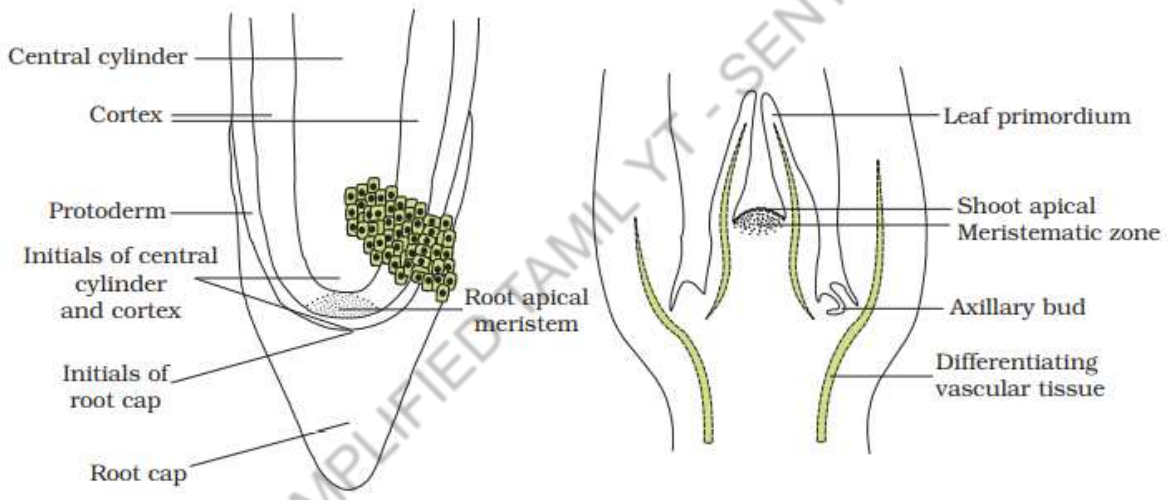


Figure 6.1 Apical meristem: (a) Root (b) Shoot

Permanent tissues:

• New cells become structurally & functionally specialised & lose ability to divide.

• All cells similar in structure & function - **simple tissues.**

1) Simple tissues - One type of cells.

• **Parenchyma** - Major, **isodiametric,** may be spherical, oval, round, polygonal, thin cellulosic walls, small intercellular space, perform photosynthesis, storage, secretion.

• **Collenchyma** - Below epidermis either as homogenous layer or patches, thick **cornered** wall due to **cellulose, hemicellulose & pectin**, may be oval, spherical or polygonal, mechanical support, spaces absent, **assimilate food if contain chloroplast.**

• **Sclerenchyma** - Long, narrow cells with thick, lignified walls, **protoplast absent,** dead, mechanical support.

i) Fibres - Thick walled, elongated, pointed.

ii) Sclereids - Spherical/oval/cylindrical, thickened dead cells, narrow lumen, **fruit walls of nuts, pulp of guava, pear & sapota, seed coat of legumes & tea leaves.**

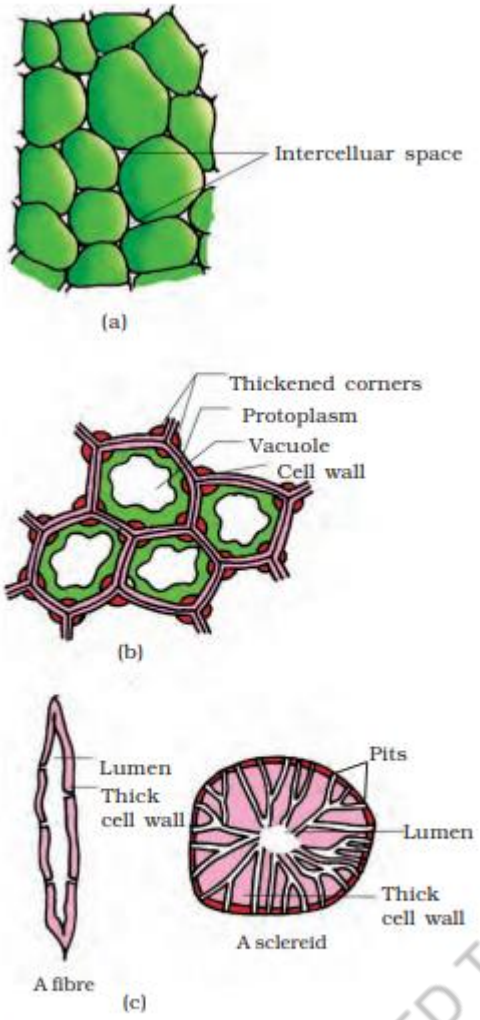


Figure 6.2 Simple tissues :
(a) Parenchyma
(b) Collenchyma
(c) Sclerenchyma

2) Complex tissues - Different types of cells perform single function.

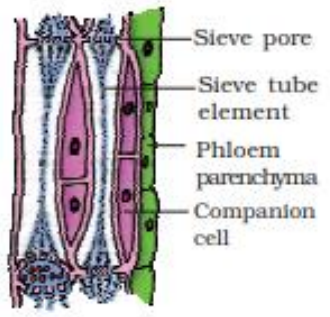
i) Xylem - Conduct water & minerals from roots to stem & leaves.

- **Tracheids -** Elongated, tube like, thick lignified walls, **tapering ends,** dead, without protoplasm.
- **Vessels - Absent in gymnosperm,** cylindrical tube made of vessel members, lignified walls, central cavity, dead, **interconnected through perforation,** characteristic feature.

- **Fibres -** Highly thickened walls, may be septate/aseptate.
- **Parenchyma -** Thin walled, living, store food in form of starch or fat or tannins, **radial conduction of water by ray parenchymatous cells.**
- Tracheids & vessels are main water transporting elements.
- **Protoxylem -** First formed primary xylem elements.
- **Metaxylem -** Later formed primary xylem.
- **Endarch -** Protoxylem towards centre & metaxylem towards periphery. **E.g: Stem.**
- **Exarch -** Protoxylem towards periphery & metaxylem towards centre. **E.g: Roots.**

ii) Phloem - Transport food material from leaves to other parts.

- **Sieve tube elements -** Long, tube like, **perforated ends to form sieve plate**, lacks nucleus when mature, controlled by nucleus of companion cells, **absent in gymnosperm.**
- **Companion cells -** Parenchymatous, maintain pressure gradient in sieve tubes, **absent in gymnosperms,** connected to sieve tubes by pit field.
- **Parenchyma -** Elongated, tapering, cylindrical, dense cytoplasm and nucleus, pits for connection, store food & **resin, mucilage, latex, absent in monocots.**
- **Fibres -** Sclerenchymatous, elongated, unbranched, pointed, thick wall, **absent in primary phloem,** fibres of jute, flax & hemp for commercial purpose.
- **Protophloem -** First formed primary phloem, narrow tubes.
- **Metaphloem -** Later formed phloem, bigger sieve tubes.



The tissue system -

1) Epidermal tissue system - Outermost covering.

- **Epidermis -** Outermost layer, elongated, compact, single layered, **parenchymatous,** large vacuole, covered with waxy thick layer - **cuticle** (absent in roots) prevent water loss.
- **Stomata –** Regulate transpiration & gaseous exchange, 2 bean shape guard cell (dumbell shape in grasses), outer walls of guard cell are thin & inner are thick, possess chloroplast & regulate opening & closing of stomata.

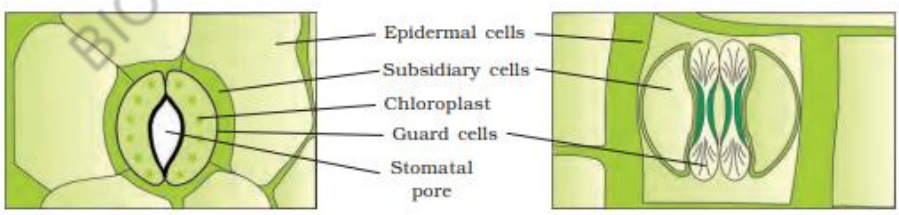


Figure 6.4 Diagrammatic representation: (a) stomata with bean-shaped guard cells (b) stomata with dumb-bell shaped guard cell

- **Subsidiary cells -** Cells of epidermis close to guard cell become specialised in shape & size.
- **Stomatal apparatus -** Stomatal aperture + subsidiary cell + guard cell.
- **Epidermal appendages -** Bear no. of hairs.
- **Root hair -** Unicellular, absorb water & mineral.
- **Trichomes -** Multicellular, branched/unbranched, prevent water loss & helps in protection.

Anatomy of Flowering Plants

2) Ground Tissue System - All tissue except epidermis & vascular.

- **Parenchymatous -** Cortex, pericycle, pith, medullary rays, primary roots of stems.
- **Collenchyma -** Hypodermis of dicot stem.
- **Sclerenchyma -** Hypodermis of monocot stem, pericycle.
- **Mesophyll -** Thin walled chloroplast containing cells in leaves.

3) Vascular Tissue System - Xylem + Phloem + Cambium (if present).

- **Radial -** Vascular tissue in alternate manner along different radii. **E.g: Roots.**
- **Conjoint -** Vascular tissue along same radius of vascular bundle. **E.g: Stem & leaves.**
- **Close -** No cambium, no secondary growth. **E.g: Monocots.**
- **Open -** Have cambium, show secondary growth. **E.g: Dicots.**

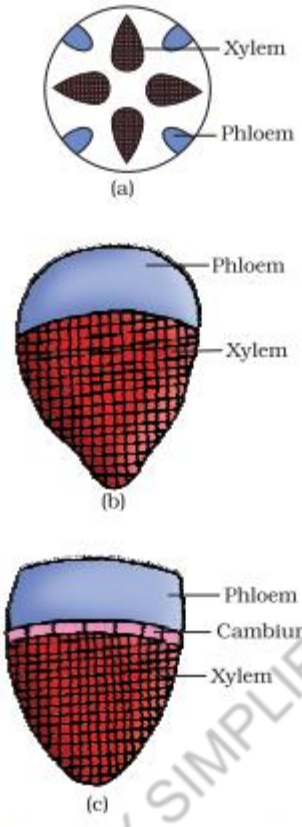


Figure 6.5 Various types of vascular bundles : (a) radial (b) conjoint closed (c) conjoint open

Anatomy of Dicot & Monocot Plants –

1) Dicot Root:

- **Epiblema -** Outermost layer, root hairs.
- **Cortex -** Thin wall parenchymatous cells, innermost layer - **endodermis,** single layer barrel shaped cell (no space, tangential & radial walls have suberin **(water impermeable),** waxy in form of casparian strips.
- **Pericycle -** Few layer thick walled parenchyma.
- **Pith -** Small, undeveloped.
- **Vascular bundle – 2 - 4 xylem & phloem, exarch.**
- **Conjuctive tissue -** Parenchymatous cells between xylem & phloem.
- **Stele -** Tissues on innerside of endodermis. **E.g: Pericycle, pith, vascular bundle.**

Anatomy of Flowering Plants

2) Monocot Root:

- Similar to dicot but has **more than 6 xylem bundles & phloem (polyarch).**
- Pith is large & well developed.

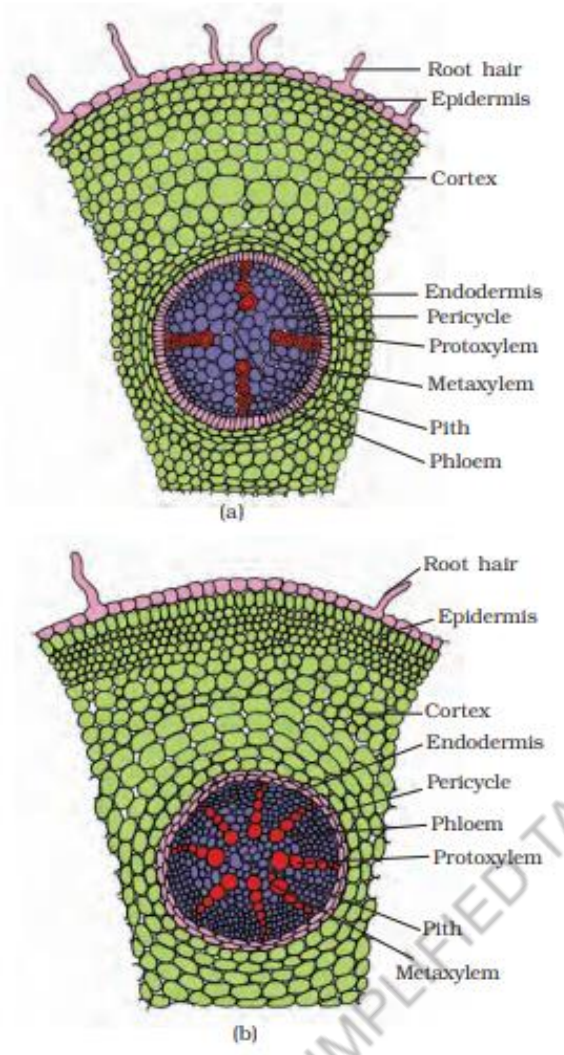


Figure 6.6 T.S. : (a) Dicot root (Primary) (b) Monocot root

3) Dicot stem:

- **Epidermis -** Outermost protective layer, thick cuticle, trichomes.
- **Cortex -** Between epidermis & pericycle.
- **Hypodermis -** Outer, **collenchymatous,** mechanical strength.
- **Cortical -** Round thin parenchymatous cells, space present.
- **Endodermis -** Innermost, **rich in starch grain - starch sheath.**
- **Pericycle -** Inner side of endodermis, **sclerenchymatous.**
- **Medullary rays -** Parenchymatous between vascular bundle.
- **Vascular bundle - Ring arrangement,** conjoint open, endarch protoxylem, 8-15 in number.
- **Pith -** Round parenchymatous cells in centre.

4) Monocot stem:

- Similar to dicot stem but scattered vascular bundles.
- **Sclerenchymatous, hypodermis,** phloem parenchyma absent.
- Conjoint closed vascular bundles.

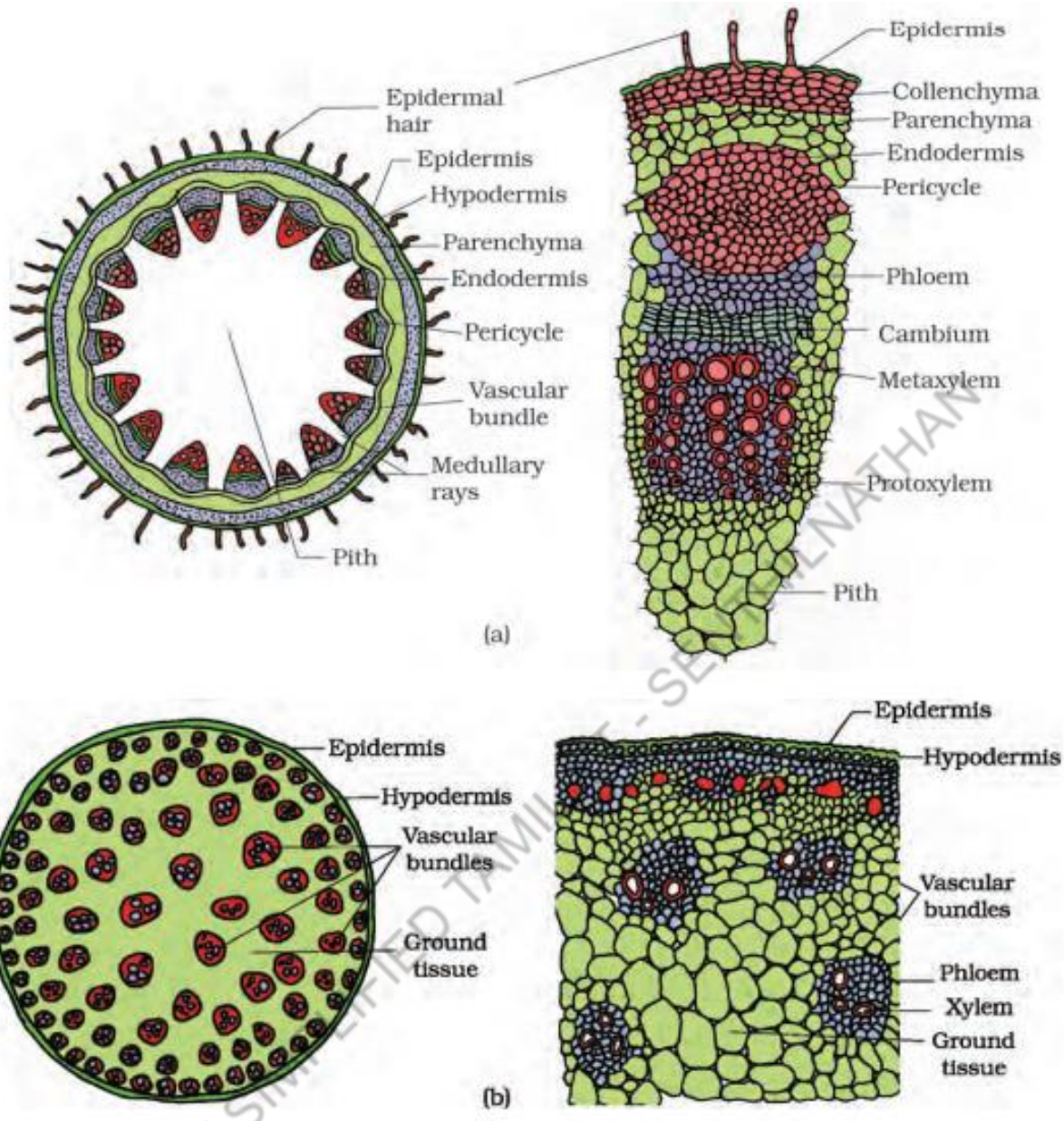


Figure 6.7 T.S. of stem : (a) Dicot (b) Monocot

5) Dorsiventral (Dicotyledonous) leaf:

- **Epidermis -** Covers upper **(adaxial)** & lower **(abaxial)**, cuticle, abaxial has more stomata.
- **Mesophyll -** Tissue between upper & lower epidermis, parenchyma.
- **Palisade parenchyma -** Adaxial, elongated, parallel, vertical cells.
- **Spongy parenchyma - Oval**/round, loose, below palisade.
- **Vascular system -** Vascular bundles in veins & midrib, surrounded by thick walled bundle sheath cells.

6) Isobilateral (Monocotyledonous) Leaf:

- Stomata are equal on both surface.
- Mesophyll isn't differentiated to spongy & palisade parenchyma.
- **Bulliform cells -** Adaxial cells modify into large, empty, colourless, cells, become turgid on absorbing water, become flaccid due to water loss so curl leaf to minimise water loss.
  E.g: Grasses.

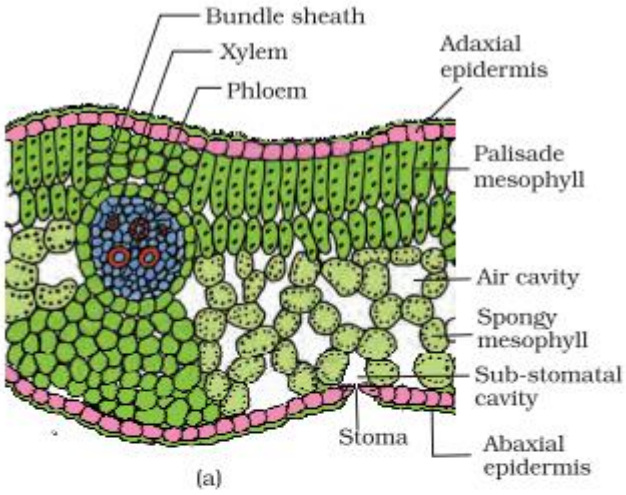


Figure 6.8 T.S. of leaf : (a) Dicot (b) Monocot

Secondary Growth –

- Increase in girth.
- 2 lateral meristem - vascular cambium & cork cambium.

1) Vascular Cambium:

- Meristematic layer responsible for cutting off vascular tissues.

a) Formation of cambial ring:

- **Intrafascicular** - Between primary xylem & primary phloem.
- **Interfascicular** - By cells of medullary rays adjoining intrafascicular cambium, continuous ring, meristematic.

b) Activity of cambial ring:

- Cambial ring becomes active, cut off new cells.
- **Secondary xylem** - Cells cut off towards pith
- **Secondary phloem** - Cells cut off towards periphery.
- Xylem is more as ring is more active on inner side.
- Primary & secondary phloem crush due to formation of secondary xylem.
- **Secondary medullary rays** - Cambium forms narrow band of parenchyma passing through secondary xylem & phloem in radial directions.

c) Spring wood & autumn wood:

- **Spring wood** - Early wood, in spring, cambium is more active, so more xylem with **wider cavities,** light, low density.

- **Autumn wood -** Late wood, in autumn, cambium is less active, few xylem with **narrow cavities,** dark, high density.
- **Annual ring -** 2 wood appear as alternate concentric rings, gives age of tree.

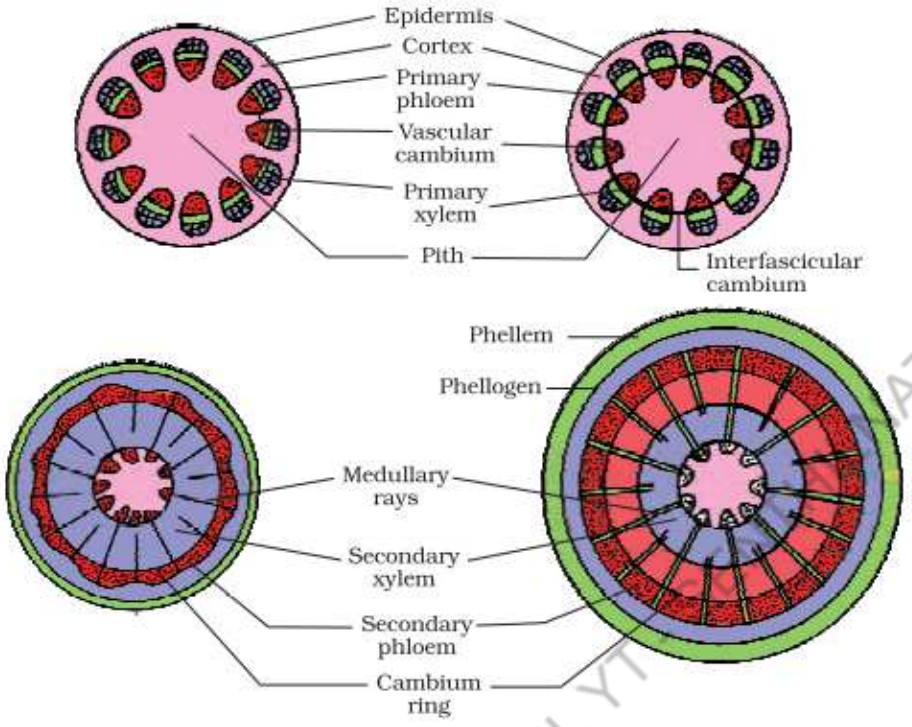


Figure 6.9 Secondary growth in a dicot stem (diagrammatic) – stages in transverse views

d) Heartwood & Sapwood:

- In old trees, secondary xylem is brown due to **tannins, oils, resin, gums,** these make it hard, durable, resistant to microbial attack.
- **Heartwood -** Dead elements with lignified walls, doesn't conduct water, mechanical support, central region of secondary xylem, also called **duramen.**
- **Sapwood -** Peripheral region of secondary xylem, lighter in colour, conduct water & mineral, also called **alburnum.**

2) Cork cambium:

- As stem increases in girth, cortical & epidermis layers break, needs to be replaced, so cork cambium develops.
- **Phellogen** (cork cambium) - Thick, narrow thin walled rectangular cells, cut off cells on both sides.
- **Phellem** (cork) - Outer cells differentiate to phellem.
- **Phelloderm** (secondary cortex) - Inner cell differentiate to phelloderm.
- **Periderm -** Phellogen + Phellem + Phelloderm.
- Cells of secondary cortex are parenchymatous & cork is impervious to water.
- **Bark -** Due to cork cambium, pressure builds, phellogen die & slough off, **tissue exterior to vascular cambium.**
- Formed early in season - early/soft bark.
- Formed late in season - late/hard bark.
- **Lenticels -** Sometimes phellogen cuts closely arranged parenchymatous cells instead of cork cells, which rupture forming lens shaped opening, permit gaseous exchange, occur in woody trees.

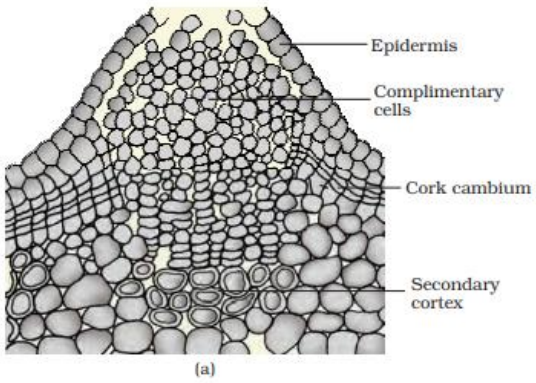


Figure 6.10 (a) Lenticel and (b) Bark

3) Secondary Growth in Roots:

- Vascular cambium is completely secondary, originate from tissue below phloem, portion of pericycle tissue, above protoxylem forming complete, continuous wavy ring.

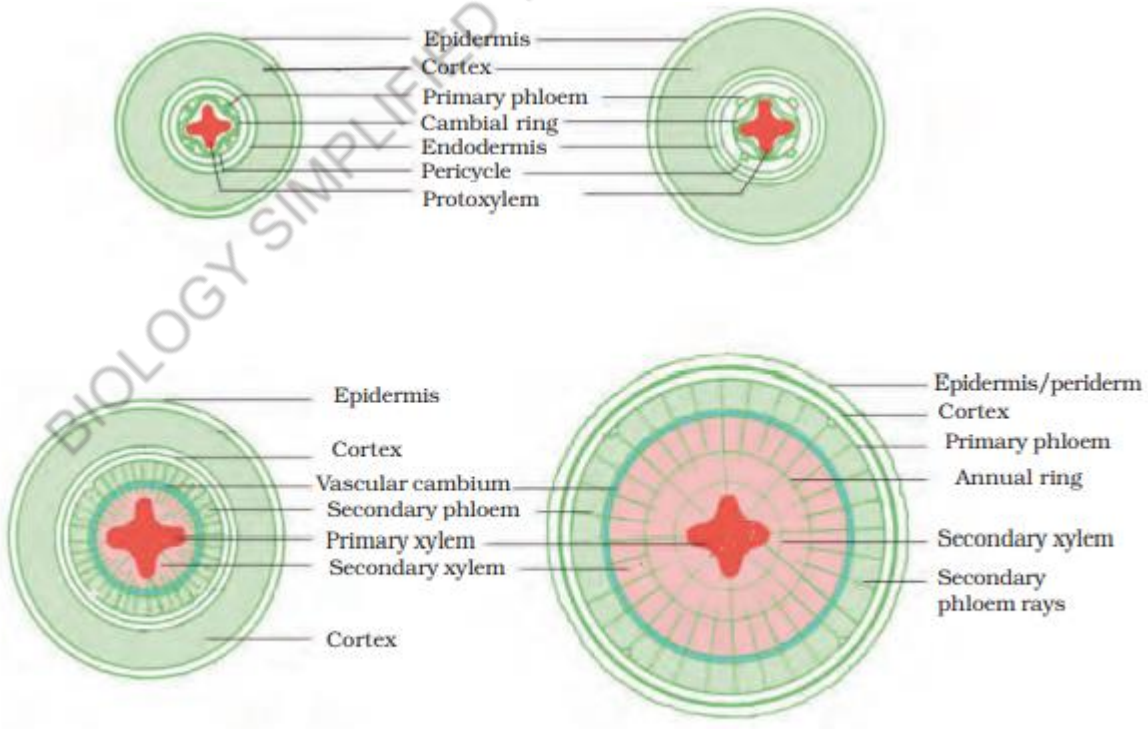


Figure 6.11 Different stages of the secondary growth in a typical dicot root

*** Secondary growth also occur in stems and roots of gymnosperms.**

Structural Organisation In Animals

Tissue:

- Group of similar cells having similar origin and performing specific function.
- Cells → Tissue → Organ → Organ system: **Division of labour.**

Animal Tissue:

1) Epithelial Tissue -

- Has free surface either facing fluid or outside environment.
- Compactly packed with little space.

a) Simple: Single layer of cells.

- **Squamous:** Single thin layer flattened cells, irregular boundary, **walls of blood vessel, air sacs of lungs.**
- **Cuboidal:** Cube like cells, ducts of glands, secretion & absorption tubular part of nephron. **E.g: Proximal convulated tubule.**
- **Columnar:** Tall & slender cells, basal nuclei, **lining of stomach & intestine,** secretion & absorption.
- **Ciliated:** Bears cilia, move particles/mucus in specific direction, **bronchioles & fallopian tubes.**

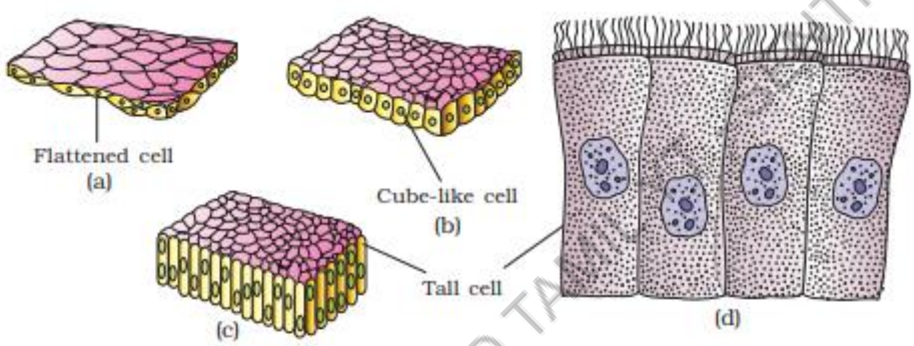


Figure 7.1 Simple epithelium: (a) Squamous (b) Cuboidal (c) Columnar (d) Columnar cells bearing cilia

- **Glandular:** Secretion.
- **Unicellular:** Isolated cell. **E.g: Goblet cell.**
- **Multicellular:** Cluster of cell. **E.g: Salivary gland.**

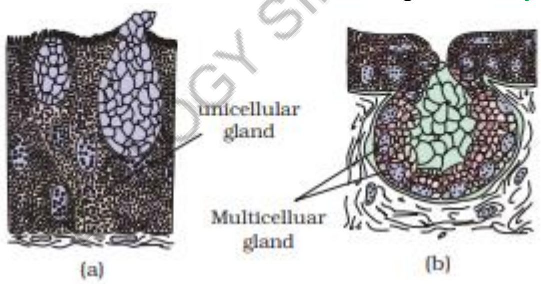


Figure 7.2 Glandular epithelium : (a) Unicellular (b) Multicellular

b) Compound epithelium:

- 2 or more cell layers, protective, covers **dry surface, moist surface of buccal cavity, pharynx, duct of salivary glands, pancreatic ducts.**

On the basis of mode of pouring of secretion:

- **Exocrine -** Secrete mucus, **saliva, earwax, oil, milk** through ducts.
- **Endocrine -** Don't have ducts, secrete hormones directly into fluid, blood.

Cell junctions:

- **Tight:** Stop substances from leaking.

- **Adhering:** Cementing to keep cells together.
- **Gap:** Communicate with each other, transfer of ions/molecules.

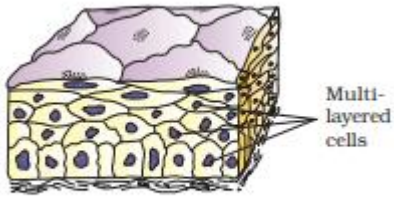


Figure 7.3 Compound epithelium

2) Connective Tissues: Most abundant, widely distributed.

- Link & support other tissues.
- Secrete fibres of protein – **Collegen/elastin except blood** which provide strength, elasticity & flexibility.
- Secrete **modified polysacharides,** act as matrix.

a) Loose connective tissue: Cells & fibres loosely arranged.

- **Areolar:** Beneath skin, framework, contain **fibroblast** (cells that produce & secrete fibres), **macrophages & mast cells,** lymphocytes, plasma cells.
- **Adipose:** Beneath skin, store fats, nutrients which aren't immediately converted to fat.

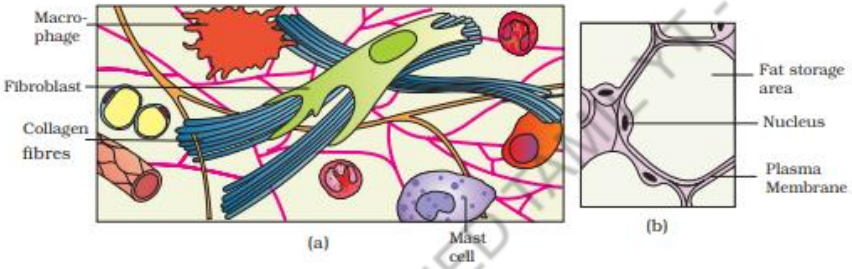


Figure 7.4 Loose connective tissue : (a) Areolar tissue (b) Adipose tissue

b) Dense connective tissue: Fibres are compactly packed.

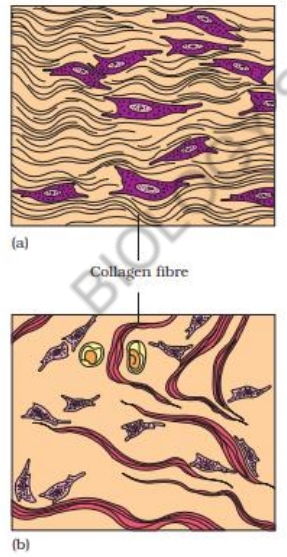


Figure 7.5 Dense connective tissue:
(a) Dense regular
(b) Dense irregular

- **Dense regular:** Collegen fibre in rows between parallel bundles of fibres.
- **Tendons:** Attach skeletal muscles to bone.

- **Ligaments:** Attach one bone to another.
- **Dense irregular:** Fibres oriented differently, present in skin.

c) Specialised connective tissue:

- **Cartilage:** Solid, pliable, resist compression, **chondrocytes** in small cavity, most of cartilage in vertebrate embryos are replaced by bones in adults, **tip of nose, outer ear joint, limbs & hands,** between **adjacent bones of vertebral column.**
- **Bones:** Hard, non-pliable, rich in calcium salts & collagen fibres, strength, structural framework of body, **osteocytes are present in lacunae (space),** bring movement with muscles. **E.g:** Limb bones - long, weight bearing, bone marrow - RBC production.
- **Blood:** Fluid connective tissue, has plasma, RBC, WBC, platelet, transport substances.

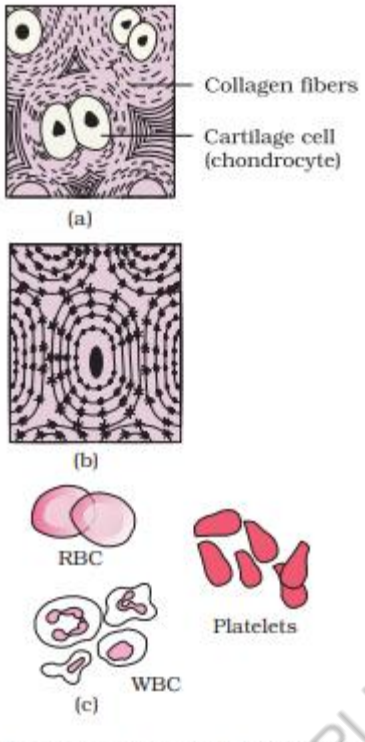


Figure 7.6 Specialised connective tissues : (a) Cartilage (b) Bone (c) Blood

3) Muscle Tissue - Long, cylindrical fibres in parallel arrays.

- Fibres are composed of **myofibrils**, contract & relax to adjust changes in environment, movement.

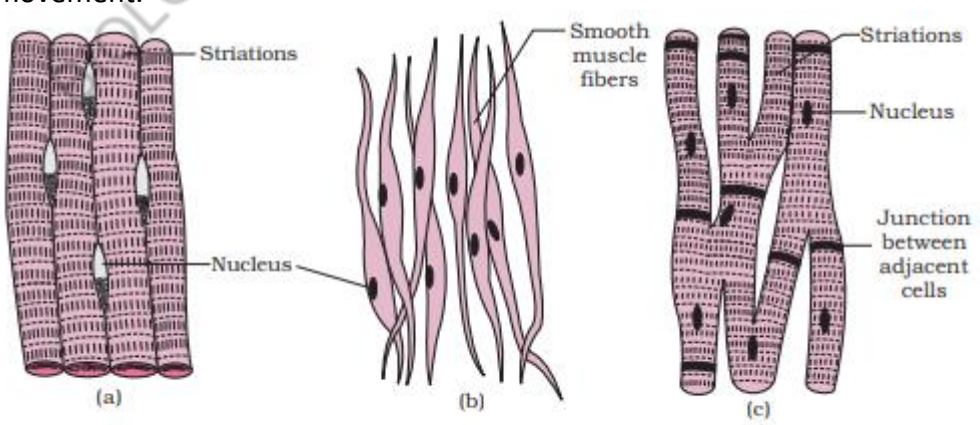


Figure 7.7 Muscle tissue : (a) Skeletal (striated) muscle tissue (b) Smooth muscle tissue (c) Cardiac muscle tissue

Structural Organisation In Animals

- **Skeletal -** Attached to skeletal bones. **E.g: Biceps.**
- **Smooth -** Taper at both ends **(fusiform),** no striation, involuntary.
  E.g: Blood vessel, stomach, intestine.
- **Cardiac -** Contractile tissue in **heart,** communication junction **(intercalated disc)** allow cell to contract as a unit.

4) Neural Tissue: Body's responsiveness to changing environment.

- Neurons are exciatable.
- **Neuroglial cells:** Protect & support neurons, more than half volume of neural tissue.
- Neuron stimulated → Electrical disturbance → Swift through plasma membrane → Disturbance at nerve ending → Stimulation/inhibition of adjacent neuron.

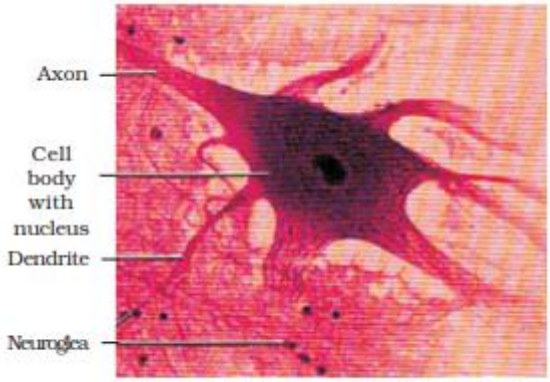


Figure 7.8 Neural tissue (Neuron with neuroglea)

Earthworm:

- Pheretima & Lumbricus.
- Reddish brown terrestrial invertebrate in upper layer of soil.
- Live in burrows by boring & swallowing.
- Can be traced by faecal deposits - **Worm casting.**

Morphology:

- Long cylindrical body with **100 - 120 similar metameres.**
- **Dorsal:** Dark median mid dorsal line (dorsal blood vessel).
- **Ventral:** Genital opening.

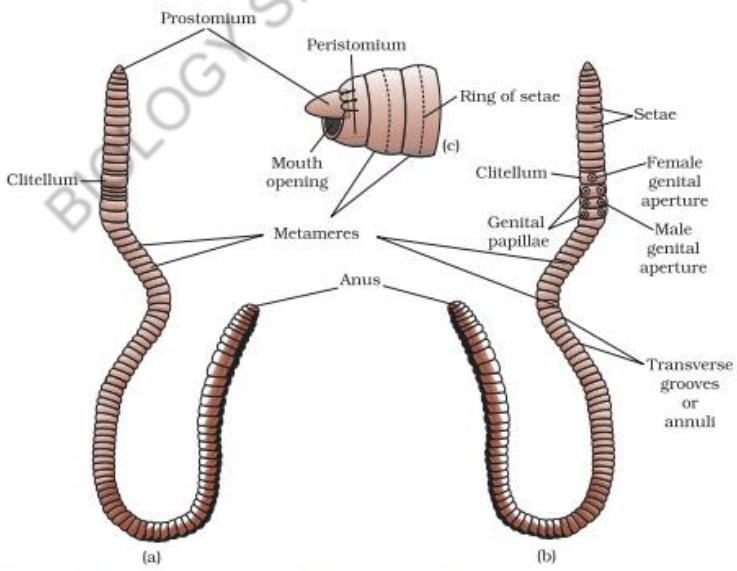


Figure 7.9 Body of earthworm : (a) dorsal view (b) ventral view (c) lateral view showing mouth opening

Structural Organisation In Animals

- **Anterior end:** Mouth & **prostomium** (cover mouth, force open cracks in soil, **sensory**).
- **Peristomium:** First body segment having mouth.
- **Clitellum:** Dark band of glandular tissue **(14 - 16 segments).**
- Body is divisible into preclitellar, clitellar & postclitellar segement .
- **4 pair of spermathecal aperture** on ventro - lateral side. **(5^{th} - 9^{th} segment).**
- **Female genital pore -** Mid ventral line of **14^{th} segment.**
- **Male genital pore –** Ventro - lateral side of **18^{th} segment.**
- Nephridiopores open on surface.
- **Setae** - **S -** shaped embedded in epidermal pits made of chitin, locomotion, can be extended/retracted, present in each segment **except 1^{st} , last & clitellum.**

Anatomy:

- Outermost thin non - cellular cuticle → epidermis 2 muscle layer (circular & longitudinal) → innermost coelomic epithelium.
- Epidermis → **Columnar epithelium** (secretory gland cells).

a) Alimentary Canal - Straight tube between 1^{st} to last segment.

- Terminal mouth open to buccal cavity **(1 - 3 segments)** then to pharynx.
- Oesophagus **(5 - 7 segment)** continue to **gizzard (8 - 9 segments)** which help in grinding soil particles & decaying leaves.
- Stomach **(9 - 14)** - neutralise **humic acid by calciferous gland.**
- Intestine **(15^{th} - last segment)** - short conical intestinal caecae on **26^{th} segment**.
- **Typhlosole -** Internal median fold of dorsal wall, increase absorption area, characteristic feature, **from 26^{th} segment to last except 23 – 25^{th}.**
- Open to exterior round aperture - anus .
- Digestive enzyme break complex food, simple molecules are absorbed.

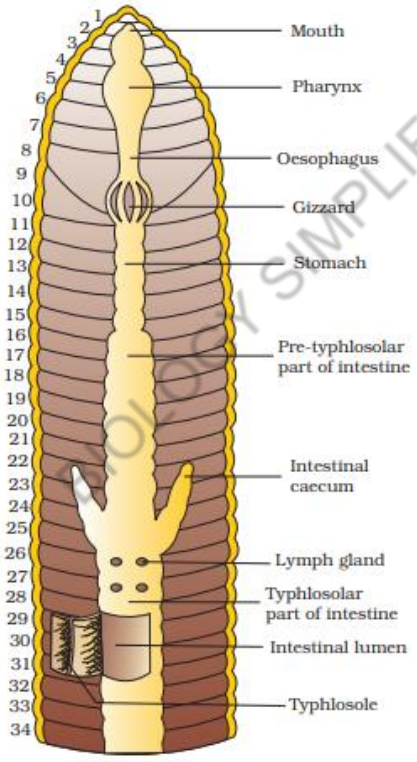


Figure 7.10 Alimentary canal of earthworm

b) Circulatory system – Closed (vessel + capillaries + heart).

- Blood confined to heart and blood vessel, flow in 1 direction.

- Blood glands – **4th, 5th and 6th segment** produce blood cells and haemoglobin.
- **Phagocytic blood cells,** smaller blood vessel supply gut, nerve cord etc.

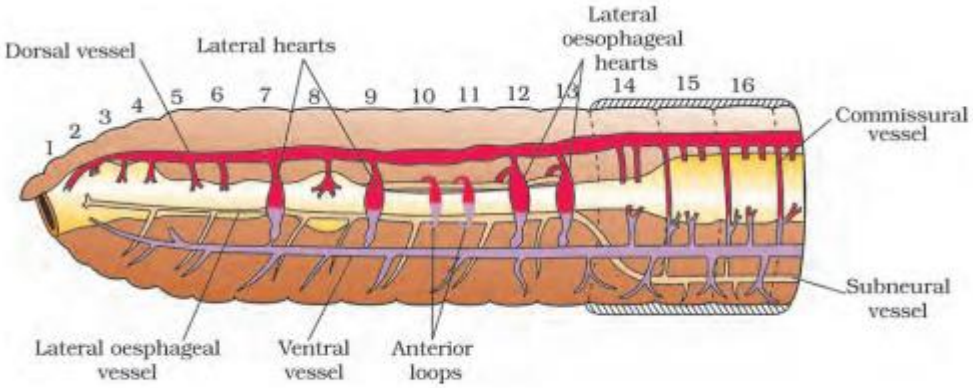


Figure 7.11 Closed circulatory system

c) Respiratory system - Lack breathing devices, through moist surface.

d) Excretory system - By coiled tubules **(nephridia).**

- **3 types of nephridia -**
- **Septal -** Both side of intersegmental septa **(15th to last segment to intestine).**
- **Integumentary -** Lining of body wall **(segment 3rd to last).**
- **Pharyngeal -** 3 paired tufts **(4th, 5th & 6th segment)** Similar in structure, regulate volume & composition of body fluid, starts as funnel collecting fluid from coelomic chamber.

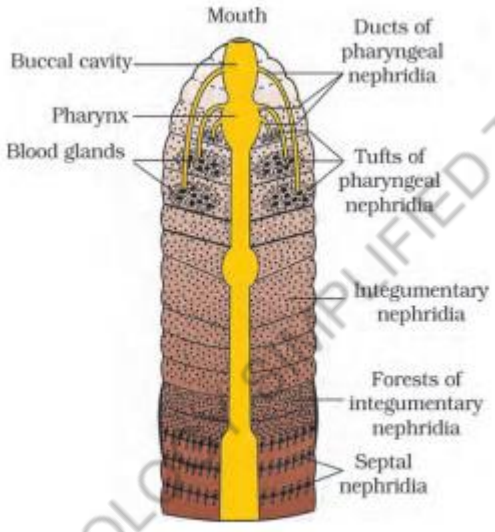


Figure 7.12 Nephridial system in earthworm

e) Nervous system - Represented by ganglia on ventral paired nerve cord.

- Anterior, bifurcating nerve cord **(3rd & 4th segment)** encircling pharynx & join ganglia dorsally to form nerve ring.
- Cerebral ganglia + Nerves - sensory input & muscular response.

f) Sensory system - No eyes.

- Has light & touch sensitive organs on anterior to distinguish intensities & vibrations.
- Chemoreceptor **(taste receptors)** to react to chemical stimuli.

g) Reproduction system - Hermaphrodite (bisexual).

- **Testes -** 2 pairs **(10th & 11th segment),** vasa deferentia run upto 18th segment to join prostatic duct.

- **Accessory glands -** 2 pairs **(17th & 19th segment).**
- Common prostate & **spermatic (vasa deferentia)** open to exterior by male genital pore on **18th segment**.
- **4 pair of spermathecae –** 6th to 9th segment (receive & store spermatozoa).
- **Ovary -** 1 pair at septa of **12th & 13th segment.**
- Ovarian funnel beneath ovary open to oviduct which open on ventral side as single median genital pore on **14th segment.**

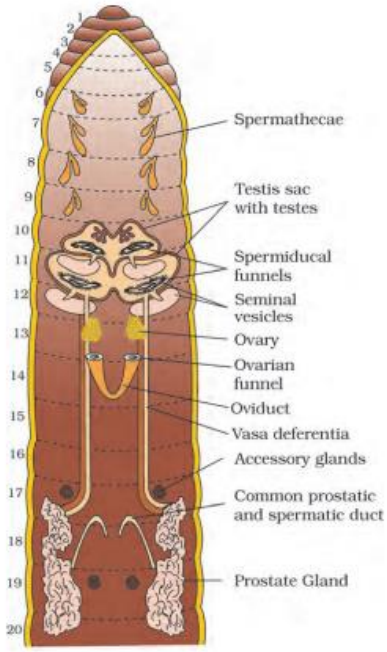


Figure 7.13 Reproductive system of earthworm

h) Cross fertilisation - Due to large distance between male & female pores.

- 2 worms mate juxtaposing opposite gonadal opening exchanging spermatophores.
- Mature sperm, egg cells & nutritive fluid are deposited in cocoons **produced by gland cells of clitellum**.
- Ova are fertilised by sperm cell within cocoon which slips off worm & deposited on soil.
- Cocoon holds embryo & after **3 weeks, each cocoon produce 2 - 20 baby worms (average 4).**
- Direct development (no larva).

Friends of farmers –

- Make burrows in soil & make it porous which help in respiration & penetration of developing plant roots.
- Process of increasing fertility of soil by earthworm – **vermicomposting.**
- Used as bait in fishing.

Cockroach –

- Brown/black, can be yellow, red in other region.
- 1/4 to 3 inches (0.6 - 7.6 cm) in size, **long antennae**, serious pests.
- Flat - extension of upper body conceals head, **noctural omnivores.**
- Found in damp place, vectors of several diseases.
- No economic importance, many species are wild.

Morphology –

- **Periplaneta Americana** - Adult, 34 - 53 mm, wings extend beyond abdomen tip in males.

Structural Organisation In Animals

- Segmented body divisible into head, thorax & abdomen.

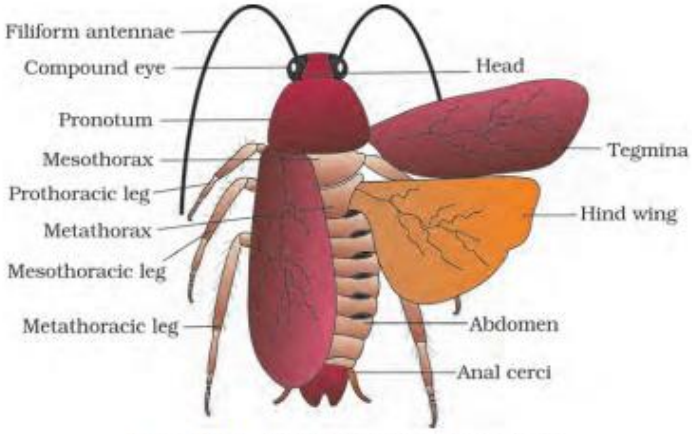


Figure 7.14 External features of cockroach

- Chitinous exoskeleton with hardened plates - **sclerites** (tergites dorsally & sternites ventrally) joined by thin flexible **articular membrane.**
- **Head -** Triangular, 90° to body axis, fusion of 6 segments, flexible neck, bear compound eyes.
- Thread like antennae from sockets in front of eyes, which has sensory receptors.
- Anterior mouth - Biting & chewing.
- **Mouthparts - Labrum (upper lip), pair of mandibles, pair of maxillae, Labium (lower lip), hypopharynx** (tongue, median lobe).

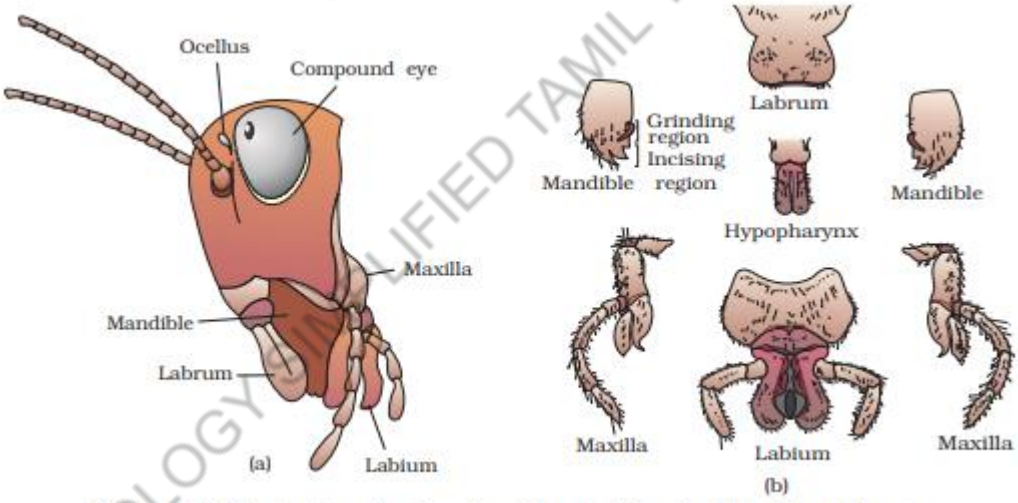


Figure 7.15 Head region of cockroach : (a) parts of head region (b) mouth parts

- **Thorax -** Prothorax, mesothorax & metathorax.
- Head is connected to thorax by neck **(short extension of prothorax)**.
- Each thoracic segment bears pair of legs.
- 1st pair of wings from mesothorax, second from metathorax.
- **Tegmina -** Forewings (mesothoracic), **opaque, leathery,** cover hind wings at rest, also called **elytra.**
- **Hind wings -** Transparent, membranous, for flight.
- Abdomen in male & female has **10 segments.**
- **Females -**7th sternum **(boat shape)** with 8th & 9th sterna form genital pouch (anterior part has **gonopore, collateral gland & spermathecal pores).**

- **Males -** Genital pouch at hind end of abdomen, dorsally by 9th & 10th terga & ventrally by **9th sternum,** contains **dorsal anus, genital pore, gonopophysis,** bear short thread like **anal style** (absent in female).
- In both sex, **10th segment** bear jointed filamentous structure - **Anal cerci.**

Anatomy:

a) Alimentary canal: Foregut + Midgut + Hindgut

- Mouth opens to tubular pharynx, leading to narrow tubular oesophagus, which open into sac like **crop** (food storing), then **gizzard or proventriculus** (grinding).
- Thick circular muscles on outer & thick cuticle on inner forming **6 chitinous plate** called teeth.
- Foregut is lined by cuticle.
- **6 - 8 blind tubule (hepatic/gastric caeca)** at junction of foregut & midgut secrete digestive juice.
- **100 - 150 yellow colour thin Malpighian tubule** at junction of midgut & hindgut to remove waste from haemolymph.
- Hindgut is broader than midgut & differentiated into ileum, colon, rectum. Rectum opens through anus.

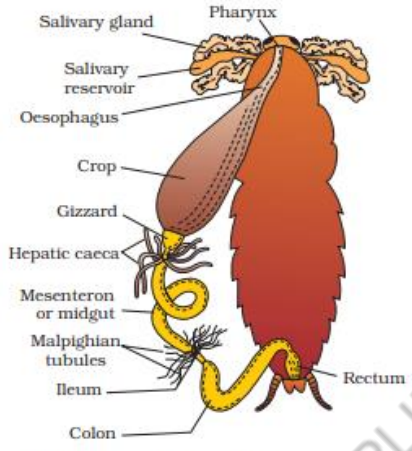


Figure 7.16 Alimentary canal of cockroach

b) Circulatory system: Open

- Poorly developed blood vessel open into haemocoel.
- **Haemolymph - Colourless plasma + Haemocytes.**
- Visceral organs in haemocoel are bathed in haemolymph.

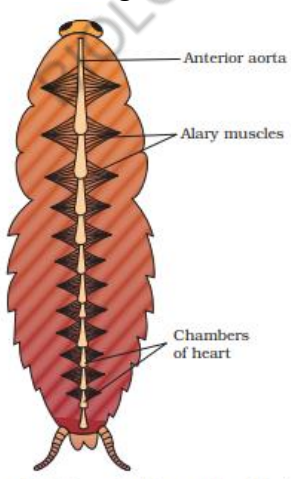


Figure 7.17 Open circulatory system of cockroach

- Heart is elongated tube like along line of thorax & abdomen, differentiated into **funnel shaped chambers** with ostia on either side.
- Blood from sinuses enter heart & pumped to sinuses again.

c) Respiratory system:

- Network of trachea open through 10 pairs of holes – **spiracles**.
- Thin branching tubes **(tracheal tubes)** carry oxygen to all parts.
- Gaseous exchange at tracheoles by diffusion.

d) Excretory system: Uricotelic, by malpighian tubules.

- Lined by glandular & ciliated epithelium.
- Absorb nitrogenous waste & convert them into uric acid.
- Fat body, nephrocyte & uricose gland also help in excretion.

e) Nervous system: Fused segmentally arranged ganglia joined by connectives.

- **3 ganglia in thorax, 6 in abdomen.**
- Head holds a bit of nervous system while rest is along **ventral part.** So, if head is cut off, it may survive for 1 week.
- **Brain - supra oesophageal ganglion** which supply nerve to antennae & compound eyes (dorsal surface of head).
- Each eye **2000 hexagonal ommatidia** (several images) -**mosaic vision** (high sensitivity less resolution), common during night.
- **Sense organs -** Antennae, eyes, **maxillary palps, labial palp, anal cerci.**

f) Reproductive system:

- Dioecious, well developed sex.

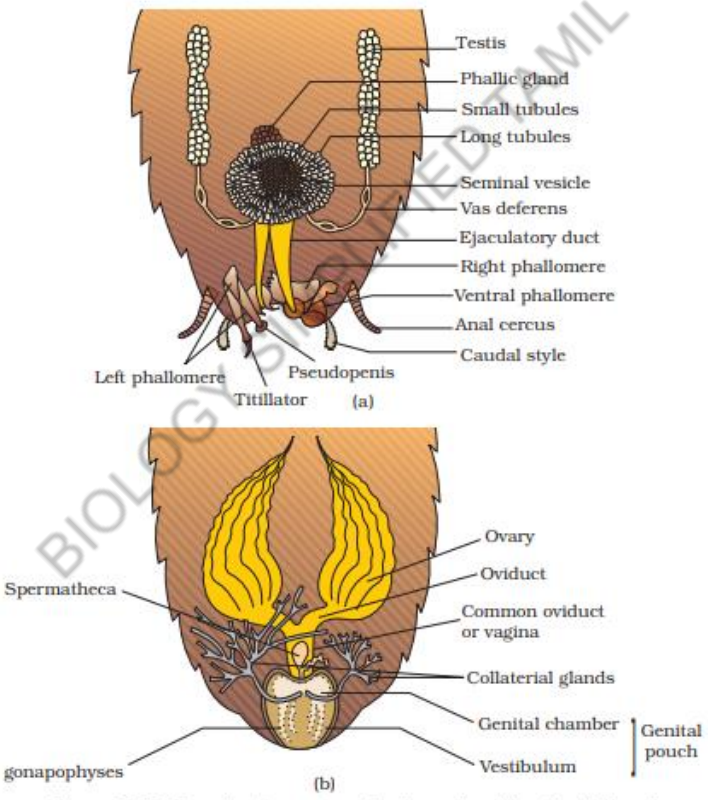


Figure 7.18 Reproductive system of cockroach : (a) male (b) female

- **Male -** Pair of testes one on each side in **4 – 6th abdominal segments,** from which arise vas deferens, open into ejaculatory duct through seminal vesicle, open into male gonopore to anus, external genitilia - **male gonapophysis/phallomere** (chitinous), sperms stored in

seminal vesicle are glued in bundle - **Spermatophores,** pair of spermatheca **(6th segment)** open into genital chamber.

- **Accessory gland -** Mushroom shaped in **6th -7th abdominal segment.**
- **Female -** 2 large ovaries **(2nd -6th segment)**, each ovary is group of 8 ovarioles, oviduct of each ovary unite into single median oviduct **(vagina)** which opens to genital chamber.

g) Cross fertilisation:

- Sperms are transferred through spermatophore.
- Fertilised eggs are encased in capsule - **oothecae** (Reddish to blackish, brown, 8mm long), dropped in crack with high humidity.
- **Female produce 9-10 oothecae (14-16 eggs each).**
- **P. Americana -** Paurometabolous (development through nymphal stage), nymph is similar to adult, moult about **13 times.**
- Next to nymphal stage has wing pads but only adults have wings.

Frogs:

- Amphibian, most common - **Rana tigrina,** poikilothermous.
- Ability to hide colour (camouflage), protective colouration - **mimicry.**
- Deep burrows in extreme cold or extreme hot.
- **Aestivation -** Summer sleep, **Hibernation -** Winter sleep.

Morphology –

- Smooth & slippery skin due to mucus.
- Olive green on dorsal side with irregular spots & pale yellow on ventral side.
- Never drinks water, only absorbs it through skin.
- Neck & tail absent, body divisible into head & trunk.
- Nostrils present, bulged eyes with **nictitating membrane** (protects them in water), tympanum receive sound signals.
- Fore limbs & hind limbs for leaping, burrowing, swimming.
- **Hind limbs -** 5 digits, larger, more muscular.
- **Fore limbs -** 4 digits.
- Webbed feet for swimming, **sexual dimorphism.**
- Male are distinguished by **sound producing vocal sacs** &**copulatory pad on 1st digit of fore limb.**

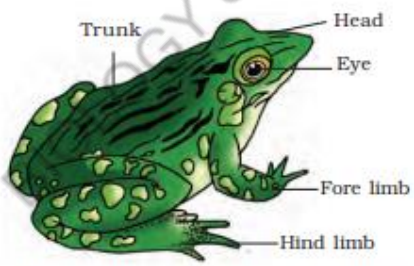


Figure 7.19 External features of frog

Anatomy –

a) Alimentary canal - Short as they are carnivores, reduced intestine.

- Mouth opens to buccal cavity which lead to oesophagus through pharynx, which opens to to stomach which constitute intestine, rectum & finally opens outside by cloaca.
- Liver secrete bile stored in gall bladder, pancreas secrete pancreatic juice.
- Food is captured by **bilobed tongue,** digestion of food by HCl & gastric juices, partially digested food - **chyme** is passed to duodenum.

- Duodenum receive bile from gall bladder & pancreatic juice from pancreas through **common bile duct.**
- Bile emulsifies fat & pancreatic juice digest carbohydrate & protein.
- Digested food is absorbed by finger like folds in intestine - **villi & microvilli**, undigested waste to rectum & passed by cloaca.

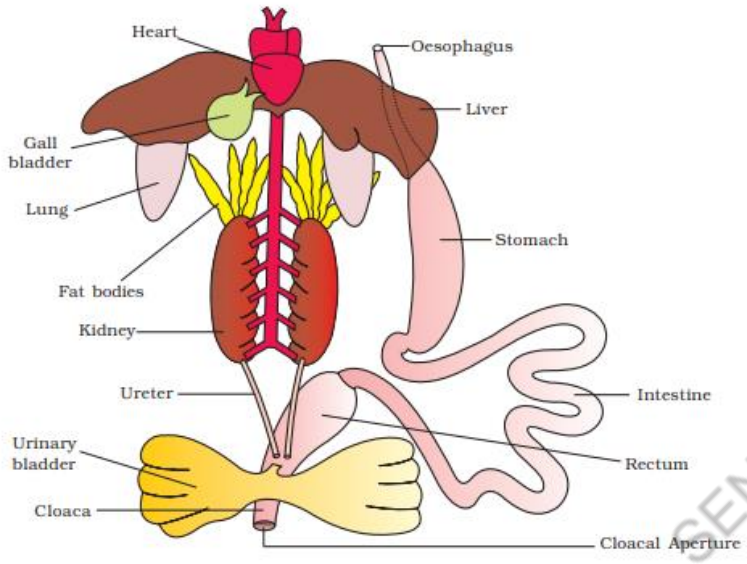


Figure 7.20 Diagrammatic representation of internal organs of frog showing complete digestive system

b) Respiratory system: Both on land & water.

- Water - **cutaneous**, by skin through diffusion.
- Land - skin & lungs **(pulmonary)** - pair of elongated, pink coloured sac like lungs in upper part of thorax.
- During **aestivation & hibernation** - gaseous exchange **by skin**.

c) Circulatory system: Well developed, closed with lymphatic system.

- Lymphatic system – lymph, lymph channel, lymph nodes.
- Involves heart, blood vessels & blood.
- Heart (3 chamber) is muscular in upper part of body cavity, covered by **pericardium.**
- Triangular structure - **Sinus venosis join right atrium,** receive blood from major veins – vena cava, ventricles open into **conus arteriosus**.
- Blood from heart to all body parts is carried by arteries & veins collect - blood from body parts to heart.
- Special venous connection between liver & intestine **(hepatic)** as well as kidney & lower parts **(renal portal).**
- Blood - Plasma + Cells (RBC +WBC/Leucocyte + Platelets).
- RBC - **nucleated**, haemoglobin, carries nutrient, water etc.
- **Lymph lacks proteins & RBCs.**

d) Excretory system: Well developed, excrete urea – **Ureotelic.**

- Pair of kidney, ureters, cloaca, urinary bladder.
- Kidney - compact, red, bean like structure, has several structural & functional unit - **uriniferous tubules (nephrons).**
- In males, 2 ureters emerge from kidney, act as urinogenital duct which opens into cloaca.
- In females, ureters & oviduct open separately in cloaca.
- Thin walled urinary bladder to rectum which opens to cloaca.
- Excretory waste by blood to kidney where its separated & excreted.

Structural Organisation In Animals

e) Nervous system: Highly evolved.
- Control & cordination - neural + endocrine.
- Endocrine glands - pituitary, thyroid, parathyroid, thymus, pineal, pancreatic, adrenal & gonads.
- **Nervous system -** Central nervous system **(brain + spinal cord),** Peripheral nervous system **(cranial+ spinal nerve)** & autonomic nervous system **(sympathetic & parasympathetic).**
- **10 pairs of cranial nerves,** brain is enclosed in brain box **(cranium).**
- **Forebrain -** Olfactory lobes, paired cerebral hemisphere, unpaired diencephalon.
- **Midbrain -** Paired optic lobes.
- **Hindbrain -** Cerebellum & medulla oblongata which passes through foramen magnum & to spinal cord.

f) Sensory organs: Cellular aggregates **except eyes & internal ears.**
- Organs of touch (sensory papillae), taste (taste buds), smell (nasal epithelium), vision (eyes), hearing (tympanum).
- **Eyes -** Spherical, in orbit of skull, simple.
- **Ear -** External ear absent, tympanum present, hearing & balancing.

g) Reproductive system: Well organised.
- **Male -** Pair of yellowish ovoid testes adhered to upper part of kidney by **mesorchium,** 10 - 12 vasa efferentia from testes enter kidney & open into **Bidder's canal**, joins urinogential duct & opens into cloaca (small median chamber passing **faecal matter, urine & sperms).**

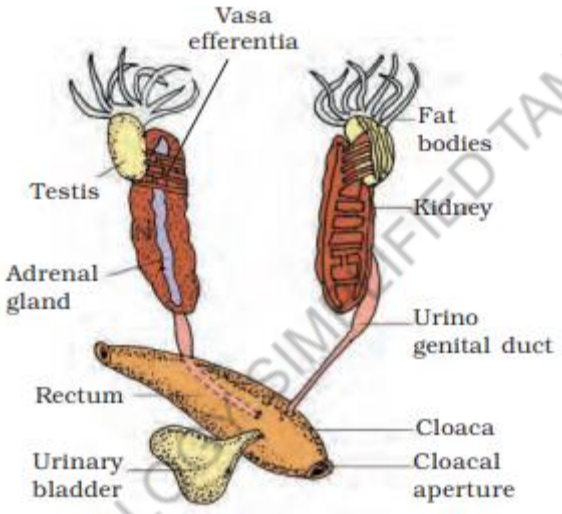


Figure 7.21 Male reproductive system

- **Female -** Pair of ovaries near kidney **(no functional connection between two),** pair of oviduct from ovary opens to cloaca, mature female lay **2500 - 3000** ova at a time.
- External fertilisation in water, indirect development.
- Larval stage - **tadpole (metamorphosis** to form adult).

Beneficial:
- Eat insects & protect crop.
- Ecological balance, important link of food chain & food web.
- Muscular legs are eaten by man.

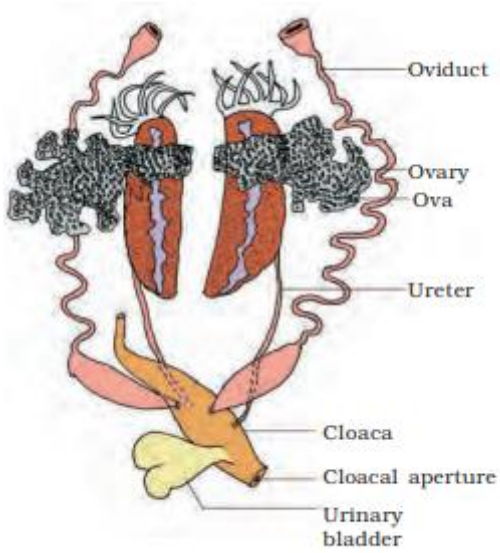


Figure 7.22 Female reproductive system

Cell: The Unit of Life

Cell: Fundamental structural & functional unit of life.

Discovery of living cell – Anton von Leuwenhoek

Discovery of nucleus – Robert Brown

Cell Theory: By **German Botanist Matthias Schleiden & british zoologist Theodore Schwann.**

- **Schleiden:** Plants are composed of different kind of cells.
- **Schwann:** Presence of plasma membrane.
  But it didn't explained how new cells were formed.
- **Rudolf Virchow:** Explained that cell divided & new cells are formed from pre-existing cells **(omnis cellula-e-cellula).**
- **Final theory:** All organism are composed of cells & new cells arise from pre-existing cells.

Cell:

- Dense membrane bound structure: **Nucleus.**
- Semi fluid matrix: **Cytoplasm** (main arena of cellular activities).
- Membrane bound distinct-structures: **Organelles.**
- Animals: **Centrosome (cell division).**
- **Mycoplasma:** 0.3 µm (smallest) to 3-5 µm bacteria
- Largest isolated single cell: **Egg of ostrich**
- **Human red blood cell:** 7µm diameter
- Longest cell: **Nerve cell.**

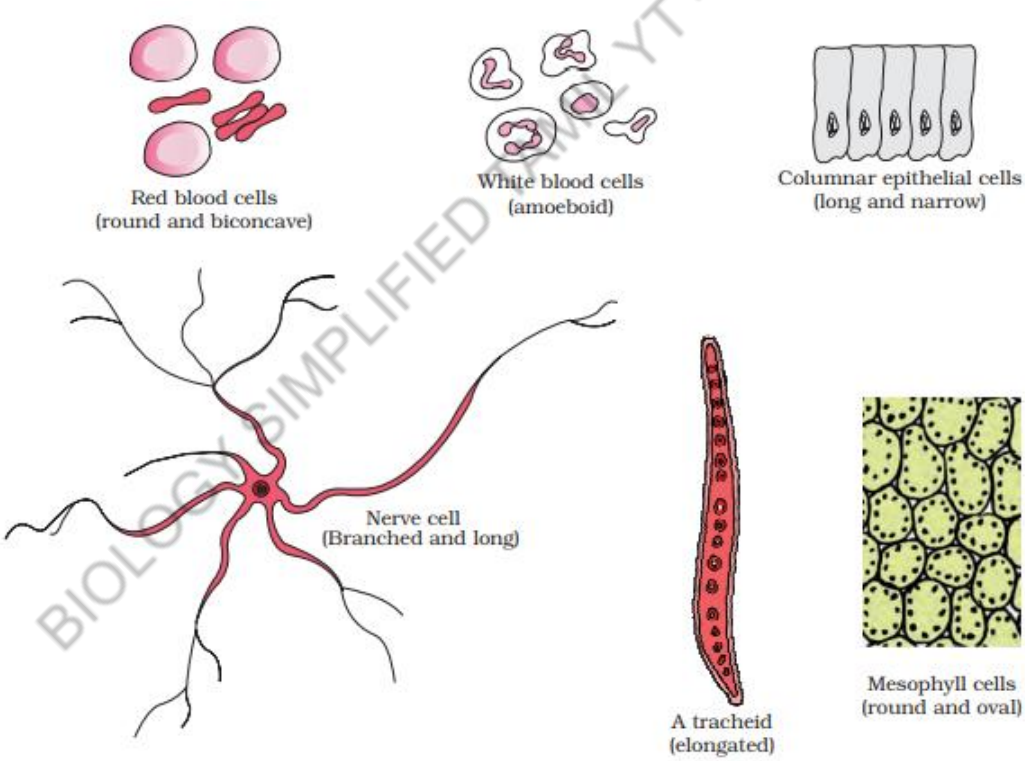


Figure 8.1 Diagram showing different shapes of the cells

Prokaryotic cell: Lack membrance bound nucleus & cell-organelles.

Eg: Bacteria, blue green algae, mycoplasma, PPLO (Pleuro Pneunomia like organisms)

- Small, multiply rapidly, no nuclear membrane.
- Bacteria can be bacillus (rod), coccus (spherical), vibrio (comma), spirillum (Spiral).
- Have cell wall **except mycoplasma,** naked genetic material.

- Genomic DNA + Small circular DNA **(Plasmid),** ribosomes present.
- Infoldings of cell membrane – **mesosome, resistant to antibiotics.**

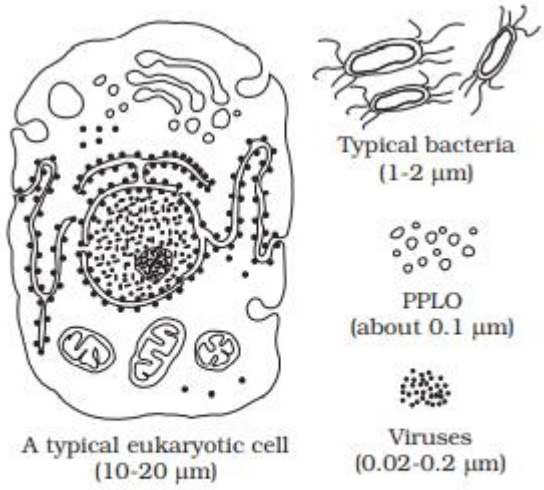


Figure 8.2 Diagram showing comparison of eukaryotic cell with other organisms

Cell Envelope & Modifications

- Outermost **glycocalyx** → cell wall → plasma membrane.
- Single protective unit.
- Glycocalyx as loose sheath – **slime layer,** as thick & tough layer – **capsule.**
- Cell wall prevent bursting & collapsing of bacterium, provide shape.
- Selectively permeable plasma membrane.
- **Gram positive:** Can be stained. **Gram negative** – can not be stained.
- **Mesosomes:** Membranous structure formed by extension of plasma membrane into cell, can be in form of vesicles, tubules & lamellae, help in **cell wall formation, DNA replication, respiration, secretion, increase surface area.**
- **Cyanobacteria:** Other membranous extensions into cytoplasm – **chromatophore** (contain Pigments).
- Thin filamentous extensions: **Flagella** if motile.
- Flagella: Filament, hook & basal body (longest- filament)
- Besides flagella, **pili** & **fimbrae** are surface structure **(no motility)**
- **Pili:** Elongated tubular structure made of protein.
- **Fimbrae:** Small bristle like fibres.
- They **attach bacteria to rocks in stream** & **to host tissues.**

Ribosme: Protein synthesis.

- Prokaryotes – 15 nm - 20 nm in size, 2 subunit – **50 S & 30 S**, together form **70 S**.
- Eukaryote – 80 S ribosome made up of **60 S** and **40 S** sub units.
- Attach to single m RNA & form chain - **polyribosome/polysome,** which translate mRNA to protein.

Inclusion bodies: Store reserve material in cytoplasm.

- Lie free in cytoplasm, not bounded by any membrane.
- **Eg: Phosphate granules, cyanophycean granule, glycogen granules.**
- Gas vacuoles: Blue green & purple & green photosynthetic bacteria.

Eukaryotic cells: Membrane bound nucleus & cell organelles.

Eg: Protists, plant, animals & fungi.

Cell: The Unit of Life

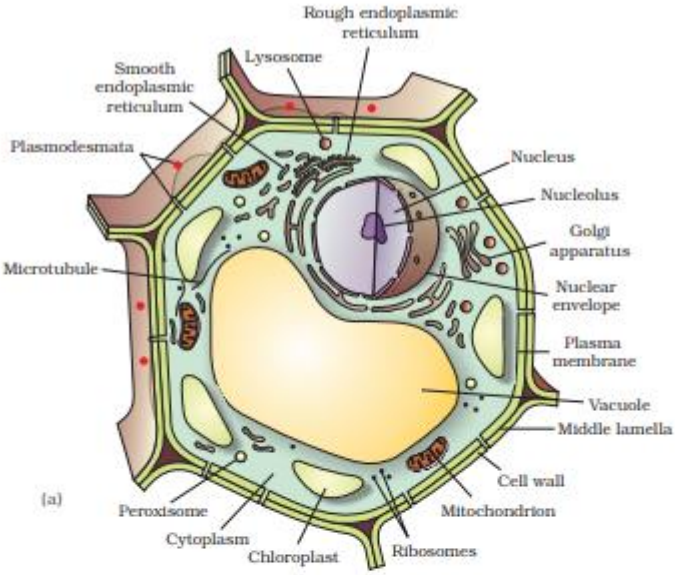


Figure 8.3 Diagram showing : (a) Plant cell (b) Animal cell

- Genetic material is organised into chromosomes.
- **Plant cells:** Cell wall, plastid, large vacuole.
- **Animal cells:** Centriole (Centrosome).

Cell Membrane: Phospholipid + Protein (bilayer)

- Lipids are arranged within membrane with **polar head (hydrophilic)** towards outer side & **tail (hydrophobic)** towards inner side. So, non polar tail is protected from aqueous environment.
- Membrane also contain **cholestrol, phosphoglyceride** (main lipid component), carbohydrate & protein.
- In human RBC: **52% protein 40% lipid,** ratio varies in different cells.
- **Peripheral protein:** Lie on membrane surface .
- **Integral protein:** Partially or totally buried in membrane.
- **Fluid Mosaic Model (1972) – Singer & Nicolson:** Quasi fluid nature of lipid enable protein movement across membrane. Protein icebergs in a sea of liquid.
- **Passive transport:** Movement of molecules across membrane without energy.
- **Neutral solute:** By simple diffusion (high concentration to low concentration)
- **Osmosis:** Water movement across membrane by diffusion.

- **Active transport:** For **polar molecules which can't cross non-polar layer,** require carrier protein, energy, can be against concentration gradient, ATP utilised. **Eg:** **Na^+ - K^+ Pump.**

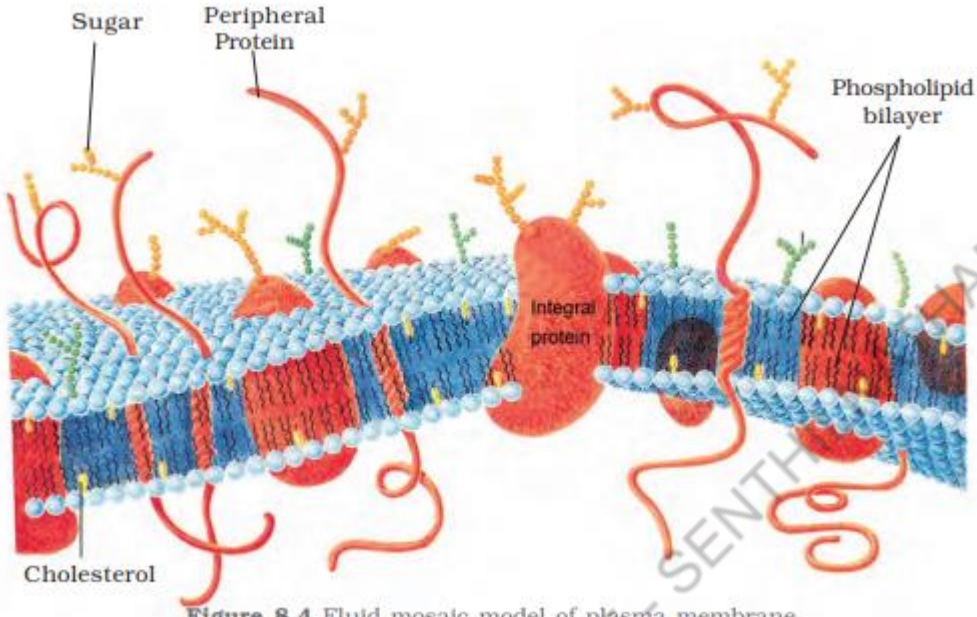


Figure 8.4 Fluid mosaic model of plasma membrane

Cell Wall: Non living, rigid

- **Algae:** Cell wall composed of **cellulose, galactans, mannans, $CaCo_3$**
- **Plants:** Cellulose, hemicellulose, pectin, protein.
- Provide shape, protection, interaction among cell, barrier to certain molecules.
- **Primary wall:** Capable of growth, diminishes as cell matures.
- **Secondary wall:** Inner side of cell ie. primary wall.
- **Middle lamellae: Calcium pectate,** holds cells together.
- Cell wall & middle lamellae are traversed by **plasmodesmata** which connects cytoplasm of cells.

Endomembrane system: Golgi complex, vacuoles, endoplasmic reticulum, lysosomes.

1) Endoplasmic Reticulum: Network of tiny tubular structures in cytoplasm.

- 2 compartments: Luminal (inside ER) & extra Luminal (cytoplasm).
- **RER:** Rough endoplasmic reticulum, ribosomes on surface, secretion and synthesis of protein, continuous with outer membrane of nucleus.
- **SER:** Smooth endoplasmic reticulum, no ribosomes, smooth, synthesis of lipid, in animal cells **synthesise steroidal hormones.**

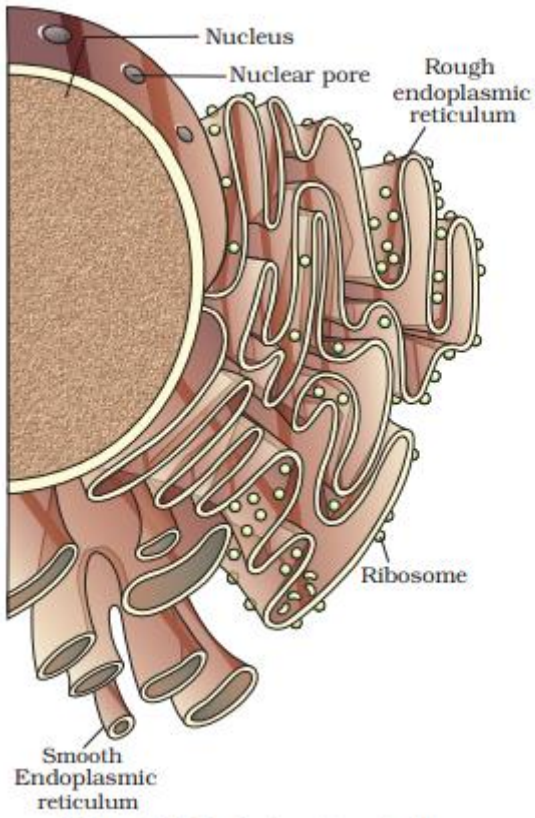


Figure 8.5 Endoplasmic reticulum

2) Golgi apparatus – By **Camillo Golgi (1898),** also called **dictyosome.**

- Densely stained reticular structure.
- Flat disc shaped sacs – **cisternae (0.5 - 1µm in diameter)** stacked parallel.
- Near nucleus - **convex cis/forming face** & **concave trans/maturing.**
- Packed materials in form of vesicles fuse from ER with cis face & move to maturing face - packaging of materials.
- Site of formation of **glycoprotein & glycolipid.**

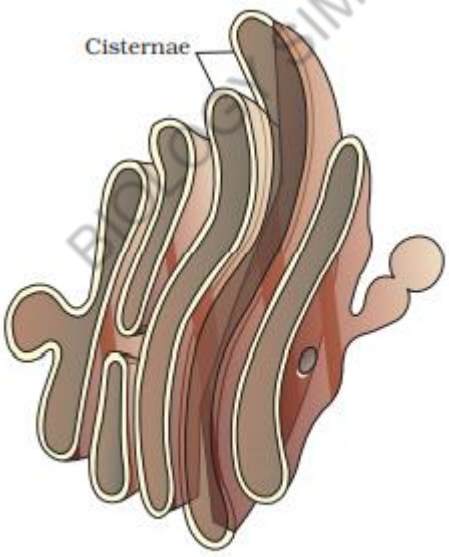


Figure 8.6 Golgi apparatus

3) Lysosomes: Membrane bound vesical structure formed by golgi apparatus.
- Has **hydrolytic enzymes –** lipase, protease, carbohydrate, sulphatase DNAses, RNAses, so called **suicidal bags** of the cell.
- Active at **acidic pH,** digest carbohydrate, protein, nucleic acid & lipids.

4) Vacuoles: Membrane bound space, single membrane – **tonoplast**
- Contains water, sap, excretory products not useful for cells.
- In plant: 90% space by vacuole, provide buoyancy, facilitate transport of ions against concentration gradient.
- **Amoeba (contractile vacuole):** Excretion, **protist (food vacuole) -** engulf food.

Mitochondria: sausage shaped/cylindrical with diameter 0.2-1 µm & length 1- 4.1 µm.
- Double membranous, site for aerobic respiration, produce energy in form of ATP, **power house of cell**.
- Inner membrane has homogenous matrix & forms infoldings - **cristae** towards matrix which increase surface area.
- Single circular DNA, RNA molecule, **70 S ribosome,** divide by fission (**semiautonomous** in nature).
- Has components for synthesis of protein.

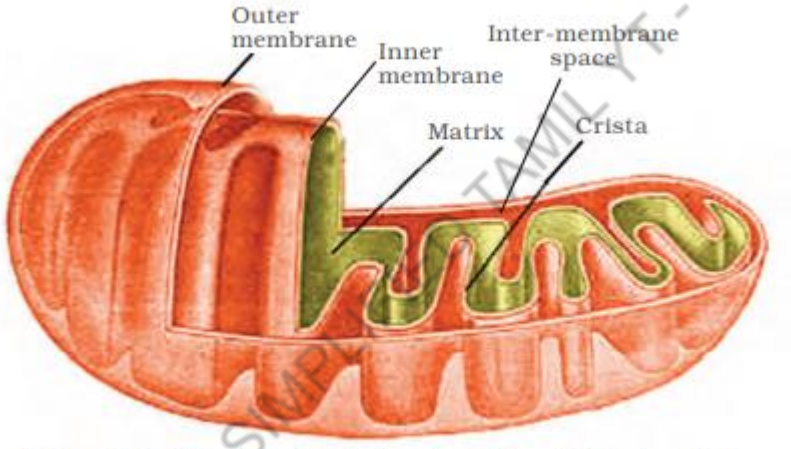


Figure 8.7 Structure of mitochondrion (Longitudinal section)

Plastids: Plant cells & euglenoids.
- On the basis of pigment:

→ **Chloroplast:** Chlorophyll & carotenoid, trap light energy.
→ **Chromoplast:** Fat solube carotenoid - carotene, xanthophyll, provide colour.
→ **Leucoplast:** Colourless, store nutrients.
  → **Amyloplast:** Store carbohydrate. **Eg:** Potato (starch).
  → **Elaioplast:** Store oils & fats.
  → **Aleuroplast:** Store protein.

***Chloroplast:** Kitchen of the plant cell, Lens shaped, oval, spherical, discoid or ribbon like, majority of them are in **mesophyll cells,** can be 1 per cell **(chlamydomonas)** to 20-40 per cell **(mesophyll).**

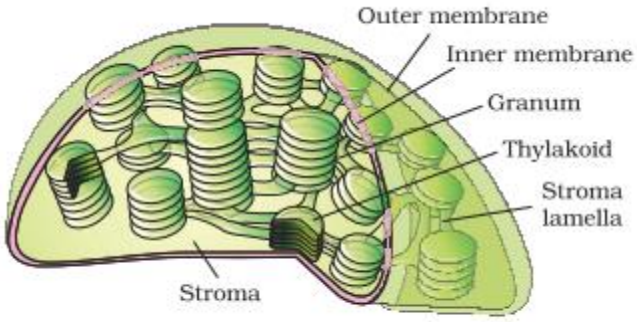


Figure 8.8 Sectional view of chloroplast

- Double membranous, inner one is less permeable.
- Contain matrix - stroma, flattened membranous sacs – **thylakoids.**
- Thylakoid are arranged in stacks – **grana**
- Flat membranous tubule connecting thylakoid – **stroma lamellae.**
- Double stranded circular DNA, **70 S ribosome**, divide by fission (semiautonomous in nature), and helps in photosynthesis.
- **Stroma has enzymes for synthesis of carbohydrate & protein.**

Ribosomes: Granular structure by **George Palade (1953)**

- Has RNA & proteins, amembranous, **80 S in eukaryote** (60S +40S)
- Has 2 subunits (large & small).
- S in 80S & 70S is **Svedberg Unit**/sedimentation coefficient.
- Indirect measure of density & size.

Cytoskeleton: Network of filamentous proteinaceous structure in cytoplasm.

- Mechanical support, motility, maintenance of shape of the cell.

Cilia & Flagella: Hair like outgrowths.

- Cilia: Small structure, work like oars, movement.
- Flagella: Long structure, cell movement.
- Both emerge from **basal bodies** & covered with plasma membrane.
- Core: **Axoneme** possess no. of microtubule running parallel to long axis. It has **9 pair of doublet of radially arranged peripheral microtubule** & **pair of central microtubule.**
- **9+2 arrangement,** central tubules are connected by bridge & enclosed by central sheath, connected to peripheral doublet by **radial spoke** (9), peripheral doublets are interconnected by linkers.

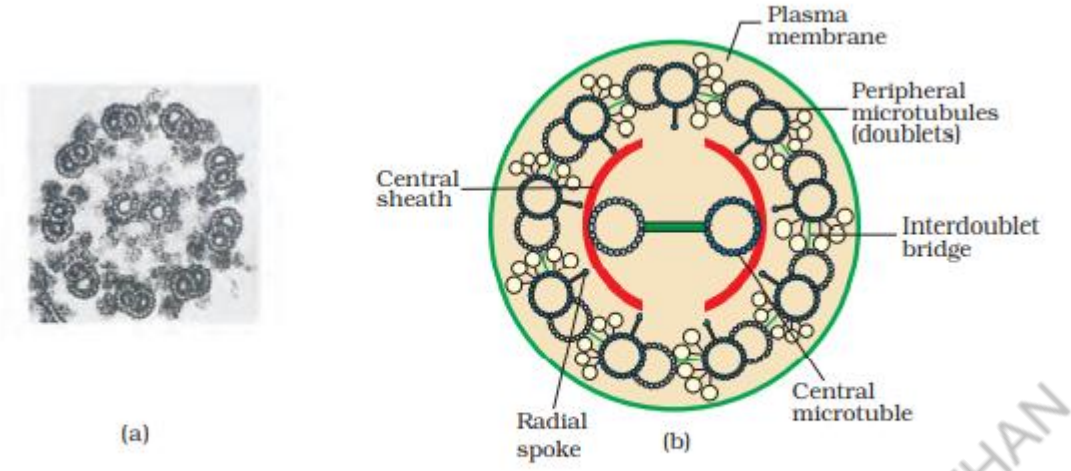


Figure 8.10 Section of cilia/flagella showing different parts : (a) Electron micrograph (b) Diagrammatic representation of internal structure

Centrosome & Centrioles:

- **Centrosome:** Contain 2 cylindrical structures – **centrioles**.
- Surrounded by amorphous pericentriolar material.
- Both centriole lie **perpendicular** in which each has cartwheel like appearance.
- 9 peripheral fibrils **(tubulin protein)** which are **triplets** & linked.
- Central part – **proteinaceous hubs** connected with peripheral triplets by **radial spokes** (protein), hence **9+ 0 arrangement.**
- Give rise to spindle apparatus during cell division & form basal body.

Nucleus: By Robert Brown (1831)

- Material of nucleus stained by **basic dye-chromatin by Flemming**
- Interphase nucleus – extended & elaborate **nucleoprotein – chromatin,** matrix & spherical bodies - **nucleoli.**
- Nuclear envelope has 2 parallel membrane with space - **perinuclear space,** outer membrane is continuous with ER.
- Membrane is interrupted by pores which help in RNA & protein movement in both direction.
- Some cells lacks nucleus. **Eg: Erythrocyte & sieve tube cells** (after maturity)
- Nucleoplasm - **Nucleolus** (spherical structure) & **chromatin.**

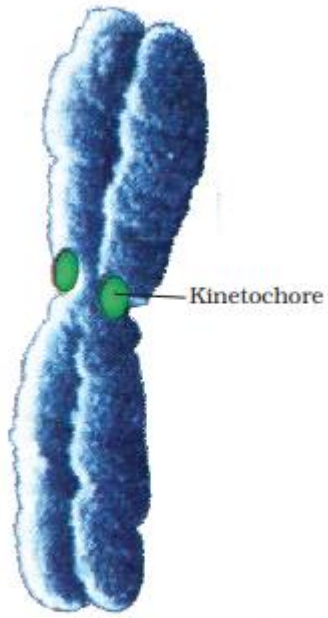


Figure 8.12 Chromosome with kinetochore

- **Nucleoli:** Amembranous, RNA synthesis, protein synthesis.
- **Chromatin:** DNA, histones (basic protein), non histone, RNA.
- Single human cell - 2m long DNA divided in 46 chromosomes.
- Every chromosome has primary constriction/**centromere,** disc shape **kinetochore** on side.
- Centromere holds 2 chromatids of chromosome.

On the basis of position of centromere;

Metacentric: Centromere forms 2 equal arms of chromosome - 'v' shaped.

Sub-metacentric: Centromere slightly away from middle (one short & one long arm) - 'J' or 'L' shaped.

Acrocentric: Centromere is close to its end (1 extremely short & 1 very long arm) - 'I' shaped.

Telecentric: Centromere has terminal centromere.

- Some chromosomes have non - staining secondary constriction giving appearance of small fragment – **satelites.**
- **Microbodies:** Membrane bound minute vesicle containing enzymes present in both animal & plant cells. They are peroxisomes, Glyoxisomes and sphaerosomes.

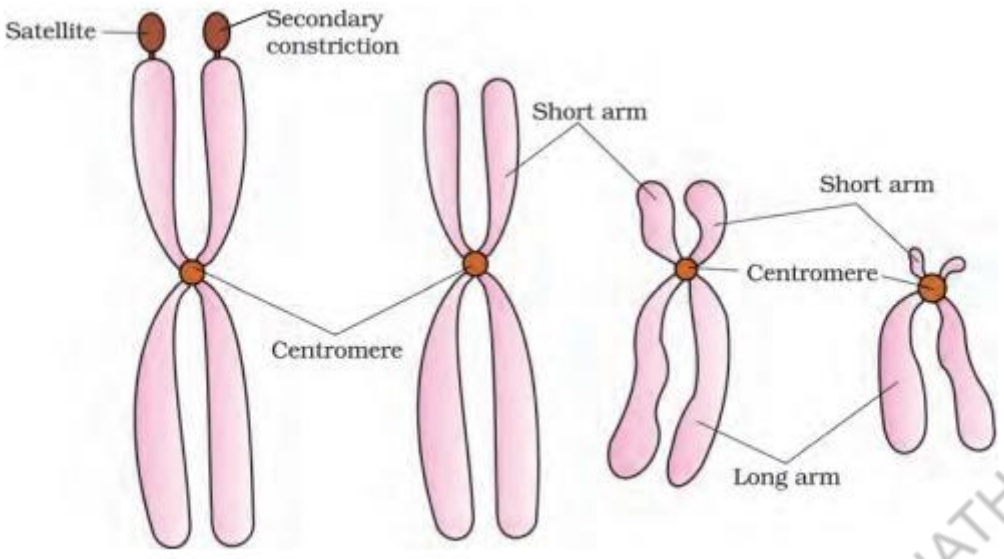


Figure 8.13 Types of chromosomes based on the position of centromere

Biomolecules

• Carbon & hydrogen are more in living organism than earth's crust.

How to analyse chemical composition?

• Grind living tissue in **trichloroacetic acid** using mortar & pestle.
• Strain thick slurry through cheesecloth.
• One is filterate **(acid soluble)** & other retentate **(acid insoluble)**.
• **For inorganic:** Dry small amount of living tissue, water evaporates & remaining material gives dry weight. If its fully burnt, carbon compounds oxidise & **ash** remains.
Ash - inorganic elements (Calcium, Magnesium etc.)
• **Biomolecules -** All carbon compounds we get from living tissues.

Primary & Secondary Metabolites

Primary: For growth & metabolism, physiological process.
Secondary: Not used for growth. **Eg:** alkanoids, rubber, spices etc. Used for commercial purpose.

Table: 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:

• **Acid soluble:** Weight from 18-800 daltons (Da), micromolecules.
Eg: inorganic compounds - sulphate, phosphate.
• **Acid insoluble:** 10000 dalton or above, biomacromolecules.
Eg: polysachharide, lipid, nucleic acid, proteins.

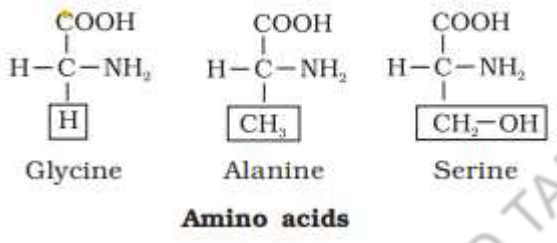
Table: Average composition of cells

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

But **lipid don't weigh more than 800 Da**, as they separate in form of vesicles.
- **Water is the most abundant chemical in living organism.**

Proteins: Linear chain of amino acid linked by peptide bonds.

- Polypeptide, **heteropolymer of amino acid** (20 types of amino acid).
- Homopolymer - only 1 type of monomer repeating n no.of times.
- **GLUT-4 transport glucose.**
- 2 types of amino acid-
  → **Essential:** Not synthesised in body, outsourced.
  → **Non-essential:** Synthesised in body, need not be outsourced.
- Transport nutrients, fight infectious organism
- Some are hormones **(insulin),** some are enzymes **(trypsin)**
- Amino acid have **amino group + acidic group** on same carbon. i.e. **α – carbon.** So, called α-amino acid **(substituted methane)**
- 4 substituent groups- Hydrogen, carboxyl group, amino, R (variable)
- If R is **hydrogen,** amino acid is called **glycine,** if methyl then amino acid is **alanine,** if hydroxyl methyl then amino acid is **Serine.**



Amino acids

- They can be –
  Acidic: **Glutamic acid**
  Basic**: Lysine**
  Neutral**: Valine**
- **Aromatic amino acid- tyrosine, tryptophan, phenylalanine.**
- Ionisable nature of $–NH_2$ & -COOH makes amino acid – **Zwitter ion**. So, their structure differ at different pH.

* **Collagen is most abundant protein in animal world.**
* **RUBISCO is most abundant protein in whole biosphere.**

Table: Some proteins and their Functions

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone, etc.)
GLUT – 4	Enables glucose transport into cells

Biomolecules

Lipids: Water insoluble, can be simple fatty acids.

- **Fatty acid : Carboxyl group + R (methyl, ethyl etc.)**
- **Arachiodonic acid** (20 carbon including carboxyl carbon)
- **Palmitic acid** (16 carbon including carboxyl carbon)
- They can be –

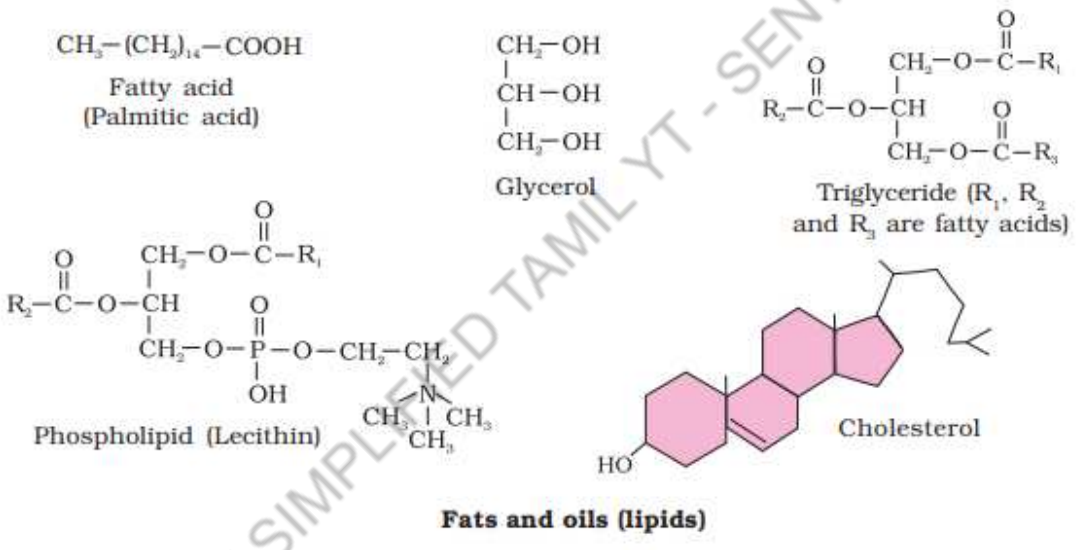
Saturated: No double bond

Unsaturated: One or more C = C double bond.

- Simple lipid: **Glycerol (trihydroxy propane)**
- Some lipid have both glycerol & fatty acid – **glyceride**
- Depending upon no. of fatty acid, they can be diglyceride, triglyceride
- These are of type

  →**Fats-** high melting point

  →**Oils-** low melting point. **Eg:** Ginelly oil.
- Some have phosphorous-phospholipid. **Eg: Lecithin**



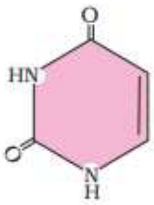
Fats and oils (lipids)

Nucleic acids: Building block-nucleotide, polynucleotide

- **Nucleotide** – Heterocyclic compound + monosachharide + phosphoric acid/phosphate.**Eg: adenylic acid, uridylic acid.**
- Heterocyclic compound – **Nitrogenous base. Eg:** [adenine, guanine] **purine** & [uracil, thymine, cytosine] **pyrimidine.**
- **Nucleoside –** sugar + nitrogenous base.
- Nucleic acid with ribose sugar – RNA & with deoxyribose sugar – DNA.
- RNA & DNA consist of nucleotides only.

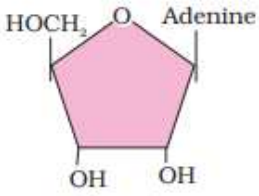
Biomolecules

Adenine (Purine)

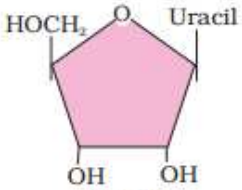


Uracil (Pyrimidine)

Nitrogen bases

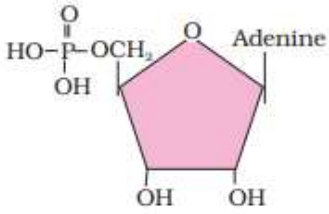


Adenosine



Uridine

Nucleosides

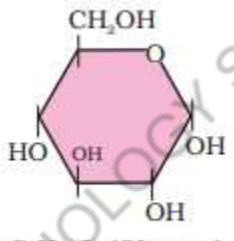


Adenylic acid

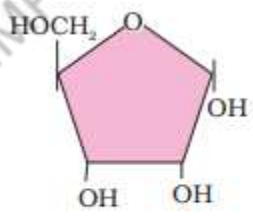
Nucleotide

Polysachharides: **Long chain of sugar, building block – monosachharide**

- Exoskeleton of arthropods – **chitin** (homopolymer).
- Mostly right end is reducing & left end non-reducing.
- **Cellulose:** Polymeric polysachharide of glucose, homopolymer, don't have complex helix so can't hold I_2.
- Paper made from plant pulp & cotton fibre- cellulosic.
- **Starch:** Store house of energy in plants, form secondary structure with helix, so hold I_2 molecules (blue colour).
- **Glycogen:** Store house of energy in animal cells.
- These can have glucosamine or N-acetyl glucosamine as modified sugar.



$C_6H_{12}O_6$ (Glucose)



$C_5H_{10}O_5$ (Ribose)

Sugars (Carbohydrates)

Structure of protein

1) Primary Structure: Positional information in protein i.e.
- First amino acid (left end) & last amino acid (right end).
- First amino acid is also called N terminal & last C terminal.

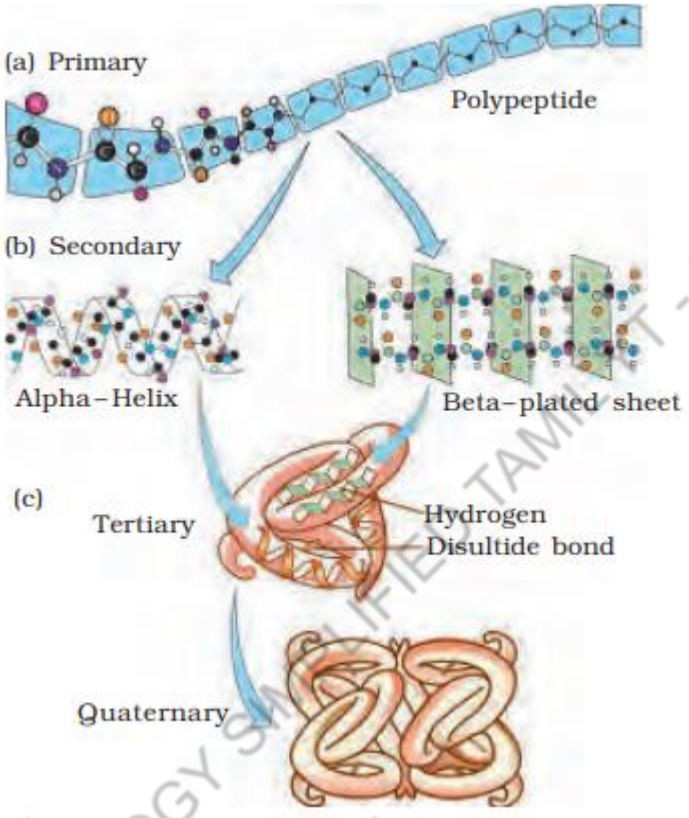
2) Secondary Structure:

- Protein thread isn't extended through out but folded in form of helix (right handed) .
  Eg: Structure of keratin protein.

3) Tertiary Structure: 3 dimensional view

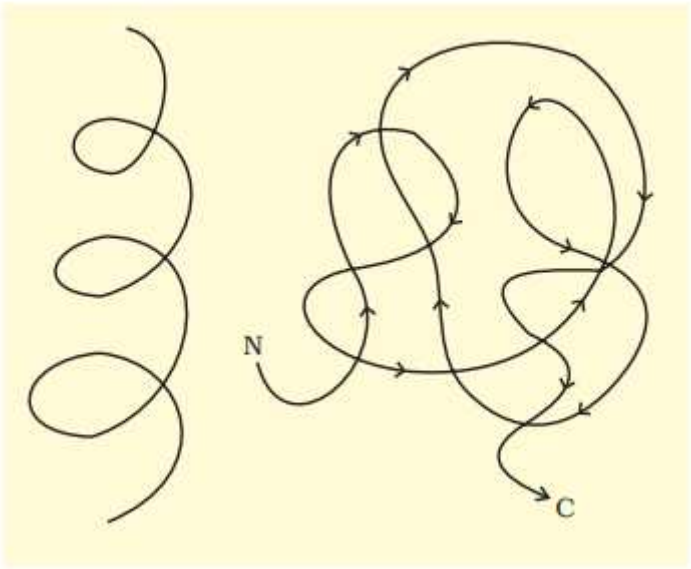
- Long protein chain is folded upon itself like hollow woollen ball.
- Necessory for **biological activities.** **Eg:** Myoglobin (Muscle protein).

4) Quaternary Structure: Assembly of more than 1 polypeptide.
Eg: Adult human haemoglobin -4 subunits (2α + 2β).



Various level of protein structure

Cartoon showing:(a) A secondary structure and (b) A tertiary structure of proteins



Nature of bond linking monomers in a polymer

1) Peptide bond: When carboxyl group of 1 amino acid react with amino group of next amino acid with elimination of water. [dehydration] – in protein.

2) Glycosidic: Formed between 2 carbon of 2 adjacent monosachharide molecule by dehydration.

3) Ester bond: Formed when 3' carbon of 1 sugar of 1 nucleotide is linked to 5' carbon of sugar of succeding nucleotide.

Bond between phosphate & hydroxyl group – ester. Ester bond on either side – **phosphodiester bond.**

Watson-Crick Model: Secondary structure of DNA.

- Double helix model of DNA, 2 antiparallel strands.
- Backbone of DNA- **Sugar-phosphate (sugar backbone).**
- Nitrogen bases are perpendicular to backbone facing inside.
- A pairs with T with 2 hydrogen bond whereas 3 H bonds between G & C.
- Each strand is like helical staircase & represented by base pair.
- At each step, strand turns 36°. One turn = **10 base pairs (B-DNA)**
- **Pitch = 34 Å,** rise per base pair = 3.4 Å

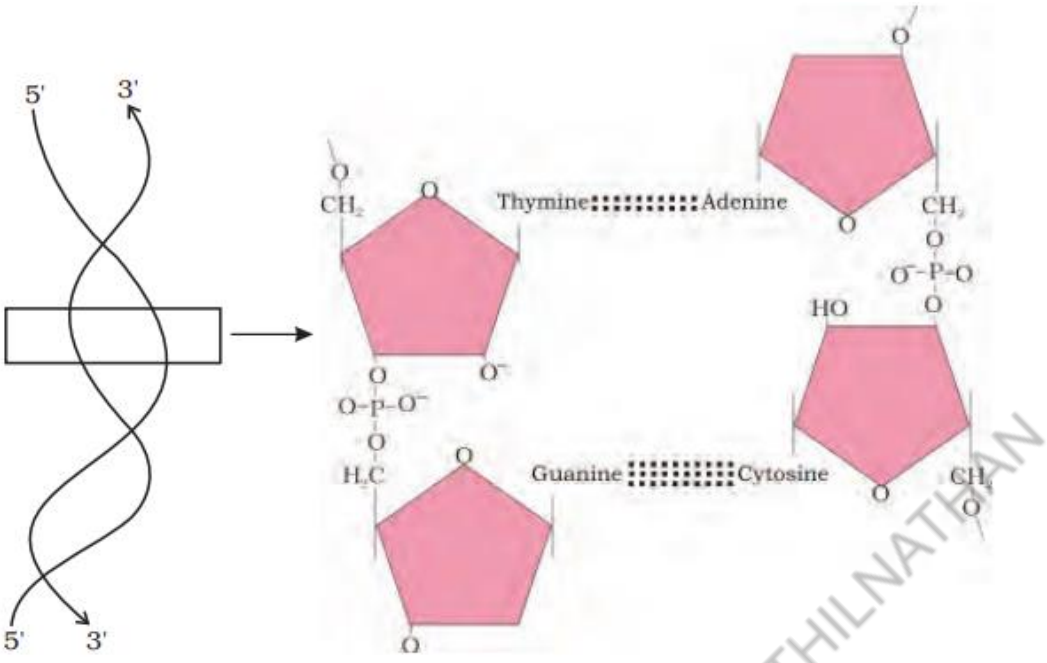


Diagram indicating secondary structure of DNA

Dynamic state of body constituents - METABOLISM

- **Turn over:** Molecules constantly change into some other & constantly made from some other.
- **Metabolism:** Breaking & making of biomolecules through chemical reaction. Metabolites are converted into each other in series of linked reaction – **metabolic pathways.**
  Eg: Removal of CO_2 from amino acid converting to amine, removal of amino group in nucleotide base.
- **Dynamic state:** Definite rate o flow of metabolites.
- Every chemical reaction is catalysed.
- Protein with catalytic power (increase rate) – **enzymes.**

Metabolic basis for living

- **Anabolic:** (Biosynthetic), complex structure from simpler.**Eg:** Acetic acid becomes cholesterol. (consume energy).
- **Catabolic:** Simpler structure from complex (release energy). **Eg:** Glucose become latic acid in muscles (10 Steps) – **glycosis.**
- **Adenosine triphosphate (ATP):** Energy currency in living system.

The living state

- Biomolecules are in metabolic flux, steady state.
- Living state is non-equilibrium state, able to perform work, can't afford to reach equilibrium, continuous energy input.
- Without metabolism, there is no living state.
- **Living state & metabolism are synonymous.**

Enzymes – **Mostly proteins, some are nucleic acid- ribozymes**

- It has primary, secondary & tertiary structures. In tertiary structure it has many crevice, one such is called **active site** (in which substrate fits).
- Through active site, it catalyses reactions at high rate.
- Inorganic catalyst work at high temperature & pressure but enzymes are destroyed at high temperature.
- Only enzymes isolated from organism living under high temperature retain catalytic power at high temperature – **thermal stability of enzyme isolated from thermophillic organism.**

Chemical Reactions

- **Physical change:** Change in shape without bond breaking. **Eg:** Ice melts to water or water becomes vapour.

- **Chemical change:** Bonds are broken & new bonds are formed.
  Eg: Inorganic- $Ba(OH)_2 + H_2SO_4 \rightarrow BaSo_4 + 2H_2O$
  Organic: Hydrolysis of starch into glucose.

- Rate is amount of product formed per unit time, also called **Velocity (specified direction also).**
- Rate doubles or decreases by half for 10°C change in either direction.
- Catalysed reaction proceed at high rate.

Eg: $CO_2 + H_2O \xleftrightarrow{Carbonicanhydrase} H_2CO_3$

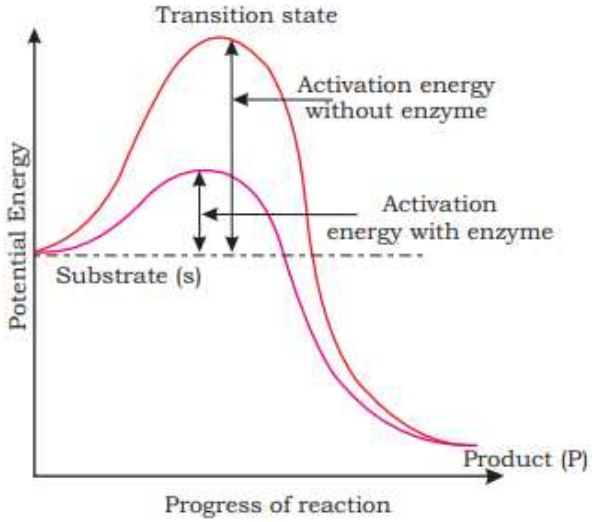
In absence of enzyme – 200 molecules of H_2CO_3 per hour.
In presence of enzyme – 600,000 molecules of H_2CO_3 per second.

- **Metabolic pathway:** Multistep chemical reaction in which each step is catalysed by same/different enzyme.
  Eg: Glucose → 2 pyruvic acid. (10 different enzyme)
  In fermentation ethanol is formed.
  In our muscle, Anaerobic condition – lactic acid is formed.
  Aerobic condition – pyruvic acid is formed.

How enzyme bring such high rate reaction?

- **Substrate:** Chemical which is converted into product.
  It binds with enzyme at active site & form ES complex **(enzyme – substarte)** called **transient phenomenon** & structure **transient state.**
- After breaking of bond, product is released.
- All intermediate structure are unstable.
- Difference in average energy content of substrate & transition state is called **activation energy**. (Enzyme brings it down).
- If product is at lower level than substrate in graph between potential energy & reaction

progress then its an exothermic reaction (Energy released).



Concept of activation energy

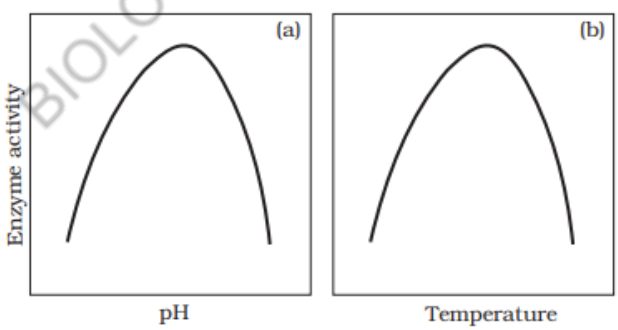
Nature of Enzyme action:

- $E + S \rightleftharpoons ES \longrightarrow EP \longrightarrow E + P$
- Substrate binds to active site of enzyme which induces enzyme to change shape & fit more tightly.
- Active site breaks bonds & enzyme product complex is formed.
- Enzymes releases product & ready to bind with another molecule.

Factors affecting enzyme activity

1) Temperature & pH:

- Enzyme show highest activity at **optimum temperature & pH**.
- Low temperature preserves enzyme (inactivates) & high temperature denatures protein
- Activity declines both below & above optimum temperature & pH.



Figures : Effect of change in : (a) pH (b) Temperature

2) Concentration of substrate:

- When concentration increases, rate increases initially but after sometime it becomes constant as enzyme molecules are less than substrate so after saturation of enzyme molecules no free enzyme molecules are left to bind with additional substrate.

- **Inhibition:** Binding of chemical shuts off enzyme activity such a chemical is **inhibitor**.
- **Competitive inhibitor:** Inhibitor resembles substrate in structure & competes with substrate for binding & decrease enzyme action.
  Eg: Inhibition of succinic dehydrogenase by melonate resembling succinate, also in control of bacterial pathogens.

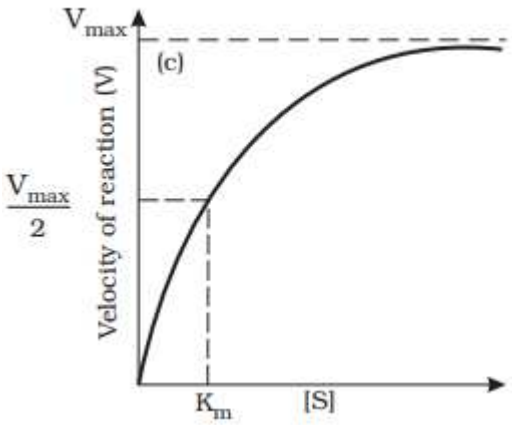
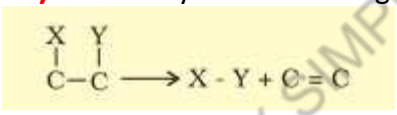


Figure : Effect of change in : Concentration of substrate on enzyme activity

Classification of enzymes: 6 Classes each with 4-13 subclass, named by 4 digit number.

- **Oxidoreductase/dehydrogenase:** Catalyse oxidoreduction
  Eg: S reduced + S' oxidised → S oxidised – S' reduced.
- **Transferase:** Catalyse transfer of group other than hydrogen. **Eg:** S-G+S' → S'-G +S
- **Hydrolase:** Catalyse hydrolysis of ester, ether, peptide, glycosidic.
- **Lyase:** Catalyse removal of groups other than hydrolysis giving double bond. Eg. -



- **Isomerase:** Catalyse inter conversion of optical, geometric positional isomers.
- **Ligase:** Catalyse linking of 2 compounds .
  Eg: Joining of C-O, C-S, C-N, P-O bonds.

Co-Factors:

- Sometimes non-protein constituent **(co-factor)** bind to enzyme to make it active. **Protein portion – apoenzyme.**

1) Prosthetic: Organic compounds tightly bound to apoenzyme.
Eg: Peroxidase catalyse breakdown of hydrogen peroxide to water & oxygen, heam is prosthetic group (part of active site)

2) Co-enzyme: Organic compound, transiently bound to apoenzyme.

- Serve as co-factor in several reaction, mostly vitamins.
  Eg: Nicotinamide adenine dinucleotide **(NAD) & NADP** contain **niacin.**

3) Metal ion: Form cordination bond with side chain at active site & 1 or more cordination bond with substrate.

Eg: **Zn** for proteolytic enzyme **carboxypeptidase.**

- Catalytic activity is lost when co-factor is removed.

Cell cycle and cell division

Cell cycle: Sequence of cell events by which a cell duplicates its genome, synthesise other constituents of cell & divides into 2 daughter cells, continuous process but DNA synthesis occur only in 1 specific stage.

Phases of cell cycle: Human cells divide once in 24 hours. For yeast its 90 minutes.
2 basic phases –

1) Interphase: Phase between 2 successive M phase.
- 95% of cell cycle, **resting phase**, prepares for division.
- Cell growth & DNA replication occur.
  Its divided into 3 phases –

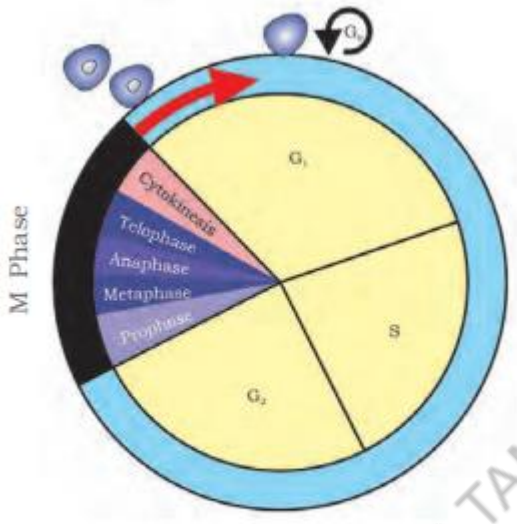


Figure 10.1 A diagrammatic view of cell cycle indicating formation of two cells from one cell

a) G_1 phase (Gap 1): Post mitotic phase, interval between mitosis & DNA replication, metabolically active cell but no DNA replication.

b) S phase (synthesis): DNA replication occur, DNA per cell doubles but **no increase in chromosome no.**, centriole duplicate in cytoplasm & DNA replication in nucleus in animals.

c) G_2 phase (Gap 2): Pre-mitotic phase, protein synthesis, cell growth continue.
- Some cells don't divide or divide ocassionally exit G_1 phase & enter inactive stage - **quiescent stage (G_0),** cells remain metabolically active but don't proliferate.
  Eg: Heart cells.
- In animals, mitotic division occur only in diploid cells but in plants, it occurs in both haploid & diploid cells.

2) M-phase : Actual cell division, starts with nuclear division, separation of daughter chromosomes, then division of cytoplasm.

M-phase : Somatic cells, diploid cells only, meristematic tissues.
- Chromosomes in parent & progeny are same – **equational division.**
- Karyokinesis involves prophase, metaphase, anaphase & telophase.

Cell cycle and cell division

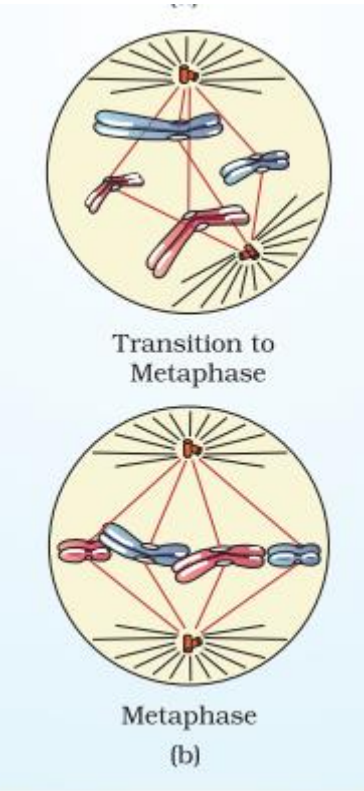
Prophase: Initiation of condensation of chromosomal material.

- Chromosomal material untangles.
- Centrosome (duplication in s phase) moves to opposite pole and radiates microtubules – **asters**.
- **Mitotic apparatus** – 2 asters + spindle fibres.
- Nucleolus, nuclear envelope, golgi complex, endoplasmic reticulum disappear at end of prophase.

Metaphase: Morphology of chromosomes studied.

- Complete disintegration of nuclear envelope, complete condensation of chromosomes (2 sister chromatids held by centromere).
- Disc shaped **kinetochore** appear at surface of centromere, site for spindle fibre attachment.
- Chromosome move to spindle equator with 1 chromatid connected from one pole by spindle fibre & other chromatid to other pole. Plane of alignment of chromosome - **metaphase plate.**

Cell cycle and cell division



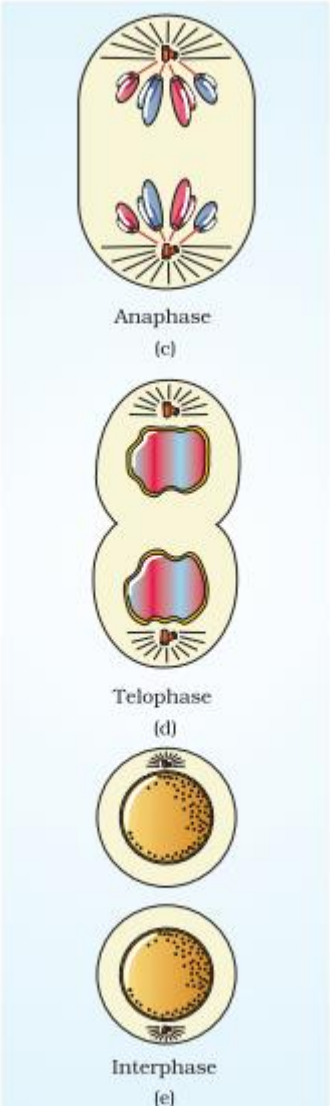
Anaphase: Centromere split, chromatid separate
- Chromatids move to opposite poles
- Chromosomes move away from equatorial plate, centromere remain directed towards pole.
- Different shape of chromosome seen in Anaphase

Telophase: Chromosomes cluster at opposite spindle poles.
- Their identity is lost, nuclear envelop develops, nucleolus, golgi complex & ER reform.

Cytokinesis: Division of cytoplasm
- **Animal cell:** By appearance of furrow in plasma membrane which deepen, joins centre dividing cytoplasm into two.
- **Plant wall:** Wall formation start in central & grow outward to meet lateral walls leading to formation of new cell wall (middle lamellae)
- In some organisms, **karyokinesis isn't followed by cytokinesis** .So, **multinucleate condition** leading to **syncytium.**

Eg: Liquid endosperm in coconut.

Cell cycle and cell division



Significance of Mitosis:

- Growth of multicellular organisms, cell repair.
- Cell growth result in disturbing nucleo-cytoplasmic ratio, so its essential for cell to divide and restore nucleo Cytoplasmic ratio.

Meiosis: Reproductive cell

- Chromosome no. is reduced to half-**reductional division**
- 2 sequential cycles of nuclear & cell division – meiosis I & meiosis II but single time DNA replication.
- 4 haploid cells are formed at end of meiosis II.

MEIOSIS I:

Prophase I: Typically longer.
Nuclear membrane start disappearing centriole duplicate, cell organelle start disappearing, centriole migrate to opposite pole, astral fibres arise
a) Leptotene: Compaction of chromosome which become visible under light microscope.

b) Zygotene: Chromosomes pair, process of association- **synapsis,** paired chromosomes – **homologous chromosomes,** synaptonemal complex formed by synapsed chromosomes is called **bivalent/tetrad.**

c) Pachytene: Appearance of recombination nodules, sites at which crossing over occur between non sister chromatids of homologous chromosome, 4 chromatid of each bivalent chromosome clearly appear as tetrad.

Crossing over: Exchange of genetic material between homologous chromosome by recombinase, recombination of genetic material.

d) Diplotene: Dissolution of synaptonemal complex, non sister chromatid separate except at site of cross over leading to X-Shaped structure - **chiasmata**, lasts for months or years in oocytes of some vertebrates.

e) Diakinesis: Terminalisation of chiasmata, chromosomes are fully condensed, meiotic spindle assembles, nucleolus disappear, nuclear envelope breaks down.

Metaphase I: Bivalent chromosome align on equatorial plate, spindle attach to kinetochore of homologous chromosome.

Anaphase I: Homologous chromosomes separate, sister chromatids remain associated at centromere.

Telophase I: Nuclear membrane & nucleolus reappear, cytokinesis follows, this is called **dyad of cells**.

Interkinesis: Stage between 2 meiotic divisions, short lived, no DNA replication.

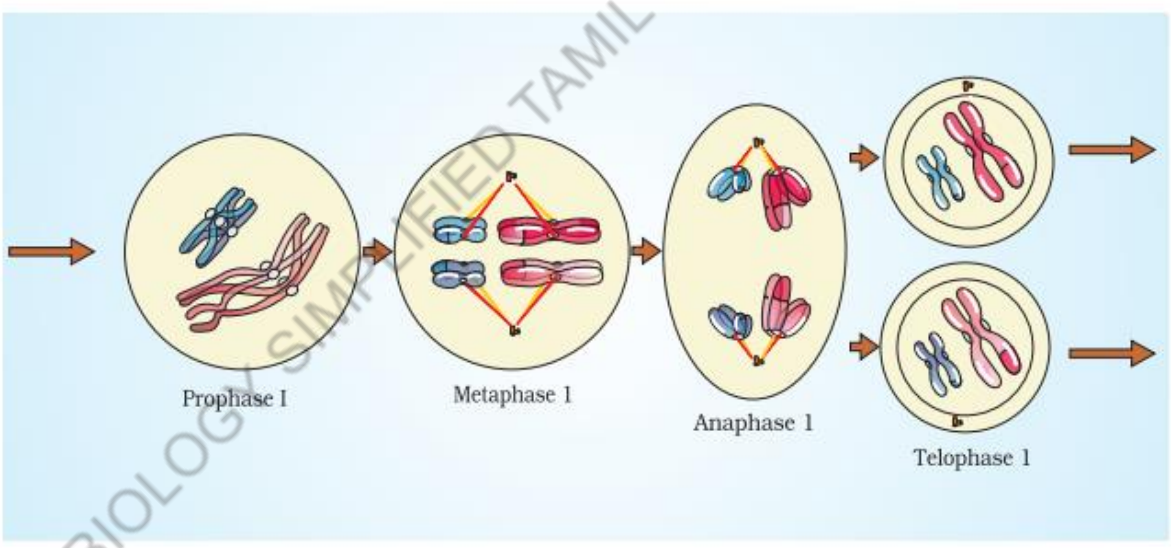


Figure 10.3 Stages of Meiosis I

Meiosis II:

Prophase II: Nuclear membrane disappear, chromosome become compact.

Metaphase II: Chromosomes align at equator & spindle fibre get attached to kinetochore of sister chromatid.

Anaphase II: Splitting of centromere, move to opposite poles by shortening of microtubules.

Telophase II: Nuclear envelope reappear, cytokinesis follows, **tetrad of cells – 4 haploid daughter cells.**

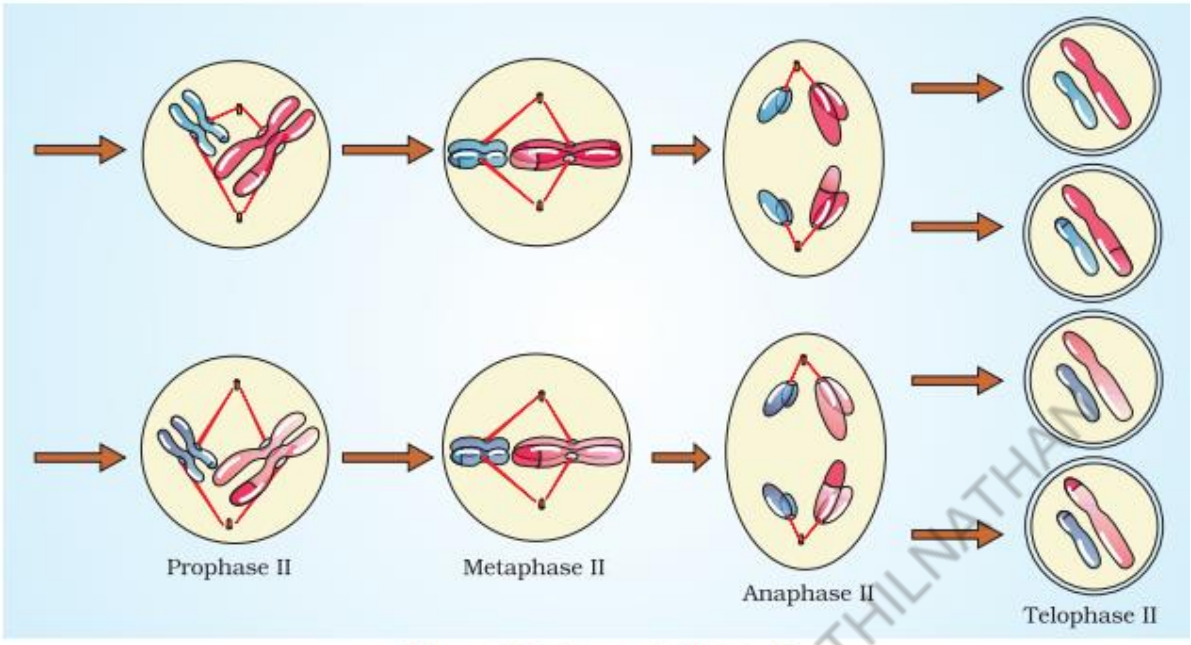


Figure 10.4 Stages of Meiosis II

Significance of meiosis:

- Conservation of specific chromosome no. of each species.
- Increases genetic variability.

Transport in Plants

Translocation: Bulk or mass transport over long distance through vascular bundles.

- Xylem: Unidirectional from roots to stem.
- Phloem Multidirectional from leaves to roots, roots to growing parts.

Means of Transport:

Diffusion: Passive, no energy required, slow

- Higher concentration to low concentration.
- Takes place in liquid, gas & solids.
- Only means of gaseous movement in plant body.
- Affected by concentration gradient, membrane permeability, temperature, pressure, size (small molecules diffuse faster), solubility of lipids (faster through membrane).

Facilitated Diffusion – No energy, highly selective, transport saturates.

- **Hydrophilic substance find difficult to pass membrane**, so they need carrier proteins to diffuse.
- From high concentration to low concentration.
- Sensitive to inhibitors.
- Rate reaches maximum when all protein transporters are used.
- Some protein channel are always open, some are controlled.
- **Porins -** proteins forming large pores in outer membrane of plastids, mitochondria & some bacteria allowing small molecules to pass.
- Transport protein in membrane rotates & releases molecule inside cell.

Eg : **Water channel made of 8 different aquaporins.**

- **Symport** – Both molecules cross membrane in same direction.
- **Antiport** – Both molecules cross membrane in opposite direction.
- **Uniport** – Molecule moves independently of other molecules.

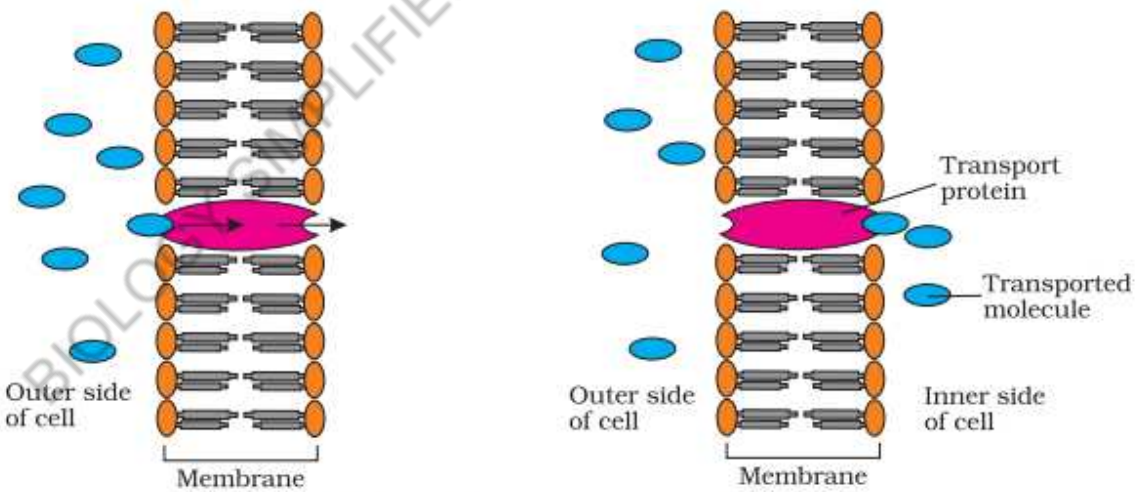


Figure 11.1 Facilitated diffusion

Transport in Plants

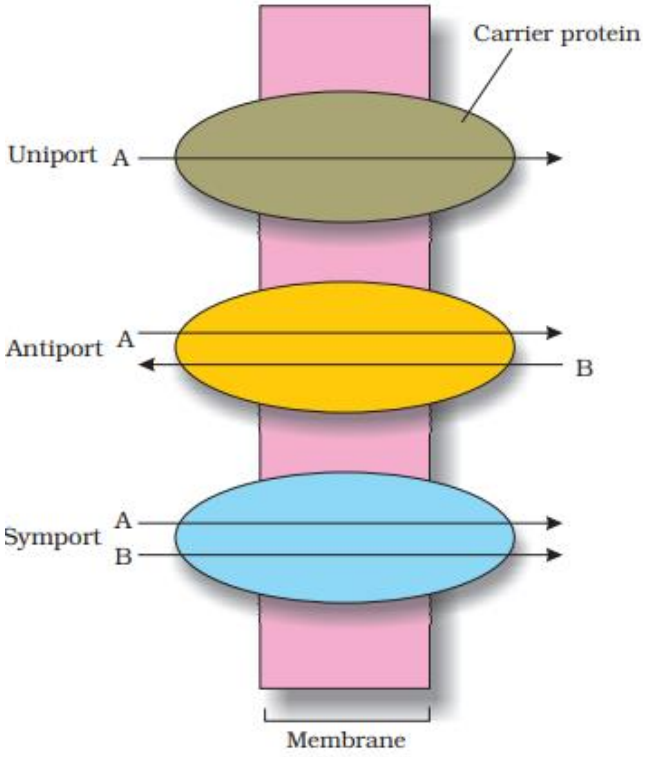


Figure 11.2 Facilitated diffusion

Active transport – Use energy, by specific membrane protein

- Transport saturates, from low concentration to high (uphill).
- Protein pumps use energy to carry substances, highly selective.

Plant – water Relations:

- Protoplasm is water in which different molecules are dissolved.
- **Watermelon-92% water; herbaceous plants- 85-90% water.**
- **Mature corn plant –** absorb **3 litres of water per day**
- **Mustard plant** absorb water equal to its **own weight in 5 hours.**
- Seed also contains water but appear dry.
- **Transpiration –** loss of water through evaporation from leaves.

Water potential – (Ψ_W): [$\Psi_W = \Psi_S + \Psi_P$]

- Water molecules possess kinetic energy, greater is the concentration of water, greater is its kinetic energy or Ψ_W.
- **Pure water has highest water potential i.e: O.**
- Water movement takes from system with higher water potential to one having low water potential.

It has 2 components –

(a) Solute potential - **(Ψ_S)** Always negative.

- When some solute is dissolved, concentration of water decrease so water potential decrease.
- Magnitude of lowering due to dissolution of solute-**solute potential.**
- **Higher solute molecules lower is Ψ_S .**
- **All solution has lower Ψ_W, from pure water.** At atmosphere pressure $\Psi_W = \Psi_S$.

(b) Pressure potential - **(Ψ_P)** Usually positive.

- When pressure more than atmospheric pressure is applied its water potential increases.
- Negative in xylem column for water transport in stem.
- Its also build when water enters plant cell due to diffusion building pressure against cell wall making it **turgid (Ψ_P↑).**

Osmosis: Diffusion of water across selectively permeable membrane.

- **Call wall is freely permeable**
- Direction of osmosis depent on pressure & concentration gradient.
- From high concentration to low concentration.
- **Osmatic pressure** – Pressure required to prevent water from diffusing, higher solute concentration high osmotic pressure.
- Osmatic pressure (+ve) = osmotic potential (-ve) – **magnitude.**

Experiment –

- Sucrose solution is separated by pure water by membrane.
- Water moves into funnel rising level of solution in it & continues till equilibrium isn't reached.

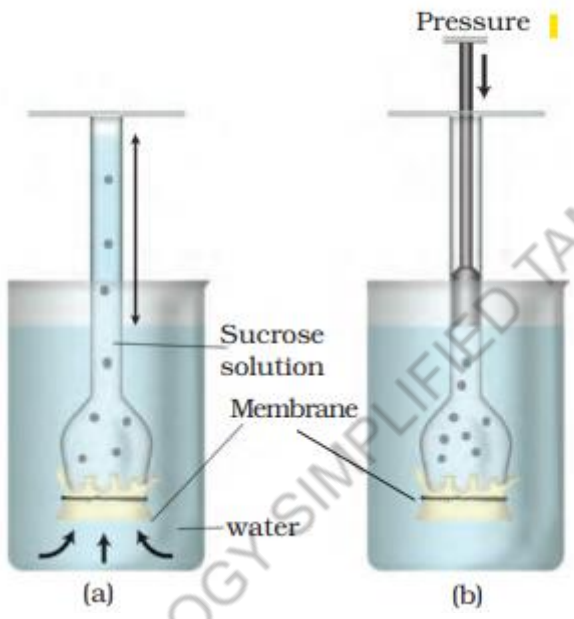


Figure 11.3: A demonstration of osmosis.Pressure can be applied as shown to stop the water movement into funnel.

Plasmolysis –

- **Isotonic –** External solution balance osmotic pressure of cytoplasm, no net flow of water, in & out water flow in equilibrium, **flaccid cell.**
- **Hypotonic –** External solution is more dilute than cytoplasm, water move into cell & builds pressure against wall - **turgor pressure,** responsible for enlargement & extension growth, cell doesn't rupture due to cell wall, **cell swells.**
- **Hypertonic** – External solution is more concentrated than cytoplasm, **plasmolysis**, water moves out of cell (first from cytoplasm then from vacuole) **cell shrinks**, reversible.

Transport in Plants

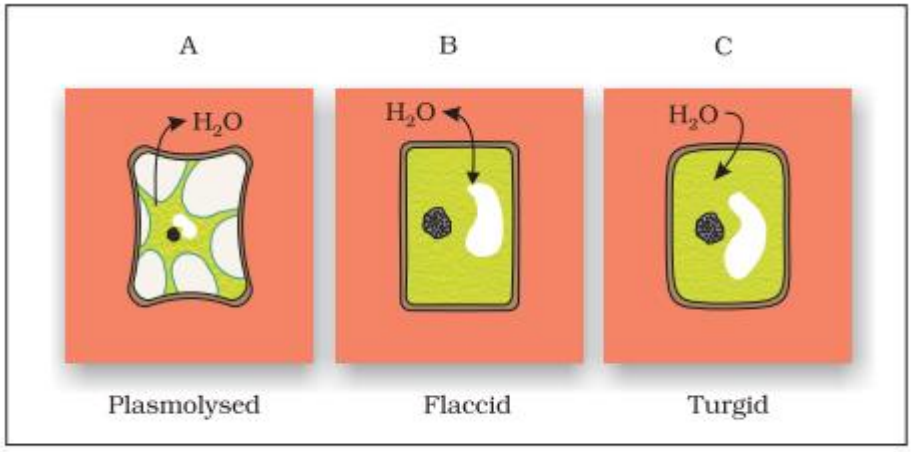


Figure 11.5 Plant cell plasmolysis

Imbibition: Water absorbed by solids, increase volume.

- From high concentration to low concentration.
- Water potential gradient & affinity between absorbant & liquid is necessary,

  Eg: Absorption of water by seeds & dry wood.

Long Distance Transport of Water –

- Diffusion can account only short distance molecule movement. So not sufficient for long distance.
- Water, mineral & food are moved by mass or bulk flow **(by pressure difference),** substance whether in solution or suspension are swept along the same pace unlike diffusion.
- Bulk flow can be either through **positive hydrostatic pressure (Eg: Garden hose)** or **negative hydrostatic pressure (Eg: Suction through straw).**

How plants absorb water?

- By diffusion in root hair (increase surface area).

  After diffusion it moves by 2 distinct ways –

1) Apoplast: Through Intercellular space & cell walls.

- System of adjacent cell wall, continuous except **casparian strips** (suberised-impermeable for water).
- Doesn't cross cell membrane, depend on gradient
- No barrier, through mass flow
- Common as cortical cells are loosely packed & offer no resistance.

2) Symplast: System of interconnected protoplast.

- Cells are connected through cytoplasmic strands extended through plasmodesmata, **slow**, down potential gradient.
- Aided by cytoplasmic streaming (Eg: **Hydrilla leaf**)
- After endodermis, water moves by symplast to reach xylem.
- **In young roots, water enters directly into xylem vessel & tracheids** (non living conduits) by **apoplast.**
- **Mycorrhiza:** Symbiotic association of fungus with root system. Hyphae have large surface area to absorb ions & water from soil & roots provide sugar & N-containing compounds to fungus.

  Eg: Pinus seeds can't germinate/ establish without mycorrhiza.

Transport in Plants

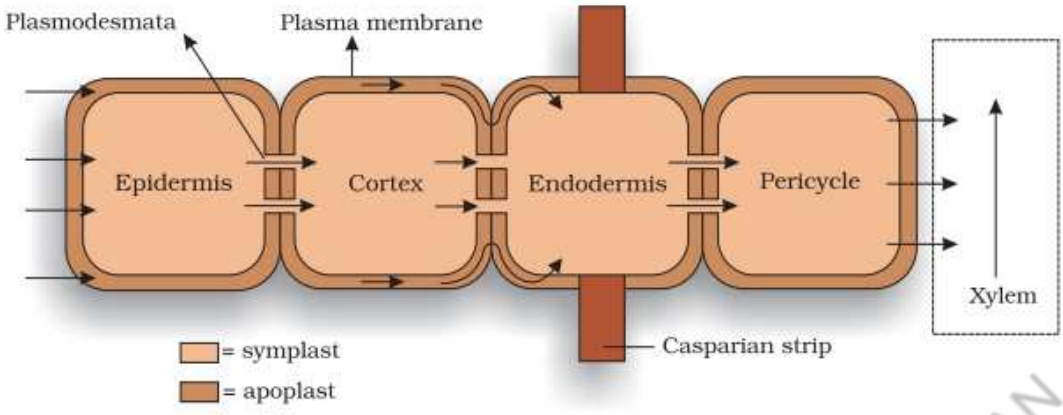


Figure 11.6 Pathway of water movement in the root

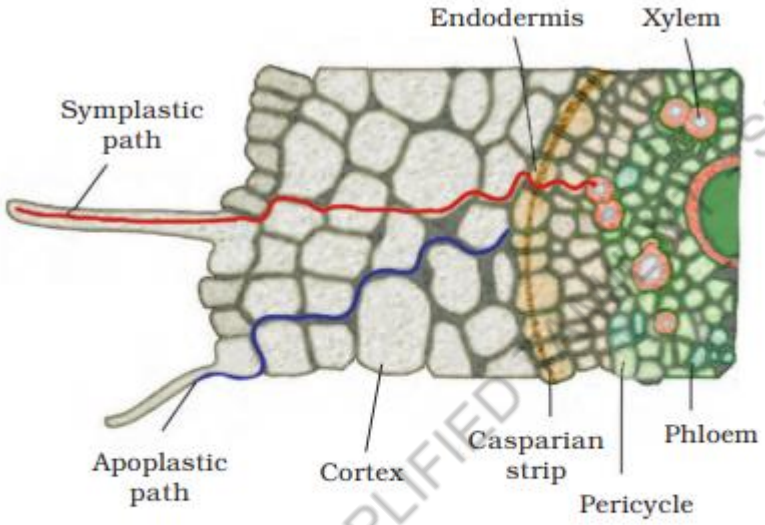


Figure 11.7 Symplastic and apoplastic pathways of water and ion absorption and movement in roots

Water movement up a plant –

1) Root pressure: Push water to small height.

- When ions from soil are actively transported into vascular bundle of roots, water follow, increases pressure inside xylem, this positive pressure is root pressure.
- No role in water movement in tall trees.
- Observable at night & early morning when evaporation is less.
- Guttation: Water loss in liquid phase through hydathodes, excess water ooze & collect near vein opening in grass & monocots, mainly during night, root pressure is involved.

2) Transpiration pull: Water can be transported upto 15m/hour.

- **Cohesion tension transpiration pull model** – water is mainly pulled, main driving force is transpiration.
- Less than 1% water reaching leaves is used in photosynthesis but most of it is lost through stomata.

Transport in Plants

- Water loss can be studied by using cobalt chloride paper which turns colour on absorbing water.

Transpiration: Mainly through stomata during day.

- No root pressure involved
- Gaseous exchange also occur by stomata
- Opening & closing of stomata is due to change in turgidity of guard cell, stomata open during day & close during night.
- **Inner wall of guard cell** (toward stomatal pore) is thick & elastic.
- **When turgidity Increase, thin outer walls bulge & force inner walls to crescent shape.**
- Cellulose microfibrils are oriented **radially rather than longitudinally** making easier for stoma to open
- When guard cells loose turgor, inner walls regain shape & guard cells become flaccid, stoma closes.
- Lower surface of dicot leaf has more stomata whereas in monocots its equal on both sides.
- **Factors:** Temperature, light, humidity, wind speed, distribution of stomata, percent of open stomata, water status of plant, canopy structure etc.
- Creates transpiration pull for absorption, supplies water for photosynthesis, transports mineral from soil, cools leaf surface **(10-15°),** maintain shape of plant cells.
- Lower concentration of vapour creates transpiration pull which can lift xylem column of water upto **130m high.**
- Ascent of xylem sap depends on –
  → **Cohesion:** Attraction between water molecules
  → **Adhesion:** Attraction of water molecules to polar surface
  → **Surface tension:** Water molecules are attracted to each other in liquid phase more than in gas phase.
- These properties give water high **tensile strength** (resist pulling force) & **high capillarity** (rise in tubes) aided by small diameter.
- Humidity of rainforest is mainly due to vast cycling of water from root to leaf to atmosphere, back to soil.
- **C_4 plants lose half as much water as C_3 for same amount of CO_2, fixed.** So C_4 are twice efficient.

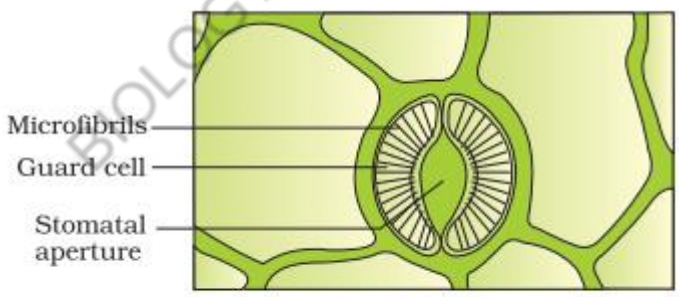


Figure11.8 A stomatal aperture with guard cells

Transport in Plants

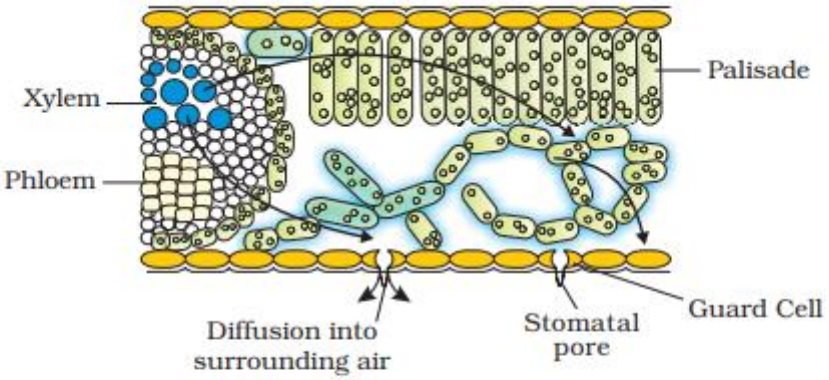


Figure11.9 Water movement in the leaf. Evaporation from the leaf sets up a pressure gradient between the outside air and the air spaces of the leaf. The gradient is transmitted into the photosynthetic cells and on the water-filled xylem in the leaf vein.

Uptake and Transport of Mineral Nutrients:

Uptake of mineral Ions – can't be passively absorbed by roots.

- They are present as charged particles which can't move across cell membrane & concentration of minerals in soil is usually less than concentration of minerals in roots.
- So, minerals enter root by active absorption, partly responsible for water potential gradient in roots, some ions move passively into epidermal cells.
- **Transport protein of endodermal cells are control points** where plant adjust quantity & type of solute reaching xylem.
- Root endodermis due to suberin transport ions in one direction only.

Translocation of Mineral Ions:

- Chief sinks for mineral elements are growing region of plants (apical & lateral meristem).
- Unloading of mineral ion occur at fine vein ending by diffusion & active uptake of cell.
- Ions are frequently mobilised from older to young leaves.
- **Elements most readily mobilised- N, P, K, S**
- **Structural component (immobilised)- Calcium**
- We can't distinguish that xylem transports only inorganic nutrient & phloem only organic.

Phloem Transport: From source to sink

- Source synthesises food & sink stores food.
- May get reverse according to season, **Eg:** Sugar in roots mobilise to become source in early spring where buds act as sink.
- **Phloem sap = water + sucrose.**

The Pressure Flow or Mass Flow Hypothesis:

- Translocation of sugar from source to sink.
- Glucose prepared is converted to sucrose which enters companion cell then phloem sieve tube cells by **active transport.** It produces **hypertonic condition in phloem.**
- Water in adjacent xylem moves into phloem which builds osmotic pressure so sap moves to low pressure areas.
- Active transport is required to move sugar out of phloem & into cells which convert it to energy, starch or cellulose. Osmotic pressure in phloem decreases & water moves out returning to xylem.

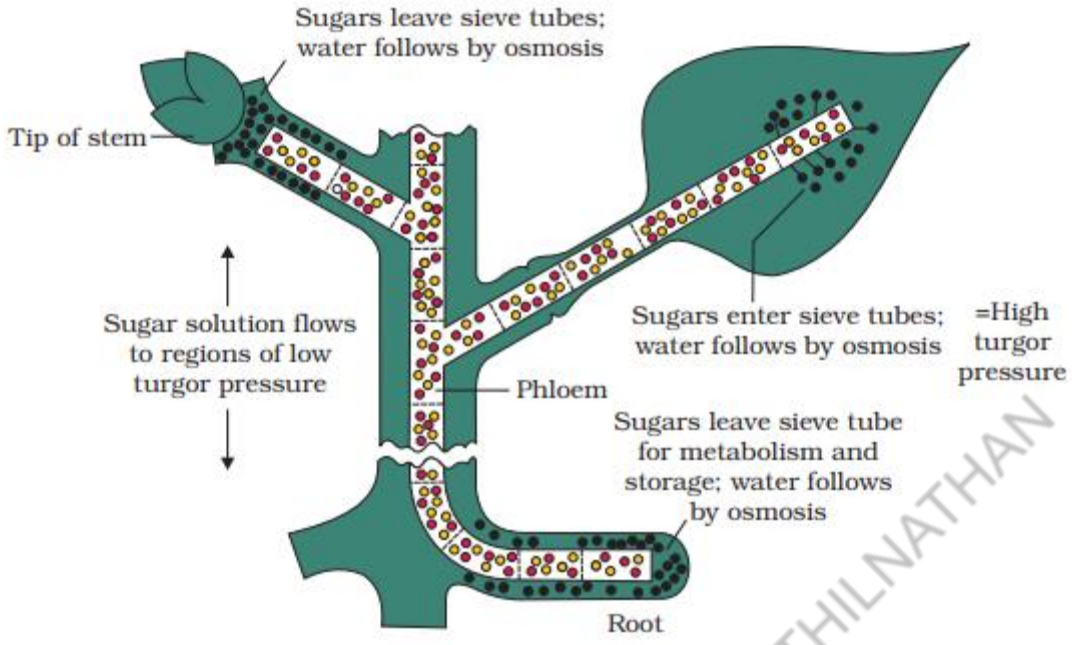


Figure11.10 Diagrammatic presentation of mechanism of translocation

Girdling experiment: To identify tissue through which food is transported.

- On trunk, a bark ring upto depth of phloem layer is removed. In absence of downward movement of food, portion of bark above ring swells.
- It shows phloem is responsible for food translocation in only 1 direction towards roots.

Mineral Nutrition

Hydroponics: By Julius Von Sachs in 1860

- Demonstrated that plants could be grown in defined nutrient solution in absence of soil- hydroponics.
- Soil free, defined mineral solution, require purified water & mineral nutrient salts, aerated solution for optimum growth.
- For production of vegetables: **Tomato, seedless cucumber, lettuce.**

Mechanism:

- Plant are grown in tube placed on slight incline. Pump circulates nutrient solution from reservoir to elevated tube end. Solution flows down & returns to reservoir due to gravity.

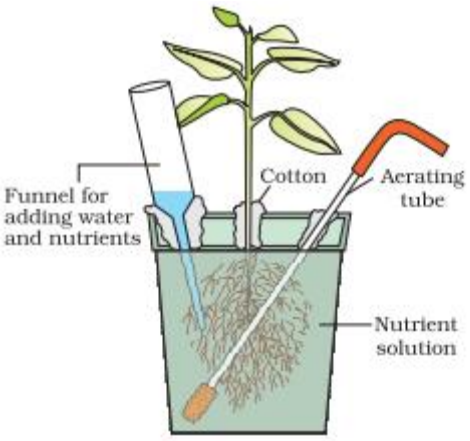


Figure 12.1 Diagram of a typical set-up for nutrient solution culture

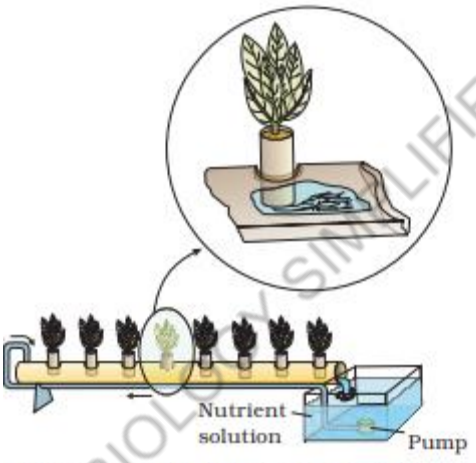


Figure 12.2 Hydroponic plant production.

Essential nutrient elements:

- More than 60 element out of 105 are found in plants.
- Some plants accumulate selenium or gold or strontium.

Criteria for essentiality:

- Element must support normal growth & reproduction. Plants don't complete their life cycle in their absence.
- Requirement must be specific & not replaceable by another element. Deficiency of one can't be met by other.
- Must be directly involved in metabolism.

Elements are divided into 2 categories –

Mineral Nutrition

1) Macronutrient: Present in large amount (in excess of 10 m mole kg^{-1} of dry matter).
Eg: C, H, O, K, N, Ca, Mg, S, P (C, H, O from CO_2, & H_2O & other elements from soil).
2) Micronutrient: (trace), in small amount (less than 10 m mole kg^{-1} of dry matter).
Eg: Fe, Mn, Cu, Mo, Zn, B, Cl, Ni .
• In addition to these, Na, Si, Co, Se are also required.

Essential elements can be grouped into 4 categories –

1) Component of biomolecule: Structural element (**Eg:** C, H, O, N)
2) Component of energy related chemical compounds: Mg in chlorophyll & P in ATP.
3) Activate or inhibit enzyme:
Zn^{+2} → Activation of alcohol dehydrogenase & Mo of nitrogenase
Mg^{+2} → Activator of Ribulose Bisphosphate carboxylase oxygenase & phosphoenol pyruvate carboxylase (carbon fixation).
4) Alter osmotic potential: K in opening & closing of stomata.

Role of Macro & Micro nutrients:

Element	Absorbed as	Function
Nitrogen	**NO_3^-, NO_2^-, or NH_4^+**	Greatest amount, required by meristematic cells & active cells, major constituent of **protein, nucleic acid, vitamin & hormones.**
Phosphorous	**$H_2PO_4^-$, HPO_4^{2-}**	Constituent of cell membrane, proteins, nucleic acid & **nucleotide,** required for phosphorylation reactions.
Potassium	**K^+**	Required by meristematic cells, buds, leaves, root tips, protein synthesis, activation of enzyme, **anion-cation balance**, opening-closing of stomata, turgidity of cell.
Calcium	**Ca^{+2}**	Required by meristematic & differentiating cells, synthesis of cell wall & formation of **mitotic spindle in cell division,** normal functioning of cell wall, regulate metabolic activity.
Magnesium	**Mg^{+2}**	Constituent of ring structure of **chlorophyll,** activates enzyme for respiration & photosynthesis, maintain ribosome structure, **Synthesis of RNA & DNA**
Sulphur	**SO_4^{2-}**	In 2 amino acids – **cysteine & methionine,** constituent of coenzyme, ferredoxin & vitamin **(thiamine, biotin, co-enzyme A).**
Iron	**Fe^{+3} (ferric)**	Large amount, constituent of **ferredoxin & cytochromes,** activates catalase enzyme, formation of chlorophyll, reversibly oxidised from Fe^{+2} to Fe^{+3}.
Manganese	**Mn^{+2}**	Activates enzyme involved in respiration, photosynthesis & nitrogen metabolism, **splitting of H_2O to liberate O_2 during photosynthesis.**
Zinc	**Zn^{+2}**	Activate carboxylases, synthesis of **auxin.**
Copper	**Cu^{+2}**	Overall metabolism, reversibly oxidised from Cu^+ to Cu^{2+}, redox reactions.
Boron	**BO_3^{3-} , $B_4O_7^{2-}$**	Uptake & utilisation of Ca^{+2}, membrane functioning, **pollen germination, cell elongation, cell differentiation,** carbohydrate translocation.
Molybdenum	**MoO_2^{2+}**	Component of nitrogenase & nitrate reductase.
Chlorine	**Cl^-**	Determine solute concentration, anion-cation balance, **water splitting reaction in photosysnthesis.**

Deficiency symptoms of essential elements:

• **Critical concentration:** Concentration of elements below which plant growth in retarded.

Mineral Nutrition

- Element is deficient when present below critical concentration.
- **Deficiency symptoms:** Morphological changes which indicate element deficiency. If deficiency continue, it may lead to death.
- Elements which are actively **mobilised** in plants & exported to young developing tissues, deficiency symptom appear in **older tissues**. **Eg:** Nitrogen, potassium & magnesium.
- Elements which are relatively **immobile** & not transported out of mature organs, deficiency symptoms appear in **young tissues**.**Eg:** Sulphur & calcium (structural components).

Deficiency symptoms :

- **Chlorosis:** Loss of chlorophyll leading to yellow leaves. By elements N, K, Mg, S, Fe, Mn, Zn, Mo.
- **Necrosis:** Tissue death by deficiency of Ca, Mg, Cu, K
- **Delay flowering:** By Mo, N, S deficiency
- **Inhibit cell division:** By Mo, N, K, S deficiency.

Toxicity of Micronutrients:

- Moderate decrease in micronutrient cause deficiency symptoms while moderate increase cause toxicity.
- Mineral ion concentration in tissues that reduces dry weight of tissues by 10 percent-toxic.
- Excess of one element may inhibit other element.

  Eg: Manganese toxicity leads to **brown spots surrounded by chlorotic veins,** compete with **iron & magnesium** for uptake, with Mg for enzyme binding, inhibit **Calcium translocation in shoot apex.**

  So, excess Mn inhibit Fe, Mg & Ca.

Mechanism for absorption of elements:

- **First phase:** Rapid uptake of ions into free space or outer cell space- **apoplast, passive,** usually occur by ion channels, trans membrane proteins (selective pore).
- **Second phase:** Slow uptake of ions into inner space – **symplast, active.**
- Movement of ions: **Flux,** inward movement into cells – **influx** & outward movement – **efflux .**

Translocation of solute: Through xylem along with ascending water stream pulled by transpirational pull.

Soil as reservoir of essential elements:

- Weathering & breakdown of rocks enrich soil with dissolved ions & inorganic salts – **mineral nutrition.**
- Soil harbours nitrogen fixing bacteria, holds water, supplies air to roots, stabilise plant.
- Fertilisers are needed to fulfill deficiency of essential elements.

Metabolism of Nitrogen:

Nitrogen Cycle :

- Plants compete with microbes for limited nitrogen in soil so, its a limiting nutrient for both natural & agricultural ecosystem.
- **Nitrogen fixation** – Conversion of nitrogen to ammonia.
- Lightning, ultraviolet radiation, industrial combustion, forest fires, automobile exhaust, power generating stations convert nitrogen to nitrogen oxides (NO, NO_2, N_2O)
- **Ammonification** – Decomposition of organic nitrogen of dead plants & animals to ammonia. Some ammonia volatises & re-enter atmosphere, but most is converted to nitrate.

Mineral Nutrition

$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$ **Nitrosomonas/Nitrococcus**

$2NO_2^- + O_2 \rightarrow 2NO_3^-$ **Nitrobacter (bacterium)**

This is **nitrification** & nitrifying bacteria are **chemoautotrophs.**

- Nitrate is absorbed by plants & transported to leaves, reduced to ammonia which forms amine group of amino acid.
- **Denitrification** – Nitrate in soil is reduced to nitrogen, by bacteria **Pseudomonas** & **Thiobacillus.**

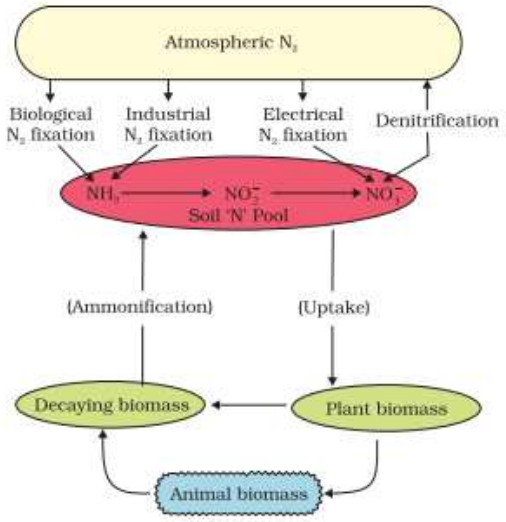


Figure 12.3 The nitrogen cycle showing relationship between the three main nitrogen pools – atmospheric soil, and biomass

Biological Nitrogen fixation:

- Reduction of nitrogen to ammonia by living organism
- **Nitrogenase** for N_2 fixation is exclusively present in **prokaryotes** called **N_2 fixers.**

$$N \equiv N \xrightarrow{NITROGENASE} NH_3$$

- Microbes can be free living/symbiotic.

Eg: Free living aerobes – Azotobacter & Beijernickia
Anaerobic – Rhodospirillum
Free living – Bacillus, Cyanobacteria like Anabaena & Nostoc

Symbiotic biological nitrogen fixation –

- **Legume – bacteria relationship –**

Eg: Rhizobium (rod shaped) with roots of legumes such as **alfalfa, sweet clover, sweet pea, lentils, garden pea, broad bean, clover bean etc.**

- Most common association on roots is nodules (small outgrowths)
- **Frankia** produce N_2 fixing nodules on roots of **non – legumes (Eg: Alnus)**
- Rhizobium & Frankia are free living in soil but symbiont in N_2 fixing.

Nodule formation –

- Rhizobia multiply, colonise roots & attach to epidermal & root hair cells. Root hair curl & bacteria invade it.
- Infectious thread is produced carrying bacteria to root cortex, where they initiate nodule formation.

Mineral Nutrition

- When bacteria are released from thread into cells, it leads to differentiation of N_2 fixing cells.
- Nodule formed establish direct vascular connection with host for nutrient exchange. It has **nitrogenase & leg haemoglobin.**
- **Nitrogenase: Mo-Fe protein**, converts nitrogen to ammonia. (first stable product), sensitive to O_2, anaerobic condition.

  $N_2 + 8e^- + 8H^+ + 16\ ATP \rightarrow 2\ NH_3 + H_2 + 16\ ADP + 16\ P_1$
- To protect nitrogenase, nodules have oxygen scavenger – **leg haemoglobin** (gives pink colour to nodules).
- Microbes live as aerobes in free living condition & anaerobes in nitrogen fixation.
- High energy input (8 ATP for each NH_3) is obtained from respiration of host cells.

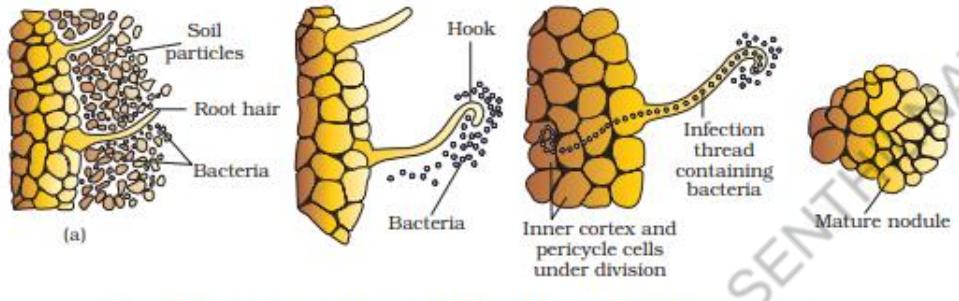


Figure 12.4 Development of root nodules in soyabean : (a) *Rhizobium* bacteria contact a susceptible root hair, divide near it, (b) Successful infection of the root hair causes it to curl, (c) Infected thread carries the bacteria to the inner cortex. The bacteria get modified into rod-shaped bacteroids and cause inner cortical and pericycle cells to divide. Division and growth of cortical and pericycle cells lead to nodule formation, (d) A mature nodule is complete with vascular tissues continuous with those of the root

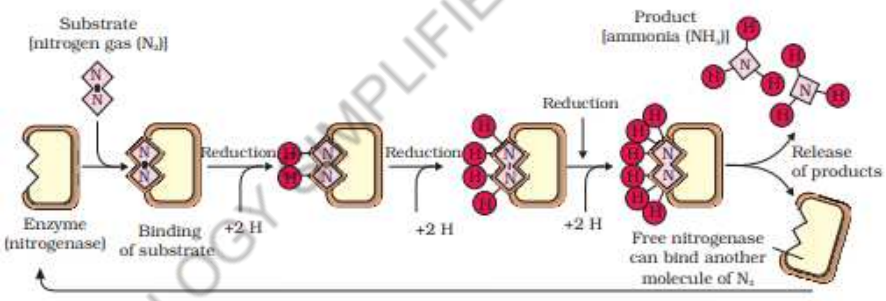


Figure 12.5 Steps of conversion of atmospheric nitrogen to ammonia by nitrogenase enzyme complex found in nitrogen-fixing bacteria

Fate of ammonia – At physiological pH, NH_3 is protonated to NH_4^+.

- Ammonium ion (NH_4^+) is toxic, so can't be accumulated.

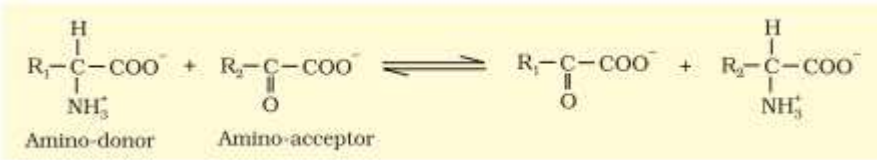
i) Reductive amination:

Ammonia reacts with **α – ketoglutaric acid** to form glutamic acid, **glutamate dehydrogenase** is used.

$$NH_4^+ + \alpha - \text{ketoglutaric acid} + NADPH \xrightarrow{Glutamate\ Dehydrogenase} \text{Glutamate} + H_2O + NADP$$

ii) Transamination:

- Transfer of amino group of one amino acid to keto group of a keto acid, **mostly glutamic acid transfers NH_2 group**, transaminase catalyse all such reactions.



- 2 important amides – **asparagine & glutamine** (structural part of protein), formed from aspartic acid & glutamic acid by addition of other amino group. Hydroxyl part of acid is replaced by NH_2^-, radicle.
- **Amides contain more nitrogen than amino acids,** they are transported to other parts via xylem.
- Along with transpiration stream, nodules export fixed nitrogen as **ureides** in **soyabean.** They have high nitrogen to carbon ratio.

Photosynthesis in Higher Plants

Photosynthesis: Physio chemical process in which plants use light energy to synthesise organic compounds.

- It is the primary source of food on earth & responsible for release of oxygen into atmosphere.
- In variegated leaf **(partially covered with black paper)** exposed to light, only green parts of it show positive starch test.
- Similarly, when a part of leaf is enclosed in a test tube containing KOH while other half exposed to air are exposed to light, only exposed part tested positive for starch.
- These showed photosynthesis occur in green parts of leaves in presence of light & CO_2

Early Experiments –

Joseph Priestely (1733-1804): Discovered oxygen, candle burning in closed bell jar extinguishes but continues to burn when mint plant is placed. Similarly mouse suffocates in closed bell jar but remains alive when mint plant is placed.

Jan Ingenhousz (1730-1799): Sunlight is essential to plant observed oxygen bubbles around green plants in sunlight, only green plants can release oxygen.

Julius Von Sachs (1854): Production of glucose when plants grow. Chlorophyll is located in special bodies where glucose is made & glucose is stored as starch.

T.W Engelmann (1843-1909): First action spectra of photosynthesis, splitted light into its components & illuminated green algae **(Cladophora)** placed in suspension of aerobic bacteria (to detect oxygen evolution), bacteria accumulated mainly in red & blue light of spectrum.

By mid 19th: $CO_2 + H_2O \xrightarrow{Light} [CH_2O] + O_2$

$[CH_2O]$ → Carbohydrate (**Eg:** Glucose)

Cornelius Van Niel (1897-1985) – Demonstrated that photosynthesis is light dependent in which hydrogen from oxidisable compound reduces CO_2 to carbohydrates.

$$2H_2A + CO_2 \xrightarrow{Light} 2A + CH_2O + H_2O$$

- O_2 evolved from green plants come from H_2O & not CO_2
- Sulphur evolved from **purple & green sulphur bacteria**, is oxidised product of H_2S which is a H-donor.

Correct equation:

$6CO_2 + 12\ H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6H_2O + 6O_2$ isn't a single reaction but a multistep process.

Where does photosynthesis occur?

- Chlorophyll allign at mesophyll boundary to attain maximum light.
- **Stroma:** Synthesised sugar turns to starch, not directly light driven, depend on products of light reaction (ATP & NADPH) so called **dark reaction (carbon reaction) carbon assimilation.**
- **Thylakoid:** Trap light energy for synthesis of ATP & NADPH, directly light driven, so called **light reaction (photochemical reaction).**

Photosynthesis in Higher Plants

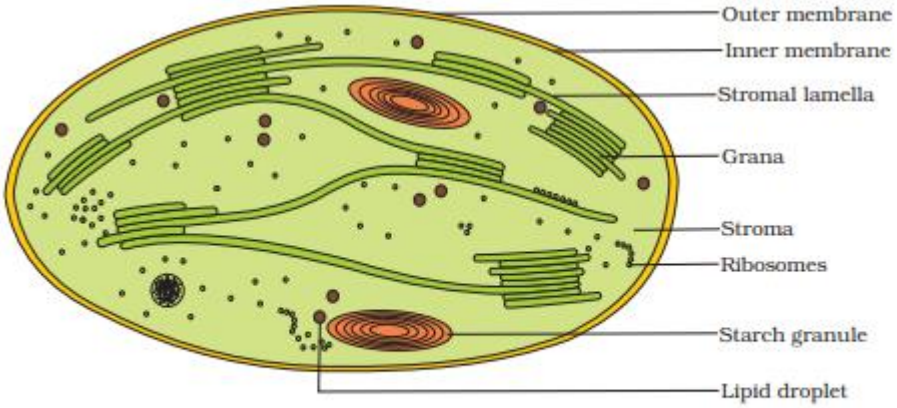


Figure 13.2 Diagrammatic representation of an electron micrograph of a section of chloroplast

Pigments in photosynthesis –

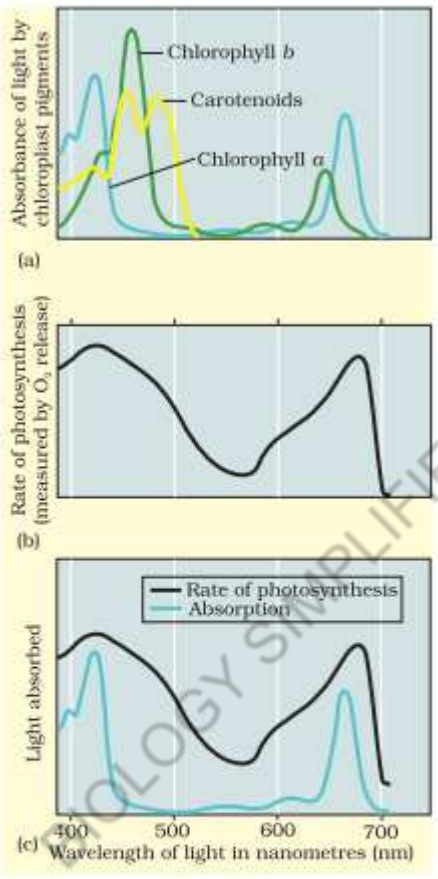


Figure 13.3a Graph showing the absorption spectrum of chlorophyll *a*, *b* and the carotenoids

Figure 13.3b Graph showing action spectrum of photosynthesis

Figure 13.3c Graph showing action spectrum of photosynthesis superimposed on absorption spectrum of chlorophyll *a*

- **Pigments:** Absorb light at specific wavelengths.
  Eg: Chlorophyll a (bright/blue green), chlorophyll 'b'(yellow green), xanthophyll (yellow) & carotenoids (yellow to yellow – orange).

Photosynthesis in Higher Plants

- Maximum absorption of chlorophyll "a" is in blue & red region which shows high rate of photosynthesis (430 nm-660 nm)
  ***Chlorophyll 'a' is the chief pigment.**
- **Accessory pigment:** Chlorophyll 'b', xanthophyll, carotenoid. They absorb light, transfer energy to chlorophyll a, enable wider range of wavelength for incoming light to be utilised, protect chlorophyll 'a' from photo-oxidation.

Light Reaction –

- Absorption of light → Water splitting → O_2 release → Formation of ATP & NADPH.
- Pigments are arranged in 2 light harvesting complex (LHC) – photo system I (PS I) & photosystem II (PS II).
- **LHC:** 100s of pigment molecules bound to proteins.
- Each photosystem has all pigment **(except 1 molecule of chlorophyll a)** forming LHC also called **antennae**.
- Single molecule of chlorophyll a forms **reaction centre.**
- **PS I:** Reaction centre of chl. a has absorption peak at **700 nm** hence called **P_{700}** whereas its **680 nm** in **PS II** so called **P_{680}.**

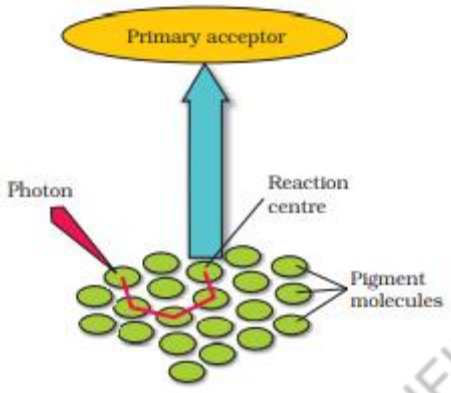


Figure 13.4 The light harvesting complex

The Election Transport:

- PS II absorb 680 nm wavelength causing electrons to exciate, which are picked by electron acceptor which passes them to **electron transport system (ETS)** having **cytochromes.**
- This movement is downhill in terms of redox potential scale.
- Electrons aren't used up but passed to PS I.
- Simultaneously, electrons in PS I exciate on receiving 700 nm wavelength, transferred to another acceptor having greater redox potential, then move downhill to **$NADP^+$.**
- Electrons reduce **$NADP^+$ to NADPH.**
- **Z Scheme:** Transfer of electrons from PS II, uphill to acceptor, down to ETS to PS I, exciatation of electrons, transfer to another acceptor & finally downhill to $NADP^+$ reducing it to NADPH + H^+.

Photosynthesis in Higher Plants

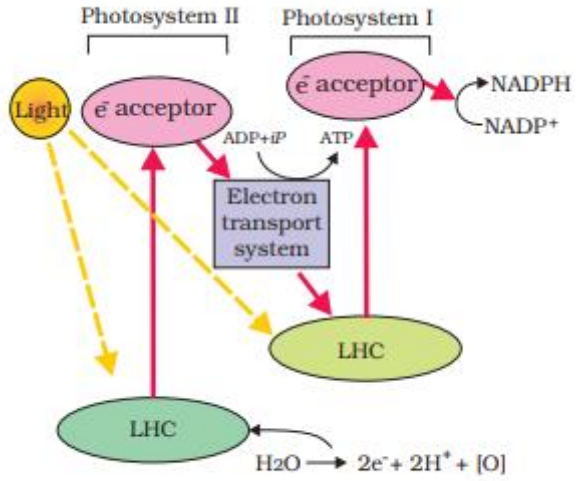


Figure 13.5 Z scheme of light reaction

Splitting of water –

- Electrons moved from PS II must be replaced.
- Its achieved by electrons due to splitting of water.

  $2H_2O \rightarrow 4H^+ + O_2 + 4e^-$
- Electrons removed from PS I are provided by PS II.

Photophosphorylation: Synthesis of ATP from ADP & P_i in presence of light.

- **Non-cyclic:** When 2 photosystem work in series, first PS II then PS I. **Eg: grana**
- **Cyclic:** When only PS I is functional, electrons are circulated within photosystem & phosphorylation occur due to cyclic flow of electrons, lack PS II & NADP reductase, excited electrons don't pass to $NADP^+$ but cycled back to PS I, results in ATP synthesis, also occur when light of wavelength beyond 680 nm are available. **Eg: Stroma Lamellae.**

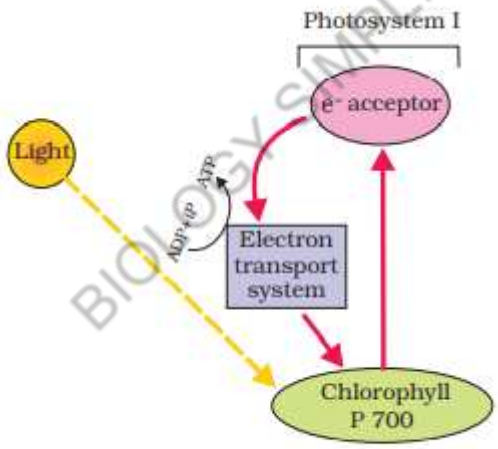


Figure 13.6 Cyclic photophosphorylation

Chemiosmotic hypothesis: Mechanism of ATP synthesis.

- In photosynthesis, proton accumulate towards innerside of thylakoid membrane (lumen) whereas in respiration, proton accumulate in intermembrane space of mitochondria.

Photosynthesis in Higher Plants

- **Proton accumulated in lumen & decrease in stroma –**
  1) Proton produced by water splitting on innerside, so H^+ accumulate in lumen.
  2) Electrons move through photosystems & protons are transported across membrane as primary electron acceptor is present towards outer membrane which transfers electron not to electron carrier but to H carrier which removes proton from stroma to lumen while transporting electron.
  3) NADP reductase is present on stroma side. Alongwith electrons from electron acceptor of PSI, protons are necessary for $NADP^+$ reduction, which are removed from stroma.
  - It leads to proton gradient & decrease in lumen pH.
  - Breakdown of this gradient leads to ATP synthesis.
  - H^+ move to stroma through transmembrane channel of CF_0 of ATP synthase.
  - ATP synthase – **CF_0** (embedded in thylakoid membrane, transmembrane channel, carries out facilitated diffusion) & **CF_1** (outer surface of thylakoid membrane).
  - Breakdown of gradient cause conformational change in CF_1 which synthesise ATP, to be used in dark reaction.
  - Chemiosmosis require membrane, proton pump, proton gradient, ATP synthase.
  - **Products of light reaction – ATP, NADPH & 0_2**

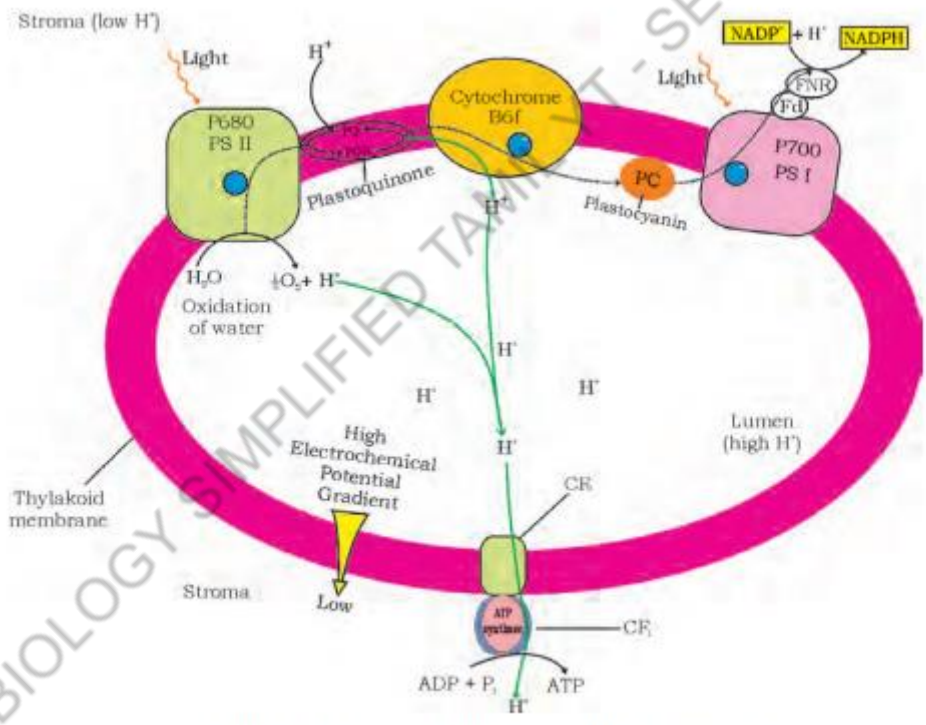


Figure 13.7 ATP synthesis through chemiosmosis

Biosynthetic phase – also called **Calvin Cycle.**

- Out of ATP, NADPH & O_2, O_2, diffuse out of chloroplast & ATP & NADPH are used in biosynthetic reaction.
- **Melvin Calvin:** Used radio active **^{14}C** in algal photosynthesis & discovered first product of CO_2 fixation - 3 - C compound called **3 phosphoglyceric acid (PG A)** – **C_3 pathway.**
- In some plant first product of CO_2 fixation is **oxaloacetic acid** (4-C compound) – **C_4 pathway.**

Photosynthesis in Higher Plants

Primary CO_2 acceptor –

- Scientists tried to find 2-C compound as primary CO_2 acceptor but ended up with 5-C ketose sugar – **Ribulose bisphospate (RUBP).**

Calvin cycle: In all plants (C_3 & C_4), RUBP is regenerated.

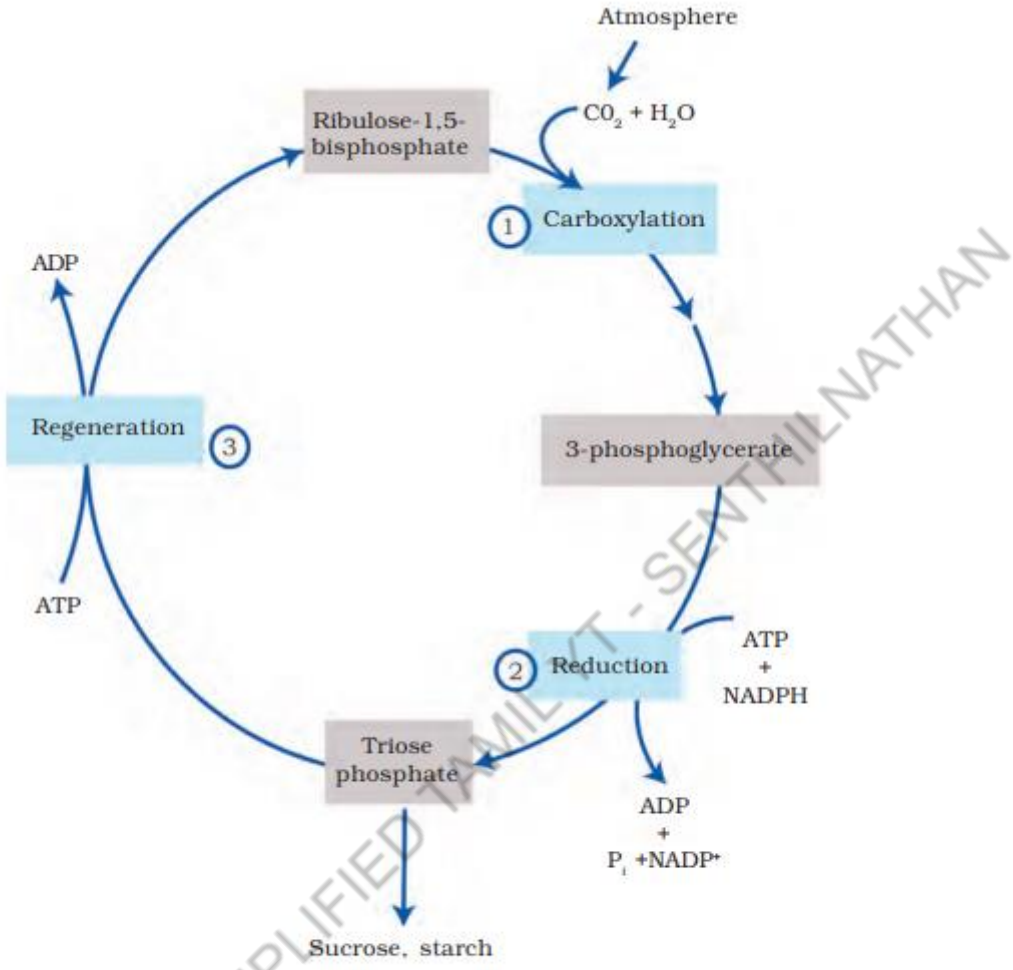


Figure 13.8 The Calvin cycle proceeds in three stages : (1) carboxylation, during which CO_2 combines with ribulose-1,5-bisphosphate; (2) reduction, during which carbohydrate is formed at the expense of the photochemically made ATP and NADPH; and (3) regeneration during which the CO_2 acceptor ribulose-1,5-bisphosphate is formed again so that the cycle continues

1) Carboxylation: Fixation of CO_2.

- RUBP is carboxylated in presence of **RUBP carboxylase** which results in **2 molecules of 3-PGA.**
- Enzyme has oxygenation activity also so called **RUBP carboxylase oxygenase (RUBisCO).**

2) Reduction: Formation of triose phosphate precursor to glucose.

- 2 molecules of 3-phosphoglycerate is phosphorylated by utilising **2 ATP** & then reduced to 2 triose phosphate by **2 NADPH** for reduction.

- **1 CO_2** $\xrightarrow{2\ ATP\ +2\ NADPH}$ **2** triose phosphate
- **6 CO_2** $\xrightarrow{12\ ATP\ +12\ NADPH}$ **12** triose phosphate

- 6 molecules of CO_2 are fixed for 1 glucose molecule. **Eg:** 6 turns of calvin cycle.

Photosynthesis in Higher Plants

3) Regeneration: Regeneration of RUBP.

- Require **1 ATP.**
- Out of 12 triose phosphate produced by fixation of 6 CO_2, 2 triose phosphate are used to make 1 glucose molecule & rest 10 (i.e. 10 x 3 = 30 C) are used for regenerating **6 molecule of RUBP** (5-C).
- For 1 CO_2 fixed 3ATP & 2NADPH are needed.
- For **6 CO_2 fixed, 18 ATP & 12 NADPH** are needed to make 1 glucose molecule.

C_4 pathway - (mostly by plants in dry tropical regions)

- Use C_3 pathway along with C_4 pathway.
- **Specialities:** Tolerate high temperature, respond to high light intensities, greater productivity of biomass, lack photorespiration, kranz anatomy.
- Large cells around vascular bundles-**bundle sheath cells** (large no. of chloroplast, thick walls **impervious to gas exchange** & no intercellular spaces). Such leaves have **Kranz anatomy (wreath or reflection of arrangement of cells).**
- Also called **Hatch & Slack Pathway**. **Eg: In maize or sorghum, sugarcane.**

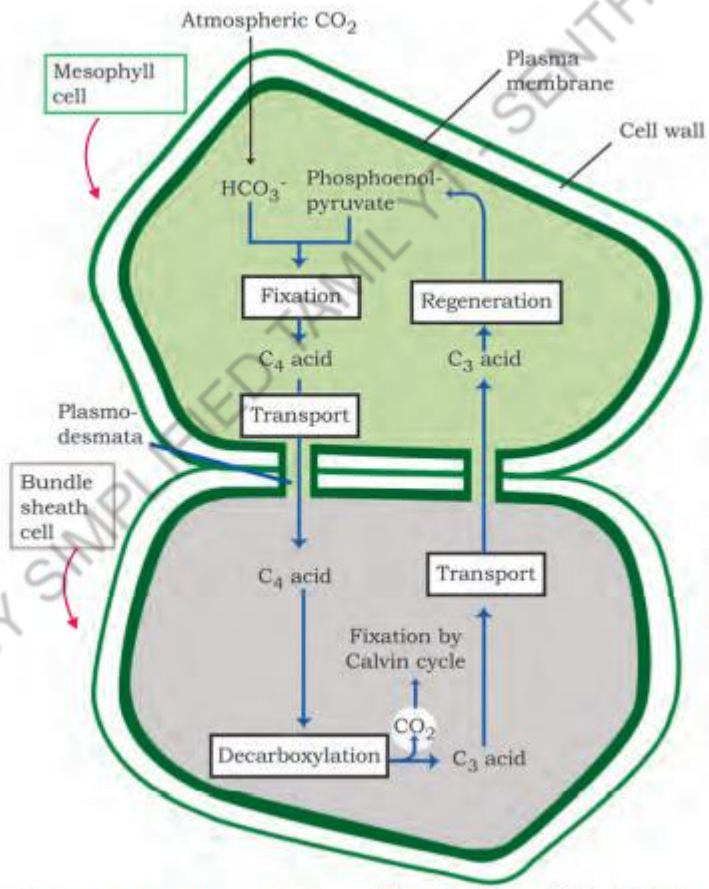


Figure 13.9 Diagrammatic representation of the Hatch and Slack Pathway

Primary CO_2 acceptor –

- 3 carbon molecule **phosphoenol pyruvate (PEP)** in presence of **PEP carboxylase** accepts CO_2 in mesophyll cells to form oxaloacetic acid **(4-C compound)**.
- **Mesophyll cells lack RUBisCO enzyme.**

Photosynthesis in Higher Plants

C_4 Cycle –

- OAA is converted to malic acid or aspartic acid (4 C compound) which are transported to bundle sheath cells where they are broken to release CO_2 & 3-carbon molecule.
- 3-C compound is transported back to mesophyll where its converted to PEP again & completes cycle.
- CO_2 released in bundle sheath cells enter C_3 pathway.
- Bundle sheath cells are **rich in RUBisCO but lack PEP case**.
- C_3 pathway occurs in mesophyll of C_3 plants but occurs in bundle sheath cells of C_4 plants.
- **C_4 plants undergo carboxylation twice.** (Mesophyll & bundle sheath).

Photorespiration: Wasteful process.

- RUBP combined with CO_2 to form 2 molecules of 3 PGA in presence of RUBisCO.
- It has greater affinity for CO_2 when $CO_2 : O_2$ is equal.

C_3 plants –

- RUBisCO binds with O_2 to form 1 molecule of **Phosphoglycerate** & **phosphoglycolate (2carbon)** - photorespiration.
- It neither synthesise sugar nor ATP or NADPH but releases CO_2 with utilisation of ATP.

C_4 plants: No photorespiration.

- Mesophyll cells lack RUBisCO while bundle sheath cells are impervious to gases so oxygenation of RUBisCO isn't possible.

Factors affecting Photosynthesis –

- **Internal factors:** Affected by plant genetic makeup & growth. **Eg:** No., size, age, orientation of leaves, mesophyll cells, chloroplasts, internal CO_2 concentration, chlorophyll content.
- **External factors:** Availability of sunlight, CO_2 concentration, water, temperature, light intensity.
- **Blackman's Law of Limiting factors (1905):** If a chemical process is affected by more than 1factor, then its rate is determined by factor nearest to its minimal value, which directly affects process if its quantity is changed.
  Eg: Despite presence of green leaf, light & CO_2, plant may not perform photosynthesis if temperature is low. If optimum temperature is given, it will start photosynthesising.

1) Light:

- At low light intensity, there is linear relationship between incident light & CO_2 fixation.
- At high light intensity, rate doesn't show further increase as other factors become limiting.
- **Light saturation** occur at 10% of full sunlight.
- Light is rarely limiting factor except for shady plants.
- Increase in light – beyond a point cause breakdown of chlorophyll & decrease photosynthesis.

Photosynthesis in Higher Plants

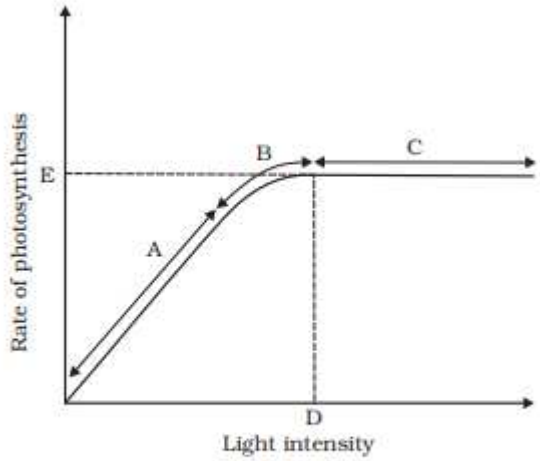


Figure 13.10 Graph of light intensity on the rate of photosynthesis

2) Carbon dioxide concentration – Major limiting factor.

- 0.03 – 0.04% in atmosphere.
- At low light condition, neither C_3 nor C_4 respond to high CO_2 condition.
- At high light condition, both show increase in CO_2 fixation.
- **C_4 show saturation at 360 µl L^{-1} while C_3 show saturation beyond 450 µl L^{-1}.**
- So, CO_2 is limiting to C_3 plants.
- C_3 respond to high CO_2 by increasing rate of photosynthesis hence high productivity. So, used in greenhouse crops like **tomatoes & bell pepper.**

3) Temperature –

- Dark reactions are temperature controlled whereas light reactions are affected to less extent.
- C_4 respond to high temperature & high rate of photosynthesis whereas C_3 have low optimum temperature.
- **Tropical plants have higher optimum temperature than temperate.**

4) Water –

- Water stress closes stomata hence reducing CO_2 available. It makes leaves wilt & reduce surface area of leaves & metabolic activity.

Respiration in Plants

- **Cellular Respiration:** Mechanism of breakdown of food material within cell to release energy & for ATP synthesis.
- Occur in cytoplasm & mitochondria.
- **Respiration:** Breaking of C - C bond of complex compounds through oxidation within cells releasing energy.
- **Respiratory Substrates:** Compounds oxidised in respiration. **Eg:** Carbohydrate, fats & proteins.
- Animals that obtain food from plants directly - **herbivores** & indirectly – **carnivores**.
- **Saprophytes:** Depend on dead & decaying matter. **Eg:** Fungi .

Breathing in Plants:

Plants **don't have special respiratory organs** because –

1) Each part takes care of its own needs.
2) Plants don't present great gaseous demands. **Roots, stems & leaves respire at rates far lower than animals.**
3) Distance for gases to diffuse isn't large. Most cells of plant have at least a part of their surface in contact with air due to loose parenchyma packing.
4) Oxygen demand is fulfilled by oxygen released inside cell during photosynthesis.

Combustion of glucose:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + H_2O + \text{energy.}$$

Glycolysis: Partial oxidation of glucose to pyruvic acid **(Key product)**

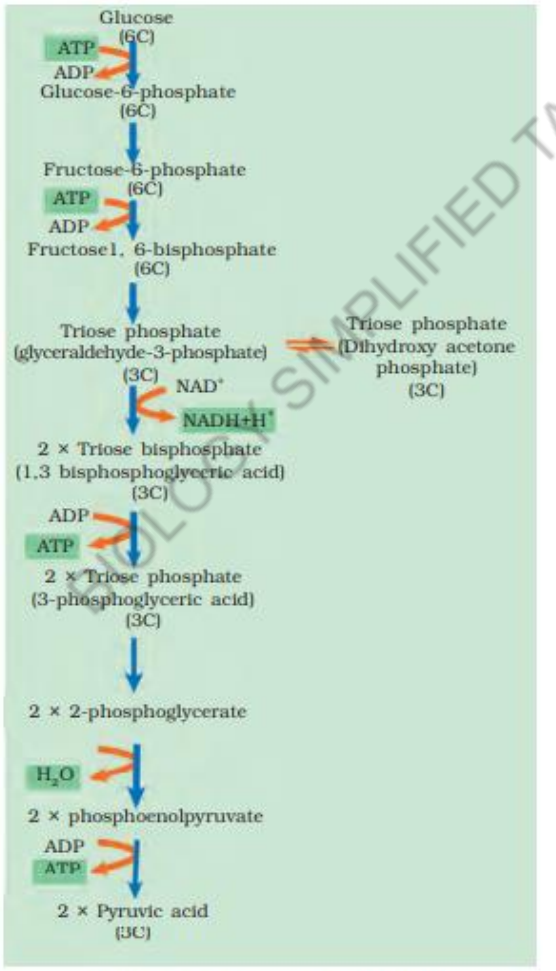


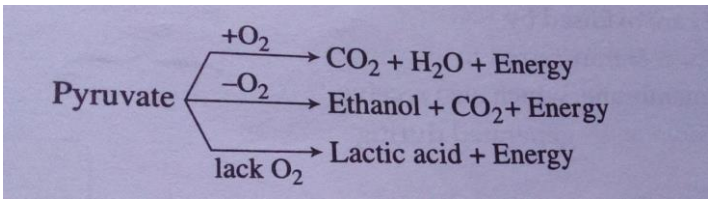
Figure 14.1 Steps of glycolysis

Respiration in Plants

- Glycos – sugar; lysis – splitting.
- Given by **Gustav Embden, Otto Meyerhof & J. Parnas – EMP pathway.**
- In anaerobes its the only respiration process.
- Occur in **cytoplasm.**
- Glucose is derived from sucrose (end product of photosynthesis).
- Sucrose converts to glucose & fructose by **invertase.**
- 10 steps controlled by different enzymes.

Energy Produced:

(2 x 2ATP) – 2ATP
Net = 2ATP
1 NADH = 3ATP
2NADH = 6ATP
Gross = (2 + 6) ATP = **8 ATP**



Fermentation: Incomplete oxidation of glucose in yeast, muscle during exercise.

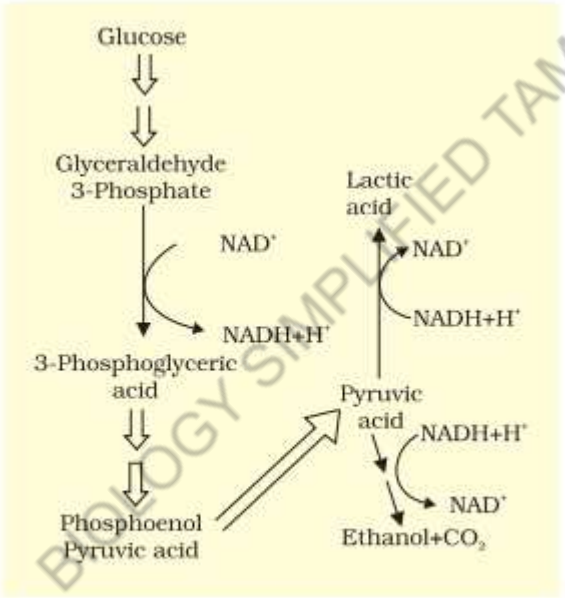


Figure 14.2 Major pathways of anaerobic respiration

- Pyruvic acid is converted to CO_2 & ethanol by **pyruvic acid decarboxylase & alcohol dehydrogenase.**
- In muscles, its reduced to lactic acid by **lactate dehydrogenase.**
- Reducing agent – **NADH + H^+** which is reoxidised to NAD^+.
- Less than 7% energy in glucose is released.
- **Yeast poison themselves when alcohol concentration reach 13%.**

Respiration in Plants

Energy Utilised:

Glycolysis ♦ 2ATP + 2NADH
Fermentation ♦ –2NADH
Net gain = 2ATP

Aerobic Respiration:

- Complete oxidation of organic substances in presence of oxygen to release CO_2, H_2O & energy.
- **Matrix of mitochondria:** Complete oxidation of pyruvate by complete removal of H - atoms leaving 3 molecules of CO_2.
- **Inner membrane of mitochondria:** Passing of electrons removed as part of H - atoms to oxygen, synthesise ATP.
- Pyruvate undergo **oxidative decarboxylation** by **pyruvic dehydrogenase** in mitochondrial matrix.

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

- 2 molecules of pyruvic acid produce 2 molecule of NADH.
- Acetyl CoA enters Krebs' cycle.

Tricarboxylic Acid Cycle: Also called **Krebs' cycle** after Hans Krebs, also called **citric acid cycle.**

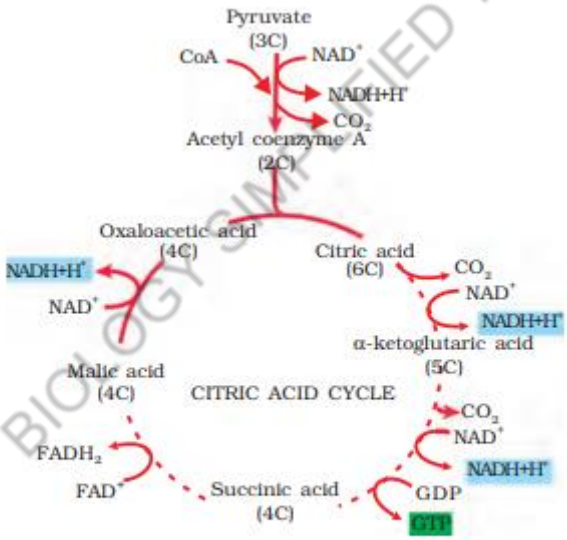


Figure 14.3 The Citric acid cycle

Energy produced:

1 Pyruvic acid = 1 GTP + 4 NADH + 1 $FADH_2$
2 Pyruvic acid = 2 GTP + 8 NADH + 2 $FADH_2$
1 GTP = 1 ATP
1 NADH = 3 ATP

1 $FADH_2$ = 2 ATP

Total = (2x1) + (8x3) + (2x2) = 30 ATP.

Glycolysis = 2 ATP + 2 NADH

- This cycle requires continued replenishment of oxaloacetic acid. NAD^+ & FAD^+ from NADH & $FADH_2$.

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

- Glycolysis & Krebs' cycle result in reduced coenzyme (10 NADH+4ATP+2$FADH_2$) which need to be oxidized.

Electron Transport System (ETS) & Oxidative Phosphorylation -

- Electrons pass from one carrier to another.
- In **inner mitochondrial membrane.**
- Passes electrons to O_2 resulting in formation of H_2O.

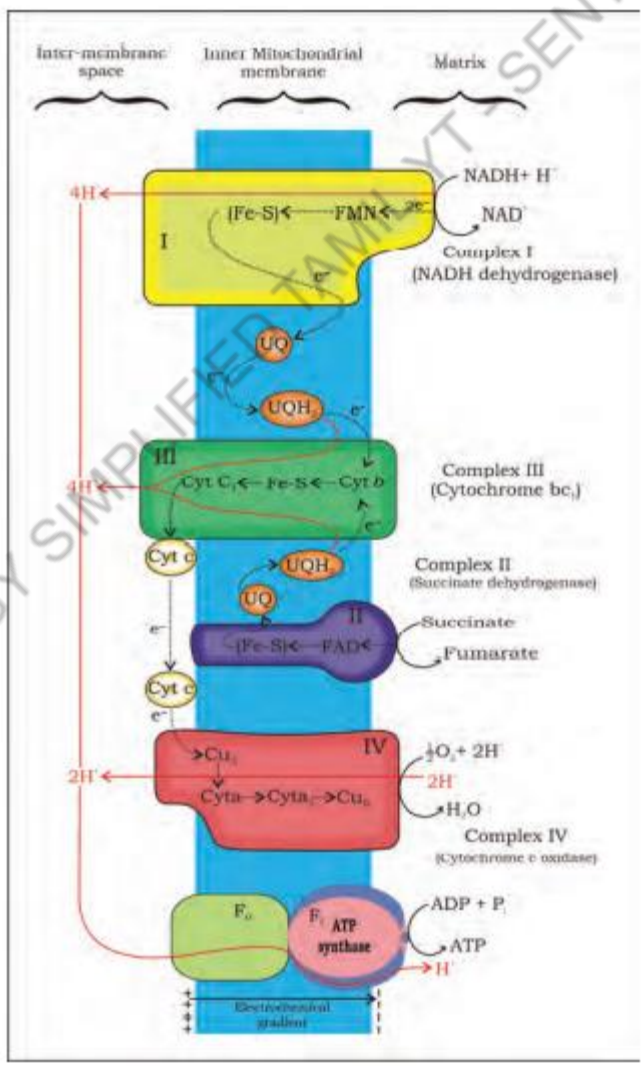


Figure 14.4 Electron Transport System (ETS)

- Electrons from NADH are oxidised by **NADH dehydrogenase (complex I)** & transferred to **ubiquinone (complex Q)** on inner membrane, which also receive electrons via **$FADH_2$ (complex II)** generated during oxidation of succinate.
- Reduced ubiquinone gets oxidised by transfer of electrons to **cytochrome c** via **cytochrome bc_1complex (complex II)**
- Cytochrome C – small protein on outer side of inner membrane, **mobile carrier** between **complex III & Iv.**
- Complex IV is **cytochrome c oxidase complex** containing cytochromes **a & a_3** (2 copper centres).
- Electrons transferred are coupled to **ATP synthase (complex V)** for ATP production from ADP & inorganic phosphate.
- Oxygen is final electron acceptor.
  $2H^+ + 2e^- + ½\ O_2 \rightarrow H_2O$ + energy
- Electron transport & H^+ movement create proton gradient & protons from intermembrane are needed to be pumped to matrix but membrane is impermeable for proton, so they are pumped through complex V.
- ATP synthase has 2 components – F_0 & F_1.
- **F_0** - integral membrane protein complex forming channel for protons to cross inner membrane.
- **F_1** - peripheral membrane protein, site for ATP synthesis.
- For **I ATP produced $2H^+$ pass through F_0** from intermembrane space to matrix.

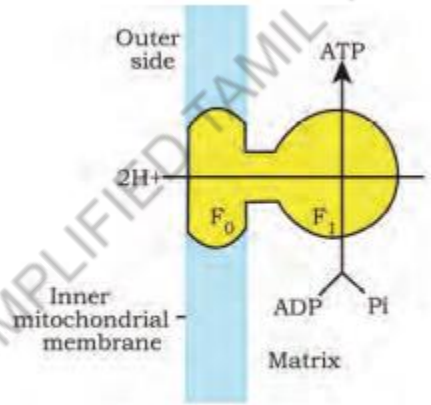


Figure 14.5 Diagramatic presentation of ATP synthesis in mitochondria

Oxidative Phosphorylation: Energy of oxidation - reduction is utilised to create proton gradient for phosphorylation unlike photophosphorylation where light is utilised for the same.

Total ATP = Glycolysis + Krebs' + ETS.

= (2 ATP + 2 NADH) + (2 GTP + 8 NADH + 2 $FADH_2$)

= [2 + (2x3)] ATP + [(2x1) + (8x3) + (2x2)] ATP

= 8 ATP + 30 ATP = 38 ATP.

*** No. of ATP synthesised depend on nature of electron donor.**

Respiratory Balance Sheet -

- Calculation of ATP are based on assumption like sequential orderly pathway (glycolysis → TCA → ETS), NADH in glycolysis is transferred to mitochondria & undergo oxidative phosphorylation, none of intermediate is utilised to synthesise other

compounds & only glucose is being respired.

- NADH is oxidised to NAD^+ slowly in fermentation whereas in aerobic respiration its vigorous.

Amphibolic pathway: Involved in both anabolism & catabolism.

Catabolism: Breakdown of complex substances to simple.

Anabolism: Synthesis of complex substances from simple.

- Fats → glycerol + fatty acid.
- If fatty acid were to be respired they are degraded to acetyl CoA & enter TCA. Glycerol converts to PGAL enter pathway.
- Protein $\xrightarrow{Protease}$ amino acids → Pyruvate.
- Traditionally, respiration is a catabolic process but now amphibolic.
- Plant withdraws acetyl Co-A for synthesis of fatty acids

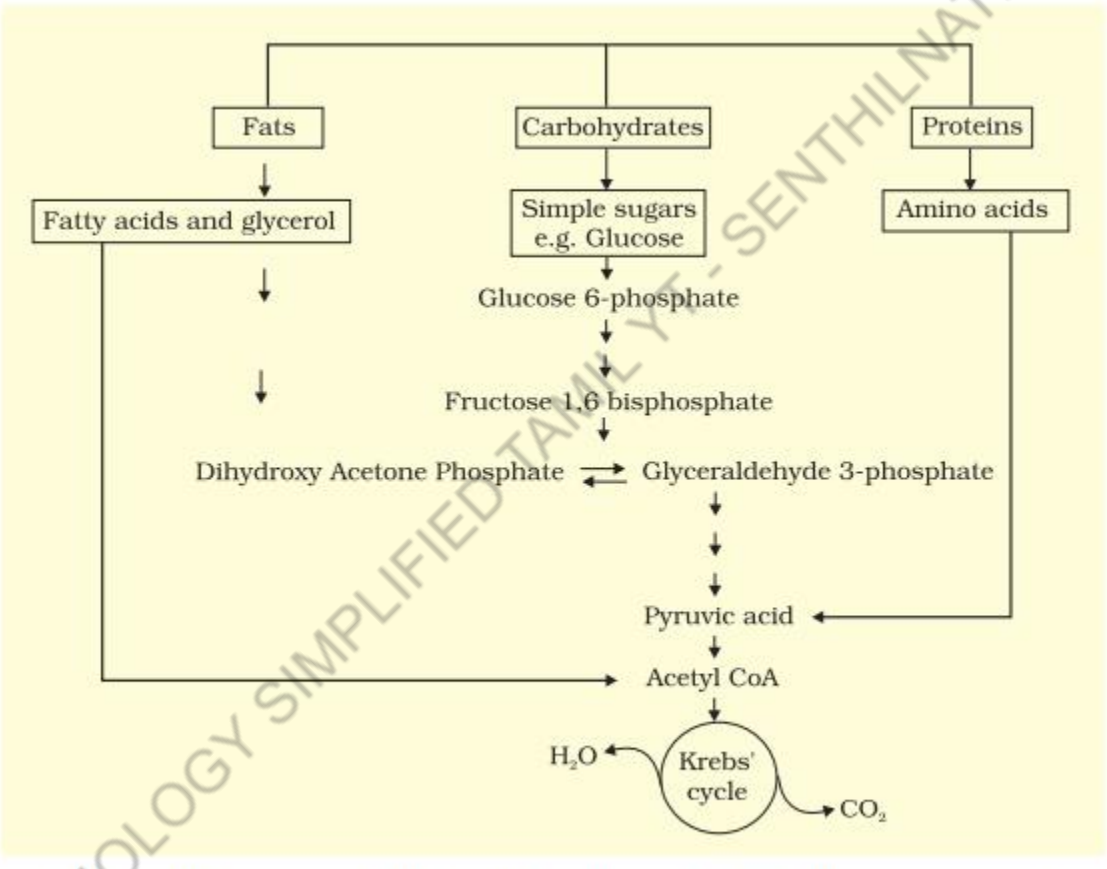


Figure 14.6 Interrelationship among metabolic pathways showing respiration mediated breakdown of different organic molecules to CO_2 and H_2O

Respiratory Quotient:

- Its the ratio of CO_2 evolved to volume of O_2 consumed in respiration. It depends on type of respiratory substrate.
- **Carbohydrate** - as substrate, RQ = 1 **i.e.** equal amount of CO_2 evolved & O_2 consumed.
  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy.$
- **Fats** - as substrate, **RQ < 1** **Eg:** Tripalmitin.
  $2(C_{51}H_{98}O_6) + 145\ O_2 \rightarrow 102\ CO_2 + 98\ H_2O + Energy$
  Tripalmitin [RQ = 0.7]

Respiration in Plants

- **Proteins -** as substrate, **RQ ≈ 0.9**
- So, glucose is used as primary substrate by plants.

- In anaerobic respiration RQ = x

$C_6H_{12}O_6 \square \blacklozenge 2C_2H_5OH + 2CO_2 + E$

$RQ = 2CO_2/O_2 = \times.$

Plant Growth and Development

- **Development:** Sum of growth & differentiation.
- **First step in plant growth: Seed germination.**

Growth: Fundamental characteristic.

- **Irreversible** permanent increase in size of organ or cells.
- Accomplished by metabolic process. **Eg:** Expansion of leaf.

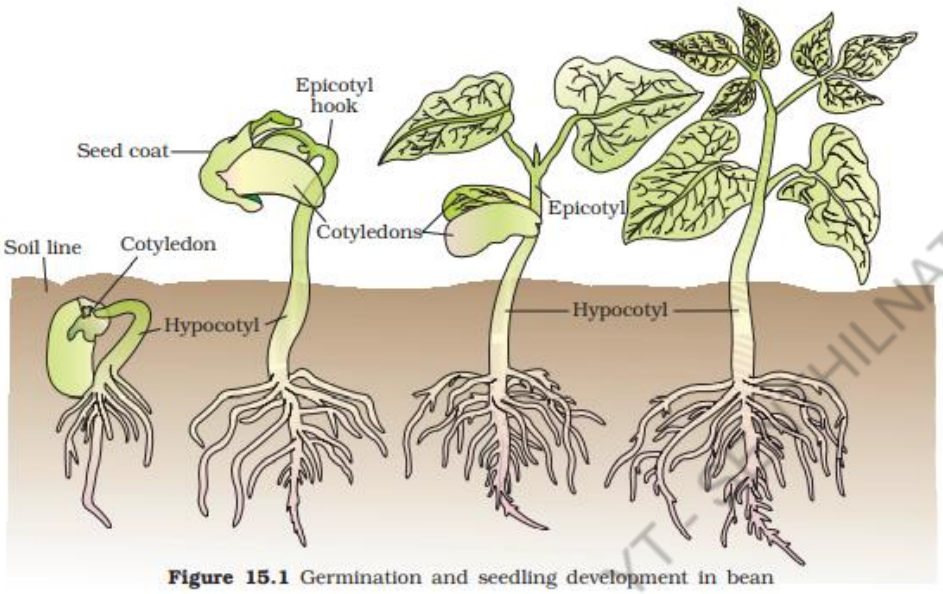


Figure 15.1 Germination and seedling development in bean

Indeterminate plant growth –

- Plant growth is continuous due to **meristems** (which divide & self - perpetuate).
- **Open form of growth:** New cells are being added to plant body by meristem activity.

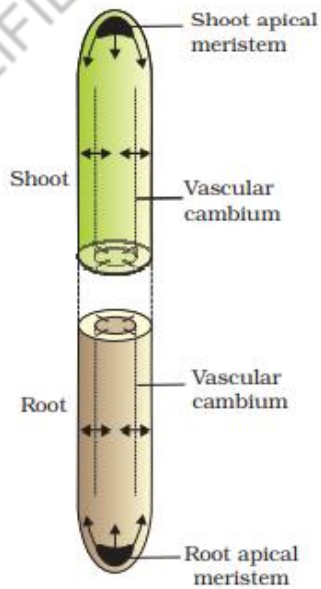


Figure 15.2 Diagrammatic representation of locations of root apical meristem, shoot aplical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ

- **Elongation of plant along axis: Primary growth** (due to meristems).
- **Increase in girth: Secondary growth** (lateral meristem - cork & vascular cambium).

Growth is Measurable –

- Growth is due to increase in protoplasm which is difficult to measure directly.
- So, growth is measured by other parameters like increase in fresh weight, dry weight **(Eg: Cells of watermelon may increase to 3, 50, 000 times),** length **(growth of pollen tube),** area, volume **(growth of leaf)** & cell no. **[1 meristem (root) of maize – 17,500 cells / hour].**

Phases of Growth:

Meristematic: Divide constantly (at root & shoot apex), rich in protoplasm, large nuclei, thin cellulosic cell wall with plasmodesmatal connection.

Elongation: High vacuolation, cell enlargement, new cell wall deposited.

Maturation: Maximum size, thick wall, protoplasmic modification.

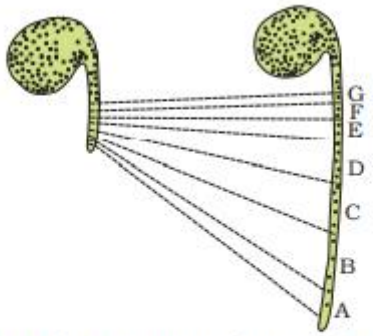


Figure 15.3 Detection of zones of elongation by the parallel line technique. Zones A, B, C, D immediately behind the apex have elongated most.

Growth Rates: May be arithmetic or geometrical.

- Increased growth per unit time

1) Arithmetic: Eg: Root elongation.

- Only one daughter cell continues to divide – mitotic division.

$$L_t = L_0 + rt$$

L_t = length at time 't',

L_0 = length at time 'zero',

r = growth rate/ elongation per unit time

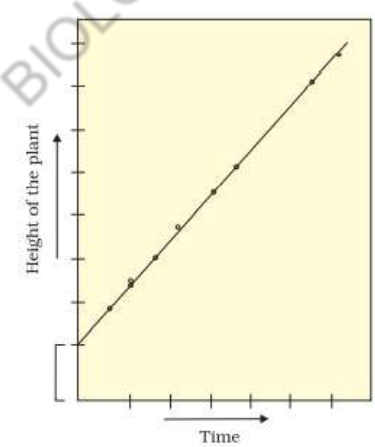


Figure 15.5 Constant linear growth, a plot of length L against time t

2) Geometric: Typical for all cells, tissue, organs.

- Initial growth is slow **(lag phase)**, increases rapidly after that **(log/exponential phase)**, then slows leading to **stationary phase.**

$$W_1 = W_0 e^{rt}$$

W_1 = final size, W = initial size, r = growth rate, t = time of growth, e = base of natural logarithm.

- **r → relative growth rate** (ability of plant to produce new plant)

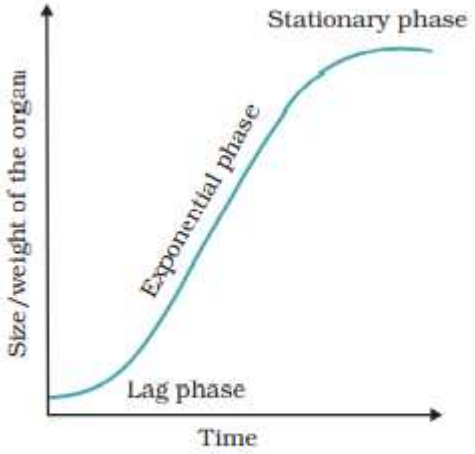


Figure 15.6 An idealised sigmoid growth curve typical of cells in culture, and many higher plants and plant organs

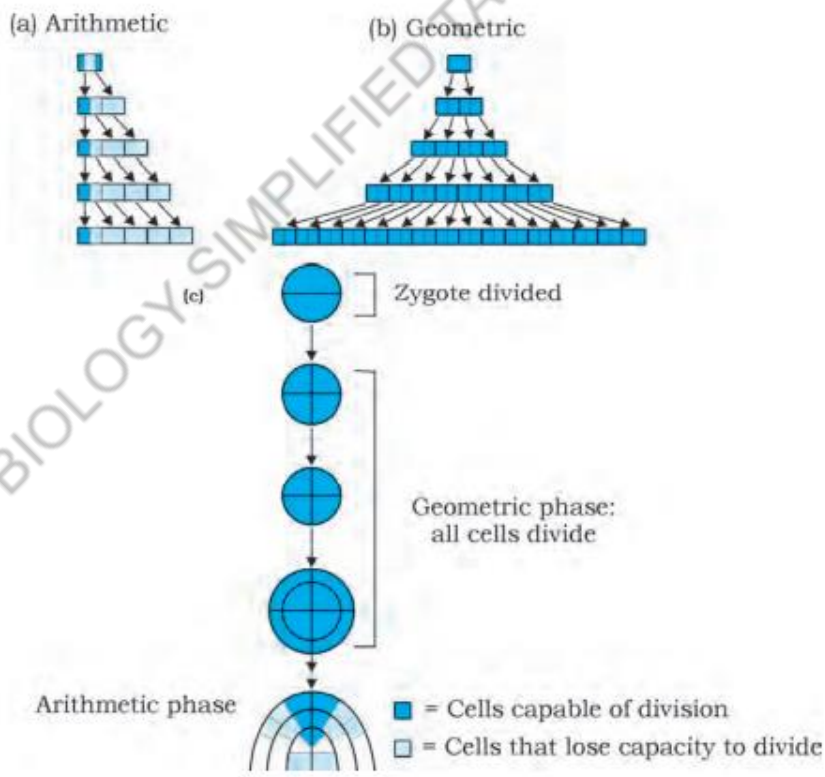


Figure15.4 Diagrammatic representation of : (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithematic phases

Plant Growth and Development

Quantitative comparison of growth:

a) **Absolute growth rate:** Measurement of total growth per unit time.
b) **Relative growth rate:** Growth of system per unit time according to initial parameters.

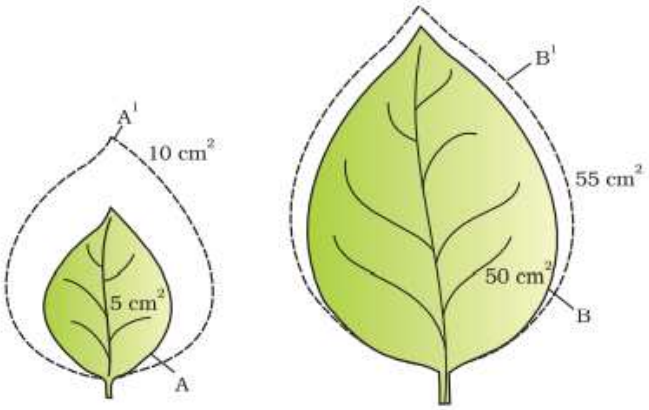


Figure15.7 Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm^2 in a given time to produce A^1, B^1 leaves.

Conditions for growth –

- **Water:** Medium for enzymatic activities
  Oxygen: Helps in releasing energy.
  Nutrient: For protoplasm synthesis & source of energy.
- Turgidity of cells help in growth.
- Optimum temperature, light & gravity also affect growth.

Differentiation, Dedifferentiation & Redifferentiation –

1) Differentiation:

- Cells of **root apical, shoot apical & cambium** undergo structural changes in cell wall & protoplasm.
- **Eg:** Cells lose protoplasm & develop strong, elastic, lignocellulosic, secondary cell wall to form **tracheary element**.

2) Dedifferentiation:

- Differentiated cells which had lost capacity to divide regain capacity of division.
- **Eg:** Fully differentiated parenchyma cells form meristems - interfascicular & cork cambium.

3) Redifferentiation:

- Meristem that are able to divide & produce cells that once again lose capacity to divide but mature to perform specific function.
- So, differentiation in plants is open as cells arising from same meristem have different structure at maturity.
- Final structure at maturity is determined by its position.
  Eg: Cells positioned away from root apical meristem differentiate as root cap cells while as epidermis those which are at periphery.

Development: Changes that organism undergoes through its life cycle.

- **Plasticity:** Development of different structures in response to environment.
  Eg: Heterophylly in cotton, coriander & larkspur.
- Leaves of of juvenile & mature coriander plant differ in shape.

- Shape of **buttercup** leaves is different in air & water.
- Depends on both intrinsic (intracellular or intercellular factor - plant growth regulator) & extrinsic (light, water, oxygen, nutrition).

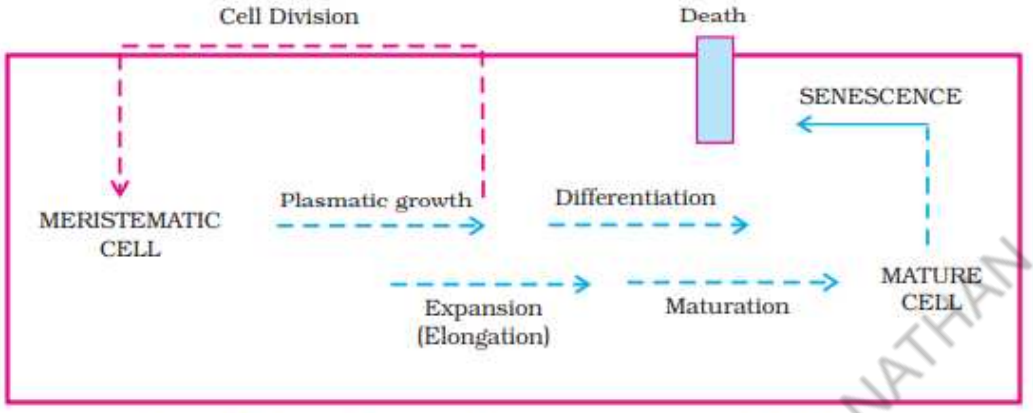


Figure 15.8 Sequence of the developmental process in a plant cell

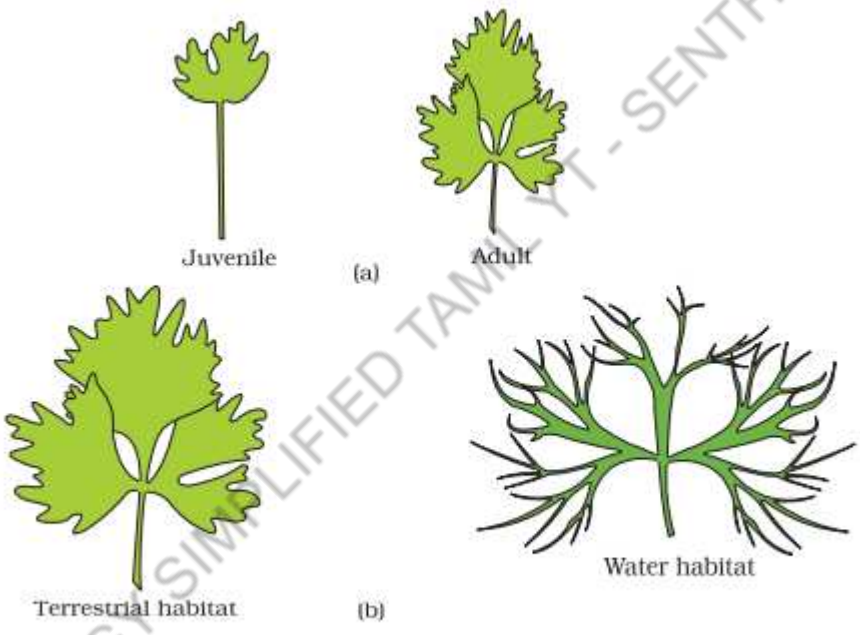


Figure 15.9 Heterophylly in (a) larkspur and (b) buttercup

Plant Growth Regulators: Small, simple molecules.

Characteristics –

- **One group: Plant growth promoters**. **Eg: Auxin, cytokinin, gibberellins,** help in cell division, cell enlargement, tropic growth, flowering, fruiting, seed formation.
- **Other group: Growth inhibiting. Eg:** Abscisic acid, dormancy, abscission, respond to wound & stresses.
- **Ethylene** fits both group but mainly **inhibitor**.
- Can be **Indole compounds** (indole 3 acetic acid), **Adenine derivative** (N^6 furfurylamino purine, kinetin), **Carotenoid** (abscissic acid), **Terpenes** (gibberellic acid) or **Gases**(ethylene).

Plant Growth and Development

Discovery of Plant Growth Regulators –

- It started when **Charles Darwin & Francis Darwin** (son) observed phototropism in **coleoptile of canary grass.** So, tip of coleoptile was site of transmittable influence.
- **Auxin:** By **F.W. Went** from tip of coleoptile of **oat seedlings.**
- **Gibberellic acid:** By **E. Kurosawa (1926)** who reported symptoms of **Bakanae** (foolish seedling disease) in **rice seedling** when they were treated with sterile filtrates of fungal pathogen **Gibberella fujikuroi**. Active substance was later called gibberellic acid.
- **Kinetin:** By **F.Skoog** who observed that from internodal segments of **tobacco stems,** callus proliferated if nutrient medium had auxin, alongwith extracts of vascular tissues yeast extract, coconut milk or DNA. Cytokinesis promoting active substance – kinetin.
- **Abscisic acid:** 3 different kind of inhibitors but had same structure – **inhibitor B, abscission II & dormin.**
- **Ethylene:** By **Cousins**, observed that ripened oranges release volatile substance which hasten ripening of unripened banana. This volatile substance - ethylene.

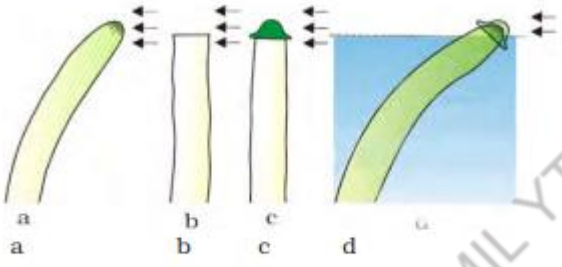


Figure 15.10 Experiment used to demonstrate that tip of the coleoptile is the source of auxin. Arrows indicate direction of light

1) Auxins: (Greek auxein - to grow).

- First isolated from **human urine.**
- Generally produced by growing apices of stems & roots.
- **Natural auxins –** Indole 3 acetic acid (IAA), indole butyric acid (IBA).
- **Synthetic auxins –** Naphthalene acetic acid (NAA), 2 - 4 dichlorophenoxyacetic acid.
- Initiate rooting in stem cutting (plant propagation).
- **Promote flowering in pineapples, parthenocarpy in tomatoes.**
- Prevent fruit & leaf drop at early stage but promote abcision in older parts.
- Herbicides **(2 – 4D kill dicot weeds)**, prepare weed free lawns.
- Inhibit growth of lateral buds - **apical dominance** but **decapitation** (shoot tip removal) leads to growth of lateral buds. Its used in **tea plantation, hedge making.**
- Control xylem differentiation, helps in cell division.

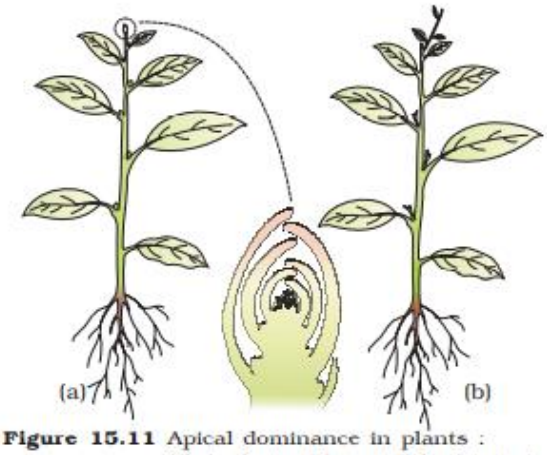


Figure 15.11 Apical dominance in plants : (a) A plant with apical bud intact (b) A plant with apical bud removed Note the growth of lateral buds into branches after decapitation.

2) Gibberellins: More than 100 in no., **acidic.**

- GA_3 (gibberellic acid) - first gibberellin.
- Increase length of axis. **Eg: Increase length of grape stalks.**
- Cause fruits like **apple** to elongate & improve shape.
- Delay senescence, so fruits can be left on tree to extend market period, **hasten maturing period** so early seed production.
- Speed up **malting process** in brewing industry.
- Promote **bolting** (internode elongation prior to flowering) in **beet, cabbage & plants with rosette habit.**
- Sugarcane store sucrose in stem, by GA_3 length of stem increase, yield increases by **20 tonnes per acre.**

3) Cytokinins: Discovered as kinetin, doesn't occur naturally.

- From autoclaved herring sperm DNA.
- Synthesised in rapid cell division area - produce new leaves, lateral shoot growth & adventitious shoot formation.
- Overcome apical dominance.
- Promote nutrient mobilisation which delay leaf senescence.
- Search for similar substance led to isolation of **zeatin** from **corn - kernels & coconut milk.**

4) Ethylene: Gaseous PGR.

- Synthesised in large amounts by tissues undergoing senescence & fruit ripening.
- Horizontal seedling growth, axis swell, **apical hook formation in dicot**, promote senescence & abscission.
- Highly effective in **fruit ripening**, enhances respiration rate in fruit ripening - **respiratory climactic.**
- Breaks seed & bud dormancy, initiate **germination in peanut seeds** & sprouting of potato tubers.
- Promote **internode elongation in rice plants** (in deep water).
- Promote root growth & root hair formation.
- Initiate flowering in **pineapple & mango.**

- **Ethephon:** As source of ethylene, readily absorbed in aqueous medium & release ethylene slowly, **hastens fruit ripening (tomatoes, apples),** accelerate abscission in fruits & flowers **(cotton, cherry, walnut),** promote **female flowers** production **(cucumber).**

5) Abscisic acid: Antagonist to GAs.

- Inhibit seed germination, close stomata, increase tolerance to stress - **stress hormone.**
- Helps seed to withstand dessication.
- Helps in seed development, maturation & dormancy.

Photoperiodism: Response of plants to period of day/night.

- **Long day plants:** Requires light exposure exceeding well defined critical duration.
- **Short day plants:** Exposure of light for a period less than critical duration.
- **Day – neutral plants:** No correlation between light exposure & flowering.
- Shoot apices modify to flowering apices before flowering but site of perception are **only leaves.**
- Hormonal substance migrate from leaves to shoot apices to induce flowering.
- Plants also need duration of dark period for flowering.
- Critical duration are different for different plants.

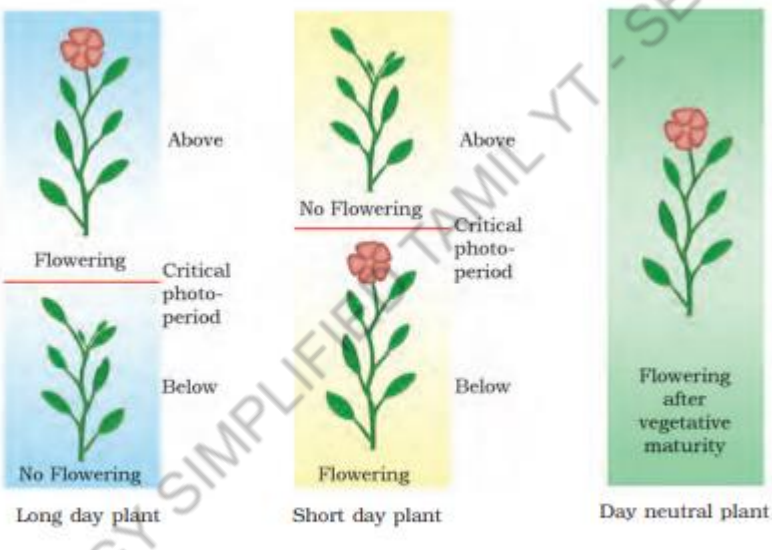


Figure 15.12 Photoperiodism : Long day, short day and day neutral plants

Vernalisation: Dependency of flowering on exposure of low temperature, both qualitatively & quantitatively.

- Enables plant to have enough time to reach maturity.
- **Spring variety:** Planted in spring & come to flower & produce grain before end of growing season.
- **Winter variety:** Planted in autumn, resume growth in spring, harvested around mid summer, if planted in spring they fail to flower.
- Another example – **biennial.**
- **Biennial:** Monocarpic plants that flower normally & die in second season.
  Eg: Sugarbeet, cabbage & carrots.

Plant Growth and Development

Seed Dormancy: Fail to germinate even in favourable condition.

- Can be due to impermeable & hard seed coat, immature embryo or chemical inhibitors like abscissic acid, **phenolic acid, para – ascorbic acid.**
- Overcome through natural or man made measures.

Eg: a) Seed coat barrier - by knives, sandpaper, shaking.

b) Inhibitory substance - chilling condition or applying chemicals like gibberellic acid & **nitrates**.

C) Change in environmental conditions (light & temperature).

Digestion and Absorption

Digestion: Conversion of complex food substances to simple absorbable form.

- Major components of food – **Carbohydrate, protein, fats.**
- Vitamins are required in small quantity.

Digestive system: Alimentary canal & associated glands.

Alimentary canal:

- **Begins with anterior part:** Mouth which leads to buccal cavity or oral cavity that has teeth & muscular tongue.

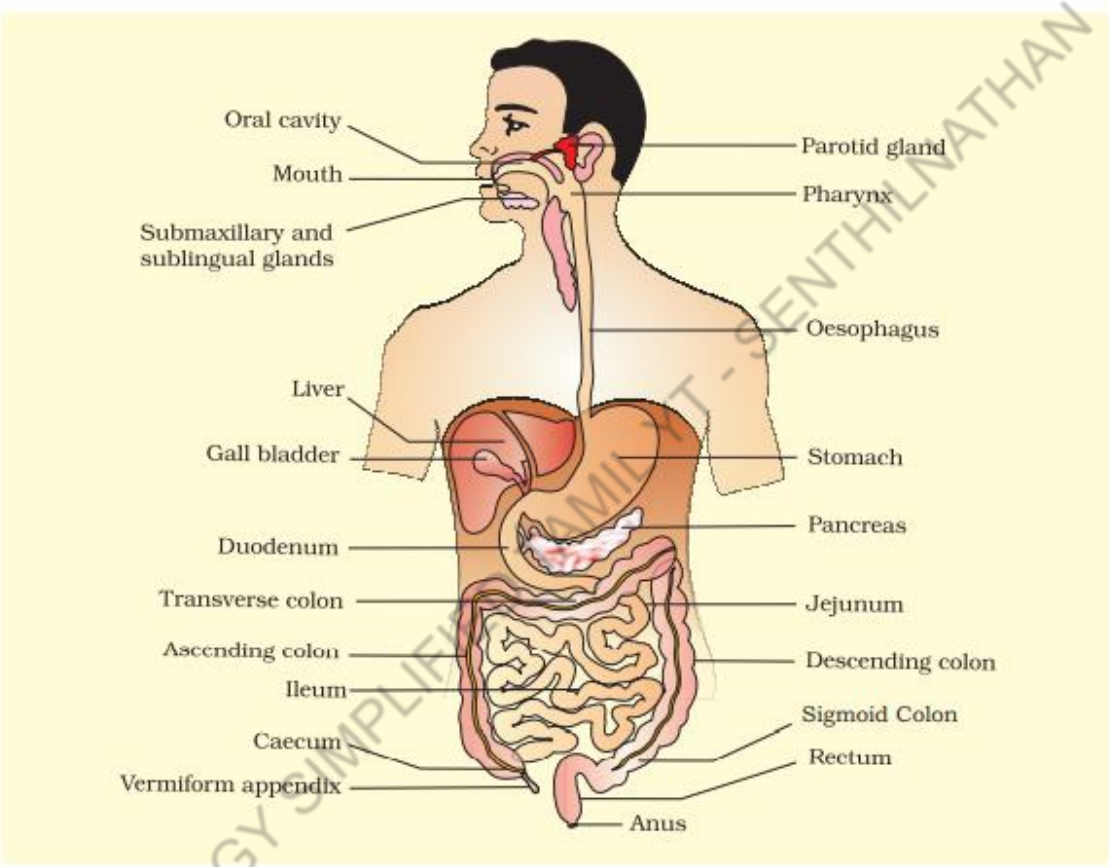


Figure 16.1 The human digestive system

Teeth –

- **Thecodont:** Tooth is embedded in socket of jaw bone.
- **Diphyodont:** 2 sets of teeth (temporary /**deciduous** & permanent).
- **Heterodont:** 4 different types of **32 permanent teeth. i.e.,** Incisors, canine, premolar & molars.
- **Dental formula:** Arrangement of teeth in each half of upper & lower jaw in order I, C, PM, M. **i.e.** $\frac{2123}{2123}$ **in Adult.**
- Hard chewing surface of teeth is made of **enamel** which help in mastication of food.

Digestion and Absorption

- Tongue is freely movable attached to floor of oral cavity by **frenulum**. Its upper surface has small projections – **papillae.** Some of them bear taste buds.
- Oral cavity leads to pharynx **(common passage for food & air)**
- Pharynx open into oesophagus & trachea **(wind pipe).**
- **Epiglottis:** Cartilaginous flap preventing entry of food into glottis.
- **Oesophagus:** Thin, long tube passing through neck, thorax & abdomen leading to J - shaped bag – **stomach.**

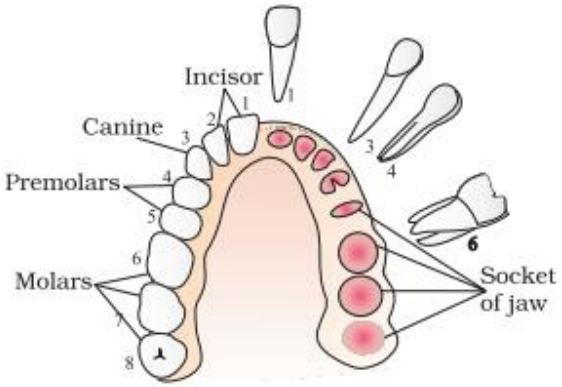


Figure 16.2 Arrangement of different types of teeth in the jaws on one side and the sockets on the other side

Stomach: Upper left portion of abdominal cavity.

- Gastro oesophageal sphincter regulate opening of oesophagus into stomach (cardiac portion)
- **Cardiac -** Oesophagus opens.
- **Fundic -** Part of stomach.
- **Body -** Main central region.
- **Pyloric -** Opens into duodenum by pyloric sphincter.

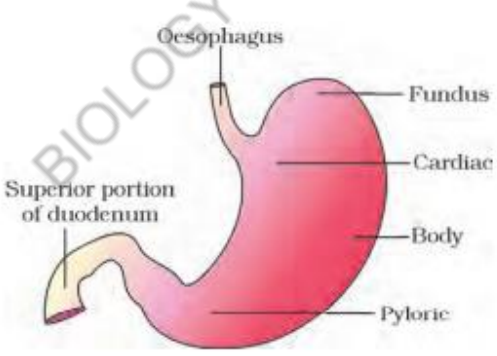


Figure 16.3 Anatomical regions of human stomach

Digestion and Absorption

Small intestine:

- Pyloric sphincter regulate opening of stomach to intestine.
- **Duodenum:** C – shaped.
- **Jegunum:** Long coiled middle portion.
- **Ileum:** Highly coiled, opens to large intestine.

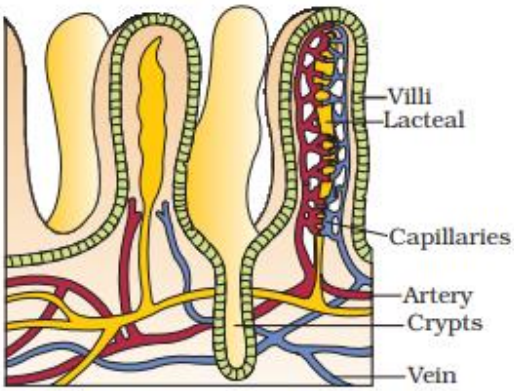


Figure 16.5 A section of small intestinal mucosa showing villi

Large Intestine :

- **Caecum:** Small blind sac hosting symbiotic micro - organism, narrow finger like tubular projection - **vemiform appendix** arise from caecum, opens to colon.
- **Colon:** Divided into 4 parts – ascending, transverse, descending & sigmoid, descending part opens to rectum.
- **Rectum:** Opens out through anus.

Walls of alimentary canal:

- **Serosa:** Outermost layer made of mesothelium.
- **Muscularis:** Inner smooth muscles & outer longitudinal muscles.
- **Sub – mucosa:** Loose connective tissue containing nerves, blood & lymph, glandless but in duodenum it has glands **(Brunner's glands)**.

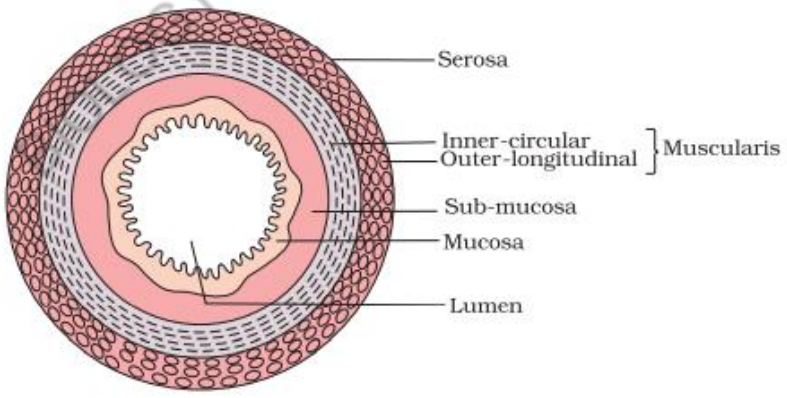


Figure 16.4 Diagrammatic representation of transverse section of gut

Digestion and Absorption

- **Mucosa:** Intermost layer, forms irregular folds **(rugae)** in stomach & small finger like foldings **(villi)** in small intestine. Villi give rise to microvilli giving brush border appearance which increase surface area. Villi are supplied by network of capillaries & large lymph vessel – **Lacteal.** Mucosal epithelium has goblet cells which secrete mucus **(lubrication)**. It forms gastric glands in stomach & crypts between villi in intestine **(crypts of Lieberkuhn).**
- **Stomach has additional oblique layer.**

Digestive Glands: Salivary gland, liver & pancreas.

1) Salivary gland: Outside buccal cavity, secrete salivary juice.

- Has **parotids (cheek), sub maxillary/sub mandibular (lower jaw) & sub linguals (below tongue).**

2) Liver: Largest gland weighing 1.2 to 1.5 kg in adult.

- Below diaphragm & has 2 lobes.
- Structural & functional unit – **hepatic lobules** which has hepatic cells in form of cords.
- Each lobule is covered by thin connective tissue – **glisson's capsule.**
- **Bile pathway -** hepatic cells secrete bile which passes by hepatic ducts & stored in thin muscular sac – **gall bladder.**
- Duct of gall bladder **(cystic duct)** & hepatic duct form common bile duct. Bile duct & pancreatic duct open into duodenum as **common hepato pancreatic duct** by **sphincter of oddi.**

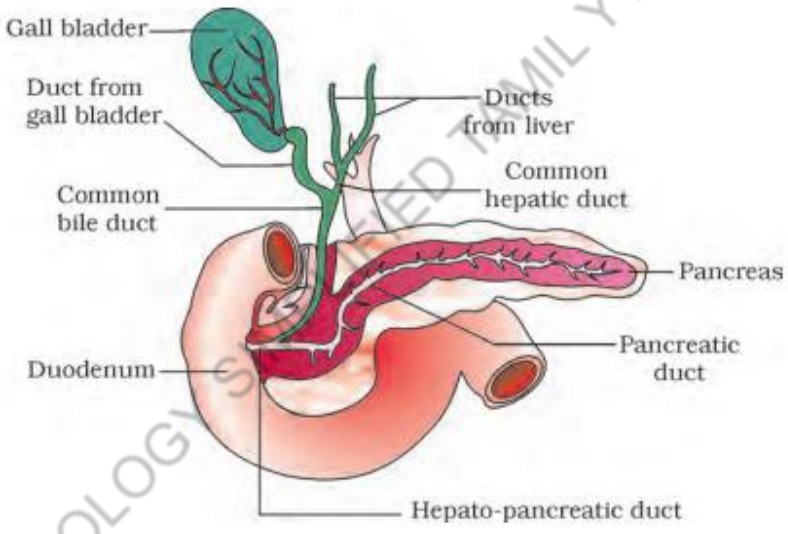


Figure 16.6 The duct systems of liver, gall bladder and pancreas

3) Pancreas: Compound gland (exocrine + endocrine).

- Between limbs of duodenum.
- **Exocrine part:** Secrete **alkaline pancreatic juice.**
- **Endocrine part:** Secrete hormones, insulin, glucagon.

Digestion of food: Mechanical + chemical.

- **Buccal cavity:** Mastication of food & facilitate swallowing.

Digestion and Absorption

- Mucus in saliva help in lubricating & adhering masticated food particles into **bolus**, which passes into pharynx & then oesophagus by **deglutition.**
- Bolus passes through oesophagus by successive wave of muscular contraction – **peristalsis.**
- Saliva secreted into oral cavity has **Na^+, K^+, cl^-, HCO_3^-, salivary amylase** (carbohydrate splitting enzyme in oral cavity) **& lysozyme** (antibacterial agent).
- Salivary amylase hydrolyse **30% starch at pH 6.8** into maltose.
- **Stomach:** Stores food for 4 - 5 hrs, 3 type of gastric cells.
  → **Mucus neck cell:** Secrete mucus,
  → **Peptic/chief cell:** Secrete pepsinogen,
  → **Parietal/oxyntic cell:** Secrete Hcl & castle's intrinsic factor **(absorption of B_{12}).**
- Food mixes with gastric juice by churning movement – **chyme.**
- Pepsinogen converts to pepsin on exposure to Hcl which converts proteins into protease & peptones (peptides).HCl provide optimum pH **(1.8)** for pepsin.
- Mucus & bicarbonate help in lubrication & protection of mucosal epithelium from Hcl.
- **Rennin -** Proteolytic enzyme in gastric juice of infants which help in milk protein digestion.
- **Gastric Lipase** is also secreted by gastric glands.

Intestine & pancreas –

- Bile pancreatic juice & intestinal juice are released in small intestine.
- **Pancreatic juice:** Trypsinogen, chymotrypsinogen, procarboxy peptidase, amylase, lipase & nuclease.

Proteins, proteoses and peptones (partially hydrolysed proteins) in the chyme reaching the intestine are acted upon by the proteolytic enzymes of pancreatic juice as given below:

Proteins, Peptones, Proteoses $\xrightarrow[\text{Carboxypeptidase}]{\text{Trypsin/Chymotrypsin}}$ Dipeptides

Carbohydrates in the chyme are hydrolysed by pancreatic amylase into disaccharides.

Polysaccharides (starch) $\xrightarrow{\text{Amylase}}$ Disaccharides

Fats are broken down by lipases with the help of bile into di-and monoglycerides.

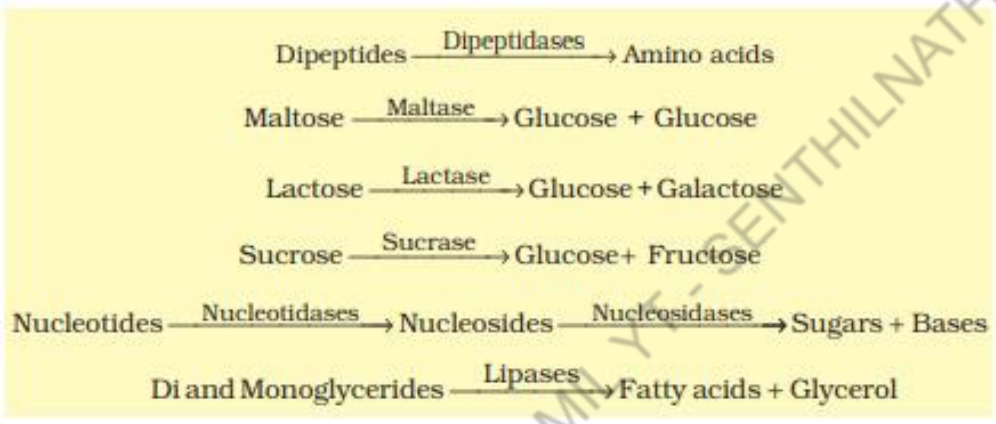
Fats $\xrightarrow{\text{Lipases}}$ Diglycerides $\longrightarrow$ Monoglycerides

Nucleases in the pancreatic juice acts on nucleic acids to form nucleotides and nucleosides

Nucleic acids $\xrightarrow{\text{Nucleases}}$ Nucleotides $\longrightarrow$ Nucleosides

Digestion and Absorption

- Trypsinogen is activated by **enterokinase** (by intestinal mucosa) to trypsin which activates other enzyme.
- **Bile –** bile pigments (bilirubin & biliverdin), bile salts, cholestrol, phospholipid, **no enzymes.** It helps in breakdown of fats to small micelle **(emulsification)** &activates lipase.
- Secretion of brush border cell of mucosa & secretion of goblet cells (intestine) – **succus entericus** (intestinal juice). It contains enzyme like dipeptidase, lipase, nucleosidase, maltase etc.
- Mucus & bicarbonate protect intestinal mucosa from acid & provide alkaline pH. **(pH 7.8)**
- Enzyme in succus entericus act on the end products of above reaction.



- Simpler substance are absorbed in jejunum & ileum &undigested & unabsorbed substances are passed to large intestine.
- **Large intestine:** Absorption of water, mineral, some drugs & secrete mucus which adheres waste particles together.
- **Undigested & unabsorbed substances - faeces** which enter caecum of large intestine through ileo caecal valve **(prevent back flow)** & temporarily stored in rectum till defecation.
- Activities of gastro - intestinal tract are under neural & hormonal control.
- Oral cavity is sensitive for sight, smell & presence of food.

Calorific value –

- **1 kcal:** Amount of energy required to raise temperature of 1 kg of water by 1°C.
- **Gross calorific value:** Amount of heat liberated from complete combustion of 1g food in bomb caloritmeter.
  Carbohydrate: 4.1 kcal/g, proteins - **5.65 kcal/g,** fats - **9.45 kcal/g.**
- **Physiologic value:** Actual amount of energy from combustion of 1 g of food.
  Carbohydrate: 4 kcal/g, proteins – **4 kcal/g,** fats - **9 kcal/g.**

Absorption of Digested Products -

1) Absorption: End products of digestion pass through intestinal mucosa into blood or lymph, maximum in small intestine.

- It can be by simple diffusion, facilitated diffusion or active transport.
- **Simple diffusion -** Glucose, amino acid & electrolyte like chloride ions.

Digestion and Absorption

- **Facilitated diffusion -** Glucose & amino acid by carrier protein.
- **Active transport -** Amino acids, glucose, electrolyte like Na^+.
- **Fatty acid & glycerol** are insoluble, can't be absorbed by blood.
  They are incorporated into small droplets – **micelle** which move to intestinal mucosa. They are re-formed into small protein coated fat globule - **chylomicron** which are transported to lacteal, which release absorbed substances into blood.

a) Mouth: Certain drugs are absorbed.
b) Stomach: Water, simple sugar & alcohol are absorbed.
c) Small intestine: Digestion is completed & final products like glucose, fructose, fatty acids, glycerol & amino acid are absorbed.
d) Large intestine: Water, some minerals & drugs are absorbed.

2) Assimilation: Absorbed substances reach tissue which utilise them for activities.

- **Defecation:** Egestion of faeces to outside through anal opening, voluntary process, by peristaltic movement.

Disorders of digestive system:

- Most common – inflammation of intestinal tract.

1) Jaundice: Liver affected, skin & eyes turn yellow due to bile pigment.
2) Vomiting: Ejection of stomach contents through mouth, controlled by medulla, nausea feeling precedes.
3) Diarrhoea: Abnormal frequency of bowel movement, increased liquidity of faeces, reduced food absorption.
4) Constipation: Faeces are retained within colon due to irregular bowel movement.
5) Indigestion: Food isn't properly digested, feeling of fullness, can be due to inadequate enzyme secretion, anxiety, food poisoning, over eating & spicy food.
6) PEM: (Protein Energy Malnutrition)

- Common in South, South East Asia, South America, West & Central Africa.
- Can cause Marasmus & Kwashiorkor.

a) Marasmus: Protein & calorie deficiency.

- In **infants (less than 1 year age).**
- Impairs growth & tissue replacement.
- Emaciation of body, thin limbs, dry, thin, wrinkled skin.
- Declined growth rate & body weight.
- Impaired growth & development of brain.
- Can be due to early replacement of mother's milk or mother having second pregnancy when older one is too young.

b) Kwashiorkor: Protein deficiency.

- In **child (more than I year in age).**
- Wasting of muscles, thin limbs.
- Failure of growth & brain development.
- Some fat is left under skin, extensive **oedema** (swelling).
- Can be due to replacement of mother's milk by high calorie, low protein diet.

Breathing and Exchange of Gases

Respiration: Exchange of O_2 from atmosphere with CO_2 produced by cells.

Respiratory organs –

- **Simple diffusion:** In lower invertebrates like sponges, flatworm, coelentrate etc.
- **Gills:** Aquatic arthropods & molluscs **(branchial respiration).**
- **Moist cuticle:** Earthworms.
- **Tracheal tubes:** Insects.
- **Lungs:** Terrestrial forms **(pulmonary respiration)**. **Eg:** In Mammals.
- Amphibians (**Eg:** Frog) can respire by skin **(cutaneous)** also and tadpole of frog respire by gills.

Human Respiratory System -

- External nostrils lead to nasal chamber opening to pharynx.
- Pharynx open into **trachea through larynx** (cartilaginous box helping in sound production – **sound box**).
- Glottis is covered by thin elastic cartilaginous flap - **epiglottis** to prevent entry of food in larynx.
- Trachea divides at **5th thoracic vertebra** into primary bronchi ending in thin bronchioles, which give rise to thin **irregular wall,** vascularised, bag like – **alveoli.**
- Trachea, primary, secondary & tertiary bronchi & initial bronchiole are supported by **incomplete cartilaginous rings.**
- **Lungs:** Network of bronchi, bronchiole, alveoli.
- Lungs are covered by double layer **pleura** with pleural fluid which reduces friction on its surface. Outer one is in contact with thoracic lining while inner one is with lung surface.
- **Conducting part:** External nostrils to bronchiole. It transports air to alveoli, clears from foreign particle, bring air to body temperature.
- **Respiratory part:** Alveoli & their ducts, actual diffusion of O_2 & CO_2.
- **Thoracic chamber:** Air tight, **dorsally by vertebral column, ventrally by sternum, laterally by ribs & diaphragm on lower side.**

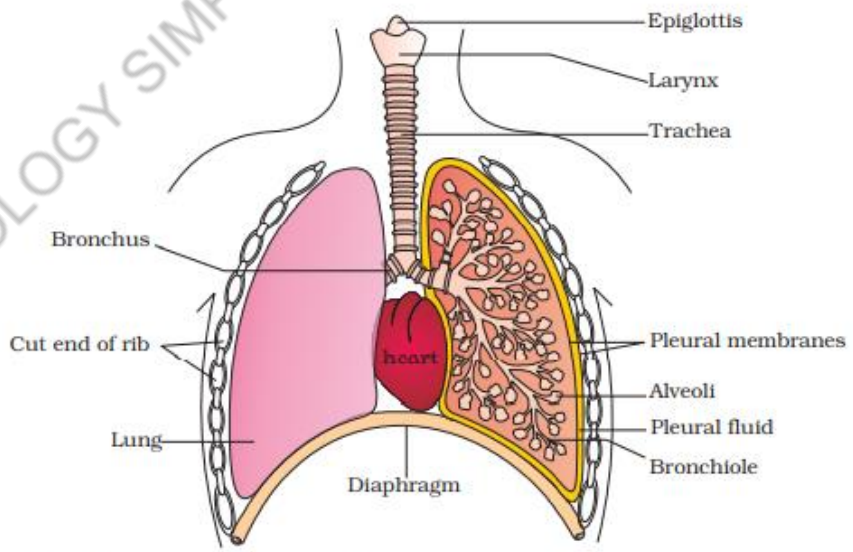


Figure 17.1 Diagrammatic view of human respiratory system (sectional view of the left lung is also shown)

Breathing and Exchange of Gases

Respiration involve –

- Breathing in O_2 & releasing CO_2, diffusion across alveolar membrane, gas transport by blood, diffusion of gases in tissues & utilisation of O_2 by cells & release of CO_2.

Mechanism of Breathing:

- **It involves two stages: Inspiration + Expiration.**
- By creating pressure gradient.

1) Inspiration: Pressure within lung **(intra pulmonary)** is less than atmospheric pressure - **negative pressure.**

- Contraction of diaphragm (volume of thoracic chamber increase).
- Contraction of **external inter costal muscle** increase volume in dorso - ventral axis.
- Increased pulmonary volume decreases pressure which forces air from outside to move into lungs. **i.e.** Inspiration.

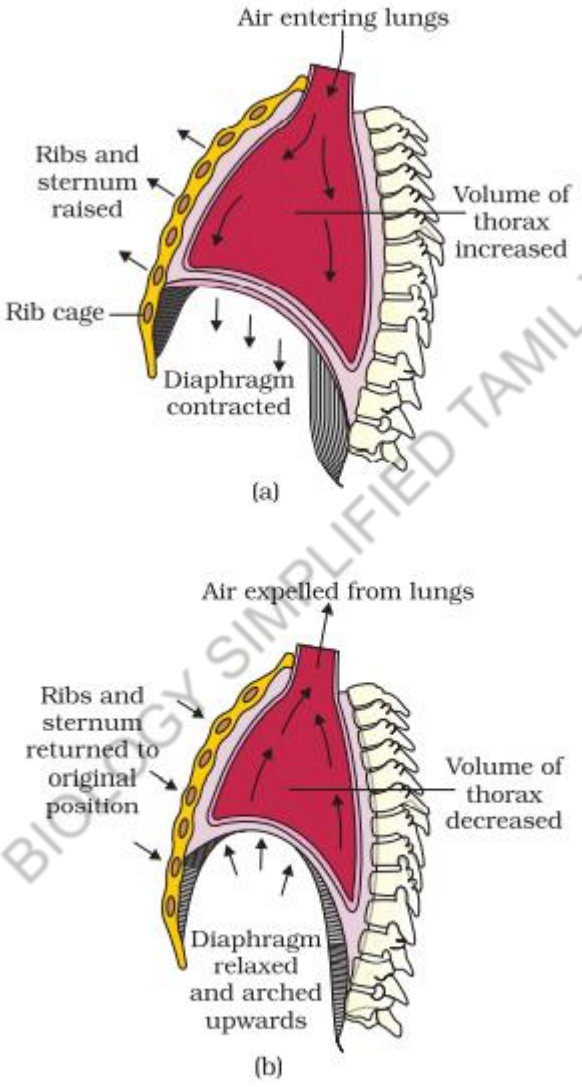


Figure 17.2 Mechanism of breathing showing : (a) inspiration (b) expiration

2) Expiration: Intra pulmonary pressure is higher than atmospheric pressure.

- Relaxation of diaphragm & **internal** inter costal muscles.
- Diaphragm & sternum return to normal position.
- Decrease in thoracic volume increases pressure causing expulsion of air from lungs.
  i.e. Expiration.

*** Healthy human breathes 12-16 times/minute**

* Volume of air involved in breathing is measured by **spirometer.**

Respiratory Volume & Capacities –

1) Tidal Volume (T.V.): Volume of air inspired/expired during normal respiration.
i.e. 500 ml.
Minute reserve volume = 500 x 12 = 6000 to 8000 ml/min.

2) Inspiratory Reserve Volume (IRV): Volume of air inspired in forceful inspiration.
i.e. 2500 - 3000 ml.

3) Expiratory Reserve Volume (ERV): Volume of air expired in forceful expiration.
i.e. 1000 - 1100 ml.

4) Residual Volume (RV): Volume of air in lungs after forceful expiration.
i.e. 1100 - 1200 ml.

5) Inspiratory capacity: Volume of air inspired after normal expiration.
i.e. TV + IRV.

6) Expiratory capacity: Volume of air person can expire after normal inspiration.
i.e. TV + ERV.

7) Functional Residual capacity: Volume of air in lungs after normal expiration.
i.e. ERV + RV.

8) Vital capacity: Volume of air person can breathe in after forceful expiration or volume of air person can breath out after forceful inspiration.
i.e. ERV + IRV + TV.

9) Total lung capacity: Total volume of air in lungs at end of forced inspiration.
i.e. RV + ERV + TV + IRV or VC+ RV.

Exchange of gases: Primary site – alveoli.

- On the basis of concentration gradient by simple diffusion.
- Depends on solubility of gas & thickness of membrane.
- **Partial pressure:** Pressure contributed by individual gas in mixture of gases, represented by pO_2 or pCO_2.

Table 17.1 Partial Pressures (in mm Hg) of Oxygen and Carbon dioxide at Different Parts Involved in Diffusion in Comparison to those in Atmosphere

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

- **Solubility of CO_2 is 20 – 25 times higher than that of O_2.**

Breathing and Exchange of Gases

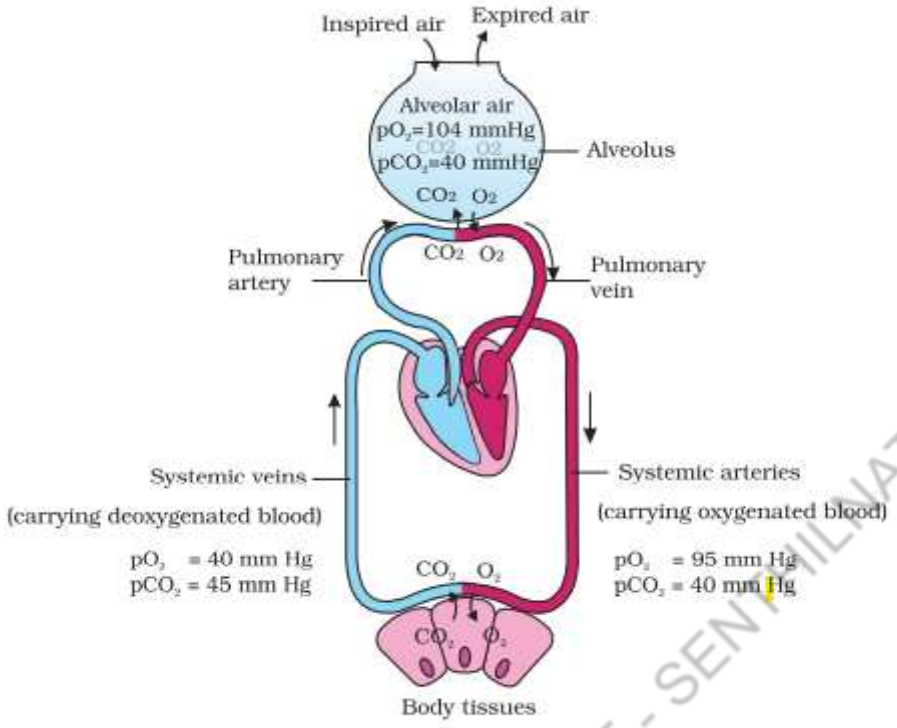


Figure 17.3 Diagrammatic representation of exchange of gases at the alveolus and the body tissues with blood and transport of oxygen and carbon dioxide

- **Diffusion membrane:** Thin squamous epithelium of all alveoli, endothelium of alveolar capillaries, basement substance between them. It is less than 1 millimetre.

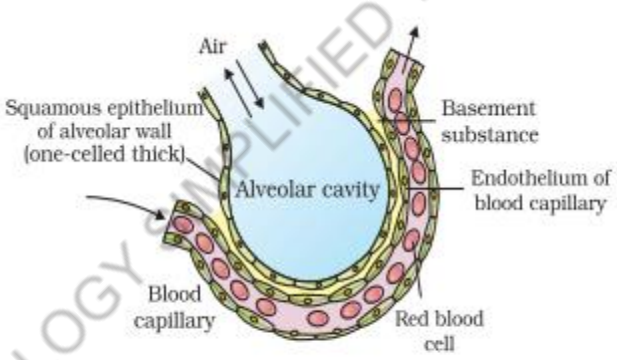


Figure 17.4 A Diagram of a section of an alveolus with a pulmonary capillary.

- Oxygen exchange occur from alveoli to blood & blood to tissues.
- Carbon dioxide exchange occur from blood to alveoli & tissues to blood.

Transport of Gases – Medium - blood.

1) Transport of Oxygen –

- Oxygen bind with haemoglobin (red colour, **iron containing pigment**) to form **oxyhaemoglobin.**
- Each haemoglobin carry $4O_2$ molecules.
- **97% O_2 by RBC & 3% in dissolved state through plasma.**

- **Sigmoid curve:** When percentage saturation of haemoglobin with O_2 is plotted against pO_2 - **Oxygen dissociation curve.**
- **Alveoli:** High pO_2, low pCO_2, low H^+ concentration, low temperature, formation of oxyhaemoglobin.
- **Tissues:** Low pO_2, high pCO_2, high H^+ concentration, high temperature, dissociation of oxygen from oxyhaemoglobin.
- Every **100 ml** of oxygenated blood deliver **5 ml** of O_2 to tissues.

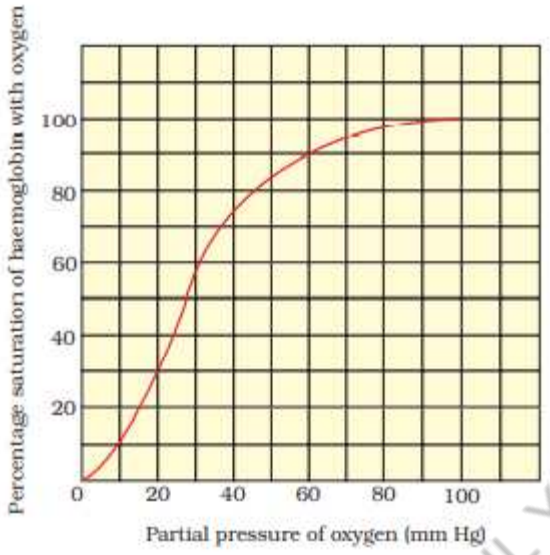


Figure 17.5 Oxygen dissociation curve

2) Transport of Carbon dioxide –

- **20 – 25% as carbamino haemoglobin, 70% as bicarbonate, 7% as dissolved state through plasma.**
- CO_2 is carried by haemoglobin as **Carbamino haemoglobin.**
- **Alveoli –** pCO_2 is less, pO_2 is high, dissociation of CO_2 from haemoglobin.
- **Tissue –** pCO_2 is high, pO_2 is low, binding of O_2 with haemoglobin.
- RBC has high concentration of carbonic anhydrase.

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

- Every **100 ml** of deoxygenated blood deliver **4 ml** of CO_2 to alveoli.

Regulation of Respiration –

- **Respiratory rhythm centre** in medulla is responsible for maintaining moderate rhythm.
- **Pneumotaxic centre** in pons region also regulates rhythm. It can reduce duration of inspiration.
- **Chemosensitive area** adjacent to rhythm centre is sensitive to CO_2 & H^+. Increase in these activate it & send signal to rhythm centre.
- Receptors associated with **aortic arch & carotid artery** recognise changes in CO_2 & H^+ & send signals.
- Role of O_2 here is insignificant.

Breathing and Exchange of Gases

Disorders –

1) **Asthma:** Difficulty in breathing causing wheezing due to inflammation of bronchi & bronchioles.
2) **Emphysema:** Chronic disorder, alveolar walls are damaged, decrease respiratory surface, major cause is cigarette smoking.
3) **Occupational Respiratory Disorder:** Common in grinding & stone breaking industry, defence mechanism fails to cope due to much dust, leads to fibrosis **(proliferation of fibrous tissues)** causing lung damage, so they must wear protective masks.

Body Fluids And Circulation

Blood:

- Connective tissue containing fluid matrix, plasma, formed elements.

Plasma: Straw colour viscous fluid, **55% blood.**

- 90 - 92% plasma - water & protein - 6 - 8%.
- Major proteins - fibrinogen **(Blood coagulation)**, globulins **(Defence),** albumin **(Osmotic balance).**
- Contains minerals like Na^{+}, Ca^{+2}, Mg^{+2}, HCO_3^{-}, Cl^{-}, glucose, amino acids, lipids etc.
- Plasma without clotting factors – **serum.**

Formed elements:

- Erythrocyte + leucocyte + platelet, **45% of blood.**

1) Erythrocyte: Red blood cells (RBC), most abundant, formed in red bone marrow, **devoid of nucleus, biconcave,** have average life span of 120 days after which destroyed in spleen **(Graveyard of RBC)**, has red coloured iron containing protein – haemoglobin. **100 ml blood has 12 - 16 g haemoglobin,** healthy adult has 5 million – 5.5 million RBC mm^{-3} of blood.

2) Leucoytes: White blood cells (WBC), colourless, lack haemoglobin, nucleated, short lived, **6000 - 8000 mm^{-3} of blood.**

a) Granulocytes: Neutrophils, Eosinophils, Basophils.

- **Neutrophils:** Most abundant **(60 -65%),** phagocytic cells.
- **Eosinophils: (2 - 3%)**, resist infection, associated with allergic reaction.
- **Basophils:** Least **(0.5 – 1%)**, secrete histamine, serotonin, heparin, involved in inflammatory reaction.

b) Agranulocytes: Monocyte, Lymphocyte.

- **Monocyte: (6 - 8%)**, phagocytic (destroy foreign bodies).
- **Lymphocyte: (20 - 25%)**, immune response (2 types - T & B).

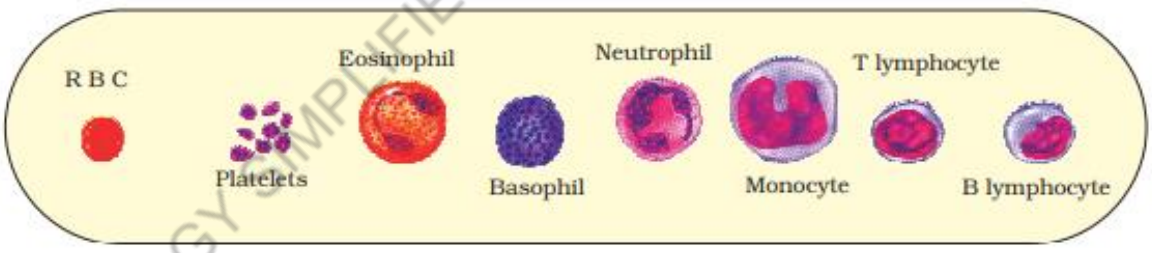


Figure 18.1 Diagrammatic representation of formed elements in blood

3) Thrombocytes: Platelets formed from megakaryocytes, coagulation of blood, **1,50,000 - 3,50,000 mm^{-3}.**

Blood Groups –

1) ABO grouping:

- Based on presence or absence of 2 surface antigens (Chemical inducing immune response) on RBC.
- Blood should be donated carefully to avoid **clumping** (RBC destruction).
- **Universal Donor - 'O'; Universal Recipient - 'AB'.**

Body Fluids And Circulation

TABLE 18.1 Blood Groups and Donor Compatibility

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

2) Rh grouping: Similar to one in Rhesus monkeys **(80% human).**

- Some are Rh positive & in whom this antigen is absent - Rh negative.
- If Rh -ve person is exposed to Rh +ve the blood it forms antibodies.
  Special case of Rh compatibility – Erythroblastosis foetalis.
- Rh -ve of pregnant mother & Rh +ve of foetus aren't exposed in first pregnancy as the two blood are separated by placenta.
- During delivery, some blood exposure occur so mother starts preparing antibodies against Rh antigen, first child is normal.
- In subsequent pregnancy, Rh antibodies may leak into foetus & destroy foetal RBC. It can cause **anaemia & jaundice.**
- Avoided by administering anti Rh antibodies in mother after delivery of first child.

Coagulation of blood: Ca^{+2} – important role.

Clot: Dark reddish brown scum formed by network of fibrins in which dead & damaged formed elements are trapped.

Cascade process:

$$\text{Inactive prothrombin} \xrightarrow{Thrombokinase} \text{Thrombin}$$

$$\text{Inactive fibrinogen} \xrightarrow{Thrombin} \text{Fibrins}$$

- Injury stimulates platelets to release factor thromboplastin which activate mechanism of coagulation.

Lymph: (Tissue fluid)

- Some water & water soluble substances move into spaces between tissue when blood passes through capillaries - **Interstitial fluid**.
- Some mineral distribution like plasma, exchange of nutrient between blood & cells occur through this.
- Elaborate network of vessel - **Lymphatic system** collects this fluid & drains to major veins. Fluid is called lymph.
- **Lymph -** Colourless, contain lymphocyte, carry hormones & nutrients. Fats are absorbed through lymph in lacteals.

Circulatory Pathway: Open & Closed.

- **Open:** Blood pumped through heart passes through vessels in body cavities called **sinuses. Eg: Arthropods & molluscs.**
- **Closed:** Blood pumped by heart is circulated through closed network of blood vessels. **Eg: Annelids & chordates.**

Body Fluids And Circulation

- **2 - chambered heart:** 1 atrium +1 ventricle, in fish.
  Heart pumps deoxygenated blood, oxygenated by gills & passed to body parts from where deoxygenated blood returns to heart. **(Single circulation).**
- **3 - chambered heart:** 2 atria + 1 ventricle, amphibians & reptiles (Except crocodile), **left atrium** receive **oxygenated blood** from gills/lungs & right one receive deoxygenated blood from body parts. They mix up in single ventricle which pumps mixed blood. **(Imcomplete double circulation).**
- **4 - chambered heart:** 2 atria +2 ventricle, in birds, mammals & crocodile, blood received by left & right atrium pass to left & right ventricle separately which pump unmixed blood. **(Double circulation).**

Human Circulatory System: Blood vascular system.

- Heart + close branching blood vessels + fluid circulated.
- **Heart: Mesodermally derived,** between lungs tilted to left in thoracic cavity, size of clenched fist, protected by double walled **pericardium,** 4 chambers - **2 atria & 2 ventricles.**
- **Inter - atrial septum:** Thin wall, separates left & right atria.
- **Inter - ventricular septum:** Thick wall, separates left & right ventricle.
- **Atrio - ventricular septum:** Fibrous tissue, separates atria & ventricle on same side.
- **Tricuspid valve:** Opening between right atrium & right ventricle, 3 muscular laps/cusps.
- **Bicuspid/Mitral valve:** Opening between left atrium & left ventricle.
- **Semilunar valves:** Opening of left ventricle into aorta & right ventricle into pulmonary artery. It allows flow in 1 direction, prevent backward flow.

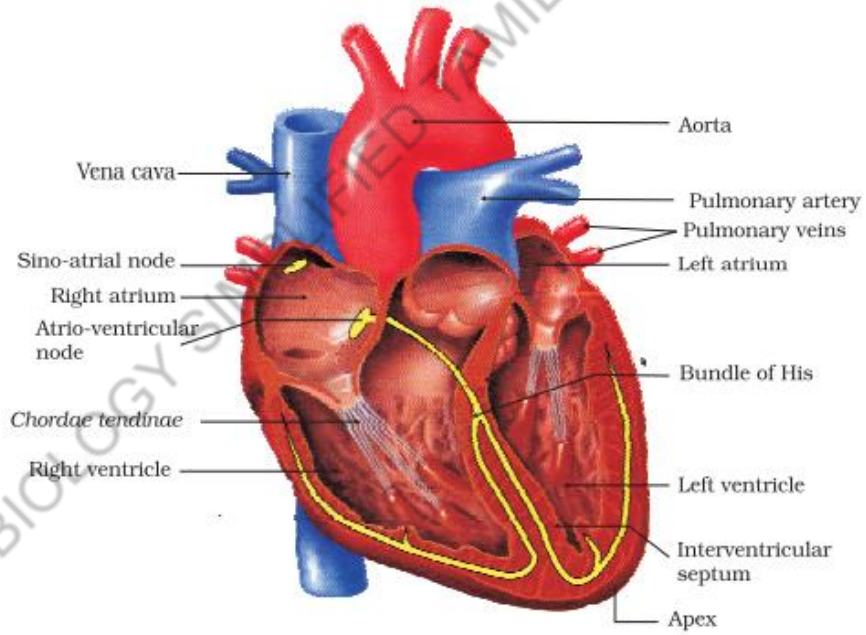


Figure 18.2 Section of a human heart

Nodal tissues: Specialised cardiac musculature in heart.

- Ventricle walls are thicker than atria.
- **Sino - atrial node (SAN):** Right corner of right atrium.
- **Atrio - ventricular node (AVN):** Lower left corner of right atrium close to atrio - ventricular septum.

- Atrio ventricular bundle passes through atrio ventricular septa to emerge on top of inter ventricular septum dividing into left & right bundle of 'His' giving rise to minute fibres - **purkinje fibres.**
- They have ability to generate action potential without external stimuli – **autoexciatable.**
- SAN generate **70 - 75 action potential in a minute.** Its called **pacemaker (Initiate & maintain rhythmic activity).**
- Our heart beats 70 - 75 times in a minute.

Cardiac Cycle: Sequential event cyclically repeated in heart.

- **Joint diastole:** 4 chambers are in relaxed state.
- **Atrial systole:** Tricuspid & bicuspid valve opens, blood from pulmonary vein & vena vaca flows into left & right ventricle. Semilunar valves are closed & SAN generates action potential which stimulates atria contraction. It increases blood flow by **30%.**
- **Ventricle systole:** Action potential is conducted by AVN & AV bundle from bundle of His which causes contraction of ventricular muscles, atria relaxes - **atrial diastole.** It increases ventricular pressure causing closure of tricuspid & bicuspid valves.
- Semilunar valves are forced open, blood flows in pulmonary artery (Right side) & aorta (Left side). Ventricles relax - **Ventricular diastole.** It leads to closure of semilunar valves.
- As ventricular pressure declines, tricuspid & bicuspid are forced open, now blood moves freely into ventricles .
- Now both atria & ventricle are in relaxed state - joint diastole. Soon SAN generate action potential & process continues.
- Heart beats 72 times means 72 cardiac cycles per minute.
- Cardiac cycle lasts for **0.8 seconds.** Each ventricle pumps **70 ml blood** in 1 cardiac cycle - **Stroke volume.**
- **Stroke volume x heart rate = Cardiac output.** Its the volume of blood pumped by each ventricle per minute. **i.e. 5 litres** (70 ml x 72 heart beat/minute).
- Cardiac output of athelete is higher than ordinary man.
- 2 sounds are produced (Heard by stethoscope) –
- **Lub:** First, closure of tricuspid & bicuspid valves.
- **Dub:** Second, closure of semilunar valves.

Electrocardiograph (ECG):

- To obtain electrocardiogram.

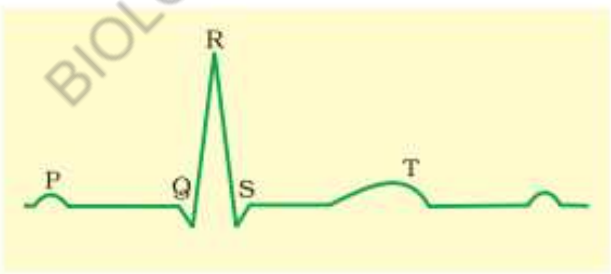


Figure 18.3 Diagrammatic presentation of a standard ECG

- Its graphical representation of electrical activity of heart during cardiac cycle.
- Patient is connected with 3 electrical leads (One to each wrist &e one to left ankle). For detailed evaluation, multiple leads are attached.

- **P – wave:** Exciatation/depolarisation of atria (Contract) – **Auricular contraction.**
- **QRS complex:** Depolarisation of ventricles (contract) - **ventricular contraction.**
- **T wave:** Repolarisation of ventricles (Excited to normal state) - systole end.
- By counting QRS in given time, heart beat rate can be determined.
- Any deviation from normal shape represent abnormality.

Double circulation:

- Blood flows through fixed route through arteries & veins.
- They consist of 3 layers: **Inner squamous epithelium (Tunica intima), smooth muscle & elastic fibres (Tunica media) & connective tissue with collagen fibres (Tunica externa).**
- Tunica media is thin in veins.
- **Pulmonary circulation** Deoxygenated blood in pulmonary artery is passed on to lungs from where oxygenated blood is carried by pulmonary vein into left atrium.
- **Systemic circulation:** Oxygenated blood in aorta is carried by arteries, arterioles & capillaries to tissue from where deoxygenated blood is collected by venules, veins & vena cava and emptied in right atrium. It provides O_2, nutrients to tissue & remove CO_2 & harmful substances from it.
- **Hepatic portal system:** Vascular connection between digestive tract & liver. It carries blood from intestine to liver.
- Special coronary system is present exclusively for circulation of blood to & from cardiac musculature through coronary artery and coronary vein.

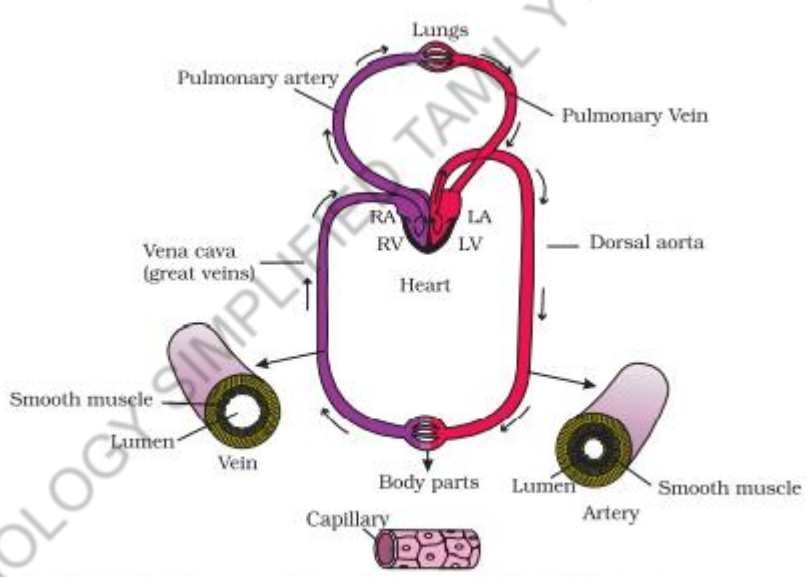


Figure 18.4 Schematic plan of blood circulation in human

Regulation of Cardiac Activity:

- Auto regulated by nodal tissues - **intrinsically regulated,** hence heart is **myogenic.**
- Neural centre in medulla moderate cardiac function through ANS.
- **Sympathetic nerves (SNS):** Increate heart beat, ventricular contraction & cardiac output.
- **Parasympathetic nerves (PSNS):** Decrease heart rate, speed of conduction of action potential & cardiac output.
- Adrenal medullary hormones increase cardiac output.

Body Fluids And Circulation

Disorders:

1) High Blood Pressure (Hypertension) - 140/90.

- Blood pressure more than normal (120/80).
- **Systolic:** 120 mm Hg, pumping pressure.
- **Diastolic:** 80 mm Hg, resting pressure.
- High BP leads to heart diseases & affect organs like brain & kidney.

2) Coronary Artery Disease: Also **Atherosclerosis.**

- Affects vessel supplying blood to heart, narrow lumen of arteries.
- Caused by deposits of calcium, fat, cholestrol & fibrous tissues.

3) Angina: Also Angina Pectoris.

- Symptom of acute chest pain when no enough oxygen reach heart muscle.
- Common in middle age & elderly people, affect blood flow.

4) Heart failure: Heart doesn't pump enough blood to meet body demand, also called **congestive heart failure** as congestion of lungs occur.

- It isn't same as cardiac arrest **(Heart stops beating)** or **heart attack** (heart muscle damaged by inadequate blood supply).

Excretory Products And Their Elimination

Excreted product:

- Ammonia, urea, uric acid, carbon dioxide, water, ions like Na^+, K^+, cl^-, phosphate, sulphate etc.

1) Ammonotelism: Process of excreting ammonia, **most toxic form,** requires large amount of water, excreted by diffusion, soluble.

Ammonotelic animals: Bony fish, aquatic amphibian, aquatic insects.

Kidney don't play significant role in its removal.

2) Ureotelic: Excrete urea, **Eg: Terrestrial amphibian, marine fish.**

Ammonia is converted to urea in liver & released into blood which is filtered & excreted by kidneys.

3) Uricotelic: Excrete uric acid in form of pellet or paste, **least toxic,** minimum loss of water. **Eg: Some reptiles, birds, insects, land snail.**

Other excretory structures – Osmoregulation + Removal.

- **Protonephridia/flame cells:** Platyhelminthes (**Eg:** Planaria), Rotifers, Annelids (some), Amphioxus.
- **Nephridia:** Earthworm & other annelids.
- **Malpighiam tubule:** Insects.
- **Antennal glands/green glands:** Crustaceans like prawn.

Human Excretory System:

- Consist of 1 pair kidney, 1 pair of ureters, urinary bladder, urethra.

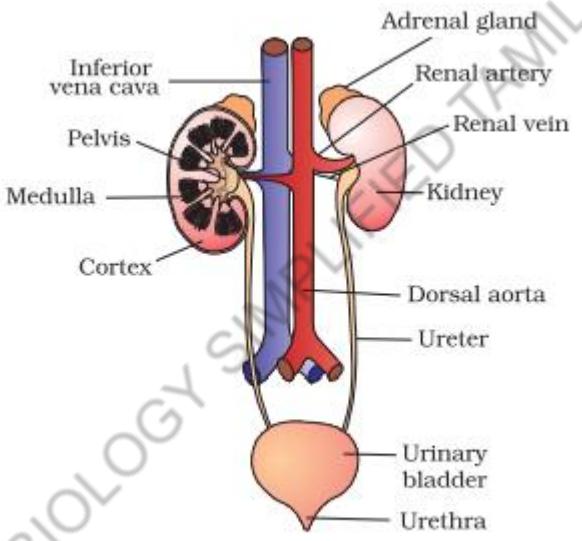


Figure 19.1 Human Urinary system

- **Kidney:** Reddish brown, bean shaped between **last thoracic & third lumbar**, close to dorsal wall of abdominal cavity, 10 – 12 cm length, 5 – 7 cm width, 2 – 3 cm thick, average weight **120 – 170 g.**
- Towards centre of inner concave surface is a notch – **hilum** through which ureter, blood vessels & nerves enter or leave.
- Inner to hilum is broad funnel shaped **renal pelvis** with projections called **calyces**.
- Outer layer of kidney is tough & inside has 2 zones – outer cortex & inner medulla.
- Medulla is divided into conical masses – **medullary pyramids** projecting into cortex.
- Cortex extends between medullary pyramids: **Column of Bertini.**

Excretory Products And Their Elimination

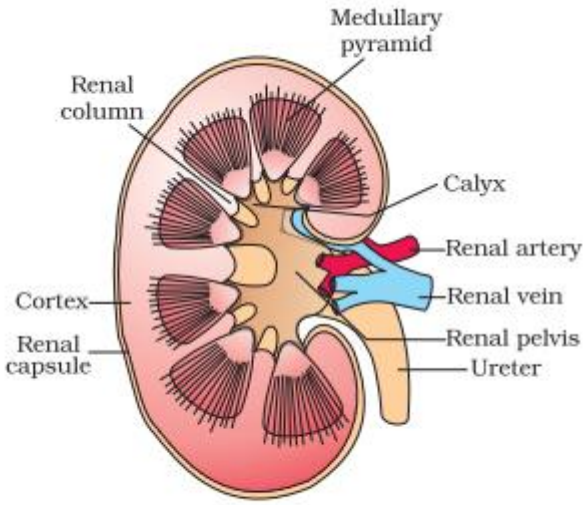


Figure 19.2 Longitudinal section (Diagrammatic) of Kidney

- Kidney has 1 million complex tubular structures - **nephrons (structural and functional unit)**, which has 2 parts - **glomerulus & renal tubule.**
- **Glomerulus -** tuft of capillaries formed by afferent arteriole.
- Renal tubule begin with double walled cup like **Bowman's capsule** enclosing glomerulus.
- **Glomerulus + Bowman's capsule – malpighian body/renal corpuscle.**
- Tubule coils to form **PCT** (proximal convoluted tubule), then hairpin shaped **Henle's loop,** its ascending loop continues to coiled region **DCT** (distal convoluted tubule) which opens to **collecting duct** which open into renal pelvis in calyces.

The different parts of nephron present in kidney are –

- **Cortex:** Malpighian corpuscle, PCT, DCT.
- **Medulla:** Loop of Henle, mostly too short & extends little into medulla: **Cortical nephrons,** but if long & runs deep into medulla: **Juxta medullary nephrons.**

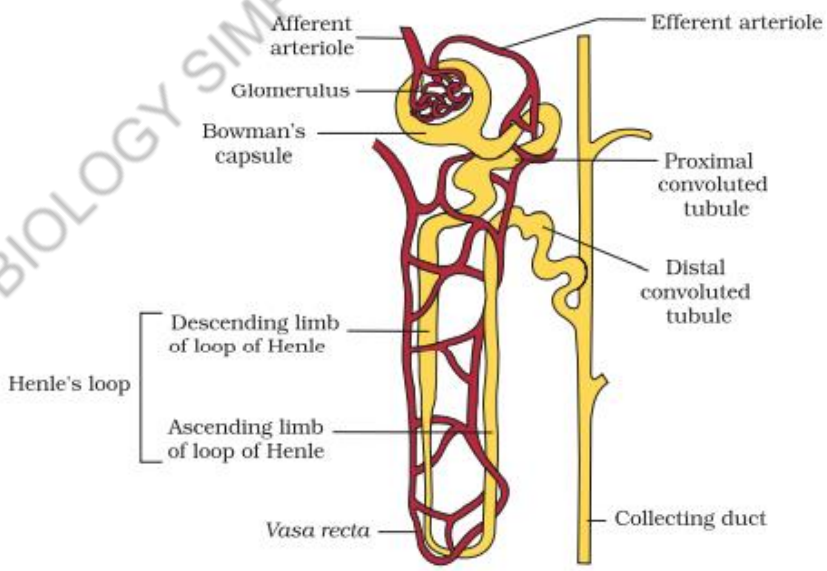


Figure 19.3 A diagrammatic representation of a nephron showing blood vessels, duct and tubule

Excretory Products And Their Elimination

- Efferent arteriole from glomerulus form fine capillary network called **peritubular capillaries.** Its minute vessel run parallel to Henle's loop forming U - shape **vasa recta** (absent or highly reduced in cortical nephrons).

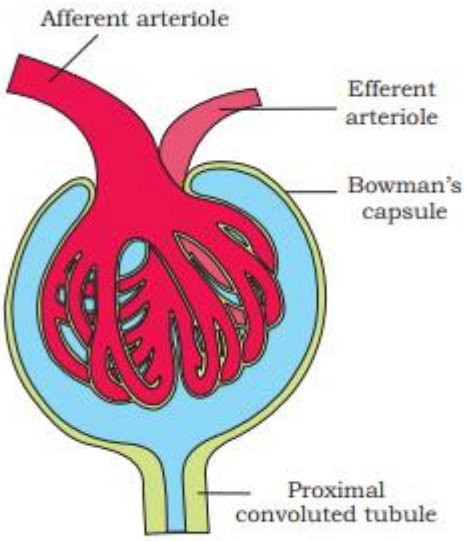


Figure 19.4 Malpighian body (renal corpuscle)

Urine Formation: Glomerular filtration+ Reabsorption + Secretion.

1) Glomerular Filtration: Filtration of blood.

- **1100 – 1200 ml blood is filtered by kidney per minute** which is 1/5th blood pumped by each ventricle in a minute.
- 3 layers involved - endothelium of blood vessels, basement membrane, epithelium of Bowman's capsule.
- Bowman's capsule's cell - podocytes are arranged in intricate manner to leave minute space - filtration slits/slit pores.
- All constituents of plasma except protein pass onto lumen of Bowman's capsule.
- So, also called **ultrafilteration.**
- **Glomerular filtration rate:** Amount of filtrate formed by kidneys per minute. **i.e. 125 ml/minute or 180 litres/day.** Fall in GFR activate juxta glomerular apparatus **(JGA)** to release **renin**. JGA is formed by modification in DCT & **afferent arteriole.**

2) Tubular Reabsorption: 99% of filtrate has to be reabsorbed.

- Can be by active or passive process in renal tubules.
- **Eg:** Glucose, amino acids, Na^+ are absorbed actively whereas nitrogenous waste, water are absorbed passively.

3) Secretion: Maintains ionic & acid - base balance of body fluids.

- Tubular cells secrete H^+, K^+, ammonia into filtrate.

Function of tubules:

1) Proximal Convulated Tubule (PCT) – 70 - 80% electrolyte & H_2O reabsorbed.

- Lined by simple cuboidal brush bordered which increase surface area for reabsorption.
- Maintain pH & ionic balance by selective **secretion of H^+, ammonia** & **absorption of K^+ ion & HCO_3^-** from filtrate.

2) Henle's loop –

- **Ascending limb:** Minimum reabsorption, impermeable to water, permeable to electrolytes, so filtrate gets diluted due to passage of electrolyte to medullary fluid.
- **Descending limb:** Permeable to water, impermeable to electrolytes, concentrates filtrate.

3) Distal Convulated Tubule (DCT): Conditional reabsorption of Na^+ & H_2O.

- Maintain pH & Na^+ - K^+ balance.
- **Reabsorb HCO_3^- - & secrete H^+, K^+ & NH_3 ions.**

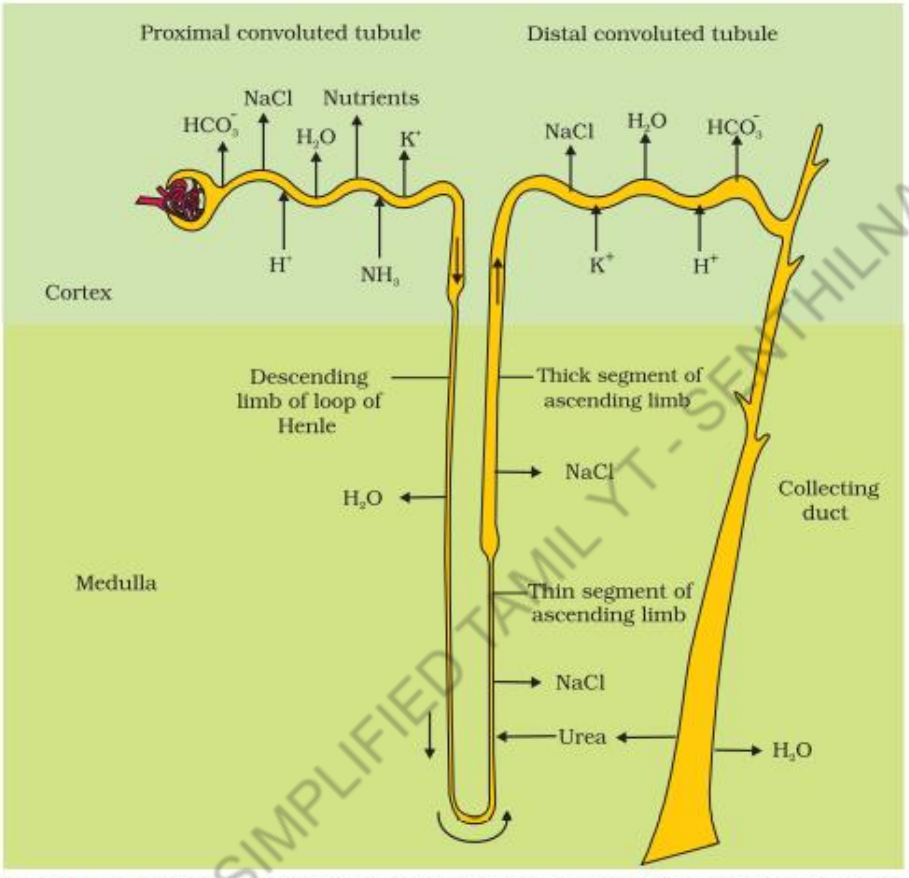


Figure 19.5 Reabsorption and secretion of major substances at different parts of the nephron (Arrows indicate direction of movement of materials.)

4) Collecting duct: From cortex to inner medulla.

- Maintain pH & ionic balance by **secreting H^+ & K^+ ions.**
- Small amount of urea passes to medulla to maintain osmolarity.
- Large amount of water is reabsorbed so, **concentrate urine.**

Mechanism of Concentration of filtrate: By Henle's loop & vasa recta.

- Flow of filtrate in 2 limbs of Henle's loop in opposite direction forms **counter current.** Similarly vasa recta forms counter current.
- Proximity between Henle's loop & vasa recta along with counter current increase osmolarity in inner medulla. **i.e.** From **300 mOsmol L^{-1} in cortex to 1200 mOsmol L^{-1} in medulla.**
- Its caused by **Nacl & urea.** Nacl transported by ascending loop of Henle's loop is exchanged by descending loop of vasa recta. So, returns to interstitium by ascending loop of vasa recta. Similary urea in ascending loop of Henle's loop return to interstitium by collecting tubule. Its **counter current mechanism.**

Excretory Products And Their Elimination

- It maintains concentration gradient in medulla, easy passage of water from collecting tubule, concentrating urine.
- **Kidneys can produce 4 times concentrated urine than initial filtrate.**

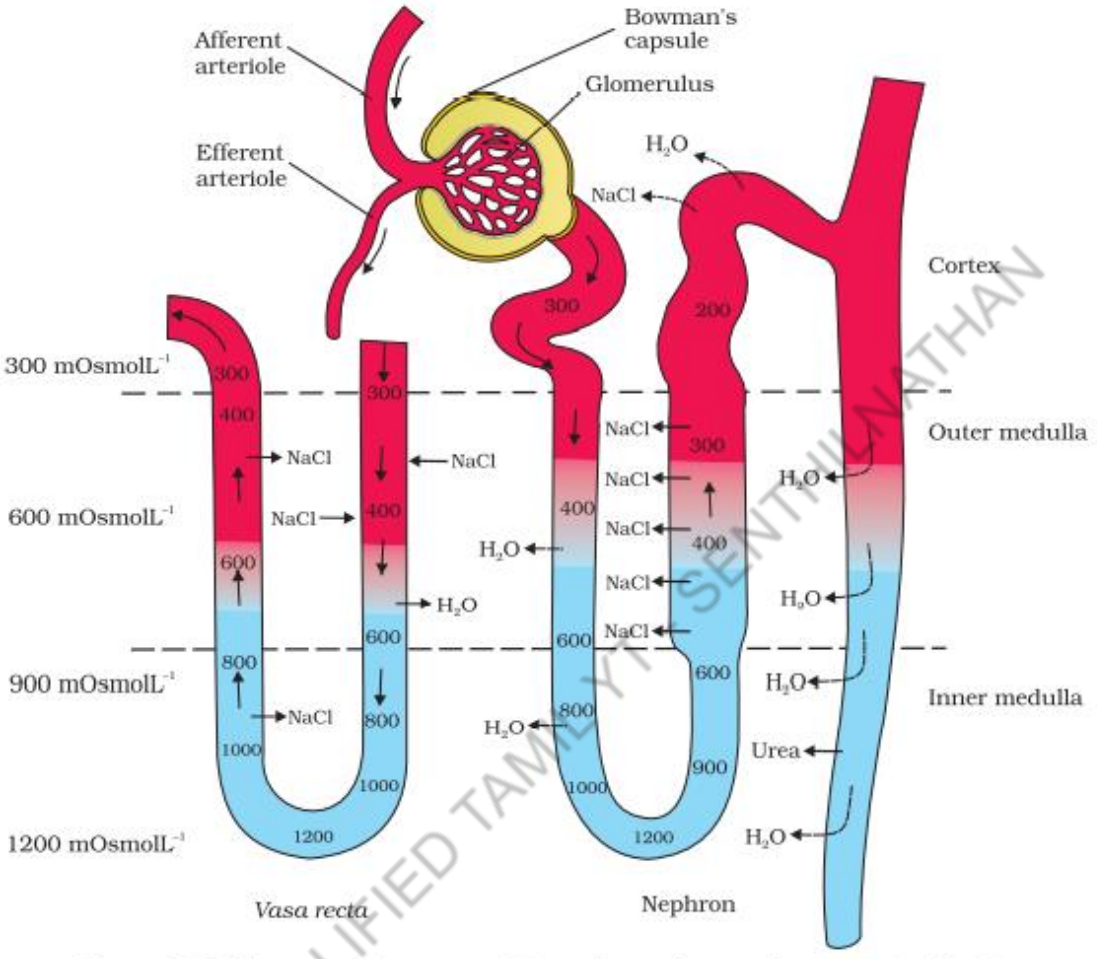


Figure 19.6 Diagrammatic representation of a nephron and *vasa recta* showing counter current mechanisms

Regulation of Kidney Function: By hormonal feedback.

1) Antidiuretic hormone (ADH): Prevent diuresis.

- Excessive loss of fluid stimulate hypothalamus to release ADH or **vasopressin** from neurohypophysis.
- Facilitate water reabsorption in DCT.
- Can affect kidney due to constrictory effect, increase blood pressure & thereby increases GFR.
- Increase in body fluid volume switch off osmoreceptor & suppress ADH release.

2) Renin - Angiotensin mechanism:

- Fall in GFR activate JG cells to release **renin** which converts angiotensinogen in blood to angiotensin I & to angiotensin II.
- Angiotensin II **(vaso constrictor)** increases GFR, activate adrenal cortex to release aldosterone which reabsorbs Na^+ & water from tubules & increases B.P. & GFR.

3) Atrial Natriuretic Factor (ANF): Vasodialator, decrease B.P.

- Increase in blood flow to atria of heart cause release of ANF.
- Checks on renin - angiotensin mechanism.

Excretory Products And Their Elimination

Micturition: Process of release of urine.

- Urine is stored in urinary bladder till voluntary signal is given by CNS.
- Signal is initiated by stretching of urinary bladder, in response, stretch receptors on wall of bladder send signals to CNS which passes on motor message to initiate **contraction of smooth muscles of bladder** & **relaxation of urethral sphincter** causing release of urine.
- Adult human excretes **1 - 1.5 litre urine/day, 25 - 30 g urea/day.**
- Urine is light - yellow coloured, acidic **(pH-6)** watery fluid & has characteristic odour.
- **Diabetes mellitus:** Presence of glucose **(Glycosuria)** & ketone bodies **(ketonuria)** in urine.

Role of other organs in excretion: **E.g:** Lungs, liver, skin.

1) Lungs: Remove large amount of CO_2 **(200 ml/minute)** & water.

2) Liver: It secretes bilirubin, biliverdin, cholestrol, steroid hormones, vitamin & drugs which pass out with digestive wastes.

3) Skin: By sweat & sebaceous glands.

- **Sweat glands:** Produce sweat (watery fluid containing **Nacl, urea, lactic acid**) facilitate cooling.
- **Sebaceous glands:** Eliminates sterols, hydrocarbon & waxes through sebum, provides protective oily covering to skin.
- **Small amount of nitrogenous waste are eliminated through saliva.**

Disorders of excretory system:

1) Uremia: Accumulation of urea in blood, highly harmful, may lead to kidney failure (urea is removed by haemodialysis).

Haemodialysis –

- Blood is drained from convenient artery & pumped to dialysing unit – **artificial kidney** after adding heparin (anticoagulant).
- Unit contain coiled cellophane tube surrounded by fluid having same composition of plasma **(except nitrogenous waste).**
- Porous membrane allows molecule passage on the basis of concentration gradient. So, nitrogenous waste move out freely clearing blood.
- Cleared blood is pumped back to body through vein after adding anti - heparin.

2) Renal failure: Kidney transplantation is an ultimate method.

- Kidney from close relative is used to minimise rejection by immune system of host.

3) Renal Calculi: Stone/insoluble mass of crystallised salts like **oxalates** in kidney.

4) Glomerulonephritis: Inflammation of glomeruli of kidney.

Locomotion And Movement

Locomotion: Voluntary movement resulting in change of place.

- Locomotory structures may not be different from those affecting other types of movements.
  Eg: Cilia helps in food movement & locomotion in Paramecium.
  Hydra use tentacles for capturing prey & locomotion.
- **All locomotion are movement but all movement aren't locomotion.**

Types of Movement:

1) Amoeboid: Effected by pseudopodia formed by protoplasm streaming.
- In macrophages, leucocytes, cytoskeletal elements like microfilaments.

2) Ciliary: In organs lined by ciliated epithelium.
- Help in removing dust in trachea & passage of ova in fallopian tube.

3) Flagellar movement: Helps in swimming of spermatozoa, maintain water current in canal system of sponges, locomotion of protozoans (Euglena).

4) Muscular: Contractile property, in limbs, jaws, tongue etc.

Muscle: **Mesodermal origin**, covers 40 - 50% of body weight.
- **Properties:** Exciatability, contractility, extensibility, elasticity.

Types of Muscles:

1) Skeletal muscle: **Voluntary,** striped appearance - **striated muscles.**
- Involved in locomotory actions & changes of body postures.

2) Visceral muscle: **Involuntary** (not under control of animal's will).
- No striation, smooth in appearance.
- In inner walls of hollow visceral organs like alimentary canal, reproductive tract etc.
- Assist in transportation of food through digestive tract & gametes through genital tract.

3) Cardiac muscle: **Involuntary** muscles of heart.
- Striated, cells assemble in branching pattern to form muscle.

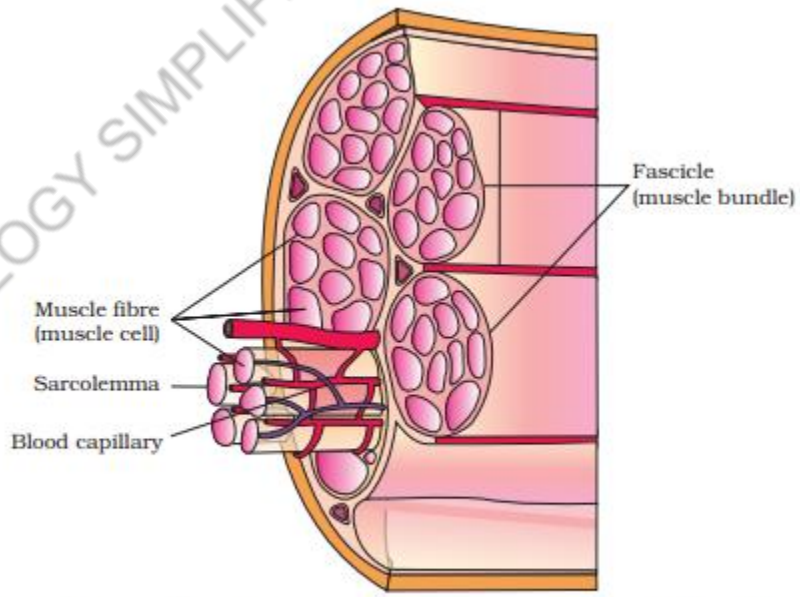


Figure 20.1 Diagrammatic cross sectional view of a muscle showing muscle bundles and muscle fibres

Locomotion And Movement

Skeletal Muscle:

- Each muscle is made of no. of muscle bundles or **fascicles** held by collagenous connective tissue layer – **fascia.**
- Each bundle contains no. of muscle fibres which are lined by plasma membrane - **sarcolemma** enclosing sarcoplasm.
- Muscle fibre is **syncitium** (many nuclei) & sarcoplasmic reticulum is store house of calcium ions.
- Sarcoplasm has no. of parallely arranged filaments - **myofibrils** which has alternate light & dark bands.
- Striated appearance is due to 2 proteins - actin & myosin which are arranged as rod like structures, parallel to each other & to longitudinal axis of myofibrils.
- **Actin:** Light bands, also called I - band **(Isotropic)**, thin filament.
- **Myosin:** Dark bands, also called A - band **(Anisotropic)**, thick filament.

Sarcomere: Functional unit of contraction.

- Thin filaments are firmly attached to 'Z' line which is an elastic fibre bisecting it.
- Thick filaments are held in middle of band by 'M' line (thin, fibrous).
- Portion of myofibril between 2 successive 'Z' line – sarcomere.
- Thin filaments on either side of thick filaments partially overlap thick filament leaving central part.
- Central part of thick filaments not overlapped by thin - 'H' zone.

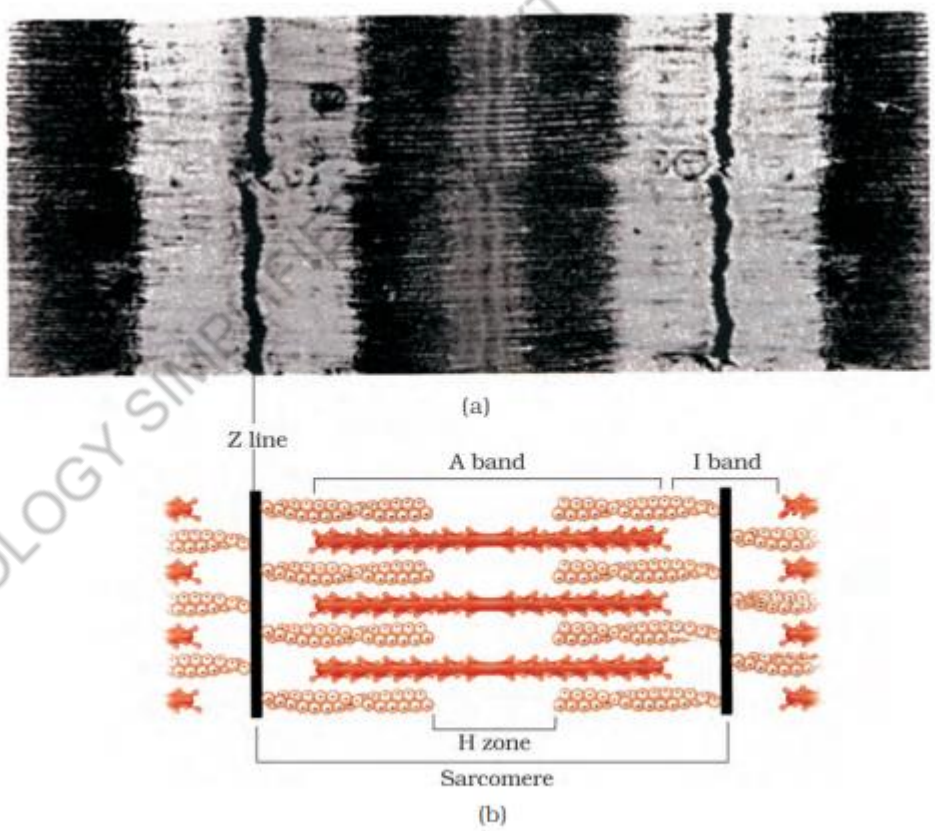


Figure 20.2 Diagrammatic representation of (a) anatomy of a muscle fibre showing a sarcomere (b) a sarcomere

Locomotion And Movement

Structure of Contractile protein –

1) Actin: Made of 2 helically wound **'F' (filamentous) actins.**

- Each 'F' actin is polymer of globular actin (G-actin).
- 2 filaments of **tropomyosin** run close to 'F' actin.
- **Troponin** (masks active binding sites for myosin) is distributed at regular intervals on tropomyosin.

2) Myosin: Made of monomeric protein - **meromyosin**

- Each meromyosin has globular head with short arm - **heavy meromyosin (HMM)** & a tail - **light meromyosin (LMM).**
- HMM projects outward at regular distance & angle from surface of myosin filament - **cross arm.**
- Head is an **active ATPase** enzyme & has binding sites for **ATP** & active site for **actin.**

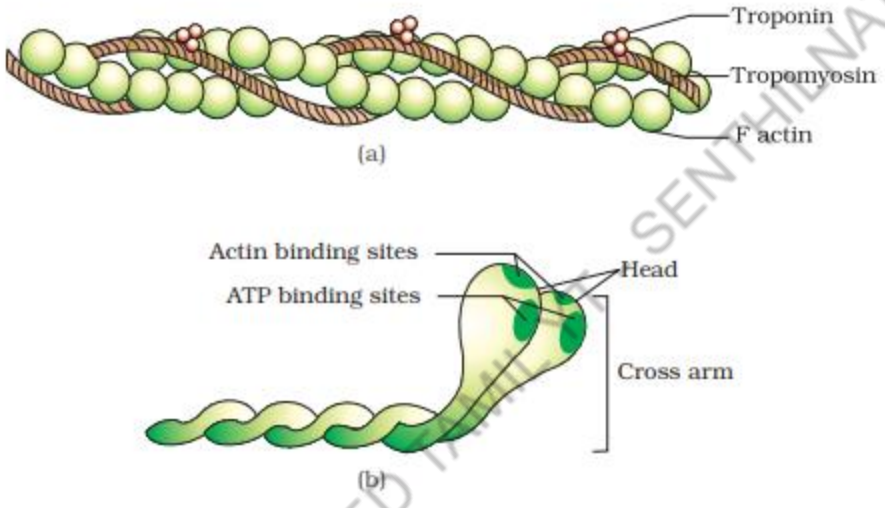


Figure 20.3 (a) An actin (thin) filament (b) Myosin monomer (Meromyosin)

Mechanism of Muscle Contraction - Sliding Filament Theory

- Contraction of muscle fibre occur by sliding of thin filament over thick filament. **Motor unit = Motor neuron + muscle fibres.**
- Initiated by signal sent by CNS via motor neuron.
- Junction between motor neuron & sarcolemma – **neuro muscular junction or motor - end plate.**
- When signal reaches here, it releases neurotransmitter **(acetyl choline)** which generates action potential in sarcolemma, which spreads through muscle & releases Ca^{+2} into sarcoplasm.
- Ca^{+2} bind with troponin on actin & removes masking of active sites for myosin head.
- Utilising energy (ATP), myosin head binds to active site on actin to form cross bridge.
- This pulls actin filaments towards centre of 'A' band, 'Z' line is pulled inwards, shortening of sarcomere, - I band reduce, 'A' bands retain length - **Contraction.**
- Myosin release ADP & Pi & goes to relaxed state, new ATP binds & breaks cross bridge. ATP is hydrolysed & cross bridge forms & continues.
- It continues till Ca^{+2} are pumped back to sarcoplasmic cisternae resulting in masking of actin filament.
- 'Z' line return to original position - **Relaxation**.

- Repeated activation of muscle lead to lactic acid accumulation due to anaerobic breakdown of glycogen causing fatigue.
- Muscle cell contain red colour oxygen storing pigment - **myoglobin**.

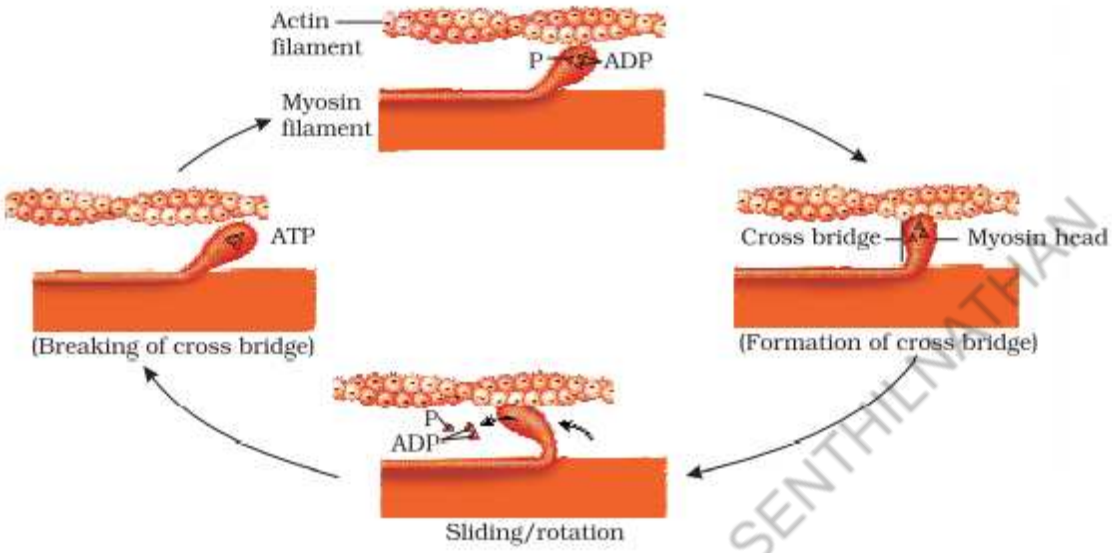


Figure 20.4 Stages in cross bridge formation, rotation of head and breaking of cross bridge

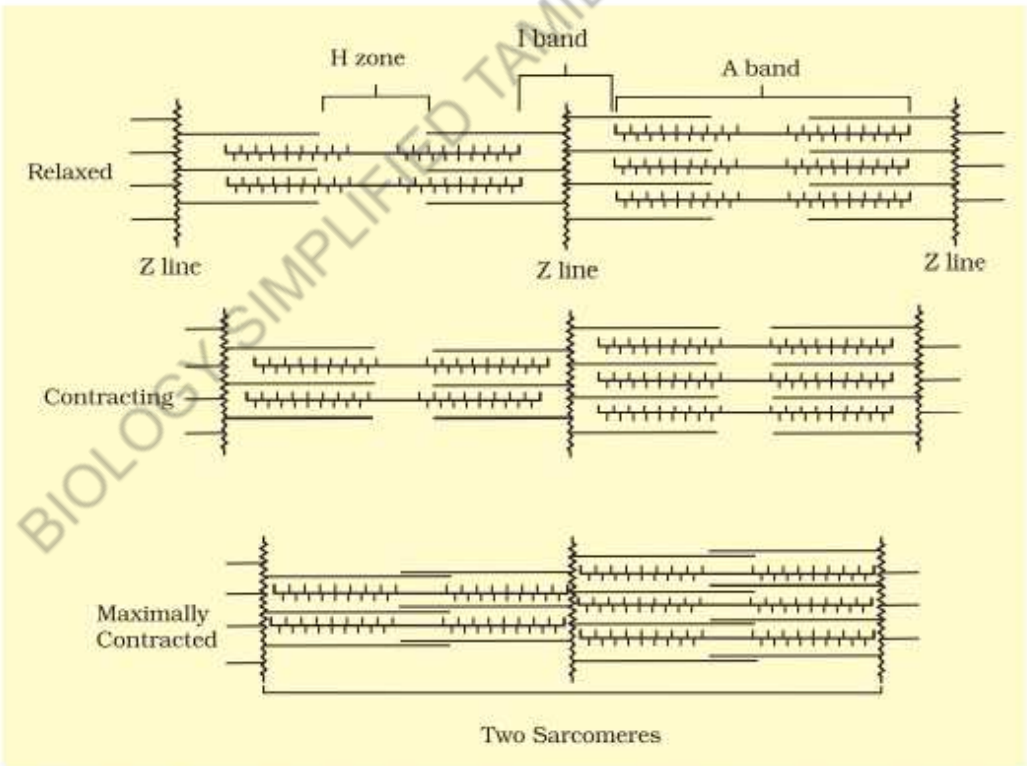


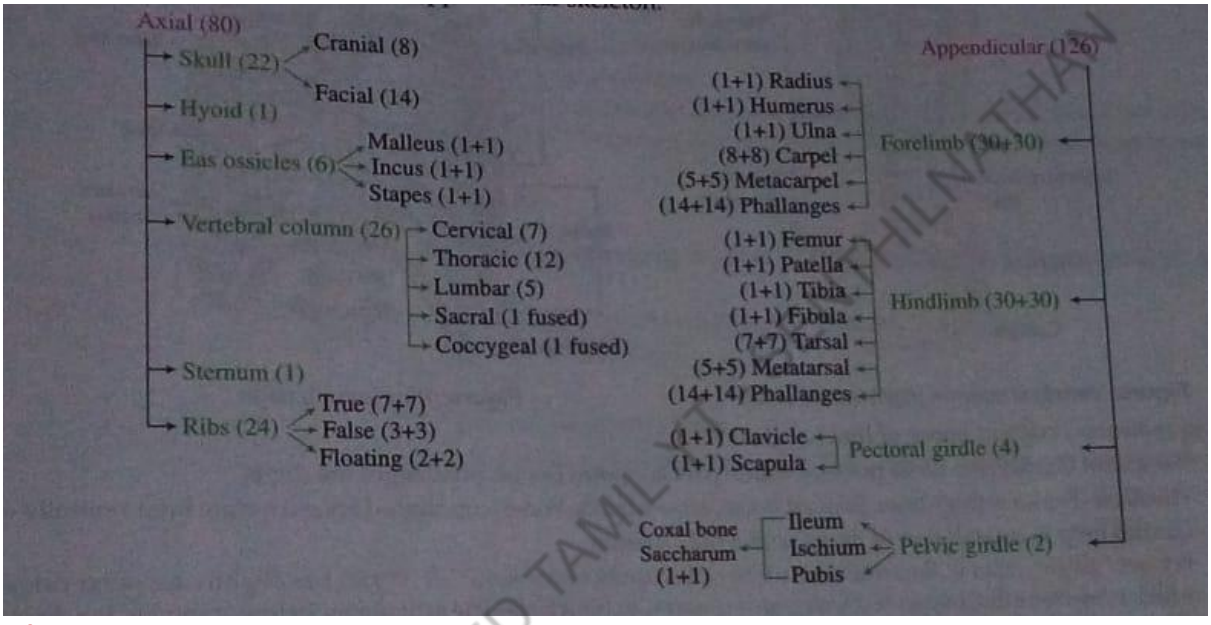
Figure 20.5 Sliding-filament theory of muscle contraction (movement of the thin filaments and the relative size of the I band and H zones)

Locomotion And Movement

- **Red Muscles:** High myoglobin, reddish, plenty of mitochondria, so also called **aerobic muscles.**
- **White Muscles:** Less myoglobin, pale or whitish, few mitochondria, lot of sarcoplasmic reticulum, depend on **anaerobic process** for energy.

Skeletal System: Bones + Cartilage (206 bones)

- 206 bones are divided into 2 categories: **Axial (80) & Appendicular (126).**
- Bone has hard matrix due to calcium salts whereas cartilage has pliable matrix due to chondroitin salts .
- Bones are grouped into 2 - axial & appendicular skeleton.



1) Axial skeleton –

- Skull + Vertebral column + Sternum + Ribs.
- **Skull:** Cranium is hard protective outer covering for brain.
- **Hyoid:** U - shaped bone at base of buccal cavity.
- **Dicondyllic skull:** Skull articulates with superior region of vertebral column with help of 2 occipital condyles.
- **Vertebral column:** Dorsal side, extends from base of skull, has central hollow portion **(neural canal)** through which spinal cord pass, protects spinal cord, supports head, serves as point of attachment for ribs, **first vertebra - atlas.**
- **Sternum:** Flat bone on ventral midline of thorax.
- **Ribs:** Thin flat bone connected dorsally to vertebral column & ventrally to sternum & has 2 articulation surface on dorsal end - **bicephalic. Rib cage = Thoracic vertebrae + ribs+ sternum.**
- **True ribs:** Dorsally attached to thoracic vertebrae & ventrally to sternum with hyaline cartilage.
- **False ribs:** Aren't connected to sternum directly but join 7^{th} rib with hyaline cartilage, also **vertebrochondral. Eg:** 8^{th}, 9^{th} & 10^{th} pair.
- **Floating ribs:** Aren't connected ventrally. **Eg:** 11^{th} & 12^{th} pair.

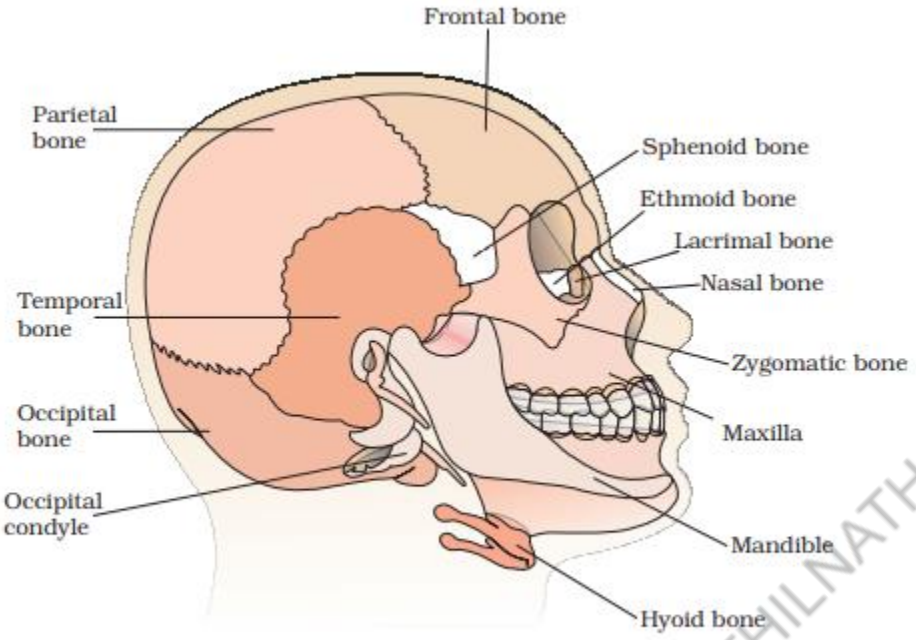


Figure 20.6 Diagrammatic view of human skull

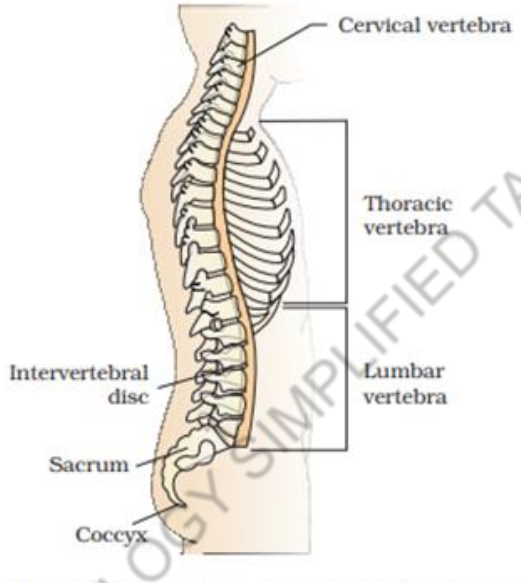


Figure 20.7 Vertebral column (right lateral view)

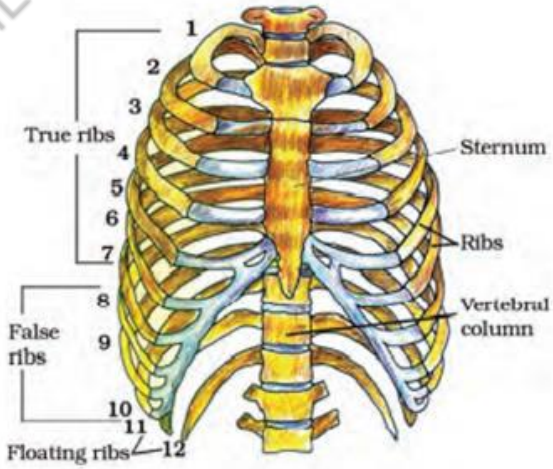


Figure 20.8 Ribs and rib cage

2) Appendicular skeleton: Bones of limbs + girdles.

- **Forelimb:** Carpals are wrist bones, metacarpals are palm bones, phallanges are digits.
- **Hindlimb:** Femur is thigh bone (longest bone), tarsals (ankle bone), cup shaped bone covering knee ventrally – **patella.**
- Girdles help in articulation of limbs with axial skeleton.
- **Pectoral girdle:** Dorsal, flat, triangular body of scapula **(between 2nd & 7th rib)** has slightly elevated ridge - **spine** which projects as flat, expanded, process - **acromion**, to which clavicle articulates. Below acromion is a depression - **glenoid cavity** which articulates with humerus head. Clavicle is long slender bone with 2 curvature – **collar bone.**

Figure 20.9 Right pectoral girdle and upper arm. (frontal view)

Figure 20.10 Right pelvic girdle and lower limb bones (frontal view)

- **Pelvic girdle:** Has 2 coxal bones each formed by fusion of 3 bones, above this fusion is a cavity - **acetabulum** to which thigh bone articulates, 2 halves of girdle meet ventrally to form pubic symphysis containing **fibrous cartilage.**

Joints: Point of contact between bones or between bones & cartilage.

- Force generated by muscle carry out movement through joints which act as **fulcrum.**

1) Fibrous joints: Don't allow any movement.

Eg: In flat skull bones fused end-to-end in form of sutures to form cranium.

2) Cartilagenous joints: Bones are joined with help of cartilages.

Eg: Between adjacent vertebrae in vertebral column.

- Permits limited movement.

3) Synovial joints: Allow considerable movement, help in locomotion.

- Has fluid filled synovial cavity between articulating surfaces.

Eg: **Ball & socket joint** (between humerus & pectoral girdle; and between femur and pelvic girdle), **hinge joint** (knee joint), **pivot joint** (between atlas & axis), **gliding joint** (between carpals), **saddle joint** (between carpal & metacarpal of thumb).

Disorders:

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

2) Muscular dystrophy: Progressive degeneration of skeletal muscle, genetic disorder.

3) Tetany: Rapid spasms in muscle due to low Ca^{+2} in body fluid.

4) Arthritis: Inflammation of joints.

5) Gout: Inflammation of joints due to uric acid crystal accumulation.

6) Osteoporosis: Age related, decreased bone mass, increased chances of fractures due to decrease in estrogen levels.

Neural Control And Coordination

Co – ordination:

- Process by which 2 or more organs interact & complement functions of one another.
- Neural system & endocrine system jointly coordinate & integrate all activities. Neural system provide point – to – point connection for quick cordination & endocrine system provide chemical integration through hormones.

Neural system:

- Has highly specialised cells - **neurons** which can detect, receive & transmit different kinds of stimuli.
- Simple in lower invertebrates. **Eg:** Hydra, better in insects (brain + ganglia + neural tissues), vertebrates have highly developed neural system.

Human Neural System:

1) Central Neural System (CNS) - Brain + spinal cord.

- Site of information processing & control.

2) Peripheral Neural System (PNS) - Nerves associated with CNS.

a) Somatic Neural System: Relays impulse from CNS to skeletal muscles.

b) Autonomic Neural System: Relays impulse from CNS to involuntary organs & smooth muscles. Its further divided into sympathetic neural system & parasympathetic neural system.

Nerve fibres are of 2 types –

i) Afferent fibres - Transmit impulse from tissues/organs to CNS.

ii) Efferent fibres - Transmit impulse from CNS to tissues/organs.

- **Visceral nervous system -** Part of peripheral nervous system, has nerves, fibres, ganglia & plexuses by which impulse travels from CNS to viscera & viscera to CNS.

Neuron:

- Structural & functional unit of neural system.

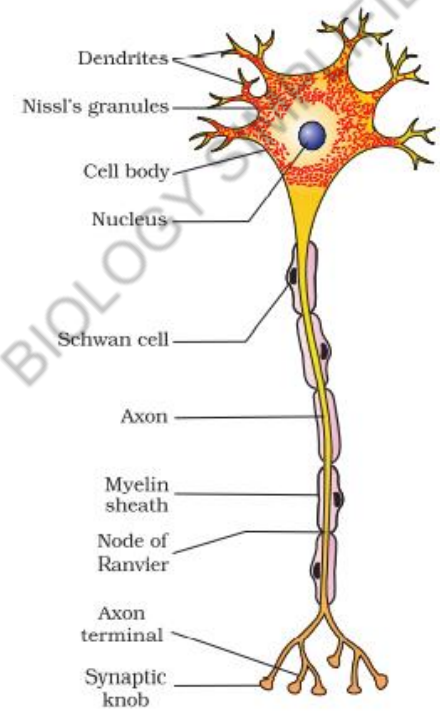


Figure 21.1 Structure of a neuron

Neural Control And Coordination

- Comprises of cell body, dendrites & axon.
- **Cell body -** Cytoplasm + cell organelles + granular bodies - **Nissl's granules.**
- **Dendrites -** Short fibres branch repeatedly & project out of cell body, contain Nissl's granules, transmit impulse towards cell body.
- **Axon -** Long fibre, branched end terminating as bulb like **synaptic knob** which has synaptic vessels containing chemicals - **neuro transmitter,** transmit impulse away from cell body to synapse or junction.
- Based on no. of axon & dendrites –

→ **Multipolar -** 1 axon & 2 or more dendrites. **Eg: Cerebral cortex.**

→ **Bipolar -** 1 axon & 1 dendrite. **Eg: Retina of eye.**

→ **Unipolar -** 1 axon only. **Eg: In embryonic stage.**

- **2 types of axon :**

→ **Myelinated -** Enveloped with Schwann cells which form myelin sheath. Gaps between 2 adjacent myelin sheath - **nodes of Raniver.**
Eg: In spinal & cranial nerves.

→ **Unmyelinated -** Enclosed by Schwann cell but doesn't form myelin sheath.
Eg: In autonomous & somatic neural system.

Generation & Conduction of Nerve Impulse:

- Neurons are exciatable as membranes are in polarised state.
- When neuron isn't conducting any impulse, axonal membrane is more permeable to potassium ions, impermeable for sodium ions & negatively charged proteins in axoplasm.
- So, axoplasm has high K^+ & negatively charged proteins & low Na^+ whereas extracellular fluid has high Na^+ & low k^+.
- This gradient is maintained by active transport of ions by **Na – k pump** transporting **3 Na^+ out & 2 K^+ into the cell.**
- So, outer surface possess positive & inner negative – **polarised.**

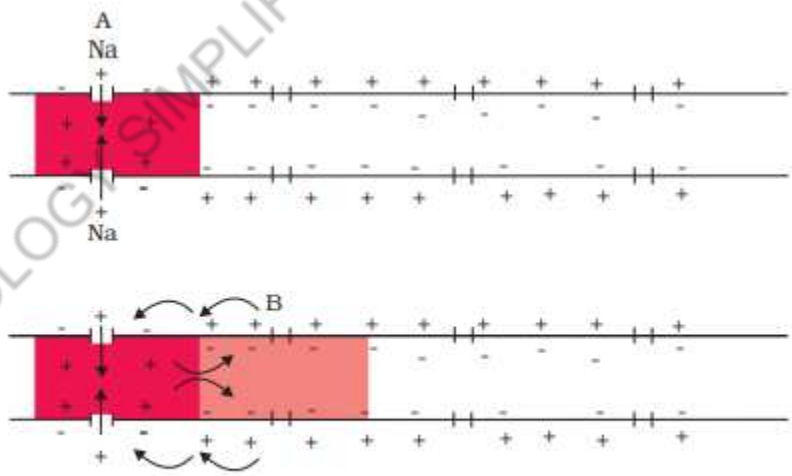


Figure 21.2 Diagrammatic representation of impulse conduction through an axon (at points A and B)

- **Resting potential -** Electrical potential difference across resting membrane.
- When stimulus is applied on polarised membrane at site 'A', membrane becomes freely permeable to Na^+, rapid influx of Na^+ & reverse polarity at that site (outer negative inner positive).
- Reversal of polarity across 2 side of membrane – **depolarised.**

Neural Control And Coordination

- **Action potential -** Electrical potential difference at site A, also **nerve impulse.**
- At site B, just ahead of A, outer is positive & inner negative. So, current flows **from A to B on inner surface & B to A on outer.**
- So, polarity at B gets reversed & action potential is generated. Impulse arrive at B & repeats along the whole length.
- This stimulus is extremely short & followed by rise in k^+ permeability.
- K^+ diffuses outside the membrane & restores resting potential.

Transmission of Impulse - Through junctions (synapse)

- **Synapse -** Formed by pre - synaptic & post - synaptic neuron, may or may not be separated by gap – **Synaptic cleft.**

1) Electrical - Pre & post synaptic neuron are in close proximity, current flows directly from 1 neuron to another, rare in our system, faster than chemical impulse.

2) Chemical - Membranes are separated by fluid filled space - **Synaptic cleft,** axon terminals contain vesicles filled with neurotransmitter helping in transmission of impulse.

- When impulse arrives at axon terminal, it stimulates movement of vesicles towards membrane which fuse with plasma membrane & release neurotransmitters in synaptic cleft, which bind to receptors in **post synaptic membrane.**
- This opens ion channels, generate potential in post synaptic neuron which may be exciatatory or inhibitory.

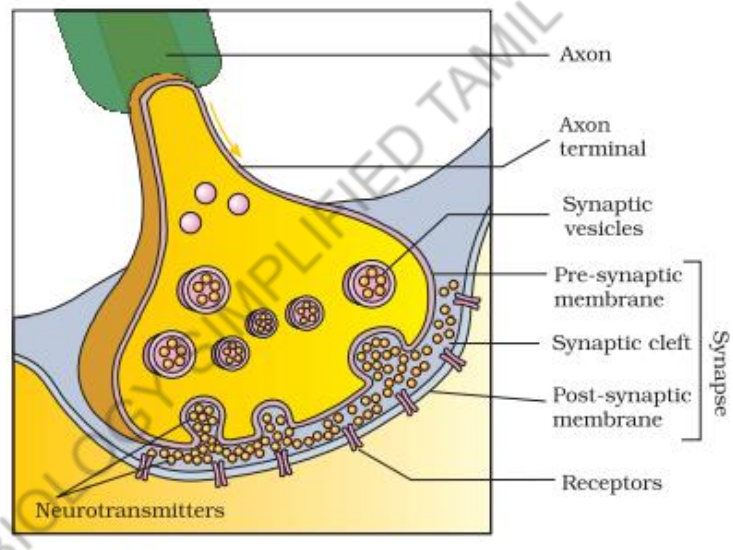


Figure 21.3 Diagram showing axon terminal and synapse

Central Neural System:

Brain:

- Central information processing organ, command & control system, controls voluntary movements, balance of the body, functioning of vital organs, thermoregulation, hunger, thirst, circadian rhythm, activity of endocrine gland, human behaviour.
- Its protected by skull, covered by **cranial meninges** with outer **duramater, middle – arachnoid & inner pia mater.**

Neural Control And Coordination

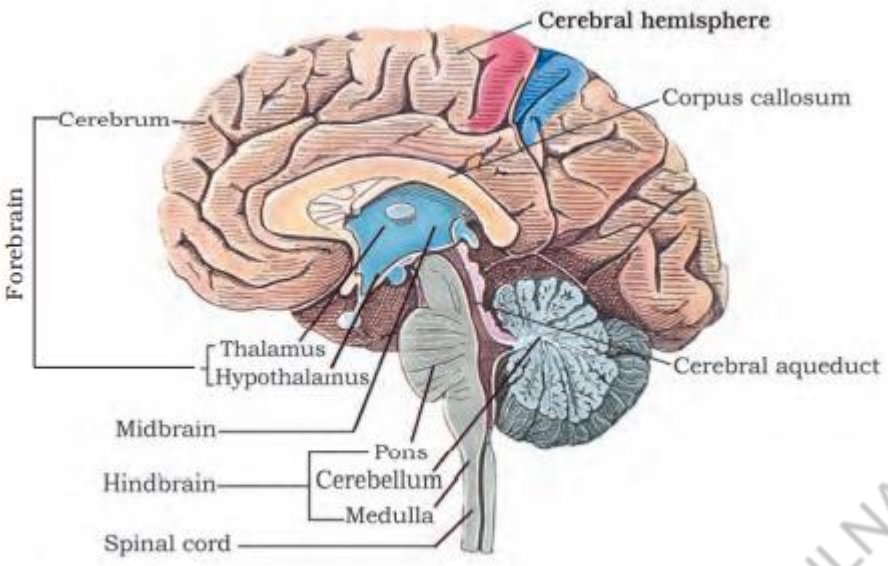


Figure 21.4 Diagram showing sagital section of the human brain

1) Forebrain – Cerebrum + Hypothalamus + Thalamus.

a) Cerebrum – Major part of brain.

- Deep cleft divides it into 2 halves, right & left cerebral hemisphere, connected by **corpus callosum.**
- Cells covering hemisphere - **cerebral cortex** also called **grey matter** due to greyish appearance (presence of neuron cell bodies).
- Cerebral cortex contains motor areas, sensory areas & association areas (intersensory association, memory, communication).
- Fibres of tract are covered with myelin sheath giving opaque white appearance called **white matter.**

b) Thalamus – Wrapped by cerebrum, major coordinating centre for sensory & motor signalling.

c) Hypothalamus – At base of thalamus, controls body temperature, urge for eating & drinking, has neurosecretory cells secreting hormones - **hypothalmic hormones.**
Along with hypothalamus, limbic system is involved in regulation of sexual behaviour, emotional reactions & motivation.
Limbic lobe/system - Inner parts of cerebral hemisphere & deep structures like amygdala, hippocampus etc.

2) Mid brain – Between thalamus of forebrain & pons of hindbrain.

- Canal called **cerebral aqueduct** passes it.
- Its dorsal portion has 4 swellings - **corpora quadrigemina.**

3) Hindbrain:

a) Pons - Fibre tracts interconnecting different region of brain.

b) Cerebellum - Convoluted surface to provide additional space for neurons.

c) Medulla - Also **medulla oblongata**, connected to spinal cord, control respiration, cardiovascular reflex & gastric secretion.
Brain stem – mid brain + pons + medulla, connects brain & spinal cord.

Neural Control And Coordination

Reflex Action & Reflex Arc –

- **Eg:** knee jerk reflex.
- **Reflex action -** Involuntary process of response to peripheral nervous stimulation without conscious thought & involve CNS.
- Afferent neuron receive signal from sensory organ & transmit impulse via **dorsal nerve root** into CNS (spinal cord).
- Efferent neuron carries signal from CNS to effector.
- **Reflex arc -** Stimulus + response.

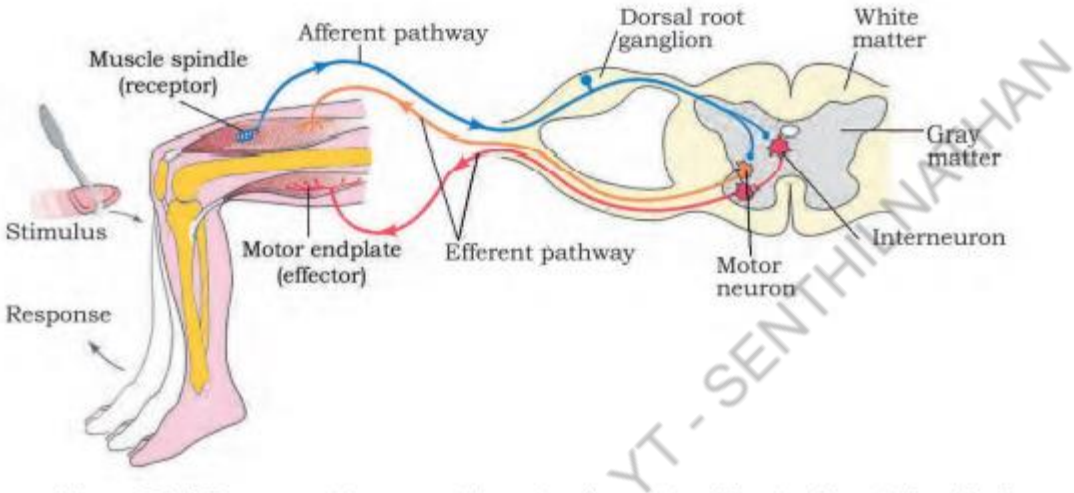


Figure 21.5 Diagrammatic presentation of reflex action (showing knee jerk reflex)

Sense organs:

- **Nose:** Has mucus - coated receptors for sensing smell – **olfactory receptors** (made of olfactory epithelium – 3 kinds of cell), extends from outside to pair of broad bean sized organs – **olfactory bulb.**
- **Tongue:** Detects taste through taste buds having **gustatory receptors.**
- Both detect dissolved chemicals & are functionally similar & interrelated.

1) Eye: Located in skull sockets - **orbits,** nearly spherical.

- Wall has 3 layers - **external sclera** (dense connective tissue), anterior portion - **cornea, middle choroid, inner retina.**
- **Choroid -** Bluish in colour, has blood vessels, thin on posterior, 2/3rd of eye ball, thick in anterior to form ciliary body.
- Ciliary body continues to form pigmented & opaque structure - **Iris** (visible portion of eye) which surrounds **pupil** whose diameter is regulated by muscle fibres of iris.
- A lens is held by ligaments attached to ciliary body.
- **Retina -** has 3 cells from **inside to outside – ganglion cells, bipolar cells & photoreceptor cells,** (rods & cones)
- Photoreceptor cells have light sensitive proteins – **photopigment.**

→ **Rods -** twilight **(Scotopic)**, have purplish red protein – **rhodopsin (derivative of vitamin A).**

→ **Cones -** daylight vision **(photopic),** 3 types of cones having their own photopigment for red, green & blue, white light is produced when equally stimulated.

- Optic nerve leave eye & retinal blood vessel enter at point slightly above the posterior pole of eye ball – **blind spot** as photoreceptor cells are absent.

Neural Control And Coordination

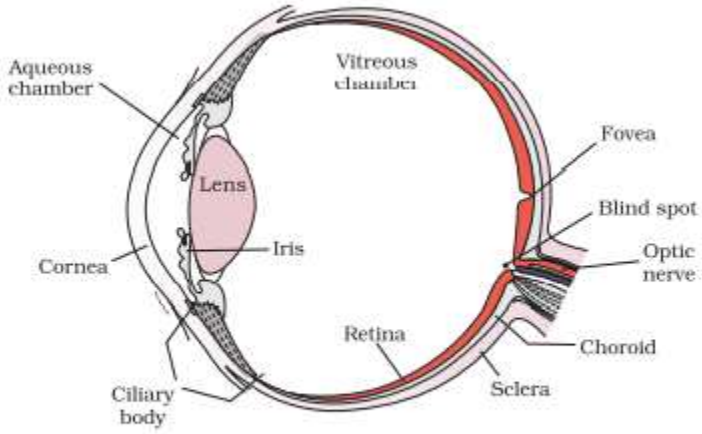


Figure 21.6 Diagram showing parts of an eye

- At posterior pole, yellowish spot – **macula lutea** with central pit – **fovea centralis** (thin portion where cones are densely packed), visual resolution is highest.
- **Aqueous chamber -** Space between cornea & lens (thin watery fluid).
- **Vitreous chamber -** Space between lens & retina (transparent gel).
- **Mechanism of vision -** light rays focus on retina through cornea & lens generate potential in photoreceptor, photosensitive compounds are composed of **opsin protein & retinal (aldehyde)**. Light dissociates retinal from opsin changing structure of opsin which changes membrane permeability & potential difference is generated, generates action potential **in ganglion through bipolar cells.** Its transmitted by optic nerves to visual cortex where impulses are analysed & image is formed on retina.

2) Ear - hearing & maintain body balance.

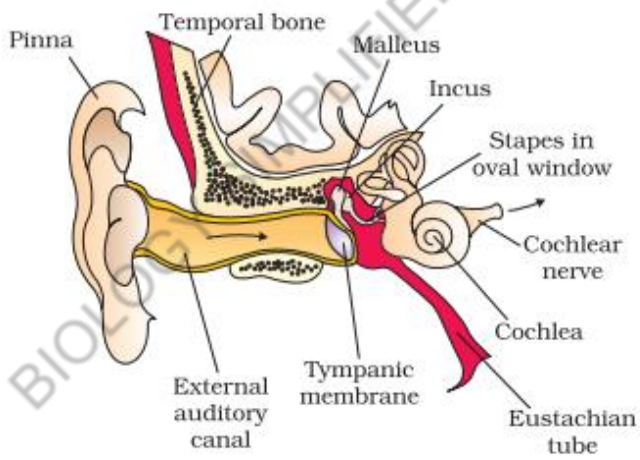


Figure 21.7 Diagrammatic view of ear

a) Outer ear: Pinna (collects vibrations in air) + external auditory meatus (extends to **tympanic membrane** - ear drum)
- Fine hairs & wax secreting glands are present in pinna & meatus.
- Tympanic membrane (connective tissue) is covered by skin on outside & mucus membrane on inside.

b) Middle ear: 3 ossicles - **malleus, incus & stapes** (chain like fashion).

- Ossicles increase transmission efficiency of sound waves to inner ear.
- Malleus is attached to tympanic membrane & stapes is attached to oral window of cochlea.
- **Eustachian tube -** Connects middle ear to pharynx, equalise pressure on either sides of ear drum.

c) Inner ear: Also **labyrinth**, has 2 parts - bony & membranous labyrinth.

- Bony labyrinth is series of channel, inside it lies membranous labyrinth surrounded by **perilymph.**
- Membranous labyrinth is surrounded by **endolymph.**
- **Cochlea -** Coiled portion, surrounded by reissner's & basilar membrane dividing perilymph filled bony labyrinth to **upper scala vestibuli** & **lower scala tympani** which ends at **oral window** & **round window** (opens to middle ear) respectively.
- Space within cochlea - **Scala media** (filled with endolymph).

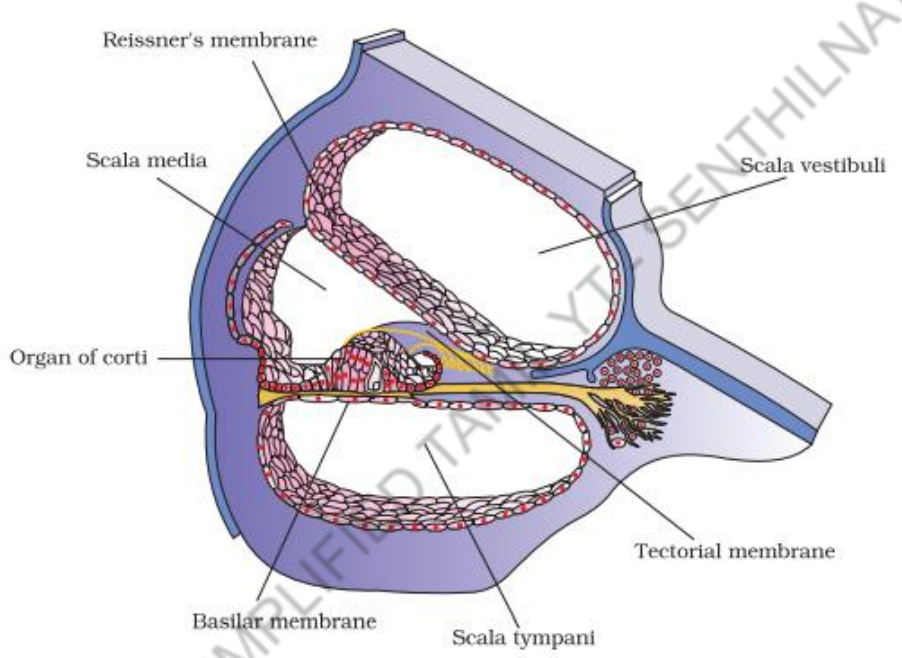


Figure 21.8 Diagrammatic representation of the sectional view of cochlea

- **Organ of corti -** On basilar membrane contain hair cells (auditory receptors) in rows, whose base is in close contact with **afferent nerve fibre** & stereocilia projects from its apical part.
- **Tectorial membrane -** Thin elastic membrane above rows of hair cells.
- Inner ear has complex system - **Vestibular apparatus** (above cochlea) Which has 3 semicircular canals & otolith **(macula is sensory part of saccule & utricle).**
- Each canal lie in different plane at right angles, have swollen base - **ampulla** having projecting ridge – **crista ampullaris** having hair cells.
- **Crista + macula** maintain body posture & balance of body.
- **Mechanism of hearing -** External ear receives sound & directs them to ear drum which vibrates & vibrations are transmitted through ear ossicles to oval window & then to cochlea fluid where they generate waves in lymph which induce ripple in basilar membrane bending hair cell, pressing them against tectorial membrane, impulse generate in afferent neurons & transmitted to auditory cortex through auditory nerves where impulse are analysed & sound recognised.

Chemical Co – Ordination And Integration

- Neural Co - ordination is fast but short lived.
- Neural system & endocrine system jointly cordinate & regulate body functions, so they combined to form Neuroendocrinology.

Endocrine glands & Hormones:

- **Endocrine glands:** Lack ducts, **ductless glands**, secrete hormones.
- **Hormones:** Non - nutrient chemicals acting as intercellular messenger & produced in trace amount by endocrine glands into blood.

Human Endocrine System: Endocrine glands + hormone producing tissues.

- Apart from endocrine bodies, gastrointestinal tract, liver, kidney, heart also produce hormones.

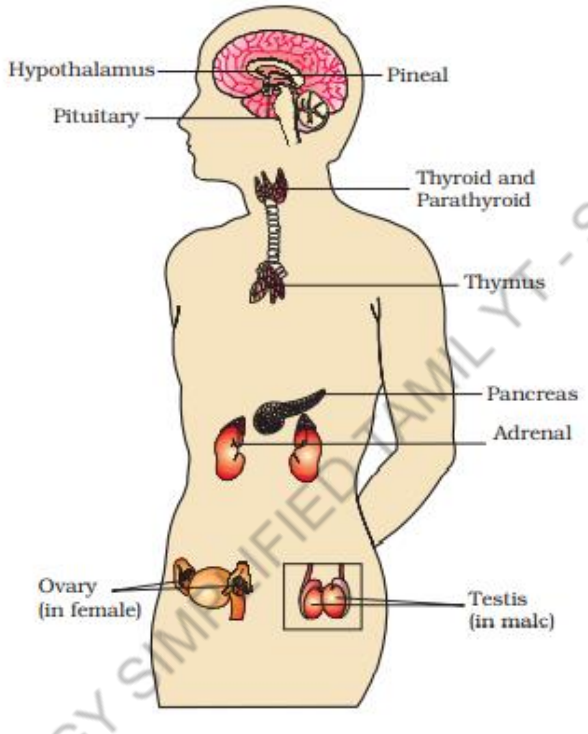


Figure 22.1 Location of endocrine glands

1) Hypothalamus: At **basal part of diencephalon,** forebrain.

- Contains neurosecretory cells called nuclei producing hormones.
- **2 types –**

→ **Releasing:** Stimulate pituitary secretion. **Eg:** Gonadotropin releasing hormone release gonadotropins from pituitary.

→ **Inhibiting:** Inhibit pituitary secretion. **Eg:** Somatostatin inhibits growth hormone from pituitary.

- These hormones originate in hypothalamic neurons, pass through axons & released from nerve endings, which reach pituitary through portal circulatory system & regulate **anterior pituitary.**
- **Posterior pituitary** is under direct neural regulation of hypothalamus.

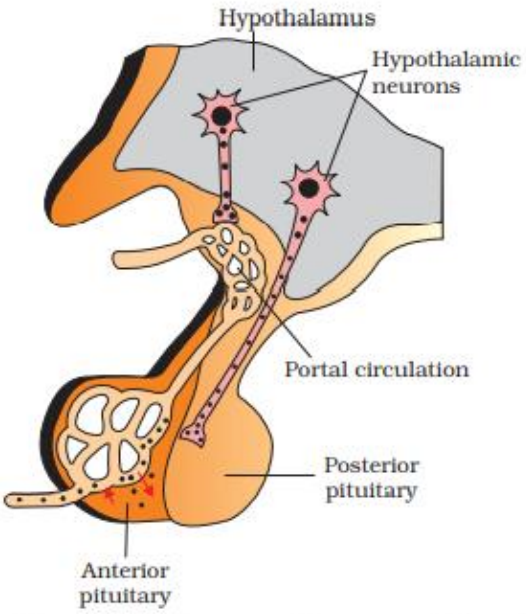


Figure 22.2 Diagrammatic representation of pituitary and its relationship with hypothalamus

2) The Pituitary Gland: In bony cavity - **sella tursica**, attached to hypothalamus by stalk.

- Divided into adenohypophysis & neurohypophysis.
- **Neurohypophysis:** Also **posterior pituitary/pars nervosa**, stores & release **oxytosin & vasopressin** synthesised by hypothalamus.
- **Adenohypophysis –**

→ **Pars intermedia:** Secrete **melanocyte stimulating hormone**.

→ **Pars distalis:** Also **anterior pituitary**, produce growth hormone, prolactin, thyroid stimulating hormone, adrenocorticotrophic hormone, luteinizing hormone, follicle stimulating hormone.

- Oversecretion of growth hormone - abnormal growth, **gigantism**, severe disfigurement (mainly face) called **acromegaly** which may lead to premature death if unchecked.
- Low secretion of growth hormone - stunted growth, dwarfism.
- **Prolactin:** Growth of mammary gland & formation of milk.
- **Oxytosin:** Act on smooth muscle & stimulate contraction (of uterus at child birth) & milk ejection from mammary gland.
- **Thyroid stimulating hormone (TSH):** Synthesise & secrete thyroid hormones.
- **Adrenocorticotrophic hormone (ACTH):** Synthesise & secrete steroid hormones – glucocorticoids from adrenal cortex.
- **Luteinizing & follicle stimulating hormone (LH & FSH):** Stimulate gonadal activity – gonadotrophins.
- In males, LH stimulates secretion of androgens from testis & FSH & androgens regulate spermatogenesis.
- In females, LH induce ovulation of follicle & maintain corpus luteum after ovulation & FSH stimulate growth of follicles.

- **Melanocyte stimulating hormone (MSH):** Acts on melanocyte & regulates skin pigmentation.
- **Vasopressin:** Stimulate reabsorption of water & electrolyte by distal tubules & reduces water loss from urine, so also called **anti-diuretic hormone (ADH).** If its impaired, it leads to dehydration - **Diabetes Insipidus.**

3) The Pineal Gland: On **dorsal side of forebrain.**

- Secrete melatonin which regulates 24 hour (diurnal) rhythm of body.
- Maintain sleep - wake cycle, body temperature, metabolism, pigmentation, menstrual cycle, defense capability.

4) Thyroid gland: 2 lobes on **either side of trachea.**

- 2 lobes are interconnected by thin flap of connective tissue - **Isthmus.**
- Compound of **follicles** & **stromal tissues.**
- Each follicle has follicular cells synthesising **tetraiodothyronine** or thyroxine (T_4) **tri - iodothyronine** & (T_3).
- Iodine is essential for normal rate of hormone synthesis.
- **Hypothyroidism:** Deficiency of iodine, enlargement of thyroid gland called **goitre**, irregular menstrual cycle in woman, during pregnancy causes defective development & maturation of body, stunted growth **(cretinism)**,mental retardation, low IQ, abnormal skin, deaf – mutism.
- **Hyperthyroidism:** Increased level of thyroid hormones due to cancer of thyroid gland & nodule development of thyroid glands.
  Exophthalmic goitre/Grave's disease: Type of hyperthyroidism, enlargement of thyroid gland, increased BMR & weight loss, protrusion of eyeballs.
- Regulate BMR, **RBC formation,** carbohydrate, fats & protein metabolism, maintain water & electrolyte balance, secrete protein hormone – **thyrocalcitonin (TCT)** regulating blood calcium levels.

5) Parathyroid Gland: 4 glands on **back side of thyroid gland.**

- One pair each in 2 lobes of thyroid gland.
- **Secrete peptide hormone: Parathyroid hormone (PTH)** which acts on bones & stimulate resorption of bone **(demineralisation/dissolution),** stimulate reabsorption of Ca^{+2} by renal tubules & from digested food, hence a **hypercalcaemic hormone** (increase blood ca^{+2} level).
- Maintains calcium balance alongwith TCT.

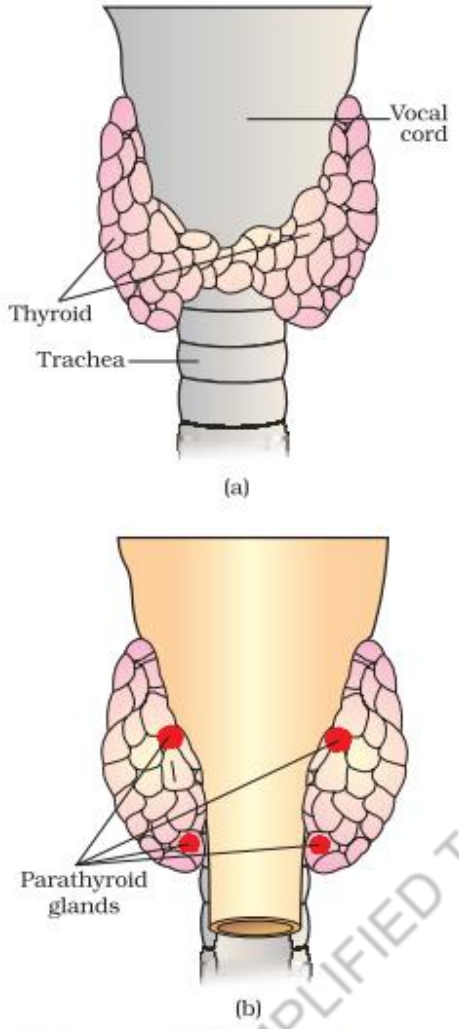


Figure 22.3 Diagrammatic view of the position of Thyroid and Parathyroid
(a) Ventral side
(b) Dorsal side

6) Thymus: Lobular structure **between lungs behind sternum** on ventral side of aorta.

- Development of immune system.
- Secrete peptide hormone - **thymosins** which help in differentiation of **T - lymphocytes** which provide cell mediated immunity & promotes production of antibodies provide **humoral immunity**.
- Degenerates in old, decreased thymosins & immune response becomes weak.

7) Adrenal Gland: One pair, each at **anterior part of kidney.**

- **2 types of tissue:** Central adrenal medulla & adrenal cortex on outside.
- **Addison's disease:** Underproduction of hormones by adrenal cortex causing acute weakness & fatigue.

a) Adrenal medulla:

- Secrete **catecholamines** (adrenaline or epinephrine & noradrenaline or norepinephrine) in response to stress & emergency condition - **emergency hormones/hormones of flight, flight and fright (3F hormone).**
- These hormones increase alertness, pupillary dilation, sweating, piloerection (rising of hairs), increase heart beat, strength heart contraction & rate of respiration, stimulate breakdown of lipid, protein & glycogen increasing glucose in blood.

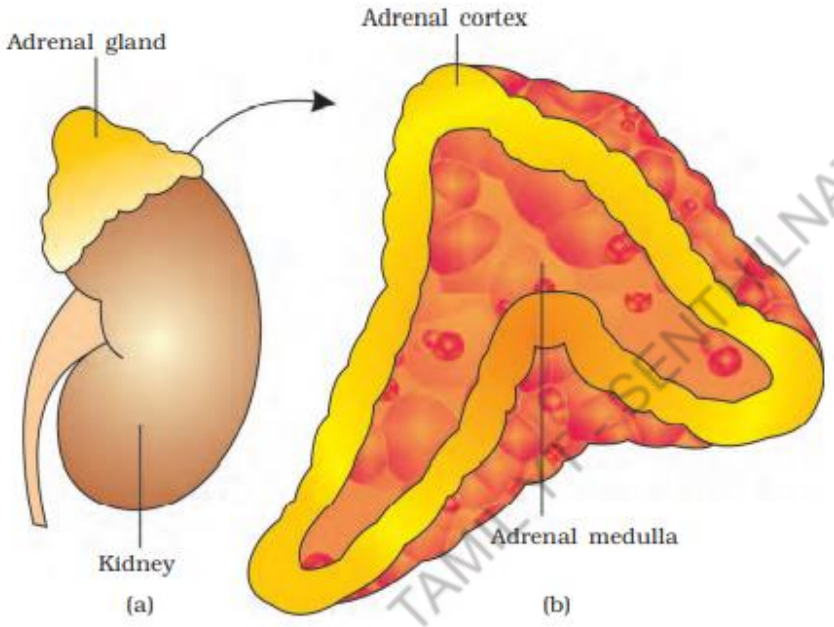


Figure 22.4 Diagrammatic representation of : (a) Adrenal gland above kidney (b) Section showing two parts of adrenal gland

b) Adrenal cortex: Secrete **corticoids.**

- **Has 3 layers: Outer zona glomerulosa, middle zona fasciculata & inner zona reticularis.**
- **Glucocorticoids:** Corticoid involved in carbohydrate metabolism. **Eg: Cortisol** - maintain cardio - vascular system & kidney function, produce anti - inflammatory reaction, suppress immune response & stimulate RBC production.
- Glucocorticoids stimulate **gluconeogenesis**, **lipolysis** & **proteolysis**, inhibit cellular uptake & amino acid utilisation.
- **Mineralocorticoids:** Corticoid regulating water & electrolyte balance.
  Eg: Aldosterone – Reabsorb Na^+ & water from renal tubules & excrete K^+ & phosphate ions, maintains electrolyte, body fluid volume, osmotic pressure & blood pressure.
- Androgenic steroid help in growth of axial hair, pubic hair & facial hair.

8) Pancreas: Composite gland (endocrine + exocrine)

- **Endocrine gland:** Has **Islets of Langerhans** (1-2 million) – 1-2% of pancreatic tissues, has 2 type of cells: α - cells & β - cells.
- α - cells secrete glucagon while β - cells secrete insulin.

- **Glucagon:** Peptide hormone, maintain normal blood glucose level, acts on hepatocytes, stimulate **glycogenolysis** (increased blood sugar), gluconeogenesis, reduces cellular glucose uptake, so also called **hyperglycemic hormone.**
- **Insulin:** Peptide hormone, acts on hepatocytes & adipocytes, enhance cellular uptake, glucose moves from blood to adipocytes & hepatocytes, decrease blood sugar, glycogenesis, also **hypoglycemic.**
- Glucose homeostasis is maintained by insulin & glucagon.
- **Diabetes mellitus:** Prolonged hyperglycemia, loss of glucose through urine & formation of ketone bodies occur.

9) Testis: Pair in **scrotal sac (outside abdomen).**

- Dual function - primary sex organ & endocrine gland.
- Has **seminiferous tubule & stromal or interstitial tissue.**
- Leydig or interstitial cells produce **androgens** mainly **testosterone.**
- Androgens regulate functions of male accessory sex organs like epididymis, vas deferens, seminal vesicle, prostate gland, urethra etc, regulate muscular growth, growth of facial & axillary hair, aggressiveness, low pitch voice, act on CNS & influence male sexual behaviour, produce anabolic effect on proteins & carbohydrate, help in spermatogenesis.

10) Ovary: Pair in **abdomen.**

- Primary female sex organ which produce 1 ovum in each cycle.
- Composed of **ovarian follicle** & **stromal tissues.**
- Produce 2 hormones - estrogen & progesterone.
- **Estrogens:** Secreted by growing ovarian follicle, stimulate growth of female secondary sex organs, development of growing follicles, appearance of secondary sex characters (high pitch voice), mammary gland development.
- **Progestrone:** Secreted by corpus luteum (by ruptured follicle), supports pregnancy, acts on mammary gland, stimulate formation of alveoli.

Hormones of Heart, Kidney & Gastrointestinal Tract –

- **Atrial Natriuretic Factor (ANF):** Peptide hormone secreted by atrial wall of heart, decrease BP by dilation of blood vessels.
- **Erythropoietin:** Peptide hormone produced by juxtaglomerular cells of kidney, stimulate **erythropoiesis** (RBC formation).
- **By gastrointestinal tract –**

→ **Gastrin:** Acts on gastric gland, stimulate secretion of Hcl & pepsinogen.

→ **Secretin:** Acts on exocrine pancreas, stimulate secretion of water & bicarbonate ions.

→ **Cholecystokinin (CCK):** Acts on pancreas & gall bladder, stimulate secretion of pancreatic enzyme & bile juice.

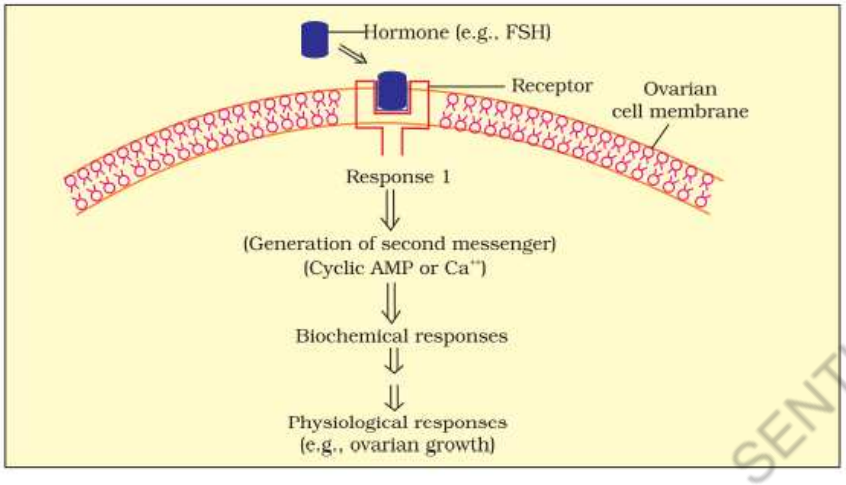
→ **Gastric Inhibitory peptide (GIP):** Inhibits gastrin secretion.

Mechanism of hormone action –

- **Hormone receptor:** Hormones produce their effects by binding to specific proteins, if present on cell membrane - **membrane bound receptors** & if inside target cell – **intracellular receptors.**
- **Hormone receptor complex:** Binding of hormone to its receptor, leads to biochemical changes in target site.

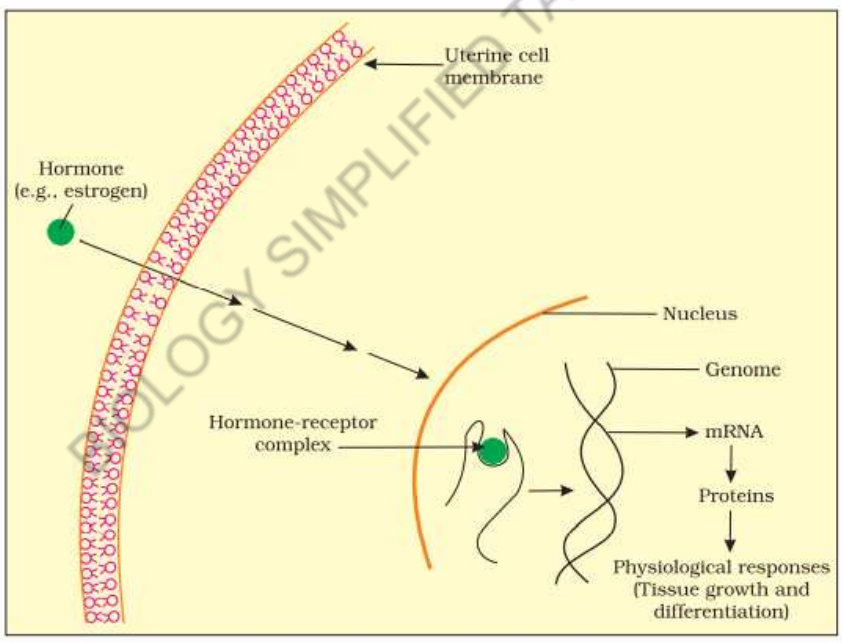
- Each receptor is specific to one hormone only, hence receptors are specific.

1) Protein hormone: Hormones interact with membrane bound receptors & don't enter target cell, generate **second messengers (Cyclic AMP, IP_3, Ca^{+2} etc.)** & regulate cellular metabolism.



(a)

2) Steroid/Iodothyronines: Hormones interact with intracellular receptors, hormone receptor complex interact with genome, biochemical action result in physiological & developmental effects.



(b)

Figure 22.5 Diagramatic representation of the mechanism of hormone action : (a) Protein hormone (b) Steroid hormone

Chemical Co – Ordination And Integration

Hormones can be divided into –

- → **Steroids:** **Eg –** Cortisol, testosterone, estradiol, progesterone.
- → **Iodothyronines:** **Eg –** Thyroid hormones.
- → **Amino acid derivative:** **Eg –** Epinephrine.
- → **Peptide, protein hormones:** **Eg –** Insulin, glucagon, pituitary hormone, hypothalamic hormones etc.