

BIOLOGY

Grade 12

Government of Nepal

Ministry of Education, Science and Technology

Curriculum Development Centre

Sanothimi, Bhaktapur

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Preface

The curriculum is the central guide that determines what is essential for teaching and learning. A textbook is one of the main tools used to deliver the intent and the content of the curriculum. Therefore, it should present relevant, practical, and useful knowledge and help develop skills for the overall development of learners in accordance with curricular aims and objectives. This textbook, '**Biology, Grade 12**', has been prepared in line with the intent of the National Curriculum Framework for School Education, 2076 and developed in accordance with Secondary Level (Grade 11-12) Biology Curriculum, 2077.

This book has been developed by a team consisting of Dr. Rakesh Prasad Bhagat, Mr. Suraj Babu Ghimire, Mr. Sumant Kumar Ranjit, Mr. Santosh Kumara Lamsal and Mr. Lav Dev Bhatta. Several people, notably, the Director General Mr. Yubaraj Paudel and Dr. Kamal Prasad Acharya, Mr. Umanath Lamsal, Mr. Keshar Bahadur Khulal, Mr. Heramba Raj Kandel, Ms. Mina Shrestha, Mr. Purushottam Ghimire, Prof. Dr. Jaya Prakash Hamal, Goma Karki, Trailokya Nath Joshi, and Mr. Sanjeev Bhandari deserve special appreciation for their valuable contributions.

Efforts have been made to make the book activity oriented and interesting to the learners. All the contents of each lesson in this book are equally important. However, teachers can adapt to the contents and tasks according to the needs of their learners and classroom contexts. This book can be used as a major resource for classroom teaching; however, it should not be considered the only source of learning. The teachers are encouraged to explore additional resources and use them to supplement the curricular contents as outlined in the curriculum. The Curriculum Development Centre always welcomes constructive feedback and suggestions for the continuous improvement of its publications.

Curriculum Development Centre
Sanothimi, Bhaktapur

2025

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Unit 1

PLANT ANATOMY



**Nehemiah
Grew
(1641-1712)**

Nehemiah Grew is known as the "Father of plant anatomy" for his pioneering research in the field. Grew was an English botanist, physician, and microscopist who used a microscope and naked eye observations to create detailed pictures of plant parts. His work is considered a turning point in the development of modern comparative anatomy. He coined the terms "tissue" and "parenchyma". He established observational basis for botany. Grew identified stamen as the male organ of the plant and pollen as seed. His training in animal anatomy led to his interest in plant anatomy. He is considered a founder

Chapter 1.1

PLANT ANATOMY

Look at the pictures of biological organization and discuss the following questions:



A B C D E

- I. Name the figure A and D.
- II. Which figure represents 'tissue'?
- III. How do you define tissue?

1.1.1 CONCEPT OF TISSUE

Tissue refers to a group of cells, having a common origin, which carries out a specific function in an organism. In addition to cells, it can have extracellular non-living material (matrix). In a biological organization, it occupies a level in between cell and organ.

Cell- Tissue- Organ- System- Organism

Tissues are of two main categories: Plant tissues and animal tissues.

Plant Tissues

Plant anatomy, primarily, deals with structure and functions of plant tissues. Plant tissues can be observed under microscope, by cutting a thin section of plant part such as root, stem, leaf, floral bud etc. Hence, Plant anatomy is concerned with the study of internal structure of plant parts.

Plant tissues form organs (such as leaves, stems, or roots), each of which perform a specific set of functions. Together, organs often work to form organ systems. Flowering plants have two distinct organ systems on the basis of location: a **shoot system**, and a **root system**.

The shoot system consists of two portions: the **vegetative (non-reproductive) parts** such as the leaves and the stems and the **reproductive parts**, which includes flowers and fruits. The shoot system generally grows above ground, where it absorbs the light needed for photosynthesis. The root system, which anchors the plant into the ground, absorbs water and minerals, and serves as a storage site for food.

1.1.2 TYPES OF PLANT TISSUES

In a vascular plant, in general, three tissue systems exist: the epidermis, the ground tissue, and the vascular tissue.

Epidermis – It is a group of cells which form the outer surface of the leaves and of the young plant body.

Ground tissue – Ground tissue is less differentiated than other tissues. Ground tissue manufactures nutrients by photosynthesis and stores reserve nutrients.,

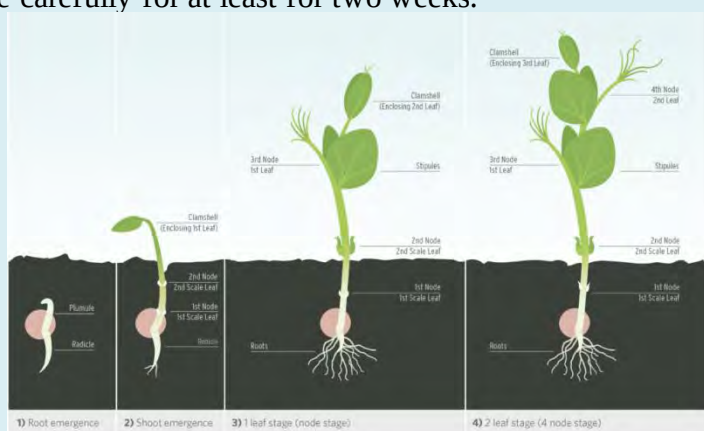
Vascular tissue – It is the group of cells which involve in conduction of materials and support.

Plant tissues can also be categorized into two types, **on basis of power of cell division**.

- a) Meristematic tissue and b) Permanent tissue

Activity 1.1

Soak the seed of any cereal (maize, wheat etc.) in water and sow on moist soil in a glass cup. Keep it in safe dark place, water it daily to keep the soil moist and observe carefully for at least for two weeks.



Fill up the table on basis of your observations.

Day :	Length of seedling/shoot (cm.)
1	
5	
10	
15	

Answer the questions on basis of your observation

- What changes did you see in length of seedling with time?
- Name the tissue responsible for such change.
- What change might have taken in root length, below the soil?

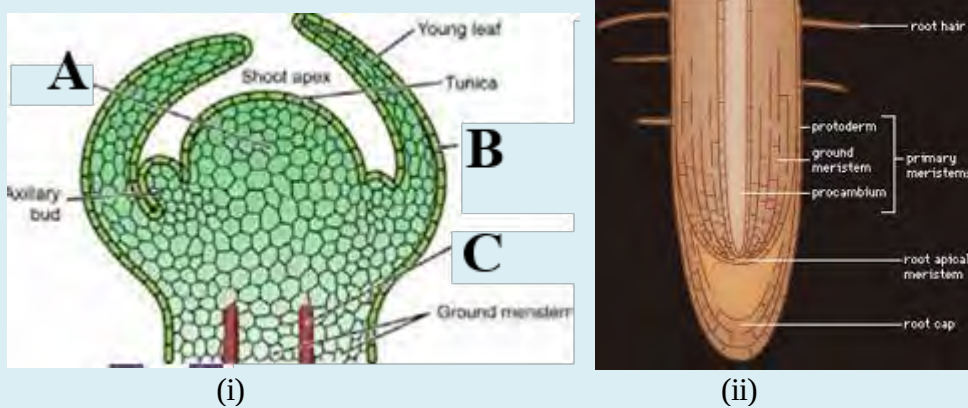
1. MERISTEMATIC TISSUE

It is a group of actively dividing cells, present in growing parts of plant. In short, it is also termed as meristem. Cells, in a meristem, are young, undifferentiated, small, living, thin walled and isodiametric, oval or round. They are compactly arranged and hence, lack intercellular spaces. Each cell has a conspicuous nucleus and dense cytoplasm but lacks reserve food and cell inclusions. Cells

exhibit a high rate of metabolism and vacuoles are generally absent. They retain the power of cell division (mitosis).

Meristems are mainly responsible for growth of the plant parts.

Activity 1.2



Study the given figures and answer the following questions.

- Which figure brings growth of root system in plant?
- In figure i), label the parts a,b and c.
- Compare any two points between figure (i) and (ii).

Types of Meristem

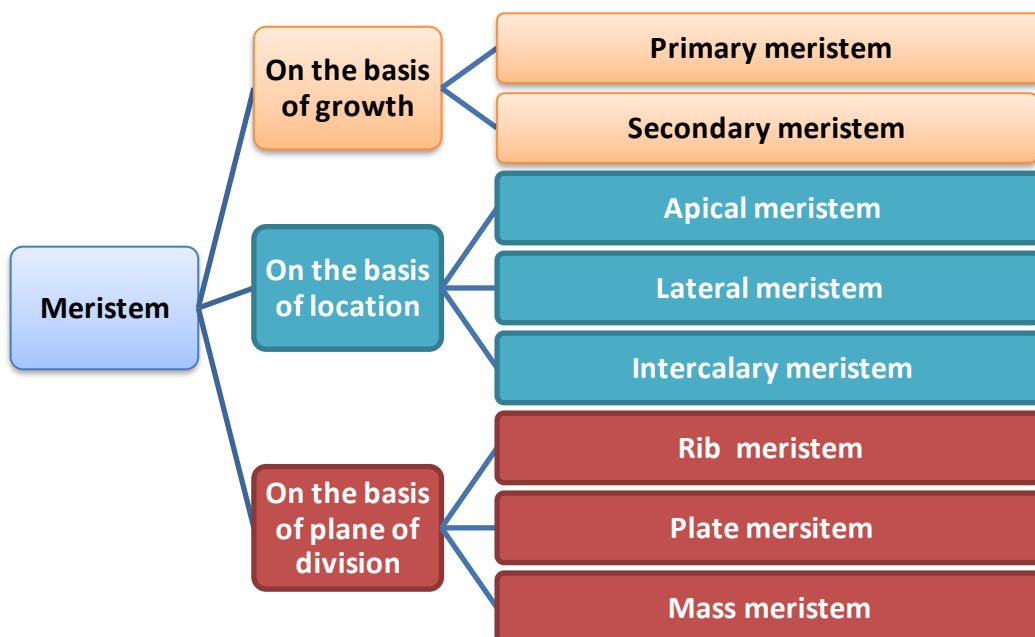


Fig: 1.1 Types of meristem

A. On basis of growth, meristems are of two types:

- Primary meristem:** It is responsible for primary growth of plant. All plants exhibit primary growth.
- Secondary meristem:** It carries out secondary growth in plants. Secondary growth is, generally, limited to dicots and gymnosperms. Example: cork cambium, inter-fascicular cambium etc.

B. On basis of location, meristems are of three types:

- a. **Apical meristem:** It is located at the tip or apex of plant parts such as root, stem, floral bud etc. It is responsible for increase in length or height of plant. Example: root apex, shoot apex etc.
- b. **Lateral meristem:** It is present along the circumference of the plant parts. Simply, it is present in lateral position. Its activity brings increase in thickness or diameter of plant. Example: Vascular cambium in stem of dicots.
- c. **Intercalary meristem:** It is situated at lower part of internodes, bases of leaves etc. It is commonly present in monocots and formed as a result of separation from apical meristem. It contributes for elongation of internodes and regaining erect posture of lodged cereals and grasses.

In most cases, intercalary meristem becomes functional for a short time and eventually differentiates into permanent tissue. It is absent in rosette plants such as cabbage, cauliflower etc.

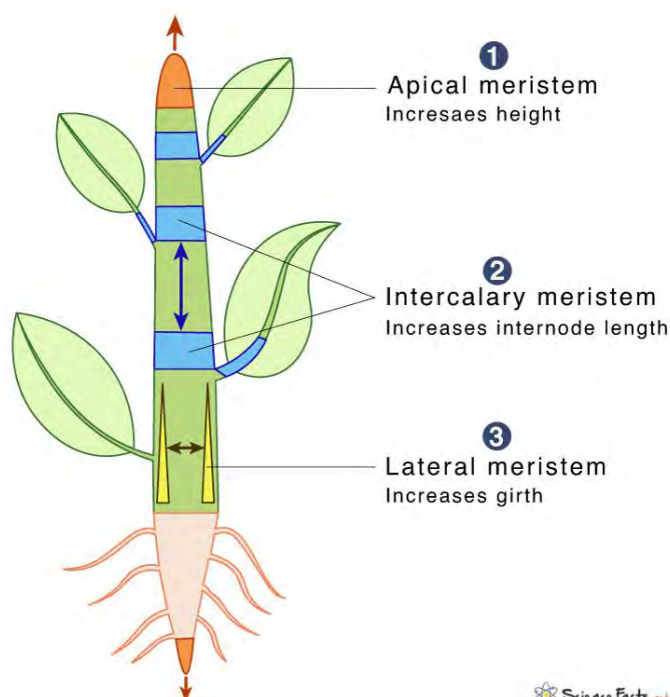


Fig: 1.2 Types of meristem on the basis of position

C. On basis of plane of division, meristems can be divided into three types:

- a. **Rib meristem:** It gives rise to long, thread like structure due to single plane of division of its cells. Lateral roots, tendrils etc. are formed by its activity.



Fig: 1.3 Types of meristem on the basis of plane of division

- b. **Plate meristem** exhibits two planes of division of its constituent cells. As a result, it increases the surface area of the plant part such as leaf.
- c. **Mass meristem** shows all planes of division, hence, is responsible for increase in volume of plant parts such as embryo, ovary etc.

Functions of meristems:

1. Pro-meristem brings embryonic growth whereas primary and secondary meristems carry out primary and secondary growths respectively.
2. Apical meristem increases height/length of plants, lateral meristem increases the circumference/ cross-section area and intercalary meristem increases inter-nodal length in maize, sugarcane and other monocots.
3. Protoderm forms epidermis, ground meristem forms ground tissues such as cortex, endodermis, pericycle, pith etc. and procambium forms vascular tissues.
4. Dermatogen gives rise to epidermis, periblem forms cortex and endodermis whereas plerome is responsible for development of stele (pericycle, vascular bundles, pith, medullary rays).

2. PERMANENT TISSUE

It is a group of mature and differentiated cells, developed from meristems. Cells may be similar or dissimilar, living or non-living or both. Cells have lost the power of division, hence, it does not bring growth of plant. It serves other functions such as storage of food, mechanical support, protection, transport etc.

Types of Permanent tissue

On basis of composition of constituent cells, permanent tissue can be divided into following three groups:

- a. Simple permanent tissue
- b. Complex permanent tissue
- c. Special or secretory tissue

a. Simple permanent tissue

A simple permanent tissue consists of homogeneous cells having a common origin. All the cells are similar in their shape, size as well as function. It is further of three different types; parenchyma, collenchyma and sclerenchyma.

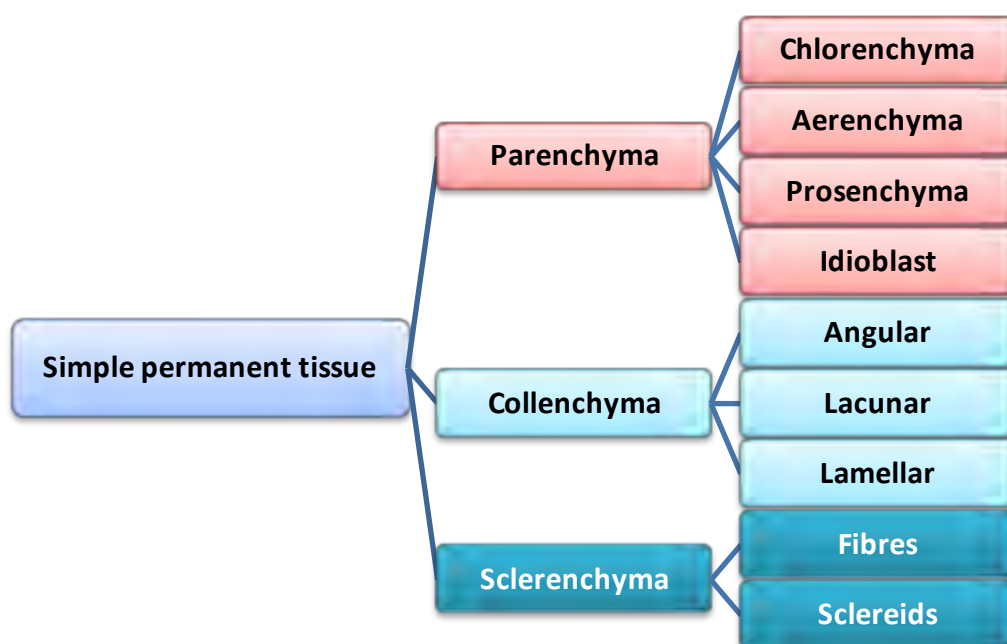


Fig: 1.4 Types of simple permanent tissue

**DID YOU
KNOW?**



The fleshy parts of all of above are made up of a common plant tissue. This tissue is called parenchyma.

i. Parenchyma

It is the most common tissue in plants and consists of less specialized group of living cells. Cells are oval or spherical in shape. They have thin cellulosic wall, nucleus, cytoplasm and vacuole. Cells are loosely arranged and possess intercellular spaces. Parenchyma is commonly present in softer or delicate parts of plants. It mainly serves for **storage of food**. However, parenchyma, often, gets modified to carry out special functions too.

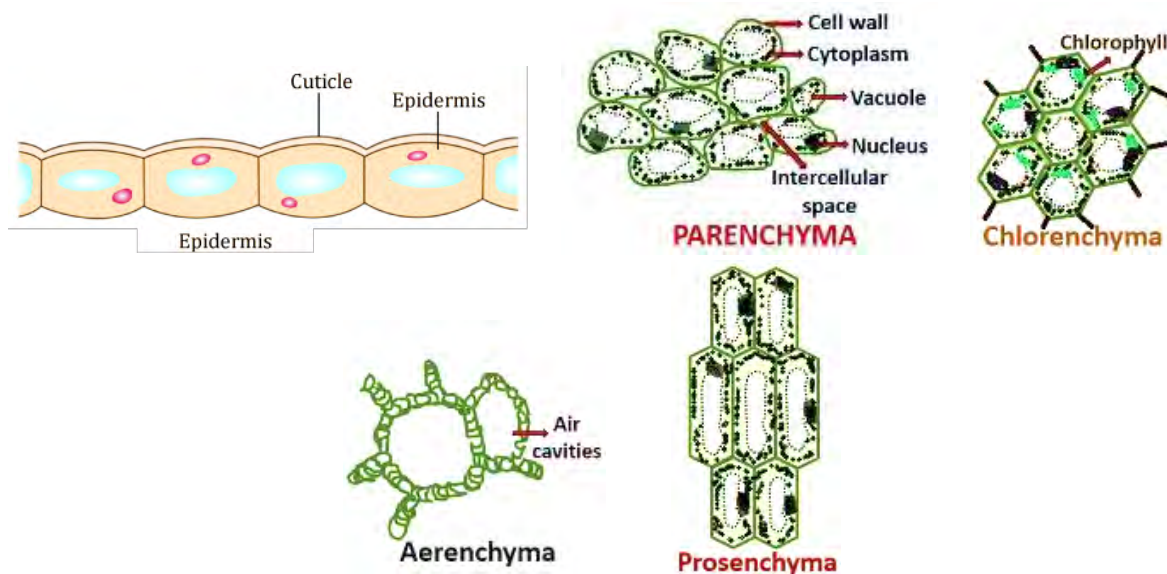


Fig: 1.5 Different types of parenchyma

Some modifications of parenchyma are as follows:

1. **Epiblema/Epidermis**: Single layer of parenchyma which forms outermost layer in root, stem, leaves. It acts as protective layer and assists for absorption of water and minerals in roots.
2. **Chlorenchyma**: Parenchyma which contains chloroplasts in its cells. It is present in mesophyll layer of leaf lamina as well as cortical cells of young stems. It carries out photosynthesis.
3. **Aerenchyma**: Parenchyma which encloses air cavities or air spaces. It is commonly present in aquatic floating plants. It makes the plant part light and buoyant.
4. **Prosenchyma**: Group of elongated, thick walled and compactly arranged living cells. It is present in pericycle, conjunctive tissue etc. and gives additional support to plant parts.
5. **Idioblasts**: Group of large sized parenchymatous cells which store cell inclusions such as tannins, oils, crystals etc.

ii. Collenchyma

It is a group of living, elongated or oval cells having irregular thickenings in their cell walls. Deposition of pectin makes uneven thickening in their walls. Cells are compact, having little or no inter-cellular spaces. Like parenchyma, cells possess nucleus, cytoplasm, vacuole and even chloroplasts. It is present in hypodermis of petiole, pedicel, and young stem of dicots. In leaf of dicots, it forms bundle sheath extensions.

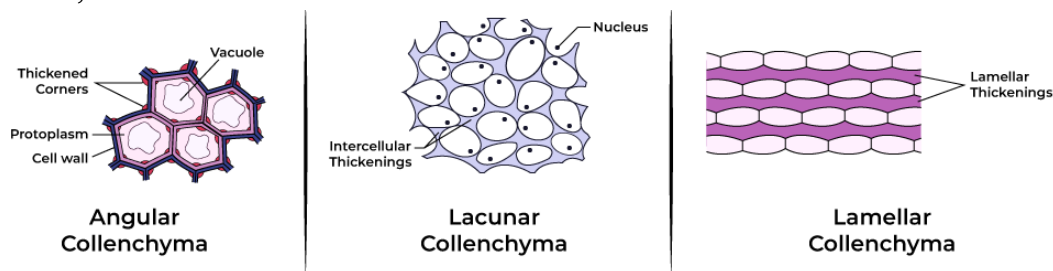


Fig: 1.6 Types of Collenchyma

Collenchyma allows **bending** and thus provides flexibility of tendrils, herbaceous stems of climbers and **prevents from tearing** of leaves. It also provides **mechanical support**. Hence, collenchyma is also regarded as living mechanical tissue.

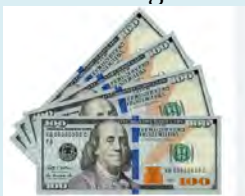
On basis of mode of thickenings in their walls, collenchyma can be of three types: angular collenchyma, lacunar collenchyma and lamellar collenchyma.

Functions of collenchyma:

1. It provides flexibility to plant parts and allows their bending.
2. It prevents lodging of herbaceous plants such as rice, maize etc.
3. It prevents tearing of leaves, due to wind.
4. It provides mechanical strength to young stem, leaves and petioles of herbaceous plant and allows their upright growth.
5. It also assists in photosynthesis and storage of food.

DID YOU KNOW?

Have you ever seen the following materials/ things?



All of them constitute a plant tissue in common. Guess, what can it be?
The answer is **sclerenchyma**.

iii. Sclerenchyma

It is a group of elongated, narrow cells with out intercellular spaces. The cells are dead, having very thick impermeable walls, due to deposition of **lignin**. Hence, it does not serve metabolic functions such as photosynthesis and storage of food. Instead, it provides strength, rigidity, stiffness and protection to plant parts. Sclerenchyma is present in seed coat (mango, guava etc.), hypodermis of monocot stem (hemp, flax etc.), bundle sheath, stony fruits like coconut, *Juglans* (Okhar) etc.

Based on the shape of cells, sclerenchyma is of two types:

1. Fibres:

Fibres are much elongated, narrow, spindle shaped dead cells with tapering ends. They are of three types; surface fibres, wood fibres and bast fibres.

2. Sclereids

Sclereids differ from fibers for having isodiametric cells with higher degree of lignification. They are often called stone cells and mainly responsible for protection. They make protective layer in seeds, hard fruits etc.

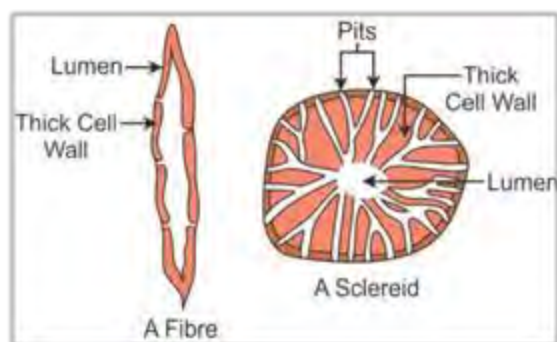


Fig: 1.7 Types of sclerenchyma

Functions of sclerenchyma:

1. Fibres provide mechanical support to different plant parts.
2. Fibres of jute, hemp, flax etc. are used to manufacture commercial products.
3. Sclereids provide hardness or stiffness to plant parts.
4. In almond, coconut etc., sclereids form stony endocarps.
5. In legume seeds, sclereids form protective covering of testa.
6. Grittiness of some fruits such as guava, pear, apple etc. is due to sclereids.

Activity: 1.1

Engage students to draw the different simple permanent tissues on chart paper by using color pencils and guide them to label the figures.

b. Complex Permanent tissue

It is a group of heterogeneous cells, co-ordinated to carry out specific function. Cells in such tissue vary in their origin, shape, size, nature and function. Complex tissues mainly take part in conduction or transport function, so, are also known as **conducting tissues**. They are of two types; **xylem** and **phloem**. They are the constituents of vascular bundles in plants. Hence, they are also termed as **vascular tissues**.

i. Xylem

It is also known as **wood/ hadrome**. It is made up of four different types of cells- **tracheids**, **vessels**, **xylem parenchyma** and **xylem fibres**. Vessels are the main elements of xylem in angiosperms.

Xylem conducts the sap uni-directionally, from root to the leaf, flower, fruit etc. through stem and branches. As most of the constituents of xylem are non-living, it also provides mechanical strength.

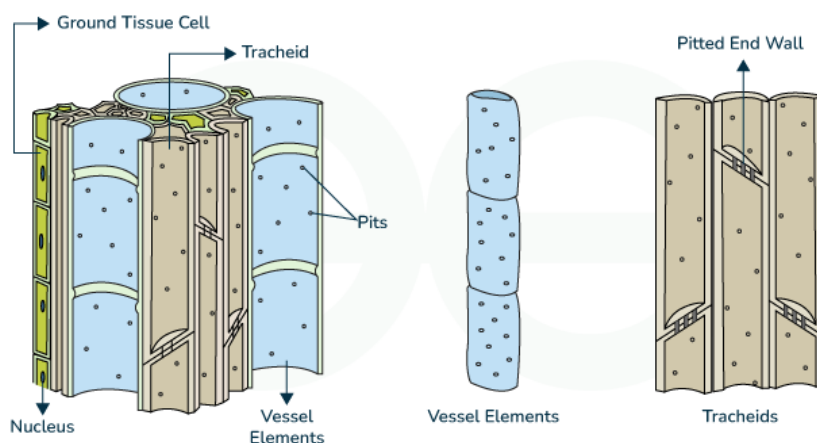


Fig: 1.8 Structure of xylem

Tracheids

Tracheids are elongated non-living cells. They possess thick walls, due to deposition of lignin, wide lumen and narrower, oblique end walls. Tracheids are main conducting elements in the xylem of lower vascular plants, such as pteridophytes and gymnosperms. In angiosperms and advanced gymnosperms, they assist vessels for upward conduction of water and minerals. Their walls exhibit various types of secondary thickenings: annular, spiral, scalariform, reticulate and pitted. Due to thickened walls, tracheids also give mechanical strength.

Vessels

Vessels are short, wide, tube-like dead cells. They have transverse or slightly oblique end walls and are placed one above another. Their end walls are completely or partially dissolved, so, appear as a continuous or unbroken channel. Their walls also show secondary thickenings: annular, spiral, scalariform, reticulate and pitted. They are also connected to tracheids through pits.

Vessels are the main conducting elements of xylem and perform upward conduction of water and minerals through their lumen. They are absent in most of the gymnosperms and pteridophytes. Due to thickened walls, vessels also provide mechanical support.

Xylem parenchyma

A group of small, thin walled, living cells associated with xylem is xylem parenchyma. Cells are polygonal in outline and lack intercellular spaces. They help in storage as well as slow lateral conduction of sap.

Xylem fibres

They are non-living, elongated and thick walled sclerenchymatous fibres, present in xylem. Xylem fibres help in mechanical support and rigidity.

Primary and secondary xylem

Primary xylem is formed during primary growth from procambium. It includes protoxylem and metaxylem. Metaxylem develops after the protoxylem but before secondary xylem. Metaxylem has wider vessels and tracheids than protoxylem. Secondary xylem is formed from vascular cambium during secondary growth. It is absent in monocots. It forms the main wood in gymnosperms and dicots.

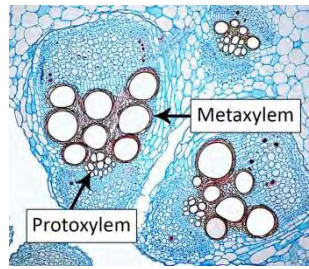


Fig: 1.9 Protoxylem and metaxylem

On basis relative position of protoxylem and metaxylem, xylem can be of following types.

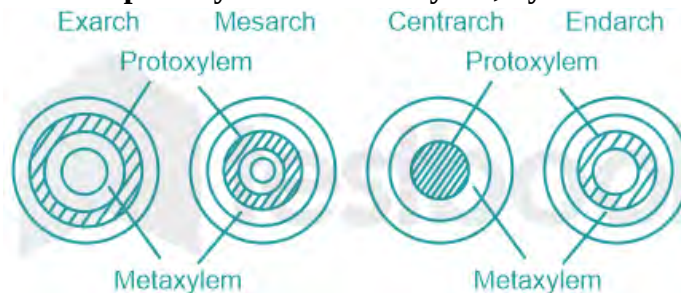


Fig: 1.10 Types of xylem on basis of relative position of protoxylem and metaxylem

Endarch: It is the condition in which protoxylem lies towards centre (pith) and metaxylem lies towards the periphery. It can be observed in stem and leaf.

Exarch: Xylem is said to be exarch, if protoxylem lies towards periphery and metaxylem lies towards the centre. It is present in roots.

Mesarch: When protoxylem lies in between metaxylems or metaxylem lies in between protoxylems in linear position, it is said to be mesarch. It is found in leaf of some dicots.

Centrarch: It is a condition of having central protoxylem, being surrounded by metaxylem. It can be observed in ferns. Diagram

ii. Phloem

It is also known as **bast/leptome**. Phloem constitutes four types of cells; **sieve tubes, companion cells, phloem parenchyma and phloem fibres**. All components are living except phloem fibres. Phloem is a complex tissue that transports the organic food from leaf to storage organs as well as all over the plant body. Here, the flow of organic food is bidirectional.

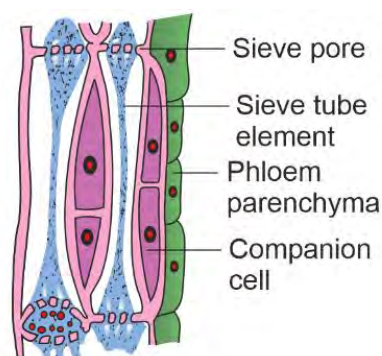


Fig: 1.11 Structure of phloem

Sieve tubes

They are wide, tubular, elongated living cells, placed end to end by transverse or oblique end walls. Their end walls are perforated, so appear as plates having several pores, known as sieve plates. Each cell, at maturity, contains a peripheral layer of cytoplasm **without nucleus**. Sieve tubes are the main components of phloem which conduct organic food through sieve pores.

Companion cells

They are smaller, narrower, elongated, living cells attached with sieve tubes. They are also called sister cells because sieve tubes and companion cells have common origin. Both of them develop from same parent cell as a result of mitosis. Each companion cell has thin cell wall, a functional nucleus and dense cytoplasm. Its nucleus also **regulates the metabolic activities of sieve tube**, hence named as companion cell. Organic food are actively secreted into, and actively removed from, sieve-tubes by their companion cells.

In phloem of gymnosperms and pteridophytes, companion cells are absent and replaced by modified parenchyma known as **albuminous cells**.

Phloem parenchyma

A group of thin wall, living, compactly arranged cells present in phloem is known as phloem parenchyma. It takes part in storage and slow conduction of food. It is absent in phloem of monocot stem.

Phloem fibres

Thick walled, dead, elongated sclerenchymatous fibres associated with phloem are phloem fibres. They provide mechanical support.

Vascular Bundle

It is the strand of vascular system in plants. A vascular bundle consists of xylem and phloem. In any plant part during primary growth, vascular bundles can be observed under microscope. Cambium may be present in it.

Types of vascular bundle:

- a) **Radial type:** When xylem and phloem occur at alternate positions at different radii, it is said to be radial vascular bundle. Such vascular bundles are present **in root**.

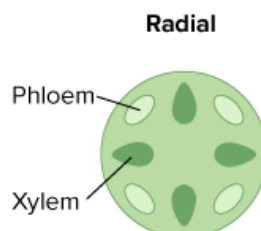


Fig: 1.12 Radial type of vascular bundle

- b) **Conjoint type:** If xylem and phloem get attached together as a single bundle, it is known as conjoint vascular bundle. It can further be of three types: collateral, bicollateral and concentric.

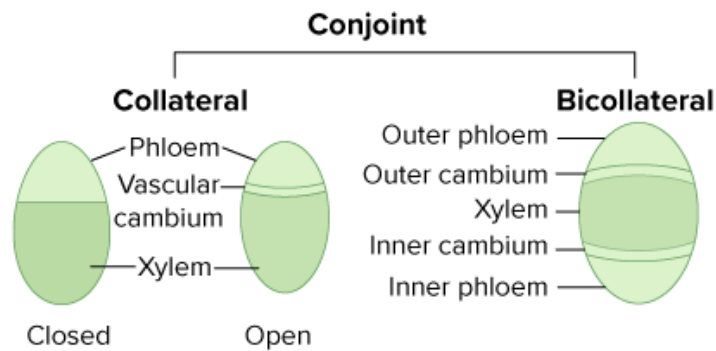


Fig: 1.13 Conjoint type of vascular bundle

In collateral type, phloem and xylem are lateral in position. Phloem lies towards outside of xylem. If there is a strip of cambium in between phloem and xylem, it is said to be conjoint, collateral and open type. Example: **Sunflower stem**. But, if there is no cambium in between them, the bundle is said to be conjoint, collateral and close type. Example: **Monocot stem**

In bicollateral type, xylem lies in between outer phloem and inner phloem. Cambia are always present in this case; outer cambium in between outer phloem and xylem as well as inner cambium in between inner phloem and xylem. Example: **Cucumber stem**.

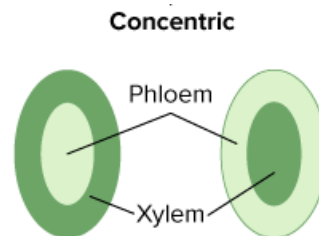


Fig: 1.14 Concentric type of vascular bundle

In concentric type, one of them (xylem or phloem), is completely encircled by another. It is also of two types; amphicribal and amphivasal.

In amphicribal type, xylem is at centre which is surrounded by phloem ring. It can be seen in **pteridophytes** and **aquatic hydrophytes**. In amphivasal type, phloem makes a central core, being surrounded by xylem. It can be observed in **stem of Dracaena, Yucca** etc.

Activity: 1.2

Collect a classification chart of vascular bundles from biology lab. Display on the whiteboard. Call students one by one and ask to describe the figure and answer the questions raised by classmates.

c. Special tissue or secretory tissue diagram

It is a tissue formed as a result of modification of simple or complex tissue and gets involved in secretion or excretion. Hence, special tissue is also known as secretory tissue. It may have special type of cavity or canal for the storage of chemical substance to be secreted.

It can be divided into two types:

i) Laticiferous tissue

It is a specialized plant tissue that produces and stores latex, a secondary metabolite that plants use for defense and wound healing. Laticiferous tissue is made up of latex cells and latex vessels that form a tube-like network throughout the plant. It produces latex that

contains compounds like peptidases, chitinases, and chitin-binding proteins that help plants defend against microbes and insects. Laticiferous tissue may also play a role in wound healing.

e.g, *Euphorbia*, *Cannabis*, *Ficus*, *Morus*, banana, cactus, rubber, papaya, sunflower etc.

ii) Glandular tissue

This tissue consists of special structures; the glands. These glands contain some secretory or excretory products. A gland may consist of isolated cells or a small group of cells with or without a central cavity.

e.g. oil glands, nectar glands, digestive glands etc.

1.1.3 ANATOMY OF DICOT AND MONOCOT ROOT

A. Anatomy of dicot root

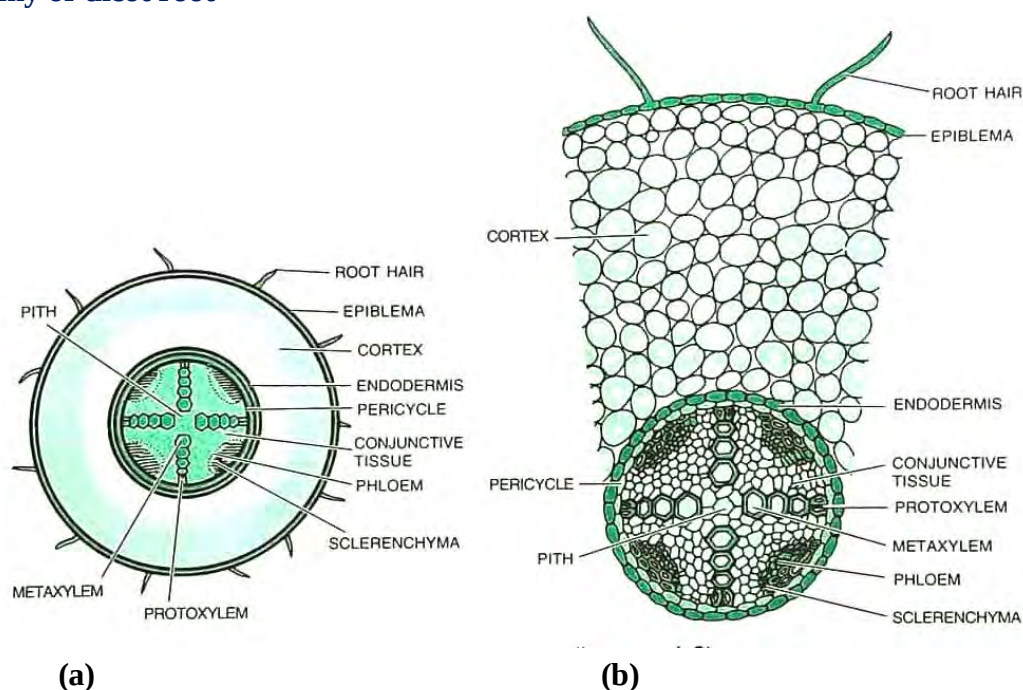


Fig: 1.15 Anatomy of dicot root (a) Diagrammatic (b) Enlarged

Transverse section of a young dicot root shows the following tissue organizations:

1. **Epiblema:** It is the outermost layer of dicot root. It consists of a single layer of thin walled compactly arranged parenchymatous cells. It is devoid of cuticle and stomata. Some of the cells give rise to unicellular root hairs, for absorption of water and minerals from soil. It also acts as protective layer. Epiblema is also called piliferous layer or rhizodermis.
2. **Cortex:** It is a multilayered zone of parenchymatous cells, lying just below epiblema. Cells are oval or spherical, thin walled and possess intercellular spaces. Chloroplasts are absent. It helps in storage of food and radial conduction of water and minerals from epiblema to inner side.

3. **Endodermis:** Below the cortex, there is a single layer of **barrel shaped** living cells, known as endodermis. It is also considered as innermost cortex. Most of the endodermal cells have thickened bands of **suberin and lignin** on their **radial and tangential walls**. These thickenings are known as **casparian strips**, which prevent water flow towards the xylem. However, few cells, lying outside of xylem, are thin walled and lack casparian strips. They are known as **passage cells** which allow water pass from cortex to xylem. Hence, endodermis is also called “Biological check post”.
4. **Pericycle:** It lies inner to endodermis and consists of one or few layers of thick walled living cells, without intercellular spaces. It gives rise to lateral roots and vascular cambium during secondary growth.
5. **Vascular bundles:** In dicot root, vascular bundles are of radial type; xylem and phloem alternate each other and at different radii. Number of vascular bundle ranges from **2 to 6**. It constitutes xylem and phloem.
 - a. **Xylem:** It makes long radiating strand and consists of vessels, tracheids and xylem parenchyma. Fibres are generally absent in young root. Vessels appear polygonal or angular in outline and are linearly arranged. Xylem shows exarch condition, as protoxylem lies towards pericycle and metaxylem extends towards pith. Xylem helps in upward conduction of water and minerals as well as mechanical support.
 - b. **Phloem:** Alternate to xylem, there is phloem in semi-lunar shape. It consists of sieve tubes, companion cells, phloem parenchyma and few fibres. It takes part in conduction of organic food.
6. **Conjunctive tissue:** It is parenchymatous in nature and consists of elongated, thin walled, compactly arranged cells, extending in between xylem and phloem. It stores food and partly contributes in the formation of vascular cambium during secondary growth.
7. **Pith:** It is the central parenchymatous region and also known as **medulla**. In dicot root, pith is **very narrow** or **absent**. It consists of oval, round or polygonal cells with or without intercellular spaces. It also stores the food.

B. Anatomy of monocot root

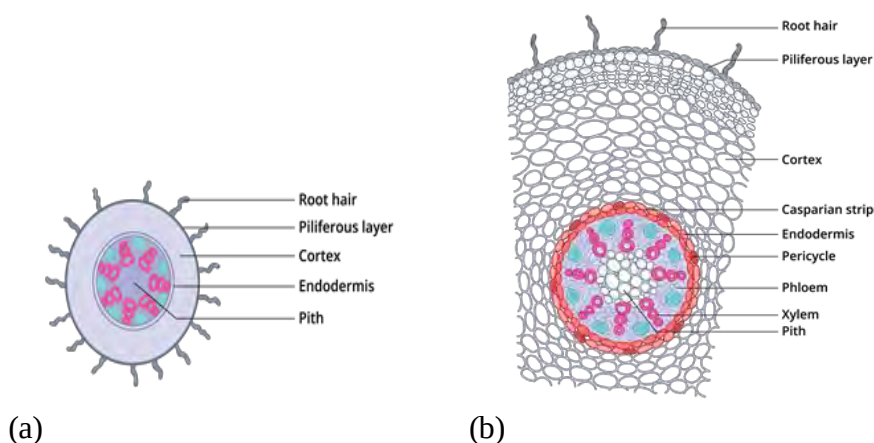


Fig: 1.16 Anatomy of monocot root (a) Diagrammatic (b) Enlarged

Transverse section of typical monocot root shows the following tissue organization.

1. **Epiblema:** It is the outermost single layer made from compactly arranged parenchymatous cells without intercellular space. Usually, epiblema has no stomata but bears unicellular root hairs.
2. **Cortex:** It is a multi-layered region below epiblema and made up of oval parenchymatous cells with intercellular spaces. The intercellular spaces usually help in gaseous exchanges, storage of starch, etc. In old roots, few layers of cortex, just below epiblema, give rise to a single or multilayered sclerenchymatous region called exodermis which helps in mechanical support to the roots. Cortex involves in conduction of water from epiblema to inner tissues.
3. **Endodermis:** It is innermost layer of cortex made from barrel shaped parenchyma. It forms a definite ring around the stele. Endodermal cells are characterized by the presence of **casparian strips**, due to deposition of suberin and lignin on their radial and tangential walls. Usually passage cells are absent in monocot roots. It regulates the inward and outward flow of water and minerals and prevents diffusion of air into xylem elements.
4. **Pericycle:** It is single layered (but multi-layered in *Smilax*) zone of thin walled parenchymatous cells, lying just below endodermis. It is the outermost layer of stele. It gives rise to **lateral roots only**. In older root, it may become sclerenchymatous.
5. **Vascular bundles:** They are radially arranged, i.e. xylem and phloem bundles alternating each other at different radii. They are **polyarch** (more than 6).
 - a. **Xylem:** Xylem is made of tracheids, vessels, xylem parenchyma and xylem fibres. It helps in mechanical support as well as conducts water and minerals in upward direction. It is exarch in arrangement. Protoxylem has smaller vessels with **spiral or annular** wall thickenings, whereas metaxylem has wider vessels with **reticulate or pitted** wall thickenings.
 - b. **Phloem:** It consists of sieve tubes, companion cells and phloem parenchyma. Usually, **phloem fibers are absent**. It helps in conduction of food.
6. **Conjunctive tissue:** It is parenchymatous tissue which separates xylem and phloem bundles. It may become sclerenchymatous in older roots.
7. **Pith:** It is large or well developed and occupies the central portion of the root. Pith consists of thin walled, oval or rounded parenchymatous cells with or without intercellular spaces. It stores abundant amount of starch grains.

Activity: 1.3

Collect the charts of root anatomy of monocot and dicot from biology lab and display them on the whiteboard. Make two group of students and let them discuss the anatomical differences. Allow the representative from each group to present summarized views.

1.1.4 ANATOMY OF DICOT AND MONOCOT STEM

A. Anatomy of dicot stem

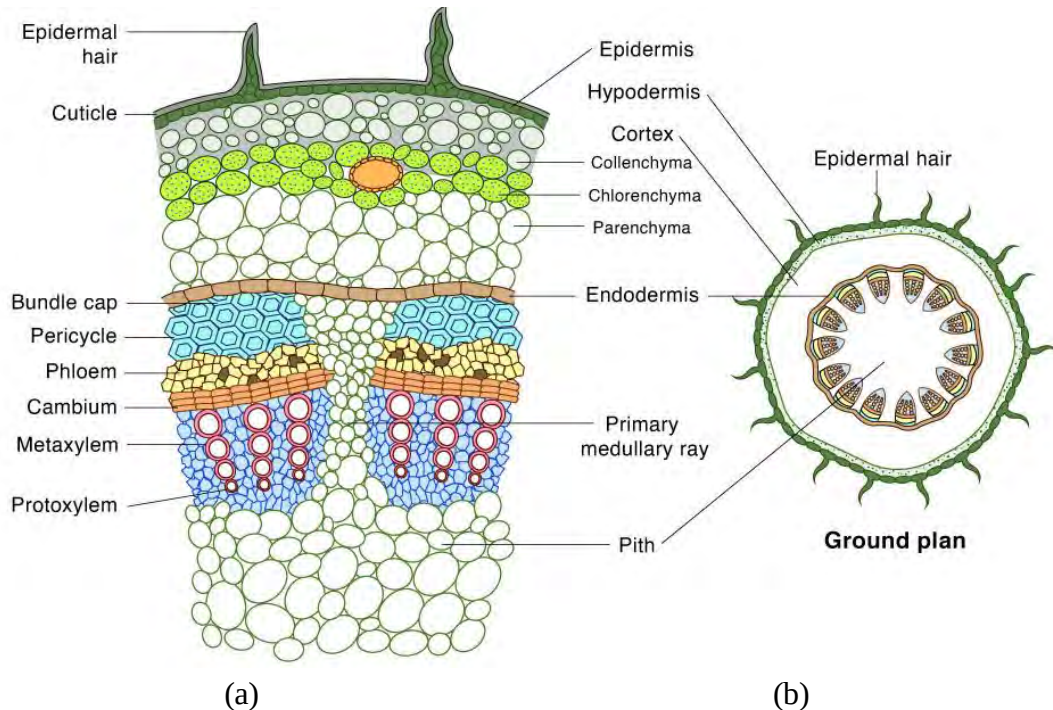


Fig: 1.17 Anatomy of dicot stem (a) Enlarged (b) diagrammatic

Transverse section of young dicot stem shows the following anatomical features.

1. **Epidermis:** It is the outermost layer of stem. It is made up of tightly packed elongated, parenchymatous cells that lack chloroplasts and are transparent. Epidermis is covered by cuticle and also bears several trichomes or multicellular hairs. **Stomata are also present** in epidermis. Each stoma is surrounded by two specialized, **kidney shaped** cells known as **guard cells**. Stomata help in gaseous exchange.
2. **Hypodermis:** It lies below epidermis and consists of 3 to 4 layers of **collenchymatous cells**. Intercellular spaces are absent, due to deposition of pectin. Below the stomata, hypodermis is either non-existent or barely visible.
3. **General Cortex:** Below hypodermis, there is narrow cortex. It is made up of oval or angular, thin walled parenchymatous cells having intercellular spaces. The outer cortical cells in very young stem have chloroplasts and hence, perform photosynthesis. The cortex also stores food.
In dicots, **like sunflower**, there are several longitudinally running **oil ducts** that go through the cortex and each oil duct has a channel that is bordered by a tiny glandular cell epithelium.

4. **Endodermis:** It is a one-celled thick, wavy layer. The endodermis is also known as innermost layer of cortex. It is composed of barrel shaped cells without intercellular spaces. Typically, **casparian strips are absent**. Cells have noticeable starch granules. Thus, the stem endodermis is also called a **starch sheath**.
5. **Pericycle:** It is a thick, layered tissue, located inside the endodermis. Pericycle is heterogeneous in nature, as it is made of alternate patches of parenchyma and sclerenchyma. Sclerenchyma appears as semilunar or semicircular patches called **bundle caps**, just above the phloem of each vascular bundle whereas the parenchymatous pericycle is located outside the medullary rays.
6. **Vascular Bundle:** Vascular bundles are numerous and are **arranged in a ring** (eustele). They are **conjoint, collateral** and **open** type. However, in *Cucurbita* stem, vascular bundles are conjoint and **bicollateral**.
 - a. **Xylem:** Xylem lies near the pith or inner part of the vascular bundles and constitutes tracheids, vessels, xylem parenchyma and xylem fibres. It is **endarch** because protoxylem lies towards the pith and metaxylem is present towards periphery. Vessels of xylem are polygonal in outline and arranged linearly. It conducts water and minerals in upward direction.
 - b. **Phloem:** It is located towards periphery, just below sclerenchymatous pericycle. Phloem is composed of sieve tubes, companion cells, phloem parenchyma and few phloem fibres. It takes part in conduction of organic food.
 - c. **Cambium:** Cambium is a narrow band of primary meristematic cells that lies between the phloem and the xylem. It is also called intra-fascicular cambium and involves in secondary growth.
7. **Medullary Rays:** They are radially elongated, loosely or compactly arranged parenchymatous cells present between adjacent vascular bundles. Through pits, ray cells come into close touch with the phloem and xylem's conducting cells. They help in radial conduction of food and water. Additionally, they exchange gases from the cortex to the pith and vice versa.
8. **Pith:** It occupies the central portion of the stem. Pith is made of polygonal, oval or spherical parenchymatous cells having intercellular spaces. It stores the food. In some dicots, such as *Cucurbita*, the middle portion of the pith separates or disorganizes to form a cavity, known as **pith cavity**.

B. Anatomy of monocot stem

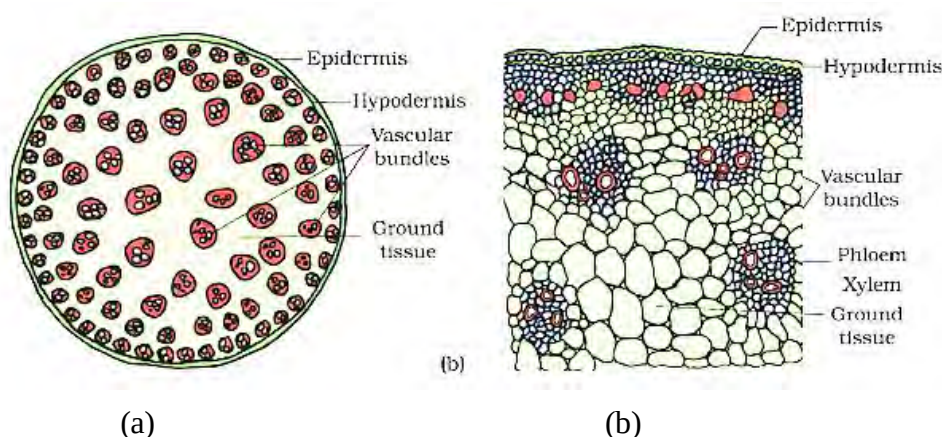


Fig: 1.18 Anatomy of monocot stem (a) diagrammatic (b) Enlarged

Transverse section of monocot stem shows following tissue organization.

1. **Epidermis:** It is the outermost layer that comprises a single layer of parenchymatous cells packed with a thick cuticle. No epidermal outgrowths are found. Epidermis acts as outer protective layer. In young stem, it also bears minute pores, known as stomata, each surrounded by two **dumb-bell shaped** guard cells. Stomata help in gaseous exchange.
2. **Hypodermis:** Few layers of sclerenchymatous cells, found below the epidermis, is known as hypodermis. It helps in providing **mechanical strength** to plants.
3. **Ground tissue:** It consists of oval or rounded, living, thin walled parenchymatous cells having prominent intercellular spaces. The ground tissue is not differentiated into cortex, endodermis, pericycle, pith and medullary rays. It is homogeneous in nature and helps in storage of food.
4. **Vascular bundles:** In monocot stem, vascular bundles are found **scattered throughout the ground tissue** (atactostele). They are **conjoint, collateral and close** type. These are small-sized and numerous in the peripheral region but larger and fewer near the centre. Each bundle is surrounded by a thin sheath of sclerenchymatous fibres, known as **bundle sheath**. Each vascular bundle consists of a phloem and a xylem. **Cambium is absent**.
 - a. **Phloem:** Phloem lies towards outer side and consists of sieve tubes, companion cells and few phloem fibres. **Phloem parenchyma are absent**. It takes part in conduction of organic food.
 - b. **Xylem:** It lies inner to phloem and consists of few but distinct vessels, tracheids, xylem parenchyma and xylem fibres. Vessels are circular in outline and arranged in characteristic V or Y shape. Xylem is **endarch**. Two larger metaxylem vessels lie at outer side and one or two smaller protoxylem vessels are present at inner side. Some of the parenchyma of protoxylem, by separation as well as disintegration, form a cavity that stores water. It is known as **water cavity**. Xylem takes part in upward conduction of sap as well as mechanical support.

1.1.5 ANATOMY OF DICOT AND MONOCOT LEAF

A. Anatomy of dicot leaf

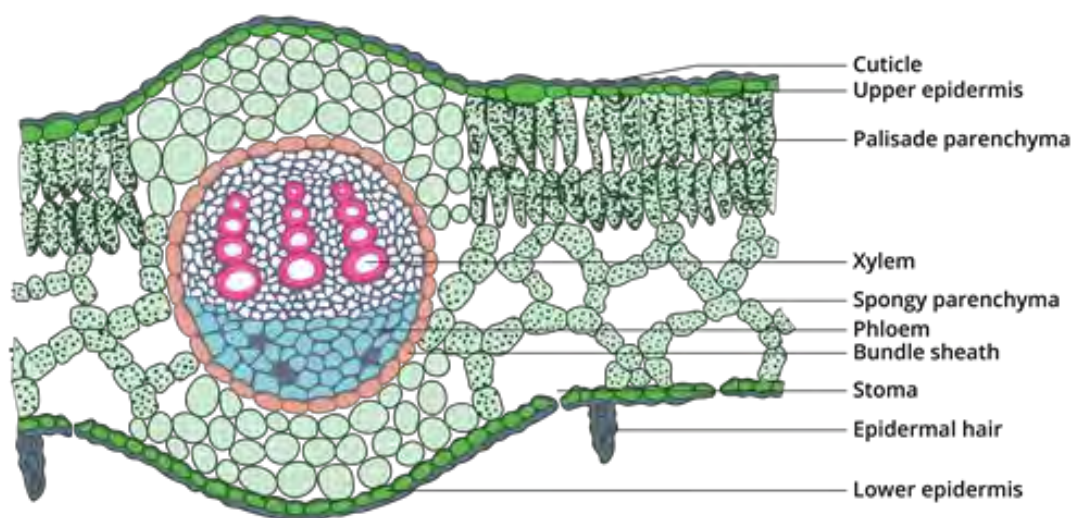


Fig: 1.19 Anatomy of dicot leaf

Vertical section of a typical dicot leaf shows following internal structures.

1. **Epidermis:** A leaf is lined by two epidermis; upper epidermis on upper surface/ adaxial surface/ ventral surface. It is more cutinized and made up of compactly arranged barrel shaped parenchymatous cells. Stomata are either **fewer in number or absent on upper epidermis**. Lower epidermis is present on lower surface/ abaxial surface/ dorsal surface. It is poorly cutinized and consists of **many stomata**. Cuticle checks loss of water, by minimizing transpiration. Stomata take part in gaseous exchange between leaf interior and outer atmosphere.
2. **Mesophyll tissue:** In between upper and lower epidermis, there extends a mass of parenchymatous tissue, known as mesophyll tissue. It consists of **abundant chloroplasts** and is main **site of photosynthesis**. In dicot leaf, mesophyll tissue is further differentiated into palisade layer and spongy layer.
 - a. **Palisade layer:** It is the chlorenchymatous zone lying below upper epidermis. It consists of elongated, parallelly placed, compactly arranged parenchymatous cells, having abundant chloroplasts.
 - b. **Spongy layer:** It lies above the lower epidermis and consists of loosely arranged parenchymatous cells having large intercellular spaces. Those spaces are filled with air, hence also known as air cavities. Cells are smaller, oval or elongated with fewer chloroplasts. Spongy layer helps in exchange of gases. The air cavity, lying adjacent to stomatal pore is known as **sub-stomatal cavity**, from where water vapours diffuse out to the atmosphere during stomatal transpiration.

3. **Vascular bundles:** In dicot leaf, vascular bundles are numerous and vary in size. They are located inside mid-rib and veins, by replacing mesophyll tissue. Vascular bundle at mid-rib is larger and size of vascular bundle goes on decreasing, when veins become narrower towards the leaf margins. Each vascular bundle is **conjoint, collateral, close** type and surrounded by a sheath of compactly arranged parenchyma, known as **bundle sheath**.
- Phloem:** It lies towards lower epidermis and is made up of sieve tubes, companion cells, phloem parenchyma and few phloem fibres. It involves in conduction of food to other parts of plant.
 - Xylem:** It is present towards upper epidermis. Xylem constitutes vessels, tracheids, xylem parenchyma and xylem fibres. Vessels and tracheids take part in conduction of water and minerals as well as mechanical support.
4. **Bundle sheath extension:** At the mid rib-region, mesophyll tissue is absent. The vascular bundle lies at centre and on either side, from bundle sheath to epidermis, a mass of **collenchymatous cells** is present. It is known as bundle sheath extension. It protects vascular bundles from damage even if the leaves are distorted by external mechanical forces such as wind, storm etc.

A. Anatomy of monocot leaf

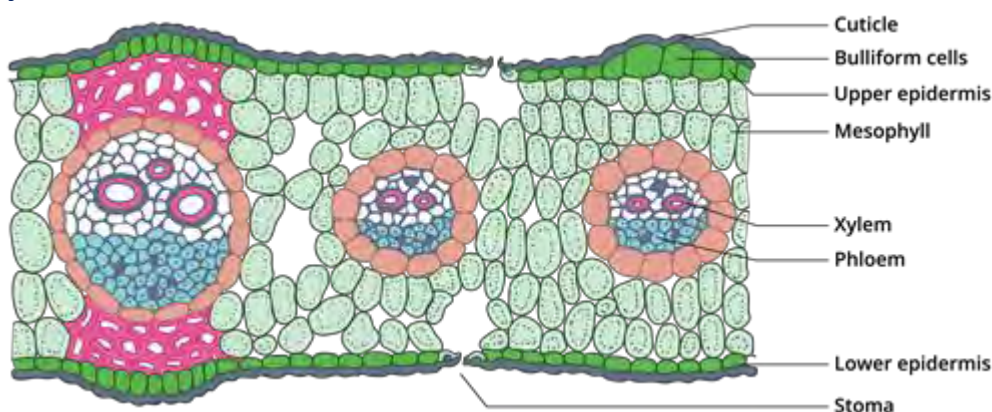


Fig: 1.20 Anatomy of monocot leaf

Under microscope, a vertical section of typical monocot leaf shows the following features.

- Epidermis:** There are two epidermis; upper epidermis and lower epidermis. Each of them consists of single layer of compact barrel shaped cells and is externally covered by cuticle layer. Stomata are uniformly present on either surfaces. Epidermis acts as outermost protective layer, check the loss of water and take part in gaseous exchange through stomata. In some monocots (eg.maize), upper epidermis has few thin walled, large turgid cells, known as **bulliform cells**. These cells help in rolling of leaf during hot and dry seasons, to minimize transpiration from leaf surfaces.
- Mesophyll tissue:** It is the parenchymatous tissue in leaf blade region and extends between two epidermis. It is homogeneous in nature and **undifferentiated**. Cells are, larger, oval or rounded, thin walled and have intercellular spaces filled with gases. They contain chloroplasts and take part in photosynthesis.

3. **Vascular bundles:** They lie parallel in position at central part of leaf and are of different size. Vascular bundles are **conjoint, collateral and close** type and surrounded by a single layer of **parenchymatous bundle sheath**.
- Phloem:** It is situated towards lower epidermis and consists of sieve tubes and companion cells and few phloem fibres. Phloem parenchyma is absent. Phloem takes part in conduction of prepared food to other parts of plant.
 - Xylem:** Each vascular bundle possesses xylem patch towards upper epidermis. It is made up of vessels, tracheids, xylem parenchyma. **Xylem fibres are less conspicuous**. Vessels are circular in outline and arranged in V-shape. Two large metaxylem vessels are present towards lower epidermis or phloem whereas a small protoxylem vessel is facing towards upper epidermis. Tracheids and vessels mainly conduct water and minerals. Additionally, they also give mechanical support.
4. **Bundle sheath extension:** In mid-rib region, between the bundle sheath cells and epidermal cells, mesophyll tissue is replaced by special supporting cells, known as bundle sheath extension. It is made of dead **sclerenchymatous cells** which safeguard vascular bundles from potential injury or damage.

Activity: 1.4

Split the students in two groups and involve them to prepare a chart diagram of dicot leaf and monocot leaf. Engage a representative of each group to display the chart on whiteboard and point out the key anatomical features. Involve each student in discussion turn by turn.

1.1.6 SECONDARY GROWTH OF DICOT STEM

Primary growth universally takes place in all plants and results in increase in height of shoot system, deeper extension of root system and formation of lateral appendages. However, secondary growth is second phase of growth which results in increase in thickness/ girth/ diameter/ cross-sectional area of root, stem, branch etc., mainly in dicots and gymnosperms. It does not take place in pteridophytes and monocots. It is also absent in leaves.

Secondary growth occurs due to the formation of secondary tissues by the activity of two types of lateral meristem: **Vascular cambium** and **cork cambium**.

Mechanism of secondary growth in dicot stem:

On the basis of the activities of vascular cambium and cork cambium, the process of secondary growth in dicot stem can be discussed under the following headings:

1. Activity of the vascular cambium
2. Activity of the cork-cambium

1. Activity of vascular cambium

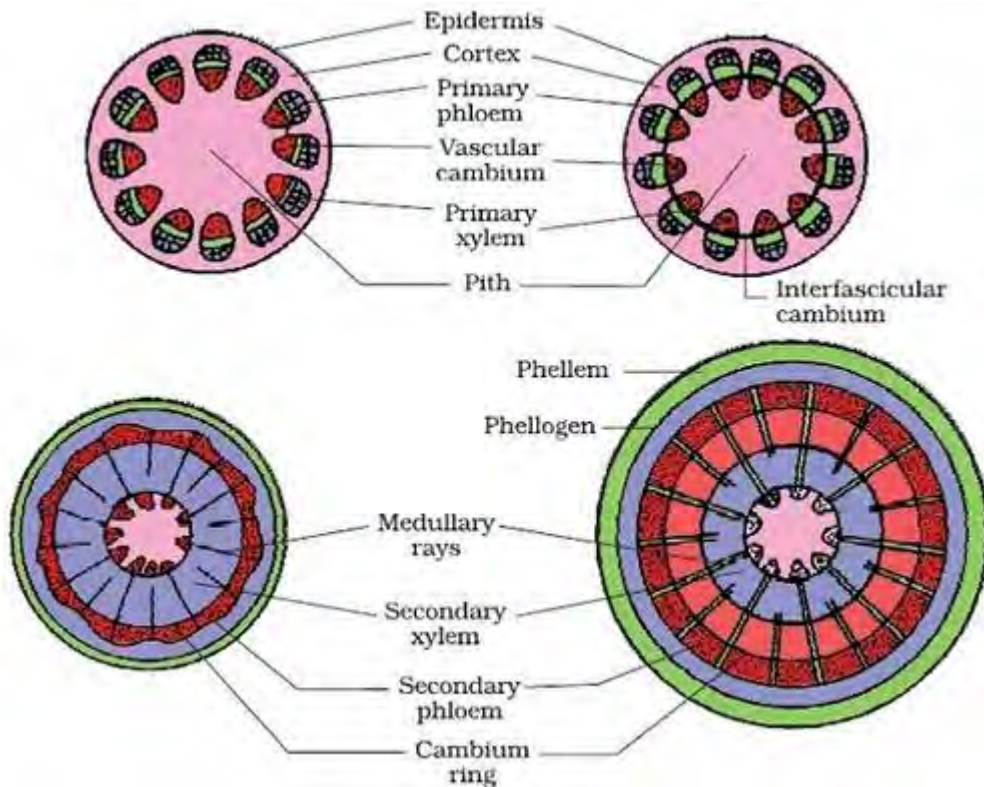


Fig: 1.21 Stages of secondary growth

Due to the meristematic activity of vascular cambium, secondary tissues are added in stellar region. So, widening of stele takes place. It is known as intra-stellar secondary growth. It adds up the number of annual rings each year. It is mainly responsible for the formation of secondary xylem(wood), namely **heartwood** and **sapwood**.

It involves the following steps:

- Formation of cambium ring:** Each vascular bundle in a dicot stem, cambium is present in between xylem and phloem. It is known as **intra-fascicular cambium**.

At the beginning of secondary growth, some cells of medullary rays, by de-differentiation, become active and show meristematic activity. As a result, new strip of cambium is formed in between adjacent vascular bundles, which is known as **inter-fascicular cambium**. Both the intra-fascicular and inter-fascicular cambia unite together to form a complete ring, known as **cambium ring**.

The cambium ring consists of a single layer of cells. There are two types of initials; fusiform initials and ray initials. Fusiform initials are elongated and spindle shaped whereas ray initials are shorter and isodiametric.

- Formation of the secondary vascular tissues:** It takes place due to the activity of **fusiform initials**. Each fusiform initial divides into two daughter cells, one of which remains meristematic and other

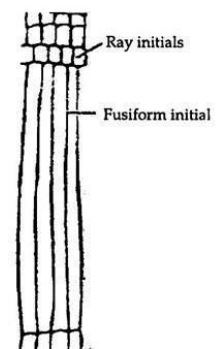
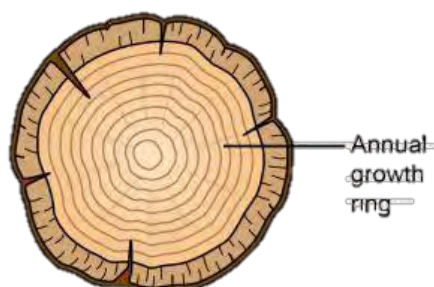


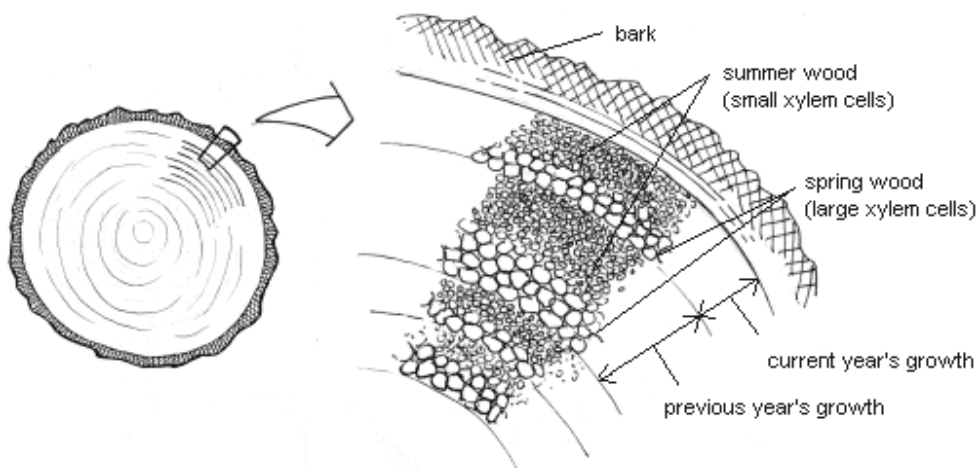
Fig. 13.1. Vascular cambium as seen in longitudinal section.

differentiates into secondary vascular tissue. The new cells formed towards **inner side** differentiate into **secondary xylem**. Likewise, the new cells formed towards **outer side** differentiate into **secondary phloem**. Normally, the cutting of new cells by cambium ring is much faster towards inner side. Hence, bulk of secondary xylem forms towards centre and thus, cambium ring moves towards the periphery.

Due to the formation of secondary xylem and secondary phloem, the primary xylem and primary phloem which were initially close, now become far apart. The layers of secondary vascular tissues are gradually added to the inner and outer side of the cambium continuously throughout the life of the plant.

- c. **Formation of secondary medullary rays:** The **ray initials** of cambium ring, divide actively and form a few narrow bands of living parenchyma cells. These form two or three layers of thick radial rows of cells passing through the secondary xylem and secondary phloem and are called secondary medullary rays. These help in radial conduction of food from phloem as well as water and mineral salts from xylem.
- d. **Formation of annual rings:** The activity of cambium is affected by seasonal variations in temperature. In moderate climate, the cambium becomes **more active in spring** and forms greater number of vessels with wider cavities, whereas in **winter season**, it becomes **less active** and forms fewer and narrower vessels. The wood formed in the spring is known as **spring wood or early wood** and that formed in the dry summer or cold winter is **autumn wood or late wood**. These two kinds of wood appear together as a concentric ring known as **annual ring** or growth ring. An annual ring refers to the ring of wood that has been added in a particular year and thus, represents the secondary growth in one year. Successive annual rings are formed year after year by the activity of the vascular cambium. Such wood is known as **ring-porous wood**. The age of the plant, thus, can be approximately determined by counting the number of annual rings. This technique is known as **dendrochronology**. It can also help to reconstruct past climate conditions, such as temperature and precipitation, by analyzing patterns in tree-ring growth which is known as **dendroclimatology**. However, in tropical trees, the activity of vascular cambium remains uniform throughout a year. So, there is no distinction between spring wood and autumn wood. It means, wood becomes homogenous and annual rings can't be seen. Such wood is referred as **diffuse-porous wood**.





- e. **Formation of heartwood and sapwood:** In the old trees, where sufficient amount of secondary growth has taken place, the secondary wood of inner side lose the power of conduction. Their cell cavities or lumens get filled with tannins, resins, gums, essential oils etc, known as **tyloses** which makes the wood harder, darker and more durable. Such wood is called **heartwood or duramen**. The heartwood ceases the conduction function and simply, provides mechanical support to the stem. However, the outer region of secondary wood, which consists of younger living xylem cells and remains yellow in colour, is called **sapwood or alburnum**. Vessels and tracheids are functional as **tyloses are absent**. It functions as conducting tissue and also as food storage tissue.



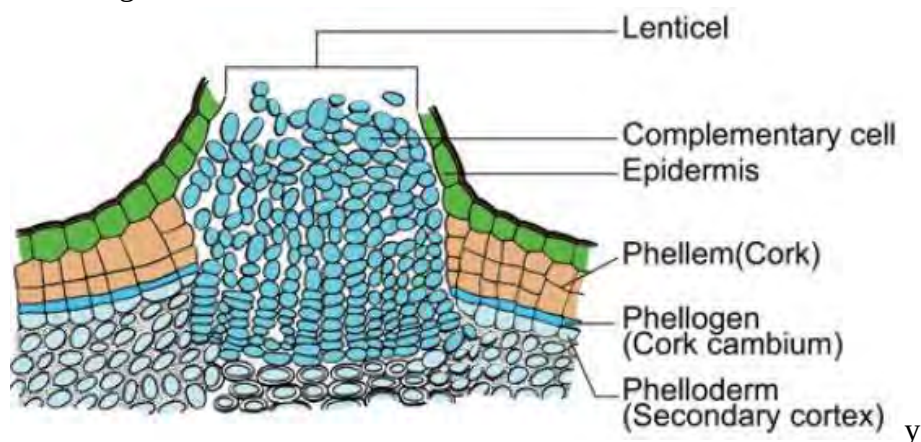
2. Activity of cork-cambium:

The marked increase in diameter or thickness of stem brought about by secondary thickening exerts a great pressure on outer tissues and results in the rupture of the cortex and epidermis. The outer cortical cells become meristematic and form a ring of cambium in extra-stellar region. It is known as **cork cambium** or **phellogen**. The secondary growth brought about by the activity of cork cambium is known as **extra-stellar secondary growth**. It results in the formation of **periderm**.

The cork cambium divides to form secondary tissue on both the sides i.e. internal and external but its **activity is more on the outer side** than on the inner side. The cells formed on the outer side constitute **phellem or cork** and those on the inner side form **phelloderm or secondary cortex**. Cork consists of dead and compactly arranged rectangular cells, having suberized walls. This layer is impervious to water, microbes etc. so, protects inner living tissues from infections and mechanical injuries. Secondary cortex is made of oval or rounded, living, thin walled parenchymatous cells without intercellular spaces. It takes part in storage of food.

These three consecutive layers; phellem, phellogen and phelloderm together are collectively known as **periderm**.

Extra-stelar growth causes rupture of epidermis and stomatal pores are replaced by open aerating pores, known as **lenticels**. Just below lenticel, cambium doesn't form cork. Instead, a mass of loosely arranged, thin walled cells are formed. These are known as **complementary cells** which help in gaseous exchange.



In this way, secondary growth in dicot stem results in the formation of **wood at central region and periderm at periphery**.

Significance of secondary growth

1. Wood produced by vascular cambium is commercially important for making various products.
2. It increases girth of the plant and heartwood provides mechanical support, sufficient enough to attain greatest height and erect position by trees.
3. It helps to find out approximate age of the tree, by counting the number of annual rings.
4. Wood rings of old trees are the best samples to know the past climate and help the researcher to predict climate change in future (dendroclimatology).
5. Corky bark produced by secondary growth protects the inner tissues from abrasion, heat, cold and infection.
6. Lenticels take part in lenticular transpiration and exchange of gases.

EXERCISE

A. Tick the correct alternatives:

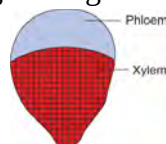
1. Plant anatomy deals with
 - a) Heredity and variations
 - b) Metabolic activities in plants
 - c) Structure and function of plant tissues
 - d) Reproduction in plants
2. Who is known as 'father of plant anatomy'?
 - a) N.Grew
 - b) G.Mendal
 - c) R. Hooke
 - d) Theophrastus
3. Which tissue makes outer lining of plant parts?
 - a) Cambium
 - b) epidermis
 - c) pith
 - d) phloem
4. Meristematic cell has
 - a) Large vacuole
 - b) no nucleus
 - c) no cell wall
 - d) high rate of cell division.
5. Which is the correct pair?
 - a) Intercalary meristem: root length
 - b) lateral meristem: plant height
 - c) apical meristem: inter-nodal length
 - d) root apex: root length
6. Lateral meristem increases
 - a) Height of plant
 - b) intermodal length of plant
 - c) cross-section area of the plant
 - d) number of flowers and fruits in plants.
7. Parenchyma that stores cell inclusions is
 - a) Aerenchyma
 - b) prosenchyma
 - c) chlorenchyma
 - d) idioblast
8. Cell wall of collenchyma consists of
 - a) Cellulose
 - b) cellulose and pectin
 - c) cellulose and lignin
 - d) lignin

9. Aerenchyma is commonly present in
 - a) Xerophytes
 - b) stem of woody trees
 - c) hydrophytes
 - d) alpine plants.
10. An elongated, narrow, non living cell with tapering ends is
 - a) Fibre
 - b) sclereid
 - c) guard cell
 - d) bulliform cell
11. Living mechanical tissue is
 - a) Parenchyma
 - b) collenchyma
 - c) sclerenchyma
 - d) idioblast
12. The empty space inside the sclerenchyma fibre is called
 - a) Pit
 - b) plasmodesma
 - c) lumen
 - d) lignification
13. Which of the following is heterogeneous tissue?
 - a) Meristem
 - b) parenchyma
 - c) sclerenchyma
 - d) xylem
14. Plant tissue which transports prepared food from leaf to other parts is
 - a) Phloem
 - b) xylem
 - c) cambium
 - d) sclerenchyma
15. Which of the following is not a component of xylem?
 - a) Vessel
 - b) tracheid
 - c) sieve tube
 - d) wood fibre
16. Phloem consists of all living cells except
 - a) Phloem parenchyma
 - b) phloem fibre
 - c) companion cell
 - d) sieve tube
17. In root of angiosperms, vascular bundles are
 - a) Radial type
 - b) concentric type
 - c) conjoint and collateral type

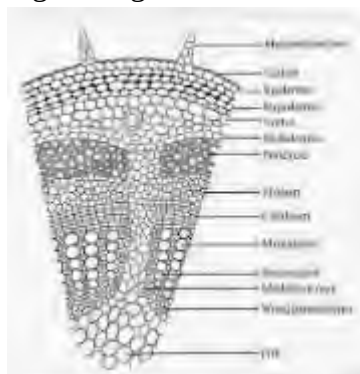
- d) conjoint and bicollateral type
18. When xylem is surrounded by phloem outside, the vascular bundle is said to be
- Concentric
 - amphicribal
 - amphivasal
 - radial.
19. In exarch xylem, protoxylem lies
- Towards the pith, inner to metaxylem
 - Towards the periphery, outer to metaxylem
 - In between outer and inner metaxylems
 - At centre, and gets completely surrounded by metaxylem.
20. Which of the following ceases conducting function of xylem elements?
- callose
 - tylose
 - suberin
 - lignin
21. Which is the best pair?
- periblem=periderm+phellem+phellogen
 - periderm= phellem+phellogen+phelloderm
 - Phelloderm= periderm+phellem+phelloderm
 - periblem= pleurome+ phellem+ phellogen
22. In leaf of a plant, which of the following is true about xylem?
- xylem is exarch
 - xylem is endarch
 - It may be either exarch or endarch
 - Its arrangement cannot be defined.
23. With secondary growth over years, what changes might have seen in the trunk of a tree?
- heartwood expands, sapwood shrinks
 - both heartwood and sapwood expand
 - heartwood shrinks, sapwood expands
 - both heartwood and sapwood shrink

B. Answer the following questions:

- Define meristem. Write its characteristic features.
- Classify meristem, on basis of the location and explain each with example.
- What is parenchyma? Discuss its modifications.
- Compare between fibre and sclereid.
- Define complex permanent tissue and write its types.
- Differentiate between xylem and phloem.
- Study the given figure and answer the following question



- b) Name the type of vascular bundle?
 - c) Which type of plants have such vascular bundles in stem?
 - d) Is secondary growth possible in such vascular bundle? Why?
8. Mention the characteristic features of dicot root anatomy.
9. Compare between the anatomy of dicot root and monocot root.
10. Study the given figure and answer



- a) Name the given figure.
 - b) What is hypodermis made up of?
 - c) Write about its vascular bundles.
11. Draw the labeled diagram of monocot stem.
12. How does dicot leaf differ from monocot leaf? Write your answer based on stomatal distribution, nature of mesophyll tissue, shape of guard cells, bundle sheath extensions.
13. What is periderm? Explain its components with labeled diagram.
14. Differentiate between early-wood and late-wood.

Long answer type questions:

1. Define plant tissues. Show the flow chart of different types of plant tissues.
2. Describe the types of simple permanent tissues with diagram.
3. What are vascular bundles. Classify them on basis of their arrangement. Describe each type with diagram.
4. Discuss the root anatomy of monocot with suitable diagram. Mention any three diagnostic features of it.
5. What is secondary growth? Describe the growth of stele with relevant diagram.

Project work:

Visit a timber factory nearby your school location. Observe the cross-section area of the cut stumps/ logs of various plants. Categorize the plants on basis of distinct annual rings are present or absent. Identify oldest tree log and justify it with evidence such as photo.

Elaborate why some of the stumps/logs had no distinct annual rings? Submit your report to the biology teacher.

Unit 2

PLANT PHYSIOLOGY



**Stephen
Hales**
(1677-1761)

Stephen Hales was an English clergyman and scientist who made significant contributions to plant and animal physiology, as well as pneumatic chemistry. He is often called the "father of plant physiology" and is known for his groundbreaking research on plant transpiration and fluid movement within plants. He conducted experiments on plants, exploring how fluids and gases move within them and whether the sap circulates in plants, as blood does in humans. His work on plant transpiration, where he measured the emission of water vapor from plants, was particularly influential.

Chapter 2.1

WATER RELATION

Discuss the following questions:

- IV. How does the smell of food travel from the kitchen to other rooms?
- V. Animals remove excess water as sweat, urine etc. Which physiological process commonly takes place in plants for the removal of unused water?
- VI. Why do some leaves have water droplets on their edges early in the morning, even when it hasn't rained?

2.1.1 GENERAL INTRODUCTION

Plant physiology is the study of plant functions and behaviour, and it includes all of the dynamic processes of growth, reproduction, metabolism, defense, and communication that keep plants alive. The majority of these activities occur at the level of cells, tissues, and organs, so it is a closely connected with plant anatomy, owing to the close association between structure and function in plants. Furthermore, because much of the metabolic activity within a live cell occurs at the molecular level, a thorough understanding of a plant physiology requires a strong foundation in chemistry and physics.

Plants rely on soils for mineral nutrients and water, which are replenished via biogeochemical cycles. Water and minerals must be carried through the xylem once they have been absorbed, and this movement is propelled by the loss of water vapour from leaves and the cohesive and adhesive characteristics of water.

Sugar-rich assimilate must also be transported through the phloem. Plant hormones are crucial for delivering messages throughout the plant body. The concentration of carbon dioxide in the leaves, the positioning of stems, roots, and leaves, and the transport and retention of water are all examples of how plants regulate their internal conditions throughout this section.

2.1.2 DIFFUSION

Diffusion is a phenomenon of random movement of ions, molecules, particles etc. from the region of higher concentration to the region of lower concentration. Diffusion continues until equilibrium is maintained. It is passive process because energy or ATP is not utilized in this process. Diffusion occurs due to the free energy i.e, kinetic energy of the ions, molecules or particles. Hence, diffusion occurs faster with rise in temperature. Diffusion takes place in vacuum as well as medium (solid, liquid as well as gases).

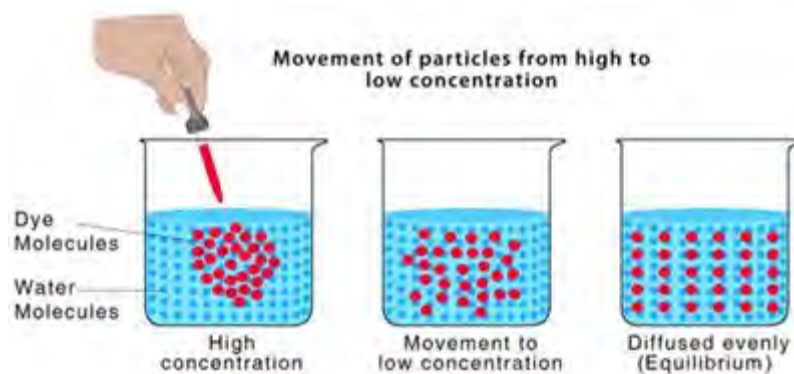


Fig: 2.1.1 (a) Leaf showing hydathode (b) Structure of hydathode



Perfume sprayed at one corner of room can be smelt at another corner due to diffusion.

Diffusion involves two components:

1. **Diffusion medium:** Substance or medium in which particles diffuse or disperse is known as **diffusion medium** or **diffusant**. It may be solid, liquid or gas. In solid medium, diffusion occurs slowly due to its compactness. Just reverse, in gas medium, as particles are loosely arranged, diffusion occurs rapidly.
2. **Diffusing particles:** Particles or molecules which scatter or disperse in the medium are **diffusing particles** or **diffusate**. Particles which are lighter, due to less density, diffuse rapidly than the heavier particles (with higher density).

Diffusion Pressure (DP)

Pressure exerted by diffusing particles due to which they diffuse in the diffusion medium is known as **diffusion pressure**. It depends on the concentration gradient of diffusing particles. Higher the concentration gradient, faster the diffusion and vice-versa.

Significance of diffusion in plants:

1. Ions and other substances spread throughout protoplasm by diffusion.
2. Passive absorption of minerals from soil water by roots of plant is diffusion process.
3. Aroma of flowers diffuses in air which helps insects to find flower and thus, ensures cross pollination.
4. Diffusion of water vapour from the leaf to atmosphere takes place through stomatal pores during transpiration in plants.
5. Diffusion is essential for translocation of solutes throughout the plant body.
6. Osmosis, a special type of diffusion involves in cell to cell movement of water through semi-permeable cell membrane.

2.1.3 OSMOSIS

Osmosis is also a passive process and a special type of diffusion. It refers to the movement of water molecules from its higher concentration to lower concentration across **semi- permeable membrane**.

A solution with higher concentration of water is said to be **hypotonic** solution. Likewise, solution with lower concentration of water is said to be **hypertonic** solution. During osmosis, water diffuses from hypotonic solution to hypertonic solution through semi- permeable membrane. A solution which can draw water by osmotic process is said to be **osmotically active solution**, which, in simple term, is hypertonic solution.

Conditions required for osmosis

1. Two solutions must have **unequal concentration** of water i.e. one hypertonic and the next, hypotonic.
2. The two solutions must be separated by **semi- permeable membrane**.

Osmosis in Plant cell

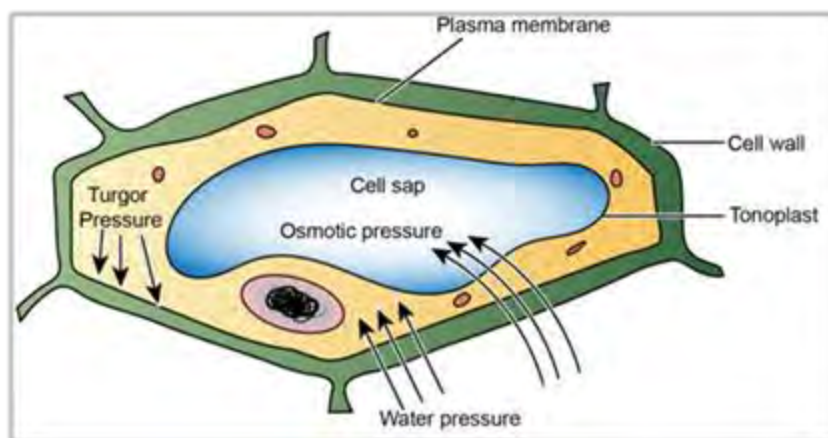


Fig: 2.1.2 Osmosis in plant cell

In a living plant cell, water enters into vacuole from surrounding solution or water from its vacuole is expelled out to surrounding solution.

Osmotic Pressure (OP)

During osmosis, water molecules diffuse from hypotonic to hypertonic solution through semi-permeable membrane. The pressure, exerted on hypertonic solution, by diffusing solvent molecules, is known as **osmotic pressure**. It can also be defined as the pressure which is required to prevent osmotic entry of water into hypertonic solution through semi permeable membrane.

Value of osmotic pressure of a given solution depends on the concentration of solute. Higher the concentration of solute in solution, higher its OP and vice-versa. For example; 20% sugar solution has more OP than that of 10% sugar solution. Likewise, pure water has less OP as compared to cell sap of normal plant cell.

OP is measured in atm or bars. It can be measured with the help of osmometer.

Activity: 2.1

Observe the effect of osmosis by using eggs.

First the shells of two raw eggs are removed. One egg is then placed in plain water and the other in a strong sugar solution. After few hours or overnights, observe both eggs. What changes occurs in them? Discuss in class.

Points to remember

Turgor Pressure (TP), Wall Pressure (WP) and Diffusion Pressure Deficient (DPD)

As water enters the cell through osmosis, it accumulates in vacuole. Consequently, vacuole increases its size and protoplasm expands. The extended protoplast exerts an outward pressure on the cell wall, which is known as turgor pressure (TP). At the same time, the cell wall, being rigid, also exerts an equal but opposite (inward) pressure, known as wall pressure (WP).

Simply, TP acts in opposite direction of OP and tends to lessen osmotic entry of water in plant cell. The net osmotic entry of water in plant cell is due to Diffusion Pressure Deficient (DPD) or Suction Pressure (SP). The term DPD was proposed by Meyer (1938) whereas SP was proposed earlier by Renner (1915). Numerically, DPD of a plant cell, can be represented as;

$$\text{DPD} = \text{OP} - \text{TP} \text{ or}$$

$$\text{DPD} = \text{OP} - \text{WP}$$

Types of Osmosis

1. Endosmosis:

When a living plant cell is placed in water, ie; hypotonic solution, water enters into the cell by osmosis. It is known as **endosmosis**. This is because the concentration of water in vacuole is less as compared to surrounding. So, cell sap is hypertonic and surrounding water is hypotonic. As a principle of osmosis, water molecules move from the region of high water concentration to the region of low water concentration through semi- permeable membranes of cell.

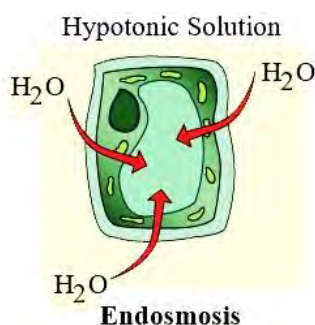


Fig: 2.1.3 Endosmosis

Due to endosmosis, size of vacuole goes on increasing and protoplast keeps on expanding. At optimum point, the protoplast of the cell becomes fully expanded. Such condition of cell is known as turgidity and the cell is said to be fully turgid.

Points to remember:

During endosmosis, *OP* of the cell gradually decreases and *TP* of the cell increases. When the cell becomes fully turgid, *OP* and *TP* become equal. Hence *DPD* of the cell becomes zero. 0 *DPD* indicates saturation point and no further entry of water occurs in the cell.

Hence, in a fully turgid cell,

$$DPD = OP - TP \quad (\text{as } OP = TP)$$

$$DPD = 0.$$

2. Exosmosis:

When a cell removes water to the surrounding solution, it is known as **exosmosis**. It takes place when a normal cell is subjected to strong or hypertonic solution. As a consequence, the cell becomes **flaccid or plasmolysed**.

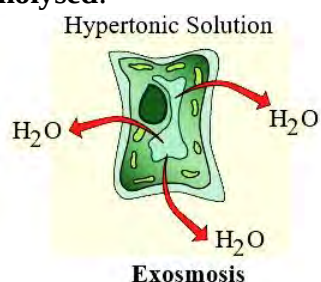


Fig: 2.1.4 Exosmosis

Significance of osmosis:

1. Plant roots absorb water from soil by osmosis.
2. Cell to cell movement of water in plant parts takes place by osmosis.
3. Osmosis results in turgidity and flaccidity of plant cells.
4. Opening and closing of stomata is due to osmotic phenomenon of guard cells.
5. Osmosis plays vital role in dehiscence of anther, sporangium, fruit etc.
6. The growth of radicle and plumule during seed germination is due to the force developed as a result of osmosis.

2.1.4 PLASMOLYSIS

Due to exosmosis in a cell, protoplasm becomes shrunken and dehydrated. This phenomenon is known as **plasmolysis**. Early stage of plasmolysis is less noticeable but when cell undergoes full plasmolysis for a long time, protoplasm becomes non-functional and permanently damaged, leading to death of the cell.

When a plasmolysed cell is placed in hypotonic solution (water), it re-gains a normal physiological state. This phenomenon is known as **deplasmolysis**.

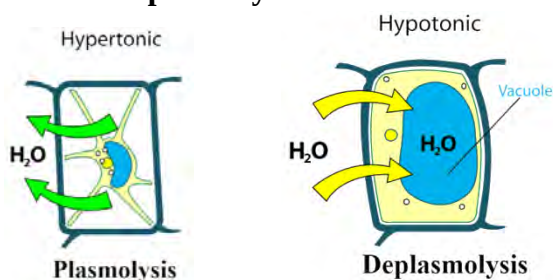


Fig: 2.1.5 Cells showing plasmolysis and deplasmolysis

Significance of plasmolysis

1. It helps in confirming whether a cell is living or dead because plasmolysis only occurs in living cells.
2. It demonstrates exosmosis in plant cell.
3. Salting of pickles, meat and fish as well as sweetening with jam and gellies prevents microbial infection because bacteria get plasmolysed and can not survive.
4. Grasses can be killed by spraying excessive salts on the ground, due to plasmolysis in their root cells.
5. It proves that cell wall is permeable in nature.

Points to remember:

As plasmolysis continues due to exosmosis, OP of the cell goes on increasing and TP goes on decreasing. In the extreme condition, TP drops to zero. Such a cell is said to be fully plasmolysed. Thereafter, no further exosmosis takes place.

Hence, in a fully plasmolysed plant cell,

DPD = OP - TP (as TP = 0),

DPD = OP

2.1.5 ASCENT OF SAP

Plants absorb water and minerals from soil which is transported to different parts to keep cells/tissues alive. Water is also used up by chlorenchymatous cells in leaves and other green parts for photosynthesis. Hence, water from root of plant reaches to upper parts of plants continuously. Such upward movement of water and minerals from roots to the leaves and other parts against gravity is known as **ascent of sap**.

Path of ascent of sap

Epiblema → cortex → endodermis → pericycle → protoxylem vessel → metaxylem vessel → xylem of stem → xylem of branch → xylem of leaf petiole → xylem of leaf (midrib/vein/veinlet) → mesophyll cell of leaf.

In angiosperms, ascent of sap occurs through **tracheary elements** (tracheids and vessels) **of xylem**. However, in gymnosperms, it occurs through tracheids only.

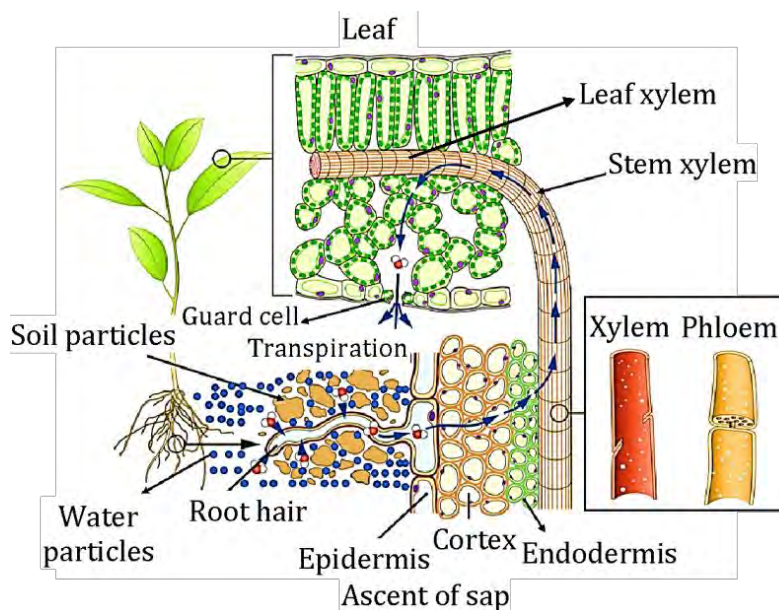


Fig: 2.1.6 Path of ascent of sap

Tracheary elements of xylem have **unbroken channel of sap** from root to leaf. **Cohesive and adhesive forces of** water enable the water column to bear tension which prevents breaking of water column. Loss of water from leaf surface, due to transpiration, creates a suction force, known as **transpiration pull**, in tracheary elements of leaf xylem and hence, tension is developed. This tension transmits downwards upto the root xylem, resulting continuous rise of sap upwards.

Significance of ascent of sap:

1. It supplies water to mesophyll cells of leaf for photosynthesis.
2. It transports the water and minerals from root cells upwards to all parts of plant, even upto the top region, through vessels and tracheids of xylem.
3. It ensures the availability of water, a major constituent of protoplasm, in all living cells of plant.
4. It ensures excess water in aerial parts of plants, which is lost to atmosphere by transpiration process.
5. It helps in better development of tracheary elements and makes them more efficient and functional in conduction process.
6. Ascent of sap directly influences the absorption of water and minerals by roots.

Activity: 2.2

TO DEMONSTRATE THE MOVEMENT OF WATER (SAP) THROUGH THE STEM OF A PLANT

Place a fresh plant twig with white flowers in a glass of water mixed with a few drops of eosin solution or food colour. Place the setup for few hours. Then observe the change in flower and discuss in class.

2.1.6 TRANSPIRATION

Water is necessary for plants. It is the main constituent of protoplasm of cells as well as raw material for photosynthetic activity. However, only a small amount of water taken up by the roots is used for growth and metabolism. The remaining 97–99.5% is lost from aerial parts of plants. Such removal of water mainly occurs by transpiration and partly, by guttation.

The removal or loss of water, in the form of vapour, from aerial parts of plants is known as **transpiration**. During transpiration, water is released in purest state through stomata, cuticle or lenticels by diffusion process.

Types of Transpiration

On basis of the path of removal of water from plant surface, transpiration can be of three types:

a) Stomatal Transpiration

It is the evaporation of water from the stomata of the plants. Stomata are minute pores present in the epidermis of aerial parts of the plant body that remain guarded by two guard cells. It contributes about 80-90% of total transpiration in plants.

Stomatal transpiration occurs in following two steps:

In the first step, there is the evaporation of water from the cell wall of turgid mesophyll cells into the sub-stomatal cavity or inter-cellular spaces. The evaporated water gets collected in the sub-stomatal cavity in the form of water vapor. This increased the water vapor pressure called density of the sub-stomatal cavity

In the second or final step, there is the diffusion of water vapor from the sub-stomatal cavity into the outer atmosphere through the open stoma. The diffusion occurs because the water vapor pressure of the sub-stomatal cavity is higher than that of the outer atmosphere.

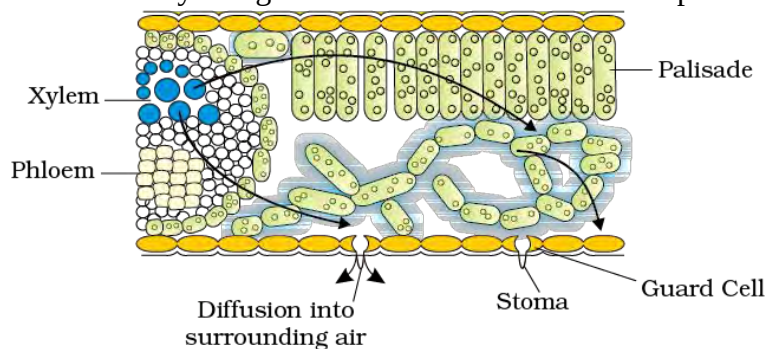


Fig: 2.1.7 Movement of water in leaf

points to remember:

- When water enters the guard cells, turgor pressure increases. So, the outer thin wall of the guard cell extends more in the outward direction which, in turn, pulls the inner thick wall outward too. This causes the stoma to open.
- However, when water moves out of the guard cells, turgor pressure decreases and the guard cells become flaccid. Under such condition, the inner walls of guard cells become intact, leaving no pore in between. Hence, the stoma closes.
- Generally, the stoma opens during the day and closes during the night.
- In dicots guard cells are kidney shaped but in monocots, they are dumbbell shaped.

- *Number and distribution of stomata varies among plants. In terrestrial forms, dicot leaves have unequal distribution of stomata (more on the lower surface) and monocot leaves have equally distributed on both surfaces.*

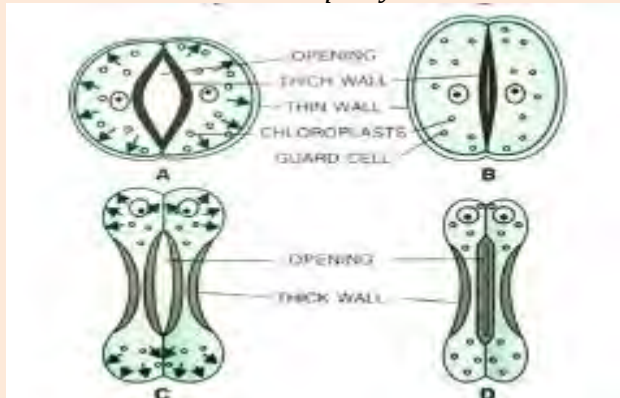


Fig: 2.1.8 Opening and closing of stomata (A) Stomata open (B) Stomata close in dicot plant (C) Stomata open (D) Stomata close in monocot plant

b) Lenticular Transpiration

Lenticels are minute openings in the bark of branches and twigs. Evaporation of water from the lenticels of the plants is known as lenticular transpiration.

Lenticels are not present in all the plants. These are generally found in the bark of woody plants. A minimal amount of water (about 0.01%) is lost through lenticels.

c) Cuticular Transpiration

It is the evaporation of water through cuticle of the plants. Cuticle is a waxy covering on the surface of the leaves of the plants. About 3-10% of the water from the leaves is lost through cuticular transpiration. During dry conditions when the stomata are closed, more water is transpired through the cuticles. Thinner the cuticle, higher the rate of transpiration and vice-versa. It is common in herbaceous, shade-loving plants.

Significance of Transpiration

Transpiration in plants has many advantages. However, it may adversely affect the growth and metabolism. Hence, transpiration is a necessary evil.

Advantages:

1. Transpiration helps in conduction of water and minerals to different parts of plants.
2. Due to continuous elimination of water from plant body, there is a balance of water maintained within plant.
3. It maintains osmosis and keeps the cells rigid.
4. A suction force is created by transpiration that helps in the upward movement of water in the plants.
5. Certain hydrophilic salts are accumulated on the surface of the leaves, which keeps the leaves moist.
6. It maintains the turgidity of the cells and helps in cell division.
7. Optimum transpiration helps in the proper growth of the plants.
8. The cooling effect of a tree is due to the evaporation of water from its leaves.

Disadvantages:

1. Transpiration slows down if the transpired water is not compensated by absorption from the soil.
2. A lot of energy is released during transpiration.
3. Plenty of unnecessary water is absorbed by the plants during the process.

Factors affecting transpiration:

External factors:

1. **Relative humidity:** With increase in relative humidity, the rate of transpiration decreases and vice versa.
2. **Carbon dioxide concentration:** For stomatal opening, the carbon dioxide concentration should be below 300 PPM. Higher CO₂ concentration results in closure of stomata.
3. **Temperature:** Although, with the rise in temperature the rate of transpiration increases but if the temperature is too high, transpiration rate decreases. At 30-35°C, stomatal closure takes place.
4. **Light:** The quality and intensity of light also affect rate of transpiration. High light intensity results in increase in temperature which results in higher rate of transpiration. Besides this, quality of light also affects transpiration. No opening of stomata takes place in green, UV and infra-red light.
5. **Wind velocity:** A wind velocity of 20 to 30 km per hour is favourable for transpiration. When wind velocity reaches 40 to 50 km per hour, transpiration rate decreases due to closure of stomata.
6. **Atmospheric pressure:** Increase in atmospheric pressure leads to decreased rate of transpiration.
7. **Water availability:** Water availability in soil is directly proportional to the rate of transpiration. When available water is more in soil, rate of transpiration increases and vice versa.

Internal factors:

1. **Leaf area:** With increase in leaf area, the frequency of stomata per unit area also increases. This results in increased rate of transpiration. Xerophytic plants which are found in dry areas, face water stress and therefore in these plants, the leaf area gets reduced or the leaves fall off early or they are modified into spines.
2. **Leaf structure:** The leaf structure also affects the rate of transpiration. Thickness of cuticle determines the rate of transpiration. If leaf surface is more cutinized, rate of transpiration decreases. If the stomata are more in number, transpiration rate is high. Similarly, the position of stomata is also important. Presence of stomata only on the lower surface of the leaf, reduces the transpiration rate. In xerophytic plants such as *Pinus*, *Nerium* etc., stomata are not found on the surface rather they are present in small cavities under the surface. Such stomata are called sunken stomata. This small stomatal cavity contains a number of hairs which help in reducing the rate of transpiration.
3. **Leaf modifications:** Several types of modifications are found in plants in order to reduce the rate of transpiration. Some examples are phylloclad in *Opuntia*, cladode in *Asparagus*, phyllode in *Acacia melanoxylon* etc.

2.1.7 GUTTATION

Have you ever observed water droplets hanging on the leaf margins of plants as shown in the figure?



- I. If yes, at what time, it is usually seen?
- II. Name some plants which show this process.
- III. Does it take place in tall and woody trees?

During nights and early mornings, when atmospheric humidity is high, some plants are unable to transpire but continue absorption of water by their root. This results in development of root pressure, which pushes the sap upwards and finally the sap is exudated from leaf tips or margins through special pores, known as **hydathodes**. This phenomenon is known as **guttation**. It commonly occurs in grasses, herbaceous dicots. For example: tomato, balsam, *colocasia* etc.

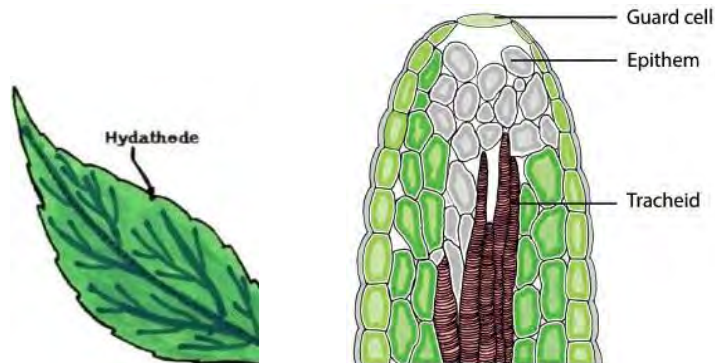


Fig: 2.1.9 (a) Leaf showing hydathode (b) Structure of hydathode

Conditions for guttation:

1. Little or no transpiration but continuous water absorption
2. Development of root pressure

Differences between transpiration and guttation

1. Transpiration takes place through stomata and lenticels. Guttation happens through hydathodes.
2. Water is lost as vapour in transpiration. Water is lost as liquid in guttation.
3. Transpiration typically takes place during daylight hours. Guttation generally occurs in the early morning or nighttime.

4. Transpiration is prevalent in high temperatures .Guttation is more common in cooler temperatures.
5. Transpiration is favoured by dry conditions. Guttation is hindered by dry conditions.
6. Transpiration involves simple diffusion. Guttation does not involve diffusion.
7. Transpiration is controlled phenomenon as it can be regulated by the opening and closing of stomata. Guttation is uncontrolled process since hydathodes do not open or close.
8. Humid conditions reduce the rate of transpiration. Humid conditions increase the rate of guttation.
9. Transpiration does not require root pressure. Guttation is driven by root pressure.
10. Transpiration only evaporates pure water. Guttation can expel sugars, salts, and amino acids along with water.
11. Transpiration provides cooling effect to plant. Guttation does not provide cooling effect.

EXERCISE

A. Tick the correct alternatives:

1. What is the cause of diffusion?
 - a. Sunlight
 - b. Kinetic energy
 - c. Chemical energy
 - d. Potential energy
2. What is the medium, where diffusion occurs, is called?
 - a. Water
 - b. Diffusant
 - c. Diffusate
 - d. Imbibant
3. What is the direction of diffusion of molecules?
 - a. from higher concentration to lower concentration
 - b. from lower concentration to higher concentration.
 - c. it has no fixed direction.
 - d. against the concentration gradient.
4. What is true about transpiration through stomata ?
 - a. It is not diffusion process.
 - b. Diffusion of water droplets from leaf to air.
 - b. Diffusion of water vapours from leaf interior to air.
 - c. Diffusion of water vapours from air to leaf interior.
5. Which of the following acts as semi permeable membrane?
 - a. Primary wal when any cell is placed in hypotonic solution
 - b. Lignified wall
 - c. Suberized wall
 - d. cell membrane
6. When does endosmosis occur?
 - a. when any cell is placed in hypotonic solution
 - b. when a living cell is placed in hypotonic solution

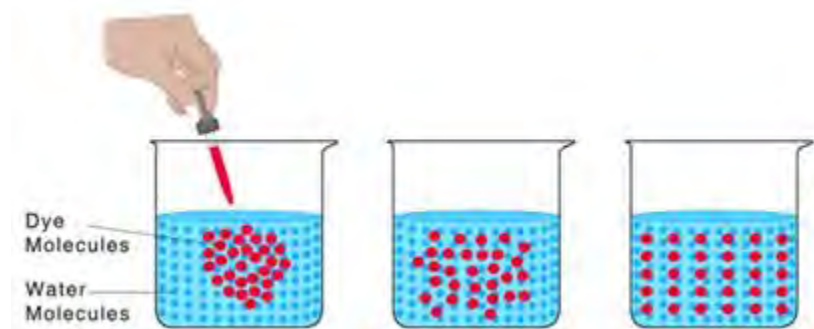
- c. when any cell is placed in hypertonic solution
 - d. when a living cell is placed in hypotonic solution
7. A plant cell has undergone exosmosis. Which statement is correct?
 - a. Its turgor pressure goes on increasing.
 - b. Cell accumulates more water and becomes turgid.
 - c. Protoplasm gets dehydrated and cell becomes flaccid.
 - d. Cell neither becomes turgid nor becomes flaccid and remains in normal state
 8. What is true about osmosis?
 - a. It occurs through any membrane.
 - b. It occurs through semi - permeable membrane.
 - c. Solvent molecules move from hypertonic solution to hypotonic solution.
 - d. Solute molecules move from hypertonic solution to hypotonic solution.
 9. What is the significance of plasmolysis?
 - a. Seed swells when soaked in water
 - b. Foul smell of dumping site spreads in surrounding.
 - c. Bacteria can not survive in pickles/ jams.
 - d. Cell bursts due to expansion of protoplasm.
 10. Which of following material shows imbibition?
 - a. Tin
 - b. Plastic
 - c. Rock
 - d. Wood
 11. What is true about imbibition?
 - a. It is endothermic process.
 - b. It causes swelling (increase in volume).
 - c. It is due to presence of hydrophobic molecules.
 - d. It occurs in living materials only.
 12. The path of ascent of sap is tracheary elements of xylem. Which of following are tracheary elements?
 - a. vessels and xylem fibres
 - b. vessels and xylem parenchyma
 - c. vessels and tracheids
 - d. tracheids and xylem fibres.
 13. What is the cause of ascent of sap?
 - a. transpiration pull
 - b. root pressure
 - c. atmospheric pressure
 - d. imbibition
 14. A plant excretes water droplets from leaf margins, mainly during humid nights or mornings. Which of the following plants exhibits such phenomenon?
 - a. Cactus
 - b. *Pinus*
 - c. Mango
 - d. *Colocasia*

15. Which part of leaf is responsible for guttation?

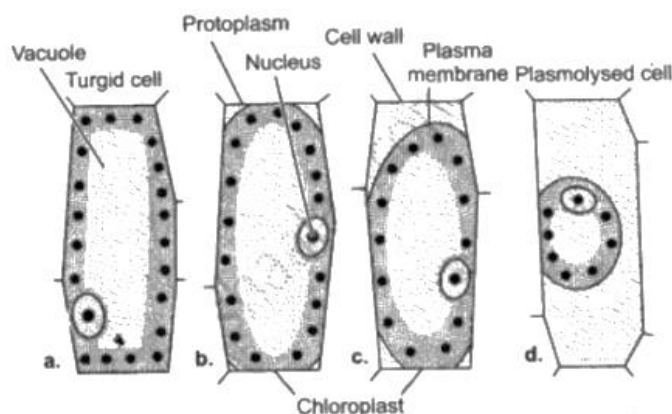
- a. stomata
- b. lamina
- c. cuticle
- d. hydathode

B. Answer the following questions:

1. Observe the figure below and answer the questions.



- a. What process does the figure represent?
 - b. What causes the spreading of dye molecules in water?
 - c. In this process, what do water molecules act as?
 - d. What effect would be seen if temperature of water is increased?
2. Define osmosis. Write its significance in plants.
3. Mention the two conditions necessary for osmosis. Does osmosis take place in non living cell/object? Why?
4. What is endosmosis? What is its effect on plant cell?
5. In the given figure, a cell has undergone successive changes, when it is placed in a solution. Answer the following questions.



- a) Is the solution hypotonic or hypertonic?
 - b) What type of osmosis is it?
 - c) The protoplast of cell has shrunk to its minimum volume. What is this phenomenon called?
 - d) What happens if the cell 'd' is placed in water. What is it called?
6. Write significance of plasmolysis.

7. Define ascent of sap. Mention three important points which make ascent of sap possible in plants.
8. Observe the figure given below and answer the questions.



- a) Why do white flowers of the twig turn into red?
 - b) Can colour change be seen in other parts too? If yes, in which part?
 - c) Transverse section of the twig under the microscope was observed as in above figure.
What can be concluded from it?
9. Define transpiration and mention its types.
 10. Write about the role of stomata in transpiration.
 11. How do diffusion and osmosis play vital role in stomatal transpiration? Give your views.
 12. Describe the role of light and temperature in transpiration.
 13. List out the advantages and disadvantages of transpiration.
 14. Write differences between transpiration and guttation.
 15. Define transpiration. Discuss the various factors affecting transpiration in plants. (1+7)

Project Work

Visit the garden, crop field, vegetable garden in early morning after rain in the night. You will notice certain plants having water droplets on the leaf surface/margins. It is due to guttation.

- a. Make a list of any ten plants that show guttation.
- b. In what type of plants is it commonly observed?
- c. Do woody plants show guttation?
- d. What conditions favour guttation process ?

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Chapter 2.2

PHOTOSYNTHESIS

Discuss the following questions:

- I. Why are most plants green? What role this colour plays in their survival?
- II. What happens to the air in a room full of plants during the day versus during the night?
- III. Can you think of any situation where photosynthesis might stop even if the plant is alive? What factors might affect it?

2.2.1 INTRODUCTION AND SIGNIFICANCE OF PHOTOSYNTHESIS

Photosynthesis is a biochemical process by which green plants, algae, and some bacteria convert light energy into biochemical energy. During this process, these organisms use sunlight to transform water and carbon dioxide into oxygen and energy-rich organic compounds, such as glucose. It is **anabolic process** because simpler inorganic compounds such as water and carbon-dioxide are used up to form high molecular weight organic compounds such as glucose.

Types of photosynthesis:

Photosynthesis is of two types:

- a) Oxygenic
- b) Non- oxygenic.

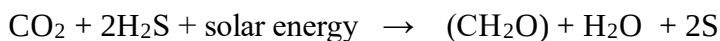
a) Oxygenic Photosynthesis

Oxygenic photosynthesis is performed by green plants including algae and cyanobacteria. In this process, water is used as an electron donor and oxygen is evolved as a byproduct. True chlorophyll (chl- a) is essential for oxygenic photosynthesis. It involves photolysis of water. The equation can be expressed as;



b) Non-oxygenic photosynthesis

It is primitive type of photosynthesis carried out by bacteria (green sulfur bacteria, purple bacteria etc.). This process uses molecules other than water (e.g., hydrogen sulfide) as electron donor. Hence, it does not produce oxygen as by-product. Instead, elemental sulfur is produced. Photosynthetic pigment such as bacterio-chlorophyll, chlorobium chlorophyll is essential for non-oxygenic photosynthesis. The equation can be expressed as;



Activity:

Fill in the gaps:

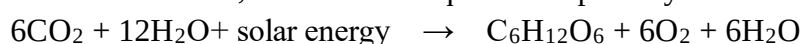
	Non-Oxygenic Photosynthesis	Oxygenic Photosynthesis
Organism		, green plants
Hydrogen donor	H ₂ S	
By product		
Pigment	Bactereiochlorophyll	

Photosynthesis in Plants

It is biochemical, anabolic and reductive process, in which light energy is absorbed by green plant to manufacture organic food, from simple molecules like CO₂ and H₂O. It is often called **carbon assimilation**.

During photosynthesis, light energy is transformed into chemical energy and stored in the form of organic matter (carbohydrates) and O₂ is evolved as by-product. The raw materials for this process are CO₂ and H₂O. CO₂ comes from air through stomata and H₂O is absorbed from the soil by roots. It mainly occurs in mesophyll cells of leaf. In a cell, photosynthesis takes place in chloroplast. So, chloroplast is often regarded as “**kitchen of the cell**”.

Evolution of oxygen in photosynthesis is due to break-down of water molecule. This process is known as photolysis of water. Hence, the balanced equation of photosynthesis in plant is;

**Significance of photosynthesis:**

1. It prepares organic food from inorganic raw materials. Food is used up by all living organisms in the nature.
2. It uses CO₂ from atmosphere and lowers the concentration of CO₂ in air to prevent from harmful effects.
3. It helps in maintaining balance of O₂ and CO₂ in atmosphere.
4. Useful plant products such as fibres, drugs, rubber, timber etc. are the outcomes of photosynthesis.
5. Fossil fuels like coal, petroleum, natural gases are also the products of photosynthesis.

2.2.2 PHOTOSYNTHETIC PIGMENTS

There are major three groups of photosynthetic pigments. They are: chlorophylls, carotenoids and phycobillins.

1. Chlorophyll:

Chlorophyll is present in thylakoid membranes of chloroplast. Chlorophyll is the dominant photosynthetic pigment and it absorbs light, mainly in the visible spectrum's blue and red areas, but not in green area. Some of the green light that strikes the plant is either scattered or reflected and hence the plants typically appear to be green in colour. In plants, chlorophylls are of five types; chl-a, chl-b, chl-c, chl-d and chl-e. Among them, the primary photosynthetic pigment is chlorophyll-

a, which is present in all green plants as well as cyanobacteria. It has molecular formula: $C_{55}H_{72}O_5$ N_4Mg and molecular weight 893 amu. Other chlorophylls assist in capturing light energy. Hence, these are accessory pigments which are confined to certain groups of plants.

2. Carotenoids:

Carotenoids are also accessory photosynthetic pigments present in chloroplast as and are of two types: carotenes and xanthophylls.

Carotenes are orange pigments with molecular formula $C_{40}H_{56}$. They absorb ultraviolet, violet, and blue light. Similarly, xanthophylls are yellow pigments with molecular formula $C_{40}H_{56}O_2$. They absorb blue and blue-green light in low light conditions, and yellow light in general.

3. Phycobillins:

They are water soluble pigments. It is responsible for maximum absorption in green parts of the spectrum. It is commonly present in red algae and blue green algae. It includes phycoerythrin, phycocyanin etc. Phycoerythrin is red pigment, dominant in red algae (rhodophyceae). It absorbs lightly blue-green/yellowish light. Phycocyanin is blue pigment, found in red as well as blue green algae. It absorbs red-orange wavelength of sunlight

Site of photosynthesis: Chloroplast

Chloroplast is also known as “*Kitchen of the cell*” as it is the site of photosynthesis. It is a semi-autonomous organelle, capable of synthesizing some of the proteins by itself, with the help of DNA and 70s ribosomes in its stroma.

Mainly two parts of chloroplasts play main role in photosynthetic process. These are: grana and stroma.

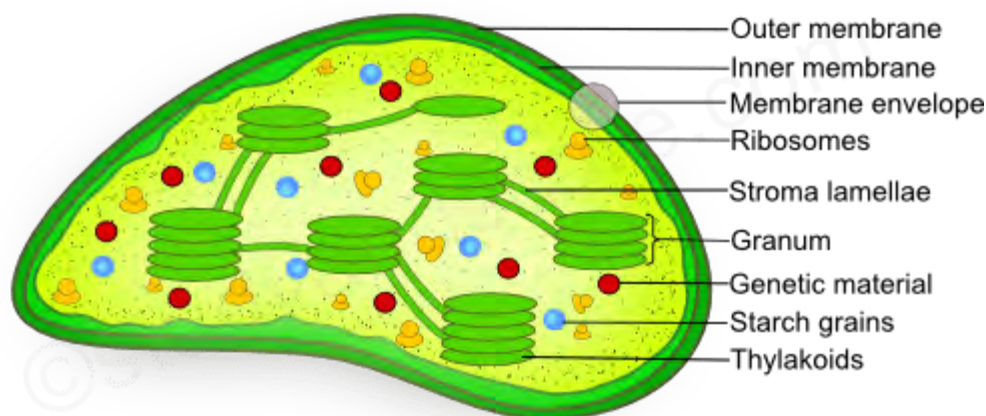


Fig: 2.2.1 Structure of Chloroplast

Grana: Grana (singular: granum) are stacks of disc-like structures formed by thylakoid membranes. Each granum can have 2-100 thylakoids, although stacks of 10-20 thylakoids are common.

Thylakoid membrane (Thylakoids): The thylakoid membrane consists of a system of interconnected membranes where the **light-dependent reactions** of photosynthesis occur. There are two types of thylakoids. Granal thylakoids are the pancake-like stacks. Stromal thylakoids are helical sheets that wrap around the grana.

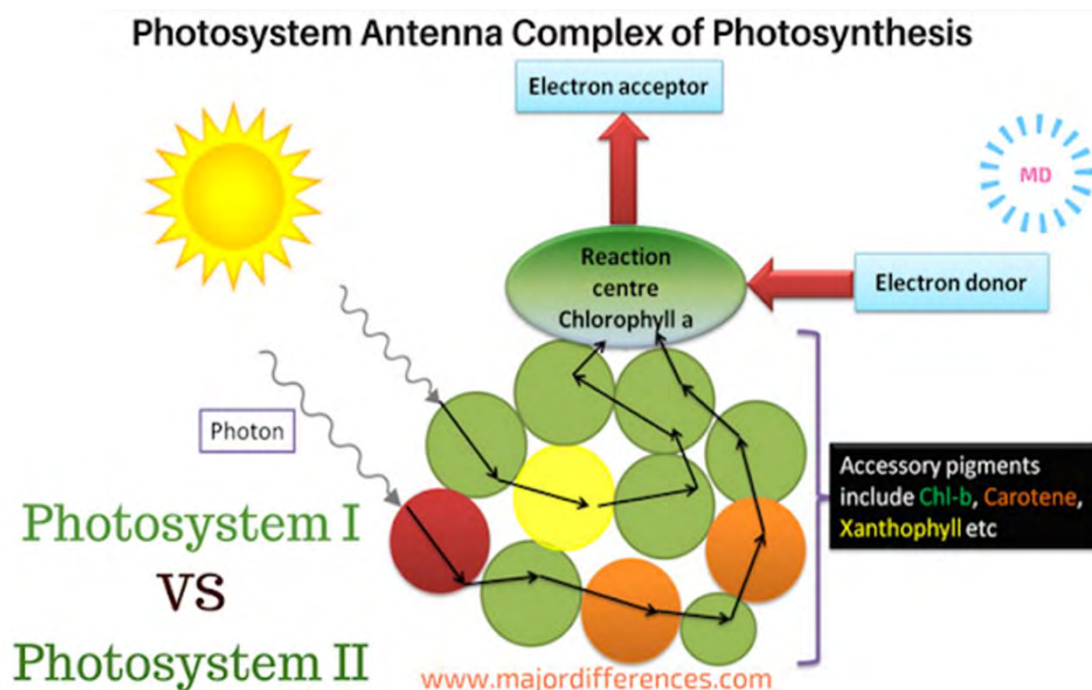
Thylakoid space (lumen): It is the interior of the granum. It contains proteins that drive the electron transport chain in photosynthesis

Stroma: The stroma is a fluid-filled space, containing enzymes, ribosomes, and DNA, inside inner membrane of the chloroplast. The thylakoid system floats within the stroma. The **dark reaction** of photosynthesis occurs in the stroma.

Photosystem

Photosynthetic pigments, such as chlorophyll a, chlorophyll b, and carotenoids, are light-harvesting molecules found in the thylakoid membranes of chloroplasts. Those pigments, along with proteins, are organized into complexes called photosystems.

Each photosystem has light-harvesting complexes that contain proteins, 300-400 chlorophylls, and other pigments. When a pigment absorbs a photon, it reaches to an excited state, meaning that one of its electrons is boosted to a higher-energy orbital.



The reaction centre of a photosystem contains a unique pair of chlorophyll a molecules, often called special pair. Once energy reaches the special pair, it will no longer be passed on to other pigments. Instead, the special pair can actually lose an electron when excited, passing it to another molecule in the complex called the primary electron acceptor. With this transfer, the electron will begin its journey through an electron transport chain.

Types of photosystem:

There are **two types** of photosystems in light-dependent reactions. They are:

Photosystem II (**PSII**) and

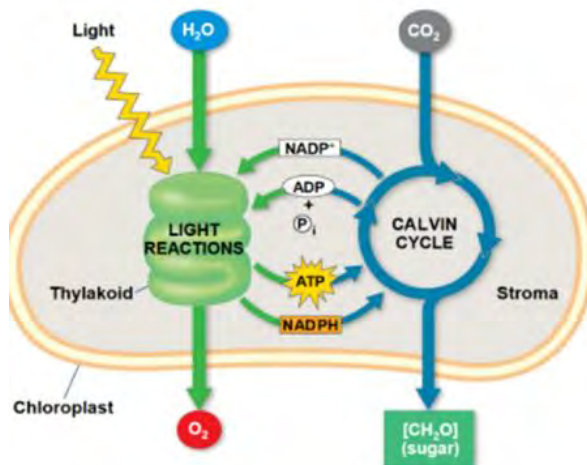
Photosystem I (**PSI**).

The chlorophyll a (special pairs) of the two photosystems absorb different wavelengths of light. The PSII special pair absorbs best at 680 nm. So, it is denoted as P₆₈₀. While the PSI special pair absorbs best at 700 nm, hence, denoted as P₇₀₀.

2.2.3 MECHANISM OF PHOTOSYNTHESIS

Photosynthesis involves two main steps.

- Light- dependent step**- Light reaction/ Primary photo-chemical reaction/ Hill's reaction
- Light-independent step**- Dark reaction/ Blackman's reaction



LIGHT REACTION OR HILL'S REACTION (PHOTOCHEMICAL PHASE).

It is the first step of photosynthesis in which radiant energy is absorbed by photosystems, present in thylakoid membranes of chloroplast. This step requires sunlight, hence, it is a light-dependent step. The absorbed light energy is ultimately converted into chemical energy; ATP (Adenosine Triphosphate) and NADPH₂ (Nicotinamide adenine dinucleotide phosphate). It can further be described under three steps:

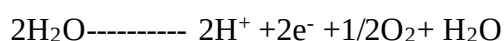
- Photo-excitation of reaction centre

At first, light of different wavelengths is absorbed by harvesting pigment molecules (chlorophylls, carotenoids and phycobillins) and handed over the energy to the reaction centre by resonance method. Each reaction centre, having a special pair of chlorophyll-a, becomes energy-rich and switches to an excited state. It is known as photo-excitation.

After excitation, the reaction centre emits a pair of electrons (energy-rich) and returns to the ground state. This cycle gets repeated several times in a fraction of a second.

- Photolysis of water

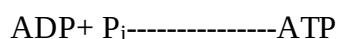
A part of the energy emitted by electrons is used up to split water molecules into protons (H⁺), electrons (e⁻) and molecular oxygen (O₂). This phenomenon is known as photolysis of water. It can be expressed as;



Electrons emitted by this process enter PSII to compensate the lost electrons by the reaction centre (P680), on excitation. Oxygen is evolved as a by-product which is either utilized in mitochondrion for respiration or removed to the atmosphere through stomatal pores.

c) Photo-phosphorylation and NADP reduction.

It is the last step of light reaction. Here, the electrons travel through a number of carrier complexes, known as electron transport chain. During the electron flow, energy is dissipated which is utilized to develop proton gradient in lumen of thylakoids and ultimately, to synthesize ATP molecules from ADP and inorganic phosphate (P_i), mediated by ATP synthetase enzyme. It is known as **photophosphorylation** or light dependent ATP synthesis. It is favoured by chemiosmosis.

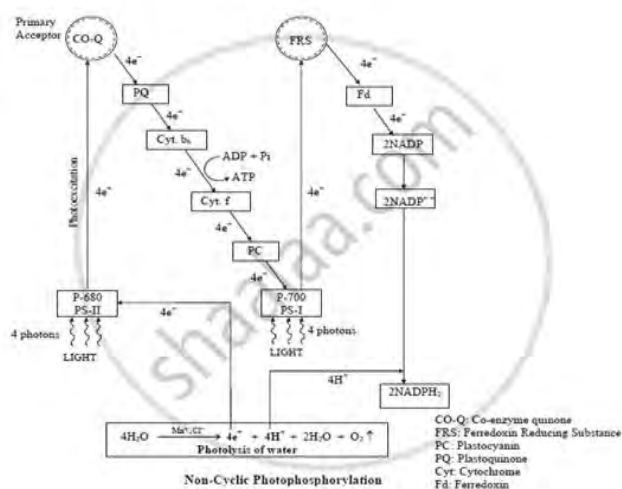


The electrons finally reach NADP reductase where NADP combines with $2e^-$ and $2H^+$ to produce NADPH_2 . This is known as NADP reduction. It takes place in linear or non- cyclic pathway only.

Photo-phosphorylation is of two types;

- i) non-cyclic photophosphorylation and
- ii) cyclic photophosphorylation

i) Non- cyclic photo-phosphorylation:

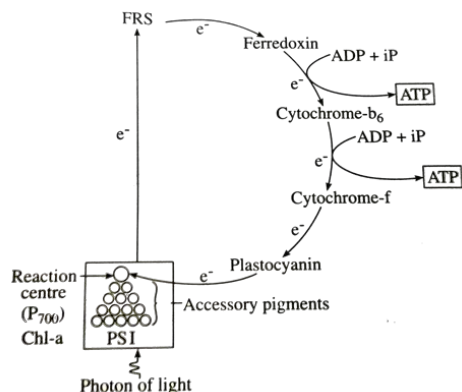


In non-cyclic pathway, light energy is absorbed first by **PSII**. The reaction centre, P_{680} , gets excited and emits electrons which are received by **primary acceptor** (phaeophytin). Now electrons pass through **plastoquinone** (Pq), **cytochrome complex** (Cyt.b₆ and Cyt.f), **plastocyanin** (Pc). Phosphorylation occurs when electrons travel through cytochrome complex. Plastocyanin (Pc) hands over the fatigued electrons to the reaction centre of **PSI** (P_{700}). Due to light absorption in PSI, these electrons become re-energized and then pass to **primary acceptor**, **ferredoxin** (Fd) and finally to **NADP reductase**. Now, those electrons bind with NADP and $2H^+$ and NADPH_2 is formed.

As electrons travel in linear pathway and do not return to the first electron donor (P_{680}), it is known as **non- cyclic photo-phosphorylation**.

It works in conjugation of **photolysis of water**. The electrons produced by splitting of water, compensate the electrons emitted from P_{680} , so that equilibrium is maintained.

ii) Cyclic photo-phosphorylation



In cyclic pathway, **PSII does not involve**. At first, due to light absorption, reaction centre of PSI (P_{700}) becomes excited and emits energy rich electrons. These electrons are accepted by **primary acceptor** (Fe-S complex). Now, electrons travel through **ferredoxin** (Fd), **plastoquinone** (Pq), **cytochrome complex** (Cyt.b₆ and Cyt.f) to **plastocyanin** (Pc). Phosphorylation takes place **twice**; first in between Fd and Pq, second at cytochrome complex. But, there is **no NADP reduction**. Finally, electrons from plastocyanin (Pc) return to the first electron donor, P_{700} . As electrons travel through cyclic pathway, it is called **cyclic photo-phosphorylation**.

It occurs independently and **does not associate with photolysis of water**. This pathway is limited to primitive autotrophs such as **bacteria**. Sometimes, plants also follow this pathway under the condition ATP requirement is more and there is excess $NADPH_2$ in chloroplast.

DARK REACTION OR BLACKMANN'S REACTION

It is the **second step of photosynthesis** in which CO_2 is fixed to organic food (carbohydrates). It involves reduction of carbondioxide, with the use of assimilatory powers (ATP and $NADPH_2$), produced by light reaction. As this step does not involve absorption of light, it is also known as **light- independent step**. In gist, it converts chemical energy to food energy. It is enzymatic process and takes place in **stroma** of chloroplast.

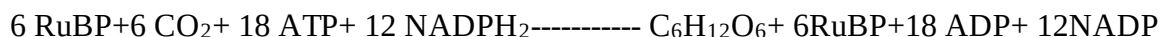
Dark reaction can take place by different pathways as follows:

- Calvin-Benson cycle/ C_3 cycle
- Hatch & Slack Pathway/ C_4 cycle
- Crassulacean Acid Metabolism (CAM) cycle.

Among them, the most common pathway is Calvin cycle.

Calvin –Benson cycle

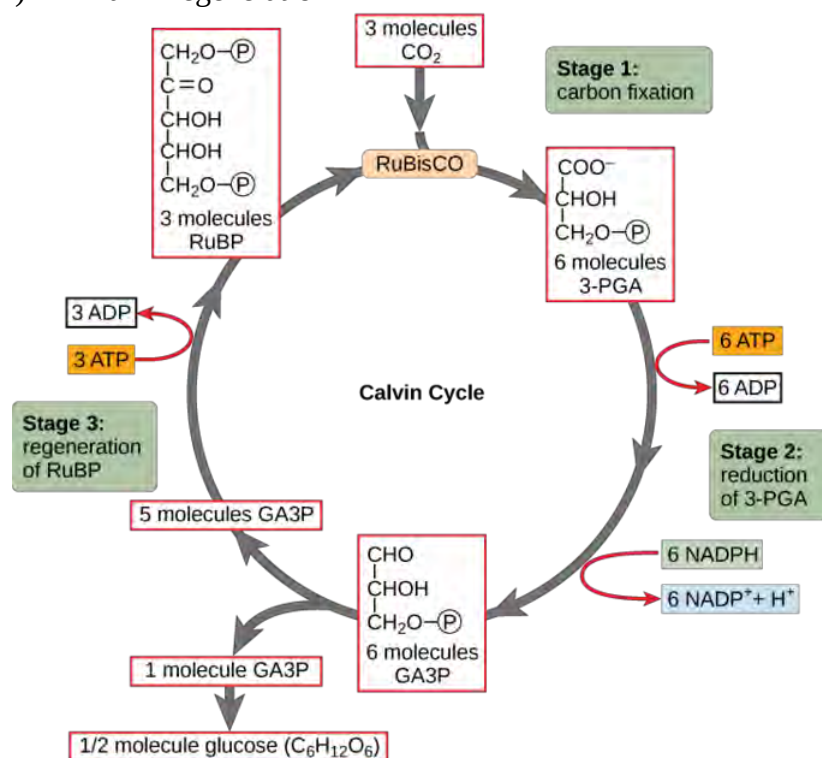
This pathway of dark reaction was first successfully studied in *Chlorella*, a green alga, by Calvin. Hence, it is known as Calvin cycle. In this pathway, first stable product is a 3-carbon compound, **phosphoglyceric acid** (PGA). Therefore, it is also called **C_3 cycle**. Overall reaction of Calvin cycle can be represented as;



Plants which follow C_3 pathway of dark reaction are termed as **C_3 plants**. About 95% of plants on the earth, are C_3 plants. Example: **rice, wheat, cotton, oat, tobacco** etc.

Calvin cycle can be discussed under following steps:

- CO_2 fixation/ Carboxylation of RuBP
- PGA reduction/ Glycolytic reversal
- RuBP regeneration



Step 1: CO_2 fixation

In the stroma, in addition to CO_2 , two other components are present to initiate the light-independent reactions: an enzyme called **ribulose biphosphate carboxylase (RuBisCo)** and three molecules of **ribulose biphosphate (RuBP)**. RuBisCO catalyzes a reaction between CO_2 and RuBP. For each CO_2 molecule that reacts with one RuBP, two molecules of 3-phosphoglyceric acid (3-PGA) form. Each turn of the cycle involves only one RuBP and one carbon dioxide and forms two molecules of 3-PGA. This process is called **carbon fixation** because CO_2 is “fixed” from an inorganic form into organic molecules.

Step 2: PGA reduction

ATP and NADPH_2 are used to convert the six molecules of PGA into six molecules of **glyceraldehyde 3-phosphate (G3P)**. This is a reduction reaction because it involves the gain of electrons by PGA. Six molecules of both ATP and NADPH_2 are used in this step.

After reduction, **one G3P molecule**, out of six, undergoes a series of reactions and finally, contributes the synthesis of $\frac{1}{2}$ glucose molecule. Hence, **for the formation of one glucose, two G3P molecules are required**.

Here, reactions take place in **reverse direction of glycolysis** (of respiration). Therefore, it is also known as **glycolytic reversal**.

Step 3: RuBP regeneration

As one G3P is exported from the cycle, the remaining **five G3P** molecules remain in the cycle and are used to regenerate **three RuBP molecules**, which enables the system to prepare for more CO₂ to be fixed. **Three more molecules of ATP** are used in these regeneration reactions.

Hence for synthesis of one glucose molecule, six CO₂ molecules are to be fixed. It means six turns of Calvin cycle must operate.

Hatch- Slack pathway/ C₄ cycle:

It is alternative pathway of Calvin-Benson cycle. It was first proposed by two physiologists; Hatch and Slack, so known as **Hatch- Slack pathway**. It is also known as C₄ cycle because the first stable product is a four carbon compound, oxalo-acetic acid (OAA). Plants which follow C₄ pathway of dark reaction are known as **C₄ plants**. Example: **maize, sugarcane, Sorghum, Amaranthus** etc.

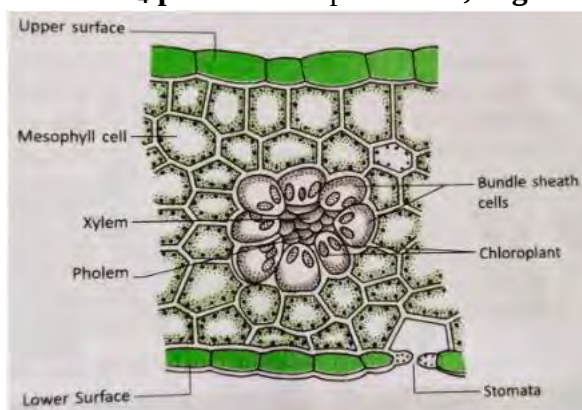


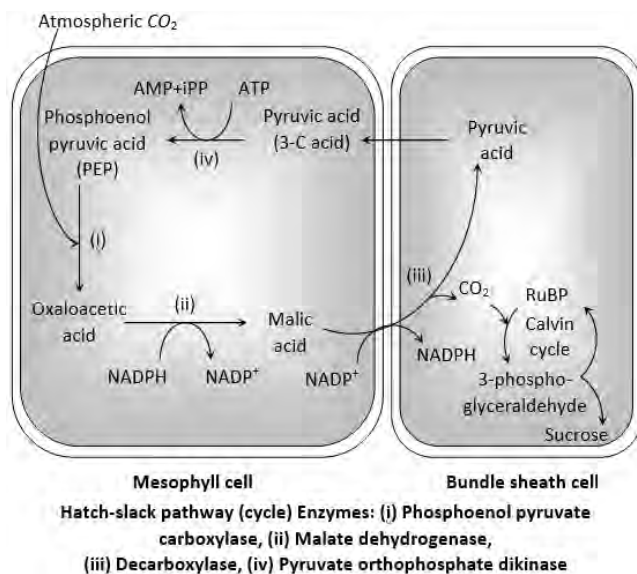
Fig:..... leaf anatomy in C₄ plants

In **mesophyll cells**, chloroplasts are **numerous, smaller in size, contain grana** but **lack the enzyme RuBisCo**. Hence, mesophyll cell chloroplasts are unable to initiate C₃ pathway. Instead, they contain the enzyme PEP carboxylase to fix the CO₂ molecule and begin the C₄ pathway.

In the leaf, each vascular bundle is surrounded by a ring of parenchymatous cells, known as **bundle sheath**. Cells of bundle sheath **contain fewer and larger chloroplasts** which **lack grana** but **contain the enzyme RuBisCo**, which fixes the CO₂ evolved from decarboxylation of malic acid and regulates C₃ cycle.

Hence, in C₄ cycle, **CO₂ fixation occurs twice**, firstly at mesophyll cell chloroplast and finally, at bundle sheath cell chloroplast. Overall chemical reaction of C₄ cycle can be represented by the following equation:





Mechanism:

In chloroplast of mesophyll cell

- i) Fixation of CO₂: CO₂ from atmosphere enters into mesophyll cell, combines with H₂O molecule and dissociates into H⁺ and HCO₃⁻. The bicarbonate ion (HCO₃⁻) combines with 3-carbon compound, phosphoenol pyruvic acid (PEP) and forms one molecule of oxaloacetic acid (OAA), 4-carbon compound. This reaction is catalyzed by **PEP carboxylase** enzyme, present in chloroplast of mesophyll cell.
- ii) Reduction of OAA: Oxaloacetic acid, then, is converted into malic acid (4-carbon compound) with the use of NADPH₂ molecule, in presence of enzyme, **malate dehydrogenase**.

Now, malic acid from mesophyll cell is transported to adjacent bundle sheath cell chloroplast through plasmodesmata.

In chloroplast of bundle sheath cell

- iii) Decarboxylation of malic acid: After entering into bundle sheath cell chloroplast, the malic acid undergoes oxidative decarboxylation and produces pyruvic acid (3-carbon compound). In this step NADPH₂ and CO₂ are also produced. This reaction is catalyzed by **NADP specific malic enzyme**.

The CO₂ released is fixed by enzyme RuBisCo and thus, glucose is synthesized through C₃ pathway in bundle sheath cell chloroplast.

However, pyruvic acid from bundle sheath cell chloroplast returns to mesophyll cell chloroplast via same route.

In chloroplast of mesophyll cell

- iv) Regeneration of PEP: Pyruvic acid, finally, utilizes two molecules of ATP and regenerates phospho-enol pyruvic acid (PEP) in chloroplast of mesophyll cell. This reaction is catalyzed by enzyme **pyruvate di kinase**.

In C₄ plants, photosynthesis continues even the concentration of CO₂ is very low (0-10 ppm). This is possible due to higher affinity of enzyme PEPcarboxylase in CO₂ fixation. Hence, there is **no photorespiration in C₄ plants**. Hence, C₄ plants are said to be **photosynthetically more efficient**.

However, in C_3 plants CO_2 fixing enzyme is RuBisCo which shows less affinity in CO_2 fixation. Particularly, when CO_2 concentration **drops below 100 ppm**, the enzyme RuBisCo **behaves as oxygenase** and thus, binds with O_2 , **leading to photorespiration**.

Photorespiration:

It is wasteful process which **yields neither glucose nor ATP**. In this process, ATPs are used up, resulting in the expenditure of energy. It is, simply, an **undesirable deviation from dark reaction**. It is also known as **C_2 cycle** as the reaction proceeds from first product, 2-carbon compound, **phosphoglycolic acid**. It involves a cyclic chain of reactions which occur in **three organelles; chloroplast, peroxisome and mitochondrion**.

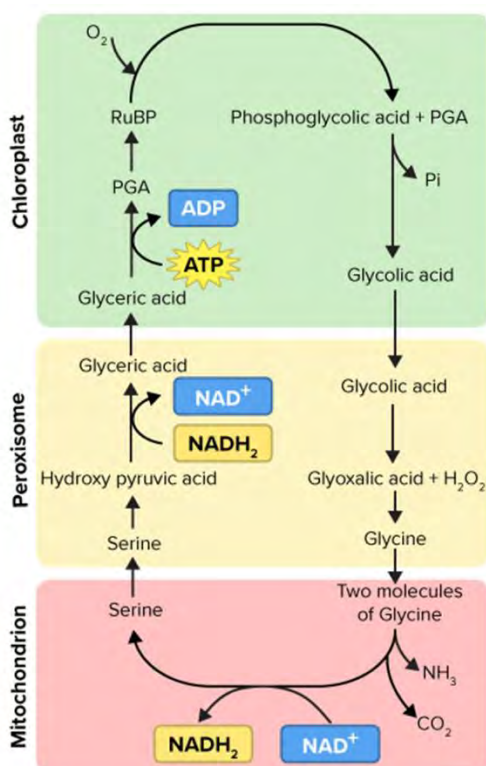


Fig.....: Photorespiration

2.2.5: FACTORS AFFECTING PHOTOSYNTHESIS

The light reaction totally depends on the availability of light, water, pigments etc and the dark reaction depends on the temperature and available CO_2

EXTERNAL FACTORS

Light: In photosynthesis light is converted to chemical energy in the food formed.

(i) **Light intensity** – Light intensity required to get the optimum value differs with different species. Usually with increase in light intensity increase in rate is noticed. The value of light saturation at which further increase in photosynthetic rate is not accompanied by an increase in CO_2 uptake is called light saturation point.

(ii) **Light quality**- Blue and red light of the spectrum is said to be the best for the photosynthesis. The maximum photosynthesis is shown to occur in the red part of the spectrum with the next peak in blue part. The green light has inhibitory effect in photosynthesis.

(iii) **Light duration** – Generally photosynthesis is independent of light duration. It is more in intermittent light than continuous light.

Carbon dioxide: Carbon dioxide is present in low concentration and form about 0.03% of total atmosphere CO_2 is natural limiting factor of photosynthesis. If the concentration of CO_2 is increased from 0.03% to 1%, the rate of photosynthesis increases. If concentration of CO_2 exceeds 1%, rate of photosynthesis decreases due to closure of stomata.

Water: Water deficiency may decrease the rate. Less availability of water may further check the rate by closing the stomata thereby affecting the entry of CO_2 .

Temperature: The optimum temperature for photosynthesis is 15°C to 35°C . If the temperature is increased too high, the rate of photosynthesis is reduced due to denaturation of enzymes involved in the process. Photosynthesis occurs in conifers at high altitude at 35°C . Some algal in hot springs can undergo photosynthesis even at 75°C . When other factors are not limiting rate of photosynthesis gets doubled for every 10°C rise in temperature until an optimum is reached.

Oxygen: Excess of O_2 may become inhibitory for the process. Enhanced supply of O_2 increases the rate of respiration simultaneously, decreasing the rate of photosynthesis. An increase in oxygen concentration decreases photosynthesis and the phenomenon is called **Warburg's effect**.

Mineral elements: Some mineral elements like Fe, Mg, Cu, Mn, Cl etc are associated with synthesis of chlorophyll and important reactions in photosynthesis like photolysis of water. So, absence of these elements decreases the rate of photosynthesis.

INTERNAL FACTORS

Chlorophyll: Chlorophyll is an important internal factor for photosynthesis since it absorbs the radiant energy of light. Light initiates the mechanism of photosynthesis by transferring its electrons and getting excited. Emerson (1929) found direct relationship between the chlorophyll content and the rate of photosynthesis. The chlorophyll deficient mutants are albinos. They can't synthesize carbohydrates by photosynthesis, so they cannot survive.

Leaf anatomy: Photosynthesis also depends upon the anatomy of leaf. If the assimilatory surface by palisade parenchyma is extensive there will be increased photosynthesis.

Leaf age: In immature leaf the rate of photosynthesis is at minimum level. A mature leaf shows photosynthetic rate at maximum. When leaf becomes old, the rate decreases.

End products: The end products of photosynthesis are carbohydrates. Accumulation of carbohydrates decreases the rate of photosynthesis. If the carbohydrates are translocated rapidly, the rate of photosynthesis increases.

Protoplasmic factors: These factors include the hydration of protoplasm and also the enzymatic activity. If there is an appreciable decrease in the hydration of the protoplasm the process of photosynthesis is inhibited because the enzymes get denatured.

EXERCISE

A. Tick the correct alternatives:

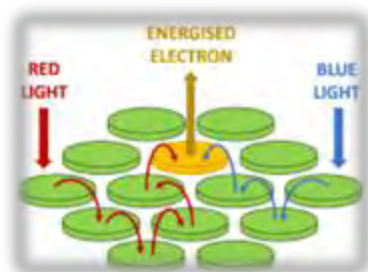
1. What is true about photosynthesis?
 - a. Anabolic process
 - b. Catabolic process
 - c. Exothermic process
 - d. Energy-yielding process.
2. Which organism shows non-oxygenic photosynthesis?
 - a. Animals
 - b. Bacteria
 - c. Cyanobacteria
 - d. Green plants
3. During photosynthesis, green plants utilize sunlight, water and CO_2 , manufacture organic food and evolve oxygen. What does the oxygen come from?
 - a. CO_2
 - b. Water
 - c. Sunlight
 - d. Chlorophyll.
4. Which statement is true about chloroplast?
 - a. Entire photosynthesis occurs at stroma.
 - b. Entire photosynthesis occurs at thylakoids.
 - c. Photosynthetic pigments are present in thylakoid membrane.
 - d. Light reaction of photosynthesis takes place at stroma of chloroplast.
5. Which is light dependent step of photosynthesis?
 - a. Hill reaction
 - b. Blackmann reaction
 - c. Hatch Slack pathway
 - d. Crassulacean acid metabolism
6. In which region of white light, effective absorption takes place?
 - a. Blue and green light
 - b. Green and red light
 - c. Blue and red light
 - d. yellow and green light.
7. In which part of photosystem, the absorbed light energy finally reaches?
 - a. Photo-centre
 - b. core molecule
 - c. Antenna molecule
 - d. Harvesting molecule
8. What is the reaction centre of PSII?
 - a. P_{600}
 - b. P_{680}
 - c. P_{700}
 - d. P_{780}

9. Which is the correct order of electron carriers between PSII and PSI?
 - a. Primary acceptor, Pc, Cyt.complex, Pq
 - b. Primary acceptor, Fd, Pq, Cyt.complex
 - c. Primary acceptor, Pq, Cyt.complex, Pc
 - d. Primary acceptor, Fd, Cyt.complex, Pc
10. What is true about cyclic photophosphorylation?
 - a. Involves PS II only.
 - b. involves photolysis of water
 - c. NADPH₂ is synthesized
 - d. Final electron acceptor is P₇₀₀
11. Which of following involves ATP synthesis during light reaction?
 - a. Photolysis
 - b. Photo-excitation
 - c. Dark reaction
 - d. Photo-phosphorylation
12. Which is the first stable compound of C₃ cycle?
 - a. Citric acid
 - b. Oxaloacetic acid
 - c. Phosphoglycolic acid
 - d. Phosphoglyceric acid.
13. What does RUBISCO stand for ?
 - a. Ribose biphosphate carboxylase
 - b. Ribose bisulphate carboxylase
 - c. Ribulose biphosphate carboxylase
 - d. Ribulose bisulphate carboxylase
14. In which step of Calvin cycle, sugar is synthesized?
 - a. CO₂ fixation
 - b. PGA reduction
 - c. RUBP regeneration
 - d. RUBP carboxylation.
15. In C₃ cycle, how many ATPs are required for the fixation of 6CO₂?
 - a. 12
 - b. 18
 - c. 24
 - d. 30
16. Under what condition, C₃ plants can not carry out photosynthesis?
 - a. When the rate of transpiration is high
 - b. When the temperature falls below 5degree Celsius.
 - c. When CO₂ concentration increases above the normal.
 - d. When CO₂ concentration becomes low, below 100 ppm.
17. Which of the following is C₄ plant?
 - a. Rice
 - b. Maize
 - c. Wheat
 - d. Grass
18. Which plant possesses Kranz leaf anatomy and dimorphic chloroplasts?

- a. C₂ plant
 - b. C₃ plant
 - c. C₄ plant
 - d. CAM plant
19. Which cells of leaf involve in C₄ cycle?
- a. Mesophyll cell and guard cell
 - b. Bundle sheath cell and guard cell
 - c. Mesophyll cell and epidermis
 - d. Mesophyll cell and bundle sheath cell

B. Answer the following questions:

1. Write about photosynthesis in plants.
2. Write balanced equation of photosynthesis. Mention its significance.
3. Briefly describe about photosynthetic pigments.
4. Study the given figure of photosystem and answer following questions.



- a. Where is it present in chloroplast?
 - b. Its reaction centre is P₇₀₀. Which photosystem is it?
 - c. What is the role of reaction centre?
 - d. Does it carry out photophosphorylation independently? If yes, which one?
5. Give a short account of light absorption mechanism in photosystem.
 6. Draw flow chart of non- cyclic photophosphorylation.
 7. Mention differences between cyclic and non-cyclic photophosphorylation.
 8. Briefly write about Hatch-Slack pathway.
 9. Differentiate between C₃ and C₄ plants.
 10. Why are C₃ plants less efficient in photosynthetic activity, as compared to C₄ plants?
 11. How do light and temperature affect photosynthesis?
 12. Define photosynthesis. Write about chlorophyll and its types.
 13. Write the mechanism of light reaction. How does it differ from dark reaction?
 14. Discuss about Calvin cycle with diagram.
 15. Discuss various factors affecting photosynthesis.

Project Work

Make a list of plants seen during field visit. Categorize the plants as C₃, C₄, and CAM on basis of photosynthetic activity. Students are encouraged to benefit from internet to classify the listed plants.

Chapter 2.4

PLANT RESPIRATION

Discuss the following questions:

- I. Do plants need oxygen like animals do?
- II. What happens to the food that plants make during photosynthesis?
- III. How is plant respiration different from photosynthesis?

2.3:1:Introduction and significance of respiration:

The phenomenon of breakdown of food materials within the cell to release energy, and the trapping of this energy for synthesis of ATP is known as cellular respiration.

Photosynthesis, of course, takes place within the chloroplasts, whereas the breakdown of complex molecules to yield energy takes place in the cytoplasm and in the mitochondria. The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called **respiration**. It is **catabolic process**. During oxidation within a cell, all the energy contained in organic food is released in a series of slow step-wise reactions controlled by enzymes, and it is trapped as chemical energy in the form of ATP. ATP is also known as **energy currency of the cell**, which is utilized in various cellular activities such as growth, development etc.

Types of respiration:

Respiration takes place by two ways. They are:

a) **Aerobic respiration**

During aerobic respiration, **oxygen is utilised**, and carbon dioxide, water and energy are released as products. The combustion reaction requires oxygen. It occurs in most of the organisms.

b) **Anaerobic respiration**

In this process, food is oxidised **without use of oxygen**. It is less efficient process and takes place in some prokaryotes, fungi etc.

Differences between aerobic and anaerobic respiration

Aerobic

- Occurs in the presence of oxygen in all living cells of higher plants
- Oxygen is required
- The substrate is completely oxidized to CO₂, H₂O and energy
- Energy liberated during oxidation of 1 glucose molecule is 38 ATP
- It takes place in cytoplasm and mitochondria

Steps involved : Glycolysis, Aerobic oxidation of pyruvic acid into CO₂ and H₂O .

1 gm glucose yields 686 kcal energy.

Anaerobic

- Occurs in bacteria, certain fungi, germinating seeds and fleshy fruits
 - Oxygen is not required
 - The end products are alcohols or acids and CO₂
 - Energy liberated during oxidation of 1 glucose molecule is 2 ATP
 - All reactions take place in the cytoplasm
 - Steps involved: Glycolysis, Conversion of pyruvic acid into alcohol/ acid and CO₂
- 1 gm glucose yields 32-50 kcal energy.

Significance of respiration

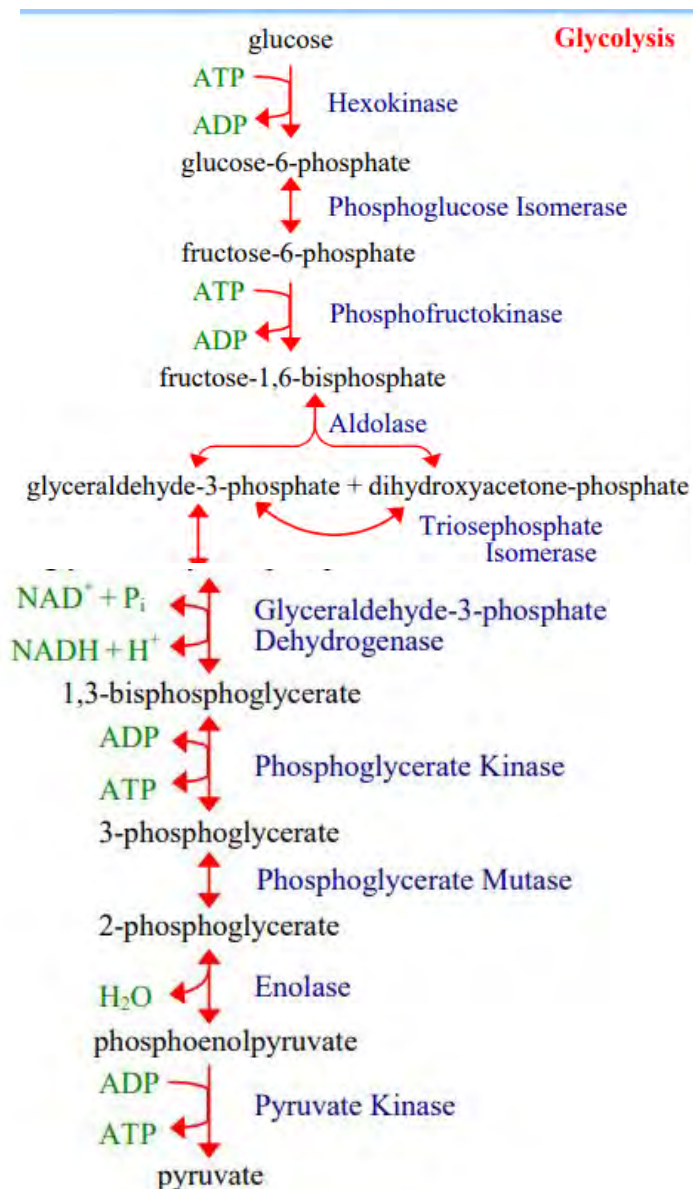
1. Respiration provides energy for biosynthesis of cellular materials such as carbohydrates, proteins, lipids etc.
2. It is also a source of energy for cell division, growth, repair and replacement of worn out parts, movement etc.
3. Various intermediates of Krebs's cycle are used as building blocks for the synthesis of other complex compounds.
4. Coupled with photosynthesis, it helps to maintain the balance between CO₂ and O₂ in the atmosphere.
5. Anaerobic respiration (fermentation) is used in various industries such as dairies, bakeries, distilleries, leather industries, paper industries, pharmaceuticals etc.

2.3.3: Mechanism of aerobic respiration:

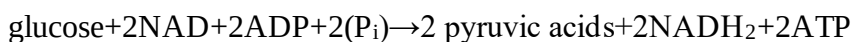
Aerobic respiration involves the following steps:

1: Glycolysis

It is the **first step** of respiration. It refers to decomposition of **glucose molecule into two pyruvic acids**. This pathway was first studied by three German scientists: **Embden, Mayerhoff** and **Paranas**. Hence, it is also called **EMP pathway** (on their names). Oxygen is not required in any of the steps of glycolysis, neither CO₂ is evolved. It takes place in the **cytoplasm** of cells. It involves 10 steps of reactions. All the steps are **reversible** and **enzyme- dependent**.



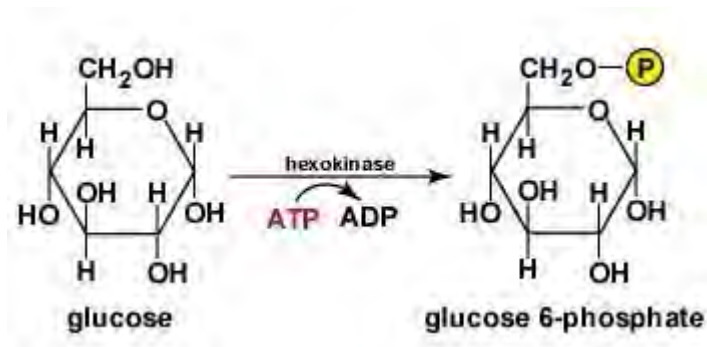
The overall reaction is:



Glycolysis does not require oxygen and can occur under aerobic and anaerobic conditions. However, during aerobic respiration, the two reduced NADH_2 molecules transfer protons and electrons to the electron transport chain to generate additional ATPs by way of oxidative phosphorylation.

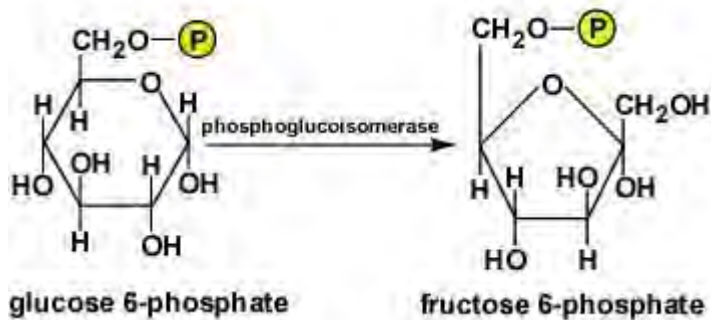
Step 1

To initiate glycolysis in eukaryotic cells, **a molecule of ATP** is hydrolyzed to transfer a phosphate group to the number 6 carbon of glucose to produce glucose 6-phosphate, in presence of enzyme **hexokinase**.



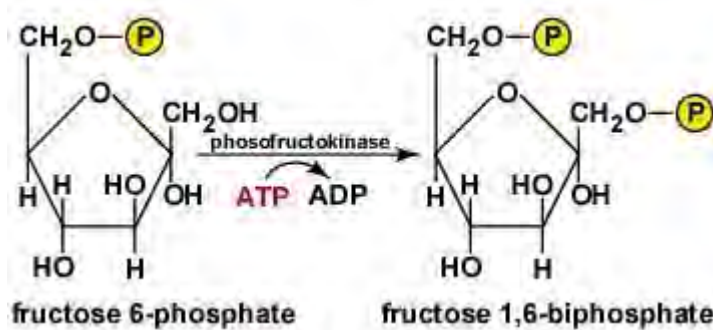
Step 2

The glucose 6-phosphate is rearranged to an isomeric form called fructose 6-phosphate. This reaction is catalyzed by **phosphohexoisomerase**.



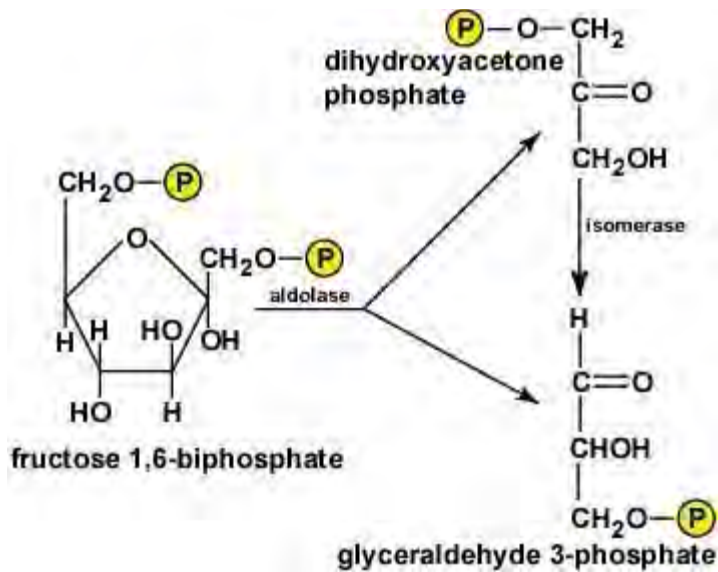
Step 3

A second molecule of ATP is hydrolyzed to transfer a phosphate group to the number 1 carbon of fructose 6-phosphate to produce fructose 1,6-biphosphate, in presence of enzyme **phosphofructokinase**.



Step 4

The 6-carbon fructose 1,6 biphosphate is split to form two, 3-carbon molecules: **glyceraldehyde 3-phosphate** and **di-hydroxy acetone phosphate**, in presence of enzyme **aldolase**.

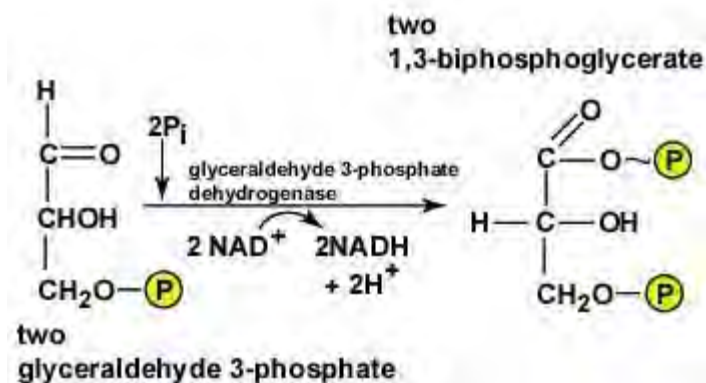


Step 5

The dihydroxyacetone phosphate is then converted into a second molecule of **glyceraldehyde 3-phosphate**, catalyzed by triose phosphate **isomerase**. Two molecules of glyceraldehyde 3-phosphate will now go through each of the remaining steps in glycolysis producing two molecules of each product.

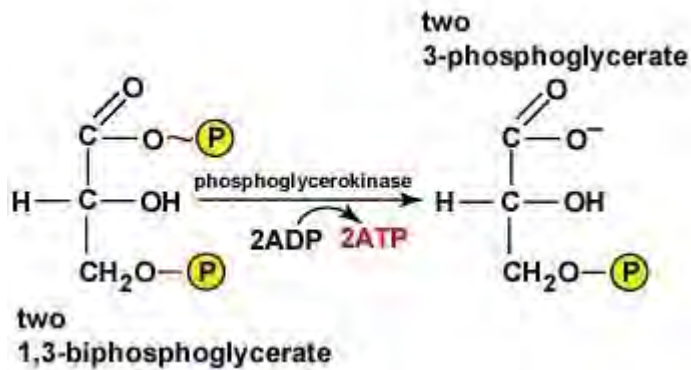
Step 6

As each of the two molecules of glyceraldehyde 3-phosphate are oxidized, the energy released is used to add an inorganic phosphate group to form two molecules of **1,3-diphosphoglyceric acid**, each containing a high-energy phosphate bond. During these oxidations, two molecules of NAD are reduced to form 2NADH_2 . During aerobic respiration, NADH_2 carry protons and electrons to the electron transport chain to generate additional ATP by oxidative phosphorylation.



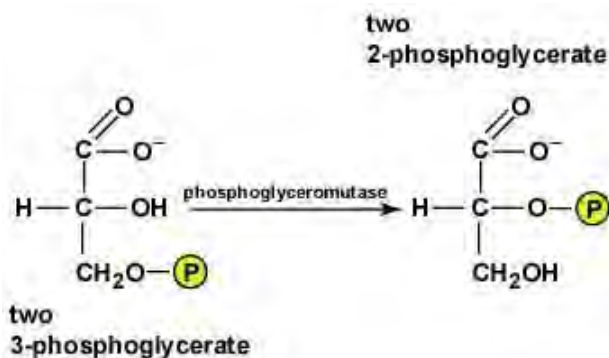
Step 7

As each of the two molecules of 1,3-diphosphoglyceric acid are converted to **3-phosphoglycerate**, with the release of ATP. This reaction is regulated by enzyme **phosphoglycerokinase**.



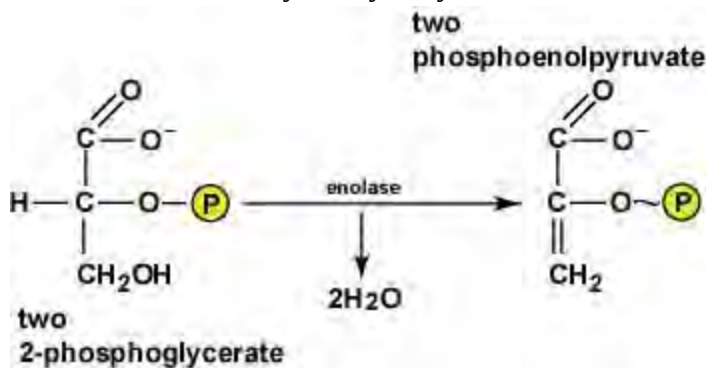
Step 8

The two molecules of 3-phosphoglyceric acid are rearranged to form two molecules of **2-phosphoglyceric acid**, in presence of enzyme **phosphoglyceromutase**.



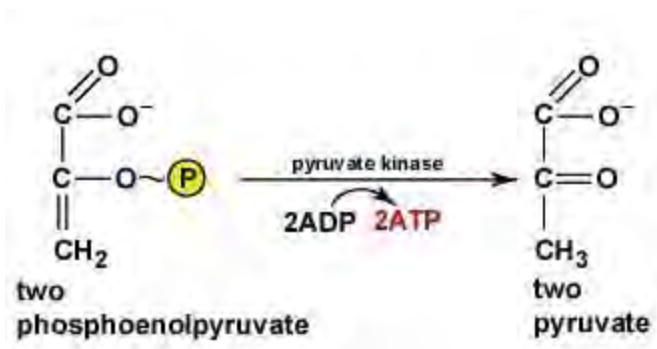
Step 9

Water is removed from each of the two molecules of 2-phosphoglycerate converting the phosphate bonds to a high-energy phosphate bonds as two molecules of **phosphoenolpyruvic acid** are produced. This reaction is catalyzed by enzyme **enolase**.



Step 10

In the final step of glycolysis, two molecules of phospho-enol pyruvic acid are converted to two molecules of **pyruvic acid**, with the release of two ATP molecules, in presence of enzyme **pyruvate kinase**.



Points to remember

Overall significance of glycolysis:

When one molecule of glucose enters glycolysis;

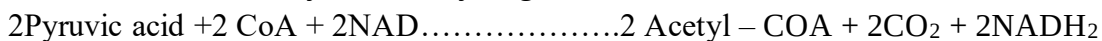
- a) 2 NADH₂ molecules are formed
- b) 2 ATP molecules are formed

2: KREBS' CYCLE

The pyruvic acid produced during glycolysis enters into the Krebs's cycle (named from the physiologist, (H.A.Kreb) for further oxidation. There is a short reaction, known as **link reaction** which **connects glycolysis with Krebs's Cycle**. In link reaction, pyruvic acid undergoes **oxidative decarboxylation** and produces **acetyl co-A**, which enters into Krebs's cycle. Other products of link reaction are **CO₂ and NADH₂** from each pyruvic acid molecule.

Link reaction can be summarized as follows:

Pyruvate dehydrogenase



Krebs's cycle is also known as **citric acid cycle** or **tricarboxylic acid cycle**. It takes place in the **mitochondrial matrix**, where all the necessary enzymes are present.

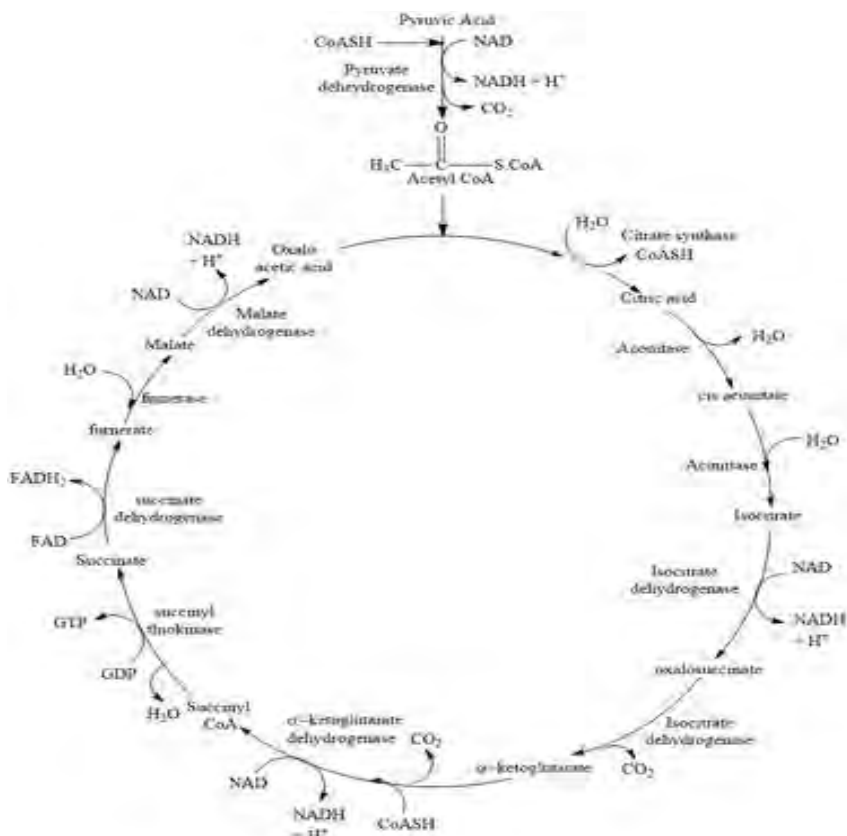


Fig: Kreb's cycle

Different steps of Kreb's cycle have been summarized as follows:

1. **Acetyl-CoA** condenses with **oxaloacetic acid** in the presence of enzyme, **citrate synthetase** and water molecule to form **citric acid**. Co-A becomes free.

Condensing enzyme

Acetyl CoA + Oxaloacetic acid.....Citric acid + CoA+ H₂O

3. **Citric acid** is dehydrated in the presence of **aconitase** to form **cis – aconitic acid**

Aconitase

Citric acid.....Cis – aconitic acid + H₂O

4. **Cis-aconitic acid** reacts with one molecule of water to form **Isocitric acid**

Cis-aconitic acid + H₂O.....**aconitase**.....Isocitric acid

5. **Isocitric acid** is oxidized to **oxalo-succinic acid** in the presence of **isocitrate dehydrogenase**. NADP is reduced to NADPH₂ in the reaction.

IC dehydrogenase

Isocitric acid + NAD..... Oxalosuccinic acid + NADH₂

6. **Oxalosuccinic acid** is decarboxylated in the presence of **oxalosuccinate decarboxylase** to form **α - ketoglutaric acid** and a molecule of CO₂ is released.

Oxalosuccinate decarboxylase

Oxalosuccinic acid..... α-ketoglutaric acid + CO₂

7. **α - ketoglutaric acid** reacts with CoA and NAD in the presence of **α – ketoglutarate dehydrogenase** complex and is oxidatively decarboxylated to form **succinyl CoA** and a molecule of CO₂ is released. NAD is reduced in the reaction.

α-ketoglutarate dehydrogenase

α -keto glutaric acid + CoA + NAD..... Succinyl-CoA + CO₂ + NADH₂

8. **Succinyl CoA** reacts with water molecule to form **succinic acid**, in presence of enzyme **succinyl thiokinase**. CoA becomes free and **one molecule of GTP** (Guanosine triphosphate) is also produced.

Succinyl thiokinase

Succinyl-CoA + H₂O + GDP + ip.....Succinic acid + GTP

GTP may react with ADP to form one molecule of ATP

GTP + ADP → ATP + GDP

9. **Succinic acid** is oxidized to **fumaric acid** in the presence of **succinic dehydrogenase** and co-enzyme FAD is reduced in this reaction.

Succinic dehydrogenase

Succinic acid + FAD.....Fumaric acid + FADH₂

10. One molecule of H₂O is added to **Fumaric acid** in the presence of **fumarase** to form **malic acid**.

Fumarase

Fumaric acid + H₂O..... Malic acid

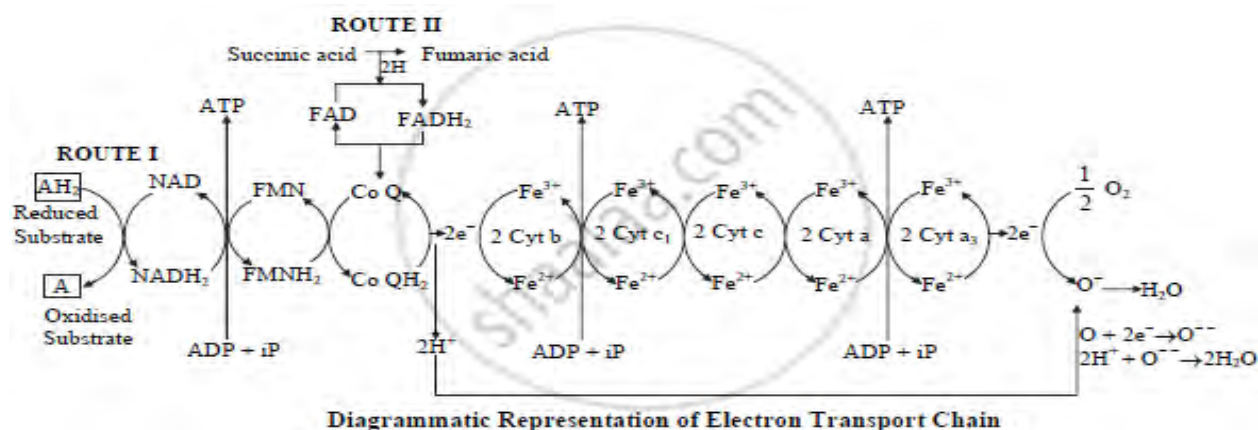
11. In the last step, **malic acid** is oxidized to **oxaloacetic acid** in the presence of **malate dehydrogenase** and one molecule of coenzyme i.e. NADH₂ is produced

Malate

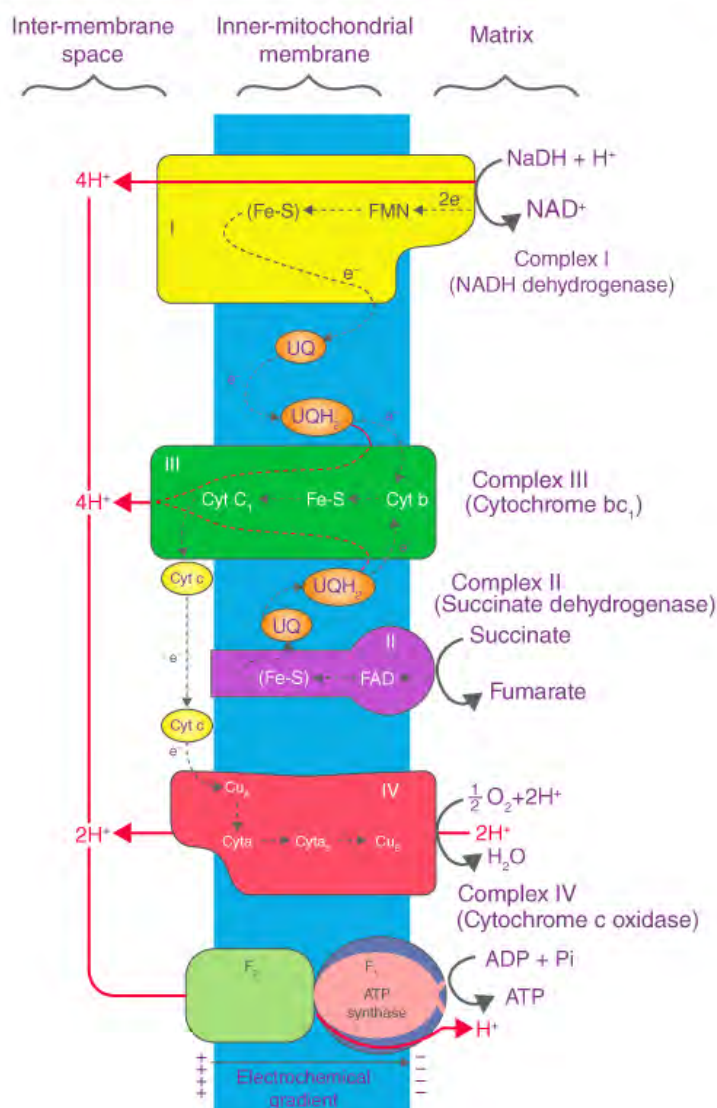
dehydrogenase

Malic acid + NAD.....Oxaloacetic acid + NADH₂

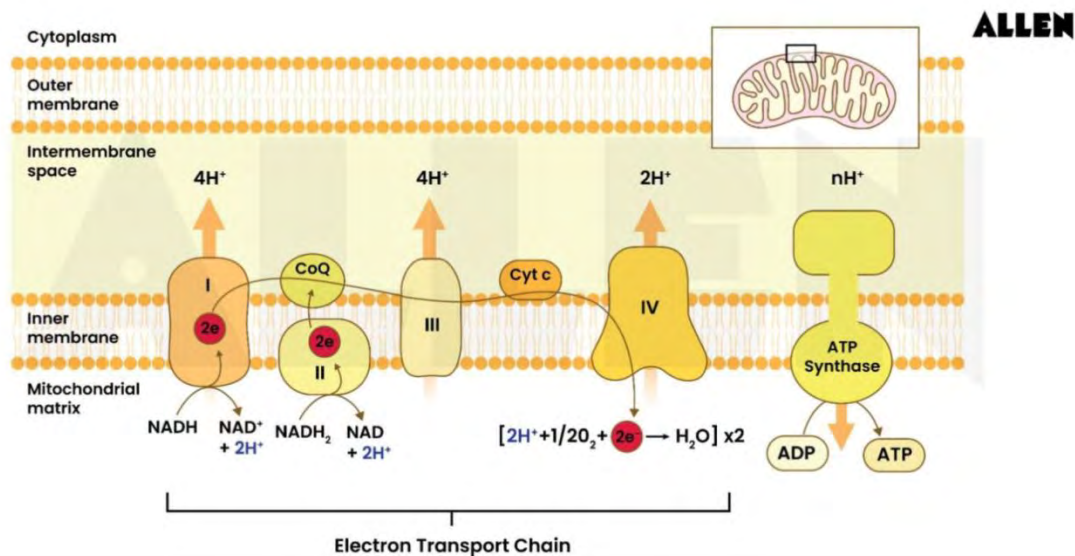
3:Electron transport chain



ELECTRON TRANSPORT SYSTEM



The electron transport chain consists of **four electron complexes**. Complex I oxidizes NADH_2 to NAD and simultaneously pumps a proton across the membrane to the inter membrane space. The two electrons released from NADH_2 are shuttled to **coenzyme Q**, then to **complex III**, to **cytochrome c**, to **complex IV**, then to **molecular oxygen**. In the process, **two more protons** are pumped across the membrane to the inter-membrane space, and **molecular oxygen is reduced** to form **water**. **Complex II** removes two electrons from FADH_2 , thereby forming FAD . The electrons are shuttled to coenzyme Q, then to complex III, cytochrome c, complex I, and molecular oxygen as in the case of NADH_2 oxidation



It is a process that begins with moving electrons through **a series of electron carriers** that undergo redox reactions: the electron transport chain. This causes **hydrogen ions to accumulate within the matrix space**. Therefore, a concentration gradient forms in which hydrogen ions diffuse out of the matrix space by passing through ATP synthase. The current of hydrogen ions powers the catalytic action of ATP synthase and **ATP is synthesized** by using ADP and P_i . It is also known as **terminal oxidation** or **oxidative phosphorylation**.

The electron transport chain is the **last step of aerobic respiration** and is the only part of glucose metabolism that uses atmospheric oxygen. At the end point of the chain, the electrons reduce molecular oxygen to **produce water**.

Anaerobic respiration

It refers to partial oxidation of food to liberate energy. It does not require molecular oxygen. Anaerobic respiration takes place in cytoplasm only.

It involves two steps:

- A) Glycolysis
- B) Fermentation.

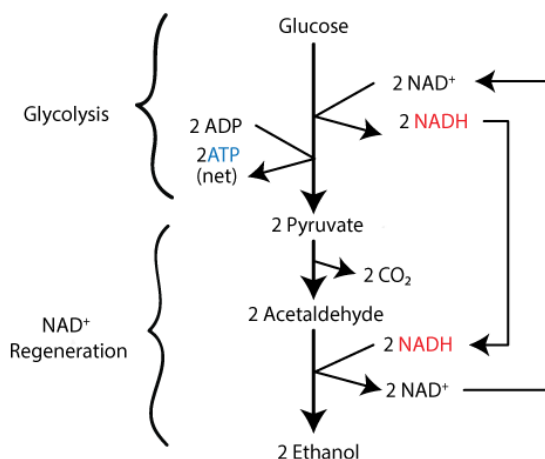
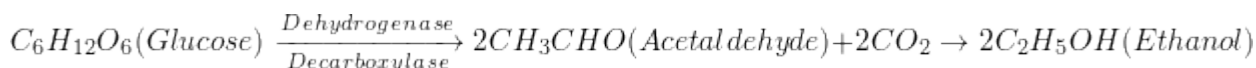
As in aerobic respiration, one glucose molecule yields 2 pyruvic acids, 2ATPs and 2NADH₂ at the end of glycolysis.

During fermentation, pyruvic acid is reduced to lactic acid, ethanol or other products. Here NAD⁺ is formed which is re-utilized back in the glycolysis process. Depending upon the product, fermentation can be of three types.

- a) Alcoholic fermentation

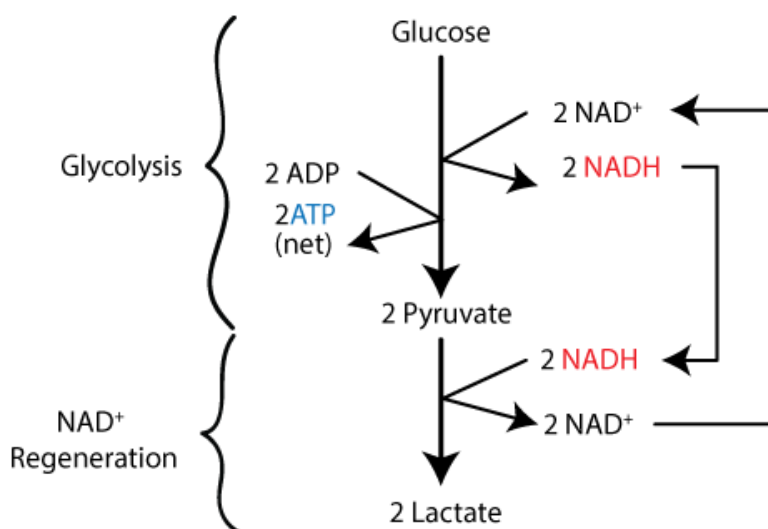
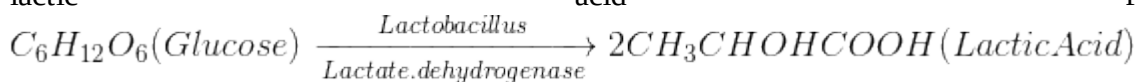
This is used in the industrial production of wine, beer, biofuel, etc. The end product is ethyl alcohol and CO₂. Pyruvic acid breaks down into acetaldehyde, and CO₂ is released in presence of pyruvate decarboxylase. In the next step, acetaldehyde is reduced to ethyl alcohol in presence of alcohol

dehydrogenase. NAD^+ is also formed from NADH , which is re- utilized in glycolysis. Yeast and some bacteria carry out this type of fermentation.



b) Lactic acid fermentation:

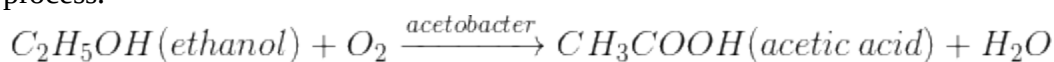
Lactic acid is formed from pyruvate produced in glycolysis. NAD^+ is generated from NADH . Enzyme lactate dehydrogenase catalyses this reaction. *Lactobacillus* prepares curd from milk via this type of fermentation. During intense exercise when oxygen supply is inadequate, muscles derive energy by producing lactic acid. This lactic acid is transported by bloodstream to other cells and gets converted back to pyruvic acids, ready to enter aerobic respiration. CO_2 is not evolved in lactic acid fermentation.



c) Acetic acid Fermentation

Vinegar is produced by this process. This is a two-step process. The first step is the formation of ethyl alcohol from sugar anaerobically using yeast. In the second step, ethyl alcohol is further

oxidized to form acetic acid using *Acetobacter*. Microbial oxidation of alcohol to acid is an aerobic process.



Factors affecting respiration

1. External factors:

Temperature: It is the most important factor affecting the rate of respiration. Normally, the rate of respiration increases to a certain limit by an increase in temperature from 5.0°C to 30.0°C. In this range, the rate of respiration increases as per **Vont Hoff's rule**. According to this, a rise in temperature by 10°C, the rate of respiration becomes double.

An increase in temperature beyond 35.0°C results in decrease in rate as the enzymes begin to denature. At very low temperatures also, enzymes become inactive and the rate of respiration decreases. In cold storage, the fruits and vegetables escape spoilage because of little respiration.

Oxygen: Oxygen is necessary for aerobic respiration because it acts as a terminal acceptor of electrons. At low concentration of oxygen, both aerobic and anaerobic respiration may take place, but when the concentration of oxygen becomes zero, only anaerobic respiration takes place.

Water: Water acts as a medium for all the metabolic activities. The protoplasm contains up to 90-95% of water. Water plays an important role in enzyme activation, gaseous diffusion, transportation, etc.

In dry seeds and fruits rate of respiration is extremely low due to the shortage of water and so these can be stored for a long duration. In the presence of water stored carbohydrates convert into soluble sugar and the rate of respiration increases.

Light: The rate of respiration is not influenced directly by light and so it takes place in the presence as well as an absence of light. However, light as a factor may influence the rate of respiration as follows:

Light causes an increase in temperature which may cause an increase in the rate of respiration. Photosynthesis results in the synthesis of sugar which acts as a respiratory substrate. In the presence of light stomata open and so, the gaseous exchange is facilitated.

Carbon dioxide: An increase in the concentration of CO_2 inhibits respiration. Hence it has an adverse effect on the germination of seeds and the rate of growth of plants. Heath experimentally proved that an increase in the concentration of CO_2 causes the closure of stomata and the rate of respiration decreases due to a shortage of oxygen.

2: Internal factors:

Protoplasm: Meristematic cells have dense and active cytoplasm and so the rate of respiration is relatively high in these cells as compared to the mature cells. The activity of protoplasm is affected by several factors such as hydration, pH, temperature, etc.

Respiratory substrate: Different types of sugars such as glucose, fructose, maltose, etc. present in the cell are quickly used in respiration. In comparison to these starch and fats need to be first converted into a soluble form and only then they can be used as a respiratory substrate. This is the

reason why in hospitals a patient is administered directly with, glucose, whereas the normal diet of healthy persons contains starch and fats.

Age of Cells: The rate of respiration is much higher in the young cells as compared to mature and old cells.

Wound and Injured part: The rate of respiration sharply increases in the wound and injured part to promote healing.

EXERCISE

A. Tick the correct alternatives:

1. Which organelle is known as power-house of cell?
 - a. Nucleus
 - b. Chloroplast
 - c. Mitochondrion
 - d. Endoplasmic reticulum
2. What does aerobic respiration involve?
 - a. Reduction of CO₂
 - b. Photolysis of water
 - c. Partial oxidation of organic food
 - d. Complete oxidation of organic food.
3. What is the site of anaerobic respiration?
 - a. Cytoplasm
 - b. Mitochondrion
 - c. Cytoplasm and mitochondrion
 - d. Chloroplast and mitochondrion
4. What is the end product of glycolysis?
 - a. Glucose
 - b. Citric acid
 - c. Pyruvic acid
 - d. Acetic acid
5. What is the net gain of ATP molecules through glycolysis?
 - a. 2
 - b. 4
 - c. 6
 - d. 8
6. What is glycolysis also called?
 - a. Hill reaction
 - b. EMP pathway

- c. Citric acid cycle
 - d. CAM pathway.
7. What does link reaction connect in aerobic respiration?
- a. Glycolysis with electron transport chain
 - b. Glycolysis with Krebs's cycle
 - c. Krebs's cycle with electron transport chain
 - d. Glycolysis with oxidative phosphorylation.
8. What is the maximum number of ATPs generated from one glucose molecule through aerobic respiration?
- a. 34
 - b. 36
 - c. 38
 - d. 40
9. What is the first stable product of Krebs's cycle?
- a. Malic acid
 - b. Citric acid
 - c. Succinic acid
 - d. Oxaloacetic acid.
10. How many ATPs are produced when one molecule of NADH_2 passes through electron transport chain?
- a. 2
 - b. 3
 - c. 4
 - d. 5
11. Which of the following step is common in aerobic and anaerobic respiration?
- a. Krebs's cycle
 - b. Fermentation
 - c. Glycolysis
 - d. Electron transport chain
12. Which part of mitochondrion generates ATP?
- a. Matrix
 - b. Cristae
 - c. Oxysome
 - d. Thylakoid

13. Which fermentation does not evolve CO₂?
- Alcoholic fermentation
 - Lactic acid fermentation
 - Acetic acid fermentation
 - All of above
14. Which of following involve in anaerobic respiration?
- Algae
 - Yeast
 - Bryophytes
 - Gymnosperms
15. What is the site for Kreb's cycle reaction?
- Matrix
 - Stroma
 - Cytoplasm
 - Nucleoplasm

B. Answer the following questions:

- Define cellular respiration. Write its significance.
- Differentiate between aerobic and anaerobic respiration.
- Define glycolysis. Why is it significant in respiration?
- Define fermentation and describe its types in brief.
- Enlist the external factors affecting respiration and describe any two of them.
- Explain EMP pathway of respiration with necessary diagram.
- What is link reaction? Explain Kreb's cycle in detail with figure.
- Describe the process of anaerobic respiration and its significance.
- Discuss various factors affecting respiration.

Chapter 2.4

PLANT HORMONES

Discuss the following questions:

- I. What might control the falling of leaves in certain seasons?
- II. Can plants respond to changes around them even though they don't have a brain?

2.4.1 INTRODUCTION

Plant growth regulators or phytohormones are organic substances produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts. Thimmann (1948) proposed the term Phytohormone as these hormones are synthesized in plants. Plant growth regulators include auxins, gibberellins, cytokinins, ethylene, growth retardants and growth inhibitors. Auxins are the hormones first discovered in plants and later gibberellins and cytokinins were also discovered.

Hormone

An endogenous compound, which is synthesized at one site and transported to another site where it exerts a physiological effect in very low concentration. But ethylene (gaseous nature), exert a physiological effect only at a near a site where it is synthesized. Hence, classified definition of a hormone does not apply to ethylene.

Plant growth regulators

Plant growth regulators can be defined as organic compounds other than nutrients, that affect the physiological processes of growth and development in plants when applied in low concentrations. They can also be defined as either natural or synthetic compounds that are applied directly to a target plant to alter its life processes or its structure to improve quality, increase yields, or facilitate harvesting.

Plant Hormone

When correctly used, the term “plant hormone” is restricted to naturally occurring plant substances, there fall into five classes; Auxins, Gibberellins, Cytokinins, Abscissic acid and Ethylene. Plant growth regulator includes synthetic compounds as well as naturally occurring hormones.

Plant Growth Hormone

The primary site of action of plant growth hormones at the molecular level remains unresolved.

Reasons

- Each hormone produces a great variety of physiological responses.

- Several of these responses to different hormones frequently are similar.
- The response of a plant or a plant part to plant growth regulators may vary with the variety of the plant.
- Even a single variety may respond differently depending on its age, environmental conditions and physiological state of development (especially its natural hormone content) and state of nutrition. There are always exceptions for a general rule suggesting the action of a specific growth regulator on plants.
- There are several proposed modes of action in each class of plant hormone, with substantial arguments for and against each mode.

Hormone groups

Auxin	-	Substances generally resembles IAA and has the ability to stimulate the elongation of coleoptiles.
Gibberellins	-	are diterpenoids, which have the ability to elongate the stem of green seedlings especially certain dwarf and rosette types.
Cytokinin	-	Usually substituted Adenines, which resembles zeatin (Naturally occurring cytokinin in Zea mays) and have the ability to stimulate cytokinesis in cultures of tobacco cells.
Ethylene	-	Gaseous regulator that stimulate is diametric growth in the apices of dicot seedlings.

2.4.2 AUXINS

Auxins are a group of phytohormones produced in the shoot and root apices and they migrate from the apex to the zone of elongation. Auxins promote the growth along the longitudinal axis of the plant and hence the name (auxeing : to grow).

The term, auxin was introduced by Kogl and Haagen- Smit (1931). Went (1928) isolated auxin from the Avena coleoptile tips by an experiment called Avena coleoptile curvature test and concluded that no growth can occur without auxin. Auxins are widely distributed throughout the plant however, abundant in the growing tips such as coleoptile tip, buds, root tips and leaves.

Indole Acetic Acid (IAA) is the only naturally occurring auxin in plants. The synthetic auxins include;

IBA :	Indole butyric acid
NAA :	Naphthalene acetic acid
MENA:	Methyl ester of naphthalene acetic acid
MCPA:	2 Methyl, 4 chloro-phenoxy acetic acid
TIBA :	2, 3, 5 Tri-iodobenzoic acid
2, 4-D :	2, 4 dichloro phenoxy acetic acid
2, 4, 5-T:	2, 4, 5 – Trichloro phenoxy acetic acid

Natural auxins may occur in the form of either free auxins- which freely move or diffuse out of the plant tissues readily or bound auxins- which are released from plant tissues only after hydrolysis, autolysis or enzymolysis.

PHYSIOLOGICAL EFFECTS OF AUXIN

1. Cell division and elongation

The primary physiological effects of auxin are cell division and cell elongation in the shoots. It is important in the secondary growth of stem and differentiation of xylem and phloem tissues.

2. Apical dominance

In many plants, if the terminal bud is intact and growing, the growth of lateral buds just below it remains suppressed. Removal of the apical bud results in the rapid growth of lateral buds. This phenomenon in which the apical bud dominates over the lateral buds and does not allow the lateral buds to grow is known as apical dominance.

3. Root initiation

In contrast to stem, the higher concentration of auxin inhibits the elongation of roots but the number of lateral roots is considerably increased i.e., higher concentration of auxin induces more lateral branch roots. Application of IAA in lanolin paste (lanolin is a soft fat prepared from wool and is good solvent for auxin) to the cut end of a young stem results in an early and extensive rooting. This fact is of great practical importance and has been widely utilized to promote root formation in economically useful plants which are propagated by cuttings.

4. Prevention of abscission

Abscission means premature detachment/ fall of leaves or flowers or fruits in plants. Natural auxins prevent the formation of abscission layer which may otherwise result in the fall of leaves, flowers and fruits.

5. Parthenocarpy

Auxin can induce the formation of parthenocarpic fruits (fruit formation without pollination and fertilization). In parthenocarpic fruits, the concentration of auxin in the ovaries is higher than in the ovaries of plants which produce fruits only after fertilization. In the later cases, the concentration of the auxin in ovaries increases after pollination and fertilization.

6. Respiration

Auxin stimulates respiration and there is a correlation between auxin induced growth and respiration. Auxin may increase the rate of respiration indirectly through increased supply of ADP by rapidly utilizing ATP in the expanding cells.

7. Callus formation

Besides cell elongation, auxin may also be active in cell division. In many tissue cultures, where the callus growth is quite normal, the continued growth of such callus takes place only after the addition of auxin.

8. Eradication of weeds

Some synthetic auxins especially 2, 4- D and 2, 4, 5-T are useful in eradication of weeds at higher concentrations.

9. Flowering and sex expression

Auxins generally inhibit flowering but in pine apple and lettuce it promotes uniform flowering.

2.4.3 GIBBERELLINS

A Japanese scientist Kurosawa found that the rice seedlings infected by the fungus *Gibberella fujikuroi* grow taller and turned very thin and pale. An active substance was isolated from the infected seedlings and named as Gibberellin.

Biosynthesis of gibberellins in plants

The primary precursor for the formation of gibberellins is acetate.

Acetate + COA → Acetyl COA → Mevalonic acid → MA pyrophosphate → Isopentanyl pyrophosphate → Geranyl pyrophosphate → GGPP → Kaurene → Gibberellins.

Distribution of gibberellins in plant

Gibberellins are found in all parts of higher plants including shoots, roots, leaves, flower, petals, anthers and seeds. In general, reproductive parts contain much higher concentrations of gibberellins than the vegetative parts. Immature seeds are especially rich in gibberellins (10-100 mg per g fresh weight).

In plants, gibberellins occur in two forms free gibberellins and bound gibberellins. Bound gibberellins usually occur as gibberellin – glycosides.

PHYSIOLOGICAL EFFECTS OF GIBBERELLINS

1. Seed germination

Certain light sensitive seeds eg. Lettuce and tobacco show poor germination in dark. Germination starts vigorously if these seeds are exposed to light or red light. This requirement of light is overcome if the seeds are treated with gibberellic acid in dark.

2. Dormancy of buds

In temperate regions, the buds formed in autumn remain dormant until next spring due to severe cold. This dormancy of buds can be broken by gibberellin treatments. In potato also, there is a dormant period after harvest, but the application of gibberellin sprouts the tuber vigorously.

3. Root growth

Gibberellins have little or no effect on root growth. At higher concentration, some inhibition of root growth may occur. The initiation of roots is markedly inhibited by gibberellins in isolated cuttings.

4. Elongation of internodes

The most pronounced effect of gibberellins on the plant growth is the elongation of the internodes. Therefore, in many plants such as dwarf pea, dwarf maize etc gibberellins overcome the genetic dwarfism.

5. Bolting and flowering

In many herbaceous plants, the early period of growth shows rosette habit with short stem and small leaves. Under short days, the rosette habit is retained while under long days bolting occurs i.e. the

stem elongates rapidly and is converted into polar axis bearing flower primordia. This bolting can also be induced in such plants by the application of gibberellins even under non-inductive short days.

In *Hyoscyamus niger* (a long day plant) gibberellin treatment causes bolting and flowering under non-inductive short days. While in long day plants, the gibberellin treatment usually results in early flowering. In short day plants, its effects are quite variable. It may either have no effect or inhibit or may activate flowering.

6. Parthenocarpy

Germination of the pollen grains is stimulated by gibberellins; likewise, the growth of the fruit and the formation of parthenocarpic fruits can be induced by gibberellin treatment. In many cases, eg. pome and stone fruits where auxins have failed to induce parthenocarpy, the gibberellins have proven to be successful. Seedless and fleshy tomatoes and large sized seedless grapes are produced by gibberellin treatments on commercial scale.

7. Synthesis of the enzyme α - amylase

One important function of gibberellins is to cause the synthesis of the enzyme α - amylase in the aleurone layer of the endosperm of cereal grains during germination. This enzyme brings about hydrolysis of starch to form simple sugars which are then translocated to growing embryo to provide energy source.

2.4.4 CYTOKININS (KINETIN)

Kinetin was discovered by Skoog and Miller (1950) from the tobacco pith callus and the chemical substance was identified as 6-furfuryl aminopurine. Because of its specific effect on cytokinesis (cell division), it was called as cytokinins or kinetin. The term, cytokinin was proposed by Letham (1963). Fairley and Kingour (1966) used the term, phyto kinins for cytokinins because of their plant origin. Chemically cytokinins are kinins and they are purine derivatives.

Cytokinins, besides their main effect on cell division, also regulate growth and hence they are considered as natural plant growth hormones. Some of the very important and commonly known naturally occurring cytokinins are Coconut milk factor and Zeatin. It was also identified that cytokinin as a constituent of t-RNA.

Naturally occurring cytokinins

Cytokinins can be extracted from coconut milk (liquid endosperm of coconut), tomato juice, flowers and fruits of *Pyrus malus*; fruits of *Pyrus communis* (Pear), *Prunus cerasiferae* (plum) and *Lycopersicum esculentum* (bhendi); Cambial tissues of *Pinus radiata*, *Eucalyptus regnans* and *Nicotiana tabacum*; immature fruits of *Zea mays*, *Juglans sp.* and *Musa sp.*; female gametophytes of *Ginkgo biloba*; fruitlets, embryo and endosperms of *Prunus persica*; seedling of *Pisum sativum*; root exudates of *Helianthus annuus* and tumour tissues of tobacco.

According to Skoog and Armstrong (1970), at least seven well established types of cytokinins have been reported from the plants.

Biosynthesis

It is assumed that cytokinins are synthesised as in the case of purines in plants (nucleic acid synthesis). Root tip is an important site of its synthesis. However, developing seeds and cambial tissues are also the site of cytokinin biosynthesis. Kende (1965) reported that cytokinins move upwards perhaps in the xylem stream. However, basipetal movement in petiole and isolated stems are also observed. Seth et al (1966) found that auxin enhances kinetin movement (translocation) in bean stems.

PHYSIOLOGICAL EFFECTS OF CYTOKININS

1. Cell division

The most important biological effect of kinetin on plants is to induce cell division especially in tobacco pith callus, carrot root tissue, soybean cotyledon, pea callus etc.

2. Cell enlargement

Like auxins and gibberellins, the kinetin may also induce cell enlargement. Significant cell enlargement has been observed in the leaves of *Phaseolus vulgaris*, pumpkin cotyledons, tobacco pith culture, cortical cells of tobacco roots etc.

3. Counteraction of apical dominance

External application of cytokinin promotes the growth of lateral buds and hence counteracts the effect of apical dominance

4. Dormancy of seeds

Like gibberellins, the dormancy of certain light sensitive seeds such as lettuce and tobacco can also be broken by kinetin treatment.

5. Delay of senescence (Richmand - Lang effect)

The senescence of leaves usually accompanies with loss of chlorophyll and rapid breakdown of proteins. Senescence can be postponed to several days by kinetin treatment by improving RNA synthesis followed by protein synthesis.

Richmand and Lang (1957) while working on detached leaves of *Xanthium* found that kinetin was able to postpone the senescence for a number of days.

6. Flower induction

Cytokinins can be employed successfully to induce flowering in short day plants.

7. Morphogenesis

It has been shown that high auxin and low kinetin produced only roots whereas high kinetin and low auxin could promote formation of shoot buds.

8. Accumulation and translocation of solutes

Plants accumulate solutes very actively with the help of Cytokinin and also help in solute translocation in phloem.

9. Protein synthesis

Osborne (1962) demonstrated the increased rate of protein synthesis due to translocation by kinetin treatment.

10. Other effects

Cytokinins provide resistance to high temperature, cold and diseases in some plants. They also help in flowering by substituting the photoperiodic requirements. In some cases, they stimulate synthesis of several enzymes involved in photosynthesis.

11. Commercial applications

Cytokinins have been used for increasing shelf life of fruits, quickening of root induction and producing efficient root system, increasing yield and oil contents of oil seeds like ground nut.

EXERCISE

A. Tick the correct alternatives:

- Which of the following is a naturally occurring auxin in plants?
 - IBA
 - IAA
 - NAA
 - 2, 4-D
- What is the primary site of auxin production in plants?
 - Stem base
 - Mature leaves
 - Shoot and root apices
 - Xylem
- A gardener removes the apical bud of a plant to encourage bushier growth. Which plant hormone's effect is being interrupted by this practice?
 - Cytokinin
 - Ethylene
 - Auxin
 - Gibberellin
- Which of the following plants parts generally contain the highest concentration of gibberellins?
 - Roots
 - Mature leaves
 - Immature seeds
 - Stem bark
- Which of the following is a physiological effect of cytokinin?
 - Inhibition of lateral bud

- b. Delay of leaf senescence
 - c. Promoting seed dormancy
 - d. Root growth inhibition
6. Which of the following best describe the relationship between kinetin and cell division?
- a. Kinetin inhibits cell division
 - b. Kinetin induced cell division especially in callus tissues
 - c. Kinetin only affects root cells
 - d. Kinetin has no role in cell division
7. In a scenario where apical dominance is strong and lateral buds are suppressed, which combination of hormones would best promote lateral bud growth?
- a. High auxin, low cytokinin
 - b. Low auxin, high cytokinin
 - c. High gibberellin, low auxin
 - d. High ethylene, low cytokinin

B. Answer the following questions:

1. What is phytohormone?
2. Explain the physiological role of auxin.
3. Describe the physiological role of gibberellin.
4. Mention the role of cytosine in plant physiology.
5. You are working in a plant tissue culture lab. The callus growth in a culture medium suddenly stops. What hormone would you consider adding to the medium to promote further growth and why?
6. A plant shows premature dropping of fruits during windy season. Which plant growth regulator would you recommend to prevent this? Explain the mechanism.
7. Discuss the commercial application of cytokinin in agriculture and how they improve crop quality or yield?

Chapter 2.5

PLANT GROWTH AND MOVEMENT

Discuss the following questions:

- I. Can plants really move although they don't have muscles like animals? What do you think?
- II. If you keep seeds in your drawer for a year and then plant them, do you think they will grow? Why or why not?

2.5.1 SEED GERMINATION

A seed is a mature ovule, which is formed after the fertilization. The outer covering of a seed is called seed-coat which is a protective covering and is known as Testa. Seeds contain a small opening called micropyle through which water enters into the seed. The inner layer below the testa is called tegmen. Inside, seeds contain embryo which consists of cotyledons, radicle and plumule. Seed contains endosperm. However, the endosperm is absent in some seeds. Hilum is a scar, where the seed breaks from the stalk of the ovule wall.

Dormant seeds are ripe seeds that do not germinate because they are subject to external environmental conditions that prevent the initiation of metabolic processes and cell growth. Under proper conditions, the seed begins to germinate and the embryonic tissues resume growth, developing towards a seedling.

Germination is an irreversible biological process by which the embryo in the seed becomes activated and begins to grow into a new seedling. Germination is usually the growth of a plant contained within a seed; it results in the formation of the seedling; it is also the process of reactivation of metabolic machinery of the seed resulting in the emergence of radicle and plumule.

In order that a seed can germinate, it must be placed in environmental conditions favorable to this process. Among the conditions required is an adequate supply of water, a suitable temperature range and, for some seeds, light.

The process of seed germination:

Germination commences with the uptake of water by the dry seed (imbibition) and is completed when a part of the embryo, usually the radicle, extends to penetrate the structures that surround it. The process of seed germination includes the following five changes or steps.

1) Imbibition: It involves absorption of water by seeds through micropyle which helps in swelling and rupture of seed coat as well as activation of hydrolytic enzymes to convert reserve food (starch, protein) into metabolically useful chemicals.

2) Respiration: Oxygen is necessary for respiration which releases the energy needed for growth. Germinating seeds respire very actively and need sufficient oxygen. If a seed is buried too deeply within the soil or the soil is waterlogged, the seed can be oxygen starved, hence unable to undergo germination.

3) Light: Most seeds are not affected by light or darkness, but many seeds, including species found in forest settings, will not germinate until an opening in the canopy allows sufficient light for growth of the seedling.

4) Temperature: Temperature affects cellular metabolic and growth rates. Seeds from different species and even seeds from the same plant germinate over a wide range of temperatures. Seeds often have a temperature range within which they will germinate, and they will not do so above or below this range. Many seeds germinate at temperatures slightly above 60-75 F (16-24 C).

Most common annual vegetables have optimal germination temperatures between 75-90 F (24-32C), though many species (e.g. radishes or spinach) can germinate at significantly lower temperatures, as low as 40 F (4 C), thus allowing them to be grown from seeds in cooler climates.

5) Scarification: It mimics natural processes that weaken the seed coat before germination. In nature, some seeds require particular conditions to germinate, such as the heat of a fire (e.g., many Australian native plants), or soaking in a body of water for a long period of time. Others need to be passed through an animal's digestive tract to weaken the seed coat enough to allow the seedling to emerge,

4) Mobilization of Reserves during Seed Germination and Role of Growth Regulators: Abscissic acid (ABA) inhibits seed germination but Gibberellins are effective in breaking seed dormancy, thus favoring seed germination.

5) Development of Embryo Axis into Seedling: Embryonal axis has two parts; hypocotyl and epicotyl. The end part of hypocotyl is known as radicle and epicotyl terminates into plumule. During seed germination, radicle elongates downwards inside the soil and gives root. Later, plumule grows upwards to develop into shoot in a seed plant or seedling.

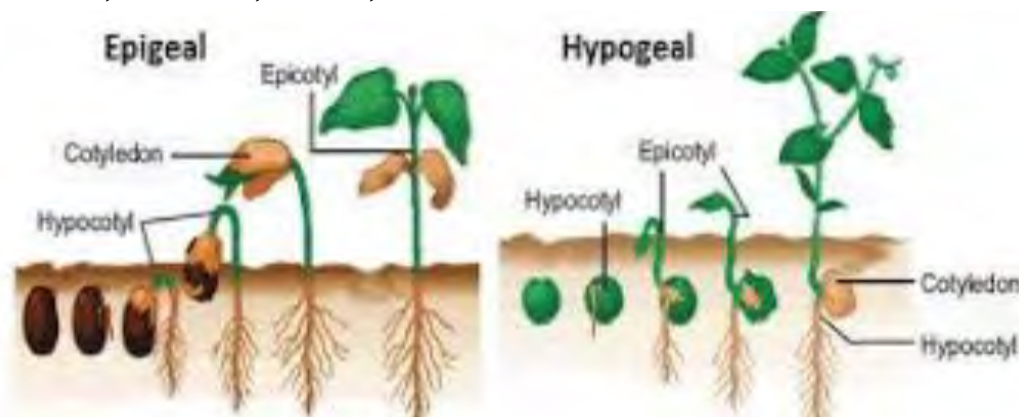
Types of seed germination

Hypogeal germination: Hypogeal germination implies that the cotyledons stay below the ground. The epicotyl (part of the stem above the cotyledon) grows, while the hypocotyl (part of the stem below the cotyledon) remains the same in length. In this way, the epicotyl pushes the plumule above the ground. In this kind of germination, the cotyledons do not come out of the soil surface. In such seeds the epicotyl (i.e., part of embryonic axis between plumule and cotyledons) elongates pushing plumule out of the soil. All monocotyledons show hypogeal germination.

Among dicotyledons, gram, pea, groundnut are some common examples of hypogeal germination.

Epigeal germination: Epigeal germination implies that the cotyledons are pushed above ground. The hypocotyl elongates while the epicotyl remains the same in length. In this way, the hypocotyl

pushes the cotyledon upward. In seeds with epigeal germination, the cotyledons are brought above the soil due to elongation of the hypocotyl. In castor, cotton, papaya, onion, flat green leaf like cotyledons can be seen in the young seedlings. Here the cotyledons, besides food storage, also perform photosynthesis till the seedling becomes independent. In some other plants like bean, the cotyledons being thick, do not become leaf-like; they shrivel and fall off after their food reserves are consumed by the seedling. Examples: Common Beans, Castor, Sunflower, Pumpkin, Watermelon, Cucumber, Gourds, Lilies etc.



Vivipary

(Viviparous Germination): Vivipary is the phenomenon of giving birth to young ones in advanced stage of development. It occurs in mammals (among animals) and mangrove plants. In mangrove plants (e.g., *Rhizophora*, *Sonneratia*, *Heritiera*, the seeds cannot germinate on the ground because of the excessive salt content and lack of oxygen in marshy habitat. In such plants seed dormancy is absent. Mangrove seeds usually germinate within the fruits which are still attached to the parent plant. This phenomenon is known as vivipary. Examples of viviparous mangroves are *Rhizophora*, *Bruiguiera*, *Kandelia*, and *Ceriops* etc. The embryo of the seed (present inside the fruit) continues growth while the latter is attached to the parent plant. Hypocotyl elongates and pushes the radicle out of the seed and the fruit. Growth continues till the hypocotyl and radicle become several centimeters long (more than 70 cm in *Rhizophora*). The seedling becomes heavy. As a result, it breaks its connection with the fruit and falls down in the salt rich muddy water in such a position that the plumule remains outside the saltish water while the tip of the radicle gets fixed in the mud. This protects the plumule. The radicle quickly forms new roots and establishes the seedling as a new plant.

2.5.2 SEED DORMANCY

Seed dormancy can be defined as the failure of a viable seed to germinate even when given favorable environmental conditions.

Under optimum conditions like moisture, temperature, and aeration, some fruits like mango and citrus germinate from the fruit. But, in some cases; fruits like apple, pear, cherry germination do not occur even if favourable conditions are provided. This phase is called 'dormancy'. Dormancy acts as the survival mechanism as these species do not germinate until adverse conditions end. Dormancy is characterised by many factors and can persist indefinitely unless specific treatment is given.

Some of the types of seed dormancy are as follows.

a) Physical dormancy (seed coat dormancy): Seed coat or seed covering may become hard, fibrous or mucilaginous (adhesive gum) during dehydration and ripening as a result. They become impermeable to water and gases, which prevents the physiological processes initiating germination. This type of dormancy is very common in drupe fruits i.e. olive, peach, plum, apricot, cherry etc. (hardened endocarp), walnut and pecan nut (surrounding shell). In various plant families, such as, Leguminosae, the outer seed coat gets hardened and becomes suberized and impervious to water.

b) Mechanical dormancy: In some fruits seed covering restricts radicle growth, resulting in dormancy of seeds. Some seed covering structures, such as shells of walnut, pits of stone fruits and stones of olive are too strong to allow the dormant embryo to expand during germination.

c) Chemical dormancy: In seeds of some fruits chemicals that accumulate in fruit and seed covering tissues during development and remain with the seed after harvest. It is quite common in fleshy fruits or fruits whose seeds remain in juice as in citrus, cucurbits, stone fruits, pear, grapes and tomatoes. Some of the substances associated with inhibition are various phenols, coumarin and abscisic acid. These substances can strongly inhibit seed germination.

d) Morphological dormancy: It is evident in seeds with embryos that are under-developed (in terms of size), but differentiated into cotyledons and hypocotyl-radical. These embryos are not physiologically dormant, but simply need time to grow and germinate. Example: celery (*Apium graveolens*).

Advantages of seed dormancy

1. It ensures the survival of seedling, under environmental stresses.
2. It is useful in the creation of a seed bank.
3. It helps to synchronize germination - ensures a population of plants at same stage of development for outcrossing
4. It also helps in seed dispersal - eg. seed coat gets scarified by passing through a bird's animal tract.

2.5.3 PHOTOPERIODISM

Photoperiodism is the phenomenon of physiological changes that occur in plants in response to relative length of day and night (i.e. photoperiod). The response of the plants to the photoperiod, expressed in the form of flowering is also called as photoperiodism. The phenomenon of photoperiodism was first discovered by Garner and Allard (1920).

Depending upon the duration of photoperiod, the plants are classified into three categories.

1. Short day plants (SDP)
2. Long day plants (LDP)
3. Day neutral plants (DNP)

1. Short day plants: These plants require a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering. These plants are also known as long-night plants. E.g. Rice, coffee, soybean, tobacco and chrysanthemum. In short day plants, the dark period is critical and must be continuous. If this dark period is interrupted with a

brief exposure of red light (660-665 nm wavelength), the short day plant will not flower. Prolongation of the continuous dark period initiates early flowering.

2. Long day plants: These plants require longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering. These plants are also called as short night plants. E.g. Wheat, radish, cabbage, sugar beet and spinach. In long day plants, light period is critical. A brief exposure of red light in the dark period or the prolongation of light period stimulates flowering in long day plants.

3. Day neutral plants: These plants flower in all photoperiod ranging from 5 hours to 24 hours continuous exposure. E.g. Tomato, cotton, sunflower, cucumber, peas and certain varieties of tobacco.

Differences between short day and long day plants

Short day plant	Long day plant
Plants flower when photoperiod is less than the critical day length.	Plants flower when photoperiod is more than the critical day length
Interruption during light period with darkness does not inhibit flowering.	Interruption during light period with darkness inhibit flowering.
Flowering is inhibited if the long dark period is interrupted by a flash of light.	Flowering occurs if the long dark period is interrupted by a flash of light.
Long continuous and uninterrupted dark period is critical for flowering.	Dark period is not critical for flowering.
Flowering does not occur under alternating cycles of short day and short light period.	Flowering occurs under alternating cycles of short day followed by still shorter dark period.

2.5.4 SENESCENCE

Like human beings, plants also grow old and undergo aging and then they die. Aging is the sum total of changes in the total plant or its organs. During aging, the plants undergo chemical and structural changes. Aging leads to senescence and later phase of development that ultimately terminates to death.

The deteriorative process which naturally terminates the functional life of an organ, organism or other life unit is collectively called senescence. Senescence is a phase of the aging process. The major characteristic of senescence is that the metabolic processes are catabolic and eventually become irreversible and terminate to death.

Senescence is not confined only to whole plant. It may be limited to a particular plant organ such as leaf and flowers or cells or cell, organelles. Senescence is closely associated with the phenomenon of aging. Aging leads to senescence. Wheat plant dies after the development of fruit. This is the senescence of an entire plant. Leaf fall in a coconut tree is an example of senescence.

Types of senescence

Leopold (1961) has proposed types of senescence patterns in plants which are as follows.

a) Overall Senescence:

This type of senescence occurs in annuals where whole plant is affected. It is also called whole plant senescence. The entire plant dies after the development of fruit and seeds. E.g. Paddy, wheat, soybean etc.

b) Top Senescence:

In top senescence, the parts remaining above the ground or (shoot system) may die, but the root system and underground system remain viable. It is also called shoot senescence.

E.g. Dock, perennial herbs.

c) Deciduous Senescence

In deciduous woody plants, all the leaves die but the bulk of the stem and root system remains viable. It is called deciduous senescence or simultaneous or synchronous senescence. E.g. Leaf fall in deciduous trees.

d) Progressive Senescence

It is a gradual death of old leaves from the base to the top of the plants. It may occur at any time. It is also called sequential senescence. E.g. Leaf fall in a coconut tree.

Causes of Senescence

1. Leaf senescence is accompanied by early loss in chlorophyll, RNA and enzymes.
2. Cellular constituents are decreased due to slower synthesis or faster break down.
3. Competition between vegetative and reproductive organs for nutrients.
4. A senescence factor (a hormone) is produced in soybean fruits that move to leaves where it causes senescence.
5. Short-day and long-night conditions induce flowering and leaf senescence.
6. Degradation of food reserves and loss of integrity in food storage cells of seeds.
7. Senescence is also hormonally controlled.

Significance of Senescence

1. The whole plant senescence occurs in monocarpic plants coinciding the seed setting and seed dispersal.
2. Due to the formation of abscission layer, the older leaves tend to fall down so that the nutrients will be diverted to the next young leaf.
3. The senescence process helps the mobilization of nutrients and of the vegetative parts of the plant into the fruits.
4. Plants escape the influence of seasonal adversity by undergoing senescence of its organs. Leaf fall in deciduous trees reduces the rate of transpiration to survive under adverse conditions.

2.5.5 ABSCISSION

Shedding of leaves, flowers and fruits is called abscission. Abscission is distinct in deciduous trees and shrubs. In autumn, all the leaves of deciduous plants fall, at about the same time giving the plants a naked appearance. In evergreen plants there is gradual abscission of leaves. The older leaves fall while new leaves are developed continuously throughout the year. In most of the

herbaceous species, however the leaves are not shed even after they die. In many cases leaves are retained in withered dry condition even after the whole shoot is dead.

Abscission is a complex physiological process. During abscission, the color of the leaves, flowers and fruits changes due to degradation of chlorophyll and the synthesis of anthocyanin pigment.

Leaf abscission takes place at the base of the petiole. The site of abscission is internally marked by a distinct zone called abscission zone. This zone is made up of one or more layers of cells arranged transversely across the petiole base. This is called abscission layer. The abscission zone is pale or brown in colour. The cells of the abscission layer separate from each other due to the dissolution of middle lamellae and the primary cellulose walls under the influence of the activity of enzymes, pectinase and cellulase. At this stage, the petiole remains attached to the stem by vascular elements only. But due to its own weight and the wind force, the leaf is detached from the stem. The broken vascular elements are soon plugged with tyloses or gums. Wound healing in cells proximal to the breaking point involves formation of a corky layer that protects the plant from pathogen invasion and excess water loss. Suberin and lignin are synthesized during healing.

Significance of Abscission

- It helps in diverting water and nutrients to the young leaves
- It is a self pruning process through which fruits and injured organs are shed from the parent plant.
- It helps in disseminating fruits and vegetative propagates.
- Abscission serves as function in removing plant parts containing waste materials.

2.5.6 VERNALIZATION

Vernalization is the process whereby flowering is promoted by a cold treatment given to a fully hydrated seed or to a growing plant. Dry seeds do not respond to the cold treatment. Due to vernalization, the vegetative period of the plant is cut short resulting in an early flowering. It is also called as yarovization. Without the cold treatment, plants that require vernalization show delayed flowering or remain vegetative. In many cases, these plants grow as rosettes with no elongation of the stem



Process of vernalization

For vernalization, the seeds are allowed to germinate for some time and then, are given cold treatment 0°C to 5°C. The period of cold treatment varies from few days to many weeks. After the cold treatment the seedlings are allowed to dry for sometimes and then sown. Vernalization prepares the plant for flowering. The cold stimulus usually perceived by the apical meristems, but in some species, all dividing cells of roots and leaves may be the potential sites of vernalization. eg. *Leennario biennis*.

Vernalization induces the plant to produce a hormone called vernalin. This stimulus can be transmitted from one plant to another through grafting. The age of the plant is an important factor in determining the responsiveness of the plant to the cold stimulus and it differs in different species. Suitable temperature for vernalization ranges between 1 to 6°C. At higher temperature from 7°C onwards, response of the plant is decreased. A temperature of about 12 to 14°C is most ineffective in vernalizing the plant. The vernalization is an aerobic process and requires metabolic energy. In the absence of oxygen cold treatment becomes completely inefficient. Sufficient amount of water is also essential. Vernalization of dry seeds is not possible.

Significance:

1. Due to vernalization the vegetative period of the plant is cut short resulting in an early flowering.
2. Vernalization increases the resistance of plants to fungal diseases.
3. It increases the cold resistance of plants.
4. In the biennials, vernalization induces early flowering and early fruit setting.
5. Flowering can be induced by grafting and this feature is used in horticulture.
6. It also helps in crop improvement.

2.5.7 PLANT MOVEMENT

Parts of the plants, their roots, their leaves, their stems all are capable of movements and in fact move continuously. The movement in plants is mostly seen as bending, turning, twisting or as elongation of plant parts.

VITAL MOVEMENTS: Irritability of protoplasm brings these movements. These movements are of two types:

- a) Autonomic movement b) Induced movement

a) AUTONOMIC MOVEMENT include

- i) Growth movements and ii) Variation movements

i) Autonomic growth movements: These movements are due to unequal growth in different parts of an organ and are irreversible. They are independent of the surroundings of plants or external stimuli.

They are further divided into four types;

Nutation: These movements occur in the growing stem of twinnings (peas or beans). The stem exhibits a kind of nodding movements in two directions. As, the stem apex shows more growth on one side at one time and a little later there is a greater growth on the opposite side. It is called nutation. This circular movement of growing stem takes place always in the same direction for the same plant species. Since, the more rapid rate of growth travels around the tip which, as it grows upwards must therefore rotate.

Circum-nutation: In spirally growing stems and tendrils, the region of greater growth passes gradually around the growing point resulting in the spiral coiling of stem and tendrils. Such a movement is called circum-nutation.



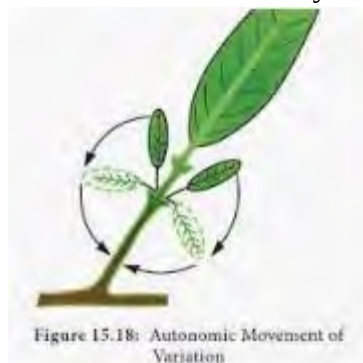
Epinasty and Hyponasty movements: They are non-directional movements in which the response is determined by the structure of the responsive organ and not the direction of the stimulus. This kind of movement is exhibited mostly by young leaves, organs having dorsiventral symmetry.

Epinasty is caused due to rapid growth on the upper surface (abaxial side), such as occurs at the time of the opening of leaves.

Hyponasty is greater growth on the lower side (adaxial side) e.g., circinate coiling and closed sepals and petals in a floral bud.

ii) Movements of variation:

They are autonomous curvature movements and are independent of external stimuli. They are not growth movements hence are reversible. These movements are also known as turgor movements because these are brought about by changes in the turgor pressure of certain sensitive cells of the plant organs. Such movements are exhibited by lateral leaflets in *Desmodium gyrans*.



b) PARATONIC/ INDUCED MOVEMENTS

These movements are affected by various external stimuli.

They are of two types;

- i) Tropic movements and ii) Nastic movements

i. Tropic movements: These are movements of curvature brought about by more growth on one side and less growth on the opposite side of plant organ induced by some external stimuli. Thus they are not reversible as they are growth movements. They are directional movements and direction of stimulus influences the orientation of responding plant organ. Stimulus is therefore directional and not diffuse. There is a directional relationship between the response and stimulus. Response occurs either towards it (positive) or away from it (negative response). They are slow movements unlike nastic movements. These movements are present in all plants and not restricted to specialized plant or plant part.

Tropism is typically shown in plant organs having radial symmetry like shoot, root. Depending upon the nature of stimuli these movements are of the following types:

Phototropism (Heliotropism): When a plant's organ curves due to unilateral light stimulus, it is called phototropism. Some parts of the plant e.g., stem moves towards light, thus is positively phototropic. Roots move away from light and they are called negatively phototropic.

Geotropism (Gravitropism): Growth of movements induced by the stimulus of gravity is known as geotropism. The secondary lateral roots and shoots show a weaker response to gravity and thus take up a position at an angle to the gravitational stimulus and are called diageotropic.

Hydrotropism: Growth movements in response to external stimulus of water are termed as hydrotropism. Roots are positively hydrotropic (i.e., bend towards the source of water). Stems are either indifferent or negatively hydrotropic. Positive hydrotropic movement of the roots is stronger than their geotropic response. As if there is scarcity of water, roots bend towards the sewage pipes and other sources of water in disregard to the stimulus of gravity.

Chemotropism: When a curvature takes place in response to a chemical stimulus. The growth of pollen tube through stigma and style towards the embryo sac occurs with the stimulus of chemical substances or growth of fungal hyphae towards sugars and peptones are examples of chemotropism.

Thigmotropism (Haptotropism): The movements which occur are due to contact with a foreign body. It is most conspicuous in tendrils which coil around support and help the plant in climbing.

Thermotropism: Curvature of plant parts towards normal temperatures from very high or very low temperatures is thermotropism.

(ii) Nastic movements:

These movements of variation or turgor movements are affected by some external stimuli such as light, temperature or contact but the direction of response is prefixed and not determined by the direction of stimuli.

In nastic movement, the stimulus is diffuse, i.e., it does not affect the organ from any definite direction and the movement, thus induced by the stimulus, is determined exclusively by the properties of the irritable cells. The response of the organ is independent of the direction of the stimulus.

- These are faster movements when compared to tropic movements.
- These are more specialized movement in function.
- They are typically shown in plant organs having dorsiventral symmetry.
- Nastic movements are shown by specialized plant and plant organ.

Nastic movements are of the following types:

i. Nyctinastic (sleeping) movements: The diurnal (changes in day and night) movements of leaves and flowers of some species which take up sleeping position at night are called nyctinastic movement. *Maranta* (Prayer plant), an ornamental house plant provides most common examples of nyctinastic response.

Depending upon the stimulus, they may be photonastic (light stimulus) or thermonastic (temperature stimulus).

Photonastic movements: Leaves of *Oxalis* take up horizontal position in sunlight and droop down during night.

Thermonastic movements: Flowers of tulips and Crocus open during high temperatures of day and close down during low temperatures of night.

Thigmonastic (Haptonastic) movements: The movements of plant in response to touch stimulus is called thigmonastic movement. Insectivorous plants show thigmonasty. e.g. when marginal glandular hair of *Drosera* come in contact with some foreign body i.e. body of insect, they show haptonastic movements.

Seismonastic movements: This type of movement is brought about in response to external stimulus of shock or touch. The best example of seismonastic movement is depicted by the leaves of sensitive plant *Mimosa pudica* (Touch- me- not).

EXERCISE

A. Tick the correct alternatives:

1. Naturally occurring auxin is
 - a. IAA
 - b. IBA
 - c. NAA
 - d. 2-4,D
2. Auxin is transported from
 - a) Root to shoot
 - b) shoot to root
 - c) stem to leaves
 - d) flower to fruit
3. Who isolated auxin from tip of Avena coleoptile?
 - a) Skoog
 - b) F.W.Went
 - c) Kurosawa
 - d) Richmand
4. Which of following is effect of auxin?
 - a. Abscission
 - b. Ripening of fruit
 - c. Apical dominance
 - d. Delay of senescence.
5. Development of seedless fruits, induced by auxins, is known as
 - a. Bolting
 - b. Abscission
 - c. Dwarfism
 - d. Parthenocarpy.

6. Which auxin is used in killing herbs?
- IAA
 - IBA
 - 2,4-D
 - All of above
7. Foolish seedling of rice is caused by
- Auxins
 - Cytokinins
 - Ethylene
 - Gibberellins
8. Which of the following is not effect of gibberellins?
- Bolting
 - Breaking dormancy
 - Stomatal closure
 - Synthesis of α - amylase
9. A cytokinin, present in maize endosperm is
- Zeatin
 - Zymase
 - Morphine
 - Napthalene
10. Culture medium, treated with higher concentration of auxin as compared to cytokinin, induces
- Flowering
 - Fruit ripening
 - Root development
 - Abscission of leaves.
11. Leaves can be made fresh and green by treatment with cytokinins. This effect is
- Apical dominance
 - Dwarfism
 - Parthenocarpy
 - Delay of senescence
12. Bolting refers to
- Rapid development of roots
 - Rapid elongation of internodes
 - Rapid production of flowers and fruits
 - Pre-mature falling of leaves, flowers and fruits

13. If cotyledons remain under the soil, the seed germination is said to be
- Epigeal
 - Hypogeal
 - Hypocotyl
 - Epicotyl
14. Main factor for seed germination is
- Air
 - Moisture
 - Temperature
 - Sunlight
15. Hypogeal germination is common in
- Monocots
 - Dicots
 - Mangrove plants
 - Pteridophytes
16. *Rhizophora* exhibits
- Hypogeal germination
 - Epigeal germination
 - Viviparous germination
 - All of above
17. Seed dormancy refers to
- Failure of viable seeds in unfavorable environmental conditions.
 - Failure of viable seeds in favorable environmental conditions.
 - Failure of non-viable seeds in unfavorable environmental conditions.
 - Failure of non-viable seeds in unfavorable environmental conditions.
18. Leguminous seeds fail to germinate due to hard and impervious seed coats. It is known as
- Mechanical dormancy
 - Physical dormancy
 - Chemical dormancy
 - Physiological dormancy
19. Flowering in plants, in response to relative length of day and night, is known as
- Phototaxis
 - Phototropism
 - Photoperiodism
 - Photosynthesis

20. For flowering in long day plants, day should be of
- 8-10 hours
 - 10-12 hours
 - 14-16 hours
 - 18-20 hours
21. Which of the following is a long day plant?
- Rice
 - Coffee
 - Radish
 - Tomato
22. A physiological process which causes ageing and ultimate death of organism is known as
- Parthenocarpy
 - Imbibition
 - Senescence
 - Vernalization
23. A process whereby flowering is promoted by a cold treatment given to a fully hydrated seed or to a growing plant is known as
- Parthenocarpy
 - Imbibition
 - Senescence
 - Vernalization
24. During vernalization, germinating seeds are treated to
- 0-5⁰ C temperature
 - 5-10⁰ C temperature
 - 10-15⁰ C temperature
 - 15-20⁰ C temperature
25. Vernalization results in
- Shortening vegetative growth and delay in flowering
 - Shortening vegetative growth and early flowering
 - Longer vegetative growth and delay in flowering
 - Longer vegetative growth and early flowering
26. For vernalization, seeds should be
- hydrated and viable
 - dehydrated and viable
 - hydrated and non- viable
 - dehydrated and non-viable

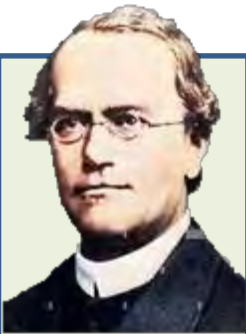
27. Plant movement, independent of external stimuli, is said to be
- Autonomic
 - Paratonic
 - Tectonic
 - Induced.
28. Autonomic movement of variation is shown by
- Tendrils in climbers.
 - Leaves in *Desmodium*
 - Leaves in *Mimosa pudica*
 - Insectivorous plants
29. Directional and irreversible growth in plants in response to external stimulus is known as
- Taxis
 - Tropism
 - Nasty
 - Turgor movement.
30. Folding of leaves of Touch-me-not plant is the best example of
- Nyctinasty
 - Thermonasty
 - Thigmonasty
 - Seismonasty

B. Answer the following questions:

- Define phytohormones and write their features.
- Describe any three physiological effects of auxins.
- Discuss the effects of gibberellins in dormancy, flowering and plant growth.
- Define apical dominance. Name the hormones which induce and suppress apical dominance.
- Elaborate bolting and parthenocarpy with suitable examples.
- Describe the role of cytokinins in tissue culture and agriculture.
- Describe the seed germination process in brief.
- Mention the factors of seed dormancy. Write the advantages of seed dormancy.
- Classify plants on basis of photoperiodism and give two examples of each.
- Point out any four differences between short-day plants and long-day plants.
- Define senescence and write its significance in plants.
- What do you mean by abscission? Write its significance.
- Define vernalization. Write its significance in plants.
- Write about autonomic growth movement in plants.
- Define paratonic or induced movements? Mention its types with example each.
- What is tropism? Describe its types with example each.
- Describe the nastic movements shown by *Drosera* and *Mimosa pudica*.

Unit 3

GENETICS



Gregor Johann
Mendel
(1822-1884)

In the 19th century, Gregor Johann Mendel, an Austrian monk, studied how traits are passed down through generation by generation by experimenting with pea plants. Working in his monastery garden, he carefully crossbred thousands of plants, finding patterns in how traits like colour, shape etc. were inherited. Mendel identified dominant and recessive traits, which became the basis of modern genetics. Though his work was not fully appreciated during his time, it later became key to understand heredity.

Chapter 3.1

GENETIC MATERIALS

Let's think about the following questions:

- i. Why siblings sometimes look so similar to each other? Or sometimes even so different?
- ii. How do you think traits like eye colour, height, or hair type are passed from one generation to another generation?
- iii. Name some traits that are inherited from your parents.

3.1.1 INTRODUCTION TO GENETICS

It is a matter of common observation that a dog always gives birth to a baby dog, not any other animals, or a watermelon seed forms only a watermelon plant not any other plant. Offspring resemble their parents. On seeing a newborn infant, the elders often remark “he or she has father’s nose”, or “mother’s eyes”, or “grandfather’s hair”, and so on. However, the offspring often have some individual characters in which they differ from one another and also from their parents. These similarities and differences are explained scientifically in a branch of biology known as Genetics.

Heredity:

The transmission of characters from one generation to another generation is called heredity.

Variation:

The difference shown by the individuals of a species and also by the offspring of the same parents is called variation.

Genetics:

It is the branch of biology that deals with the study of heredity and variation.

3.1.2 GENETIC MATERIALS

Genetic materials are the substances that cause the transmission of characters from parents to offspring. The study of genetic material is at the heart of understanding life itself. From the very first organisms to complex multicellular life forms, genetic material shapes everything about an organism i.e. from its development to its characters and even how it adapt over generation. Genetic material is commonly DNA or rarely RNA (in some viruses).

The genetic materials (DNA and RNA) are macro-molecules and made up of chain of nucleotides. A nucleotide consists of pentose sugar, nitrogenous base and phosphoric acid.

1. Pentose sugar: Pentose sugar is 5-carbon containing sugar. Two types of pentose sugars are present viz. ribose sugar (in RNA) and deoxyribose sugar (in DNA).

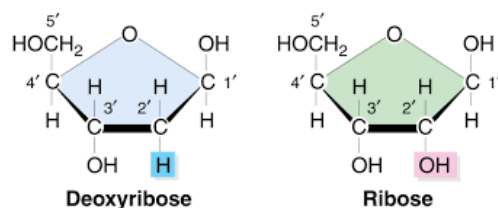


Figure 3.1.1 Structure of pentose sugar

2. Nitrogenous bases: They are categorized into two classes:
 - a. Purine base: There are two rings in their structure. Purines are Adenine (A) and Guanine (G).
 - b. Pyrimidine base: There is one ring in their structure. Pyrimidines are Cytosine (C) present in both DNA and RNA, Thymine (T) present in DNA only and Uracil (U) present in RNA only.
 - c. Phosphoric acid: It has a phosphate group that connects two nucleotides by phosphodiester bond.

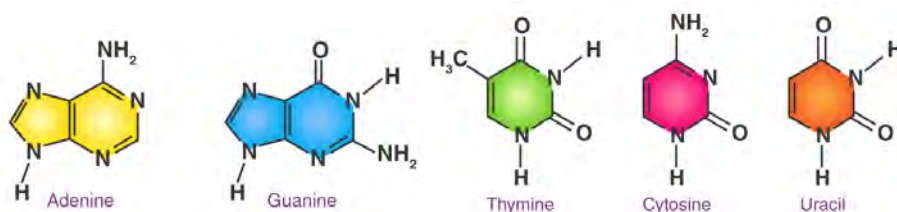
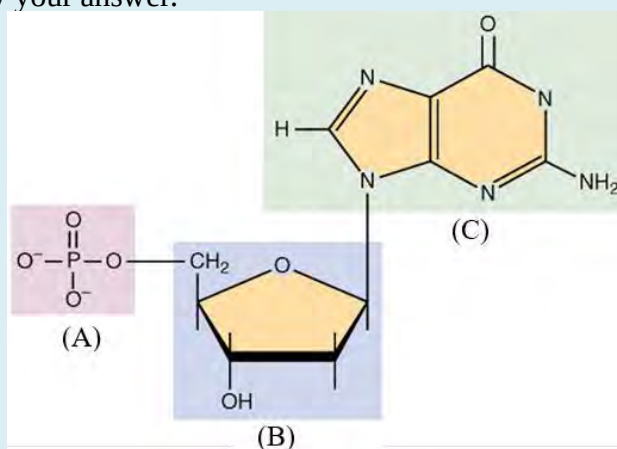


Figure 3.1.2 Structure of Nitrogenous Bases

Activity: 3.1

Study the given figure and answer the following questions:

- i. Name A, B and C.
- ii. What is represented in the given diagram?
- iii. If a hydroxyl group (OH) is replaced with a hydrogen atom (H) in figure B, what will be the name of figure B?
- iv. Would the resulting molecule still be considered a component of DNA? Justify your answer.



3.1.3 DEOXYRIBONUCLEIC ACID (DNA)

DNA is genetic material in all organisms except RNA virus. In prokaryotic cells, it is found in cytoplasm. In eukaryotic cells, it is primarily found in nucleus while small amounts also present in mitochondria and plastid. DNA is a big molecule made up of many units called deoxyribonucleotides. A deoxyribonucleotide has deoxyribose sugar, nitrogenous base and phosphoric acid. In a strand of DNA, units are joined together by phosphodiester bond.

Structure of DNA

J.D. Watson, an American biologist, and F.H.C. Crick, an English chemist, in 1953, designed the double helical model of DNA molecule to explain its structure.

The characteristics of DNA are as follows:

1. DNA consists of two strands that twist around each other to form a double helix.
2. The two strands of DNA run in opposite directions, with one running in 5' to 3' and other 3' to 5'.
3. The double helix is of constant diameter of about 2 nm.
4. The double helix has major groove and minor groove.
5. A set of one major groove and one minor groove is one complete turn.
6. The distance of one complete turn is about 3.4 nm.
7. The sides of the helix are made up of alternating sugar (deoxyribose) and phosphate groups, forming the backbone of the structure and the bases project inside.

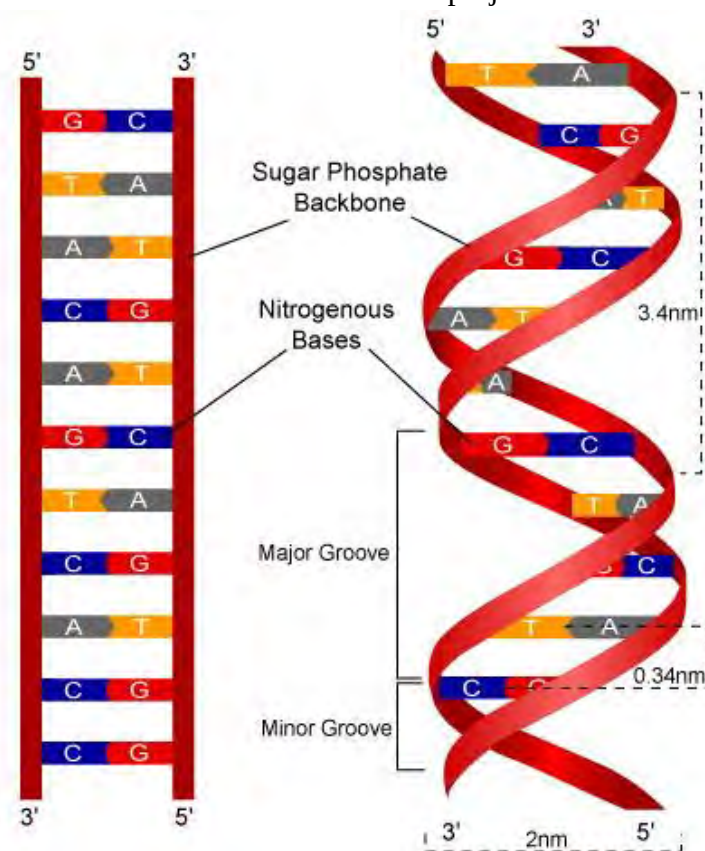


Figure 3.1.3 Watson and Crick Model of DNA

- i.e. $\frac{G+A}{T+C} = 1$, This properties are known as Chargaff's rule.

1. It carries hereditary characters from parents to the young ones.
2. DNA copies genetic information to pass it to cells of the next generation.
3. Crossing over in DNA produces genetic recombination.
4. Changes in components of DNA create variations and new species.
5. Transcription of DNA synthesizes RNAs for different cell functions.
6. It regulates cell metabolic reactions through RNA and protein synthesis (Central Dogma).

RNA is present in all the living cells. RNA is synthesized in nucleus but found in nucleolus, cytoplasm, mitochondria, plastid and ribosome. RNA is a polymer of ribonucleotides. Each ribonucleotide is made up of ribose sugar, nitrogenous bases and phosphoric acid. The nitrogenous bases found in RNA are Adenine, Guanine, Cytosine and Uracil. It is single stranded structure. Single stranded RNA can fold on itself and get coiled into a pseudohelix. Like DNA, RNA also has directionality with one end being the 5' end and other being 3' end based on the orientation of the sugar phosphate backbone. Nitrogenous bases can be arranged in any sequence which is complementary to their sequence of DNA template. For example, if a sequence of DNA template is CAATGA then a sequence of RNA is GUUACU.



1. **Messenger RNA (mRNA):** Carrier of genetic information from DNA to ribosomes for protein synthesis.
2. **Ribosomal RNA (rRNA):** Stable RNA linked with ribosomes. It helps in protein synthesis.
3. **Transfer RNA (tRNA):** Acts as an adapter, carrying amino acids to the protein synthesis site.

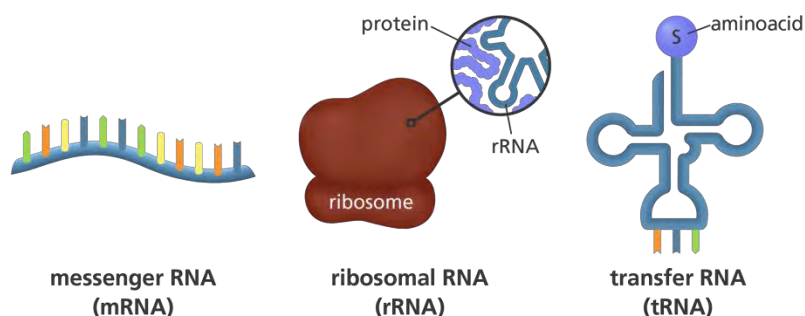


Figure 3.1.5 Different types of RNA

Functions of RNA

RNA plays several critical roles in cellular processes. They are primarily related to the storage, transfer and translation of genetic information. Following are the major functions of RNA:

1. mRNA carries genetic information from DNA to ribosomes for protein synthesis.
2. tRNA brings amino acids to the ribosome to build protein based on mRNA instruction.
3. rRNA forms part of the ribosome, where proteins are synthesized.
4. RNA act as a genetic material in certain viruses.
5. Some RNA molecules function as enzyme, which catalyze biochemical reactions, such as cleavage of RNA.

Activity: 3.2

Create an informative and artistic comparison chart of DNA and RNA.

3.1.5 DNA REPLICATION

Living cells must be able to duplicate their entire set of genetic instructions every time they divide. Likewise, multicellular organisms must be able to pass on complete copies of their genetic information to future generation. This requires that the instructions are stored in a form that is capable of being replicated. DNA replication is the process through which a double stranded DNA molecule is duplicated, resulting in two identical copies of the original DNA. This process is essential for cell division, ensuring that each new cell receives an exact copy of the genetic material. After the DNA replication, one of the DNA molecules passes to the daughter cell while the other remains in the mother cell. DNA replication involves the separation of the two strands of DNA, followed by the synthesis of complementary strands to form two complete, identical DNA molecules.

Types of DNA replication

Based on the way the original DNA strands are conserved and how the new DNA strands are synthesized, DNA replication is of following types:

1. **Conservative Replication:** Conservative replication produces two copies of DNA in which one DNA molecule contains only parental strands and other DNA molecule contains only new stand.

2. **Semi-conservative replication:** Semi-conservative replication produces two copies of DNA in which each DNA molecule contains one of the original strand and one new strand.
3. **Dispersive replication:** Dispersive replication produces two copies of DNA in which both DNA molecules will have distinct regions of either both original strands or both new strands.

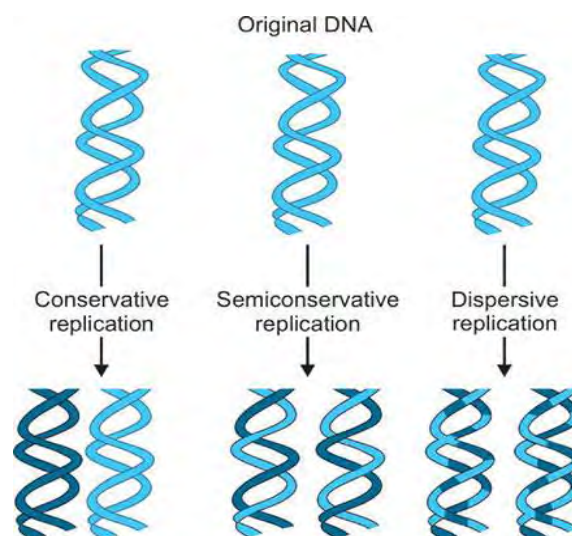


Figure 3.1.6 Different types of DNA replication

Semi-Conservative mode of DNA replication

This method of DNA replication is described as semi-conservative method because each daughter DNA molecule is a hybrid conserving one parental polynucleotide chain and another new polynucleotide chain. The steps of semi-conservative DNA replication are described as follows:

Initiation

The initial step in DNA replication is initiation, which involves the unwinding of the double helix structure of DNA. The DNA strands start separating at a specific point called **origin of replication (Ori site)**, from where separation slowly progresses to the other end. This process is carried out by the enzymes **helicase**. Viral and Prokaryotic DNA generally forms a single point of origin of replication while eukaryotic DNA forms number of origin of replication. The enzyme helicase unwinds the DNA by breaking the hydrogen bonds that hold the complementary base pairs together, resulting in the separation of the two DNA strands. Each strand acts as a **template** for the synthesis of the new strand. The unzipping of the double stranded DNA forms a Y-shaped structure called **replication fork**.

Once the strands are separated, the enzyme **primase** steps in and synthesizes a short segment of RNA, called the **RNA primer**, on each of the separated DNA strands. This RNA primer provides a starting point for **DNA polymerase**, enabling it to begin synthesizing the new DNA strands by adding nucleotides in the correct order.

Elongation

During elongation, an enzyme called **DNA polymerase** adds DNA nucleotides to the 3' end of the template. The replication proceeds from 5'-3' direction only in the new DNA strand. The DNA polymerase can add nucleotide in 5'-3' direction only, since the two strands of DNA are anti-parallel. Thus DNA polymerase produces continuous stretch in one strand only. This is called a **leading strand**. In other strand that open in 5'→3' direction, DNA polymerase produces

discontinuous fragments of DNA molecules in 5'→3' direction, these discontinuous fragments are called **Okazaki fragments**. These discontinuous fragments synthesize in opposite direction of replication fork. Thus this strand is called **lagging strand**. The RNA primer in both strands is removed by DNA polymerase and synthesizes a short segment of complementary DNA to seal the gap. Then the strands are joined together by **DNA ligase**.

Termination

Termination occurs when replication reaches the end of the DNA molecule. The result of DNA replication is two DNA molecules consisting of one new and one old chain of nucleotides. This is why DNA replication is described as semi-conservative, half of the chain is part of the original DNA molecule, half is brand new. Following replication the new DNA automatically winds up into a double helix.

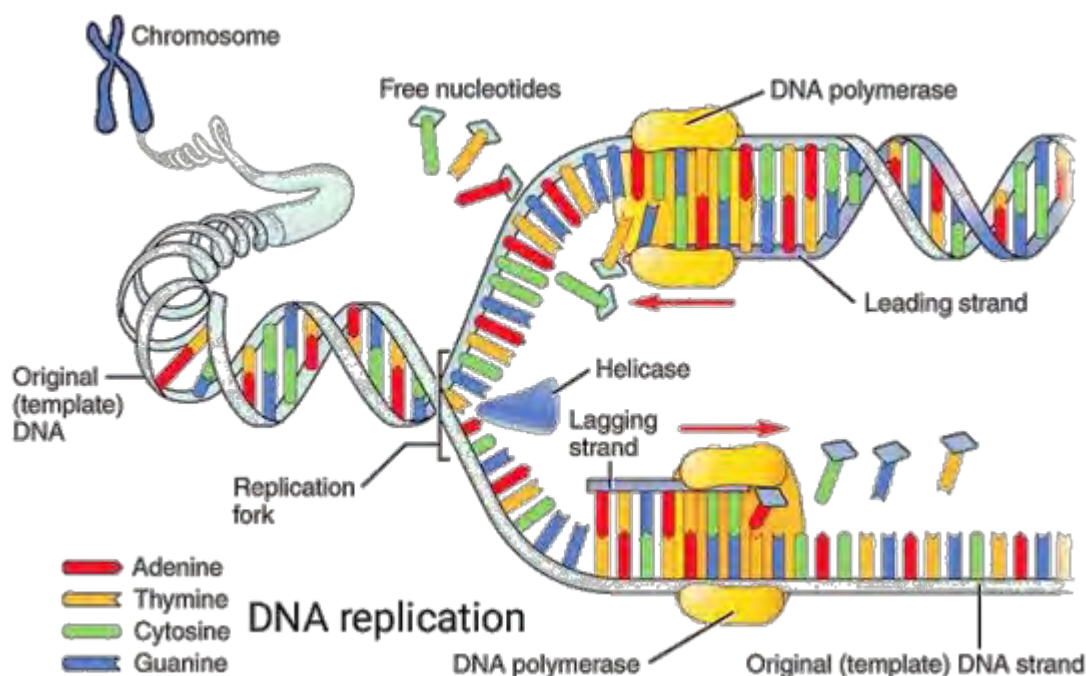


Figure 3.1.7 Semi-conservative mode of DNA replication

3.1.2 GENETIC CODE

The DNA carries genetic information from cell to cell and generation to generation. Genetic information is expressed in the form of protein. Proteins are made up of 20 different types of amino acids. The amino acids are made up of sequences of nucleotide bases i.e. adenine (A), cytosine (C), guanine (G) and thymine (T) found in the DNA of living organism. A sequence of three bases codes for one amino acid which is called codon. Each codon specifies a particular amino acid, the building block of proteins.

The specific order of nitrogenous bases in RNA which can translate the message of DNA to amino acid is called genetic code. Thus, a genetic code is a set of instructions that cells use to produce proteins, which are essential for life.

Characteristics of Genetic Code:

The genetic code of DNA has the following major characteristics:

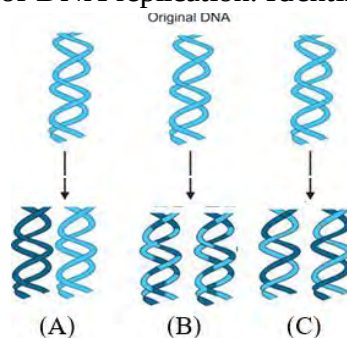
1. **Triplet Nature:** The genetic code is triplet code. It uses groups of three nitrogenous bases known as codons. Each codon specifies a single amino acid.
For example: The codon AUG represents the amino acid, methionine.
2. **Non-overlapping:** The adjacent codons do not overlap, they do not share any base. Each single base is a part of only one codon.
For example: The sequence ACUAAG is read only as ACU and AAG, and not as ACU, CUA, UAA, AAG.
3. **Punctuationless:** The genetic code is continuous without any punctuation marks between codons.
For example: If CCUCAGC..... is an order of nitrogenous bases in mRNA, it forms the codon CCU, CAG, and C.....
4. **Universality:** The genetic code is universal, i.e. a given codon specifies the same amino acid in almost all organisms, from bacteria to human.
5. **Degeneracy:** Multiple codons can specify the same amino acid. This means there are 64 possible codons but only 20 amino acids, so many amino acids are specified by more than one codon.
For example: Glycine is specified by four codons, GGU, GGC, GGA, and GGG.
6. **Nonsense or Terminator codons:** Three codons (UAA, UAG, and UGA) of 64 codons do not specify any amino acids. These are termed nonsense codons. The nonsense codons stop or terminate the process of protein synthesis.
7. **Initiation or start codons:** The codons AUG and GUG are called the initiation or start codons as they begin the synthesis of protein in every organism.
8. **Colinearity:** The relationship between the sequence of nitrogenous bases of DNA and mRNA with the sequence of amino acids in the polypeptide chain is called the principle of colinearity. The DNA code words will be complementary to the mRNA code words.
For example: A sequence of nucleotides in DNA like ATG GGA CTT, which is transcribed into mRNA as AUG GGA CUU.

EXERCISE

A. Tick the correct alternatives:

1. Name the nitrogenous bases is found in RNA but not in DNA?
 - a. Adenine
 - b. Guanine
 - c. Cytosine
 - d. Uracil
2. What type of bond connects the sugar and phosphate in RNA backbone?
 - a. Hydrogen bond
 - b. Ionic bond
 - c. Peptide bond
 - d. Phosphodiester bond
3. Which of the following correctly pairs nitrogenous bases in DNA?
 - a. Adenine-Guanine and Cytosine-Thymine
 - b. Adenine-Thymine and Cytosine-Guanine
 - c. Adenine-Cytosine and Guanine-Thymine
 - d. Adenine-Uracil and Cytosin-Guanine
4. How many nucleotide bases form one codon in the genetic code?
 - a. 1
 - b. 2
 - c. 3
 - d. 4
5. Which of the following statements about the genetic code is true?
 - a. It overlaps in codons
 - b. It is universal for all organisms
 - c. One codon specifies multiple amino acids
 - d. It has punctuation marks
6. Which of the following enzyme unwinds the DNA helix during replication?
 - a. DNA polymerase
 - b. Ligase
 - c. Helicase
 - d. Primase
7. Which of the following best explains why one strand is synthesized continuously and the other discontinuously during replication?
 - a. Helicase works only one direction
 - b. DNA polymerase can only add nucleotides in the 5' to 3' direction
 - c. One strand has more A-T content
 - d. The lagging strand is longer

8. Study the given figure of types of DNA replication. Identify the types A, B and C.

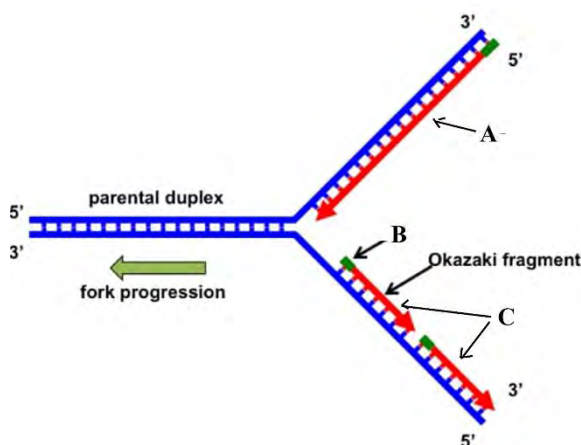


- A – Conservative, B – Semi conservative, C- Dispersive
 - A - Semi conservative, B – Conservative, C – Dispersive
 - A – Consevative, B – Dispersive, C – Semi conservative
 - A – Dispersive, B – Semi conservative, C – Dispersive
9. If a DNA molecule has 2000 base pairs, how long will the molecule be approximately?
- 680 nm
 - 340 nm
 - 2000 nm
 - 34 nm
10. If a drug is developed that strengthens the hydrogen bonds between DNA base pairs, what cellular process would be most directly affected?
- Formation of the sugar-phosphate backbone
 - Transcription and DNA replication
 - Transport of mRNA
 - Digestion of nucleotides in the cytoplasm

B. Answer the following questions:

- Define heredity and variation.
- What are the three components of a nucleotide?
- Differentiate between purine and pyrimidine bases.
- Describe the structure and function of DNA with necessary diagram.
- Describe the structure and function of RNA with necessary diagram.
- What are the three types of RNA? Describe them.
- Define genetic code. Mention the characteristics of it.
- Describe the semi-conservative mode of DNA replication with appropriate diagram.
- Compare the leading and lagging strands during DNA replication.
- If the DNA template strand is TACGGA, what will be the RNA sequence formed?

11. A scientist extracts a nucleic acid and finds that it contains uracil but no thymine, and ribose sugar is present. Identify the molecules. In which organisms might this serve as the genetic material?
12. A student is given a nucleotide containing ribose sugar, adenine and phosphate. Is it a component of DNA or RNA? Justify your answer.
13. Study the given diagram and answer the following questions:



- What is shown in the figure?
- Label A, B and C.
- Name the enzymes that add DNA nucleotide to the template.
- What is Okazaki fragment?

Project Work:

Prepare a 3D model showing the structure of DNA using coloured beads, wires or craft material or locally available materials.

Chapter 3.2

MENDELIAN GENETICS

Let's discuss the following questions:

- I. Have you heard the words “dominant” or “recessive” before? What do they mean in biology?
- II. Why do some traits are more common in a population than others?
- III. If parents have brown eyes, do their children can have blue eyes? Why or why not?

3.2.1 GENERAL TERMINOLOGY

Some general terminologies of genetics are given below:

1. Gene

A gene is a small segment of DNA that contains the instructions for making a specific protein or functional RNA molecule.

2. Allele

Allele is one of the other forms of the same gene responsible for determining contrasting characters and is found at the same place on a chromosome. For example, the allele of pure tall is ‘T’.

3. Homozygous organism

An organism having two identical alleles is known as homozygous organism. For example: Organism having ‘TT’ or ‘tt’ are homozygous.

4. Heterozygous organism

An organism having two different alleles is known as heterozygous organism. For example: Organism having ‘Tt’ is heterozygous.

5. Dominant and recessive character

When a cross is made between two parents with a contrasting pair of characters, in the first generation only one character appears while another character remains suppressed. The character that appears in the first generation is called dominant character while the character that remains suppressed in the first generation is called recessive character. For example, in a cross between pure tall (TT) and pure dwarf (tt) pea plant, the offspring is tall (Tt), here tall is dominant character and dwarf is recessive character.

6. Hybridization

The process of crossing two genetically different organisms to produce offspring (hybrid) is called hybridization.

7. Hybrid

The intermediate offspring produced by crossing two genetically different parents is called hybrid.

8. Phenotype

The physical or morphological appearance of the individual which is a reaction of the genotype and environment is called phenotype.

9. Genotype

The genetic character of the individuals inherited from both parents irrespective of whether they are expressed or not is called genotype.

10. Monohybrid cross

A cross between two parents having single pair of contrasting trait is known as monohybrid cross.

11. Dihybrid cross

A cross between two parents differing in two pairs of contrasting traits is known as dihybrid cross.

12. First filial generation

The offspring obtained by the cross of pure breeding individuals are known as first filial generation (F₁ generation).

13. Second filial generation

The offspring obtained by selfing of F₁ individuals are known as second filial generation (F₂ generation).

14. Punnett square

It is a checker board or graphic method to study all possible results of various cross. Male gametes are placed horizontally while female gametes are placed vertically. All possible combinations are filled in squares by combining gametes from both the parents. For example, a punnett square showing second filial generation of monohybrid cross is shown below

	t	t
T	Tt	Tt
T	Tt	Tt

Figure 3.2.1 Punnett square showing F₂ generation of monohybrid tall

3.2.2 MENDEL'S EXPERIMENT

Gregor Jahann Mendel conducted breeding experiments on garden peas (*Pisum sativum*) in the garden of his monastery. He selected seven contrasting characters from 34 varieties of garden peas. He did experiments for seven years and then presented his work at **Natural History Society of Brunn in 1865**. He was the first to formulate the principle of heredity. Though his work was published in 1866, it failed to get attention till 1900 when three scientists, De Vries in Holland, Correns in Germany and Tschemark in Austria rediscovered his work and began to make use of his findings. His laws form the basis of the science of genetics, and he is remembered as the **father of genetics**.

1. Selection of Material

Mendel selected garden pea plant (*Pisum sativum*) for his experiment because of certain special advantages. These are given below:

- a. Pea plants have several pairs of clearly contrasting traits (e.g., tall vs. short, round seeds vs. wrinkled seeds).

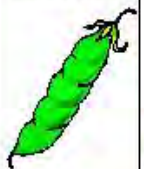
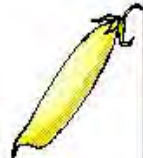
Seed Shape	Seed Color	Pod Shape	Pod Color	Flower Color	Flower Location	Plant Size
Round 	Yellow 	Inflated 	Green 	Purple 	Axial 	Tall 
Wrinkled 	Green 	Constricted 	Yellow 	White 	Terminal 	Short (Dwarf) 

Figure: 3.2.2 Seven contrasting characters of *Pisum sativum* noted by Mendel

- b. The flowers are naturally self-pollinating because the stamens and pistils are enclosed within the petals.
- c. Cross-pollination (hybridization) is easy to perform by hand, allowing Mendel to control which plants bred with each other.
- d. Pea plants have a short life cycle, so many generations can be studied in a short period.
- e. They can be grown easily in pots or gardens and are simple to care for and manage.
- f. Each plant produces a large number of seeds, which provides plenty of data for analysis.
- g. The hybrids (offspring) of pea plants are fertile, meaning they can reproduce and pass traits to the next generation.

2. Selection of parents

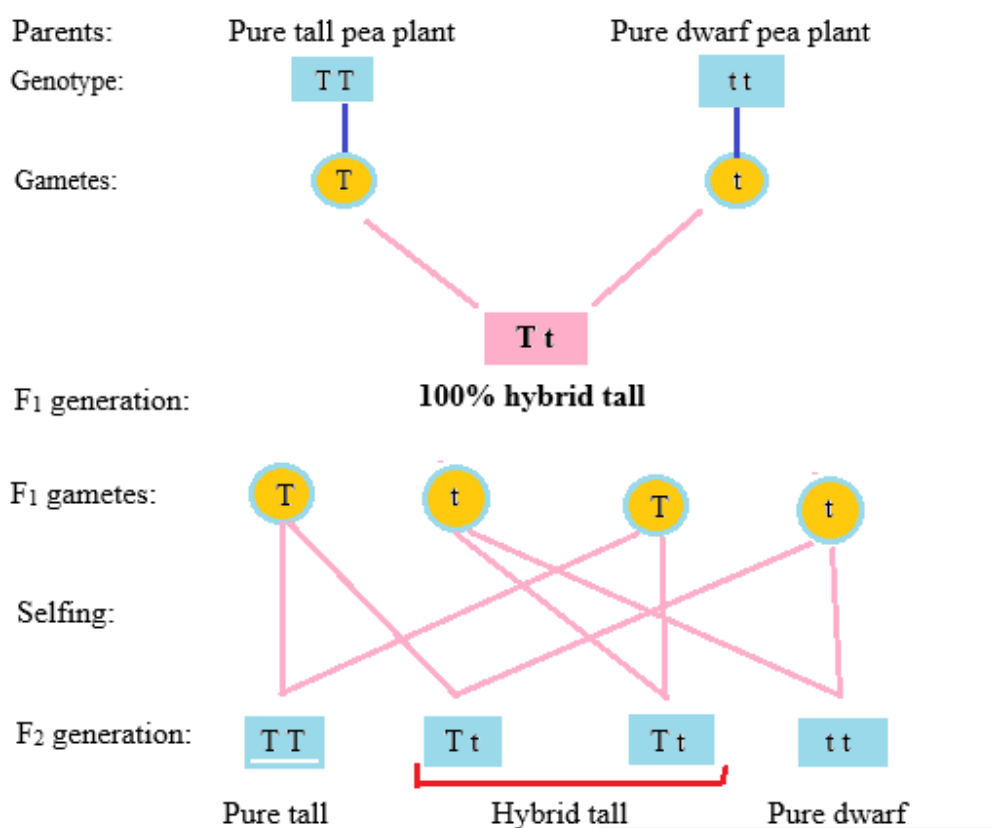
Mendel selected true breeding or pure breeding forms of the all seven traits of pea plant. He confirmed the plant as pure breeding by selfing the plant for several generations. For example, to obtain a pure tall variety, Mendel self-fertilized tall pea plants for many generations until all the offspring consistently grew tall. He repeated this process for each of the seven traits to obtain genetically pure varieties.

3. Hybridization

Hybridization is the process of obtaining hybrids by crossing two genetically different parents. Mendel began his work by studying the inheritance of a single trait at a time (monohybrid crosses). Once he identified clear patterns of how traits were passed on, he moved on to study the inheritance of two contrasting trait together (dihybrid crosses).

Monohybrid cross

A monohybrid cross is a genetic cross that involves only one pair of contrasting traits. In his experiments, Mendel studied one trait at a time from the seven pairs of contrasting characters found in pea plants. For example, to study the inheritance of plant height, he crossed a pure breeding tall plant (TT) with a pure breeding dwarf plant (tt). These parent plants were referred to as the **parental generation, or the P generation**. He first removed stamens of the tall plant before maturation of anther, then transferred the pollens from the dwarf plants to the pistil of tall plants. When the seeds matured, he planted them and observed the results. All the seeds gave rise to tall plants. The resultant hybrid offspring were named as **first filial or F₁ plants or generation**. He also performed reciprocal cross, i.e. he also carried out experiments by the deposition of pollen of tall plant in the stigma of dwarf plant.



Phenotypic ratio: 3:1 (tall:dwarf)

Genotypic ratio: 1:2:1 (pure tall: hybrid tall: pure dwarf)

Figure: 3.2.3 Monohybrid cross between pure tall pea plant with pure dwarf pea plant upto second filial generation

Activity: 3.3

Select one contrasting trait like colour of flower in pea or shape of seed etc. and draw monohybrid cross upto second filial generation. Predict the genotypic and phenotypic ratio of the offspring.

Dihybrid cross

A dihybrid cross is a genetic cross that involves two pairs of contrasting traits. In his experiments, Mendel studied two traits at a time from the seven pairs of contrasting characters found in pea plants. For example, to study the inheritance of plant height and colour of flower, he crossed a pure breeding tall plant having red flower (TTRR) with a pure breeding dwarf plant having white flower (ttrr). He first removed stamens of the tall plant having red flower before maturation of anther, then transferred the pollens from the dwarf plant having white flower to the pistil of tall plant having red flower. When the seeds matured, he planted them and observed the results. All the seeds gave rise to tall plant having red flower. The resultant hybrid offspring were named as **first filial or F₁ plants or generation**. He also performed reciprocal cross, i.e. he also carried out experiments by the deposition of pollen of tall plant having red flower in the stigma of dwarf plant having white flower.

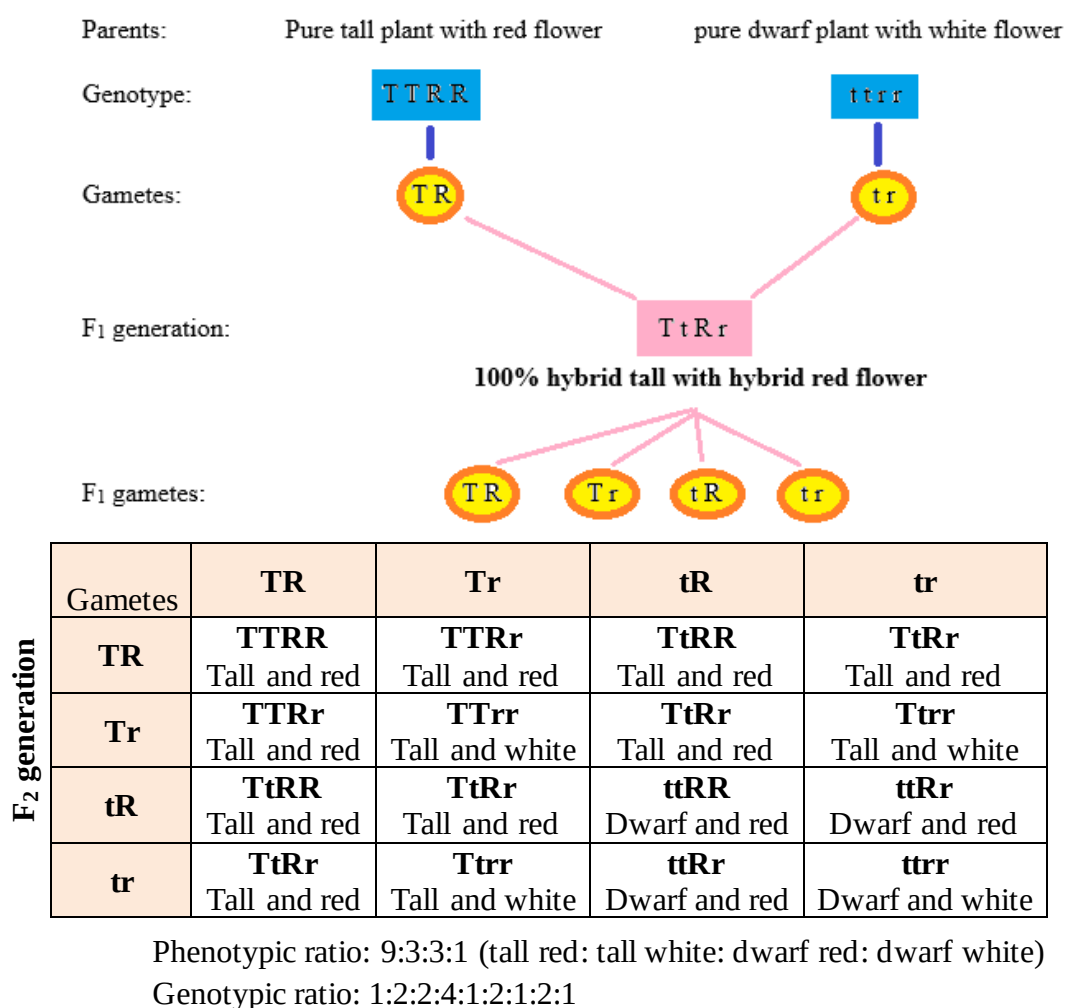


Figure: 3.2.4 Dihybrid cross between pure tall having red flower with pure dwarf having white flower pea plant upto second filial generation

Activity: 3.4

Select two contrasting trait like height of plant and colour of flower in pea or Colour and shape of seed etc. and draw dihybrid cross upto second filial generation. Predict the genotypic and phenotypic ratio of the offspring.

4. Self-pollination of F₁ plants

The F₁ plants were allowed to undergo self-pollination. The flowers were kept covered from the beginning with paper bags to avoid contamination with foreign unwanted pollen, and the seeds produced by all F₁ plants were again collected and plants grown from them. These plants were named as the **second filial generation (F₂ generation)**. Mendel performed self-pollination of F₁ plant in both monohybrid as well as dihybrid cross.

3.2.3 LAWS OF INHERITANCE

On the basis of experiments, Mendel gave three laws or principle known as laws of inheritance:

1. Law of Dominance

The law of dominance states that “When two pure organisms with a pair of contrasting characters are crossed, only one character of the pair appears in the first filial generation, while the other character remains hidden. The character that appears in hybrid is called dominant character while the character that is hidden is called recessive character.”

In a monohybrid cross of homozygous tall (TT) and dwarf (tt) pea plant, the offspring produced in F₁ generation are heterozygous tall (Tt). Here, the character tall (T) is dominant and the character dwarf (t) which is suppressed is recessive.

2. Law of Segregation or Law of purity of gametes

The law of segregation states that “two alleles of a trait remain together in heterozygous individual without contamination or blending, but they separate or segregate during the formation of gamete.” As a result of this segregation, each gamete receives only one of the two contrasting alleles. It means gametes are pure for a particular trait. So, this law is also called law of purity of gametes.

In a monohybrid cross, the F₁ hybrid inherits both alleles (T) and (t). These alleles do not blend in the F₁ generation but retain their individual identities. The recessive allele (t) is not affected or altered by the presence of the dominant allele (T). During gamete formation, the alleles segregate and each gamete receives either T or t. In the F₂ generation, when gametes combine randomly during fertilization, the reappearance of dwarf plants occurs. This is due to the separation of alleles and random combination during reproduction, which confirms Mendel’s law of segregation.

3. Law of Independent Assortment

The law of independent assortment states that “when two or more pairs of contrasting alleles are inherited together, the inheritance of one pair occurs independently of the other. In other words, the alleles of different genes assort into gametes randomly and independently, and they do not remain linked.” This means the distribution of one trait does not influence the distribution of another allowing for various genetic combinations in the offspring.

In a dihybrid cross, when tall pea plant having red flower (TTRR) is crossed with dwarf pea plant having white flower (ttrr), all the offspring in the F₁ plants were hybrid tall having hybrid red flower (TtRr) in F₁ generation. When these F₁ hybrids are allowed for self breeding, the F₂ generation

shows four types of phenotypes like tall with red flower, tall with white flower, dwarf with red flower and dwarf with white flower are produced. This shows that alleles for height of the plant and alleles for colour of the flower are inherited independently.

3.2.4 GENE INTERACTION

Mendel's laws of dominance, segregation and independent assortment are true for a number of traits in sweet peas and have been confirmed to apply on many traits in plants and animals. However, these laws do not apply universally and there are number of exceptions. Some are described below:

1. Incomplete Dominance

According to Mendel's law of dominance, out of two traits of the parents, only one trait appeared in F_1 generation. For example, when cross is made between tall pea and dwarf pea plant, the offspring produced may be either tall or dwarf. However, this is not true of all characters or organisms. There are some characters or genes that are not dominant or recessive. In this condition both the genes of the contrasting characters express as a blend (mixture). As a result, the hybrid produced by crossing two pure individuals does not resemble either of them, but is midway between them. This is known as incomplete dominance. Incomplete dominance is found in both plants and animals. The plant like snapdragon (*Antirrhinum majus*) and 4 O' clock plant (*Mirabilis jalapa*) and animals like Andalusian fowls show incomplete dominance.

Incomplete dominance in 4 O' clock plant (*Mirabilis jalapa*)

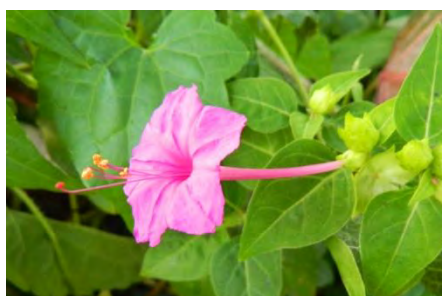


Figure: 3.2.5 *Mirabilis jalapa* (Nepali name: Malati phool)

In *Mirabilis jalapa*, when cross is made between pure red flowered and pure white flowered plant, all the F_1 offspring were pink in colour. Neither red nor white is completely dominant, so that both colours appear in the hybrids as a blend which is pink. When two of the hybrid plants with pink flowers are crossed, the F_2 generation includes plants with red, pink and white flowers in the usual Mendelian ratio of 1:2:1.

From the F_2 generation, it becomes clear that there is no blending of genes. If blending had occurred, the original pure traits would not have appeared. It explains that both the red flower allele and the white flower allele express themselves when present together. Red allele is not completely dominant over white allele and so white allele also express in the presence of red allele.

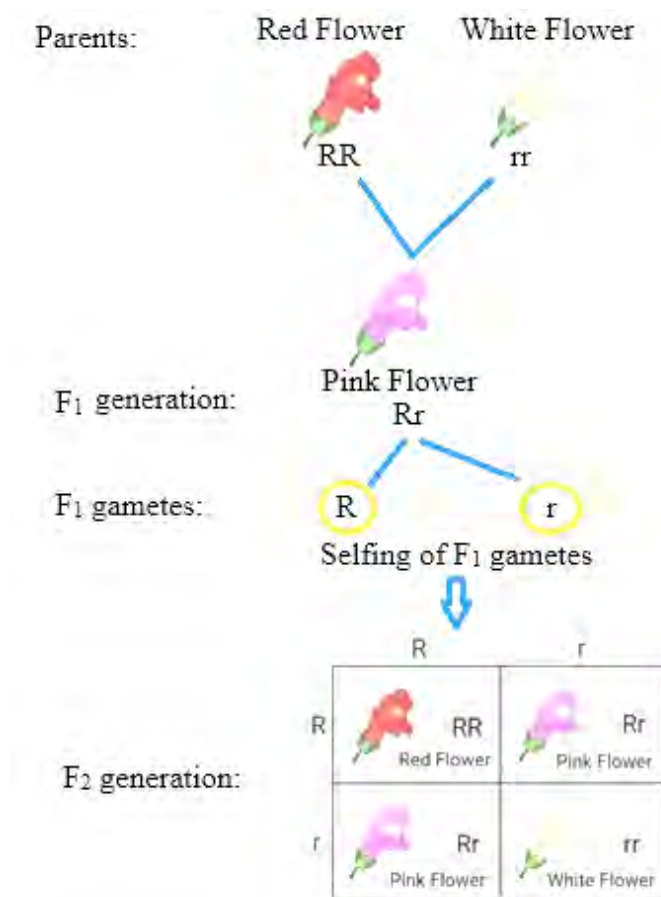


Figure: 3.2.6 Incomplete dominance in *Mirabilis jalapa*

2. Co-dominance

Co-dominance is also an exception to Mendel's law of dominance. According to Mendel's law of dominance, the offspring in F₁ generation resemble to only one parent because only one allele is expressed in F₁ generation. But, in co-dominance both the alleles of a gene equally express in F₁ generation. This is known as co-dominance. The blood group of human is best example of co-dominance. The marriage between people having homozygous blood group A ($I^A I^A$) and homozygous blood group B ($I^B I^B$) produced offspring having blood group AB ($I^A I^B$). The allele I^A produces antigen A while I^B produces antigen B, which are equally found in the blood of the person having blood group AB. Here both I^A and I^B alleles are fully expressed.

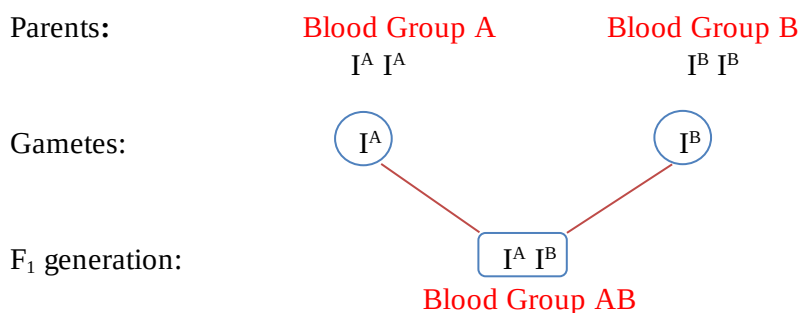


Figure: 3.2.7 Co-dominance in blood group AB of human

EXERCISE

A. Tick the correct alternatives:

1. What is gene?
 - a. A type of cell
 - b. A segment of DNA coding for a protein or RNA
 - c. A chromosome
 - d. An enzyme
2. Which of the following is a homozygous genotype?
 - a. Tt
 - b. TT
 - c. XY
 - d. TX
3. Which term refers to the physical appearance of an individual?
 - a. Genotype
 - b. Phenotype
 - c. Allele
 - d. Trait
4. In the dihybrid cross ($TTRR \times ttrr$), which gametes are produced by the F_1 plants?
 - a. TR and tr only
 - b. Tt and Rr
 - c. TR, Tr, tR, tr
 - d. TT, tt, RR, rr
5. Why do the recessive traits reappear in the F_2 generation after being hidden in the F_1 generation?
 - a. Due to dominance of recessive allele
 - b. Because they mutate back
 - c. Because of segregation and recombination of alleles
 - d. Because blending occurs in F_1 generation
6. In pea plants, yellow seeds are dominant to green. If heterozygous yellow seeded plant is crossed with a green seeded plant, what ratio of yellow and green seeded plants, would you expect in F_1 generation?
 - a. 9:1
 - b. 1:3
 - c. 3:1
 - d. 50:50
7. A geneticist notices that a trait appears intermediate in hybrids, but original traits reappear in F_2 generation. What inheritance pattern is likely?
 - a. Complete dominance
 - b. Incomplete dominance
 - c. Co-dominance
 - d. Polygenic inheritance
8. If a red flowered *Mirabilis jalapa* plant is crossed with a pink flowered plant, what will be the expected flower colour ratio in the offspring?
 - a. 1 red : 1 white
 - b. 1 red : 1 pink
 - c. 1 red : 2 pink : 1 white
 - d. All pink
9. Which of the following crosses will give tall and dwarf pea plants in same proportions?
 - a. $TT \times tt$

- b. $Tt \times tt$
 - c. $TT \times Tt$
 - d. $tt \times tt$
10. Round seed trait (R) is dominant over wrinkled (r) seed trait in pea. Heterozygous round seeded plant (Rr) is crossed with wrinkled seeded plant (rr). What is the possibly progeny?
- a. 302 round : 102 wrinkled
 - b. 210 round : 95 wrinkled
 - c. 105 round : 99 wrinkled
 - d. 103 round : 315 wrinkled

B. Answer the following questions:

1. Define recessive character and dominant character.
2. What are the genotype and phenotype of F1 generation in a monohybrid cross between TT and tt plants?
3. Arrange these in order of size, smallest first:
Cell, Nucleus, DNA molecules, Chromosome, Gene
4. Differentiate between monohybrid and dihybrid cross.
5. How is incomplete dominance different from Mendel's law of dominance?
6. Why is blood group AB considered an example of co-dominance?
7. State Mendel's law of dominance with an example.
8. Why did Mendel choose pea plants for his experiments?
9. Describe Mendel's law of independent assortment with the help of a dihybrid cross.
10. In a species of plant, there are two alleles of the gene that determines leaf shape. One allele produces round leaves, and the other produces oval leaves. Heterozygous plants have round leaves. Which allele is dominant? Explain.
11. If a tall plant with red flowers (TrRr) is self-pollinated, what are the chances of obtaining a dwarf plant with white flowers in F2 generation? Show using a punnett square.
12. A student observes a 9:3:3:1 ratio in the offspring of a cross. What type of cross has been performed and which of Mendel's law does it demonstrate?
13. In human beings blue eye colour is recessive to brown eye colour. A brown eyed man has a blue eyed mother.
 - a. What is the genotype of the man and his mother?
 - b. What are the possible genotypes of his father?
 - c. If the man marries a blue eyed woman, what are the possible genotypes of their offspring?
14. A pure breeding (homozygous) tall pea plant was crossed with a homozygous dwarf pea plant. All of the offspring had the genotype Tt. Several of these offspring were crossed together. There are 302 tall plants and 99 plants were dwarf. Construct a complete genetic diagram to explain this result.
15. Study the table and answer the following questions:

Gametes		RY	rY	Ry	ry
	RY	RRYY	RrYY	RRYy	RrYy
	rY	RrYY	rrYY	RrYy	rrYy
	Ry	RRYy	RrYy	RRyy	Rryy
	ry	RrYy	rrYy	Rryy	rryy

- Name the dominant and recessive traits.
- What was the parent genotype if the table shows F₂ generation?
- What is the F₂ phenotype ratio?

Project work

To recognize and analyze Mendelian inherited traits and connect observed patterns with the principles of dominant and recessive inheritance from Mendel's experiments.

Methods:

- Form group on the basis of number of students.
- Students will Observe or ask 10-15 peers about each trait from the given table.

S.N.	Trait	Dominant	Recessive
1.	Earlobes	Free hanging	Attached
2.	Tongue Rolling	Can roll	Cannot roll
3.	Widow's peak	Present	Absent
4.	Hitchhiker's thumb	Straight	Bent
5.	Dimples	Present	Absent
6.	Freckles	Present	Absent

- Note the traits in observation table.
- Now, combine the results of all groups and tally how many students have each trait.
- Calculate the phenotypic ratio of each trait (e.g. 10 free hanging: 3 attached= 10:3)
- Identify which traits appear more frequently, hypothesizing which traits are dominant and recessive.

Observation table

S.N.	Name of students	Earlobes	Tongue rolling	Widow's peak	Hitchhiker's thumb	Dimples	Freckles

Chapter 3.3

LINKAGE AND CROSSING OVER

Let's discuss the following questions:

- I. Find some examples where traits seem to come in pair (like eye colour and hair colour) in families?
- II. Why don't siblings always look exactly the same even if they have the same parents?

3.3.1 LINKAGE

A gene is the basic unit of heredity that controls the traits or characteristics of an organism. These genes are found on structure called chromosomes. Since each organism has thousands of traits like eye colour, height, blood type, skin colour etc., it must also have thousands of genes. However, the number of chromosome is much smaller than the number of traits. This means that each chromosome must carry many genes. All these genes present on the same chromosome are said to be **linked gene** and should be inherited together. The tendency of linked genes inherits together in same progeny without change in original sequence is called **linkage**. Linked gene does not follow Mendel's law of independent assortment. Linked genes are present in a group called linkage group. The number of linkage groups in a species is equivalent to its haploid number of chromosome. Thomas Hunt Morgan discovered the phenomenon of linkage during his experiment in *Drosophila melanogaster*.

Types of Linkage:

The types of linkage are given below:

1. Complete Linkage:

When genes are tightly linked and located very close to each other on the same chromosome, they show a very low frequency of recombination. In such cases, only parental (non-crossover) types of gametes are usually produced. This condition is known as complete linkage, where the linked genes are not separated during gamete formation, from generation to generation. As a result, the offspring inherit the same combinations of traits as the parents, and no new genetic combinations are formed. Complete linkage is rare type. The phenomenon of complete linkage is shown by *Drosophila* having grey body with normal wings and black body with vestigial wings.

When a male *Drosophila* with a grey body and normal wings (GGNN) is crossed with a female with a black body and vestigial wings (ggnn), all the F₁ offspring have grey bodies and normal wings (GgNn). When these F₁ flies (GgNn) are test crossed with ggnn flies (black body, vestigial wings), the F₂ generation shows only two types of offspring:

1. Grey body with normal wings
2. Black body with vestigial wings

This occurs because the genes for body colour and wing type are completely linked and are inherited together. As a result, the F_1 hybrid produces only two types of gametes, each carrying the parental combination of genes, with no recombination.

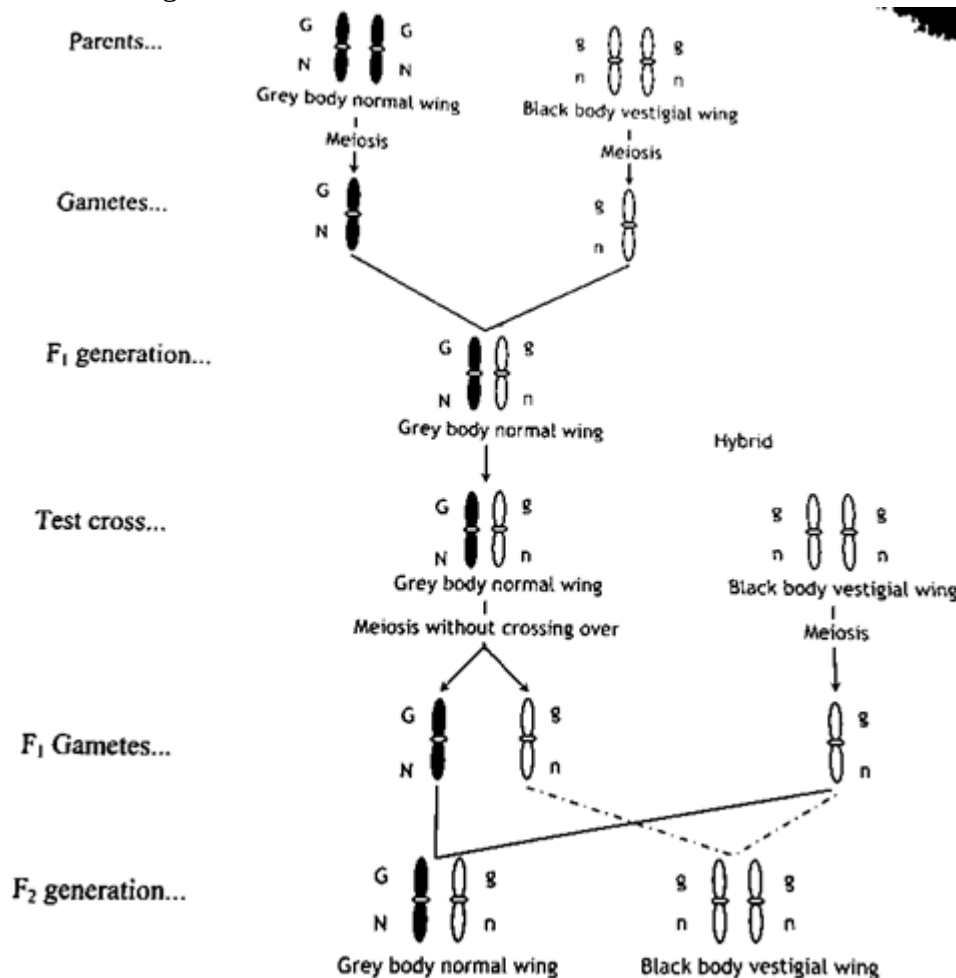


Figure: 3.3.1 Complete linkage in *Drosophila melanogaster*

2. Incomplete Linkage:

When genes are located on the same chromosome but are not very close to each other, they show a higher frequency of recombination. In such cases, both parental and recombinant types of gametes are produced. This condition is known as incomplete linkage. The linked genes are separated during gamete formation due to crossing over. As a result, the offspring show new combinations of traits along with parental types, increasing genetic variation.

Incomplete linkage is more common than complete linkage. The phenomenon of incomplete linkage can be explained in maize plant. When a maize plant with coloured and full seeds ($CCFF$) is crossed with one having colourless and shrunken seeds ($ccff$), all the F_1 offspring produced have coloured and full seeds ($CcFf$), showing the dominant traits.

In a test cross, these F_1 hybrids ($CcFf$) are crossed with plants having colourless and shrunken seeds ($ccff$). The resulting offspring include four different combinations:

1. Coloured and full (CcFf) – parental
2. Coloured and shrunken (Ccff) – recombinant
3. Colourless and full (ccFf) – recombinant
4. Colourless and shrunken (ccff) – parental

This happens due to incomplete linkage, where the genes for seed colour and seed texture are located on the same chromosome but are not very close together. As a result, crossing over occurs in the F₁ hybrid, leading to the formation of both parental and non-parental (recombinant) types of gametes. This allows for genetic variation among the offspring.

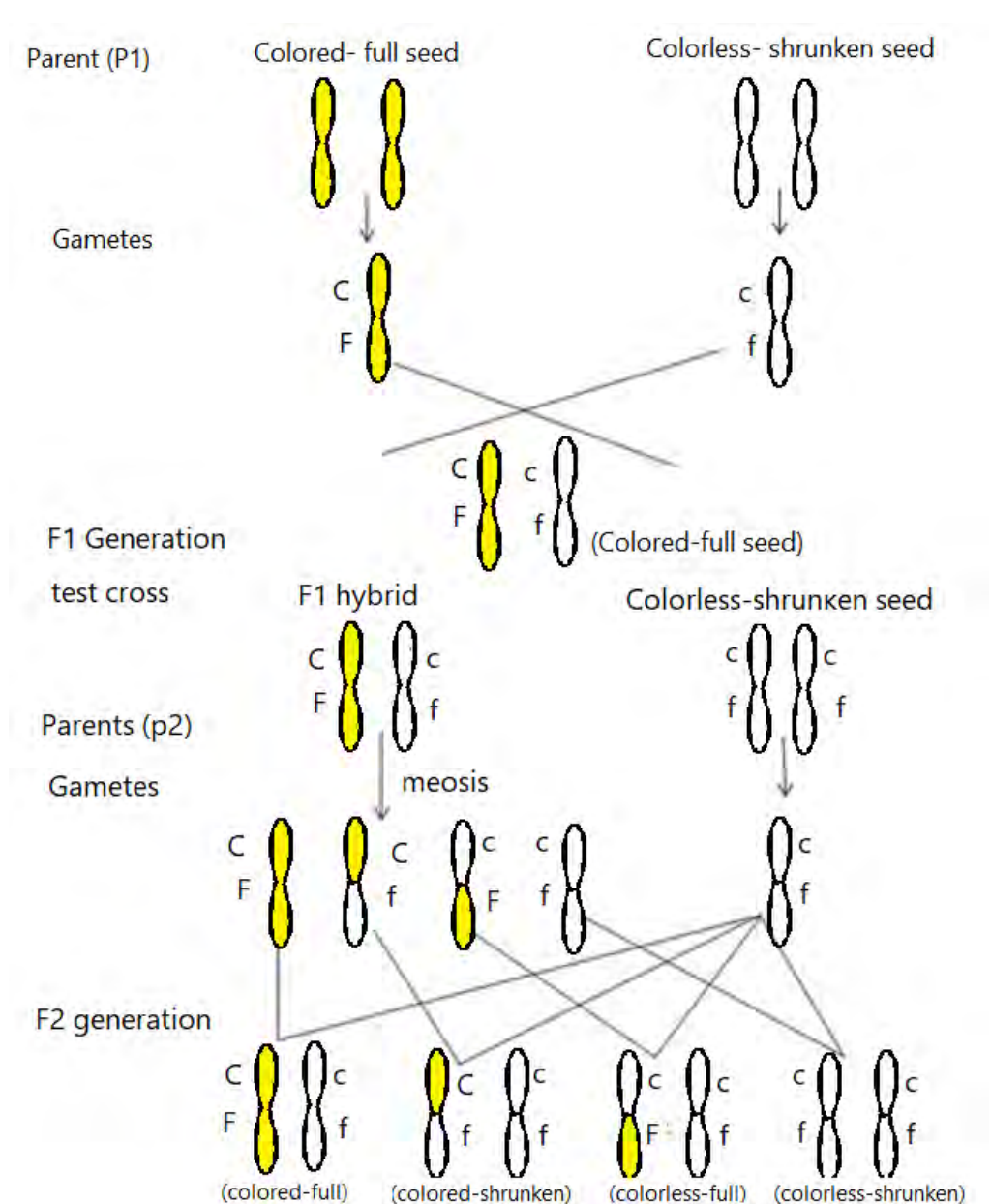


Figure: 3.3.2 Incomplete linkage in maize

3.3.2 SEX LINKED INHERITANCE

There are two types of chromosomes i.e. autosomes or somatic chromosome and sex chromosome. Autosomes help to control the vegetative characters while sex chromosome determines the sex of the organism. For example: human beings have 23 pairs of chromosome, among them 22 pairs are autosomes and 1 pair is sex chromosome. Female has 44+XX chromosomes and male has 44+XY chromosome. *Drosophila* has 3 pairs of chromosome, among them 2 pairs are autosomes and one pair is sex chromosome. The genes which are present in autosomes are called autosomal genes. The genes present in sex chromosome are called sex linked genes and inheritance of such gene is called sex linked inheritance. Thus, sex linked inheritance is a process of inheritance of traits in successive generations from parents to the offsprings due to linked genes of sex chromosome. For Example: Haemophilia, colour blindness, eye colour in *Drosophila* etc.

Characters of sex linked inheritance are as follows:

1. Sex linked gene are present on the sex chromosome, mostly on the X-chromosome.
2. Sex linked traits are usually recessive.
3. X-linked trait appear more frequently in male than female.
4. Male can not transmit sex linked trait to his son because sex linked genes are present in X chromosome and X chromosome in son is always from female not from male.
5. Female can transmit sex linked trait to both son and daughter.
6. X-linked traits often pass from carrier mothers to affected sons and from affected fathers to carrier daughters. This is called criss-cross inheritance.

1. Sex Linked inheritance in Human (Colour blindness)

Colour blindness is the inability of a person to distinguish red, green or both the colours from other colours. The gene for the normal vision is dominant. Colour blindness is caused by defective recessive gene attached to the X-chromosome.

a. Cross between colour blind male and normal female

If a colour blind male marries a normal female, all daughter and son have normal vision but daughter is carrier. Because they are heterozygous, they will not be colour blind. None of the sons would be colour blind. All would be normal because the X-chromosome they carry is from the normal female.

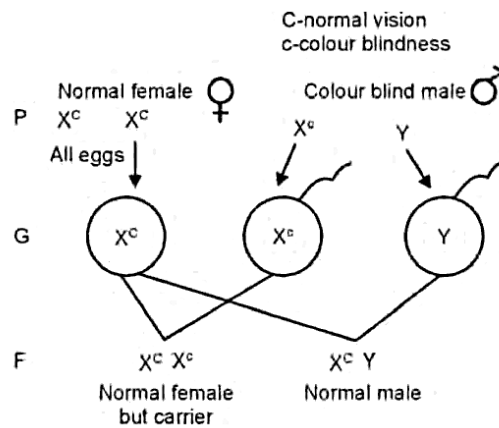


Figure: 3.3.3 Cross between colour blind male and normal female

b. Cross between carrier female and normal male

If a carrier female marries a normal male, 25% of their sons are colour blind, 25% of their sons are normal, 25% daughters are normal and the remaining 25% daughters are carrier.

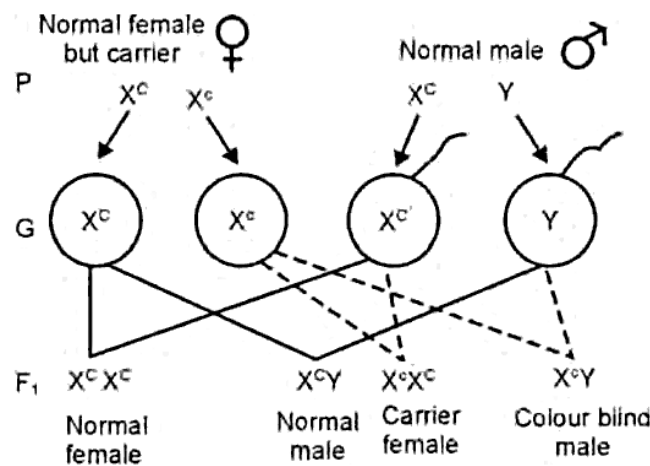


Figure: 3.3.4 Cross between carrier female and normal male

c. Cross between colour blind female and normal male

If a colour blind female marries a normal male, 50% female are carrier and 50% male are colour blind.

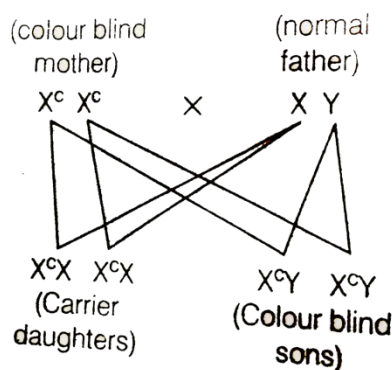


Figure: 3.3.5 Cross between colour blind female and normal male

d. Cross between carrier female and colour blind male

If a carrier female marries colour blind male, the offspring produced are 25% carrier female, 25% colour blind female, 25% normal male and remaining 25% are colour blind male.

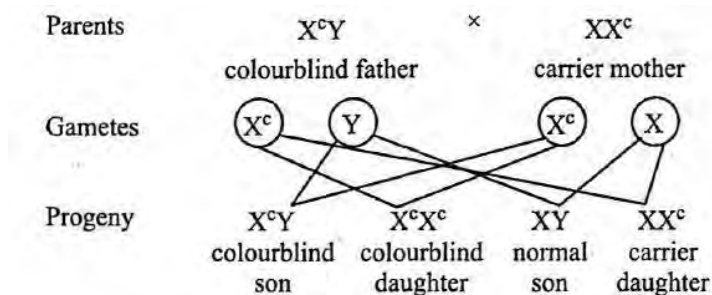


Figure: 3.3.6 Cross between carrier female and colour blind male

By analyzing the results of above crosses following conclusion is predicted:

1. The colour blindness gene is present in X-chromosome.
2. A female has two X chromosomes so has to be recessive homozygous to express colour blindness but in male there is only one X chromosome, colour blindness allele expresses even in recessive condition. This is the reason why colour blindness is more common in male than in female.
3. Father can transfer colour blindness gene to his daughter only while mother can transfer to both son and daughter.
4. A father cannot transmit sex-linked trait to his son as X-chromosomes comes from mother.
5. Female are carrier of gene. Male are never carrier.
6. Colour blind female always have colour blind father and always produce colour blind sons.
7. Colour blind females produce colour blind daughters only when husband is also colour blind.

2. Sex Linked inheritance for Eye colour in *Drosophila*

Thomas Hunt Morgan, an American zoologist along with his associates studies the inheritance of eye colour in *Drosophila melanogaster*. He was awarded the Nobel Prize in 1933 for this invention. Morgan was sure that since genes present on chromosomes controlled the traits, the mutations also occurred in the genes. Morgan's study was based on experiments on fruit fly, *Drosophila*, a small fly about 2 mm in size seen hovering around over ripe fruits. He selected *Drosophila* for study of sex linked trait because of following reasons:

1. It can be easily cultured in the jars containing suitable medium.
2. It reproduces rapidly and in large numbers. Just a pair of flies can give rise to hundreds of offspring in a single mating.
3. The life cycle is short (10-15 days) which is helpful in rapid study and analysis of result.
4. They breed throughout the year.
5. Less number of chromosome (4 pairs) so sex chromosome can be easily distinguished.
6. The sexes of *Drosophila* are easily distinguishable. The male is smaller, darker and has a blunt abdomen while the female is larger, and has a lighter and a narrower abdomen.

Experiments done by Morgan in *Drosophila*

T.H. Morgan, discovered a male fly with white eyes in his culture. The normal eye colour of fruit fly is red. White eye colour was a mutant form and by number of experiments or crosses, Morgan

noticed that the inheritance of eye colour in *Drosophila* was associated with the sex of the parents. Sex linked gene in *Drosophila* is present in X-chromosome. Morgan crossed red and white eyed *Drosophila* in different ways which are given below:

Cross: I Cross between normal red eyed female with white eyed male

Morgan crossed normal red eyed female with white eyed male *Drosophila* and found that F₁ progeny had only red eyed males and red eyed females. By this he came to a conclusion that red colour of eye is dominant over white colour of eye. Then, he crossed red eyed males of F₁ progeny with red eyed females of F₁ progeny. He got the results as given below:

- All F₂ females were red eyed
- Half of F₂ males were red eyed
- Half of F₂ males were white eyed
- The ratio of red eyed to white eyed was 3:1

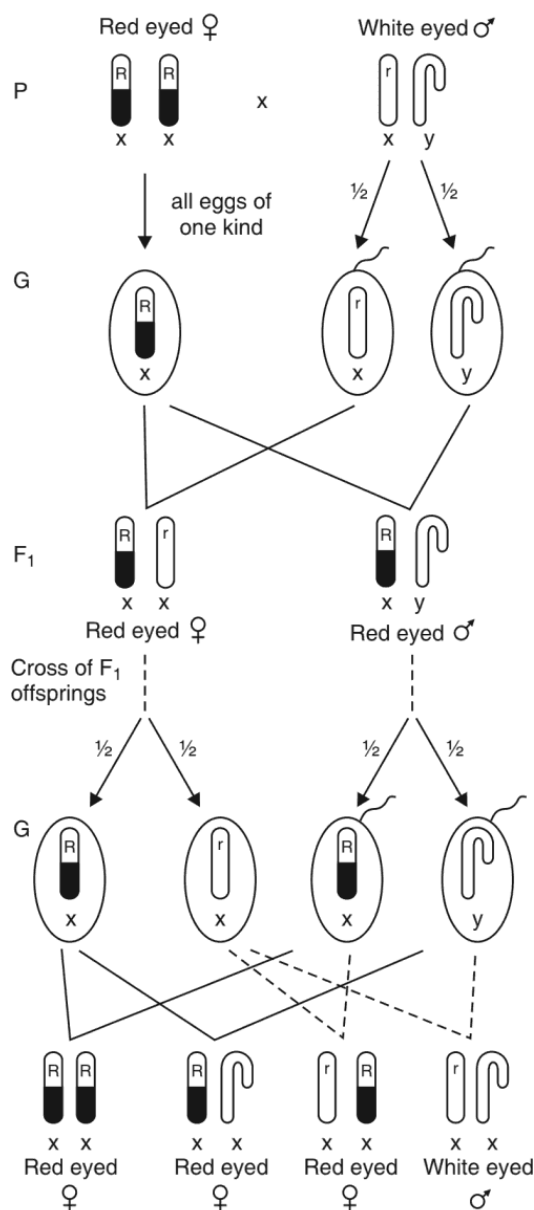


Figure: 3.3.7 Cross between normal red eyed female with white eyed male

Cross: II Cross between F₁ red eyed females with white eyed males

Morgan crossed F₁ red eyed females with white eyed males. The red eyed and white eyed females and males were produced in an equal proportion. It led to a conclusion that white eye colour is not restricted to the male but also present in female.

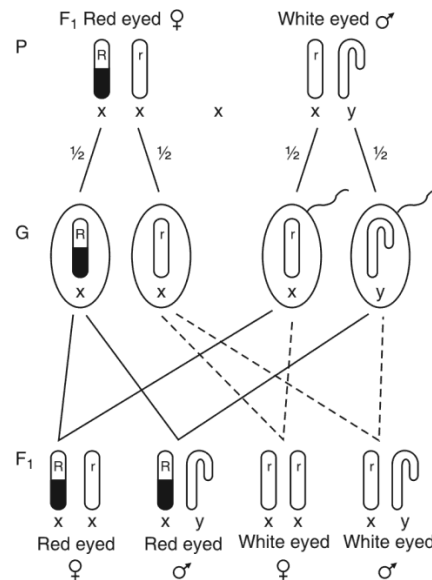


Figure: 3.3.8 Cross between F₁ red eyed females with white eyed males

Cross: III Cross between white eyed female with red eyed male

Morgan crossed, white eyed female with red eyed male *Drosophila*. It was the reverse of cross I. The result were all males were white eyed and all females were red eyed.

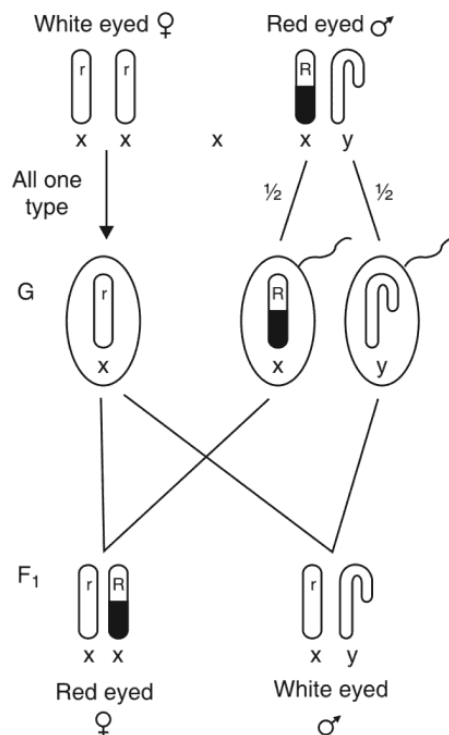


Figure: 3.3.9 Cross between white eyed female with red eyed male

By analyzing the results of cross I, II and III, Morgan concluded that

1. White eye colour in *Drosophila* was sex linked trait. It was found more frequently in male than female.
2. Red eye colour in *Drosophila* was dominant over white eye colour.
3. Sex linked gene was recessive and was present in X-chromosome.
4. Sex linked gene was inherited from to 50% of grandson though F₁ female.
5. Male could transmit sex-linked trait only to daughter.

Activity: 3.5

To prepare a chart of sex-linked traits in Humans

Prepare a neatly organized chart listing common sex linked traits in humans such as haemophilia, colour blindness etc. For each trait, identify the chromosome involved, whether the gene is dominant or recessive, and who is more likely to be affected- male or female.

S.N.	Trait name	Chromosome involved	Dominant/recessive	More affected (Male or female)

3.3.3 CROSSING OVER

Crossing over is the mutual exchange of the corresponding parts of the adjacent paternal and maternal chromatids of the synapsed homologous chromosomes, producing new combinations of genes. The chromatids resulting from the interchange of segments are known as recombinants. The term crossing over was given by Thomas Hunt Morgan. Crossing over occurs during prophase I of meiosis cell division. The actual exchange of genetic material takes place in pachytene but it starts in zygotene and ends in diakinesis.

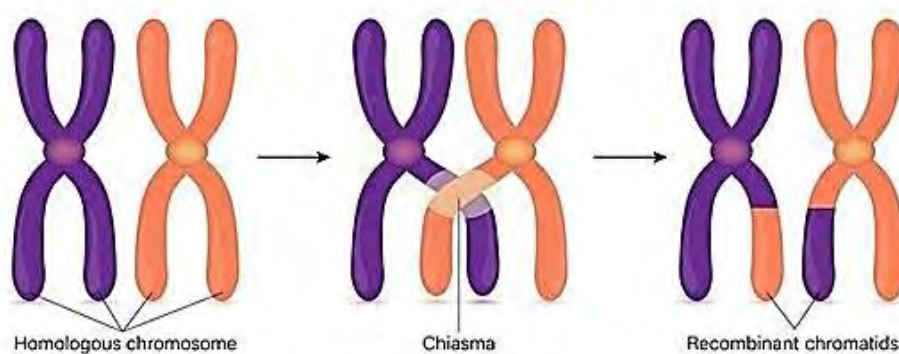


Figure: 3.3.10 Crossing over

According to number of chiasmata (point at which it occurs), crossing over may **single** (one chiasmata is formed), **double** (two chiasmata are formed) or **Multiple** (more than two chiasmata are formed).

Significance of crossing over

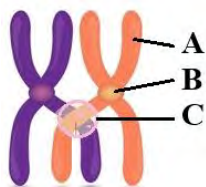
1. Crossing over increase genetic variation by exchanging DNA between homologous chromosomes, which leads to new combinations of traits in offspring.
2. It ensures the offspring are genetically different from their parents and siblings, promoting individuality.
3. Crossing over supports evolution by providing the raw material for natural selection.
4. It plays a role in adaptation, as the increased variation allows populations to better survive changing environments.
5. It increases immunity of organisms.
6. It helps to produce better crop and animal varieties.

EXERCISE

A. Tick the correct alternatives:

1. What is number of linkage group in man?
 - a. 23
 - b. 46
 - c. 44
 - d. 2
2. Which of the given law is not followed by linked genes?
 - a. Law of segregation
 - b. Law of dominance
 - c. Law of independent assortment
 - d. Law of purity of gametes
3. In *Drosophila*, how many pairs of chromosomes are autosomes?
 - a. 1
 - b. 2
 - c. 3
 - d. 4
4. A mother is a carrier for colour blindness and the father has normal vision. What is the probability that their son will be colour blind?
 - a. 0%
 - b. 25%
 - c. 50%
 - d. 100%
5. Which chromosome carries the gene for eye colour in *Drosophila*?
 - a. Y chromosome
 - b. X chromosome
 - c. Autosome
 - d. Sex chromosome
6. Why can males only transmit sex-linked traits to their daughters and not to their sons?
 - a. Sons inherit Y chromosome from father, not X
 - b. Sons inherit only autosomes from father
 - c. Males do not pass on genes
 - d. Males transmit mitochondrial DNA to daughters only
7. In which phase of meiosis does the actual exchange of genetic material take place?
 - a. Leptotene
 - b. Zygotene
 - c. Pachytene
 - d. Diakinesis
8. What is the point at which crossing over occurs called?
 - a. Centrosome
 - b. Centromere
 - c. Chiasmata
 - d. Chromonema

9. Why is crossing over during meiosis important in the long term survival of a species?
 - a. It prevents chromosome mutations during cell division.
 - b. It ensures the correct number of chromosomes in gametes.
 - c. It creates genetic diversity, which allows populations to adapt to changing environments.
 - d. It guarantees offspring will inherit only the best traits from both parents.
10. Name the process shown and label A, B and C of the given diagram.



- a. Replication, A – centromere, B – chromatid, C – chiasmata
- b. Crossing over, A – Chromatid, B – chiasmata, C – chromatid
- c. Crossing over, A – Chromatid, B – chromatid, C – Chiasmata
- d. Crossing over, A – Chromatid, B – Chromatid, C - Chiasmata

B. Answer the following questions:

1. What is linkage? What are the different types of linkage?
2. Describe the complete linkage with example.
3. Describe incomplete linkage in maize.
4. Why is *Drosophila* selected for the study of sex linked inheritance?
5. What is sex linked inheritance? Describe it with reference to eye colour of *Drosophila*.
6. Explain the sex linked inheritance of colour blindness in man.
7. What is crossing over? Mention its significance.
8. Explain the role of crossing over in creating genetic variation.
9. If a red eyed female fruit fly heterozygous for the eye colour gene is crossed with a white eyed male, what will be the expected phenotypic ratio of the offspring? Explain your answer with a punnett square.
10. A colour blind man marries a normal vision woman. Their children have normal vision. Draw a genetic diagram to suggest an explanation for this.
11. Fruit flies can have normal wings or vestigial wings. The allele for normal wings is 'N' and is dominant while the allele for vestigial wings is 'n' and is recessive.
 - a. Write down the three possible genotypes and their phenotypes.
 - b. Construct a complete genetic diagram to show the offspring that are produced when a heterozygous fly mates with a fly that is homozygous for the normal wing allele.

Chapter 3.4

MUTATION AND POLYPLOIDY

Let's discuss the following questions:

- I. Have you noticed some fruits are seedless, like watermelons or bananas? How do you think that happens?
- II. Why do some people have extra fingers or toes at birth?
- III. Why do scientists and farmers try to modify plants genetically?

3.4.1 GENERAL INTRODUCTION

The Dutch botanist Hugo de Vries is widely credited with coining the term "mutation" in 1901, while studying the evening primrose (*Oenothera lamarckiana*). He noticed sudden, unexpected changes in the plant's traits (like flower size or leaf shape) that were passed down to the next generation.

Thomas Hunt Morgan's *Drosophila* experiments (1910s) linked mutations to chromosomes. Morgan demonstrated that this new trait was due to a change in a specific gene located on a chromosome.

Mutation can be defined as the certain heritable change in amount or content and organization of genetic material of organism that result in change in appearance. It is a heritable change in the DNA (or RNA for some viruses) sequence of an organism. Mutations can occur spontaneously during DNA replication or be induced by external factors like radiation, chemicals, or viruses. While some mutations are harmful and cause genetic disorders or cancer, others can be beneficial, driving evolution by providing adaptations such as disease resistance. Mutations are the raw material for evolution and play a crucial role in genetic research, medicine, and biotechnology, including applications like gene therapy and genetically modified crops. Understanding mutations helps scientists study heredity, evolution, and disease mechanisms.

3.4.2 TYPES OF MUTATION

On the basis of scale of change mutation are of two types. They are:

1. Gene mutation (Point mutation or micro mutation)

It is the type of mutation in which single gene (small scale change in DNA sequence) is affected. The primary cause of gene mutation is error during DNA replication. They are also of three types:

a) Substitution mutation

In a substitution mutation, one nucleotide base is replaced by another in the DNA sequence. This results varying effect on protein formation. On the basis where one base is replaced by another, we can further classify them into two types: transitions and transversions.

- i. A **transitional mutation** occurs when a purine base is replaced by another purine, or a pyrimidine base is replaced by another pyrimidine. Transitional mutations are generally more common than transversions, partly because they involve less drastic chemical changes and can sometimes have less impact on the resulting amino acid due to the degeneracy of the genetic code (where multiple codons can code for the same amino acid).

Purine to Purine: $A \leftrightarrow G$

Pyrimidine to Pyrimidine: $C \leftrightarrow T$

- ii. A **transversional mutation** occurs when a purine base is replaced by a pyrimidine, or a pyrimidine base is replaced by a purine. Transversional mutations are generally less common but can often lead to more significant changes in the amino acid sequence. The mutation responsible for **sickle cell anemia** (a GAG to GTG change in the beta-globin gene, leading to a glutamic acid to valine substitution) is a transversion (A is replaced by T in the coding strand).

Purine to Pyrimidine: $A \text{ or } G \leftrightarrow C \text{ or } T$

Pyrimidine to Purine: $C \text{ or } T \leftrightarrow A \text{ or } G$

b) Frameshift mutation

A frameshift mutation is a type of gene mutation caused by the insertion or deletion of one or more nucleotides in a DNA sequence, resulting in shifting of reading frame of the codons during translation. It changes the entire amino acid sequence downstream of the mutation. Protein formed after change is completely different so does not function as normal. **Huntington's disease** is caused by special type of addition mutation and **Cystic Fibrosis** is caused by deletion mutation.

Example:

Original DNA: ATG CAT GTA TGA (codes for: Met-His-Val-Stop).

After Insertion (A):

ATG (ACA TGT ATG) → Shifts reading frame → new protein sequence.

After deletion (C):

ATG (ATG TAT GAT) → Shifts reading frame → new protein sequence

c) Nonsense mutation

It takes place due to conversion of sense codon into nonsense codon which stops the synthesis of protein. There are three "stop" codons (UAA, UAG, UGA in mRNA) that signal the ribosome to terminate protein synthesis. In a nonsense mutation, a base substitution converts an amino acid-coding codon into one of these stop codons. Consequence of this mutation is premature termination of protein synthesis. Such truncated

proteins are almost always non-functional. **Duchenne muscular dystrophy** is an example of disorder caused by production of essential protein caused by premature termination due to nonsense mutation

Example :

Original DNA Sequence: TAC AAA ****CGA**** GTC CTA ATT

mRNA Sequence: AUG UUU ****GCU**** CAG GAU UAA

Mutated DNA Sequence: TAC | AAA | ****TGA**** | GTC | CTA | ATT

Mutated mRNA Sequence: AUG | UUU | ****UGA**** | CAG | GAU | UAA

Here UGA is stop codon, hence premature termination occurs at UGA.

2. Chromosomal mutation (macro mutation)

Chromosomal mutations are large-scale changes in the structure or number of chromosomes impacting large segments of DNA and potentially many genes. The primary cause of chromosomal mutation is disjunction failure during cell division. Such mutations can lead to a wide range of effects, from having no noticeable impact to causing severe developmental disorders, genetic diseases (like Down syndrome), or even being lethal, depending on the specific genes affected and the extent of the change.

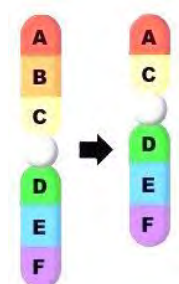
There are two types of chromosomal mutations:

a) Structural changes in chromosome (chromosomal aberration)

Structural chromosomal mutations involve changes in the physical arrangement or composition of a chromosome. These include change within homologous chromosome known as intrachromosomal modification and change between two non-homologous chromosomes known as interchromosomal modification. Intrachromosomal modification includes **deletions** (loss of a segment), **duplications** (extra copies of a segment), **inversions** (reversal of a segment), and interchromosomal modification includes **translocations** (exchange of segments between non-homologous chromosomes). These types of mutations causes abnormal gamete formation.

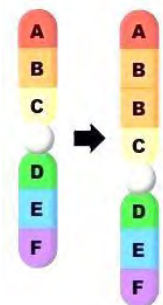
i. Deletion mutation

It occurs when a segment of DNA is lost. The severity of a deletion depends on the size of the deleted segment and the importance of the genes it contained. Small deletions might have no noticeable effect, especially if the missing information is redundant or non-coding. However, larger deletions can lead to significant genetic disorders, developmental abnormalities, or even be lethal, as the organism loses essential genetic instructions.



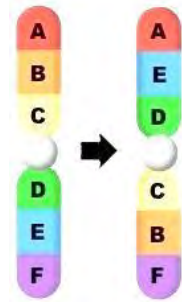
ii. Duplication mutation

It occurs when presence of extra copy of segment of DNA. This means that a particular set of genes or even a single gene is repeated. The consequences of a duplication mutation are highly variable. In some cases, having extra genetic material can be beneficial, providing raw material for evolutionary change and the development of new gene functions over time. However, excessive duplications can lead to genetic disorders due to an imbalance in gene dosage, disrupting normal cellular processes and development.



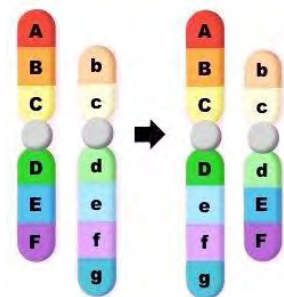
iii. Inversion mutation

It occurs when a segment of chromosome breaks off and rearranged in a reverse direction. Inversion doesn't result in a loss or gain of genetic material. If the breakpoints of the inversion occur within a gene, they can disrupt its function. Inversions can lead to problems during meiosis, specifically during the pairing of homologous chromosomes, as the inverted segment in one chromosome cannot align properly with the non-inverted segment in its partner. This can result in the formation of abnormal gametes with deletions or duplications, leading to reduced fertility or offspring with genetic disorders.



iv. Translocation mutation

This involves movement of segment of DNA of one chromosome to another non homologous chromosome. This exchange can be reciprocal, where two non-homologous chromosomes swap segments, or non-reciprocal, where a segment breaks off one chromosome and attaches to another without any exchange. It also does not cause loss of genes. Individual may be phenotypically normal but produces gametes with imbalance set of chromosomes which can lead to recurrent miscarriages, infertility, or offspring with severe developmental disabilities.



b) Genomic mutation (change in number of chromosome)

Genomic mutation involves a change in the total number of chromosomes within a cell. It is also called **ploidy**. The most common cause is non-disjunction, an error during cell division (meiosis or mitosis) where homologous chromosomes or sister chromatids fail to separate properly. This can lead to **aneuploidy**, where an individual has an abnormal number of chromosomes or **polyploidy**, where an organism has more than two complete sets of chromosomes. These changes in chromosome number often have significant impacts on an organism's development and viability, frequently leading to severe genetic disorders or lethality.

i. Aneuploidy

Aneuploidy is the process of loss or addition of one or more particular chromosome from a diploid set of chromosome. Organism in which aneuploidy phenomenon takes place is called aneuploids. They form abnormal gametes and can cause high mortality rate, reduce fertility and various genetic disorders.

Aneuploids may be hypoploidy (loss of one or more chromosomes from diploid set) or hyperploidy (addition of one or more chromosomes from diploid set).

Types of hypoploidy

- **Nullysomy ($2n-2$):** In this mutation there is absence of both homologous chromosomes of a pair. This type of mutation is typically lethal.
- **Monosomy ($2n-1$):** In this mutation there is absence of one chromosome from a diploid set. Autosomal monosomy is lethal. Sex chromosomal monosomy leads to severe disorder like Turner syndrome.

Types of hyperploidy

- **Trisomy ($2n+1$):** In this mutation there is presence of an extra copy of one chromosome in a diploid set. Autosomal trisomy causes disorders like Down's syndrome while sex chromosome trisomy causes disorder like Klinefelter syndrome.
- **Tetrasomy ($2n+2$):** In this mutation there is presence of two extra copies of one chromosome (four copies total). It is less common than trisomy. One of the well documented autosomal tetrasomy disorder is Tetrasomy 18p. A notable example of sex chromosome tetrasomy is Tetrasomy X in which a female has 4 X chromosomes.
- **Pentasomic ($2n+3$):** In this mutation there is presence of three extra copies of one chromosome are present in addition to the normal two copies. Pentasomy is a rare type and can lead to severe developmental abnormalities.
- **Hexasomic ($2n+4$) :** In this mutation there are four extra copies of one chromosome in a diploid set. It is an extremely rare.

ii. Euploidy

It is the condition where an organism has addition or loss of complete set of chromosomes from a diploid set of chromosome. The organisms in which the euploidy takes place are called euploid. Unlike aneuploids, euploids generally do not show harmful effects unless the level of polyploidy is extremely high. It is common in plants but rare in animals. Euploidy may be **Monoploidy** and **Polyploidy**.

- **Monoploidy:** It involves loss of complete one set of chromosome from diploid set. The resulting offspring have only one set of chromosome i.e. $2n-n=n$. It results in formation of smaller size of organism e.g. male wasp, bee etc.
- **Polyploidy:** It involves the addition of one or more sets of chromosome in diploid set of chromosome. The resulting offspring have more than two set of chromosomes i.e. triploid ($3n$), tetraploid ($4n$), pentaploid ($5n$), Hexaploid ($6n$) etc.

3.4.3 POLYPLOIDY

In general an organism has two set of chromosomes. Few organisms consist of more than two sets of chromosomes, such organisms are called polyploids and the condition is called polyploidy. It results from abnormalities during meiosis or fertilization. Polyploidy is very common in plants and play an important role in evolution, speciation and crop improvement. In animals, it is rare and usually harmful.

Types of polyploidy

1. Autopolyploidy:

It arises by increase in the number of chromosome sets of the same species. For instance, a diploid species having two similar chromosomes set 'AA' will change into autriploid 'AAA' by duplication of the chromosomes of one set, and into an autotetraploid 'AAAA' by duplication of the chromosome of both the sets. Seedless watermelon, grapes, banana are autopolyploids.

2. Allopolyploidy:

It develops in a hybrid between two species by doubling of chromosome sets AB to AABB. The allopolyploidy have multiple sets of two different genomes. They behave as new species. The example of allopolyploidy is *Raphanobrassica* produced by a crossed between two plants of different genera (radish and cabbage).

Significance of polyploidy

Following are the significance of polyploidy:

1. Polyploidy helps in the evolution of new plant species.
2. It often makes plants grow larger with bigger leaves, fruits and flowers.
3. Polyploidy can produce seedless fruits like banana, watermelon, grapes etc.
4. It improves crop productivity and makes plants more resistant to diseases.
5. Plant breeders use polyploidy to create better hybrid crops.
6. Scientists use polyploidy in research to better understand how genes and chromosomes work.
7. It may increase the immunity of organism.

3.4.4 IMPORTANCE OF MUTATION

Positive importance of Mutation:

1. Mutations create genetic variation, which is essential for evolution.
2. They can introduce beneficial traits that help organisms adapt to changing environments.
3. Useful mutations in plants and animals can improve food production.
4. Mutations help scientists understand genes, diseases, and how cell work.
5. They are used in plant breeding to develop disease resistant and high yielding crops.

Negative importance of mutation:

1. Some mutations cause genetic disorders, like Down syndrome or sickle cell anemia.
2. Harmful mutations can lead to diseases like cancer.
3. They can reduce fertility or cause birth defects in humans and animals.
4. Mutations may produce weak or non-viable organism in nature or farming.
5. Uncontrolled mutations can disrupt ecosystems if harmful traits spread.

EXERCISE

A. Tick the correct alternatives:

1. What is the cause of sickle cell anemia?
 - a. Insertion mutation
 - b. Transition mutation
 - c. Transversion mutation
 - d. Duplication mutation

2. Which type of gene mutation replaces a purine with another purine?
 - a. Trasversion
 - b. Frameshift
 - c. Inversion
 - d. Transition

3. Which type of euploidy involves only one set of chromosomes?
 - a. Diploidy
 - b. Monoploidy
 - c. Triploidy
 - d. Tetraploidy

4. Which of the following set of chromosome do a girl having turner's syndrome has?
 - a. 46+XY
 - b. 44+XX
 - c. 45+XO
 - d. 47+XXY

5. What is the chromosome set of an autotetraploid organism if the original diploid set is 'AA'?
 - a. AA
 - b. AAA
 - c. AABB
 - d. AAAA

6. The sequence of bases in a DNA is ATG AAA GGG CCC TTT which one of the following is a frameshift mutation?
- ATG GAA AGG GCC CTT T
 - ATG AAG GGC CCT TT
 - ATG AAA GGG CCC TTT
 - Both a and b

B. Answer the following questions:

- What is mutation? Compare the characters of gene mutation and chromosomal mutation.
- A plant species normally has 14 chromosomes ($2n=14$). What would be the chromosome number in its tetraploid and hexaploid forms?
- Write the positive and negative importance of mutation.
- What is polyploidy? Describe its types and also mention its significance.
- A cell was found to have 45 chromosomes instead of the normal 46. Predict which type of chromosomal mutation has occurred, and discuss its possible phenotypic outcomes.

Project Work:

Divide the students into groups and assign each group a case study of a genetic disorder caused by mutations, such as Sickle cell Anemia, Haemophilia, Down Syndrome, or Cystic Fibrosis. Each group will read, discuss and prepare a short presentation on the causes, symptoms and type of genetic mutation involved. Then group will present in class.

Unit 4

EMBRYOLOGY



Panchanan
Maheshwari
(1904-1966)

He was a pioneering Indian botanist. He made groundbreaking contributions to the study of **angiosperm reproduction**, especially in **embryo sac development**, **double fertilization**, and **endosperm formation**. Maheshwari was the first to introduce **test-tube fertilization** in plants, opening new avenues in plant breeding and hybridization. He emphasized the role of **experimental embryology** in understanding plant development. His work laid a strong foundation for modern plant reproductive biology and inspired generations of scientists.

Chapter 4.1

ASEXUAL REPRODUCTION

Let's discuss the following questions:

- iv. Do you think all plants require seeds to grow?
- v. Can new plants grow from parts like roots, stems or leaves? Can you give examples?
- vi. What are the advantages or characteristics of plants produced by such method?

4.1.1 ASEQUAL REPRODUCTION

The mode of reproduction that does not involve the fusion of gametes or formation of seed through fertilization is known as **asexual reproduction**. Asexual reproduction produces genetically identical offspring from a single parent. It enables rapid colonization, do not require pollinators and ensures survival in stable environment. But due to lack of genetic variation reduces adoptability of plants to changing environments. Such type of reproduction method is also known as **apomixis**.

There are two types of apomixis:

1. Agamospermy (Asexual seed formation)

In agamospermy, embryos develop without fertilization. There are three methods by which embryos can develop without fertilization. They are

a. Adventive embryony (Nucellar embryony)

In this type embryo is developed from diploid cells of nucellus or integuments (somatic cells). Such process is observed in plants like *Citrus* spp like orange and lemon, *Optunia*, *magnifera indica* etc.

b. Recurrent Agamospermy

In this type embryo is developed from diploid egg cell (diplospory) or other diploid cells in ovule (apospory) without fertilization (parthenogenetically). The process is called recurrent because it can repeat indefinitely without recombination maintaining same genotype. Such process is observed in species like *Taraxacum officinale* commonly known as “dudhe jhar”, *Rubus ellipticus* (Aiselu), *Poa* commonly known as blue grass etc.

c. Non recurrent Agamospermy

This type of reproduction is rare form where embryo is developed from haploid egg cell without fertilization and produces non identical offspring. Such process is observed in species like *Musa* spp. (wild banana), grapes etc.

2. Vegetative propagation

Vegetative reproduction is the form of asexual reproduction in angiosperm in which new plants are developed from vegetative parts of a plant like root, stem, leaf and bud without

fertilization and forming seed. The process results in formation of genetically identical offspring of parent plants. Such offspring are also known as **clones**.

4.1.2 VEGETATIVE PROPAGATION

Vegetative propagation may occur naturally or can be done artificially as well.

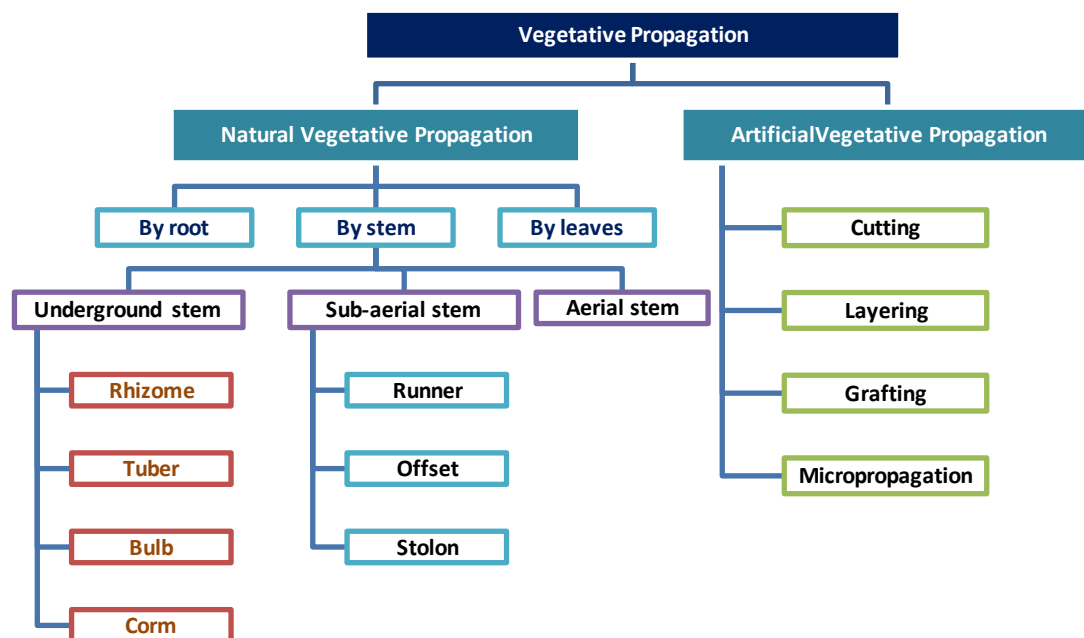


Figure: 4.1.1. Types of vegetative propagation

1. Natural vegetative propagation

Natural vegetative propagation is a form of asexual reproduction in plants where new plants grow from the vegetative parts like root, stem or leaves without formation of seed. The various methods of vegetative propagation occurring naturally are as follows:

a. Vegetative propagation through root

Root develops adventitious buds which sprout out under favorable conditions and forms new plant on separation. Such process is observed in plants like Guava, sweet potato, *Asparagus* etc.

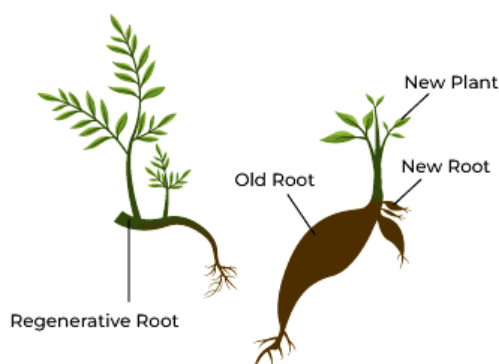


Figure: 4.1.2. Vegetative propagation through root in sweet potato

b. Vegetative propagation through stem

Stem may be underground, aerial or subaerial which can propagate to give new plant.

i) Underground stem

1) Rhizome

Rhizomes are horizontally growing underground stem with nodes and internodes. New shoots and roots arise from nodes. Examples: ginger, turmeric, bamboo etc.

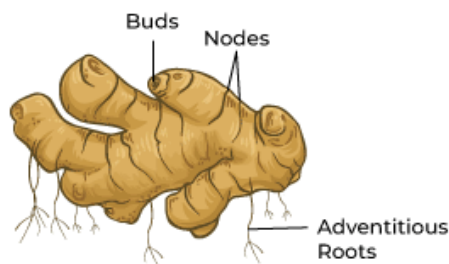


Figure: 4.1.3. Vegetative propagation through rhizome of ginger

2) Tuber

They are swollen underground stem modified for storage of food. It consist buds which under favorable condition develop into new plants. Examples: potato, yam etc.

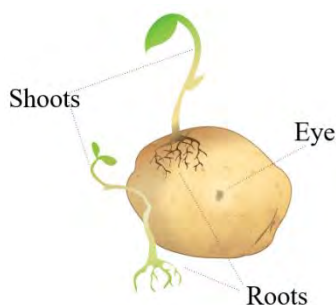


Figure: 4.1.4. Vegetative propagation through tuber of potato

3) Bulb

They are Underground stems with fleshy leaf bases storing food and a central bud. Later buds develop into new bulb. Examples: onion, garlic tulip etc.

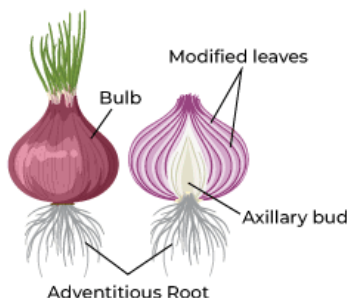


Figure: 4.1.5. Vegetative propagation through bulb of onion

4) Corm

They are solid, fleshy underground stems covered by papery leaves. New corms develop from parent corm. Examples Gladiolus, Crocus (**Kesar**), *Colocasia esculenta* (**Pidalu**).

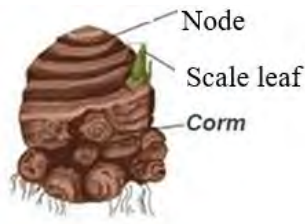


Figure: 4.1.6. Vegetative propagation through corm of Pidalu

ii) Sub aerial

1) Runner

Runners are slender, horizontal stems growing along the ground and produces new plants at nodes. Example: Cyanodon (**dubo**), *Oxalis* etc.

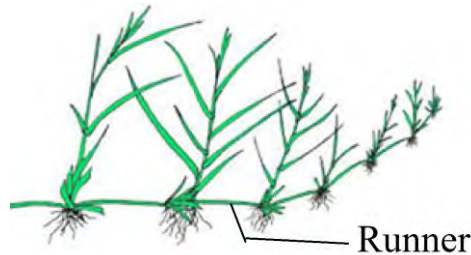


Figure: 4.1.7. Vegetative propagation through runner of Cyanodon

2) Offset

Offsets are horizontal stem that grows on surface of water, producing new plants at nodes. Examples: Water hyacinth, *Pistia* etc.



Figure: 4.1.8. Vegetative propagation through offset of *Eichornia*

3) Stolon

They are slender stem in which a part of branch lies completely below the soil and a part of branch lies completely above the ground. The branch breakdown to form a segment which can develop independent as a new plant. Examples: Strawberry, mint etc.



Figure: 4.1.9. Vegetative propagation through stolon of strawberry

c. Vegetative propagation through leaves

Some plants develop adventitious buds on leaves. They remain dormant when attached to the plant but when they get in contact with moist soil, they develop into new plants. Examples: *Bryophyllum*, *Begonia*, *Adiantum* (walking fern).



Figure: 4.1.10. Vegetative propagation through leaves *Bryophyllum*

2. Artificial vegetative propagation

Artificial vegetative propagation is a technique used to create new plants from existing plant material. It involves techniques like cuttings, layering, grafting or micro propagation to produce new plants that are genetically identical to the parent plant. It is a common practice in horticulture and agriculture, allowing for the propagation of desirable traits and the rapid production of new plants.

a. Cutting

Cutting is a common method of vegetative propagation where a part of a plant (stem, leaf, or root) is cut and planted to grow into a new independent plant. This method is widely used in horticulture for cloning desirable plants quickly and efficiently.



Figure: 4.1.11. Vegetative propagation by cutting

b. Layering

It is the process of inducing roots from a part of a plant while it is still attached to the rooted parent plant. In the simple layering method, a soft branch is bent, made a cut up to the vascular region, and buried under the soil. After a few days, the buried part produces roots. The rooted branch is then cut off to develop as a new plant. It is also known as mound layering.

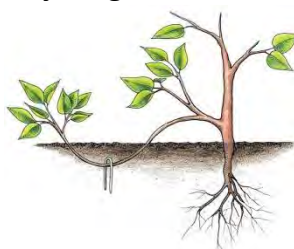


Figure: 4.1.12. Vegetative propagation by simple layering

In the serpentine layering method, a soft branch is taken, cut in multiple places, and buried in many places under the soil to produce many new plants.



Figure: 4.1.13. Vegetative propagation by compound (serpentine) layering

Air layering (Gootee) method involves removing a section of bark from a branch and covering it with grafting clay (consists soil, dung, auxin, mosses, hey etc.) and rapped by polythene bag. After few days covered part produces root. They branch with root is cut and developed as a new plant.

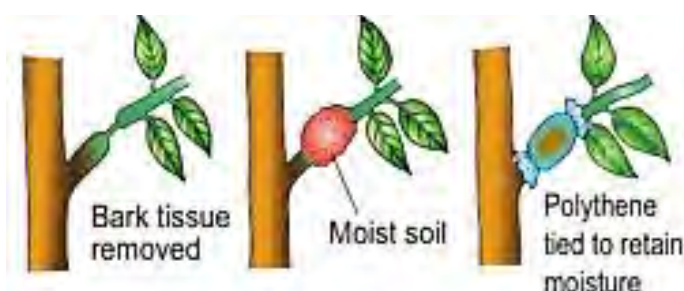
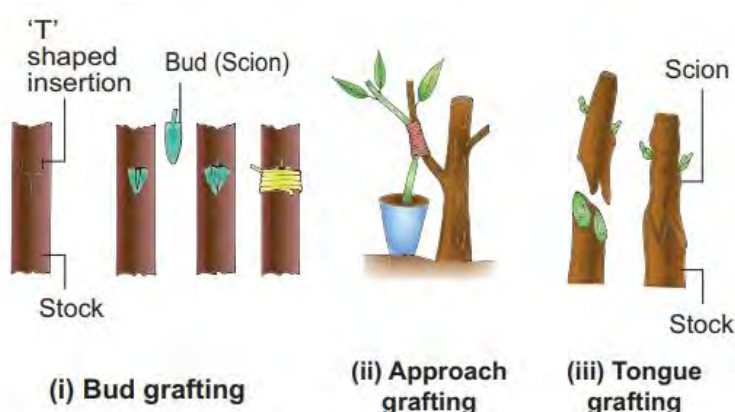


Figure: 4.1.14. Vegetative propagation by aerial layering

c. Grafting

Grafting is a key vegetative propagation technique involving joining two plants together to create a single organism. This process allows for the combination of desirable traits from two different plants. The upper portion of the graft, providing desired traits is known as **scion** and the lower portion, providing strong roots and disease resistance is known as **stock**. Scion is joined the stock as to produce successful union of cambium. Some examples of grafting are shown the following diagram.



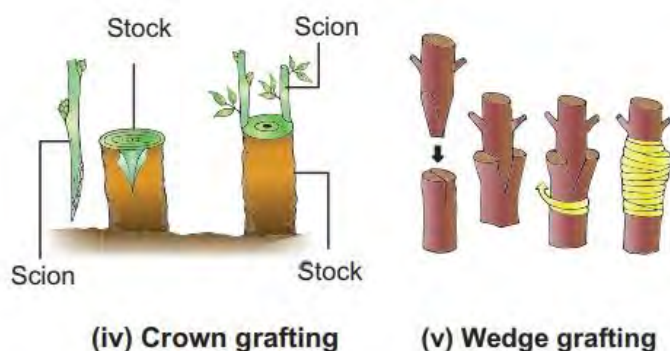


Figure: 4.1.15. Vegetative propagation by grafting (different types of grafting)

d. Micro propagation

Micro propagation is the method of artificial vegetative propagation by employing plant tissue culture through which numerous similar plants can be developed from a small piece of explant. It is conducted under sterile laboratory conditions with the aid of nutrient media and plant hormones. The technique ensures fast, mass propagation of healthy and disease-free plants within acceptable economic limits. It finds wide applications in agriculture, horticulture, and conservation.

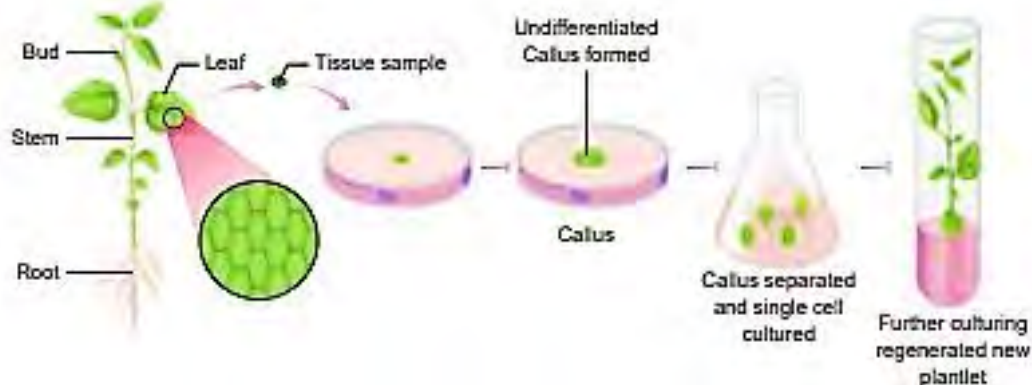


Figure: 4.1.16. Micropropagation

Advantages of vegetative propagation

1. Vegetative propagation results in the reproduction of plants at a much faster pace than seed reproduction.
2. It produces progenies that are genetically identical; therefore, the inheritance of desired characters is ensured.
3. It allows the multiplication of plants escaping from effective seed production, e.g., banana and sugarcane.
4. It ensures uniform growth and yield for all propagated plants.
5. It helps in the production of disease-free plants among which one is micro propagation.
6. It is highly efficient for large scale commercial cultivation of high value crops.

Disadvantages of vegetative propagation

1. Vegetative propagation is a slow method of plant reproduction than seed.
2. Because vegetative propagation does not create genetic variability, plants remain susceptible to the attack of diseases and insects.
3. Rapid spread of diseases can result if the parent plant is diseased.
4. The plant produced may have a shorter life than that of seed-grown plants.
5. It is not applicable to all plant species, as some do not propagate efficiently by vegetative means.
6. Excessive use of the same clones can lower the diversity of the farmed areas.

Activity: 4.1

Work in pair or small group and prepare chart paper showing different types of vegetative propagation. Include both natural and artificial methods with diagram and examples. After finishing, displayed in class.

EXERCISE

A. Tick the correct alternatives:

1. Which of the following is a method of asexual reproduction in angiosperms where embryos develop without fertilization?
 - a. Vegetative propagation
 - b. Agamospermy
 - c. Self-pollination
 - d. Cross-pollination
2. In which type of apomixis does the embryo develop from diploid cells of the nucellus or integuments?
 - a. Recurrent Agamospermy
 - b. Non-recurrent Agamospermy
 - c. Adventive embryony
 - d. Vegetative propagation
3. Which of the following is an example of a plant that reproduces through rhizomes?
 - a. Potato
 - b. Onion
 - c. Ginger
 - d. Sweet potato
4. What is the horizontal stem that grows along the ground and produces new plants at nodes called?
 - a. Tuber
 - b. Runner
 - c. Offset
 - d. Stolon
5. Which of the following is a disadvantage of vegetative propagation?
 - a. Rapid reproduction
 - b. Genetic variation
 - c. Susceptibility to diseases

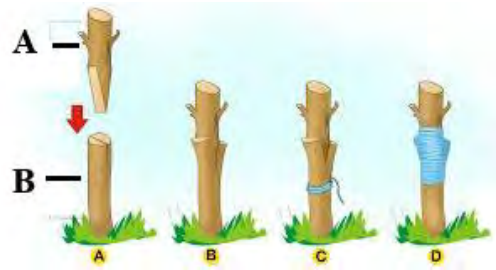
- d. Uniform growth
- 6. Name the small piece of plant used in micropropagation.
 - a. Clone
 - b. Explant
 - c. Graft
 - d. Scion
- 7. Study the given diagram of strawberry plant. Name the method of vegetative propagation shown in the figure.



- a. Bulbil
- b. Runner
- c. Rhizome
- d. Tuber
- 8. A rare orchid species is on the verge of extinction. Scientists plan to multiply it rapidly in the lab. Which of the following will help achieve this?
 - a. Cross pollination
 - b. Grafting
 - c. Tissue culture using explants
 - d. Cutting and layering
- 9. Why is it ecologically dangerous when aquatic weeds like *Eichornia* propagate through offsets?
 - a. They increase pollinator diversity
 - b. They reduce water pollution
 - c. They spread rapidly and choke water bodies

B. Answer the following questions:

1. What is vegetative propagation?
2. What is micropropagation?
3. What is layering? Describe the process of layering with diagram.
4. Differentiate between cutting and grafting.
5. How can vegetative propagation be useful in preserving the genetic traits of a plant?
6. You have a healthy rose plant in your garden. How would you propagate more rose plants using vegetative methods? Describe the steps.
7. A nursery uses grafting to produce mango saplings. What could be the advantages of this method over growing mangoes from seeds?
8. Observe the given diagram and answer the given questions.



- What type of vegetative propagation is shown in the diagram?
 - Label A and B.
 - Name one plant that reproduces by this method.
 - State two advantage of this method.
9. Why vegetative propagation is considered both a benefit and a risk in modern agriculture? Support your answer with real world examples.

Project Work:

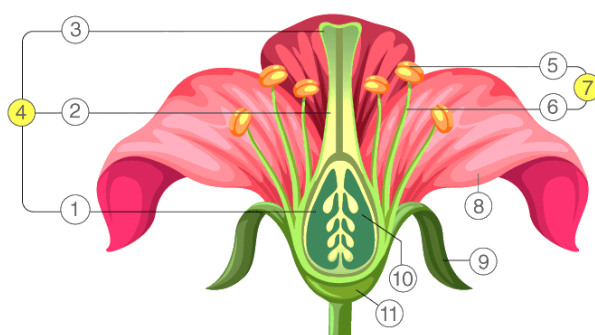
Conduct a survey within the community, interviewing experienced farmers or gardeners about the plants they propagate vegetatively, the methods they use, the timing, and any specific tips or tricks they have learned over time. Prepare a report and present in class.

Chapter 4.2

SEXUAL REPRODUCTION

Let's discuss the following questions:

- Dou you know what is the importance of flower in angiosperm?
- Why do flowers have different colours?
- Have you ever seen bees or butterflies around flowers? What do you think they are doing?
- Can you label all these parts of flower?



4.2.1 GENERAL INTRODUCTION

Flower is the main organ of plants that takes part in sexual reproduction. It has four main parts i.e. calyx, corolla, androecium and gynoecium. The calyx protect the flower during bud stage while corolla are the colourful parts which attract pollinators for pollination. Androecium are the male reproductive organ and gynoecium are female reproductive organ of the flower. The reproductive organs produce their respective gametes for sexual reproduction. Sexual reproduction involves the formation of male and female gametes, fusion of them to form seed inside fruit. In general it includes gamete formation, pollination, fertilization and seed formation.

Activities: 4.1

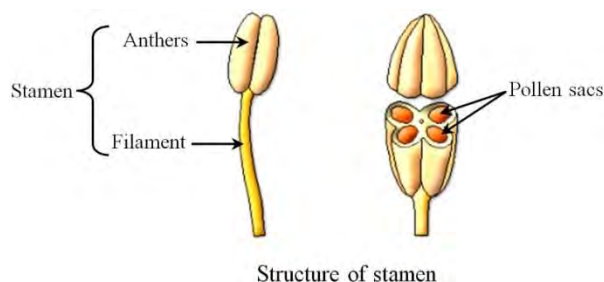
Collect flowers of any angiosperm species common in your locality. Carefully dissect one of the flower to identify and study the different whorls: calyx, corolla, androecium (stamens), and gynoecium (pistil/carpel).

4.2.2 GAMETOGENESIS

Gametogenesis is the process of development of gametes. Two types of gametes are formed during sexual reproduction, thus, the gametogenesis in plants can be studied under two heading: microsporogenesis and megasporogenesis.

1. Microsporogenesis

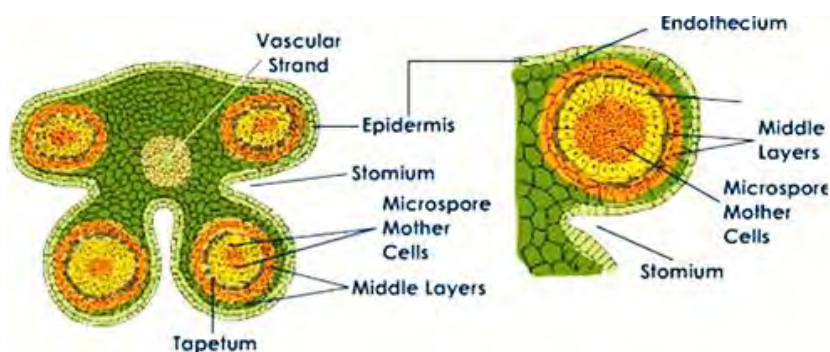
Microsporogenesis is the process of formation and maturation of microspores (pollen grains) inside the microsporangia (pollen sacs) of the anther in flowering plants (angiosperms) through meiotic division.



The anther is the part of the stamen (the male reproductive organ of a flower) that produces and contains pollen grains. A typical anther is bilobed, joined together by a connective tissue called the connective. Each lobe of the anther usually contains two thecae, which are pollen sacs or microsporangia. Therefore, a typical bilobed anther is also described as dithecous (having two thecae per lobe) or tetrasporangiate (having four microsporangia in total).

A cross-section of a young anther lobe, shows following layers :

Epidermis: This is the outermost protective layer, usually made of a single layer of cells. It protects the developing pollen sacs and may play a role in anther dehiscence (the opening of the anther to release pollen).



Endothecium: it is located just below the epidermis, single-layered and has cells with fibrous thickenings (often made of cellulose). These thickenings play a crucial role in anther dehiscence by contracting as they dry out, causing the anther to split open. This layer provides structural support and also helps in the release of pollen.

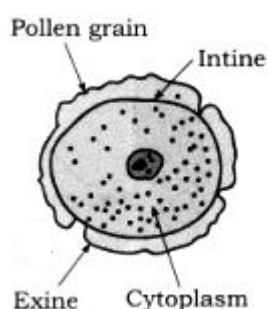
Middle Layers: These are 1-3 layers of thin-walled parenchyma cells located below the endothecium. These cells provide nourishment to the developing microspores. They are short-lived and may disappear as the anther matures.

Tapetum: This is the innermost layer of the anther wall, surrounding the sporogenous tissue (cells that will undergo meiosis to form microspores). The tapetum is a crucial nutritive layer for the developing pollen grains. Its cells are typically large, multinucleate or have polyploid nuclei, and are rich in cytoplasm.

The primary sporogenous tissue in microsporangium divides mitotically and differentiates into microspore mother cell (MMC). The MMC undergoes meiotic division and forms tetrad microspore or pollen cells.

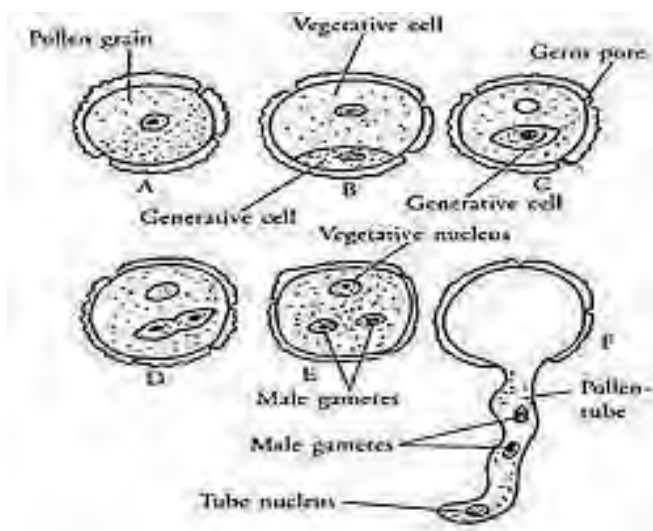
Structure of pollen

Pollen grains have a hard coat, usually made of sporopollenin that protects them as they move from the male part to the female part of flowering plants. Pollen grains consist of three main parts: an inner cytoplasm, an inner wall (intine) of cellulose and pectin, and a tough outer wall (exine) that is often made of sporopollenin. There are thin areas or openings in the pollen wall (exine) which later allow the pollen tube to emerge during germination known as germ pores.



Micro gametogenesis

Micro gametogenesis is the process by which a microspore (haploid cell) develops into a mature male gametophyte (pollen grain). It occurs inside the anther of flowering plants and leads to



the formation of sperm cells for fertilization.

The nucleus of the microspore undergoes mitotic division which results in the formation of two cells within the pollen grain:

- A larger cell called the vegetative cell (also known as the tube cell). It has an irregularly shaped nucleus and abundant cytoplasm rich in food reserves. This cell will be responsible for the development of the pollen tube.

- A smaller cell called the generative cell. It has a spindle-shaped nucleus and sparse cytoplasm. Initially, the generative cell is attached to the wall of the pollen grain, but it soon becomes detached and floats within the cytoplasm of the vegetative cell in many angiosperms.

In many angiosperm species (over 60%), the pollen grain is shed from the anther (pollination occurs) at this two-celled stage – containing the vegetative cell and the generative cell. After pollination generative cell divides mitotically to produce two male gametes (sperm cells) later in pollen tube.

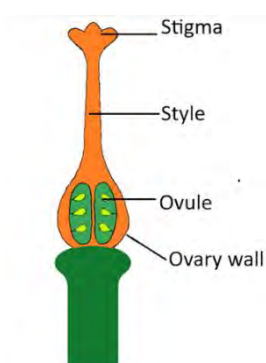
In the remaining angiosperm species (around 40%), the generative cell undergoes a second mitotic division, either within the pollen grain before it is shed or after the pollen grain has landed on the stigma and the pollen tube has started to grow. This division of the generative cell produces two male gametes.

The mature male gametophyte is therefore a three-celled structure in these species, consisting of the vegetative cell and two male gametes enclosed within the pollen grain wall. In species where the pollen is shed at the two-celled stage, the male gametes are formed later within the pollen tube.

When pollen falls on stigma it absorbs fluid and swell up. Outer exine then ruptures at germ pore and intine protrude out and forms pollen tube.

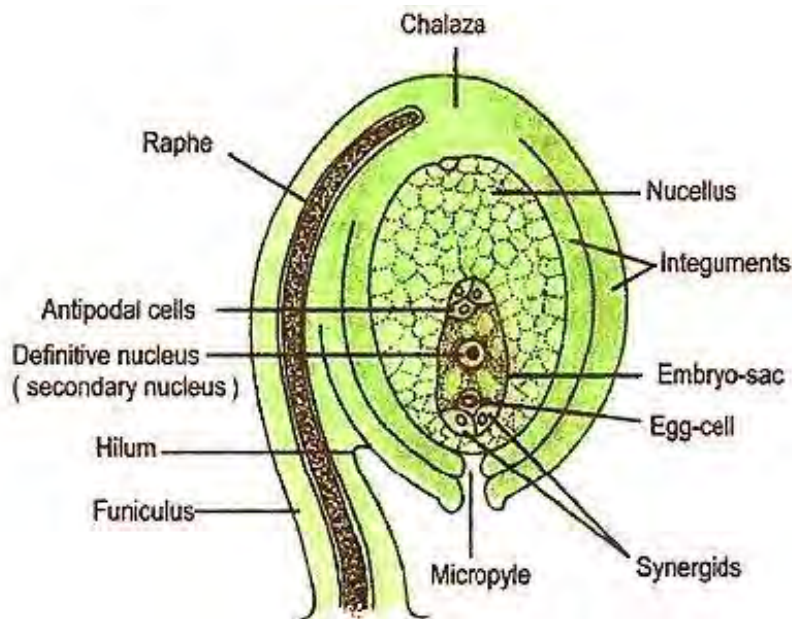
2. Megasporogenesis

Megasporogenesis is the process of formation of haploid megaspores from a diploid megaspore mother cell within the ovule. It occurs within the **ovule**. Single unit of gynoecium is called carpel of pistil which consists of stigma, style and ovary. Ovule lies within ovary.



Structure of ovary

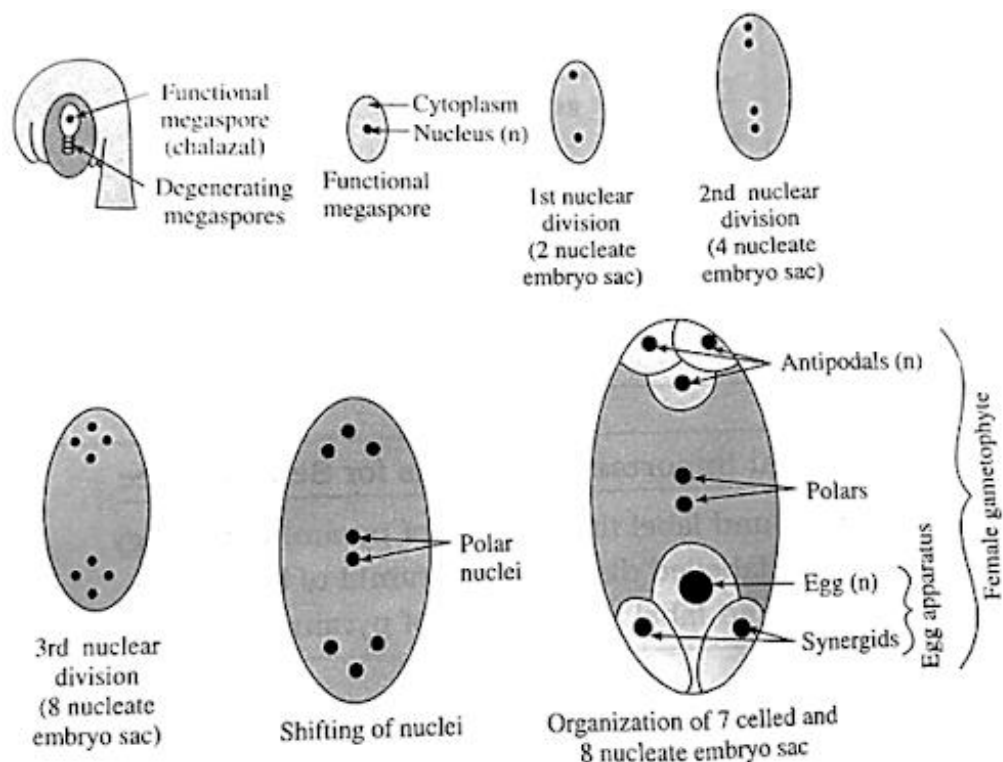
It consists of a central nucellus containing the female gametophyte (embryo sac), surrounded by one or two protective layers called integuments. The integuments enclose the nucellus except for a small opening called the micropyle. The ovule is attached to the ovary wall via a stalk called the funiculus, and the point of attachment leaves a scar called the hilum. The base of the ovule opposite the micropyle is the chalaza. The orientation of these parts defines different types of ovules.



The development of a megaspore, or megasporogenesis, begins with a diploid megaspore mother cell (MMC) within the ovule. Cells in the nucellus towards micropile end enlarges in size and acts as archisporial cell. It either directly acts as MMC or differentiate into sporogenous tissue and forms MMC. This MMC undergoes meiosis, resulting in a linear tetrad of four haploid megaspores. Typically, three of these megaspores degenerate, and only one functional megaspore survives.

Megagametogenesis

Megagametogenesis is the process by which the functional haploid megaspore develops into the mature female gametophyte, also known as the embryo sac. The nucleus of the functional megaspore undergoes three successive mitotic divisions without immediate cell wall formation. This results in an 8-nucleate stage. These eight nuclei then organize themselves within the embryo sac. Typically, one nucleus from each pole migrates to the center and fuses to form the diploid central cell (containing the polar nuclei). At the micropylar end, three cells differentiate: the egg cell and two flanking synergids. At the chalazal end, three other cells differentiate as the antipodals. Thus, the mature embryo sac is typically 7-celled and 8-nucleate.



4.2.3 POLLINATION

Pollination is the process of transferring pollen grains from the anther (male reproductive part) of a flower to the stigma (female receptive part) of the same or a different flower. This step is essential for fertilization to occur in seed plants. Pollination can be broadly categorized into self-pollination (transfer within the same flower or between flowers of the same plant) and cross-pollination (transfer between flowers of different plants of the same species).

1. Self-pollination

Self-pollination is the process where pollen grains are transferred from the anther to the stigma of the same flower or to another flower on the same plant. This occurs in bisexual flowers and can be further divided into:

- **Autogamy:** Pollen transfer to the stigma of the same flower. Adaptations like homogamy (synchronous maturation of anther and stigma) and cleistogamy (flowers remaining closed) favor autogamy.
- **Geitonogamy:** Pollen transfer to the stigma of another flower on the same plant. While it involves different flowers, it is genetically similar to autogamy as the pollen originates from the same plant.

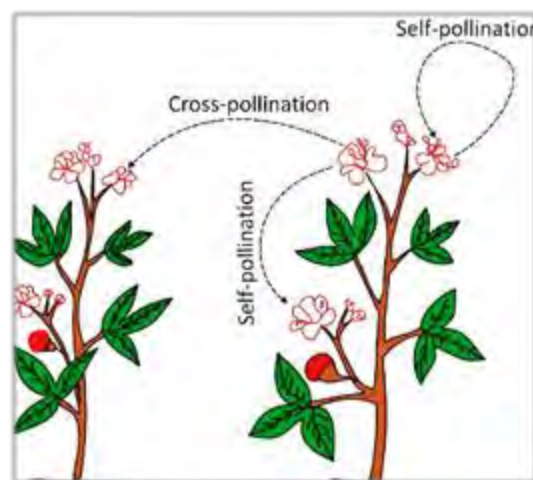
Advantages of self-pollination

1. It maintains pure line
2. It is more economical (less pollen is required)
3. It is independent of other factor

4. Flower do not require to develop attractive parts
5. It ensures seed production
6. It prevents the introduction of new genetic variations

Disadvantages of self-pollination

1. It does not allow to introduce new characters
2. It decreases adaptability of races
3. It does not cause variation in new generations
4. Continuous self-pollination may lead to extinction of races
5. It may allow to carry unwanted characters to new individuals
6. It does not play role in evolution



2. Cross pollination

Cross-pollination is the transfer of pollen grains from the anther of a flower on one plant to the stigma of a flower on a genetically different plant of the same species. This process is the primary mechanism for sexual reproduction in many angiosperms and plays a vital role in promoting genetic diversity within a population. Unlike self-pollination, which involves the transfer of pollen within the same plant, cross-pollination requires the involvement of external agents to carry the pollen between individual plants.

Based on factors cross pollination may be:

a. Anemophily

It is the pollination occurred by air. In such plants pollen are light and non-sticky, flower contains single ovule in ovary and numerous flowers are placed in inflorescence.

b. Hydophily

The type of pollination is occurred by water. Such pollination is rare, mostly in monocots (observed in about 30 genera only). All aquatic plants are not hydophily. Pollen grains in such plants are covered by mucilaginous covering.

c. Zoophyly

The type of pollination is occurred by biotic agents. In such plants flowers are large, colorful and rich in nectar. Small flowers present in cluster. Examples of zoophily are as follows:

- i. Entomophily- by insects
- ii. Ornithophily – by birds
- iii. Chiropterophily – by bats
- iv. Ophiophily – by snakes
- v. Anthrophily- by human

Advantages

1. Self-sterility can continue their race
2. Cross pollination induce variation
3. It helps in evolution
4. It provides better adaptability to plants
5. New and more useful varieties are formed
6. It results in high productivity
7. Defective characters are eliminated

Disadvantages

1. This process is highly expensive
2. This process depend on factors
3. Some undesirable character may remain
4. Useful characters may spoil
5. This process need to create attractive parts
6. Seed production is less ensured

Activity: 4.2

Visit a garden and observe different flowers. Classify them based on pollination agents (wind, insect, bird, water). Compare floral adaptations (color, scent, nectar, pollen structure). Present with a chart with labeled diagrams.

4.2.4 FERTILIZATION

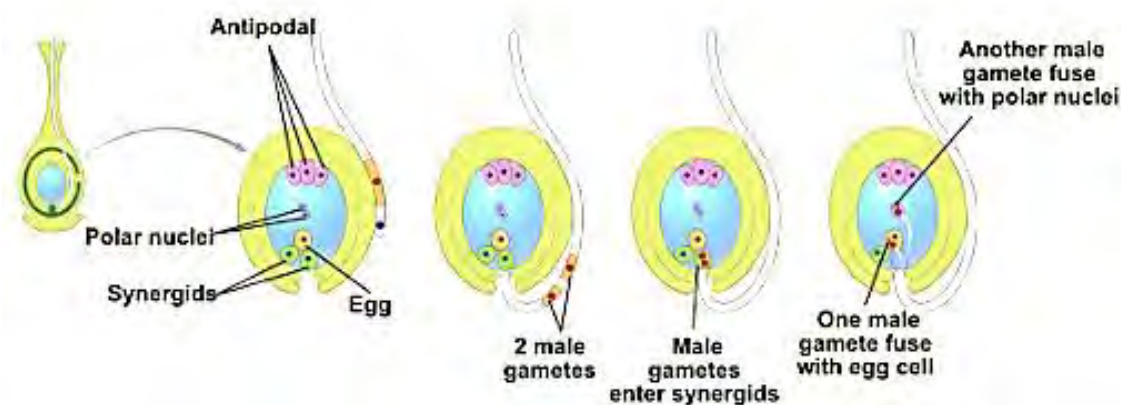
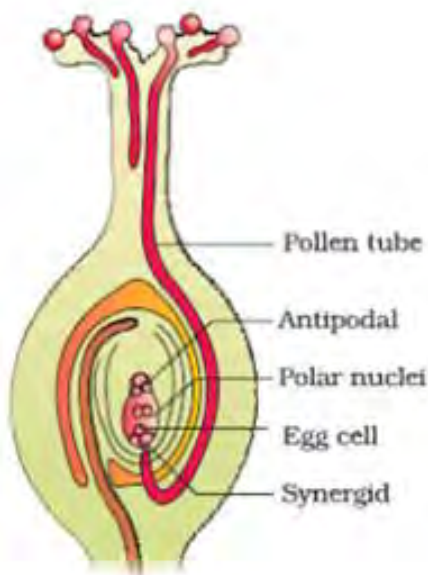
Fertilization in angiosperms is a unique process called **double fertilization**. It occurs after a pollen grain lands on the stigma, germinates to form a pollen tube, and grows through the style to reach the ovule, typically entering through the micropyle. The type of fertilization that occurs through the development of a pollen tube is called siphonogamy.

The processes of fertilization are described below:

1. Entry of pollen tube: The pollen tube carries two male gametes (sperm cells).It penetrates the embryo sac, usually by entering one of the synergids and then degenerating that synergid. Pollen tube usually enters through micropile end, such process is known as porogamy. If it enters through other part than micropile end it is called aporogamy.

2. Syngamy: One of the male gametes fuses with the egg cell (located at the micropylar end of the embryo sac). This fusion results in the formation of a diploid zygote (2n), which will eventually develop into the embryo. This fusion is the true fertilization.

3. Triple Fusion: The second male gamete moves towards the central cell (a large cell in the center of the embryo sac containing two polar nuclei, which may have already fused to form a diploid secondary nucleus). This second male gamete fuses with the polar nuclei (or the secondary nucleus), resulting in the formation of a triploid primary endosperm nucleus (PEN) ($3n$). This process is called triple fusion because three haploid nuclei are involved. The primary endosperm nucleus divides repeatedly to form the endosperm, a nutritive tissue that will nourish the developing embryo.



4.2.5 EMBRYOGENESIS

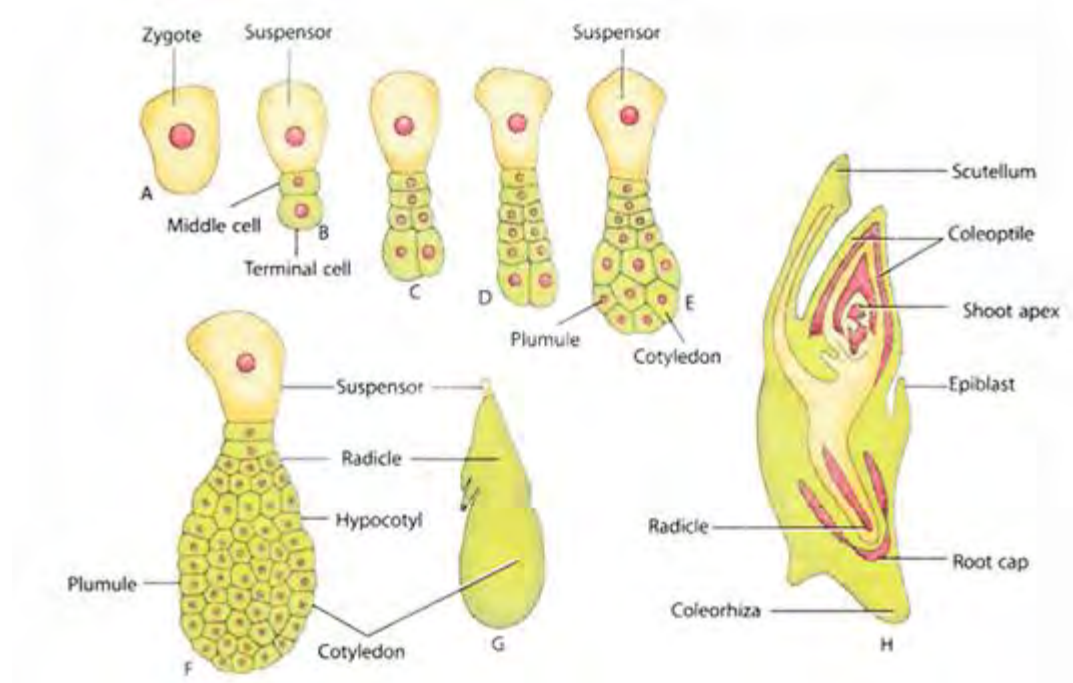
The diploid zygote formed after fertilization develops into the embryo. The process of formation of embryo from zygote is called embryogeny or embrogenesis. The formation of embryo in dicot and monocot has no differences in early development but there are some differences in the later stage of development.

1. Development of embryo in Monocotyledonous plants

Monocot embryo formation follows a specific pattern during seed development. It begins with the zygote formed after fertilization. The zygote undergoes asymmetric division, producing a small terminal cell (which develops into the embryo) and a larger basal cell (which forms the suspensor, later degenerating).

The terminal cell divides transversely to form two cells. The top cell after a series of divisions forms plumule and a single cotyledon. Cotyledon called scutellum, grows rapidly and pushes the terminal plumule to one side. The plumule comes to lie in a depression.

The middle cell, after many divisions, forms hypocotyl and radicle. It also adds a few cells to the suspensor. In some cereals both plumule and radicle get covered by sheaths developed from scutellum called coleoptile and coleorhiza respectively.



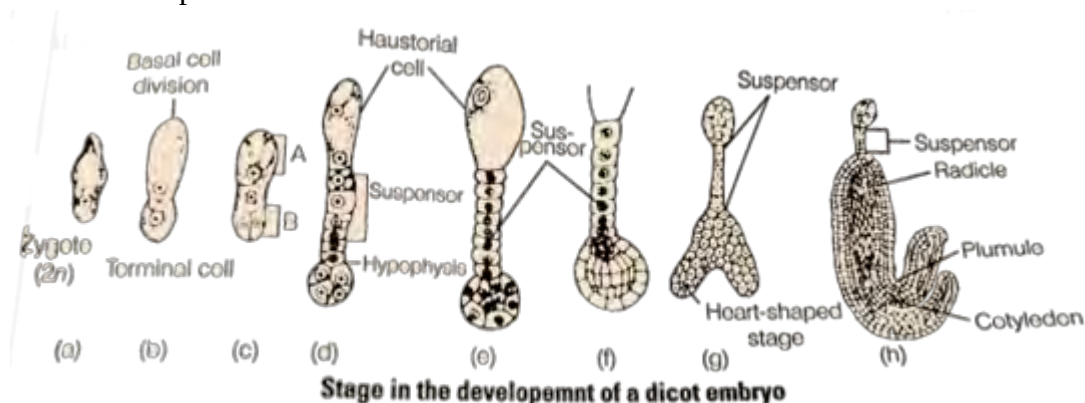
2. Development of embryo in dicotyledonous plants

The zygote divides to form two cells. They are basal which develops into suspensor and terminal cell which give rise to embryo.

The basal cell divides transversely and forms 6- 10 cell. The first cell near terminal cell forms hypophysis (give rise to apex of radicle and root cap) and lowermost cell enlarges to form haustorium.

The terminal cell undergoes vertical and transverse division to produce 8 cell embryo. The lower tier of four cells forms hypocotyl and radicle while upper tier forms plumule and cotyledon.

It divides vertically as well as transversally to globular embryo, later it a heart shaped and finally develops into a dicot embryo as shown in the diagram. It consists two cotyledon, near the cotyledon plumule and near suspensor radicle is formed.



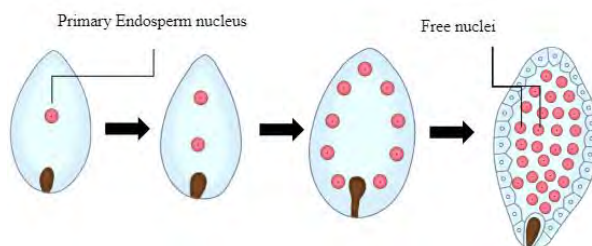
4.2.6 DEVELOPMENT OF ENDOSPERM

Fusion of male gamete and secondary nucleus forms endosperm in angiosperm. Male gamete is haploid and secondary nucleus is diploid resulting in formation of triploid primary endosperm nucleus (PEN). Endosperm is rich in reserved food materials that are used for the nutrition of developing embryos. After endosperm development, embryo development takes place.

Endosperm is formed by three methods:

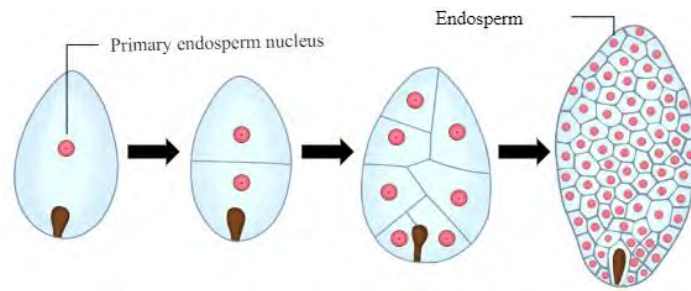
1. Nuclear type

In this process PEN divides mitotically without wall formation to produce large number of nuclei. A big central vacuole appears in center pushing nuclei to periphery. Later wall develops and multicellular endosperm is formed. Examples include coconut. In coconut the outer part of the endosperm, consists of a fleshy tissue called coconut meat and the central part which is present in the center form a milky water called coconut milk.



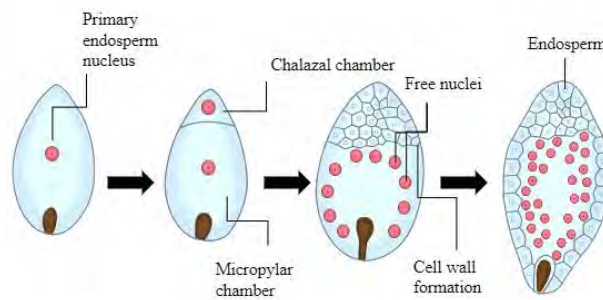
2. Cellular type

In this process of cellular endosperm formation, cell wall formation occurs during each nuclear division. It leads to the formation of the cellular endosperm and is commonly seen in Petunia, Balsam, and Datura.



3. Helobial type

The process of helobial endosperm formation is an intermediate type between cellular and nuclear type endosperm formation. Here the first division of the primary endosperm nucleus is followed by the cell wall formation. This will result in the formation of two cells called chalazal and micropylar cells. In this type, the chalazal cell mostly does not divide and act as a base cell, whereas the micropylar cell divides further similarly to the nuclear endosperm. The free nuclear stage is then followed by the cell wall formation. This type of endosperm is normally found in the monocotyledons. Examples include *Eremurus*.



EXERCISE

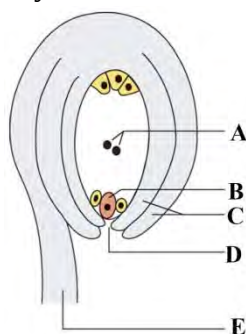
A. Tick the correct alternatives:

1. Which of the following is the female reproductive part of a flower?
 - a. Calyx
 - b. Corolla
 - c. Androecium
 - d. Gynoecium
2. Which layer of the anther provides nutrition to the developing pollen grains?
 - a. Epidermis
 - b. Endothecium
 - c. Tapetum
 - d. Middle layer
3. How many microsporangia are typically found in a bilobed anther?
 - a. Two
 - b. Three
 - c. Four
 - d. One
4. How many male gametes are carried by the pollen tube?
 - a. One
 - b. Two
 - c. Three
 - d. Four
5. Which of the following develops into the embryo in a flowering plant?
 - a. Endosperm
 - b. Zygote
 - c. Polar nuclei
 - d. Ovary wall
6. If the micropyle of an ovule is blocked, which process will be directly affected?
 - a. Pollination
 - b. Pollen tube entry
 - c. Formation of antipodals
 - d. Differentiation of megaspore mother cell
7. A plant breeder wants to maintain a pure line of a particular plant variety. Which pollination strategy would be most effective for this purpose?
 - a. Anemophily
 - b. Cross pollination
 - c. Autogamy
 - d. Entomophily

8. Which of the following correctly represents the nuclear condition after fertilization events in angiosperms?
- Zygote-haploid; Endosperm-diploid
 - Zygote-diploid; Endosperm-triploid
 - Zygote-triploid; Endosperm-diploid
 - Both Zygote and Endosperm- triploid

B. Answer the following questions:

- What is microsprogogenesis? Where does it occur?
- Describe the structure of a mature female gametophyte (embryo sac).
- Why cross-pollinated plants are better adapted for evolution?
- What type of pollination is practiced by flowers pollinated by bats? Mention some floral adaptation supporting it.
- Mention the advantages and disadvantages of self pollination.
- Compare between self pollination and cross pollination.
- Explain the process of fertilization with diagram.
- Write short notes about endosperm.
- Explain the microgametogenesis and the formation of male gametophyte.
- Explain the development of the female gametophyte in angiosperms with necessary diagram.
- Observe the given diagram carefully and answer the following questions:



- Name the figure.
 - Label B, C, D and E.
 - Which one of the following triploid after fertilization?
 - Which one of the following form zygote after fertilization?
12. Describe the role of the suspensor in embryo development, highlighting the differences observed between monocot and dicot plants.

Project work

Create a 3D model/diagram showing pollen tube entry into the ovule, syngamy (fusion of male gamete + egg) → Zygote and triple fusion (second male gamete + polar nuclei) → Endosperm. Use clay, paper, or digital tools or other materials for representation.

Unit 5

BIOTECHNOLOGY



**Herbert
Boyer**



Stanley

Herbert Boyer and Stanley Cohen are pioneers of modern biotechnology for developing recombinant DNA technology in 1973. They used enzymes and plasmids to transfer genes between organisms, laying the foundation for genetic engineering. Their work led to major advances in medicine and industry, including the founding of Genentech, the first biotech company.

Chapter 5.1

BIOTECHNOLOGY

Discuss the following questions:

- VII. Can science be used to change the DNA of a living organism? Why or why not?
- VIII. Is it possible to make a copy of an animal, like a sheep or a dog? What would that mean?

5.1.1 BIOTECHNOLOGY

Introduction to Biotechnology

Biotechnology has history back thousands of years with practices like selective breeding of crops and livestock, and the fermentation of food and beverages (e.g., bread, cheese, beer) using microorganisms.

- Ancient Times: Early applications of microbial processes (fermentation) for food preservation and production.
- 19th Century: Louis Pasteur's work on fermentation and pasteurization set the groundwork for understanding microbial processes. Gregor Mendel's discoveries in genetics provided insights into heredity.
- Early 20th Century: Industrial-scale production of antibiotics (like penicillin) and other biochemicals using microorganisms.
- Mid-20th Century: Discovery of the structure of DNA by Watson and Crick (1953) revolutionized biology. Development of recombinant DNA technology (gene cloning) in the 1970s marked the birth of modern biotechnology, allowing for the manipulation of genetic material.
- Late 20th/Early 21st Century: Emergence of genomics, protein analysis, gene editing (CRISPR), and advanced biomanufacturing, leading to significant advancements in medicine, agriculture, and industry.

Biotechnology is the application of biological organisms, systems, or processes to create or modify products or processes for a specific use. It integrates principles from biology, chemistry, engineering, and computer science to develop technologies that address challenges in various sectors, including healthcare, agriculture, industry, and environmental management.

Areas of Biotechnology

Biotechnology is a vast field often categorized by color codes:

Red Biotechnology (Medical Biotechnology): Focuses on medical and pharmaceutical applications, including:

- a. Development of new drugs and vaccines.
- b. Gene therapy and personalized medicine.
- c. Diagnostic tools and regenerative medicine.

Green Biotechnology (Agricultural Biotechnology): Applied to agricultural processes, such as:

- a. Development of genetically modified (GM) crops for enhanced yield, pest resistance, or nutritional value.
- b. Biofertilizers and biopesticides.
- c. Animal breeding and health.

White Biotechnology (Industrial Biotechnology): Utilizes biological processes for industrial production, including:

- a. Production of biofuels, bioplastics, and enzymes.
- b. Development of sustainable manufacturing processes.
- c. Bioremediation of industrial waste.

Blue Biotechnology (Aquatic Biotechnology): Exploits marine and aquatic organisms for various applications, such as:

- a. Discovery of new drugs from marine sources.
- b. Development of aquaculture practices.
- c. Production of bioenergy from algae.

Gold Biotechnology (Bioinformatics and Nanobiotechnology): Involves the use of computational tools for biological data analysis (bioinformatics) and the application of nanotechnology in biological systems (nanobiotechnology).

Social and Ethical Issues in Biotechnology

The rapid advancements in biotechnology raise significant social and ethical considerations. Genetic Engineering and Gene Editing may raise concerns about altering human germline cells for non-medical enhancements, leading to potential social inequalities. This may create fear of unpredicted effects on the environment or human health from genetically modified organisms (GMOs).

Regarding Privacy and Data Security, biotechnology raises concerns about Genetic discrimination, is when someone is treated unfairly in things like jobs or insurance because of what their genes might show about their future health, even if they're healthy now. Furthermore, it highlights the importance of Confidentiality of Genetic Information, ensuring the secure handling and ethical use of personal genetic data."

Another big issue is Access and Equity: because these new treatments and products are often very expensive, not everyone can afford them, which makes health differences between people worse. There's also a Global Divide, meaning wealthier countries get to use these benefits more than developing ones.

Then there's Animal Welfare. When we use cloning or change animals genetically for research or to make medicines, it brings up ethical questions about how these animals are treated.

Intellectual Property is another tricky area. People debate whether companies should be able to patent genes or living things, as this can control who gets to use them for research or treatment.

5.1.2 PLANT TISSUE CULTURE

Living organisms have special abilities to regenerate and repair themselves. In plants, this ability is particularly strong, developing from a unique property called **totipotency**. Plant Tissue Culture (PTC) is a powerful biotechnology technique that utilizes this natural ability.

Plant Tissue Culture (PTC) is a collection of techniques used to grow plant cells, tissues, organs, or even a whole plant in an artificial, sterile (germ-free) environment. This is done on a specially prepared food mixture called a **nutrient medium**, under controlled laboratory conditions. The key principle behind PTC is **totipotency**, which means that most living plant cells have the genetic potential to develop into a complete, new plant if given the right conditions.

The concept of plant tissue culture dates back to the early 20th century. In 1902, Gottlieb Haberlandt, often called the "father of plant tissue culture," first came up with the idea of growing single plant cells on their own. Even though he couldn't grow a whole plant, his ideas were crucial for future developments. Later, in the mid-20th century, big breakthroughs happened when scientists discovered important plant growth chemicals like auxins and cytokinins, and also created special food mixtures called nutrient media (like MS medium). These discoveries finally made it possible to grow entire plants from just a few cultured tissues, marking the start of modern plant tissue culture.

Basic Principles and Requirements of Plant Tissue Culture

For successful plant tissue culture, several basic conditions and materials are essential:

Basic Principles:

- 1) **Totipotency:** The fundamental principle that any living plant cell, given appropriate conditions, has the potential to regenerate into a whole plant.
- 2) **Aseptic (Sterile) Conditions:** All procedures must be carried out in a sterile environment to prevent contamination by bacteria, fungi, or other microorganisms. Microbes grow much faster than plant cells and would quickly destroy the culture.
- 3) **Defined Nutrient Medium:** A carefully prepared mixture of essential nutrients is required. This medium provides all the food and growth signals the plant cells need.
- 4) **Controlled Environment:** Factors like temperature, light (intensity and duration), and humidity must be precisely controlled in a growth chamber.

Key Requirements:

- 1) **Explant:** The small piece of plant part (like a leaf, stem tip, root, or even a single cell) taken from the mother plant to start the culture. The quality and type of explant are crucial.
- 2) **Nutrient Medium:** Contains:
 - a) **Macronutrients and Micronutrients:** Essential mineral salts for plant growth (e.g., nitrogen, phosphorus, potassium, calcium, magnesium, iron).
 - b) **Carbon Source:** Usually sucrose (sugar), as the cultured cells cannot perform full photosynthesis initially.
 - c) **Vitamins:** Organic compounds necessary for cell metabolism.
 - d) **Plant Growth Regulators (Hormones):** Mainly **auxins** (for root development and cell division) and **cytokinins** (for shoot development and cell division). The ratio of these

hormones determines how the plant grows (e.g., more auxin for roots, more cytokinin for shoots, balanced for callus).

e) **Gelling Agent (for solid media):** Like agar, to make the medium solid.

3) **Aseptic Environment:**

Laminar Air Flow Cabinet: A workstation with filtered air to prevent contamination.

Sterilization Equipment: Autoclave (for heat sterilization of media and glassware), alcohol, or bleaching agents (for surface sterilization of explants).

4) **Culture Vessels:** Test tubes, jars, or petri dishes, usually made of glass or plastic that can be sealed.

5) **Growth Chamber:** A room or cabinet where temperature, light, and humidity are precisely controlled.

Steps in Plant Tissue Culture (Micropropagation)

The most common application of PTC is **micropropagation**, which is the rapid multiplication of plants under sterile conditions. The general steps involve:

1. **Explant Selection and Sterilization:** A healthy, young explant is chosen from the parent plant and thoroughly surface sterilized to remove microbes without harming the plant tissue.
2. **Initiation of Culture:** The sterilized explant is placed on a suitable nutrient medium in a sterile culture vessel. This stage aims to establish a clean and growing culture.
3. **Callus Formation and Multiplication (Optional but common):** The explant often grows into an unorganized mass of cells called a **callus**. This callus can be divided and multiplied to produce many more cells. By adjusting the hormone balance in the medium, these callus cells can be encouraged to form shoots.
4. **Shoot Development (Multiplication):** The callus or initial explant is encouraged to produce multiple shoots by adjusting the plant growth regulators (often higher cytokinin to auxin ratio). These shoots are then subcultured (transferred to fresh medium) to multiply further.
5. **Rooting:** Once enough shoots are produced, they are transferred to a different medium (often with a higher auxin to cytokinin ratio) to encourage root development, forming small plantlets.
6. **Acclimatization/Hardening:** The plantlets developed in the lab are delicate. They are gradually moved from the high-humidity, sterile lab conditions to a more natural environment (like a greenhouse) to help them adapt before being planted in soil. This process is called hardening or acclimatization.

Process of Plant Tissue Culture

EXPLANT SELECTION & STERILIZATION

Healthy young tissue → Surface sterilized (e.g., bleach/alcohol)



INITIATION OF CULTURE

Sterilized explant → Placed on nutrient medium (agar + hormones)



CALLUS FORMATION (Optional)

Explant → Forms callus (undifferentiated cells) → Multiplied via subculturing



SHOOT DEVELOPMENT

Callus/explant → Transferred to cytokinin-rich medium → Multiple shoots grow



ROOTING

Shoots → Moved to auxin-rich medium → Roots develop (plantlets form)



ACCLIMATIZATION

Lab-grown plantlets → Gradual exposure to natural conditions (greenhouse → soil)

Types and Applications of Plant Tissue Culture

Plant tissue culture has diverse applications across agriculture, horticulture, and industry:

Types of Tissue Culture Techniques:

- 1) **Micropropagation:** Large-scale, rapid production of genetically identical plants (clones).
- 2) **Callus Culture:** Growth of an unorganized mass of cells (callus) for various studies or as an intermediate step for organ or plant regeneration.
- 3) **Suspension Culture:** Growth of isolated plant cells or small cell aggregates in a liquid nutrient medium, often used for producing valuable secondary metabolites.
- 4) **Meristem Culture:** Culturing the shoot tip (meristem) to produce disease-free plants, especially useful for virus-infected plants, as meristematic tissue is often virus-free.
- 5) **Anther/Pollen Culture:** Culturing anthers or pollen grains to produce haploid plants (plants with half the usual number of chromosomes). These are useful in plant breeding to quickly develop pure lines.
- 6) **Embryo Culture:** Culturing young embryos, often used to rescue embryos from wide crosses that would otherwise fail to develop, or to overcome seed dormancy.
- 7) **Protoplast Culture:** Culturing isolated plant cells without a cell wall (protoplasts). These can be used for somatic hybridization (fusing protoplasts from different species to create new hybrid plants).

Applications:

1. **Fast Plant Duplication (Micropropagation):** We can make thousands or even millions of exact copies of a single plant very quickly, any time of the year. This is great for valuable plants like orchids, bamboo, potatoes, and bananas.
2. **Making Disease-Free Plants:** It helps produce plants that are free from diseases, especially viruses. This is crucial for crops like potato, sugarcane, and banana, which often get viruses when grown traditionally.
3. **Saving Plant Varieties (Germplasm Conservation):** We can store important or endangered plant types for a very long time, sometimes by freezing their tissues.
4. **Producing Useful Chemicals:** Plant cells grown in labs can be used to make valuable chemicals for medicines, flavors, or perfumes (like shikonin or taxol).

5. **Creating New Plant Variations (Somaclonal Variation):** Sometimes, growing plants in tissue culture causes small genetic changes. These changes can accidentally lead to new, better types of plants.
6. **Improving Plants & Genetic Engineering:** Plant tissue culture is a key step to introduce new genes into plants (making "transgenic plants"). This helps create crops with better features, like being resistant to pests or needing less water.
7. **Growing Plants All Year:** It allows us to produce plant material continuously, no matter the weather or season.

5.1.3 PLANT BREEDING

Plant breeding is the field in which science, art and technology are combined to improve plants for human benefits. From ancient times, when early farmers saved seeds from their best-performing plants, to today's high-tech laboratories utilizing genetic engineering, plant breeding has played a pivotal role in feeding the world and addressing agricultural challenges.

The genetic improvement of economically important plant on a scientific basis is called plant breeding.

Objectives of plant plants breeding

1. Develops superior crop varieties for cultivation.
2. Enhances the quality of fruits and seeds in plants.
3. Breeds disease-resistant varieties (e.g., rust-immune wheat, blight-immune potatoes).
4. Produces varieties adapted to specific climates and soils.
5. Modifies crop maturity periods.
6. Improves plant lodging resistance.

Methods of plant breeding

Plant breeding methods can broadly be categorized into conventional (traditional) and modern approaches.

1. Conventional Plant Breeding Methods:

These methods have been used for centuries and rely on selection and hybridization.

a. Selection:

Mass Selection: The simplest method. A large number of phenotypically similar plants with desired traits are selected from a mixed population, and their seeds are bulked to grow the next generation. (e.g., early farmers saving seeds from the best plants).

Pureline Selection: Used in self-pollinated crops. A single, superior plant is selected, and its progeny (which are genetically identical to the parent due to self-pollination) are multiplied to form a new variety.

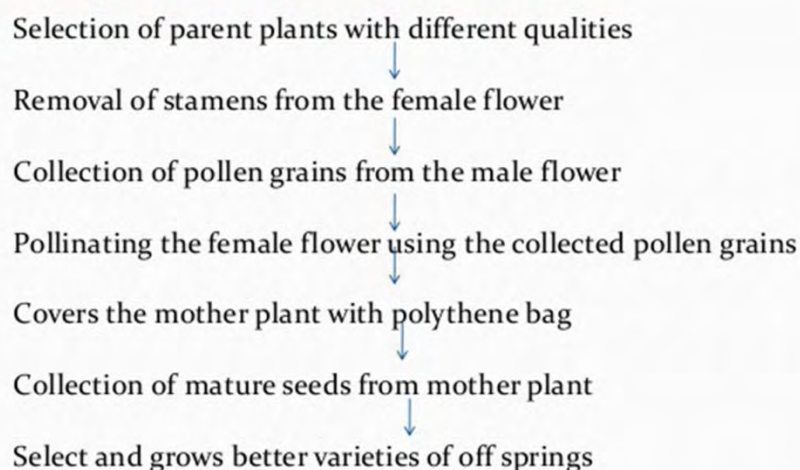
Clonal selection: is a plant breeding method used for asexually propagated crops, where genetically identical individuals (clones) are derived from a single parent plant.

- b. **Hybridization (Crossbreeding):** The intentional crossing of two genetically different parent plants to combine desirable genes from both into a single offspring is called hybridization.

Following are the types of hybridization;

1. **Intra-specific hybridization:** It is useful for the improvement of self-pollinated crops. With this method, several new varieties of crops can be evolved.
2. **Inter-specific hybridization:** In this method, the cross is made between the two different species of same genera for develop a new species
3. **Intergeneric hybridization:** In this method the crop is made between two different genera of same family. For e.g. a new species of wheat *Triticum aestivum* is produced by crossing between a species of wheat *Triticum monococcum* with wild grass *Aegilops* species.

Steps of hybridization



Modern Plant Breeding Techniques:

These techniques often complement or accelerate conventional breeding.

1. **Mutation Breeding:**
It includes genetic mutations (changes in DNA) using physical agents (e.g., radiation) or chemical mutagens to create new variability. Desirable mutants are then selected.
2. **Polyploidy Breeding:**
Creating or exploiting plants with more than two sets of chromosomes. Can lead to larger fruits, improved vigor, or sterility (e.g., seedless watermelons).
3. **Tissue Culture Techniques (Microprapagation):**
Micropropagation allows for the rapid production of numerous genetically identical plantlets from a tiny tissue sample. Embryo rescue is used to save hybrid offspring from wide genetic crosses that would typically fail, by culturing their immature embryos.
4. **Genetic Engineering (GMOs):**
This process can directly modifying a plant's DNA by inserting genes from other organisms (or the same organism) to introduce specific new traits (e.g., herbicide resistance, insect resistance like Bt cotton/corn).

5.1.4 DISEASE RESISTANCE PLANTS

Disease resistant plants are those plants that have the natural or engineered ability to prevent or reduce the impact of infections caused by pathogens such as bacteria, viruses, fungi or parasites. These plants possess certain genetic traits that enable them to recognize and defend against specific diseases, often through structural barriers, chemical responses or immune like mechanisms. The development of disease resistant varieties is a major focus in agriculture and biotechnology, as it helps increase crop yield, reduce the need for chemical pesticides and ensure food security. The following are some major disease resistant crop varieties grown in Nepal:

1. Rice: CO-20, IR-8, IR-20, IR-22, Basmati-370, Mansuli, etc.
2. Maize: Rampur Yellow, Kakani Yellow, Khumal Yellow, etc.
3. Wheat: Kalyan-227, NP-120, PO-18, UP 262, S-227 etc.
4. Potato: Kufri red, Kufri Jyoti, Kufri Shakti, Kufri sindoori etc.

5.1.5 GREEN MANURE AND BIOFERTILIZERS

Plants need several kinds of nutrients for their growth and development. They get these nutrition from soil. Due to continuous cultivation the nutrition content in the soil decreases so it is necessary to supply the nutrition to the soil artificially. For this people use **chemical fertilizers**. Chemical fertilizers are the substance synthesize artificially and are used to enhance the nutrition quality of soil. However, chemical fertilizers have several harmful effects like:

1. They alter the chemical composition of soil.
2. Harm the soil microorganisms.
3. Decreases the **water holding capacity** of the soil.
4. Causes environmental **pollution**.
5. They are **expensive**.

To avoid the above problem and meet the nutrient requirements of the soil, **organic fertilizers** are used.

ORGANIC FERTILIZER

Organic fertilizers are the substances either living beings or decaying matter of the living beings that can add the essential nutrients to the soil.

- They are categorized into two groups:
 1. Manure
 2. Bio fertilizers

1. Manure

The decaying organic matter added to the soil to increase its nutritional quality is termed as **manure**.

The manures are of following types:

1. Compost manure

2. Farm-yard manure
3. Green manure
4. Vermicompost

1. **Compost manure:**

Organic matters obtained from the decaying of plant materials like vegetables, fodder, agricultural residues, paper etc. in specially designed pits is termed as compost manure.

2. **Farm-yard manure:**

It is the most commonly used manure. It is obtained from cattle dung, residue of fodder, straw etc. which are allowed to decay with the help of soil microorganisms.

3. **Green manure:** If the green plants are directly used as the manure in the field it is called green manure. Mainly leguminous crops are used as green manure. Most common crops used as green manure in Nepal are: Dhaincha (*Sesbania rostrata*), Khesari (*Lathyrus sativus*), soyabean (*Glycine max*) etc.

4. **Vermicompost:**

It is eco-friendly compost produced from municipal garbage, agriculture residue, food processing wastes, kitchen wastes etc. by growing of earthworm. Earthworms are very well known as “Nature’s ploughman” or “Farmer’s friends” which promote soil aeration, crush and mix the soil particles, converts complex nutrients into simpler forms and promote the activities of beneficial bacteria in the soil.

Importance of green manure in agriculture

Following are some importance of green manure in agriculture:

1. They are **cheap** and **easily available**.
2. They **supply essential nutrients** to the soil.
3. They improve **aeration** of the soil.
4. They **increase the crop yield** from 30% - 50%.
5. They **reduce the alkalinity** of soil.
6. They **increase the soil microbial activity**.
7. They are **environmental friendly**.

2. Biofertilizer

Biofertilizers are the biological agents that can add the nutrients of the plants to the soil. The main source of biofertilizers are **bacteria, fungi, cyanobacteria** etc.

1. **Bacteria as biofertilizer:**

Several **symbiotic** and **non-symbiotic** bacteria add nitrogen in the soil and increase the fertility of soil. Some of them are discussed below:

- a. ***Rhizobium*:** *Rhizobium* occurs symbiotically that fix atmospheric nitrogen and makes it available to plants. *Rhizobium* culture are now raised in laboratory for artificial inoculation

in leguminous plants to promote nodulation and crop yield. The soil on which leguminous plants are cultivated is rich in nitrogen.

- b. ***Azotobacter*** and ***Bacillus polymyxa***: They are free living and fix atmospheric nitrogen and make available to crops.
- c. ***Azospirillum***: They are non-symbiotic bacteria, can fix nitrogen independently in soil. They are suited for crops like maize, sugarcane, wheat etc.
- d. The main source of biofertilizers are bacteria, fungi, cyanobacteria etc.

2. Cyanobacteria (Blue green algae) as biofertilizer:

Cyanobacteria are photosynthetic, prokaryotic organism which fix nitrogen asymbiotically. They are active nitrogen fixers. In general, heterocysts containing cyanobacteria are responsible for increasing fertility of soil by nitrogen fixation. Examples: *Anabaena*, *Nostoc*, *Calothrix* etc.

3. Fungi as biofertilizer:

Some fungi show the symbiotic association with the roots of higher groups of plants called as **mycorrhiza**. The mycorrhiza may be located at the root surface (**ectomycorrhiza**) or it may be present inside the root (**endomycorrhiza**). These fungi help in absorption of minerals and water, covert non available phosphorous into available form, produce growth promoting substances and also protect against soil pathogens.

ADVANTAGES OF BIO-FERTILIZERS

Following are the advantages of biofertilizers:

1. They are **cheap**.
2. They increase the **productivity** of crops.
3. They provide all **essential nutrients** to the soil.
4. They improve **soil aeration** and **water holding capacity** of soil.
5. They are **sustainable** i.e. they are used once, they replicate themselves and remain active in the following years.
6. Some biofertilizers excrete **antibiotics** which act as pesticides.
7. They are **environmental friendly**.

DISADVANTAGES OF BIO-FERTILIZERS

Although biofertilizers have several advantages, it has some limitation:

1. They do not show quick response.
2. The amount of nutrients provided by them are not sufficient for high yielding of crops.
3. They need more technical knowledge as compared to other form of fertilizers.

5.1.6 GENETIC ENGINEERING

Traits or characters of organisms are the expressions of genes they bear in chromosomes. When genes are altered, it results modification in the characters in the organism. The technique of altering the genetic makeup of organism, by introducing any foreign gene or removing existing gene, is called genetic engineering.

Genetic engineering is also known as gene therapy, recombinant DNA technology, gene manipulation etc.

It is the latest and advanced technique in biological sciences that has brought revolution in the field of medicine, agriculture, horticulture, animal husbandry, forensic science as well as microbiology.

Genetic engineering is a new type of genetic modification. It is the purposeful addition of a foreign gene or genes to the genome of an organism. A gene holds information that will give the organism a trait. Genetic engineering is not bound by the limitations of traditional plant breeding. Genetic engineering physically removes the DNA from one organism and transfers the gene(s) for one or a few traits into another. Since crossing is not necessary, the 'sexual' barrier between species is overcome. Therefore, traits from any living organism (donor species) can be transferred into a plant (target species). This method is also more specific in that a single trait can be added to a plant.

General method of genetic engineering or recombinant DNA technology

The process of genetic engineering requires the successful completion of a series of five steps.

Step 1: DNA Extraction

DNA extraction is the first step in the genetic engineering process. In order to work with DNA, scientists must extract it from the desired organism. A sample of an organism containing the gene of interest is taken through a series of steps to remove the DNA. An enzyme, restriction endonuclease is employed to cut the desired gene precisely from the chromosome of donor organism.

Step 2 : Gene Cloning

The second step of this process is gene cloning. During DNA extraction, all of the DNA from the organism is extracted at once. Scientists use gene cloning to separate the single gene of interest from the rest of the genes extracted and make thousands of copies of it.

Step 3 : Gene Design

Once a gene has been cloned, genetic engineers begin the third step, designing the gene to work once inside a different organism. This is done in a test tube by cutting the gene apart with enzymes and replacing gene regions that have been separated.

Step 4 : Transformation

The modified gene is now ready for the fourth step in the process, transformation or gene insertion.

Since plants have millions of cells, it would be impossible to insert a copy of the transgene into every cell. Therefore, tissue culture is used to propagate masses of undifferentiated plant cells called callus. These are the cells to which the new transgene will be added.

The new gene is inserted into some of the cells using various techniques. Some of the more common methods include the gene gun, agrobacterium, microfibers, and electroporation. The main goal of each of these methods is to transport the new gene(s) and deliver them into the nucleus of a cell without killing it. Transformed plant cells are then regenerated into transgenic plants. The transgenic plants are grown to maturity in greenhouses and the seed they produce, which has inherited the transgene, is collected. The genetic engineer's job is now complete. He/she will hand the transgenic seeds over to a plant breeder who is responsible for the final step.

Applications of Genetic Engineering

Medicine, research, industry and agriculture are a few sectors where genetic engineering applies. It can be used on various plants, animals and microorganisms. The first microorganism to be genetically modified is bacteria.

1: In Medicine: Genetic engineering can be applied to:

Manufacturing of drugs

Creation of model animals that mimic human conditions and,

Gene therapy

Human growth hormones

Follicle-stimulating hormones

Human albumin

Monoclonal antibodies

Antihemophilic factors

2;Vaccines

In Research: Genes and other genetic information from a wide range of organisms can be inserted into bacteria for storage and modification, creating genetically modified bacteria in the process.

3: In Industry:

Transformation of cells in organisms with a gene coding to get a useful protein.

Medicines like insulin, human growth hormone, and vaccines, supplements such as tryptophan, aid in the production of food (chymosin in cheese making) and fuels are produced using such techniques.

4: In Agriculture:

Genetically modified crops are produced using genetic engineering in agriculture.

Such crops are produced that provide protection from insect pests.

It is used or can be used in the creation of fungal and virus-resistant crops.

5:Genetic engineering can be applied to other areas:

- Conservation
- Natural area management
- Microbial art

Benefits of Genetic Engineering:

- The production of genetically modified crops is a boon to agriculture.
- The crops that are drought-resistant, disease-resistant can be grown with it.
- As described earlier, genetic disorders can be treated. The diseases such as malaria, dengue can be eliminated by sterilising the mosquitoes using genetic engineering.
- Therapeutic cloning

Challenges of Genetic Engineering

- The production of genetically-engineered entities may result in an adverse manner and produce undesired results which are unforeseen.

- With the introduction of a genetically-engineered entity into one ecosystem for a desirable result, may lead to distortion of the existing biodiversity.
- Genetically-engineered crops can also produce adverse health effects.
- The concept of genetic-engineering is debated for its bioethics where community against it argue over the right of distorting or moulding the nature as per our needs.

5.1.7 GENETICALLY MODIFIED ORGANISMS (GMOS)

Organisms whose genes have been altered by genetic engineering are said to be genetically modified organisms (GMOs). They are also called transgenic organisms.

GMOs are of following three types.

- a) Transgenic plants: eg. Golden rice, Transgenic tomato etc.
- b) Transgenic animals: eg. Transgenic cow, goat, chicken, pig etc.
- c) Transgenic microbes: eg. *E.coli*, yeast, *Rhizobium meliloti* etc.

Advantages:

- Introduction of 'nif gene' in non leguminous plants enhances the productivity through nitrogen fixation.
- Cows, buffaloes, pigs, goats, poultry etc. improves quantity as well as quality of their products.
- It increases the nutritional values, resistivity against pests in crops.
- Transgenic animals are used as model organisms for pilot survey in effectiveness of human vaccines.

Disadvantages:

- Pollens of transgenic plants can cross pollinate with natural crops or their wild relatives. Hence, they are vulnerable to genetic contamination and loss of diversity of pure lines.
- GMOs may cause unexpected allergies in humans.
- Transplanting organ from animal to humans may create social, religious as well as ethical issues.
- Use of genetically modified seeds may face a great threat i.e, widespread crop failure due to pest attack.

5.1.8 BIOPESTICIDES

Bio-pesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered bio-pesticides.

Types:

Biopesticides fall into three major classes:

1: Biochemical pesticides :

These are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest.

Biochemical pesticides include substances that interfere with mating, such as insect sex pheromones, as well as various scented plant extracts that attract insect pests to traps.

2:Microbial pesticides:

They consist of a microorganism (e.g., a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests.

The most widely used microbial pesticides are subspecies and strains of *Bacillus thuringiensis* (Bt.). Each strain of this bacterium produces a different mix of proteins and specifically kills one or a few related species of insect larvae such as moth, flies and mosquitoes.

3:Plant-Incorporated-Protectants (PIPs):

These are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the Bt pesticidal protein and introduce the gene into the plant's own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest.

Advantages:

- Biopesticides are usually inherently less toxic than conventional pesticides.
- Biopesticides generally affect only the target pest and closely related organisms, in contrast to broad spectrum, conventional pesticides that may affect organisms as different as birds, insects and mammals.
- Biopesticides often are effective in very small quantities and often decompose quickly, resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.
- When used as a component of Integrated Pest Management (IPM) programs, biopesticides can greatly reduce the use of conventional pesticides, while crop yields remain high.

Disadvantages:

- **Slower Action:** Biopesticides often take longer to kill pests compared to synthetic pesticides, which can be a concern if the pest infestation is severe.
- **Lower Efficacy and Shorter Persistence:** They may not be as effective in controlling pests or last as long as conventional pesticides, potentially requiring more frequent applications.
- **Susceptibility to Environmental Conditions:** Biopesticides are more vulnerable to factors like temperature, humidity, and sunlight, which can affect their effectiveness.
- **Increased Knowledge Requirements and Cost:** Successful use of biopesticides requires more expertise than conventional pesticides, including understanding how to apply them effectively and how to mitigate environmental factors. Likewise, biopesticide production can be more expensive than that of conventional pesticides, due to the need for specialized facilities and processes.
- **Limited Availability:** The commercial availability of certain biopesticides may be limited, making it harder for farmers to access and use them.

- **Host-Specificity:** Some biopesticides are highly specific to certain pests, which can be beneficial in some cases but may not be suitable if a wide range of pests need to be controlled.
- **Potential for Resistance Development:** While resistance to biopesticides is less common than to synthetic pesticides, it can still occur in some cases.
- **Regulatory Hurdles:** The regulatory processes for biopesticides can be complex and may differ significantly from those for conventional pesticides, which can hinder their development and commercialization.

5.1.9 BIOENGINEERING

Bioengineering is a multidisciplinary field that applies engineering principles to biological systems and processes to address challenges in areas like medicine, healthcare, and agriculture. It involves combining biology, engineering, and other sciences to develop new technologies, materials, and processes that can improve human health and well-being.

Key aspects of bioengineering include:

- **Applying engineering principles to biological systems:** This involves using mathematical modeling, computer simulations, and other engineering tools to understand and manipulate biological processes.
- **Developing new technologies:** Bioengineering can lead to the creation of new medical devices, diagnostic tools, and therapeutic interventions.
- **Improving materials:** Bioengineers can create new materials with specific properties, such as biocompatible polymers or advanced scaffolds for tissue engineering.
- **Solving problems in various fields:** Bioengineering has applications in diverse areas, including disease prevention and treatment, agricultural production, and environmental remediation.

Examples of bioengineering applications:

- **Medical devices:** Designing artificial organs, hearing aids, pacemakers, and other devices that can restore or enhance bodily functions.
- **Biomaterials:** Developing new materials for tissue engineering, implants, and drug delivery systems.
- **Bioprocessing:** Optimizing industrial processes for the production of pharmaceuticals, biofuels, and other products using biological systems.
- **Genetically modified organisms (GMOs):** Applying genetic engineering techniques to improve crops, develop new diagnostics, and create new therapies.
- **Environmental remediation:** Developing bioremediation technologies to clean up polluted sites using microorganisms or plants.

Applications :

- **Devices** such as synthetic bone, teeth, pacemaker, hearing aid etc. have been developed that substitute the damaged body parts.

- It has been possible to develop artificial kidneys, heart valves, blood vessels, bones of arm, leg, hip, knee and other joints.
- Transgenic organisms have been developed for chemical and pharmaceutical manufacturing.
- It is used to make surgical devices and systems such as robotic and laser surgery.
- Monitoring the vital signs and blood chemistry has been possible due to bioengineering.
- It is also applied to make imaging devices like ultrasound, X-ray, CT, particle beams and magnetic resonance imaging (MRI).

5.1.10 FOOD SAFETY

Food safety refers to handling, preparing and storing food in a way that prevents foodborne illness that ensure the food remains safe for consumption. It plays a crucial role in protecting public health by preventing diseases caused by harmful bacteria, viruses and parasites such as *Salmonella*, *E. coli*, *Listeria*, etc. These pathogens can cause serious symptoms including diarrhea, fever, vomiting, etc. Understanding and applying food safety practices helps reduce the risk of contamination and illness, and this understanding is deepened by defining two key concepts: toxicity and hazard.

Toxicity refers to a substances ability to cause harm or injury under any conditions, while a hazard is the likelihood that harm will occur if the substance is not used correctly or in the proper amount. Hazards may be physical, chemical, or biological in nature and they can lead to negative health effects for consumers.

5.1.11 FOOD SECURITY

Food security is a fundamental aspect of human well-being, ensuring that every individual has consistent access to sufficient, safe and nutritious food necessary for an active and healthy life. Food security ensures that every person consistently has access to enough safe and nutritious food to lead a healthy and active life. This concept compasses four key components:

5. Availability:

This refers to the presence of sufficient quantities of food through domestic production, imports or food aid. It ensures that food is physically present in markets, stores, or households.

6. Acces:

Beyond mere availability, access pertains to individual ability to obtain appropriate foods for a nutritious diet. This includes having adequate resources to acquire food, considering factors like income, food prices, and distribution systems.

7. Utilization

Utilization involves the proper use of food, emphasizing nutritional value, food safety and preparation methods. It also considers individual's health status, ensuring that the body can effectively absorb and metabolize nutrients.

8. Stability:

Stability ensures that the other three components: availability, access and utilization are consistently maintained over time. It addresses the resilience of food systems against shocks like economic crises, natural disasters, or seasonal food shortages.

EXERCISE

A. Tick the correct alternatives:

1. Which plant growth regulator promotes shoot development in tissue culture?
 - a. Auxin
 - b. Cytokinin
 - c. Gibberellin
 - d. Ethylene
2. Which tool is used to maintain a sterile environment during tissue culture?
 - a. Autoclave
 - b. Laminar air flow cabinet
 - c. Ethyl alcohol
 - d. Oven
3. Which bacteria is symbiotic and forms nodules on leguminous plants to fix atmospheric nitrogen?
 - a. *Azotobacter*
 - b. *Rhizobium*
 - c. *Bacillus polymyxa*
 - d. *Azospirillum*
4. What are biofertilizers?
 - a. Artificial chemicals used to kill weeds
 - b. Microorganisms that enrich soil nutrients
 - c. Insects that help pollinate crops
 - d. Machines used for farming
5. Biopesticides are mostly derived from..
 - a. Fossil fuels
 - b. Synthetic chemicals
 - c. Natural materials like bacteria, fungi and plants
 - d. Plastic and metal compounds
6. Which of the following is a common food safety practice?
 - a. Eating leftover food after one week
 - b. Washing hands before handling food
 - c. Storing meat at room temperature
 - d. Leaving food uncovered
7. When a country does achieve food security?
 - a. When rich people have enough food.
 - b. When everyone has physical and economic access to sufficient food.

- c. When only crops are grown in large amounts.
 - d. When it imports all its food.
8. A food company adds excessive artificial coloring to snacks without labeling it. Which aspect of food safety is being violated?
- a. Hygiene
 - b. Proper labeling and information
 - c. Packaging
 - d. Nutritional value

B. Answer the following questions:

1. What is totipotency in plants?
2. Name any two genetically modified crops.
3. List any five examples of disease resistant crops grown in Nepal.
4. What does 'GMO' stand for?
5. Show the process of micropropagation using a flowchart.
6. Write short notes on hybridization.

Unit 6

ANIMAL TISSUE



Marie Francois
Xavier Bichat
(1771-1802)

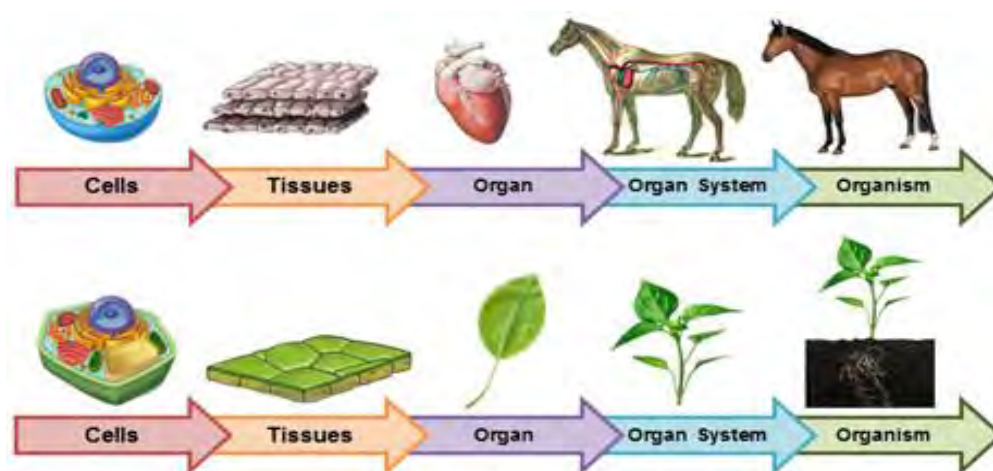
Marie Francois Xavier Bichat (1771-1802 AD) was a French anatomist and pathologist. He coined the term '**tissue**' in terms of animal anatomy. He was the first to propose that tissue is a central element in human anatomy, and he considered organs as collections of often disparate tissues, rather than as entities in themselves for which he is considered '**founder of animal histology**'. Although he worked without microscope, he distinguished twenty-one types of elementary tissues from which organs of the human body are made up of. For this contribution, he is recognized as '**father of histology**'.

Chapter 6.1

ANIMAL TISSUE

Have a look at the figure given below and discuss following questions with your classmates.

1. How is tissue different from cell, organ, and organ-system in an organism?
2. Does tissue, in animal and plants act as building block and form organs?



From cells through tissues, organs, organ-systems to organism

Group of **cells** form **tissues**, group of tissues make up **organs**, group of organs form **organ-systems**, and group of organ systems form **organisms** or **species of organisms**.

Tissue of animal and plant acts as **building block** and form organs.

Do you know?

Karl Mayer (1801): coined the term histology.

Marcello Malpighi (1628-1694): is founder of histology.

Animal tissue is a **group of cells** having common **origin** but, its **structure**, **location**, and **function** may be similar or dissimilar. Cells of the animal tissue may or may not secrete **matrix**. If cells of the animal tissue secrete matrix, the matrix may have **ground substance** and **fibres** in connective tissue and **ground substance** only in rest of the types. Hence, connective tissue has three histo-components: **cells**, **matrix**, and **fibres**, while epithelial, muscular, nervous tissue have two: **cells** and **matrix**.

Activity

Enlist phylum-wise **grade of organization** of **major phyla** of **Metazoa** by arranging **cells, tissues, organs, or organ-system** in respective phylum.

Types of animal tissue

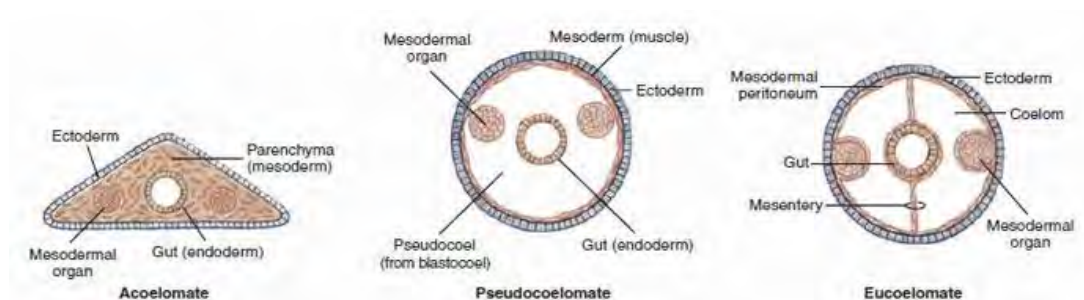
Animal tissues, on the basis of **origin, structure, location, and function**, are four types: epithelial, connective, muscular, and nervous tissue.

Do you know?

Animal tissue was seen for the first time in **Phylum-Coelenterata** hence, this phylum is said to possess **tissue grade of organization**.

6.1 Epithelial tissue

Observe the figures given below and discuss following questions with your class friends.



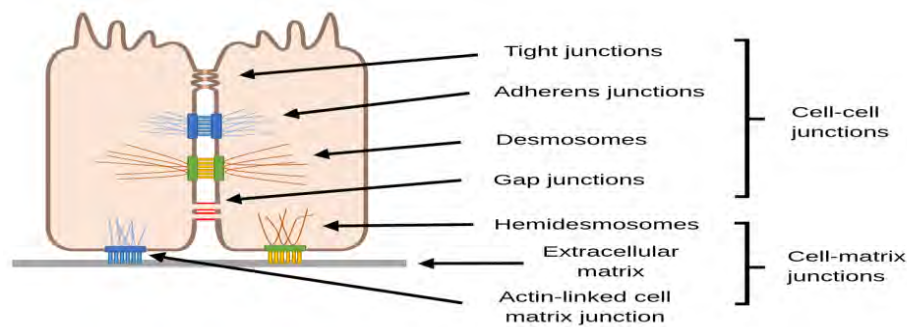
Acoelomate, pseudocoelomate, and coelomate

1. In how many surfaces, do acoelomate, pseudocoelomate, and coelomate cover, line, protect, form, and secrete?
2. What do these surfaces indicate?

In **acoelomate**, e.g., **flatworm**, there are **two surfaces** – one covering and one lining. In **pseudocoelomate**, e.g., **roundworm**, there are **three surfaces** – one covering and two linings. In coelomate, e.g., **earthworm**, there are **four surfaces** – two covering and two linings. The innermost lining of flatworm, roundworm, and earthworm form glands and secrete enzymes, or hormones, or both. The surfaces of flatworm, roundworm, and earthworm protect. All the surfaces indicate epithelial tissue.

Epithelial tissue, also called **epithelium** is **covering, lining, forming, and secreting tissue** because it **covers** body surface, organs, and tissues; **lines** coelomic cavities; **forms** glands and blood vessels; and **secretes** enzymes as well as hormones.

Epithelial tissue has most numerous **cells**. The single cell-layer of simple epithelium and innermost cell-layer of many cell-layered compound epithelium is resting on **basement membrane**. The basement membrane is made up of **collagen** which is **white** in colour. Epithelial tissue is **avascular** because there is no blood vessels or supply. So, receiving of nutrition and gases and expulsion of wastes are done by the process of **diffusion**.



Cell junctions in epithelial cells of epithelial tissue

Epithelial tissue has minimal **matrix** or **extracellular matrix** (ECM) which lacks fibres. Because, epithelial tissue has minimal matrix therefore, it has minimal **ground substance**, **extracellular space** (ECS) or **extracellular fluid** (ECF), **intercellular space** (ICS) or **intercellular fluid** (ICF). Whatsoever may be, all epithelial cells are closely held together by **cell junctions**.

The cell junctions are four types: **tight junction** (e.g., **zonula occludens**), **adherens junction** (e.g., **zonula adherens**), **desmosome** (e.g., **macula adherens**), and **gap junction** (e.g., **septate junction**).

Functions of epithelium are **covering**, **lining**, **forming**, and **secreting**. Besides these, it functions in **protection**, **circulation** or **movement**, **excretion**, **diffusion**, **exchange**, **filtration**, **absorption**, etc.

Do you know?

Out of the four types of animal tissues, epithelial tissue covers **largest surface area** of animals, e.g., skin coverage of man is 1.6-1.8 m².

Epithelial tissue is **originated** from all the **three germ layers**: ectoderm, mesoderm, and endoderm.

Types of epithelial tissue

Epithelial tissues, based on layers of cells, are two types: simple and compound epithelium.

1. Simple epithelium

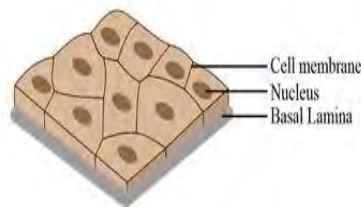
Simple epithelium has single layer of cells resting on basement membrane. The cells are either squamous, cuboidal, and columnar in shape or combination of cuboidal and columnar.

Simple epithelium, on the basis of shape of cells, it possesses, are four types: simple squamous, simple cuboidal, simple columnar, and pseudostratified epithelium.

I. Simple squamous epithelium

Simple squamous epithelium has single layer of squamous cells. The squamous cells are thin, flattened, and polygonal with flattened, and oval-shaped nucleus. Simple squamous epithelium is also called **tessellated**, **pavement** or **mosaic epithelium**.

Simple squamous epithelium is located in **alveoli of lungs** for gaseous exchange, in **Bowman's capsule** for ultrafiltration, in **coelom** for lining the cavities, in **viscera** for covering the organs, in **descending limb of the loop of Henle** for selective reabsorption, and in **capillary** for the formation capillary as well as circulation of blood.



Simple squamous epithelium

Simple squamous epithelium formed by endoderm is **endothelium**, e.g., **capillary**, **endocardium** of heart, and **tunica interna** or internal lining of artery and vein.

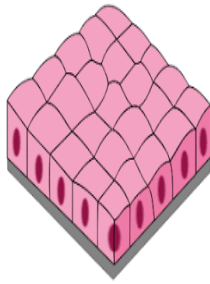
Similarly, simple squamous epithelium formed by mesoderm is **mesothelium**, e.g., **parietal epithelium** of body-wall, **visceral** or **splanchnic epithelium** of gut-wall, **visceral covering**, and **mesenteries**.

II. Simple cuboidal epithelium

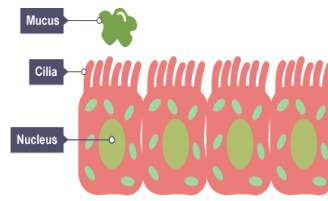
Simple cuboidal epithelium has single layer of cuboidal cells. The cuboidal cells are moderate-sized, polyhedral-shaped having equal height and width, and with large, spherical, and centrally placed nucleus.

Simple cuboidal epithelium may be non-ciliated without cilia on its free border, ciliated with cilia on free border, or brush-bordered with microvilli on free border.

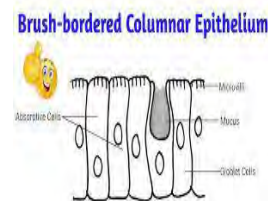
Non-ciliated cuboidal epithelium is located: in ovary, thyroid vesicles, inner surface of cornea, and lens of eye for **secretion**; on surface of ovary for **ova formation**; in kidney tubules for **selective reabsorption**, **tubular secretion**, and **excretion**; and in salivary and pancreatic ducts for the supply of salivary and pancreatic juice, respectively.



Non-ciliated cuboidal



Ciliated cuboidal



Brush-bordered cuboidal

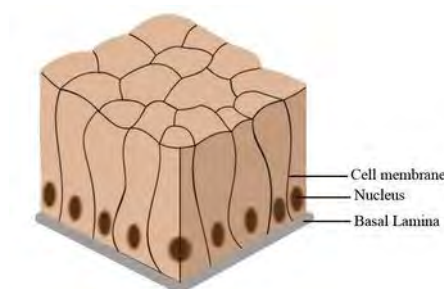
Ciliated cuboidal epithelium is located in respiratory bronchioles for filtering air.

Brush-bordered cuboidal epithelium is located in proximal convoluted tubule (PCT) of nephrons for selective reabsorption.

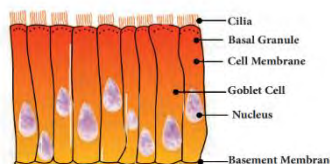
III. Simple columnar epithelium

Simple columnar epithelium has single layer of columnar cells. The columnar cells are tall-sized, cylindrical in shape having height exceeding width, and with elongated, oval-shaped nucleus situated at basal region.

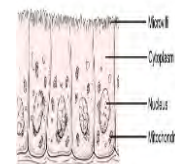
Simple columnar epithelium may be non-ciliated without cilia on free border, ciliated with cilia on free border, or brush-bordered with microvilli on free border.



Non-ciliated columnar



Ciliated columnar



Brush-bordered

Non-

Non-ciliated columnar epithelium is located in gall bladder for storage of bile, in stomach and intestine for secretion, absorption, and excretion.

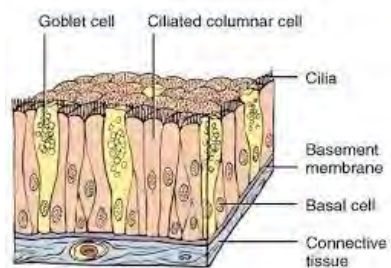
Ciliated columnar epithelium is located in fallopian tube for the capture of ovum, in oviduct for conducting ova, and in neurocoel for circulating cerebro-spinal fluid (CSF).

Brush-bordered columnar epithelium is located in intestinal mucosa for absorption.

IV. Pseudostratified epithelium

Pseudostratified epithelium has single layer of **cuboidal** and **columnar cells**, all resting on the same basement membrane. The cuboidal cells only touch basement membrane whereas the columnar cells touch basement membrane on one side and has free border on opposite. Out of all the columnar cells, nearly half columnar cells support the epithelium and rest half modified on free surface. The modification is two types: out of all the modified columnar

cells, some columnar cells become **goblet cells** secreting mucous and rest columnar cells become **ciliated cells** provided with cilia. So, this epithelium, is obviously, **ciliated columnar epithelium** with functional modification for air filtration.



Pseudostratified epithelium

Pseudostratified epithelium is located in upper respiratory tract, trachea, bronchi, and bronchioles for **filtering** dust or solid particles in air.

Activity

Prepare in **tabulated form**, location and function of pseudostratified epithelium found in human respiratory organ from the upper respiratory tract up to its last location.

2. Compound epithelium

Compound epithelium has many layers of cells, out of which the innermost layer of cells rests on basement membrane and the topmost layer of cells consists of free border. The cells on free border are either squamous, cuboidal, columnar, or may be rounded. The cells resting on basement membrane are cuboidal or columnar. The squamous, cuboidal, or columnar cells on free border may be modified for special functions or may not.

Compound epithelium, on the basis of stress or tension, it bears, are two types: stratified and transitional epithelium.

I. Stratified epithelium

Stratified epithelium bears no stress and has no specific function but general function only.

On the basis of cells either squamous, cuboidal or columnar, it possesses of free border, stratified epithelium is three types: stratified squamous, stratified cuboidal, and stratified columnar epithelium.

i. Stratified squamous epithelium

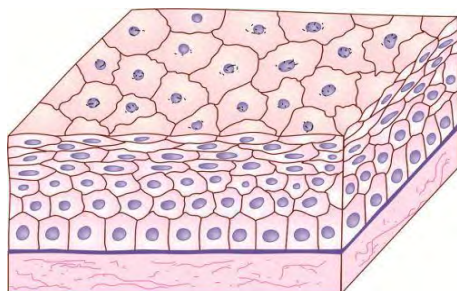
In stratified squamous epithelium, out of many layers of cells, topmost five or six layers of cells are squamous. Rest layers of cells up to basement membrane are cuboidal or columnar.

Stratified squamous epithelium, based on whether keratin is secreted or not on free border, is two types: non-keratinized and keratinized epithelium.

A. Non-keratinized epithelium

Non-keratinized epithelium, also called **stratified non-keratinized squamous epithelium** has smooth surface on free border because keratin is not secreted.

Non-keratinized epithelium is located in buccal cavity, gullet, oesophagus, anus, and vagina for keeping the surface moist.



Non-keratinized epithelium



Keratinized epithelium

B. Keratinized epithelium

Keratinized epithelium also known as **stratified keratinized squamous epithelium** has rough surface on free border because keratin is secreted.

Do you know?

Keratin is **scleroprotein** secreted only by vertebrates on their outer body surface. It is located on **skin** and its **derivatives**. The derivatives are **scales** of fishes; **dry scales, spines, scutes, and claws** of reptiles; **feathers, beak, dry scales, and claws** of birds; and **hair/fur, horn, hoof, nail, claw, scale, and spines** of mammals.

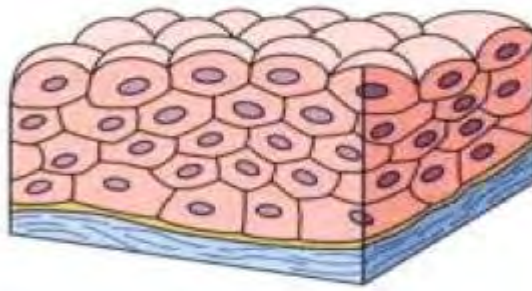
Keratinized epithelium is located in skin and its derivatives for functioning as waterproof, scratchproof, protection, and insulator.

ii. Stratified cuboidal epithelium

In stratified cuboidal epithelium, out of many layers of cells, topmost five or six layers of cells are cuboidal. However, rest layers of cells up to basement membrane is cuboidal or columnar.

Project work

Collect all types of **keratin derivatives** from vertebrates like fish, reptiles, aves, and mammals. Arrange them accordingly by gluing them on a large-sized sheet paper.

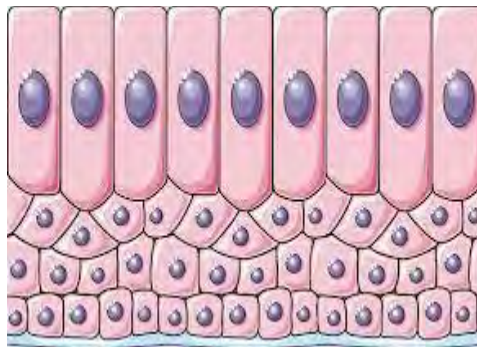


Stratified cuboidal epithelium

Stratified cuboidal epithelium is a **rare-type epithelium** and is located in the duct of salivary, sweat, and mammary glands.

iii. Stratified columnar epithelium

In stratified columnar epithelium, out of many layers of cells, topmost five or six layers of cells are columnar. However, rest layers of cells are cuboidal or columnar.



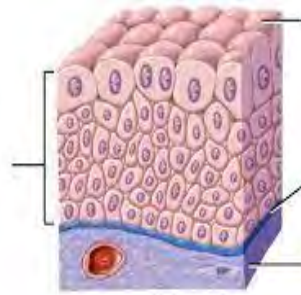
Stratified columnar epithelium

Stratified columnar epithelium is an **uncommon-type epithelium** and is located in conjunctiva, pharynx, anus, male urethra, vas deferens, and salivary glands.

II. Transitional epithelium

Transitional epithelium bears stress or tension and has specific function to do. It is also called **urothelium** or **plastic epithelium**. It possesses five or six layers of unique cells, which can transition from rounded, cuboidal shape in a relaxed state to a flattened, squamous shape when stretched during function. Its basement membrane is noticed during relaxed condition but not during stretched condition.

Transitional epithelium is located in renal pelvis, ureter, urinary bladder, and urethra for permitting high expansion.



Transitional epithelium: stretched (left) and relaxed (right)

Modified epithelium

In modified epithelium, modification in epithelial cells occurs on free border. Generally, modification or specializations are six types: ciliated, brush-bordered, neuro-sensory, pigmented, germinal, and glandular epithelium.

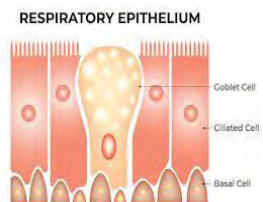
1. Ciliated epithelium

In ciliated epithelium, cilia are present on free border of cells.

Ciliated epithelium, on the basis of type of cilia present on cells, is two types: kino-ciliated and stereo-ciliated epithelium.

I. Kino-ciliated epithelium

Kino-ciliated epithelium has cilia with 9+2 arrangement of microtubules.



Kino-ciliated epithelium



Stereo-ciliated epithelium

Kino-ciliated epithelium is located in respiratory organs for the movement of mucous, in female reproductive organs for the movement of ova, and in neurocoel for the movement of CSF.

Do you know?

Each cilium or flagellum has **9+2 arrangement** of **microtubules**, i.e., nine **duplets** in periphery and two **singlets** in centre.

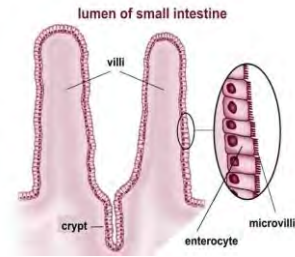
II. Stereo-ciliated epithelium

Stereo-ciliated epithelium has cilia without microtubules hence, sometimes designated as **0+0 arrangement**.

It is located in epididymis for sperm maturation and storage.

2. Brush-bordered epithelium

In brush-bordered epithelium, microvilli are found on free border of cells.

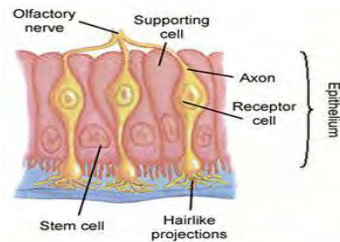


Brush-bordered epithelium

Brush-bordered epithelium is located in kidney tubules and small intestine for increasing absorptive surface area of cells.

3. Neuro-sensory epithelium

In neuro-sensory epithelium, sensory hairs present on the free border are connected to nerve fibre.

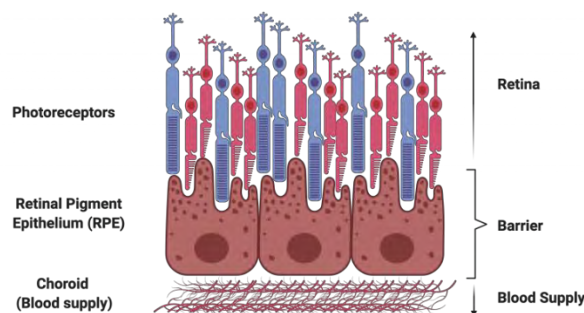


Neuro-sensory epithelium

Neuro-sensory epithelium is located in olfactory epithelium for smelling.

4. Pigmented epithelium

In pigmented epithelium, pigment or colour is secreted by pigment-containing cells.

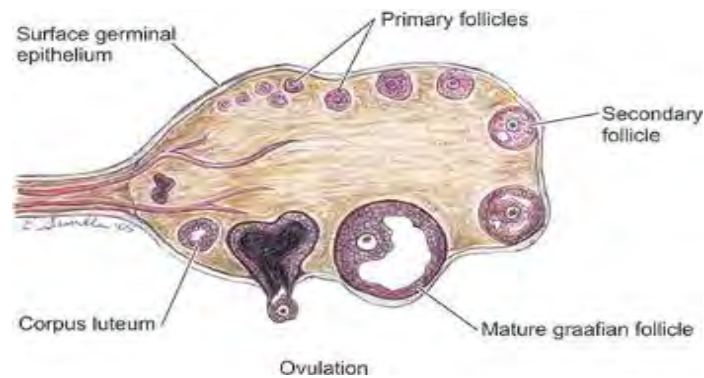


Pigmented epithelium

Pigmented epithelium is located in pigment-containing cells of retina.

5. Germinal epithelium

Germinal epithelium is located in gamete forming cells of testes and ovaries.



Germinal epithelium

6. Glandular epithelium

Glandular epithelium has enzyme and hormone secreting cells called **glands**. Glands are many types:

I. Glands, based on presence or absence of ducts including secretion of enzymes or hormones, are three types: exocrine, endocrine, and heterocrine glands.

i. Exocrine glands

Exocrine glands which are provided with ducts secrete enzymes, e.g., gastric and intestinal glands. Exocrine glands are also called **ducted glands** or glands with ducts.

ii. Endocrine glands

Endocrine glands which are ductless secrete hormones, e.g., pineal and pituitary gland. Endocrine glands are also known as **duct-less glands**.

iii. Heterocrine glands

Heterocrine glands which are also known as **mixed glands** have ducts in some part and are ductless in rest. The part with ducts secrete enzymes and the part without ducts secrete hormones, e.g., pancreas.

II. Glands, on the basis of consistency of secretion, are three types: serous, mucous, and mixed glands.

i. Serous glands

Serous glands secrete watery fluid, e.g., sweat and tears gland.

ii. Mucous glands

Mucous glands secrete mucous, e.g., goblet cells.

iii. Mixed glands

Mixed glands secrete both watery fluid and mucous.

III. Glands, based on quantity of secretion, are three types: apocrine, merocrine, and holocrine glands.

i. Apocrine glands

Apocrine glands secrete in pinch of the cell, e.g., mammary glands.

ii. Merocrine glands

Merocrine glands secrete little amount of the cell, e.g., salivary glands and pancreas.

iii. Holocrine glands

Holocrine glands secrete whole content of the cell hence, cell is ruptured after secretion, e.g., sebaceous glands.

IV. Glands, on the basis of number of cells, are two types: unicellular and multicellular glands.

i. Unicellular glands

Unicellular glands possess single cell, e.g., mucous-secreting goblet cell.

ii. Multicellular glands

Multicellular glands possess many cells, e.g., sudoriporous or sweat gland, liver, and thyroid gland.

V. Glands, based on simplicity or complexity in structure (unbranched, branched, or coiled), shape (tubular or alveolar/acinar), and secretion (single-unit or multi-unit) are two types: simple and compound glands.

i. Simple glands

Simple glands may have unbranched or branched structure with tubular or alveolar shape, but with single secretory unit.

On the basis of structure, simple glands are five types: simple tubular, simple branched tubular, simple coiled tubular, simple alveolar, and simple branched alveolar.

A. simple tubular, e.g., intestinal glands.

B. simple branched tubular, e.g., gastric and uterine glands.

C. Simple coiled tubular, e.g., sweat gland.

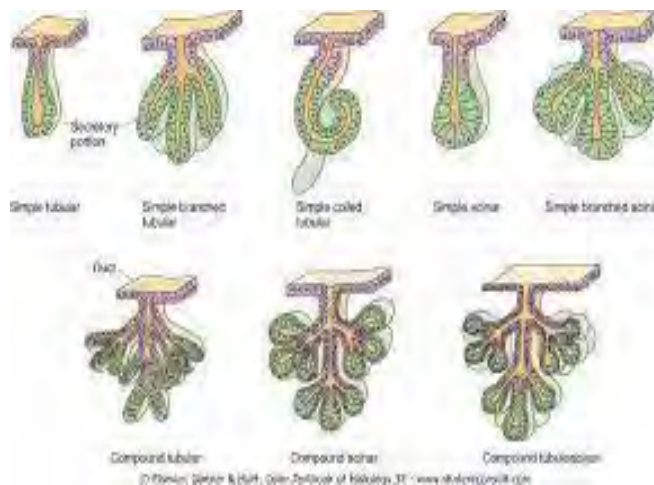
D. Simple alveolar or **simple acinar**, e.g., seminal vesicles.

E. Simple branched alveolar or **simple branched acinar**, e.g., skin glands.

ii. Compound glands

Compound glands have branched structure, with tubular or alveolar shape, and with many secretory units.

Based on structure, compound glands are three types: compound tubular, compound alveolar, and compound tubule-alveolar.



Glandular epithelium

A. Compound tubular, e.g., liver.

B. Compound alveolar or **compound acinar**, e.g., salivary glands.

C. Compound tubulo-alveolar or **compound tubule-acinar**, e.g., pancreas and mammary glands.

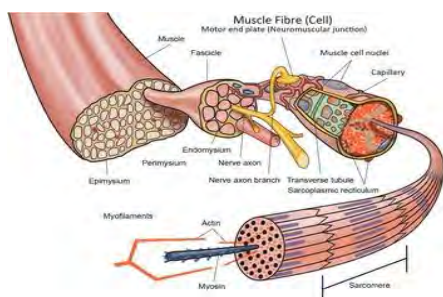
Activity

Enlist **covering**, **lining**, **forming**, and **secreting** epithelial tissue present in different organs and systems of human beings.

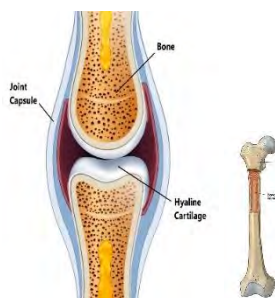
6.2 Connective tissue

See the figures given below and discuss following questions with your classmates?

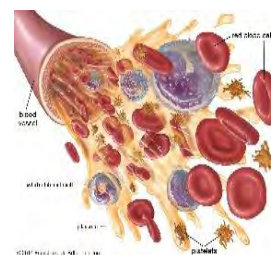
1. Out of the three figures A, B, and C, which one shows support, which one circulate, and which one bind?
2. How are these figures linked with one another?



A



B



C

Out of the three figures, figure A shows 'bind', figure B 'support', and figure C 'circulate'. All are linked with one another because they are types of connective tissue.

Connective tissue **binds** similar as well as dissimilar tissues, **supports** animals in forming structural framework of the organs as well as whole animal itself, and **circulate** materials from one place to another.

Connective tissue has fewer number of **cells**, most abundant **matrix**, and abundant **fibres** in such a way that cells and fibres seem to float in matrix however, it is known that matrix and fibres are secreted by cells.

Connective tissue **functions** in connecting similar to similar or dissimilar to dissimilar tissues in such a way that it forms parts of the organs, whole organs, whole system, and entire body of animals including circulation of materials inside the body.

Connective tissue is considered **most abundant** animal tissue.

Connective tissue is **originated** from **mesoderm**.

Types of connective tissue

Connective tissue, based on whether it binds, supports, or circulates, is classified into three types: proper, supportive, and fluid connective tissue.

1. Proper connective tissue

Proper connective tissue binds similar as well as dissimilar tissues. It binds its own type, i.e., proper with proper; binds its own type with supportive, and also binds supportive with supportive, but never binds nervous tissue. The nervous tissue is bounded by nervous tissue itself, i.e., neurones by neuroglia. Following are the cells, matrix, and fibres found in proper connective tissue.

I. Cells

Although, there are fewer number of cells in proper connective tissue but, on the basis of structure and function, cells are five types: fibroblasts, mast cells, histocytes, lymphocytes, and plasma cells.

i. Fibroblasts

Fibroblasts are principal cells of proper connective tissue. They are elongated and irregular in shape having protoplasmic processes. They secrete **matrix** and **fibres**.

ii. Mast cells

Mast cells, which are modified **basophils** are oval in shape. They secrete **matrix** containing heparin, histamine, serotonin.

Heparin which is **anticoagulant** inhibits coagulation of blood.

Histamine exhibits **allergy**, shows **inflammation**, and performs **vasodilation**, i.e., dilates artery to supply more blood than required.

Serotonin performs **vasoconstriction**, i.e., constricts the same dilated artery to bring it into normal diameter. Mast cells are found in proper connective tissue only.

iii. Histocytes

Histocytes, which are modified **monocytes** are large amoeboid cells. They are also named as **histiocytes**. Because histocytes are **macrophage**, they are **phagocytic** in nature engulfing and destroying inert foreign particles, dead cells, and microbes. Like mast cells, histocytes are also found in proper connective tissue only.

Do you know?

Histocytes are **macrophage** in **proper connective tissue**, similarly, are **dust cells** in lungs, **Hassal's corpuscles** in thymus glands, **Kupffer cells** in liver, **Langerhans cells** in skin, **mesangial cells** in kidney, **microglia** in brain, **monocytes** in blood, **osteoclasts** in bone, and **splenic macrophage** in spleen.

iv. Lymphocytes

Lymphocytes, which is a type of WBCs are constituent of blood. Besides blood, they are also found in proper connective tissue. They secrete **antibodies** or **immunoglobulins** for neutralizing effect of viruses, bacteria, and toxins.

v. Plasma cells

Plasma cells which are called **cartwheel cells** are modified **lymphocytes**. They secrete **antibodies** or **immunoglobulins** for neutralizing foreign proteins called **antigens**.

II. Matrix

Matrix, which is most abundant, consists of **glycoprotein**, **muco-polysaccharide**, and **hyaluronic acid** dissolved in water. The matrix is either jelly-like or gel-like.

Jelly-like matrix is translucent due to less quantity of glycoproteins, muco-polysaccharides, and hyaluronic acid mixed in more quantity of water.

Gel-like matrix is opaque due to more quantity of glycoproteins, muco-polysaccharides, hyaluronic acid mixed in less quantity of water.

III. Fibres

Fibres, which are abundant, are composed of insoluble proteins.

Based on types of protein they contain, structure they have, colour they possess, and functions they do, these fibres are three types: collagen, elastic, and reticulate fibres.

i. Collagen fibres

Collagen fibres, which are made up of insoluble protein **collagen** are **white** in colour. Hence, these fibres are also called **collagenous** or **white fibres**. These fibres are thick, parallel, wavy, unbranched, inelastic, and grouped in bundle.

Collagen fibres function to permit desired movement or required movement or even no movement.

ii. Elastic fibres

The elastic fibres which are composed of insoluble protein **elastin** are **yellow** in colour. Therefore, these fibres are also known as **yellow fibres**. These fibres are thin, non-parallel, non-wavy, branched, and elastic, and without bundle.

Elastic fibres function permitting full length movement.

iii. Reticulate fibres

Reticulate fibres which are made up of insoluble protein **reticulin** are **colourless**. Hence, these fibres are called **colourless fibres**. These fibres are also named as **reticular fibres**. These fibres are ultrathin, delicate, occur singly, and form network.

Reticulate or reticular fibres form structural framework called **stroma** in various organs, e.g., liver, spleen, etc.

Do you know?

If **collagen fibres** are boiled in water, it is converted into protein called **gelatin**.

Types of proper connective tissue

Proper connective tissue, on the basis of matrix, is two types: loose-matrix and dense-matrix connective tissue.

I. Loose-matrix connective tissue

In loose-matrix connective tissue, cells and fibres are embedded in **jelly-like matrix**.

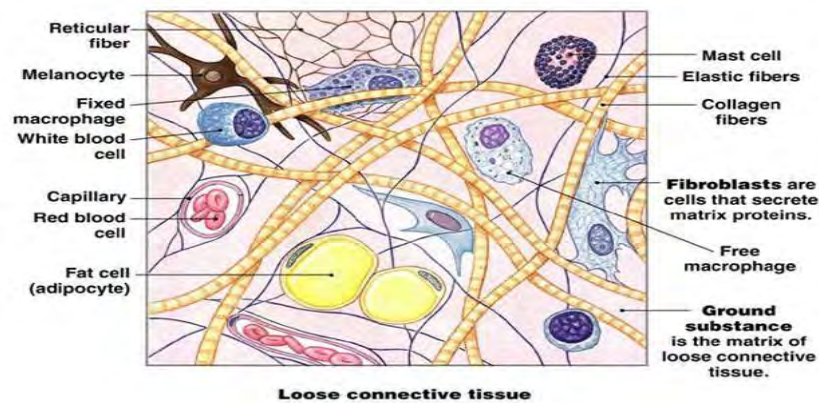
Based on structure, function, and modification, loose-matrix tissue is divided into two types: areolar and adipose tissue.

i. Areolar tissue

Areolar tissue is **soft** and **loose** connective tissue therefore it is called **loose connective tissue**.

It is located beneath skin connecting skin with muscles.

It packs in between skin and muscles and in between sub-mucosa and muscularis mucosa. So, it is also known as **packing tissue**.



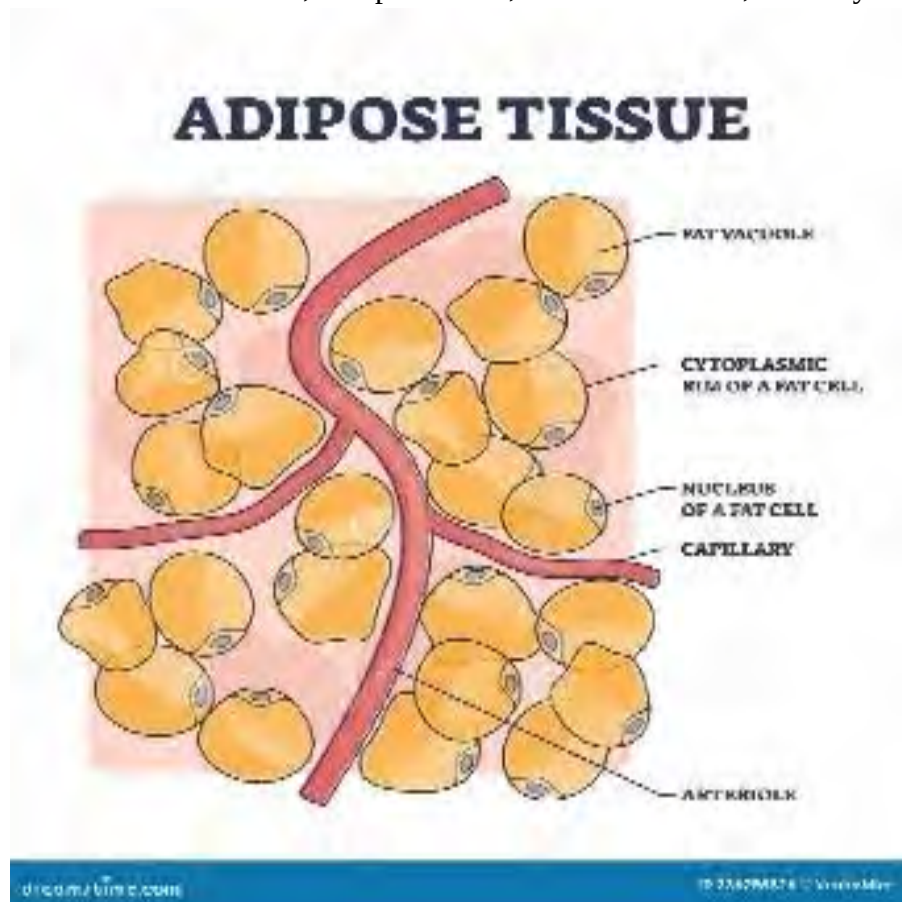
Areolar tissue

ii. Adipose tissue

Adipose tissue is modified areolar tissue provided with **adipocytes**. Adipocytes are large oval or spherical cells secreting fat so, adipocytes are also called **fat-secreting cells**. Hence, adipocytes-containing adipose tissue is also known as **fatty tissue**.

Adipocytes of adipose tissue are two types: white and brown adipocytes.

White adipocytes which are white in colour secrete white- and yellow-coloured fat. Such fat is located in abdomen of man, hump of camel, blubber of whale, fat body of frog, etc.



Adipose tissue

Brown adipocytes which are brown in colour secrete brown colour fat. Such fat is located in migratory fish and bird, hibernating rat, and newly born baby, etc.

Prominent location of adipose tissue like abdomen of man, hump of camel, and fat-body of frog is to store fat as emergency food.

Other prominent location of adipose tissue like **panniculus adiposus**, i.e., sub-cutaneous fat of man and **blubber** of whale is to act as insulator as well as buoyant.

General location of adipose tissue like surrounding the kidneys and behind the eyes is to act as cushion to protect the kidneys and eyes from external shock and injury and reduce their internal friction.

Other general location of adipose tissue like yellow bone marrow is to form blood corpuscles in emergency.

Do you know?

Pigmented connective tissue which is a loose-matrix connective tissue is located in human dermis (of skin), iris, and choroid (middle coat of eye).

II. Dense-matrix connective tissue

In dense-matrix connective tissue, cells and fibres are embedded in **gel-like matrix**.

Based on structure, function, modification, and types of fibres, it is classified into three types: dense connective, elastic connective, and reticular tissue.

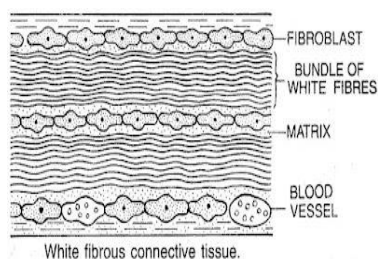
i. Dense connective tissue

Dense connective tissue is **hard** and **dense** due to the presence of collagen fibres hence it is also called **fibrous connective tissue**.

On the basis of whether bundle of collagen fibres are thick or thin, dense connective tissue is categorized into three types: white fibrous tissue, tendon, and ligament.

A. White fibrous tissue

Few fibroblasts of white fibrous tissue secrete thick bundle of collagen fibres.



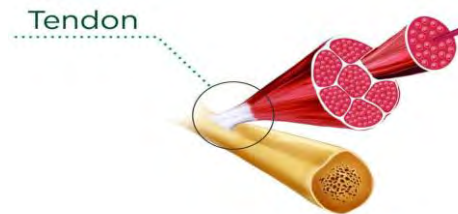
White fibrous tissue

White fibrous tissue is located in suture joints of skull bones to maintain immovability, in sclerotic of mammalian eye to provide strength, in perichondrium of cartilage and in periosteum of bone forming strongest cover.

When white fibrous tissue covers cartilage through perichondrium and bone through periosteum, it is named as **sheath**.

B. Tendon

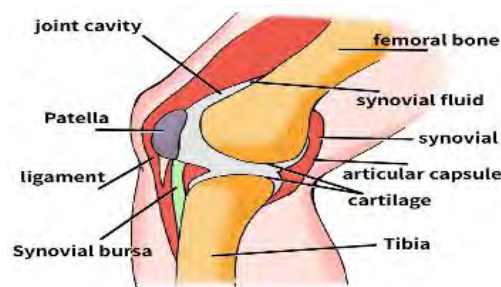
Few fibroblasts of tendon secrete thin bundle of collagen fibres. It connects bone to muscle or muscle to bone.



Tendon

C. Ligament

Few fibroblasts of ligament secrete thick bundle of collagen fibres along with some elastic fibres. It connects bone to bone.



Ligament

ii. Elastic connective tissue

Elastic connective tissue is **hard** and **dense** with elastic fibres so it is also known as **yellow fibrous connective tissue**. It is located in larynx (as component), trachea, bronchi, bronchioles, lungs, and wall of arteries to reduce friction.

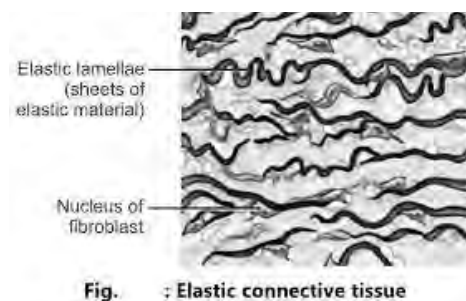
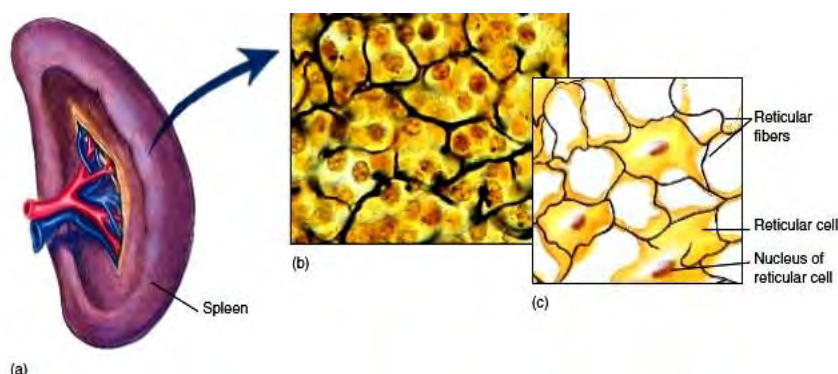


Fig. Elastic connective tissue

Elastic connective tissue

iii. Reticular tissue

Reticular tissue is **hard** and **dense** with reticulate fibres therefore it is also called **reticulate connective tissue**. It forms structural framework called **stroma** of the organs like liver, spleen, lymph node, and lymphatic organs, etc. It connects unstripped muscles.



Reticular tissue

2. Supportive connective tissue

Supportive connective tissue supports animals in forming structural framework of the organs and whole of the animals.

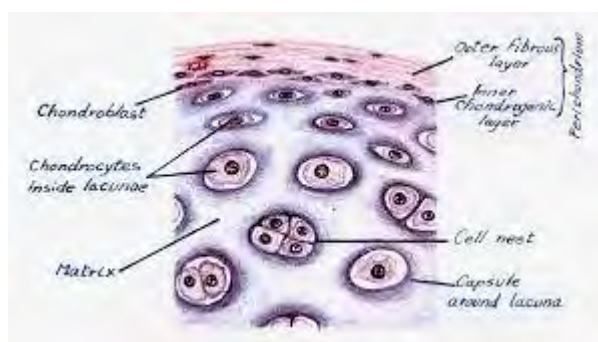
Based on the types of cells, matrix, and fibres, supportive connective tissue is classified into two types: cartilage and bone.

I. Cartilage

Cartilage is strong, avascular, and flexible supportive connective tissue. It comprises cartilage forming immature and undifferentiated cells called **chondroblasts** involved in cell division and development. It equally comprises cartilage forming mature and differentiated cells known as **chondrocytes** that carry out specialized functions. Chondroblasts and chondrocytes occur single or in group of twos, threes or fours within lacuna (pl. lacunae) filled up with liquid.

Cartilage consists of semisolid, semi rigid, and semi hard matrix having muco-protein called **chondrin** secreted by chondrocytes.

Cartilage may contain fibres formed by chondrocytes which, when present, are either collagen or elastic fibres.



Chondroblasts/Chondrocytes in lacunae

Cartilage is always covered by **perichondrium** which is absent at the articular surface. The main function of cartilage is to work as shock absorber.

Do you know?

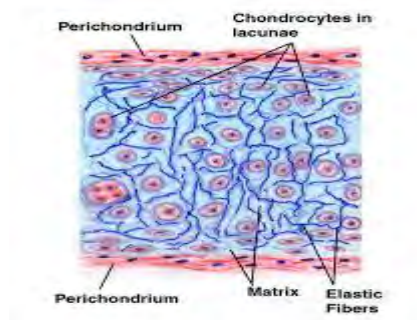
Cartilage is **avascular**, i.e., there is no blood supply or no blood vessels. So, receiving nutrition and gases and expulsion of wastes are done by the process of diffusion.

Cartilage, on the basis of presence or absence of fibres including the structure, modification in structure, location, and function, four types: hyaline, calcified, fibro-, and elastic cartilage.

i. Hyaline cartilage

Hyaline (Gk., **hyalos**, clear or transparent) cartilage is clear or transparent because of the absence of fibres. It is also called **gristle**. It is most abundant cartilage.

Hyaline cartilage which is located at the end of long bones acts as shock absorber and helps in reducing friction.



Hyaline cartilage

Hyaline cartilage which is located at the ventral end of ribs and where it is known as **coastal cartilage** acts as shock absorber and reduces internal friction.

Hyaline cartilage which is located in nasal septum (of nose) forms part of the nose, widens it, and acts as shock absorber.

Hyaline cartilage forms larynx and becomes its part.

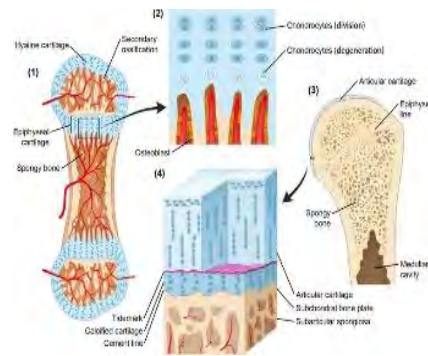
Hyaline cartilage is located in trachea, bronchi, and bronchioles permitting no collapsing to these organs.

Hyaline cartilage forms endoskeleton of Cyclostomata (lamprey and hagfish) and Chondrichthys (ratfish, shark, skate, and ray).

Hyaline cartilage also forms endoskeleton of vertebrate embryo to support the embryo in its early stage.

ii. Calcified cartilage

Calcified cartilage is modified hyaline cartilage coated with calcium carbonate (CaCO_3).



Calcified cartilage

Calcified cartilage is located in supra scapula (of pectoral girdle) and pubis (of pelvic girdle) to provide hardness and rigidity to supra-scapula and pubis.

iii. Fibro cartilage

Fibrocartilage has abundant collagen fibres hence, it is also known as **white fibrous cartilage**. It has **no perichondrium**. It is **strongest cartilage**.

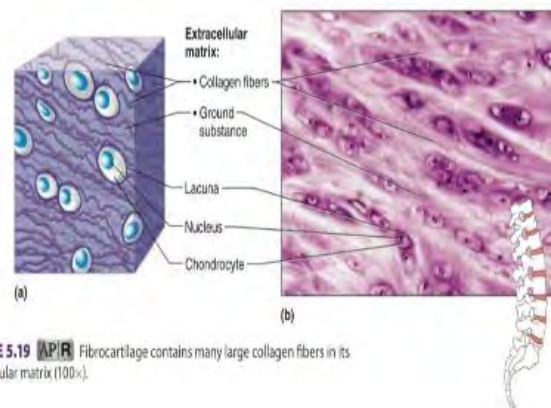


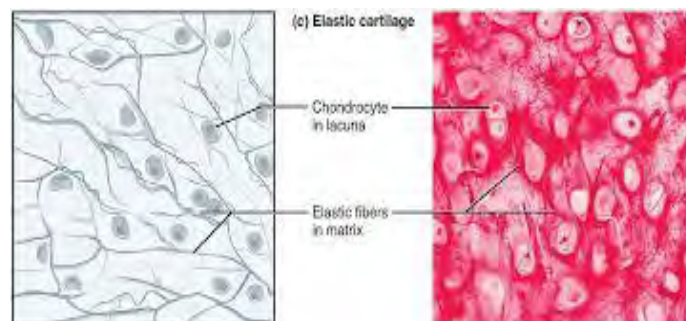
FIGURE 5.19 **APIR** Fibrocartilage contains many large collagen fibers in its extracellular matrix (100 $\times$).

Fibro cartilage

Fibrocartilage is located in **intervertebral joints** and **pubis symphyses** to provide **strength**.

iv. Elastic cartilage

Elastic cartilage has abundant elastic fibres hence, it is also known as **yellow fibrous cartilage**.



Elastic cartilage

Elastic cartilage forms larynx to become its part, acts as shock absorber, and reduces friction.

Elastic cartilage forms pinna, i.e., external ears of mammals to receive sound waves and also acts as shock absorber.

Elastic cartilage is located at the tip of nose to give its shape.

II. Bone

Bone is strongest, vascular, and non-flexible supportive connective tissue. It comprises bone forming immature and undifferentiated cells called **osteoblasts** involved in cell division and development. It equally comprises bone forming mature and differentiated cells known as **osteocytes** that carry out specialized functions. Osteoblasts and osteocytes occur single within lacuna which is having protoplasmic processes known as **canaliculi** (sing. canaliculus).

Lacuna is filled up with liquid.

Bone consists of solid, rigid, and hard matrix having muco-protein known as **ossein** secreted by osteocytes.

Bone has no protein fibres like proper connective tissue.

Bone is covered by white fibrous connective tissue called **periosteum** which is absent at the articular surface.

Bone is **vascular**, i.e., it possesses blood vessels or is supplied by blood.

Main function of bone is to support vertebrates by forming endoskeleton.

Bone, on the basis of its formation, three types: cartilaginous, membranous, and sesamoid bone.

i. Cartilaginous bone

Cartilaginous bone is formed by ossification of cartilage hence, it is also called **replacing bone**, e.g., limb bones and vertebrae.

ii. Membranous bone

Membranous bone is formed by ossification of intramembranous membrane so, it is also known as **investing** or **dermal bone**, e.g., skull, jaw, ribs, pectoral girdle, etc.

iii. Sesamoid bone

Sesamoid bone is formed by ossification of tendon or ligament, e.g., patella, fabellae.

Bone, based on its shape and size, four types: flat, irregular, short, and long bone.

i. Flat bone

Flat bone is flat in shape, e.g., frontal, parietal, occipital, and temporal bone of skull; sternum and ribs of thoracic cage; and ilium of pelvic girdle.

ii. Irregular bone

Irregular bone is irregular in shape, e.g., facial bones, ear ossicles, and vertebrae.

iii. Short bone

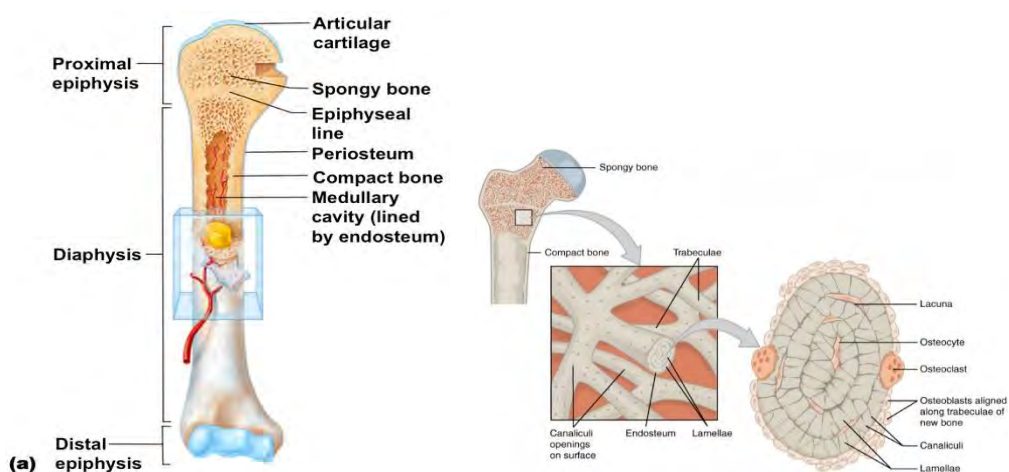
Short bone is short and small in size, e.g., carpals and tarsals.

iv. Long bone

Long bone is long and large in size, e.g., limb bones excluding carpals and tarsals. Long bone, on the basis of strength, texture, and type of bone marrow it has, consists of two parts: epiphysis and diaphysis.

A. Epiphysis

Epiphysis is extremity or end part of bone and has **red bone marrow** having **myeloid tissue** containing stem cells. Here, stem cells convert into **haematopoietic tissue** and form blood corpuscles. Because, epiphysis part of the long bone is spongy in texture, soft in consistency, present in extremity, end part of bone, having honeycomb like structure, and formed of trabeculae, it is also called **spongy bone**, **soft bone**, **extremity bone**, **end bone**, **cancellous bone** or **trabecular bone**, respectively. Epiphysis lacks **osteon**, i.e., **Haversian system**.



Mammalian long bone

T. S. of epiphysis of mammalian long bone

B. Diaphysis

Diaphysis is middle part of bone and has **yellow bone marrow** having **fatty tissue** possessing stem cells. Here, stem cells generally form fat, cartilage, and bone but, in emergency, some of the stem cells convert into haematopoietic tissue and manufacture blood corpuscles. Fatty tissue which secretes yellow colour fat remains inside **bone marrow cavity**. Because, diaphysis part of the long bone is compact in texture, hard in consistency, present in middle, constitutes handle like structure, and forms cortex or outer layer of bone, it is also known as **compact bone**, **hard bone**, **middle bone**, **shaft** or **cortical bone**, respectively. Diaphysis possesses **Haversian system** or **osteon**.

Do you know?

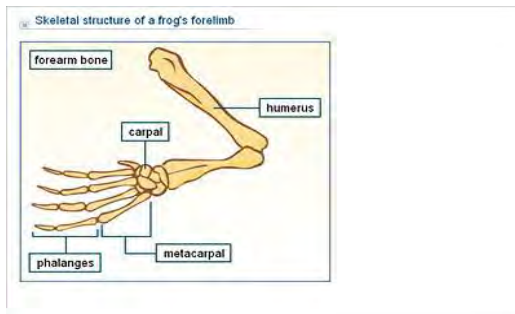
When **yellow colour fat** is mixed in **red bone marrow** it becomes **yellow bone marrow**.

Transverse section (T. S.) of diaphysis of Amphibian and Mammalian bone reveals following structures.

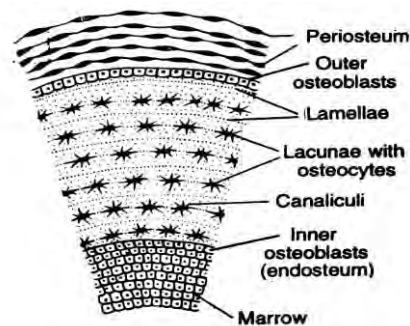
a. T. S. of diaphysis of Amphibian long bone (from outer to inner): periosteum, outer osteoblast, lamellae (without osteon), inner osteoblast, and bone marrow cells.

Do you know?

If bone is burnt in fire, it becomes **brittle** but if it is kept in KOH, it is **unaffected**.

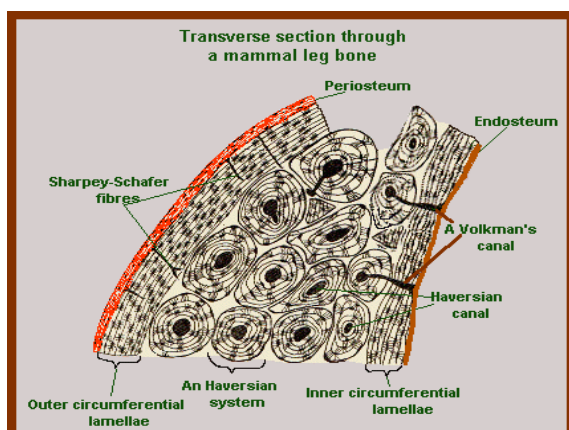


Amphibian long bone

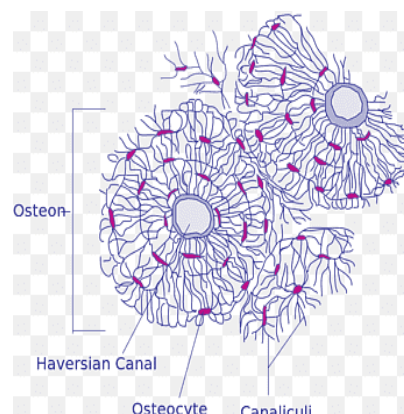


T. S. of diaphysis of Amphibian long bone

b. T. S. of diaphysis of long bone of Mammal (from outer to inner): periosteum, outer circumferential lamellae (without osteon), middle lamellae (with osteon), inner circumferential lamellae (without osteon), inner osteoblast, and bone marrow cells.



T. S. of diaphysis of Mammalian long bone



T. S. of diaphysis of Mammalian long bone showing osteon, i.e., Haversian canal

The middle lamellae of mammalian bone have three to four concentric layers. Each layer has many **Haversian system** or **osteon** arranged in circumference or circle of the concentric layer.

Each osteon has three to four concentric layers of osteocytes. The canaliculi of inner concentric layers of osteocytes converge to form longitudinal canals called **Haversian canals** that are connected to the transverse canals known as **Volkman's canal** forming Haversian system or osteon.

Bone forms endoskeleton of bony fish to mammal to support them. Other functions of bone are haemopoiesis, formation of fat, formation of cartilage, etc.

Do you know?

Largest human bone is **femur** and smallest **stapes**, strongest human bone is **femur** and weakest **clavicle**, hardest human bone is **mandible** and hardest material **enamel**.

Bone is composed of 65% inorganic compound, 15% organic compound, and 10% water. Inorganic compound consists of salt and organic compound comprises proteins. Out of the total salt, **calcium phosphate** constitutes 95% and rest 5% is constituted by magnesium phosphate, calcium carbonate, and sodium chloride. Protein found in bone is **osseine**.

Activity

Put a long bone in dil. HCl or H₂SO₄ and boil it for about half an hour. Observe, what happens to this bone? Be ensure **whether you can cut the T. S. of this bone or not?**

3. Fluid connective tissue

Fluid connective tissue has blood cells in fluid produced due to haemopoiesis or haematopoiesis hence, it is also called **haemopoietic** or **haematopoietic tissue**. Fluid connective tissue flows inside blood vessels so, it is also known as **vascular tissue**. Fluid connective tissue **transports** or **circulates** materials from one place to another therefore, it is also called **mobile connective tissue** or **circulatory fluid**. Circulatory fluid is one of the components of **circulatory system** and its function is to serve in transportation of **materials**, **regulation** of body, and **protection** against diseases. Fluid connective tissue has **cells** in **fluid matrix** but has no fibres.

So, on the basis of cells and fluid matrix or composition of cells in fluid matrix, fluid connective tissue is two types: blood and lymph.

I. Blood

Blood is **circulatory fluid** flowing inside blood vessels like artery, capillary, and vein. It is one of the components of **blood vascular system**. It is **8%** of **human bodyweight** (a human male weighing 70 kg has 5.6 L of blood and a human female weighing 60 kg has 4.8 L of blood).

Do you know?

Hardest animal tissue is **bone** and softest animal tissue **blood**.

Blood is **heavier** than water, **salty** (0.9% NaCl) in taste, acts as **buffer**, and slightly **alkaline** with a pH of 7.4. Buffering action of blood is due to the presence of NaHCO_3 and its slight alkalinity is due to maintenance of the ratio of NaHCO_3 and H_2CO_3 . Blood has **cells** in **fluid matrix** hence, it is obvious that it has two parts: plasma and blood cells.

i. Plasma

Plasma is **fluid matrix**, **fluid** or **liquid part** of blood. It is **55%** of the **total volume** of blood. It has 90% **water**, 7% **plasma proteins**, and 3% **materials**. Plasma proteins are dissolved in water. Examples of plasma proteins are **albumins** and **globulins**. Albumins maintain blood osmotic pressure. Globulins maintain transportation of materials (e.g., **α -globulin** and **β -globulin**) as well as natural and acquired immunity to infection (**immunoglobulins**, e.g., **γ -globulins**). Materials to be transported in plasma are simple food, gases, nitrogenous wastes, lactic acid, hormones, minerals, vitamins, toxic chemicals, medicine, heparin, etc.

ii. Blood cells

Blood cells are also called **blood corpuscles**, **solid part**, or **formed elements**. Blood cells constitute a composition of 45% of the total volume of blood. Blood cells are formed by yolk sac, liver, spleen, thymus gland, lymph node, and bone marrow. Blood cells like RBCs, granular WBCs, and thrombocytes are formed by **myeloid tissue**, i.e., red bone marrow and blood cells like agranular WBCs in adult by **lymphoid tissue**, i.e., lymph nodes, tonsils, and spleen. Formation of blood cells is known as **haemopoiesis** or **haematopoiesis**.

Do you know?

Blood cells are called **corpuscles** as they have short life-span and can also float, move, or roll in plasma inside blood vessels.

Blood cells, on the basis of types of cells, their structure, and function, are three types: red blood cells, white blood cells, and platelets.

A. Red blood cells

Red blood cells are so called as they are red in colour. They are **haemoglobin-bearing cells**. They are also called **red blood corpuscles** or **erythrocytes**. Red blood cells or red blood corpuscles are abbreviated as RBCs. Main features of RBCs needed for their explanation are: shape, size, colour, and structure. Shape of RBCs is **rounded** or **oval**.



Human RBCs

They are **biconvex** in amphibian and **biconcave** in mammalia. Largest RBCs are found in amphibian followed by reptilian, birds, and fish. **Smallest** RBCs are present in mammalia. RBCs are **red** in colour due to iron-containing **haemoglobin** as a result of which whole of the blood looks red in colour. RBCs of fish, amphibian, reptilian, and bird possess nucleus, Golgi bodies, centrosomes, ribosomes, and mitochondria hence, their RBCs perform aerobic respiration whereas above mentioned **cell organelles are absent** in mammalian RBCs therefore, mammalian RBCs conduct **anaerobic respiration**.

Do you know?

Biconcave shape of mammalian RBCs increases maximum surface area for O₂-binding. Non-nucleated RBCs of mammals can accommodate maximum number of O₂.

RBCs function to carry oxygen in the form of **oxyhaemoglobin** and carbon dioxide in the form of **carbaminohaemoglobin**. **Lifespan** of amphibian RBCs is **100 days** whereas that of mammalian RBCs **120 days**. Number of RBCs in a healthy human male is **5 million mm⁻³** and that of female **4.5 million mm⁻³**. RBCs are formed from **erythroblasts** in liver, spleen, and kidney of the larva of frog and liver and spleen in the adult frog. Similarly, RBCs are formed from erythroblasts in liver of human foetus and bone marrow in human adult. Formation of RBCs is called **erythropoiesis**. Ratio of RBCs: WBCs:: 600:1

Do you know?

Among mammals, smallest RBCs are found in musk deer (*Moschus moschiferous*). Nucleated mammalian RBCs are found only in camel and llama.

B. White blood cells

White blood cells are so called because they are white in colour. They are **phagocytic**, **allergy-showing**, and **defense-making cells**. They are also known as **white blood corpuscles** or **leucocytes**. White blood cells or white blood corpuscles are abbreviated as WBCs. Main features of WBCs for their explanation are: shape, size, colour, and structure. Shape of WBCs may be oval or irregular hence, not constant. Smallest WBCs is lymphocytes, largest WBCs is monocytes, whereas neutrophils, eosinophils, and basophils are variable in size. WBCs are white in colour. WBCs have cytoplasm with or without granules and their nucleus with or without lobes.

Do you know?

A healthy person should have 15 g haemoglobin per 100 ml of blood. If a person has 12 g or less haemoglobin per 100 ml of blood than the person is said to be **anaemic**.

Total count (TC) of WBCs is 4500 to 10,000 mm⁻³. Differential count (DC) of WBCs is expression of its different types in percentage. Their lifespan is 12-20 days. WBCs are formed from **stem cells**. Formation of WBCs is **leucopoiesis**. Ratio of WBCs:RBCs:: 1:600.

WBCs, on the basis of presence or absence of granules in cytoplasm and presence or absence of lobes in nucleus, are two types: granulocytes and agranulocytes.

a. Granulocytes

Granulocytes are WBCs with granules in cytoplasm and nucleus with lobes.

Based on number of lobes in nucleus, the granulocytes are three types: neutrophils, basophils, and eosinophils.

1. Neutrophils

Neutrophils have three to five lobes in nucleus. They are most abundant WBCs as they constitute 60-70%. They are phagocytic hence, they are most active.

2. Basophils

Basophils have two to three lobes in nucleus. They are least abundant WBCs because they constitute 0.5-1.0%. They are involved in showing allergy.

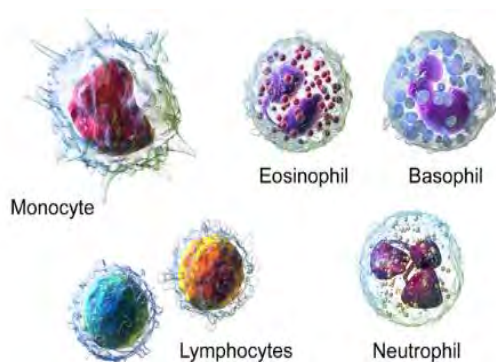
3. Eosinophils

Eosinophils which are also called **acidophils** have two lobes in nucleus. They constitute 60-2-4%. More than 4% of eosinophils indicate allergy and parasitic infection.

b. Agranulocytes

Agranulocytes are WBCs without granules in cytoplasm and nucleus without lobes.

On the basis of shape of nucleus and function, agranulocytes are two types: lymphocytes and monocytes.



White Blood Cells

Human WBCs

1. Lymphocytes

Lymphocytes possess spherical nucleus. They constitute 20-25%. They are involved in antibodies formation hence, protect from pathogens.

Based on their release and maturity, the lymphocytes are two types: B- and T-lymphocytes.

Do you know?

Initial **B** of B-lymphocytes indicates bone marrow and initial **T** of T-lymphocytes indicates thymus gland.

I. B-lymphocytes

B-lymphocytes are formed in bone marrow and directly release in blood for their proper function.

II. T-lymphocytes

T-lymphocytes are formed in bone marrow and are carried to thymus gland for their maturity after which they are released in blood. Because of the function they perform, they are variously called **T-cells**, **T₄-cells**, **CD₄-cells**, or **helper cells**.

2. Monocytes

Monocytes possess horseshoe-shaped nucleus. They constitute 3-8%. They are phagocytic.

Do you know?

Diapedesis is amoeba-like movement of WBCs in narrow blood capillary.

Leucopenia is decreased number of WBCs.

C. Platelets

Platelets which are also called **thrombocytes** are thromboplastin-releasing cells. Platelets have irregular shape with variable structure as they are **cell-fragments** in mammals. They are smallest among blood cells. They are colourless. Their function is to form thromboplastin important for blood-coagulation. Their lifespan is 7 to 10 days. Their number vary from 0.15 to 0.4 million mm⁻³.



Human Platelets

Do you know?

Thrombocytes are found in the blood of vertebrates like fish, frog, lizard, bird, and mammal however, thrombocytes of mammals are called **platelets** as they are cell fragments while in fish, frog, lizard, and bird, they are cells.

Blood-clotting

Damaged cells form and release thromboplastin which forms thrombokinase. The **prothrombin** is converted into thrombin with the help of thrombokinase and Ca⁺⁺. The

fibrinogen is converted into fibrin by the action of thrombin. The damaged cells and fibrin forms **clot**.

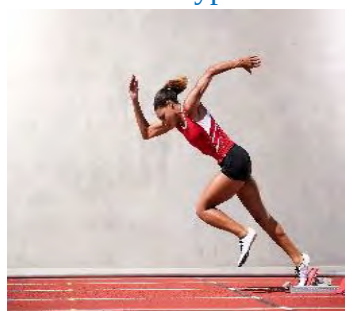
II. Lymph

Lymph is circulatory fluid flowing inside lymphatic vessels like lymphatic capillary, lymphatic ductule, lymphatic duct, thoracic duct, and right lymphatic duct which finally drains lymph into subclavian vein of venous system. Lymph is one of the components of **lymphatic system**. Out of the total lymph formed, 50% is formed in **interstitial space** (ISS) of lymphoid tissue like lymph nodes, thymus gland, spleen, tonsils, and adenoids and rest 50% in the ISS of non-lymphoid tissue, liver. Lymph has **cells** in **ground substance** or **matrix** hence, it is clear that it has two parts: plasma and lymphocytes. Lymph is similar to interstitial fluid (ISF), intercellular fluid (ICF), extracellular fluid (ECF) or tissue fluid.

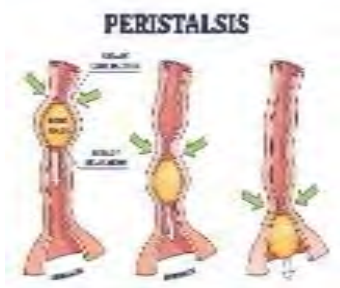
6.3 Muscular tissue

Have a look at the figures given below and discuss following questions with your classmates.

1. What actions do the figures A, B, and C show?
2. In which action, fatiguing occurs immediately, after sometime, and never?
3. With what type of tissue, are these actions associated



A



B



C

Figures A, B, and C, respectively show volunteer actions like running, in which immediately fatiguing occurs; in-volunteer actions of peristalsis (of food), in which fatiguing occurs after sometime; and in-volunteer actions of heart beating, in which fatiguing never occurs. All these volunteer and non-volunteer actions are associated with muscular tissue.

Muscular tissue, which is also known as **muscle** is **contractile tissue**.

Muscle has numerous **cells** called **myocytes** in minimal **matrix** or **extracellular matrix** (ECM). Cells or myocytes of striped, unstriped, and cardiac muscles are also called **muscle fibres** having thin and thick contractile proteins – **actin** and **myosin**, respectively.

Muscular tissue functions to perform **locomotion** and **movement**. To do so, muscle needs **excitation**. After getting excitation, muscular tissue exhibits contraction and relaxation.

Contraction is decreasing in size of the muscle and doing function while **relaxation** is increasing in size of the muscle **or** returning to its original size and coming to rest.

Muscle is **mesodermal** in origin.

Types of muscular tissue

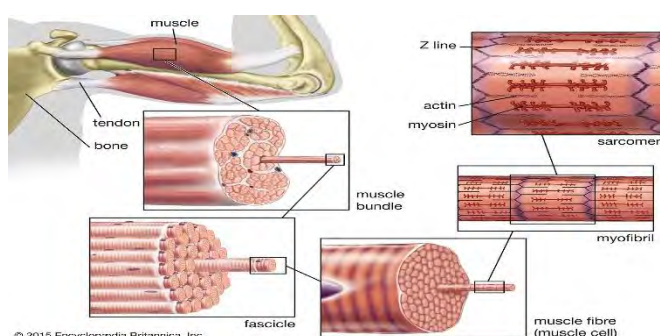
Muscular tissue based on structure and function is three types: striped, unstriped, and cardiac muscle.

1. Striped muscle

Striped muscle which is also called **striated** or **skeletal muscle** has many elongated and narrow, unbranched, and cylindrical **muscle fibres** with **transverse stripes**.

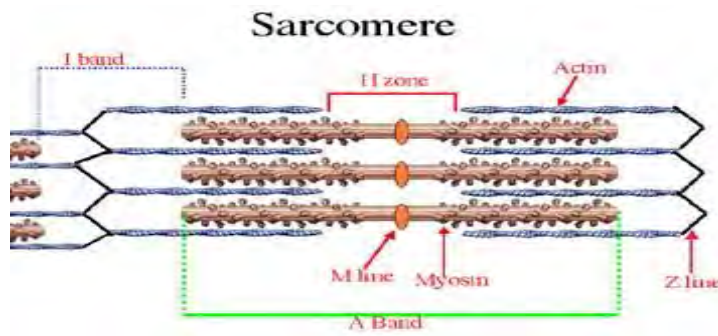
A single striped muscle fibre which has many **myofibrils** with transverse stripes in the form of alternate **dark** and **light bands** is a single **syncytial myocyte** having many **nuclei** in **sarcoplasm** covered by **sarcolemma**. Each dark band of myofibril or myofibre through which light can't pass has thick protein filament called **myosin**. Each light band through which light can pass has thin protein filament known as **actin**.

A **sarcomere** is basic contractile unit of myofibril or myofibre. The sarcomere has transverse Krause's band (K-band), K-line, or Z-line on its either side, each of which is beset with adjacent actin filaments however, actin filaments of corresponding sarcomere are arranged alternate. Inserted in between two adjacent and longitudinally placed actin



Striped muscle

filaments are myosin filament. The whole of the myosin filament constitutes dark band whereas actin filaments of either side of the Z-line constitute light band. The gap between two opposite actin filaments occupied only by myosin is called H-band while corresponding part of actin and myosin on either side of H-band is known as M- band.



A sarcomere of striped muscle

The vertical line situated in the centre of H-band is called M-line. During muscle contraction, M-band occupies whole sarcomere whereas during relaxation it returns to its original position. Again, during muscle contraction, H-band disappears but it reappears during muscle relaxation.

Many **myofibrils** of striped muscle combine to form one **myofibre**, many myofibres of the striped muscle unite to form one **fascicle** or **bundle**, many fascicles of striped muscle combine to form a **block**, e.g., bicep and tricep.

A myofibre of striped muscle is covered by **endomysium**, a fascicle by **perimysium**, and the block by **epimysium**.

Striped muscle is composed of 75% water, 20% protein constituting actin and myosin, and 5% others like K, Ca, and glycogen.

Striped muscle is two types: red and white muscle.

Red muscle with **myoglobin** is found in man and goat while **white muscle** without myoglobin is found in athletes and fish.

'**Sliding filament theory**' proposed by **Huxley and Hanson** is most convincing theory of muscle contraction.

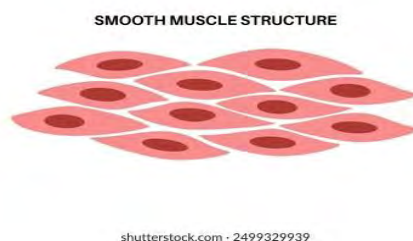
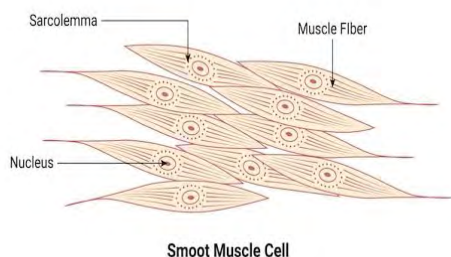
Generally, striped muscle wraps bones and is also located in the organs like tongue and oesophagus. It is **voluntary** in nature hence, fatigues immediately.

2. Unstripped muscle

Unstripped muscle which is also known as **non-striated** or **smooth muscle** has many muscle fibres.

A single unstripped muscle fibre is a single myocyte. Unstripped myocyte is **spindle-shaped** with **tapering ends** covered by **sarcolemma**. It is **uninucleated** having **actin** and **myosin filaments** dispersed in **sarcoplasm**.

Myocytes of unstriped muscle are connected with each other in such a way so as to form **sheet**.



Myocytes of unstriped muscle

Unstriped muscle forming sheet

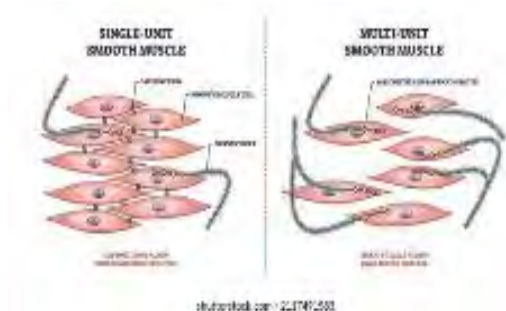
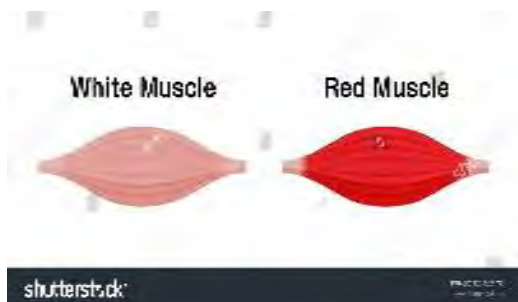
Unstriped muscle is two types: single- and multi-unit.

I. Single unit

Single unit unstriped muscle is that which contracts as a single unit just like as being joined together, e.g., found in urinary bladder and alimentary canal.

II. Multi-unit

Multi-unit unstriped muscle is that which contracts separately as independent from one another, e.g., arrector pilli and blood vessels.



Striped muscle (white and red)

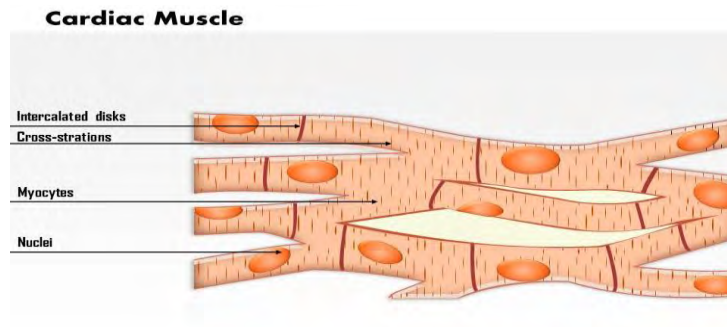
Unstriped muscle (single-unit and multi-unit)

Unstriped muscle is located in alimentary canal performing **peristalsis**. It is **involuntary** in nature hence, fatigues after sometime, generally after 10-12 hrs.

3. Cardiac muscle

Cardiac muscle which is also known as **heart muscle** has many elongated but narrow, branched, and cylindrical **muscle fibres** with **faint** transverse stripes (deep transverse stripes in striped muscle). Cardiac muscle fibres form network with one another.

A single cardiac muscle fibre which has many **myofibrils** with alternate but faint **dark** and **light bands** (deep transverse stripes in striped muscle) is a single myocyte called **cardiocyte**. It is covered by sarcolemma, has single **nucleus** in **sarcoplasm**, and is separated from adjacent or corresponding cardiocyte through **intercalated discs**. Besides this, rest of the features of myocytes of striped muscle resemble to that of cardiomyocytes of cardiac muscle.



Cardiac muscles

Cardiac muscle resembles to some extent to that of striped muscle and to some extent with that of unstriped muscle. Cardiac muscle resembles to that of striped muscle in structure because both cardiac and striped muscles have transverse striations with dark and light bands however, dark and light bands of striped muscle are deeper, but they are faint in cardiac muscle. Cardiac muscle resembles to some extent to that of unstriped muscle in function because both cardiac and striped muscles are involuntary however, unstriped muscles fatigue after sometime but cardiac muscle never fatigues.

Do you know?

Total number of human muscles is 639. The largest **gluteus maximus** occurs in buttock, smallest **stapedius** is found in ear, longest **sartorius** occurs in thigh, and strongest **masseter** is found in lower jaw.

Many cardiocytes are joined together with one another to form **sheet** of cardiac muscle.

Cardiac muscle is **least abundant muscle** among all types of muscle.

Cardiac muscle which is located in heart only, conducts for the origin of heartbeat including pumping of the blood. It is involuntary in nature and never fatigues.

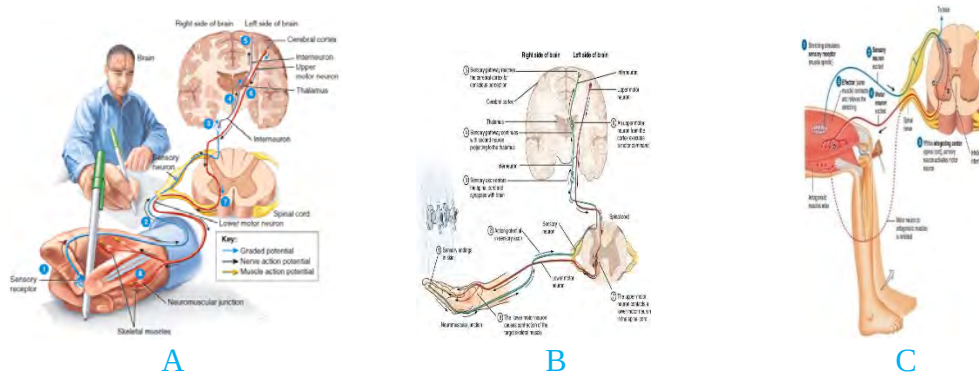
Activity

Make a list of the number of human muscles involved in the action of laughing, working, running, jumping, swimming, cycling, etc.

6.4 Nervous tissue

Observe the figures given below and discuss following questions with your class friends.

1. How would you explain the figures A, B, and C in terms of nerve impulse conduction, nervous tissue, neurons, and neuroglia?



Figures A, B, and C indicate control, coordination, integration, and regulation of one's own body (of human) through nerve impulse conduction performed by nervous tissue with the help of neurons supported by neuroglia.

Nervous tissue **controls, coordinates, integrates, and regulates** organisms.

Nervous tissue has numerous elongated **cells**, each with axon called **nerve fibre** and minimal **matrix**.

Nervous tissue performs **nerve impulse conduction**.

Nervous tissue is **ectodermal** in origin.

Types of nervous tissue cells

Nervous tissue, on the basis of structure and function, possesses two types of cells: neuroglia and neurone.

1. Neuroglia

Neuroglia, which is also called **non-neuronal cell** is **forming, connective, protective, phagocytic, secretory, and equilibrium-maintaining cell** of neurones.

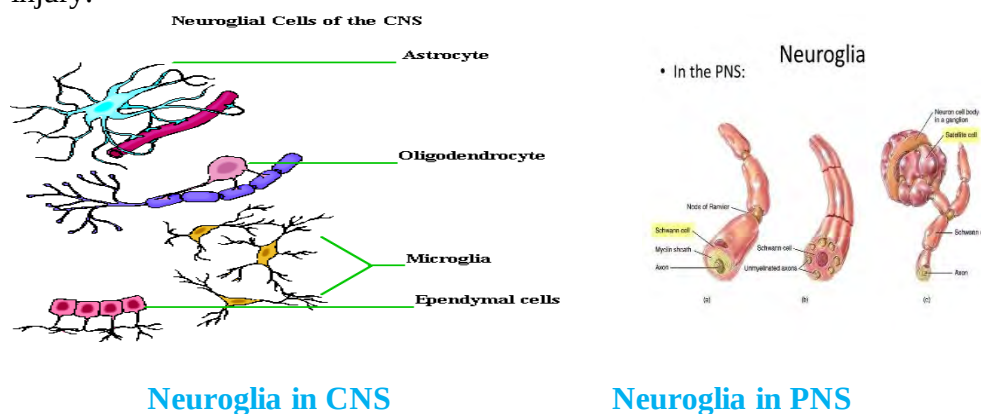
Neuroglia can perform **mitosis**.

Neuroglia functions to **form, connect, protect, support, phagocytize**, and to **maintain equilibrium** of the neurones. Neuroglia are found in both CNS and PNS.

Neuroglia which are found in CNS, i.e., brain and spinal cord are four types: astrocyte, oligodendrocyte, microglia, and ependymal cell.

I. Astrocyte

Astrocyte, which is star-shaped regulate neuro-environment of the organisms and heal brain injury.



Neuroglia in CNS

Neuroglia in PNS

II. Oligodendrocyte

Oligodendrocyte forms myelin sheath of neurones.

III. Microglia

Microglia are macrophages devouring bacteria and debris of dead neurones.

IV. Ependymal cell

Ependymal cell lines ventricles and secrete CSF.

Neuroglia which are present in PNS, i.e., cranial and spinal nerves are two types: stellate and Schwann cell.

I. Stellate cell

Stellate cell surrounds soma and regulate nutrients including other functions.

II. Schwann cell

Schwann cell forms myelin sheath and heal the injury.

Neuroglia are **ectodermal** in origin except microglia which is **mesodermal**.

2. Neurones

Neurones, which are also known as **neuronal cells** are **structural** and **functional unit** of nervous tissue as well as nervous system.

Do you know?

Human neurones perform mitosis in a **foetus** of up to eight months after which mitosis completely ceases.

Neurones can't perform mitosis hence, they can't regenerate.

Neurones are **ectodermal** in origin.

Neurones function creating **sensitivity**, **excitability**, and **conductivity**.

Generally, neurones have two parts: soma and neurite.

I. Soma

Soma, which is also called **cell body**, **cyton**, or **perikaryon** is generally **star-shaped**. The soma is covered by **plasma membrane** inside which lies **cytoplasm** having **nucleus** with nucleolus and cell organelles including **Nissl's granules**. The Nissl's granules are nothing rather than RNA along with ribosomes and RER. The soma is **gray** in colour. The soma generally occurs in brain.

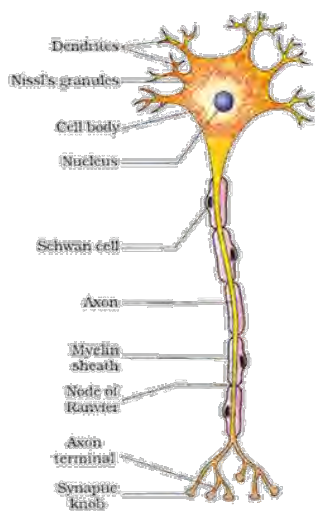
II. Neurite

Neurite, which is also known as **nerve process** emerges from soma.

Neurite, on the basis of structure and function, is two types: dendrite and axon.

i. Dendrite

Dendrite, which was previously known as **dendron** has many processes each of which is short and branched. The dendrite which is extension of plasma membrane along with cytoplasm of soma carry nerve impulse inside soma hence, dendrite is called **sensory** or **afferent process** of neurone.



Multipolar neurone

ii. Axon

Axon, which is also called **nerve fibre** and which emerges from soma as a conical elevation called **axon hillock** is single, unbranched, and longest process of neurone. The plasma membrane of soma which is continued as axon is known as **axolemma**. The cytoplasm of soma which flows inside axon is called **axoplasm**. Nissl's granules are absent at the axon hillock. Axon, at its end, is branched into many **telodendria**, each of which is beset with **axon terminal** or **end bulb**. The middle part of the axon in between axon hillock and telodendria is

either covered by oligodendrocytes in CNS or by Schwann cells in PNS. The plasma membrane of each oligodendrocyte or Schwann cell covering axon is called **neurilemma** and cytoplasm inside oligodendrocyte or Schwann cell is known as **neuriplasm**. The neurilemma, in its outside, may or may not secrete white-coloured fatty layer covering called **myelin sheath**. The myelin sheath is made up of phospholipids hence, axon with myelin sheath is called **myelinated nerve fibre** or **myelinated neurone** which is **white** in colour. The axon without myelin sheath is known as **non-myelinated nerve fibre** or **non-myelinated neurone** which is **gray** in colour. The axon whether myelinated or non-myelinated carry nerve impulse from soma to another neurone hence, the axon is known as **motor** or **efferent process** of neurone.

Myelinated nerve fibre functions for insulation of axon causing saltatory nerve impulse conduction thus, creating faster impulse velocity. Non-myelinated junction of the myelinated nerve fibre is called **node of Ranvier**. The node of Ranvier doesn't occur in non-myelinated nerve fibre. End bulb of telodendria of an axon forms **synapsis** with **end plate** of dendrite of another neurone.

Nerve fibre or neurone, on the basis of its connection with receptors or effectors or its location, three types: sensory, motor, and intermediate.

I. Sensory nerve fibre or sensory neurone

Sensory nerve fibre or sensory neurone, which is also called **afferent nerve fibre** or **afferent neurone** connect receptors with CNS.

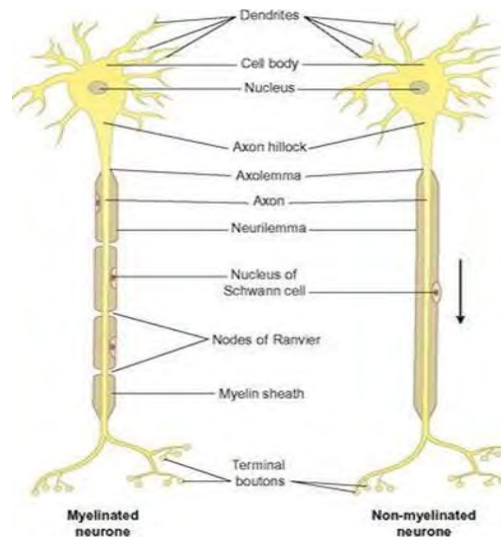
II. Motor nerve fibre or motor neurone

Motor nerve fibre or motor neurone, which is also called **efferent nerve fibre** or **efferent neurone** connect CNS with effectors.

III. Intermediate nerve fibre or intermediate neurone

Intermediate nerve fibre or intermediate neurone, which is also called **adjustor nerve fibre** or **adjustor neurone** is located in CNS and lies in between sensory and motor neurone.

Nerve fibre or neurone, based on presence or absence of myelin sheath, two types: myelinated and non-myelinated.



I. Myelinated nerve fibre or myelinated neurone

Myelinated nerve fibre or myelinated neurone, which is also known as **medullary nerve fibre** or **medullary neurone** has **long** and **white nerve fibre** with **myelin sheath** for **fast nerve impulse** along with **node of Ranvier**.

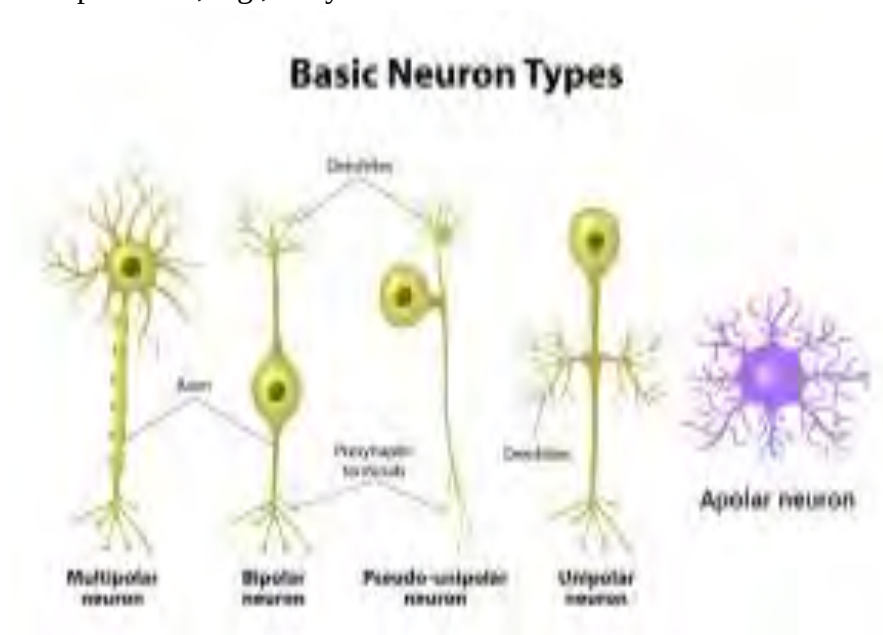
II. Non-myelinated nerve fibre or non- myelinated neurone

Non-myelinated nerve fibre or non-myelinated neurone which is also called **non-medullary nerve fibre** or **non-medullary neurone** has **short** and **gray nerve fibre** without myelin sheath for **slow nerve impulse** and without node of Ranvier.

Neurone, on the basis of structure and function, five types: apolar, pseudopolar, unipolar, bipolar, and multipolar.

I. Apolar neurone

Apolar neurone, which is also known as **un-polar neurone** has no neurites in soma but only protoplasmic processes, e.g., in hydra.



II. Pseudopolar neurone

Pseudopolar neurone, which is also known as **pseudo-unipolar neurone** has a nerve fibre emerging from soma. The nerve fibre of pseudopolar neurone bifurcates in such a way that one joins CNS and another PNS, e.g., in dorsal root ganglia.

III. Unipolar neurone

Unipolar neurone has a neurite emerging from soma. The neurite of unipolar neurone bifurcates in such a way that one becomes dendrite and the other axon, e.g., in dorsal root ganglia of vertebrates.

Activity

Enlist four types of animal tissues in tabulated form, first by showing presence and absence of cells, matrix, and fibres and second by showing abundance of cells, matrix, and fibres.

IV. Bipolar neurone

Bipolar neurone has two neurites emerging from soma in opposite direction, e.g., in retina.

V. Multipolar neurone

Multipolar neurone has many branched dendrites and a long nerve fibre emerging from soma, e.g., in brain and spinal cord.

Activity

Mention similarities and differences between all the four types of animal tissues.

Neurone, based on gray or white colour of its whole or part, two types: gray matter and white matter.

I. Gray matter

Gray matter is that part of neurone in which whole of the neurone looks gray, e.g., outer part of brain and inner part of spinal cord.

II. White matter

White matter is that part of neurone in which nerve fibre of neurone looks white, e.g., inner part of brain and outer part of spinal cord.

Project-work

Select any five human organs from any system, e.g., digestive system like buccal cavity, tongue, teeth, gullet, and oesophagus and then ensure that out of four types of animal tissues, how many types are found in these organs? Make a record of the same.

Points to remember

Epithelial, muscular, and connective tissue: were seen for the first time in Phylum-Platyhelminthes.

Epithelial, muscular, connective, and nervous tissue: were seen for the first time in Phylum-Platyhelminthes.

Fascicle (of nerves) is small bundle of nerves.

Fewer **cells**, most abundant **matrix**, and abundant **fibres** are present in **connective tissue** among the four types of animal tissues.

Many fascicles unite to form a large **bundle** (of nerves).

Nervous tissue is considered **primitive animal tissue** among the four types of animal tissues.

Neurones are longest animal tissue.

Nissl's granules, also known as **trigoid granules** are found in cell body of neurons.

Node of Ranvier, also known as **neurofibril node** is the part of an axon or nerve fibre.

Numerous **cells** and minimal **matrix** are present in **epithelial tissue** among the four types of animal tissues.

Numerous **cells**, each cell called **muscle fibre** and minimal matrix are present in **muscular tissue** four types of animal tissues.

Numerous elongated **cells**, each with axon called **nerve fibre** and minimal **matrix** are present in **nervous tissue** among the four types of animal tissues.

Exercise

A. Tick the correct alternative.

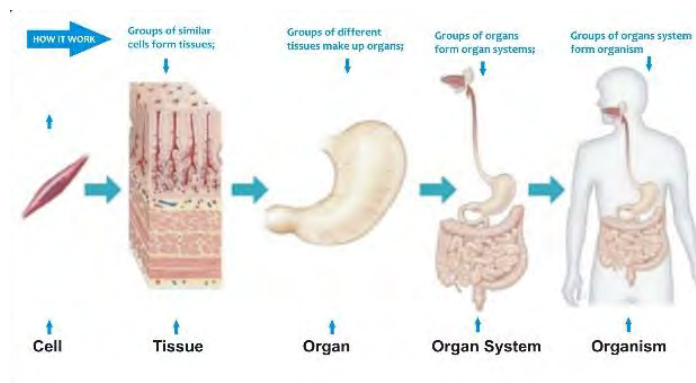
1. Who coined the term tissue?
a. Grew b. Bichat c. Mayer d. Robert Hooke
2. What is meant by a tissue?
a. Group of cells of similar origin b. Group of cells of dissimilar origin
c. Group of similar or dissimilar cells d. Group of unrelated cells
3. Which of the following tissue is not animal tissue?
a. Epithelial tissue b. Connective tissue
c. Parenchymatous tissue d. Muscular tissue
4. Which one of the following animal tissue is originated from all the three germ layers?
a. Epithelial tissue b. Connective tissue c. Muscular tissue d. Nervous tissue
5. Which one of the following statements is incorrect regarding epithelial tissue?
a. Cells are compactly packed b. Provides a covering for some parts of the body
c. Cells may have cilia d. It doesn't have free border.
6. Which one of the following is mesothelium?
a. Tunica interna b. Capillary c. Splanchnic epithelium d. Endocardium
7. Presence of basement membrane is the characteristic features of
a. epithelial tissue b. connective tissue c. muscular tissue d. nervous tissue
8. The mucosal layer of intestine is made up of
a. Stratified squamous epithelium b. Stratified cuboidal epithelium
c. Stratified columnar epithelium d. Transitional epithelium
9. Which of the following tissue is found in skin?
a. Stratified squamous epithelium b. Stratified cuboidal epithelium
c. Stratified columnar epithelium d. Pseudostratified epithelium
10. Which one of the following epithelium forms innermost lining of vagina?
a. Cuboidal epithelium b. Columnar epithelium
c. Stratified keratinized epithelium d. Stratified non-keratinized epithelium
11. Plastic epithelium is
a. striated muscle b. non-striated muscle c. urothelium d. cardiac muscle
12. Which one of the following animal tissue is most abundant?
a. Epithelial tissue b. Connective tissue c. Muscular tissue d. Nervous tissue
13. All the three components of cells, matrix, and fibres are present in

- a. epithelial tissue b. connective tissue c. muscular tissue d. nervous tissue
14. Which cells of areolar tissue are able to move and ingest foreign particles?
a. Fibroblasts b. Mast cells c. Plasma cells d. Histocytes
15. Which one of the following tissue possesses fat globules?
a. Areolar tissue b. Adipose tissue
c. Loose connective tissue d. Dense connective tissue
16. Suture joints in skull bones is
a. areolar tissue b. white fibrous tissue
c. elastic connective tissue d. reticular tissue
17. Which of the following fibre is present abundantly in tendon?
a. White collagen fibre b. Yellow elastic fibre
c. Colourless reticulate fibre d. Red muscle fibre
18. Dense connective tissue contains tendon and ligament. If tendon connects muscle to bone, which structure is connected by ligament?
a. Bone to bone b. Muscle to bone c. Muscle to muscle d. Tendon to ligament
19. Ligaments are connective tissue. What are ligaments made up of?
a. Predominantly white collagen fibres b. Predominantly yellow fibres
c. Both white and yellow fibres d. Only white fibres
20. Which one of the following is avascular?
a. Tendon b. Ligament c. Cartilage d. Bone
21. Haversian system is diagnostic feature of bone. This system is present in which one of the following animal?
a. Amphibians b. Reptile c. Aves d. Mammal
22. The human RBCs is
a. spherical and biconvex b. spherical and biconcave
c. rounded and biconvex d. rounded and biconcave
23. The function of erythrocytes is one of the following.
a. Engulfing bacteria b. Producing antibodies c. Carrying oxygen d. Clotting blood
24. Which pair of white blood cells contains phagocytic cell?
a. Monocytes and eosinophils b. Monocytes and neutrophils
c. Eosinophils and basophils d. Monocytes and lymphocytes
25. Excess number of white blood corpuscles in the blood results in a condition called
a. Down syndrome b. Leukemia c. Dengue d. Haemophilia
26. Which one of the following myocytes of the muscles are syncytial?
a. Striped muscles b. Unstriped muscles c. Heart muscles d. Smooth muscles
27. The epimysium is the covering of of striped muscles.

- a. myofibril b. myofibre c. fascicle d. block
28. The muscle responsible for the movement of tongue and speech is one of the followings.
a. Striated muscle b. Unstriated muscle c. Cardiac muscle d. Smooth muscle
29. Which one of the following muscle has no stripes?
a. Skeletal muscle b. Smooth muscle c. Voluntary muscle d. Cardiac muscle
30. Arrector pilli is associated with
a. striped muscle b. unstriated muscle c. cardiac muscle d. striated muscle
31. Which one of the following muscle has intercalated disc?
a. Striped muscle b. Unstriated muscle c. Cardiac muscle d. Voluntary muscle
32. In the wall of heart, there is presence of cardiac muscles. Which of the following is correct for cardiac muscle?
a. Striped and voluntary b. Unstriated and voluntary
c. Striped and involuntary d. Unstriated and involuntary
33. Which one of the following tissue connect neurones?
a. Areolar tissue b. White fibrous tissue c. Reticular tissue d. Neuroglia
34. Which one of the following animal tissue perform no mitosis?
a. Epithelial tissue b. Connective tissue c. Muscular tissue d. Nervous tissue
35. Which one of the following is macrophage in CNS?
a. Histiocytes b. Microglia c. Dust cells d. Langerhans cells
36. In which part of the neurone, do you find Nissl's granules?
a. Cyton b. Axon c. Axon terminal d. All
37. The bipolar neurones are found in
a. brain b. spinal cord c. retina d. dorsal root ganglia
38. The gray matter is found in
a. outer part of brain and spinal cord
b. inner part of brain and spinal cord
c. outer part of brain and inner part of spinal cord
d. inner part of brain and outer part of spinal cord
39. Which one of the following cells produce cerebrospinal fluid?
a. Neurosecretory cells b. Ependymal cells c. Goblet cells d. Mast cells
40. Which one of the following is longest animal tissue?
a. Epithelial tissue b. Connective tissue c. Muscular tissue d. Nervous tissue

B. Short answer questions.

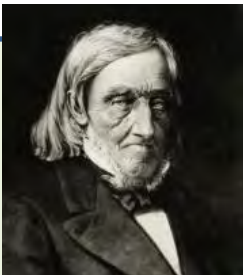
1. Explain in short the figure mentioned below.



2. How would you elaborate different types of simple epithelium in animals? Support with diagrams.
3. Write similarities and differences between simple and compound epithelium.
4. Do you know tessellated epithelium? How is tessellated epithelium different from simple cuboidal and simple columnar epithelium?
5. Discuss the rare- and uncommon-type epithelium with their structure, function, and location.
6. Is there any epithelium known as plastic epithelium? If so, how would you make an explanation of this epithelium?
7. Summarize modified or specialized epithelium
8. What do you mean by glandular epithelium? Describe different types of glands in animals?
9. Mention the types and functions of connective tissue.
10. Give an account of areolar tissue.
11. Compare and contrast between cartilage and bone.
12. Describe Haversian canal system.
13. Write short note on formed elements.
14. Describe the structure of voluntary muscle.
15. Draw a well-labelled diagram of multipolar neurone (No description is required).

Unit 7

DEVELOPMENTAL BIOLOGY



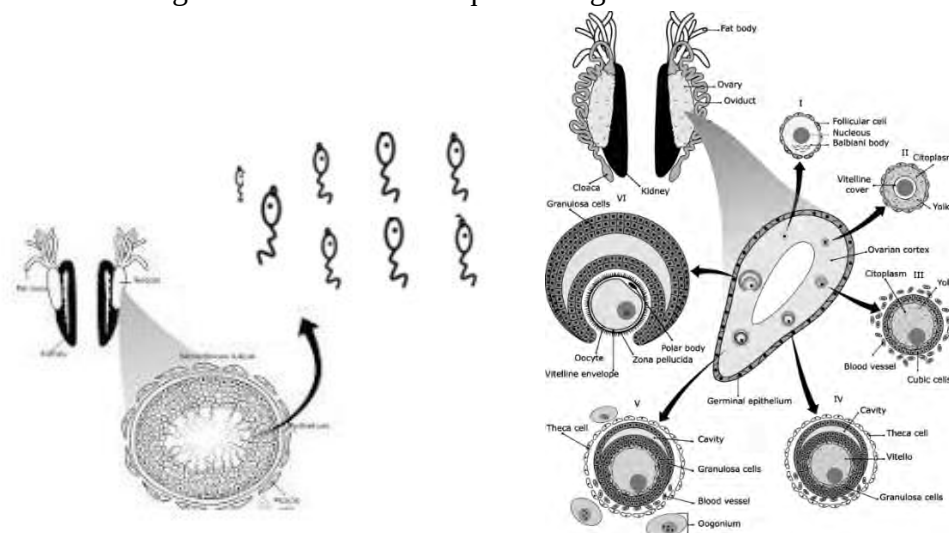
Karl Ernst von
Baer
(1792-1876)

Karl Ernst von Baer (1792-1876) was a famous German Scientist, widely known as “the father of embryology”. He performed groundbreaking discoveries in the field of embryology. He discovered the mammalian ovum egg cell (in dog’s ovary) in 1826. He formulated laws of embryonic development which are known as Baer’s law. His discovery confirmed that mammal like birds and amphibian also began life from a single egg cell. Such a finding was a key milestone in embryology and reproductive science.

Chapter 7.1

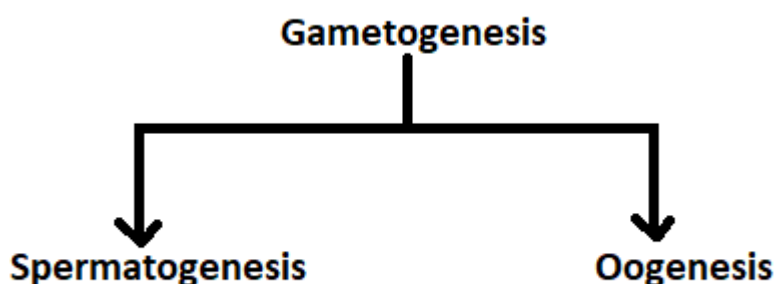
GAMETOGENESIS

Observe the diagrams and discuss the questions given below.



- What is gametogenesis? Is it important for sexual reproduction?
- In which part of body does gametogenesis occur?
- Which type of cell division mainly contribute in gametogenesis? How?

In sexual reproduction, a single celled zygote develops into a complete multicellular organism. Zygote is formed by the fusion gametes (sperm and ovum). Gametes or sex cells are the specialized cells formed in gonads by a specific biological process called gametogenesis. Gonads are the primary reproductive organs in animals. Testes are male gonads whereas ovaries are female gonads. Hence, the process of formation of gametes in the primary reproductive organs is called gametogenesis. Meiosis cell division plays a crucial role in the formation of gametes. During this, Number of chromosomes is reduced to half in daughter cells or gametes. Gametes are also called haploid cells. Meiosis is essential in sexually reproducing animals for maintaining stable chromosomal number i.e., diploid state in zygotes.



Formation of sperms occurs in male gonad or testis by the process called spermatogenesis. Similarly, Production of the ova or female sex cells takes place in the ovaries and the process is called oogenesis.

Spermatogenesis

In this process, haploid and microscopic sperms are formed in the semeniferous tubules of testis. This process takes place under the influence of some gonadial hormones such as Follicle Stimulating hormone, testosterone etc. The process of spermatogenesis completes in 3 phases: Multiplication phase, Growth phase and Maturation phase

i. Multiplication phase:

Testis contains numerous semeniferous tubules and each is internally lined by diploid cells (cuboidal epithelium) called germinal epithelium. These cells are also called primordial germ cells. Such cells divide repeatedly by mitosis to produce large number of spermatogonia (sperm mother cells).

ii. Growth phase:

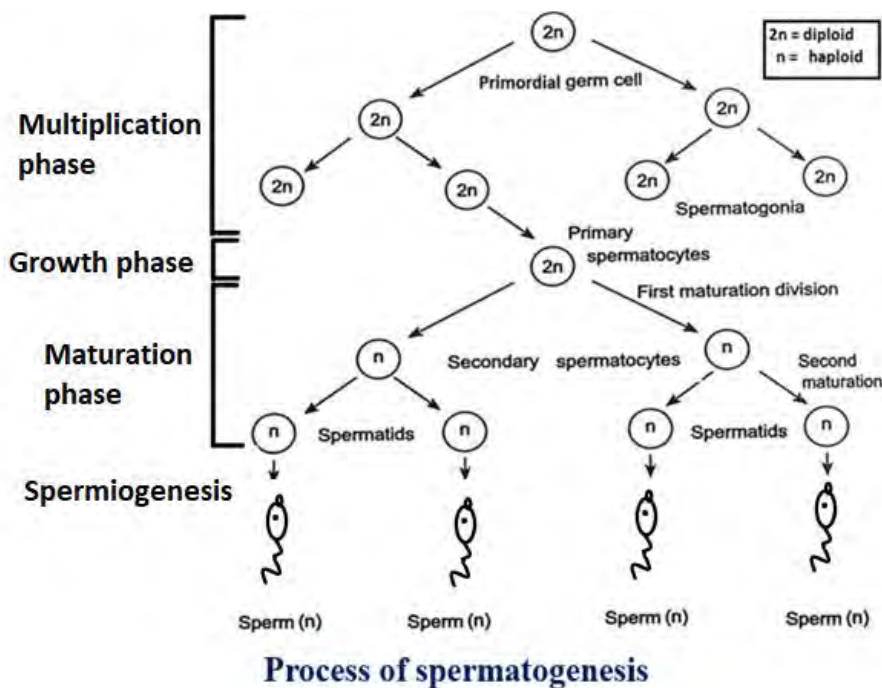
Each spermatogonium grows in size by accumulating nutrients obtained from nursing cells and changes into primary spermatocyte. At this time, DNA replication, protein synthesis also occurs

iii. Maturation phase

In this phase, Primary spermatocyte undergoes meiotic cell division. Meiosis completes in two steps: -Meiosis I and Meiosis II. Meiosis I is called first maturation in which primary spermatocyte divides to produce haploid secondary spermatocytes. Secondary spermatocyte undergoes meiosis II or second maturation to produce spermatids. As a result, four haploid spermatids are produced. Spermatids are spherical precursor cells to mature sperm cells and not fully functional sperm cells, as they lack some structures and capabilities of a mature sperm. Hence, these cells undergo spermiogenesis process to produce motile and functional sperms. Following structural changes in spermatids occurs during spermiogenesis (spermateliosis):

- Tail develops for locomotion
- Acrosome develops from Golgi bodies
- nucleus becomes narrower
- cytoplasm is reduced.

In Frog, Mature sperms are released into the lumen of the semeniferous tubules which are arranged in the form of sperm bundles. Release of sperms into lumen of semeniferous tubule is called Spermiation.



Structure of sperm

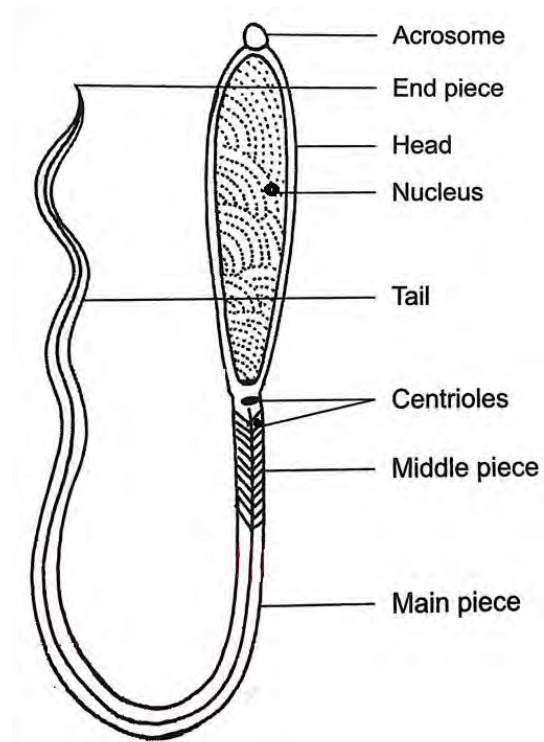
A sperm is a motile and elongated cell that consists of head, middle piece (body) and tail (flagellum).

1. Head:

Head is the broader part that contains smaller haploid nucleus. There is a conical cap-like structure present at its terminal region called acrosome. Acrosome contains sperm lysin (hyaluronidase) enzyme that helps in penetration of the egg membrane during fertilization.

2. Middle piece

It is the middle part of sperm which contains two centrioles (proximal centrioles and distal centrioles) and numerous mitochondria. Proximal centriole has a major role in the initiation of cleavage after the formation of zygote. Distal centriole gives rise to axial filaments. Middle piece is also called energy chamber as it contains mitochondria that provide energy for the movement of sperms.

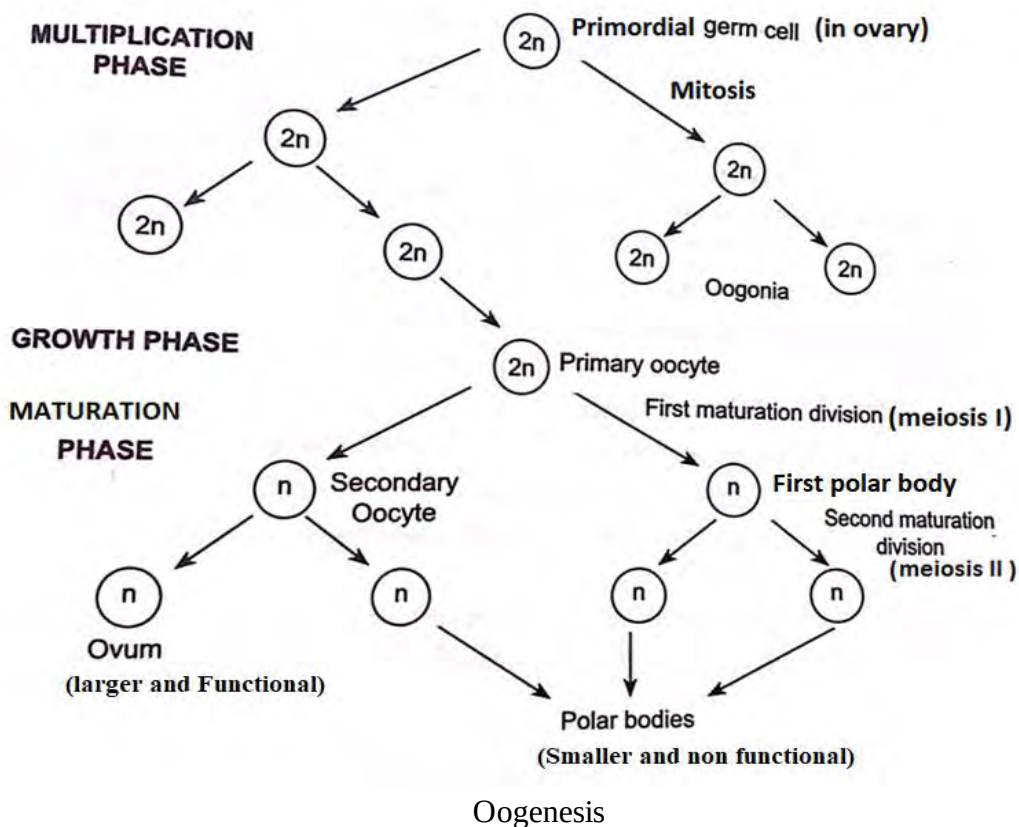


3. Tail

Tail is the posterior whip like, vibratile part of sperm behind middle piece. It is many times longer than the head. Sperms swim with the help of tail in the fluid like medium. Tail contains axial filaments with 9+2 arrangement of microtubules

Oogenesis

In oogenesis, formation of functional and mature female gametes or ova takes place in ovary. Oogenesis occurs under the influence of some hormones such as follicle stimulating hormone (FSH), leutinizing hormone (LH) etc. Like spermatogenesis, oogenesis also involves 3 stages: -



1. Multiplication phase:

Ovary is internally lined by cuboidal epithelial cells called germinal epithelium. Germinal epithelial cells are called primordial germ cells which divide rapidly by mitosis to produce large number of diploid oogonia or egg mother cells.

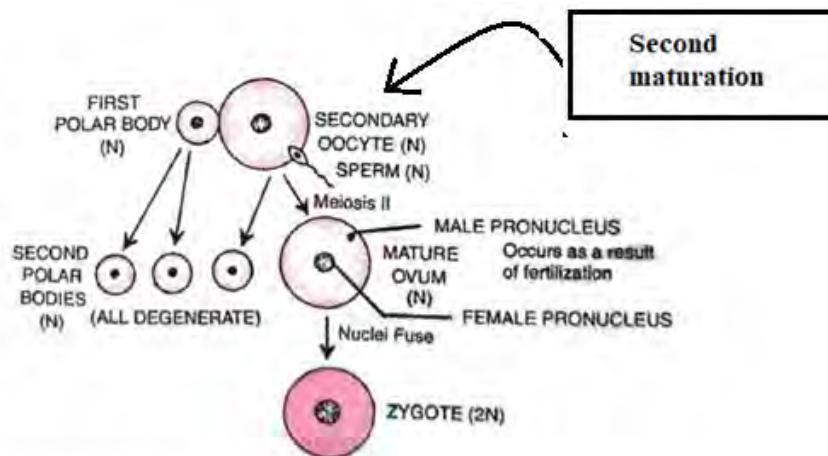
2. Growth phase:

Each oogonium grows by accumulating nutrients, yolk and gets transformed into primary oocyte.

3. Maturation phase:

Now, Primary oocyte undergoes meiosis which consists of meiosis I and meiosis II. Meiosis I is also called first maturation phase and meiosis II is the second maturation phase. In meiosis I, diploid primary oocyte divides to produce two unequal sized haploid daughter cells. Larger one with more cytoplasm is called secondary oocyte and smaller one with little cytoplasm is called polar body (polocyte). In meiosis II, secondary oocyte divides to form a larger ovum and smaller polar body. Polar body may divide again to produce two polar bodies. Thus, each primary oocyte finally produces one functional ovum and 2-3 polar bodies. As the polar bodies don't take part in reproduction, they get degenerated soon.

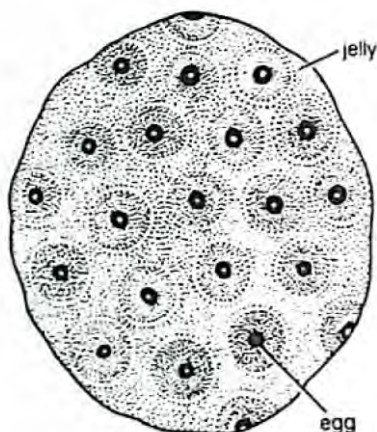
In oogenesis, maturation of secondary oocyte occurs only after the sperm has entered it for fertilization which is shown in the diagram given below.



Fertilization showing second maturation

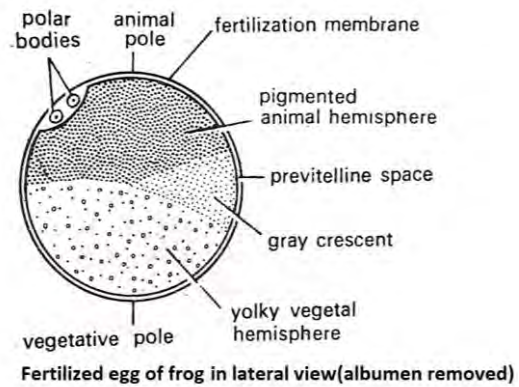
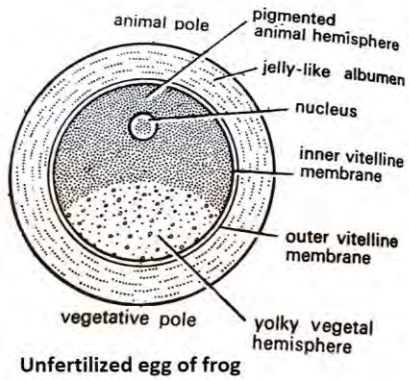
Structure of ovum

Frog lays eggs in the form of secondary oocytes. Each secondary oocyte or unfertilized egg of frog is spherical in shape and measures about 1.75-2mm in diameter. It is non-cleidoic (without hard shell), externally surrounded by double layered vitelline membrane (outer vitelline and inner plasma membrane). Furthermore, there is a thick layer of jelly like albumen around the vitelline membrane. The function of albumen is to protect the egg from desiccation, parasitic infection, protect the embryo, maintain warmth and being distasteful; prevents the egg from being eaten by predator. The ovum consists of two regions: upper half is animal hemisphere and lower half is vegetal hemisphere. Animal hemisphere contains nucleus, black pigmented cytoplasm and other cellular organelles but without yolk. Black pigmentation is due to the presence of some elements like melanin and nickel. Such pigments absorb solar radiation and protect egg and also retain heat energy within. Egg of frog contains moderate amount of yolk called Mesolecithal and yolk is concentrated towards the vegetal pole and called telolecithal egg. Eggs are blackish white in colour; stucked together by jelly like substance and laid in water in the form of spawn.



Spawn of frog

The animal hemisphere of egg is always facing the sun and the vegetal hemisphere containing heavier yolk, is always facing the lower side.

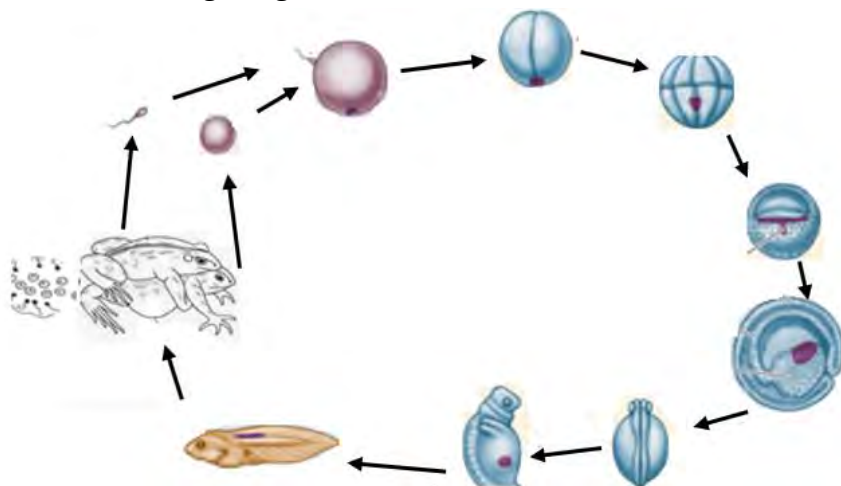


In the fertilized egg of frog, grey crescent is formed opposite to the entry of sperm. Grey crescent is grey coloured crescentic zone formed due to the inward movement of superficial pigments. Grey crescent marks the position of blastopore of future embryo.

Chapter 7.2

DEVELOPMENT OF FROG

Observe the diagram given below and make discussion on following questions

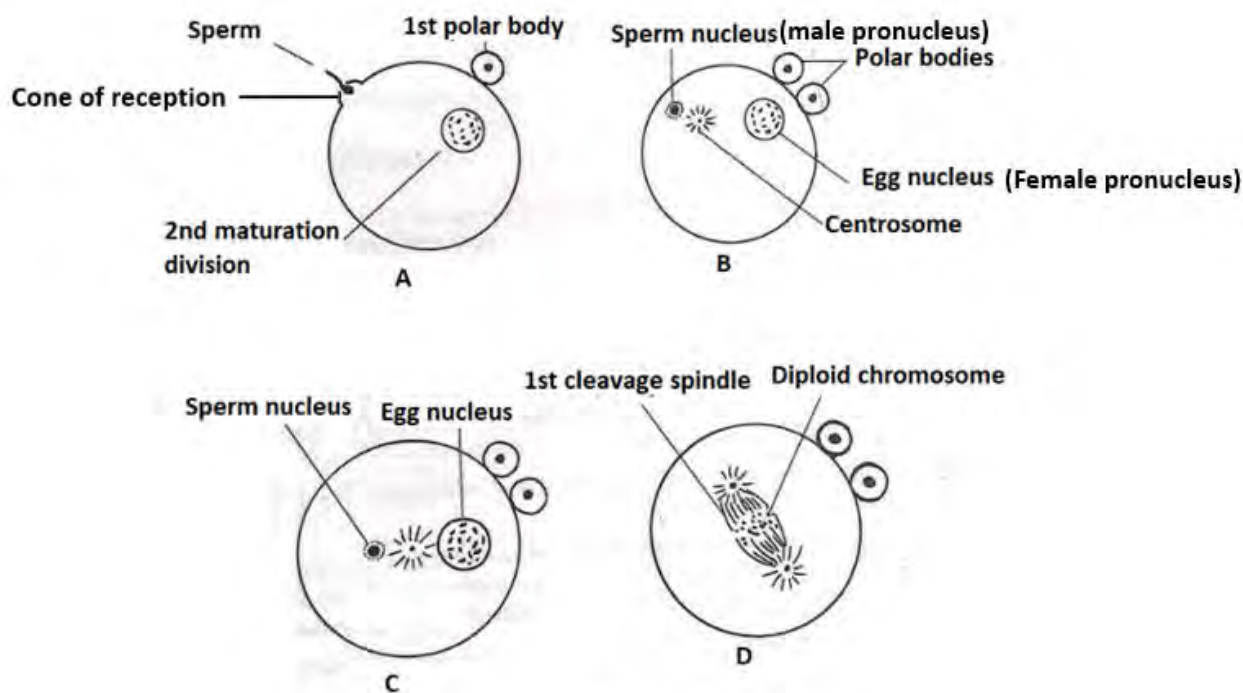


- How does fertilization occur in frog?
- Is frogs' development direct or indirect?
- Do you know the developmental stages of frog?

Process of Fertilization

During breeding season (rainy season) male frog produces a specific sound to attract female frog for mating purpose. Female frog recognizes it and approaches male frog. Male frog mounts upon the back of female and grasp female firmly with the help of nuptial pads developed on its fore limbs. Such a sexual embrace is called amplexus. At the time of amplexus, eggs are laid in the form of secondary oocytes (spawn) through cloaca by female frog. Meanwhile, male frog discharges sperms over the eggs. The process of discharging sperms with seminal fluid over the egg is called insemination. Then, fertilization occurs by the fusion of sperm and ovum.

Fertilization is external that takes place in water. Sperm always enters the egg through animal hemisphere in which head and middle piece enter but tail is left outside. During fertilization, at the contact point of sperm to the egg, vitelline membrane is slightly raised into a small conical papilla like structure called cone of reception or receptive cone. Then, sperm penetrates the vitelline membrane of egg by its cap like structure acrosome that contains proteolytic enzyme; sperm lysin. After the sperm has entered, vitelline membrane becomes thick and impermeable to other sperms and becomes fertilization membrane. Passage of sperm nucleus (now male pronucleus) inside the ovum towards egg nucleus (now female pronucleus) is marked by a dark streak called sperm path or penetration path. Now, these haploid pronuclei get fused to form diploid zygote and restore diploid chromosomal number i.e., 26. After the zygote is formed, centrioles move apart and start forming spindle fibers. Chromosomes of both nuclei are aggregated in the middle to prepare for cleavage.



Process of fertilization

Effects of fertilization

The process of fertilization brings a number of significant changes in the egg of frog. Which are mentioned below:

- Entry of sperm causes maturation of secondary oocyte and formation of second polar body
- Cytoplasm of zygote contract and expel small quantity of fluid to perivitelline space forming thick and tough fertilization membrane.
- Formation of fertilization membrane ensures monospermy. (Sperm lysin can't dissolve fertilization membrane)
- Process of fertilization introduces centriole which is lacking in ovum.
- On the opposite side of sperm entry, there is an inward movement of superficial pigment resulting crescentic area in the animal hemisphere. This region is grey colored instead of normal dark and hence called grey crescent.
- Grey crescent marks the position of dorsal lip of blastopore in the future embryo
- Egg was radially symmetrical before fertilization but appearance of grey crescent makes fertilized egg bilateral symmetrical.

(In adult, grey crescent marks future dorsal surface, animal pole marks future anterior end and vegetal pole marks future posterior end).

Significance of fertilization

- Forms diploid zygote leading to embryonic development
- Introduces centrosomes into ovum
- Prevents polyspermy
- Provides stimulus for the second maturation of unfertilized ovum
- Brings variation

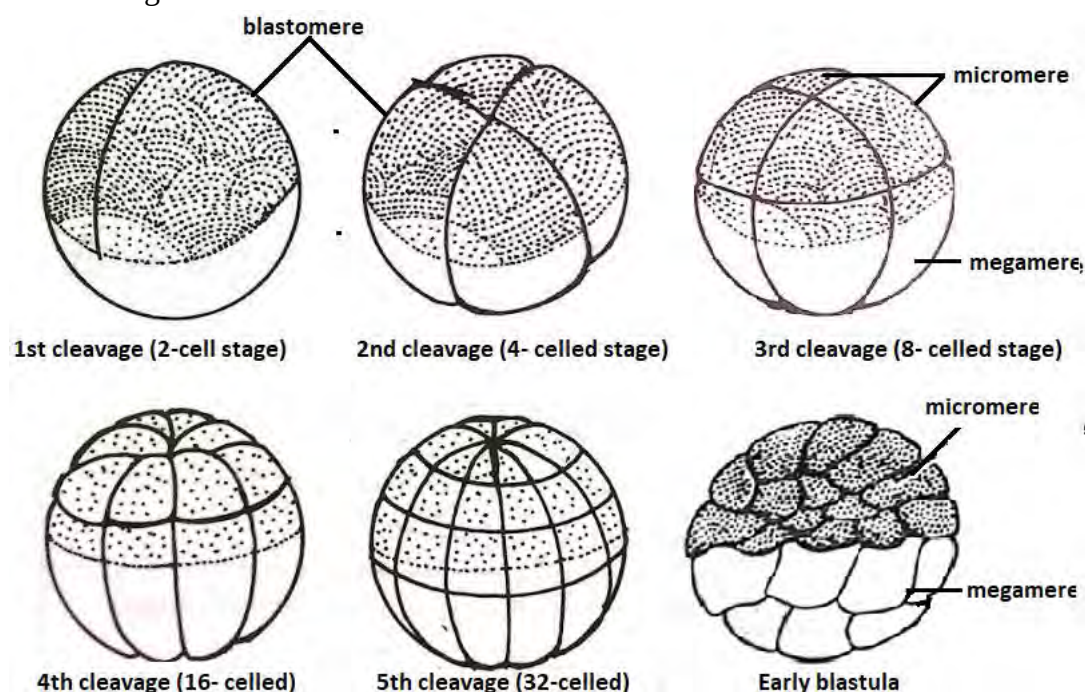
Activity

Create a visual comparison chart of fertilized and unfertilized egg of frog on the chart paper. Write at least six differences between these type of eggs. Also write few similarities.

Cleavage

Cleavage is defined as the repeated mitotic division of zygote to form multicellular embryo. In this process, size of embryo remains same but the number of cells increases. This phenomenon starts in frog after 2-3 hours of fertilization. The type of cleavage in frog is holoblastic and unequal. Holoblastic cleavage means zygote is completely divided from animal pole to vegetal pole into two halves. The sequential event in cleavage of frog is given below:

- First cleavage is meridional (vertical and equal) division along a median longitudinal axis passing from animal pole to vegetal pole of zygote.
- First cleavage results into two similar and symmetrical cells called blastomere and stage is 2-celled stage.
- Second cleavage is also meridional but at right angle to the first cleavage, producing four equal blastomere, 4 celled stages
- Third cleavage is horizontal or latitudinal but a little above the equatorial plane producing 8 unequal blastomere, called 8 celled stage.
- Now the upper four, smaller and pigmented and yolk free cells are called micromere (epiblast) and lower four larger yolk laden cells are called megamere or macromere (hypoblast)
- Fourth cleavage is also meridional (vertical), occurs by two synchronous division forming sixteen celled stage
- Fifth cleavage is horizontal, occurs by two divisions but synchronous, resulting thirty-two celled stage where upper 16 smaller cells are micromeres and lower 16 larger cells are megameres.



Project work

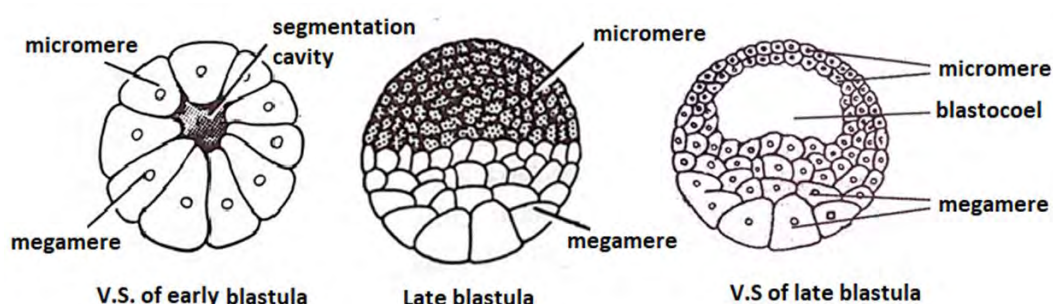
Prepare a model that describes the process of cleavage in frog development using TT balls and marker. Start with zygote and show the division into 2-celled, 4-celled, 8-celled, 16-celled and 32 celled and clearly label each stage on the model.

Morula

The embryo in the form of mulberry shaped solid ball of cells after fifth cleavage (32 celled) is called morula stage and the phenomenon is morulation. It is different from the blastula by the absence of blastocoel.

Blastulation

At the stage, when only 8 cells are present in the embryo, a small central fluid filled space called segmentation cavity starts to appear. This cavity slowly enlarges, leading to the formation of the embryonic stage with the hollow ball of cells called blastula. Such process of formation of blastula is called blastulation. In blastula, yolk free smaller micromeres at the animal hemisphere divide more rapidly but larger yolk laden megameres in the vegetal hemisphere divide slowly as the division is interfered by the yolk. A large hollow cavity is completely formed inside the embryo which is called blastocoel or segmentation cavity. Blastocoel is filled with albuminous fluid which provides nutrition to the developing embryo. Albuminous fluid is composed of carbohydrates, albumen, water etc. and secreted by peripheral cells lining the blastocoel. In a fully formed blastula, blastocoel is a hemispherical cavity entirely present in the animal hemisphere.



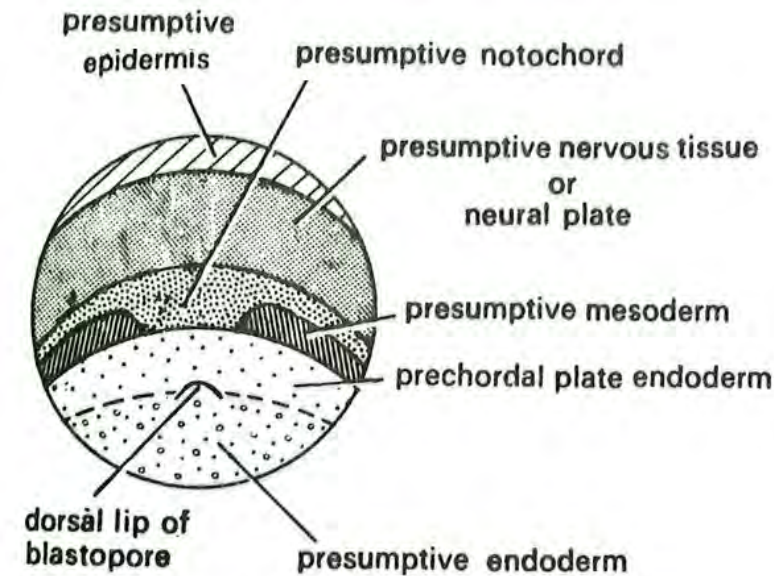
Dome shaped roof of blastocoel consist of numerous black pigmented micromeres but floor is composed of yolk laden larger macromeres. Blastula of frog is also called coeloblastula as multi layered cells are present around the blastocoel. Generally, blastula is called monoblastic or single layered embryo.

Presumptive areas (Fate map) of blastula

In the developing embryo, Presumptive areas or prospective areas are the specific areas in blastula that will give rise to specific tissues and structures in future. In frog, after the observation of blastula by microsurgery and specific stains, following presumptive areas or fate map were found:

- Nearly the whole of pigmented animal or anterior half is presumptive ectoderm which is further divided into presumptive epidermis and presumptive neural plate
- The grey crescent region consists of cells which are destined to become mesoderm and notochord.
- The unpigmented yolky vegetative or posterior half consists of cells that will form endoderm

- A small mid-dorsal part of blastula called the prechordal plate produces endoderm and mesenchyme



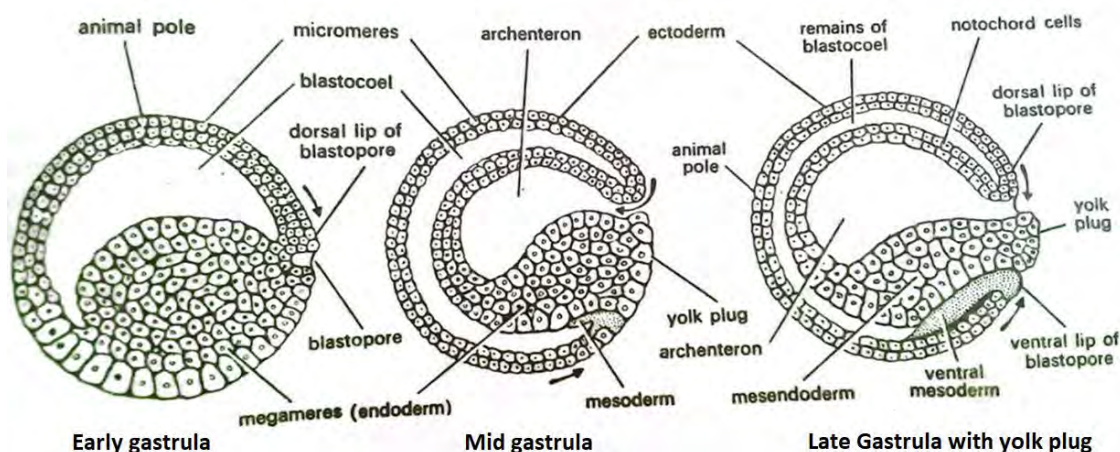
Presumptive area on blastula

Gastrulation

It is the process in which series of changes occurs in embryo transforming blastula into a diploblastic or two layered gastrula. This process involves mass migration (morphogenetic movement) and rearrangement of blastomeres. Prof. Vogt. studied gastrulation in frog by intra-vitum staining of embryo. Major events that occur in gastrulation are:

1. Epiboly:

Micromeres or pigmented cells in the animal pole divide rapidly and spread gradually over the megameres of vegetal pole. Vegetal pole is entirely covered by micromeres except in the region of yolk plug



2. Emboly or invagination

A few blastomeres (endodermal cells), a little behind the grey crescent of blastula get pushed inward to form a crescentic groove or depression. The groove gradually sinks, forming a new cavity called archenteron cavity (future gut). Archenteron opens outside through blastopore (future anus in deuterostomes) which is surrounded by lateral lips, dorsal lip and ventral lip. When archenteron

increases in size, blastocoel gets reduced or obliterated. The floor and side of fully formed archenteron cavity consist of endodermal cells or megameres and the roof consist of chorda-mesodermal cells (chorda cells or notochordal cells)

3. Contraction of lip of blastopore

In this phase, Contraction of the lips of blastopore occurs from all the sides, i.e., dorsal, ventral and lateral, resulting in a narrower and smaller blastopore. This process creates more pressure on the underlying yolky megameres. Consequently, some megameres protrude out in the form of plug through the blastopore and this embryonic stage is yolk plug stage.

4. Involution (rolling in ward)

In this process, migration of micromere from the animal pole towards and along the dorsal lip of the blastopore. The migrated cells lie along the roof of archenteron cavity forming the chorda-mesodermal layer. Similarly, involution of future mesoderm forming cells occurs also from ventral and lateral sides.

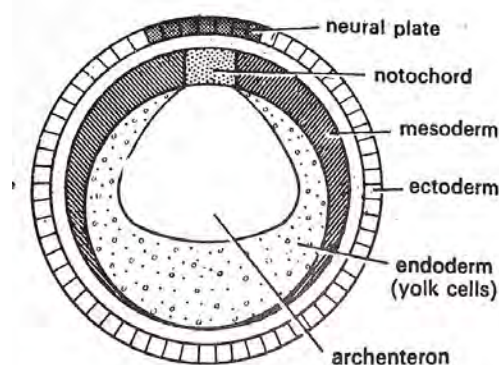
5. Rotation of the embryo

Embryo rotates by 90 degree within fertilization membrane and establish antero-posterior axis, become parallel to the water surface. Animal hemisphere of embryo, now, lies in front and blastopore in the postero-dorsal position. Cause of rotation is due to the shifting of heavier endodermal cell and lying below chorda-mesodermal cells, shifting of blastocoel towards vegetal pole and change of center of gravity of embryo.

Finally, in a complete gastrula, blastocoel completely disappears and embryo at this stage is diploblastic with ectoderm and meso - endoderm.

Formation of primary germ layers and their fate

After the completion of the gastrula stage, further development in the embryo proceeds and develops into a three-layered embryo. Outer layer of micromeres forms ectoderm and inner layer of megameres forms endoderm. Chordamesoderm further proliferates and megameres also contribute to the formation of middle sheet or mesoderm in between ectoderm and endoderm.



Frog. Gastrula in T. S. showing three primary germinal layers.

Fate of germinal layers

Each germ layer will give rise to the particular structures or organ in the developing embryo called the fate of germ layers. Germ layers have predetermined role in the development of entire body of an animal. In frog, fate of germ layers is listed in the table below:

Primary ectoderm	Primary mesoderm	Primary endoderm
• Epidermis and cutaneous gland • Epithelium of conjunctiva • Olfactory and auditory organs • Lining of cloaca and mouth cavity • Lens cornea and retina • Brain and spinal cord • The ganglion cells • Infundibulum • Pineal body • Pituitary gland • Enamel of teeth	• Notochord • Pericardium and peritoneum • Voluntary and involuntary muscles • Cartilage and bone • All connective tissue (ligaments, adipose tissue etc.) • Blood, blood vessels • Dermis of skin • Vascular, excretory and reproductive system • Medullary sheath, neurilemma, neuroglia of brain and spinal cord • Spleen • Sclera and choroid of eye	• Mucosa of alimentary canal • Gastric and intestinal gland • Liver, pancreas, bile duct and pancreatic duct • Pharynx, eustachian tube, tonsils, thymus, thyroid gland • Larynx, trachea, lungs • Lining of urinary bladder

Importance of gastrulation

- Germ layer formation
- Body axis established
- Cell movement and morphogenesis
- Induction of organ development
- Establishment of notochord and neural tube
- Cell fate determination

Activity

Paste several organ cards (provided by your teacher or friends) on a germ layer board prepared from chart paper and discuss on it

Organogenesis

It is the process of formation of different organs and tissues from the germ layers: ectoderm, mesoderm and endoderm.

1. Neurulation or neurogenesis (formation of neural tube)

The process of formation of nerve cord or neural tube from the ectoderm in embryo is called neurulation. The sequential events that occur during neurulation are:

- The ectodermal cells of presumptive neural plate area thicken to form mid-dorsal neural plate.
- An open midline depression appears in the neural plate called neural groove.

- iii. At the same time, either side of the neural groove or neural plate raises up as neural folds (ridges).
- iv. Neural groove further sinks down
- v. Finally, neural folds grow to meet and fuse with each other in the middle.
- vi. Now, the open neural groove is changed into a closed neural tube, gets separated from the ectoderm and remains below it
- vii. Anterior and posterior ends of the neural tube are open for a short time, which become closed very soon.
- viii. Anterior wider part of neural tube forms brain and posterior region develops into spinal cord
- ix. The hollow cavity of neural tube is called neurocoel, develops as cavities of brain and spinal cord

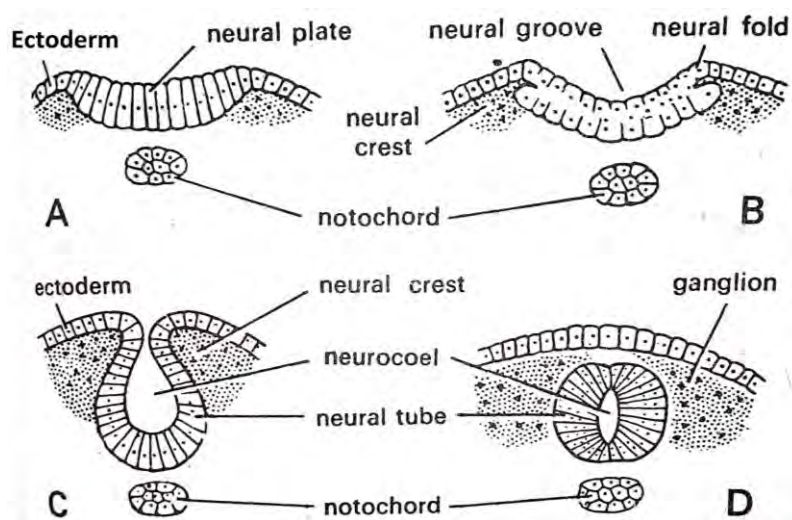


Figure: Neurogenesis and notogenesis

2. Notogenesis or notochord formation:

Notochord is the flexible, gelatinous, supporting rod like structure found in embryos of all chordates. In vertebrates, it is replaced by vertebral column. The process of formation of notochord is called notogenesis. It is mesodermal in origin. Notochord formation in frog takes place by following ways:

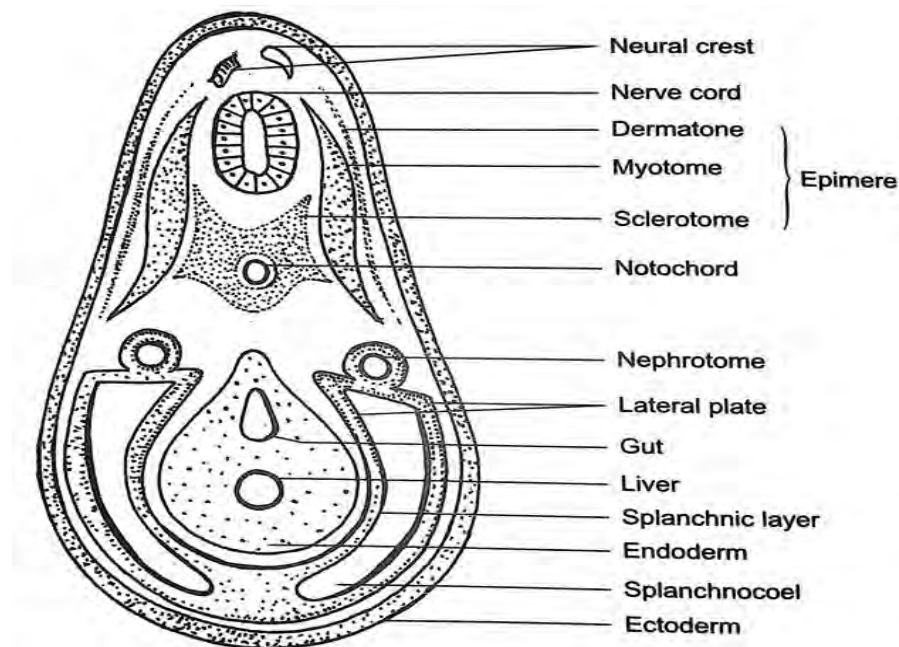
- i. The chorda cells lying in the mid dorsal region of roof of archenteron, separates from adjacent mesodermal cells.
- ii. These cells form cylindrical rod like structure called notochord, below the neural plate.
- iii. Notochord consists of characteristic vacuolated cells.
- iv. A double layered sheath is developed around the notochord, called notochordal sheath.
- v. Notochord forms the primary axial support of the embryo

3. Coelom formation

Coelom is the space or cavity lying between body wall and gut. It is formed by splitting of mesoderm in frog, hence the coelom is true and also called schizocoel. The process of formation of coelom in frog can be summarized under following points:

- i. Hypomere (lateral plate mesoderm) splits to form outer somatic (parietal) layer and inner splanchnic (visceral) layer
- ii. A small cavity is formed between these two layer is called splanchnocoel which is the beginning of coelom.

- iii. The cavity extends downwards to fuse with that of the other side.
- iv. The splanchnocoel of both side unite mid-ventrally below the gut to form U- shaped cavity
- v. Somatic layer unites with the ectoderm to form somatopleure or body wall
- vi. Visceral layer unites with the endoderm to form splanchnopleure or gut wall.



Coelom formation

- vii. The most dorsal and thick mesoderm closer to notochord is called epimere.
- viii. While forming mesodermal somite from epimere, also forms myocoel (a narrow cavity)
- ix. Myocoel appears in each mesodermal somite which itself differentiates into 3 parts:
 - outer thin dermatome: becomes dermis
 - middle thick myotome: develops into muscles
 - inner thin sclerotome: contributes to vertebral portion of skeleton

Project work

Prepare a model about the formation of coelom from the mesoderm from locally available materials.

Exercise

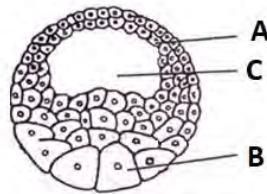
Choose the best alternative

1. What is the final product of spermatogenesis?
 - a. A viable sperm
 - b. Four sperms
 - c. four viable eggs
 - d. A sperm and three polar bodies
2. In which body organ does gametogenesis occur?
 - a. Liver
 - b. Gonads
 - c. kidney
 - d. Heart
3. What is the main function of acrosome in the sperm of frog?
 - a. To provide energy for movement
 - b. Storing genetic material
 - c. Nourishing sperms
 - d. To penetrate egg
4. Which part of the egg in frog contains yolk?
 - a. Animal pole
 - b. Perivitelline space
 - c. Vegetal pole
 - d. Albuminous layer
5. Which of the following hormone stimulate ovulation in frog?
 - a. Oestrogen
 - b. Progesterone
 - c. Testosterone
 - d. Leutinizing hormone
6. Which of the following structure surrounds the developing oocytes of frog?
 - a. Sertoli cells
 - b. Chorion
 - c. Follicular cells
 - d. Corpus luteum
7. What triggers the completion oogenesis in frog?
 - a. Hormonal changes
 - b. Male croaking sound
 - c. Cleavage
 - d. Entry of sperm into egg
8. What does the formation of grey crescent signify in frog's fertilization?
 - a. Site of sperm entry
 - b. Makes embryo asymmetrical
 - c. Marks the position of dorsal lip of blastopore
 - d. Involves the formation of blastocoel
9. Which of the following describes role of blastocoel in the blastula stage of development?
 - a. It is the site where ectoderm forms.
 - b. It is the cavity filled with yolk
 - c. The fluid filled cavity which provides space for cell differentiation and development.
 - d. It is the place where neural tube forms
10. What is the major event of epiboly of frog gastrulation?
 - a. Mesodermal cell moves inward to form archenteron
 - b. Ectodermal cells spread to cover the entire surface of embryo
 - c. Cell of endoderm involute to form yolk plug
 - d. Dorsal lip of blastopore form.

11. When the embryo of frog is exposed to a chemical that inhibits signaling molecules involved in the formation of mesoderm. What effect would this likely have on coelom formation in the embryo?
- The embryo would form an ectodermal coelom instead of a mesodermal coelom.
 - The mesoderm would fail to develop, and the embryo would lack a coelom.
 - The coelom would form normally, but the mesoderm would remain undifferentiated.
 - The embryo would form an expanded coelom but with defects in the organ systems.

Answer the following question in brief.

- What is spermatogenesis? Describe it with a chart.
- How does oogenesis occur in frog? Describe briefly
- Identify figure A and B. write any four differences between A and B.
- Describe the entire process of cleavage in frog with diagrams.
- In the development of frog, an embryonic stage appears with a fluid filled cavity. What is this stage called? Describe briefly about its formation.
- What is gastrulation? What are the major events of gastrulation? Describe
- Which germ layer contribute to the formation of nervous system in amphibians? Describe the process involved in the formation of neural tube.
- What is schizocoel? How is it formed? Describe the entire process.
- Observe the given diagram and answer the following question.



- Which embryonic stage is shown?
- Label A, B and C.
- Write any two differences between A and B.

Unit 8

HUMAN BIOLOGY



William
Beaumont
(1785-1853)

William Beaumont (1785-1853) was an American army surgeon who pioneered the research on human digestive system by observing the process of digestion in the stomach. He gained popularity through his experiment on Alexis St. Martin, a patient with a stomach wound that left an opening. He observed digestion in real time through the opening. He discovered how chemical digestion occurs in the stomach with the help of gastric juice. This work laid the foundation of modern digestive physiology and he is well known as the father of gastric physiology.

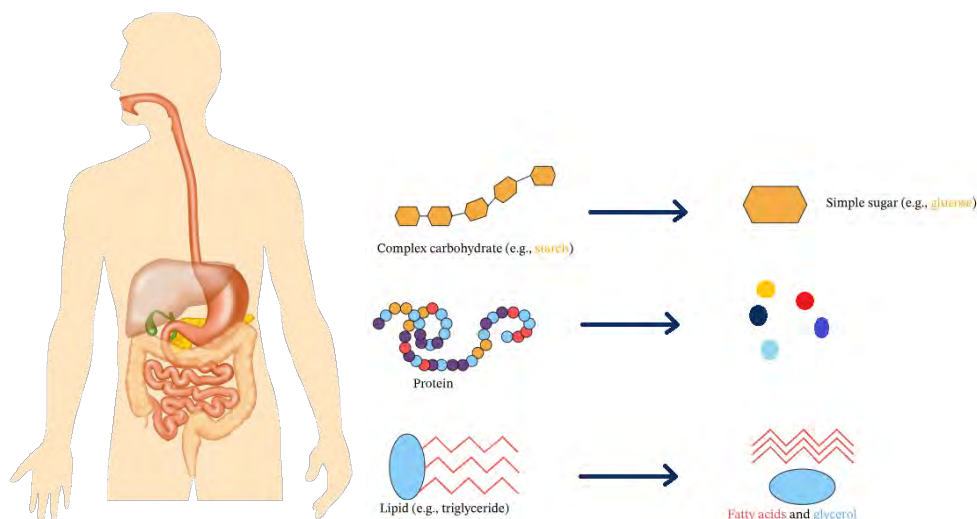
Chapter 8.1

DIGESTIVE SYSTEM

On the basis of given context, answer the following questions.

Imagine that there is a big family feast which you are enjoying at your home. You ate a variety of food like pulau or plain rice, naan bread, chicken curry, omlette, green vegetables etc. and sweets as dessert. Afterwards, you feel heavy or satiated and sleepy.

- Have you ever wondered how your body digest such food?
- What happens to rice, bread, sweets once they enter mouth?
- What happens to omelette and chicken curry?
- You feel energized after eating? why?



- How do you think digestive system is interrelated with other systems of your body?

Nutrition is the process of obtaining substances by living beings for their growth development and to meet energy needs. Food is the substance which is taken in to supply nutritive elements or nutrients. Nutrients are the chemical substance present in the food. They are essential for growth repair of tissues producing gametes, protection from diseases and energy. Nutrients are classified as organic nutrients and inorganic nutrients. Organic nutrients are carbohydrates, lipid, protein and vitamins whereas inorganic nutrients are minerals and water.

Some nutrients such as carbohydrate protein and fat cannot be utilized by our body directly in the form that we take. They should be converted or broken down into simpler and diffusible forms and the process is digestion. Hence, digestion is the catabolic process of conversion of complex food particles into simpler and absorbable forms. Organ system involved in this process constitutes digestive system. Digestion occurs by two processes: mechanical and chemical. Mechanical process is the conversion of larger food particles into smaller or fine state so that various enzymes can easily act on it. Chemical process is the conversion of complex organic compounds in the food into simpler diffusible forms such as starch to glucose, protein to amino acid etc. in the presence of enzymes.

Broadly, Digestive system can be defined as the assemblage of organs associated with the ingestion of food, digestion, absorption, assimilation and egestion of undigested food particles in the form of faeces.

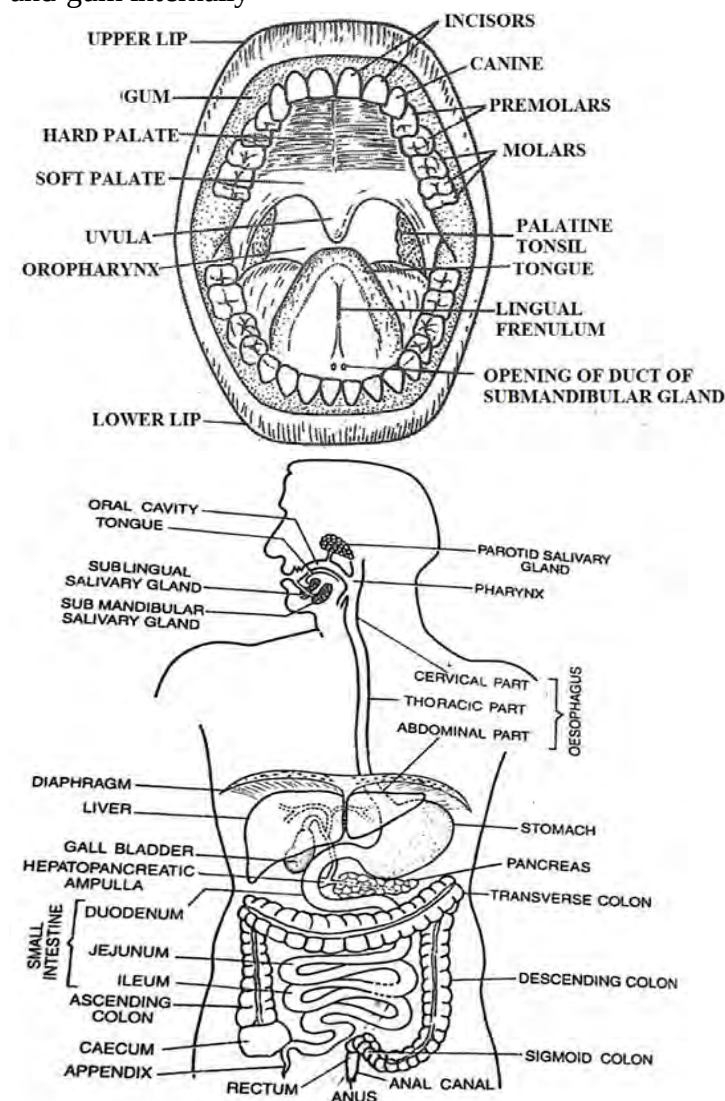
Human digestive system consists of alimentary canal, associated digestive glands and physiology of digestion. Alimentary canal is a long, coiled and complete tube of variable diameter extending from mouth to anus. measures 9-10 m length. It consists of following parts:

1. Mouth

Mouth is the first part of the alimentary canal lying just below the nose. It is a transverse opening bounded by two movable lips; upper lip and lower lip. It helps in ingesting food.

2. Vestibule

Mouth leads into a narrow space called vestibule lying between lips and cheeks externally and teeth and gum internally



Human alimentary canal

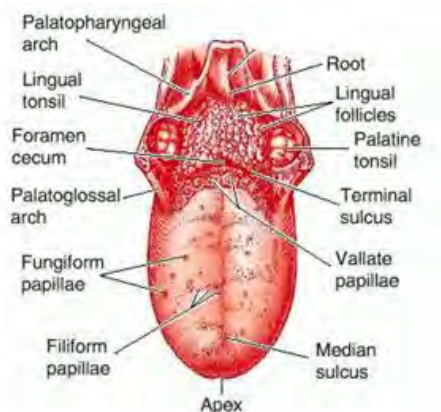
3. Buccal cavity or oral cavity:

Vestibule opens into a large, spacious cavity called buccal cavity which is internally lined by stratified squamous epithelium. It consists of three parts:

Palate: It is the roof of the buccal cavity which is formed by palatine bone and maxilla. The entire surface of palate can be divided into anterior hard palate and posterior soft palate. The hard palate is arched and bears transverse ridges called palatine rugae whereas posterior soft palate is smooth and fleshy and it helps in swallowing of food smoothly and easily. There is a small conical muscular structure hanging from hinder part of soft palate called uvula or velum palati. Uvula prevents the entry of food into the nasal chamber through internal nostrils from oral cavity during swallowing.

b. Tongue

- Tongue is the triangular, protrusible and flat muscular organ on the floor of buccal cavity. It is composed of striated muscle and attached to the floor of oral cavity by a mucosal strand called lingual frenulum. The anterior part of tongue is free but posteriorly attached to the hyoid and mandible. The upper surface of the tongue is unequally divided into anterior oral surface and posterior pharyngeal surface by an inverted V shaped groove called terminal sulcus. Similarly, upper surface of tongue is rough and provided with small elevations called papillae. The specific cells found in the papillae of tongue are taste buds which detect taste.



In human tongue there are three types of papillae namely circumvallate papillae, filiform papillae and fungiform papillae.

Circumvallate: These papillae are situated at the basal region of tongue. They are 7-12 in number and are large sized with many taste buds.

Filiform: they are more numerous, filamentous, smallest papillae occupying anterior 2/3 part of tongue. These papillae are without taste buds.

Fungiform: these papillae are located at the edge and tip of the tongue. Fungiform papilla mushroom head like, more numerous than vallate. they are with taste buds.

Do you know?

Foliate papillae are absent in human but found in rabbit on the posterolateral side of the tongue.

Two types of glands present in the tongue are Ebner's glands and Weber's gland which secrete lipase and mucus respectively.

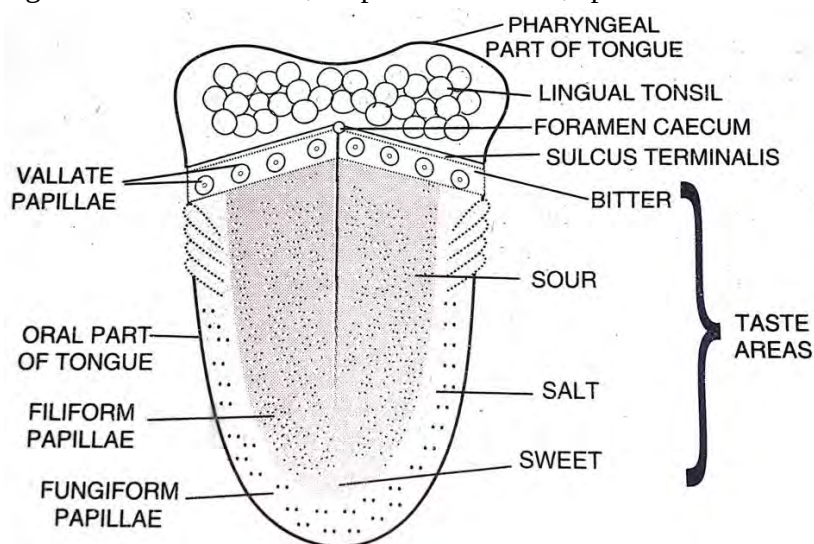
Tongue detects all five basic tastes such as sweet, salt, sour, bitter and umami. Sweet taste is detected by the tip of tongue. Lateral side of the tongue towards the front detects sour taste and

towards the back detect salt taste, posterior side of the tongue detect bitter taste. Except the very middle, all parts of tongue can detect umami (savory) taste.

Do you Know?

Chili is not a taste. It is a burning sensation or spiciness while chewing chilli peppers which is due to a chemical called capaicin. TRPV1 receptor cells present in the mouth respond to this chemical.

Functions of tongue are to detect taste, help in mastication, speech and in swallowing food.



Teeth:

Teeth are the hard structures of ecto-mesodermal origin, found in both jaws. Human teeth are thecodont (teeth embedded in sockets), diphyodont (two sets of teeth erupt in the life span) and heterodont (different shape and sized teeth). First set of teeth in child is called milk teeth or deciduous teeth which are replaced by permanent teeth in the age of about 6-18 years. Wisdom teeth erupt after the age of 20.

On the basis of shape, teeth are of four types: incisor, canine, premolar and molar. Incisor teeth have sharp edges and used for cutting and biting food. Canine teeth are dagger shaped and have pointed sharp edge for tearing and piercing. premolars and molar teeth are with many cusp for crushing and grinding the food particles. Premolars have one or two roots whereas upper molars have three roots and lower molars have two roots.

Dental formula: $\frac{2.12.3}{2.1.2.3}$ (for adults) or $I \frac{2}{2}, C \frac{1}{1}, PM \frac{2}{2}, M \frac{3}{3} \times 2 = 32$

$\frac{2.1.0.2}{2.1.0.2}$ (for children) or $I \frac{2}{2}, C \frac{1}{1}, PM \frac{0}{0}, M \frac{2}{2} \times 2 = 20$

Structure of human tooth

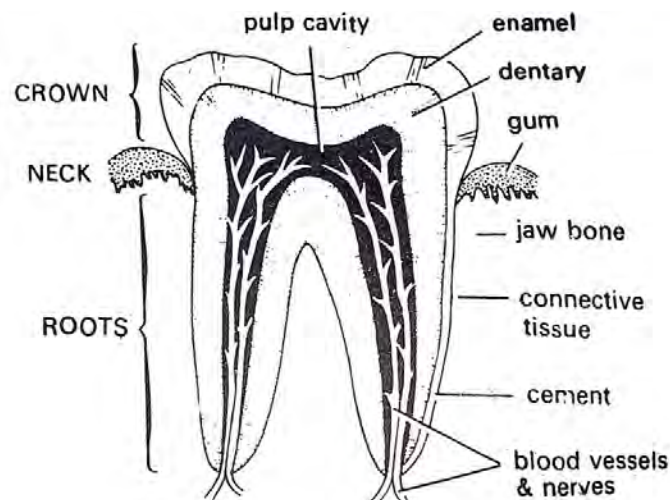
L.S. of human tooth shows 3 distinct regions: crown, neck and root:

i. Crown:

It is the upper exposed glistening part projecting above the gum out of jaw bone. Crown is enamel coated part where enamel is secreted by ameloblast cells. The bulk of tooth is composed of dentine or ivory secreted by odontoblast cells.

ii. Neck:

This is a short part lying between crown and root inside the gum.

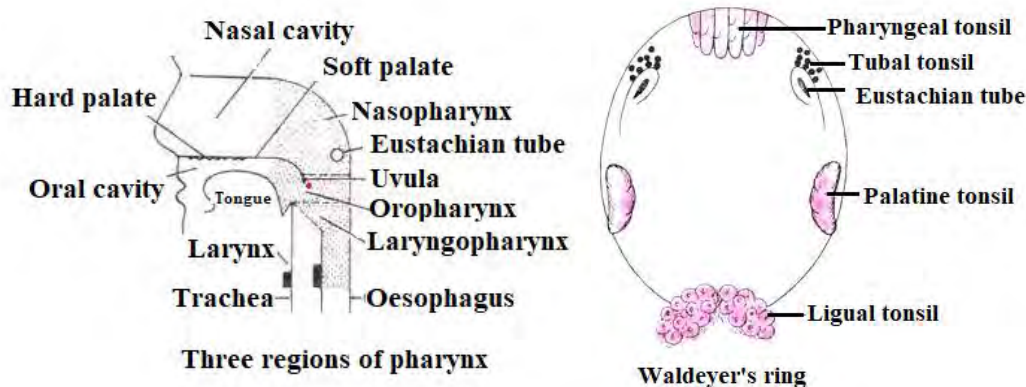


iii. Root

Root is covered and fixed to a jaw bone by a layer of cement and and vascular periodontal membrane. In the centre of tooth lies a narrow pulp cavity which is filled with loose connective tissue, blood vessels, nerves and odontoblast cells.

4. Pharynx

Pharynx is a short vertical tube of 12cm lying behind the buccal cavity which serves as the common passage for food and air. Pharynx is incompletely divided into three regions: upper nasopharynx, middle oropharynx and lower laryngopharynx. Internal nostrils and eustachian tube from middle ear open into nasopharynx. Through the oropharynx, food and air pass down. Laryngopharynx leads into wind pipe (trachea) and food pipe (oesophagus) through the openings called glottis and gullet respectively.



There is a flap of fibroelastic cartilage which guards glottis called epiglottis and the function of epiglottis is to prevent passing of food towards the respiratory tract. Many patches of lymphoid tissue are found in the pharyngeal region such as lingual tonsil, palatine tonsil, Pharyngeal tonsil (nasopharyngeal and tubal tonsil). A group of tonsils guarding oropharynx and nasopharynx in the form of ring is called waldeyer's ring.

5. Oesophagus:

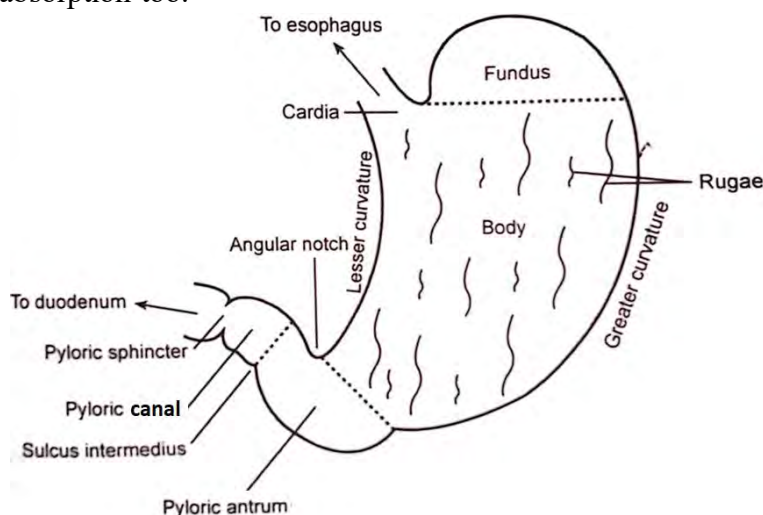
Oesophagus is a long narrow muscular tube of 25 cm length and it pierces diaphragm at the level of hiatus or 10th thoracic vertebra. The opening of oesophagus to the stomach is called cardiac orifice which is guarded by cardiac sphincter (checks back flow of food). The round balls of food that

move down through the oesophagus by peristalsis is called bolus. Peristalsis is the characteristic movement of alimentary canal brought about by the rhythmic contraction and relaxation of smooth muscles. Outermost layer of oesophagus is not serosa but a fibrous layer called tunica adventitia as it lies outside of coelom. Oesophagus is internally lined by non-keratinized stratified squamous epithelium. Similarly, inner wall (mucosa) of oesophagus also consists of many longitudinal folds, making it distensible. Goblet cells are found throughout the mucosa but lacks digestive gland.

6. Stomach:

Stomach is the most dilated, distensible, J shaped and hollow muscular bag like structure. It is placed obliquely below the diaphragm in abdominal cavity on the left side. Stomach is attached with the dorsal body wall by mesogaster (during embryonic development). It measures 30 cm length and 15 cm width. The Inner concave surface of stomach is called lesser curvature and outer convex surface is called greater curvature. There is a large apron like peritoneal fold which attaches to the greater curvature of stomach is called greater omentum (also stores fat), cover the intestine anteriorly.

Greater omentum is often called ‘the policeman of abdomen’ as it localize infections within abdomen. Stomach is divided into 4 regions: cardia, fundus, body and pyloric. Cardiac is the narrow upper part into which the oesophagus opens and guarded by cardiac sphincter. Fundus is the dome like proximal part of stomach and contains some gases. Body or corpus is the middle region of stomach containing longitudinal folds called gastric rugae. Pyloric part is the distal narrow and tubular part consisting of wider pyloric antrum and narrow pyloric canal. The mucosa layer of stomach contains gastric glands which consist of multicellular peptic glands, unicellular oxyntic cells, and goblet cells. Stomach functions as storage and mastication and partially involved in digestion and absorption too.



Do you know?

Castle's intrinsic factor is a glycoprotein secreted by oxyntic cells in the stomach that helps in Vitamin B12 absorption from ileum.

7. Small intestine

Small intestine is a long narrow and convoluted muscular tube-like structure of about 6.5m length, it is held in position by mesenteries. The entire inner wall of small intestine has circular folds of

mucous membrane called plicae circulares (valves of kerkring). Small intestine consists of three parts: duodenum, jejunum and ileum.

i. Duodenum

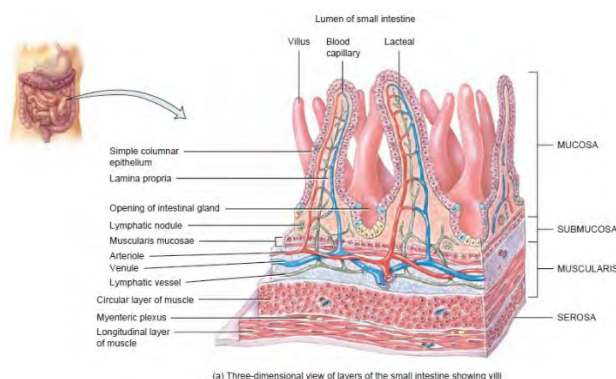
Duodenum is first, C-shaped and shortest part of small intestine and measures about 30 cm length. This part receives bile juice from liver and pancreatic juice from pancreas through hepatopancreatic duct or ampulla of Vater. The opening of hepatopancreatic duct to the duodenum is guarded by sphincter of Oddi. Glands on the inner wall of duodenum are crypts of lieberkuhn and brunners gland. Crypts of lieberkuhn is simple tubular gland whereas brunners gland is branched tubular gland. Duodenum is the major site of digestion and provided with leaf like villi.

ii. Jejunum:

It is the middle part of small intestine of 2.5 m length. Its wall is thicker and highly vascularized than ileum. Jejunum serves as the passage of food.

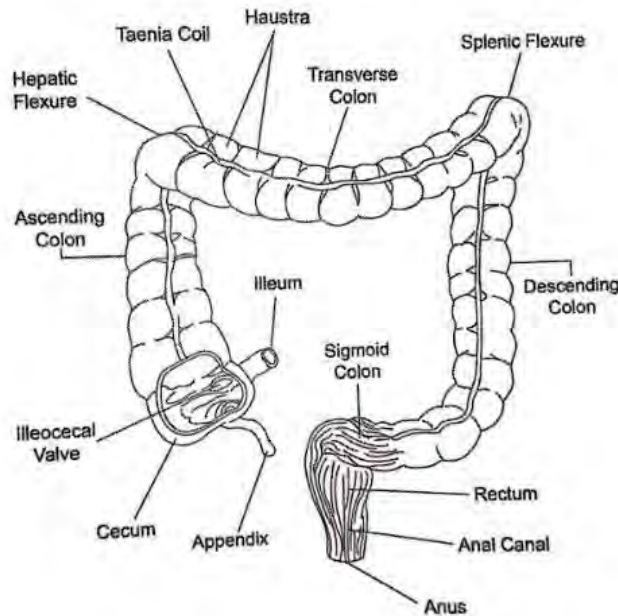
ii. Ileum

This part is the longest and much convoluted part of small intestine, measuring about 3.5 m length. The inner lining of its wall is thrown into numerous finger like vascularized folds called villi. It is the main site of the absorption of digested food. Lining absorptive cells are with microvilli called brush-bordered epithelium. Small nodules of white lymphoid tissue found in the ileum are payer's patches (MALT) which consists of phagocytic cells. Payer's patches are also called intestinal tonsil. Ileum opens into the caecum of large intestine through ileo-caecal opening guarded by ileo-caecal valve.



8. Large intestine

Small intestine finally leads into a wide muscular tube of about 1.5 m long, called large intestine. This part is without villi and microvilli. It is mainly involved in the absorption of water, temporary storage and discharge of undigested food particle in the form of faeces or stools. large intestine consists of 3 parts: caecum, colon and rectum.



Caecum:

It is a small blind and dilated sac that receives ileum of small intestine through ileo-caecal opening guarded by ileocaecal valve. There is a small slender worm like projection arising from caecum is called vermiform appendix which is believed to function as lymphoid tissue.

Colon

The middle and inverted U-shaped part of large intestine is called colon. It can be divided into four parts: Ascending colon, transverse colon, descending colon and sigmoid colon.

The small sacculations or pouches found in the colon which gives segmented appearance to the colon are called haustra. Three horizontal bands of smooth muscle found throughout the entire length of colon are teniae coli. In the colon inhabits a bacteria called *E. coli* which is a normal gut flora, synthesizing vitamin K and some other B vitamins.

Rectum

Rectum is the last part of large intestine which is of about 15cm length. It is a slightly dilated sac, with inner longitudinal folds and large blood vessels. This part stores faeces till defaecation.

9. Anal canal and anus

Rectum lead finally into a canal of about 2-4 cm length called anal canal. This canal internally contains about 6-12 longitudinal folds called anal column. Anal canal opens exteriorly by an opening called anus, situated between buttocks. Anal canal is also guarded by two sphincters called Internal anal sphincter (involuntary) and external anal sphincter (voluntary).

Activity

Create a powerpoint presentation on the alimentary canal of human being and present it in the class.

Associated digestive glands

1. Salivary glands:

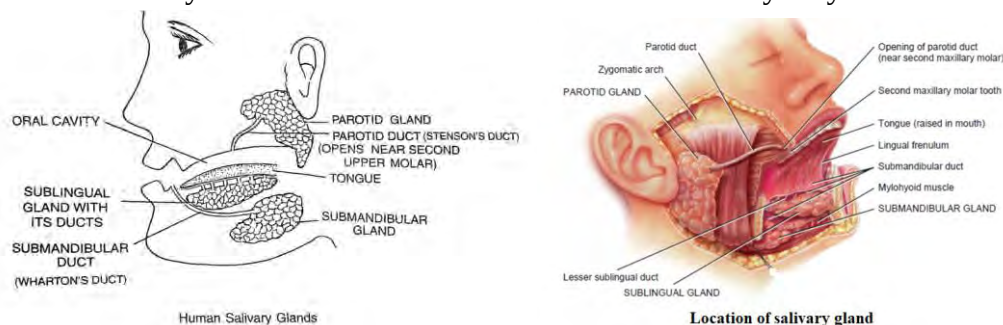
Salivary glands are found inside buccal cavity, produce saliva which is drained through ducts. There are altogether three pairs of salivary glands found in human:

Parotid salivary gland

Parotid salivary glands are the largest salivary glands situated near the ears. The duct of parotid salivary gland is called Stensen's duct which open into the vestibule region opposite to upper second molar teeth. These glands contribute 25% of total saliva. Their secretion contains maximum salivary amylase. Viral infection in parotid gland causes mumps.

Sublingual salivary gland

These glands are the smallest salivary glands lying beneath the tongue and their ducts are called ducts of Rivinus. They contribute 5% of total saliva. Sublingual salivary glands open into the floor of buccal cavity. Their secretion contains mucus and salivary amylase.



iii. Sub-mandibular salivary gland

They are medium sized salivary glands, situated at the angle of lower jaw under the tongue. They discharge their secretion through the duct, called Wharton's duct. These glands contribute 70 % of total saliva volume which contain amylase and mucus.

Saliva

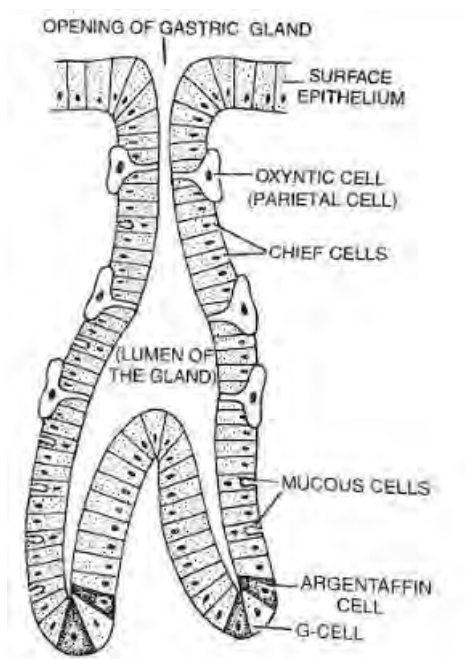
Saliva is the secretion of salivary glands which is viscous, colourless and cloudy fluid of slightly acidic nature (pH 6.8). About 1-1.5 liter of saliva is secreted per day. Saliva contains water, some electrolytes (Na^+ , K^+ , Cl^- , HCO_3^-), salivary amylase, lysozyme (antibacterial), lingual lipase, mucus, immunoglobulin etc.

Functions

- i. It moistens food and facilitates in swallowing,
- ii. It keeps oral cavity clean
- i. The antibacterial enzyme i.e lysozyme in saliva kills microbes.
- ii. Saliva contains some digestive enzymes such as salivary amylase and lingual lipase which Initiates digestion of starch and lipid.

2. Gastric glands

- Gastric glands consist of numerous, microscopic, branched tubular glands formed by the inner lining or mucosa of stomach. Secretion is called gastric juice. Three different types of cells found in the gastric gland are chief cells, oxyntic cells and goblet cells. The function of chief cells is to secrete pro-enzymes such as pepsinogen and prorenin (only in infants) and small amount of gastric lipase and amylase. Oxyntic cells secrete hydrochloric acid (HCl) and goblet cells secrete mucus that forms protective coat on the inner wall (mucosa) of stomach and protect from the effect of HCl. Gastric gland also contains argentaffin cells (entero-endocrine gland) which further consists of G-cells, secrete gastrin hormone.



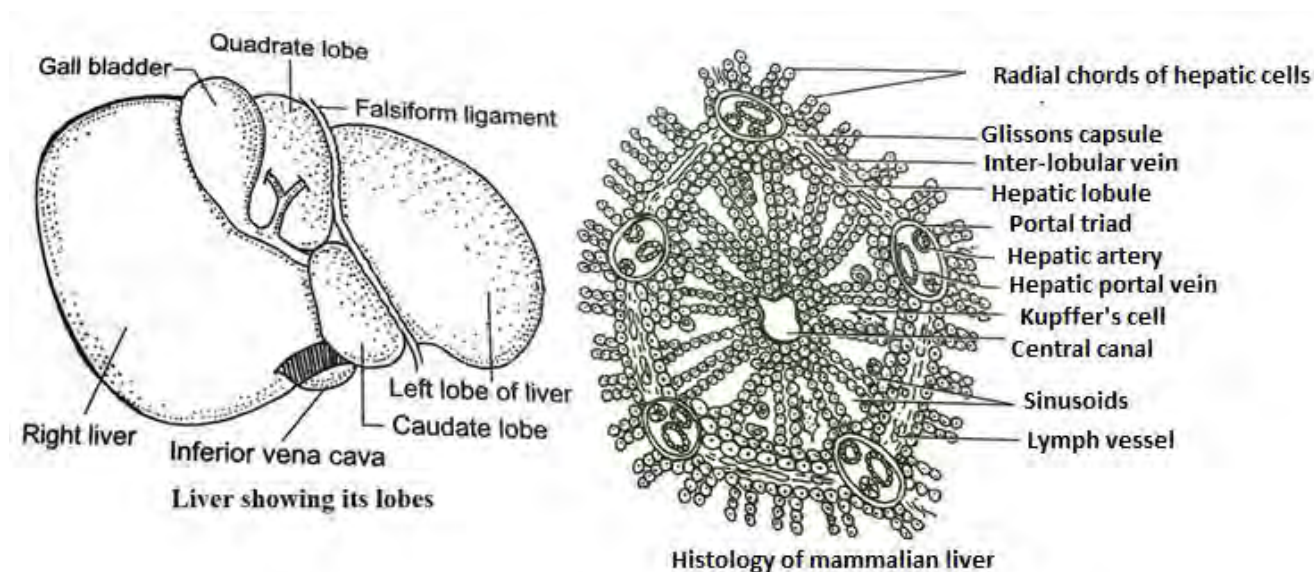
Gastric juice

Gastric juice is a thin, transparent or light coloured liquid that contains mucus, HCl and digestive enzymes such as pepsinogen, prorenin (in infants only), gastric lipase, gastric amylase. Secretion of gastric juice is about 2-3 litre/day. pH of gastric juice is about 2.5 in adult and 5 in infants.

Function of this juice is to make food acidic for the activation of pro-enzymes, destroy microbes in food, digest bones, make the food slippery.

3. Liver

Liver is the largest gland or visceral organ of reddish-brown color, on the right side of abdominal cavity just below the diaphragm. It weighs about 1.5 kg. Falciform ligament divides the liver into right lobe and left lobe. The former is further divided into right lobe proper, a quadrate lobe and caudate lobe. There is a small, thin walled, dark green and pear-shaped sac attached to the posterior surface of liver by a connective tissue, called gall bladder. Hepatic duct from right and left side of the liver unite to form a common hepatic duct which join with cystic duct from gall bladder to form common bile duct. Now, the Common bile duct runs posteriorly and join pancreatic duct to form hepatopancreatic duct or Ampulla of vater. The opening of bile duct to the pancreatic duct is provided with a muscular sphincter called sphincter of Boyden.



The opening of hepato-pancreatic duct to the duodenum is guarded by a muscular flap called sphincter of oddi.

Histologically, liver consists of many, about 1,00,000 polygonal hepatic lobules which are separated by dense connective tissue called Glisson's capsule. Each polygonal lobule contains intralobular vein at the centre. Hepatic cells or hepatocytes are arranged in radial rows in the form of cords from the centre of polygonal lobules, similar to the spokes of a wheel. Between the hepatic cells lie canaliculi which unite into bile ductule (herring's canal) and bile ductules again unite to form bile duct. The spaces between the radial rows are called hepatic sinusoids which contain phagocytic kupffer's cells. Ito cells are also found in liver which store fat and Vitamin A. At the angular interval of hepatic lobules are portal canal which consists of portal vein, hepatic artery and interlobular bile duct. These three structures form portal triad.

Function of liver

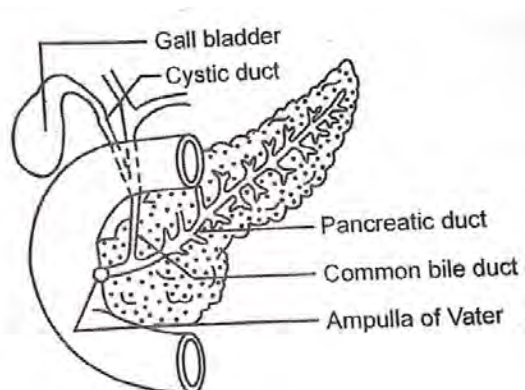
- 1) Hepatic or liver cells secrete alkaline bile juice of pH 8.6 which is stored in gall bladder. Bile is composed of bile salts, bile pigment, cholesterol, lecithin, inorganic salts etc.

Functions of bile juice are:

- i. Bile juice contain bile salts such as sodium bicarbonate, sodium glycocholate and sodium taurocholate. Bile juice break down larger fat into smaller fat globules, which is called emulsification.
 - ii. Bile neutralizes acidic chyme.
 - iii. Bile salts help in the absorption of fat and fat-soluble vitamin.
 - iv. Bile prevents bacterial growth and also enhance peristalsis.
- 2) Liver is involved in glycogenesis (conversion of glucose to glycogen), glycogenolysis (conversion of glycogen to glucose), gluconeogenesis (formation of new glucose from non-carbohydrate sources such as amino acid, fatty acid, glycerol etc.)
 - 3) Liver also participates in lipid metabolism which is by the conversion of excess glucose and amino acids into fats.
 - 4) Liver performs the function of deamination and detoxification. (Deamination is the process of removal of $-NH_2$ from amino acid which produces ammonia and conversion of highly toxic ammonia to less toxic urea is called detoxification).

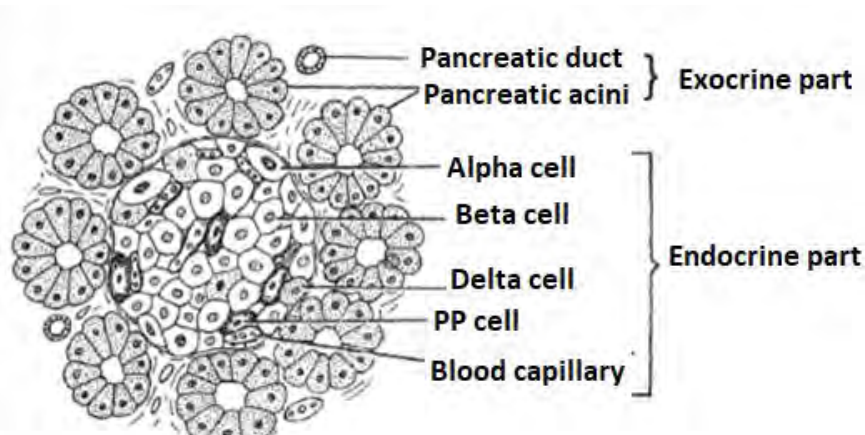
- 5) Liver contains phagocytic cells called kupffers cells which engulf harmful microbes, dead cells and foreign matter.
- 6) Bile juice contain bile pigments like bilirubin (yellow) and biliverdin (green) and other wastes which are passed out with faeces.
- 7) Liver produces RBCs in embryo, hence called haemopoetic organ.
- 8) Liver synthesizes blood clotting factors or plasma proteins such as prothrombin and fibrinogen.
- 9) Liver secrete heparin as anticoagulant.
Worn out RBCs are broken down in liver cells where bile pigments are the excretory product derived from the disintegration of haemoglobin of dead RBCs.
- 10) Liver synthesizes vitamin A, stores Fe, Cu, Fat soluble vitamins and vitamin B12.
- 11) Liver is the main site of heat production due to high metabolic activity in it.

Pancreas



Pancreas is a soft, greyish pink coloured, irregular, flat and lobulated gland, weighing about 60 gm. It measures about 14cm length and 2.5 cm width. This gland is situated posterior to stomach, in the C-shaped curvature of duodenum. Pancreas can be divided into 4 regions: head, neck, body and tail. Many smaller ducts in the pancreas unite to form main pancreatic duct or duct of Wirsung. The main pancreatic duct unites with common bile duct and finally form hepatopancreatic duct which leads into the duodenum. Accessory pancreatic duct (duct of Santorini) may also arise from main pancreatic duct which directly opens into the duodenum. Pancreas is also called mixed or heterocrine gland as it functions as both exocrine and endocrine gland.

Histologically, Exocrine part (99%) of the pancreas consists of large number of pancreatic lobules or acini. These acini are embedded in connective tissue containing blood vessels, nerves, pancreatic duct etc. Each acinus consists of central lumen or pancreatic ductule surrounded by secretory epithelial cells. Secretory epithelial cells secrete pancreatic juice and pour into pancreatic lumen. Pancreatic juice is drained through hepato-pancreatic duct and duct of Santorini to duodenum. Pancreatic juice is slightly alkaline pH 8.4 containing sodium bicarbonate and three proenzymes- trypsinogen, chymotrypsinogen, pro-carboxypeptidase, and pro-elastase. Other enzymes in this juice are amylase, lipase, DNase, RNase



T. S of pancreas

Intestinal glands:

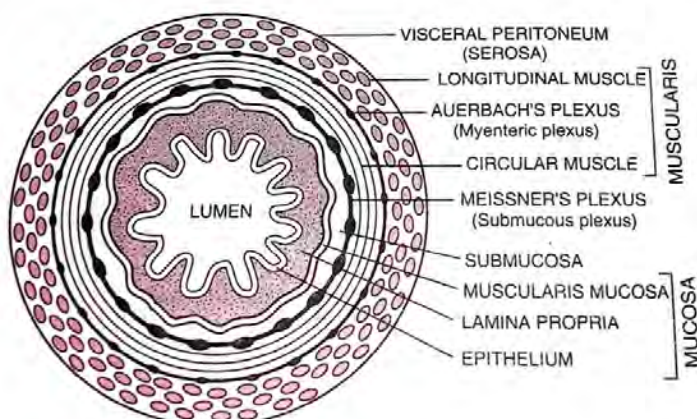
Intestinal glands are formed by the inner epithelium of small intestine and they are of two types: Brunner's gland and crypts of Lieberkuhn. Brunner's glands are branched tubular glands, only found in duodenum; in sub-mucosa. Brunner's glands mainly secrete mucus and a little enzymes. Mucus protects duodenal wall from acidic gastric juice. Crypts of Lieberkuhn are simple tubular glands present throughout the mucosa of the small intestine. Secretion of these glands is called succus entericus or intestinal juice which is slightly alkaline (pH 7.8) and contains enzymes such as maltase, sucrase, lactase, enterokinase, lipase, nuclease etc.

Activity

Prepare a table on a chart paper outlining the location, secretion and function of the different glands of gastrointestinal tract. Paste it on the wall and discuss.

Histology of alimentary canal

Histologically, Alimentary canal consists of four fundamental layers:



1. Serosa: It is the outermost layer composed of squamous epithelium (mesothelium) and a very thin layer of loose connective tissue. (In oesophagus, serosa is absent which is replaced by fibrous layer called tunica adventitia)
2. Muscularis: This layer consists of outer longitudinal and inner circular muscle. These are the smooth muscles, creating peristalsis in digestive tract. Between these layers lies loose connective tissue with a network of nerve and ganglia called Auerbach's plexus or Myenteric plexus.

3. Sub-mucosa: Submucosa is the layer of loose connective tissue that contains blood vessels, lymphatic ducts, nerves etc. This layer also contains ganglia with nerve network called Meissner's plexus or submucous plexus.
4. Mucosa: Mucosa is the innermost layer which is variously folded forming innumerable pits, glands and villi. It consists of following layers:
 - a. Muscularis mucosa: a thin layer of inner circular muscle and outer longitudinal muscle.
 - b. Lamina propria: a thin layer of loose connective tissue containing blood capillaries, lacteals, nerves etc.
 - c. Epithelium: innermost, simple columnar, often modified as glandular and ciliated. (Oesophagus contains non-keratinized stratified squamous epithelium in mucosa).

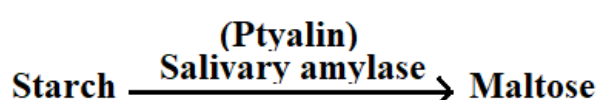
Physiology of digestion

Processes and mechanisms involved in breaking down of complex food, absorbing nutrients, and expelling undigested waste from the body is the physiology of digestion. In this process, conversion of complex and insoluble forms of food particles into simpler and soluble forms occurs. As mentioned earlier, physiology of digestion is accompanied by mechanical or physical and chemical or enzymatic process. Our food consists carbohydrate, protein, fat, vitamins, minerals and water. Carbohydrate, protein, fat are complex macromolecules which are converted or hydrolysed into simpler soluble forms such as glucose, amino acids, fatty acids and glycerol. Various enzymes or hydrolases play crucial role in chemical breaking down of food. Vitamins, minerals and water don't require digestion as they are readily absorbed by the wall of intestine.

Gastrointestinal hormonal regulation and neural control are the key processes to ensure that the digestion goes on efficient manner.

Digestion in oral cavity

Food is chewed or masticated in buccal cavity chiefly with the help of teeth, aided by tongue and lips mechanical digestion. Tongue manipulates food during chewing, mixing up with saliva and swallowing.

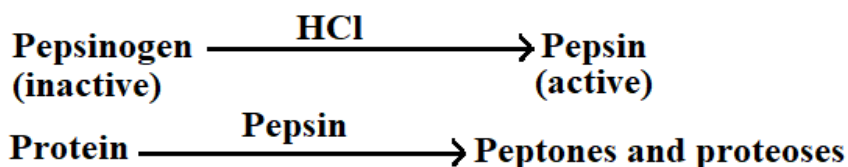


Saliva contains mucus which lubricates or moistens the food and food is transformed into bolus. Saliva also contains enzymes such as salivary amylase (ptyalin), lysozyme and lingual lipase. About 30% of starch digestion occurs in oral cavity in the presence of salivary amylase. Lysozyme kills harmful bacteria present in the food. Now, food is swallowed through pharynx in the form of bolus (round ball of food) and then passes down via oesophagus by peristalsis.

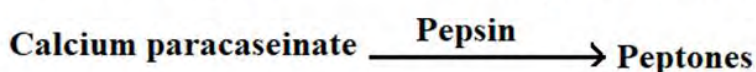
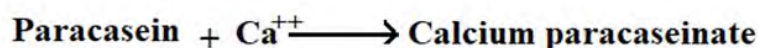
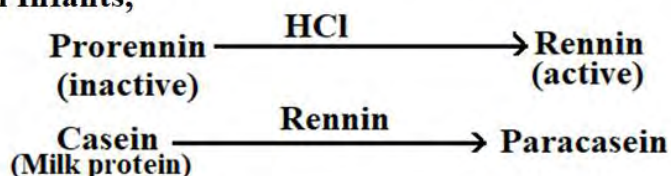
No digestion in pharynx and oesophagus.

Digestion in stomach:

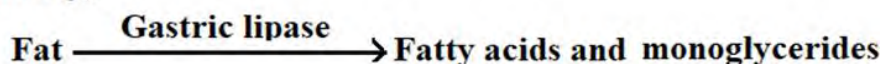
Food remains in stomach for about 4-5 hours. At that time, it is mixed and churned thoroughly with the gastric juice. Gastric juice contains HCl, inactive pepsinogen and prorenin, little amount gastric amylase and gastric lipase. HCl kills harmful microbes in food and also converts pepsinogen (inactive) to active pepsin and inactive prorenin to active rennin. Pepsin also changes more pepsinogen to pepsin so it is also called autocatalyst.



In Infants,



Similarly,



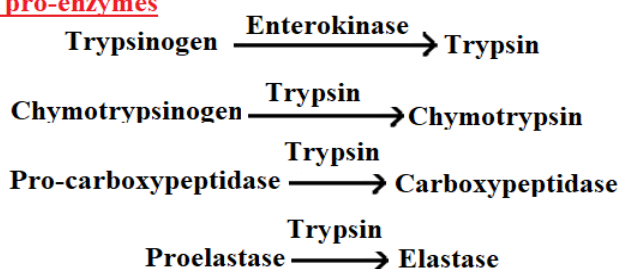
The semi-digested, semisolid and acidic food in the stomach is called chyme. Chyme enters duodenum through pyloric opening guarded by pyloric sphincter for further digestion.

Digestion in small intestine:

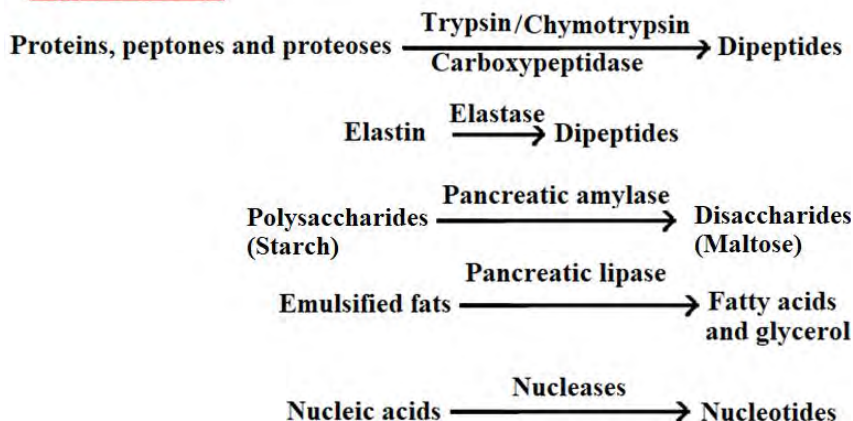
In the duodenum, chyme is mixed with bile juice, pancreatic juice and intestinal juice. Bile juice contains no enzymes. Instead, it emulsifies fat as it contains bile salts, lecithin, bile pigments etc. It also neutralizes acidic chyme and creates alkaline medium and this environment favors the further chemical reactions in duodenum.

Pancreatic juice contains pro-enzymes such as trypsinogen, chymotrypsinogen, procarboxypeptidase, pro-elastase. Also contains pancreatic amylase, pancreatic lipase and nuclease enzymes. Trypsinogen (inactive) is changed to trypsin (active) by enterokinase secreted by intestinal mucosa. Which in turn activates other pro-enzymes. Activation of pro-enzymes and digestion of food in the duodenum is shown in the given reactions:

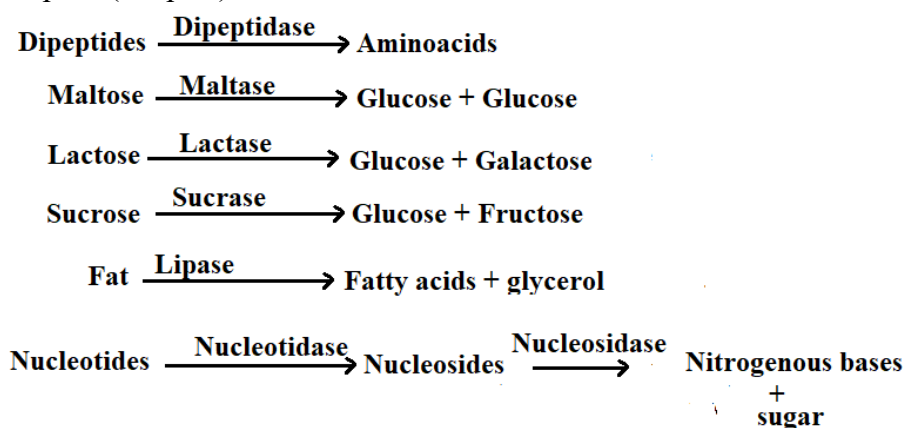
Activation of pro-enzymes



Digestion of food



Intestinal juice or succus entericus is secreted by intestinal glands (Brunner's gland and crypts of Lieberkuhn) in small intestine. Various enzymes in succus entericus are dipeptidase, maltase, sucrase, lactase, lipase (steapsin), nucleotidase and nucleosidase.



The undigested and unabsorbed substances are passed to the large intestine.

No digestion of food takes place in large intestine.

Do you know?

Chyle is the white or pale yellow fluid taken up by lymph capillaries from the intestine during digestion.

Absorption of nutrients

In intestine, all steps of digestion occur very close to its mucosa. Moreover, it is the major site of absorption of nutrients from digested food where 90% absorption occurs. Absorption is the process in which end products of digestion pass through mucosa of alimentary canal into the blood and lymph.

The simpler soluble substances; end products of digestion are absorbed by the villi present in the inner wall of intestine. Mechanisms involved in this process are simple diffusion, osmosis, facilitated diffusion and active transport.

Amino acids, glucose, galactose, Na^+ are absorbed by active transport. Fructose transport occurs by facilitated diffusion i.e., through carrier proteins. Small amount of glucose and amino acids are also absorbed by simple diffusion. Water is absorbed by osmosis; Vitamin B complex and C vitamins are absorbed by simple diffusion.

Fatty acids and glycerol are absorbed by simple diffusion but they do not reach blood stream directly. Fatty acids combine with bile salts and lecithin(phospholipid) to form spherical water-soluble droplets called micelles. Micelles diffuse into the intestinal cells (Enterocytes). In the endoplasmic reticulum of enterocytes, they are further transformed or re-synthesized into small protein bounded fat droplets called Chylomicrons. Chylomicrons are then released from these cells into lacteals or lymph duct. Lymph ducts open into the large thoracic lymph duct and the latter finally leads into left subclavian vein or blood stream.

In large intestine, absorption of some water, minerals and drugs occurs. *E. Coli* living in colon feed on undigested food particle and synthesize vitamin B12, B1, B2, and K which are absorbed by colon itself.

Assimilation

Absorbed nutrients are transported by blood to the various tissues of the body where they are utilized for producing energy.

Egestion or Defecation

This process is the elimination undigested food particles in the form of faeces through anal opening. Faeces are lubricated and easily passed due to the mucus secreted in large intestine, especially in rectum. Faeces contains undigested dietary fibres, inorganic salts, water, bacteria, little mucus, fat etc. Colour of faeces is due to the presence of stercobilin (oxidation product of bile pigment) and smell is because of toxic amines indoles, skatole and some other sulphur containing compounds. Rectum stores faeces and contracts to expel it out through anal aperture; by the relaxation of anal sphincters.

Project work

Prepare an infographic explaining how different types of food are processed in the digestive system and how they contribute to overall nutrition.

Regulation of gastro-intestinal secretions

Different part of the alimentary canal secretes several hormones regulating gastrointestinal secretion major types are given in the given table

Gastro intestinal hormones	Sources	Target organs	Action
Gastrin	Stomach	Stomach	Stimulate gastric gland to secrete gastric juice
Entergastrone (GIP)	Duodenum	Stomach	Inhibit gastric secretion
Secretin	Duodenum	• Pancreas, • liver • stomach	• Release bicarbonates in pancreatic juice • Increase the secretion of bile juice • Decrease the gastric secretion

Cholecystokinin	Small intestine	• Gall bladder • Pancreas	• Contract the gall bladder to release bile • Stimulates pancreas to secrete pancreatic juice
Enterocrinin	Small intestine	Small intestine	Stimulates crypts of lieberkuhn
Duocrinin	Duodenum	Duodenum	Stimulates Brunners gland

Project work

Create a 3D model of the human digestive system showing how food travels from mouth to stomach, intestine and finally exit through anus.

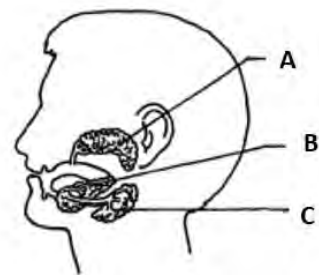
Exercise

- Which of the following type of gland is present in stomach?
 - Branched tubular
 - Coiled tubular
 - Simple tubular
 - alveolar
- What is the hardest substance of human body?
 - Enamel
 - Ossein
 - dentine
 - chondrin
- Which part of the alimentary canal is chiefly responsible for the absorption of nutrients?
 - Small intestine
 - Stomach
 - Large intestine
 - Pancreas
- Which of the following is the main function of oesophagus?
 - Digestion of food particle
 - Passage of swallowed food
 - Absorption
 - Mastication
- Which of the following enzyme changes trypsinogen into trypsin?
 - Enterokinase
 - Pepsin
 - sucrase
 - hydrochloric acid
- Which of the following duct is also called duct of Santorini?
 - Main pancreatic duct
 - Accessory pancreatic duct
 - Pancreatic ductule
 - hepatopancreatic duct
- Phagocytic cells in liver are called.....
 - Kupffer cells
 - Peyers patches
 - hepatocytes
 - Ito cells
- What is the duct of sub-mandibular salivary gland called?
 - Whartons duct
 - Duct of rivinus
 - Stensons duct
 - duct of santorini
- Which of the following sentence best describes the impact of HCL in the stomach on enzymatic activity?
 - HCl inhibit working of enzymes.

- b. HCl slow down the digestion of fats
 - c. HCl activates pepsinogen to pepsin and aid in digestion of protein
 - d. HCl reduces the effectiveness of enzymes.
10. A person with chronic diarrhea is losing significant amount of electrolyte and water. Which part of the digestive system is mainly responsible for absorbing water?
- a. Small intestine
 - b. Stomach
 - c. large intestine
 - d. oesophagus
11. Where is bile produced in the body?
- a. Gall bladder
 - b. Liver
 - c. Lungs
 - d. Hepatic duct
12. Which of the following is the characteristic of human teeth?
- a. Heterodont, acrodont and polyphyodont
 - b. Heterodont, thecodont and polyphyodont
 - c. Homodont acrodont and diphyodont
 - d. Heterodont, thecodont and diphyodont

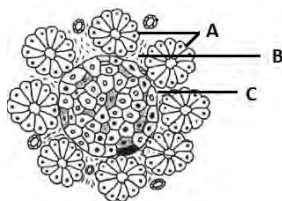
Answer the following questions in brief.

- What is the spacious cavity immediately behind the mouth? List out the structures present in it and briefly describe them.
- Observe the given diagram and answer the following questions.
 - Label the parts A, B and C?
 - What do A, B and C secrete? What is the function of their secretion?
 - Name their ducts.
- Describe the structure of L.S of human tooth.
- Identify the gland which produce bile juice. Describe its morphology,
- Describe the process of digestion in the small intestine?
- What is absorption? How are the end product of carbohydrate, protein and fat digestion absorbed?
- Describe the process of digestion of protein throughout the gastrointestinal tract.
- Observe the given diagram and answer the following questions.
 - Label the parts A, B and C?
 - Write any three differences between A and C?
 - Function of A and C?



Long answer questions.

- What is digestive system? Describe the various organs of alimentary canal involved in the digestion of food.
- Elucidate the biochemical processes involved in the digestion of carbohydrate protein and fat including enzyme functions and their regulatory mechanism.



Chapter 8.2

RESPIRATORY SYSTEM

John Scott Haldane (1860-1936) is a well-known British physiologist also called “Father of oxygen therapy” for his contribution on human respiration. His important discovery was about how oxygen and carbon dioxide are exchanged in lungs. He developed method to measure gases in blood and lungs that help to improve safety in mines and submarines. He also studied about the effect of altitude and toxic gases.



Study the given situation and discuss questions.

Situation 1

Think about a normal day. When you are sitting in a classroom and reading a book, you are breathing quietly and steadily.

Situation 2

Now, imagine you are participating in the annual sports program organized by your school. While running on a track, your breathing rate slowly and gradually increases. You might notice that your breath becomes deeper and rapid.

Questions

- What organs are involved in breathing? Can you name major organs?
- What might be the primary reason of increase in breathing rate during exercise?
- During normal breathing, you breathe through nose instead of mouth? What advantage might this provide?

Respiratory system is the collection of organs and structure which work together to facilitate gaseous exchange between the body and external environment. Furthermore, this system is concerned with the oxidation of food inside the tissues to release energy.

Mechanical and chemical process primarily involved in respiration are:

- Entry of fresh air from outside to lungs and exit of foul air from lungs to outside.
- Release of energy in tissues by the oxidation of food.

Types of respiration

On the basis of oxygen requirement, it is of two types:

1. Aerobic:

This type of respiration needs oxygen to break down glucose molecule. It is a highly efficient process and occurs in cytoplasm and mitochondria of the cell. In this process, glucose is fully oxidized to yield a large amount of energy in the form of adenosine triphosphate (ATP). Such type of respiration is done by majority of the organisms such as humans, most animals, plants and some bacteria. One molecule of glucose in aerobic respiration releases 38 ATP molecules.

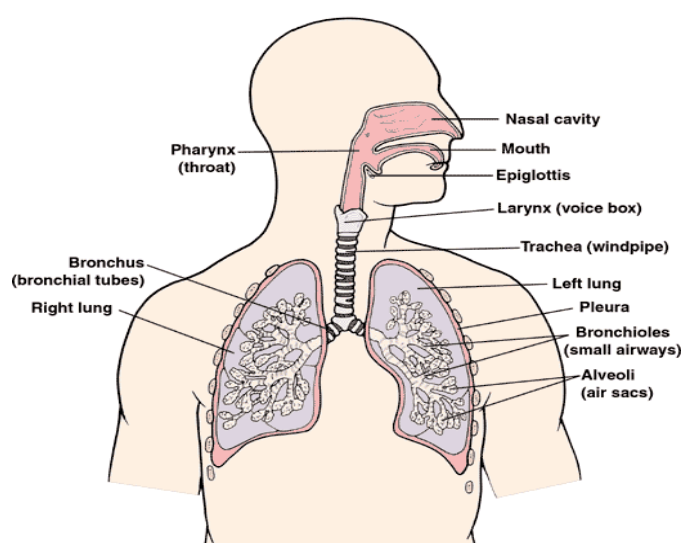
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$ (Energy)

2. Anaerobic:

Anerobic respiration takes place without the involvement of oxygen which is also called fermentation. It is less efficient process that occurs in cytoplasm only. Glucose is partially broken down into other byproducts like lactic acid in animals and ethyl alcohol with carbon-dioxide in yeast and some bacteria. It is found in fruits, germinating seeds, endoparasites like *Taenia*, *Ascaris* and in some bacteria. This process yields low ATP i.e only 2 ATP molecules are released from a molecule of glucose.



Human respiratory organs are described below:

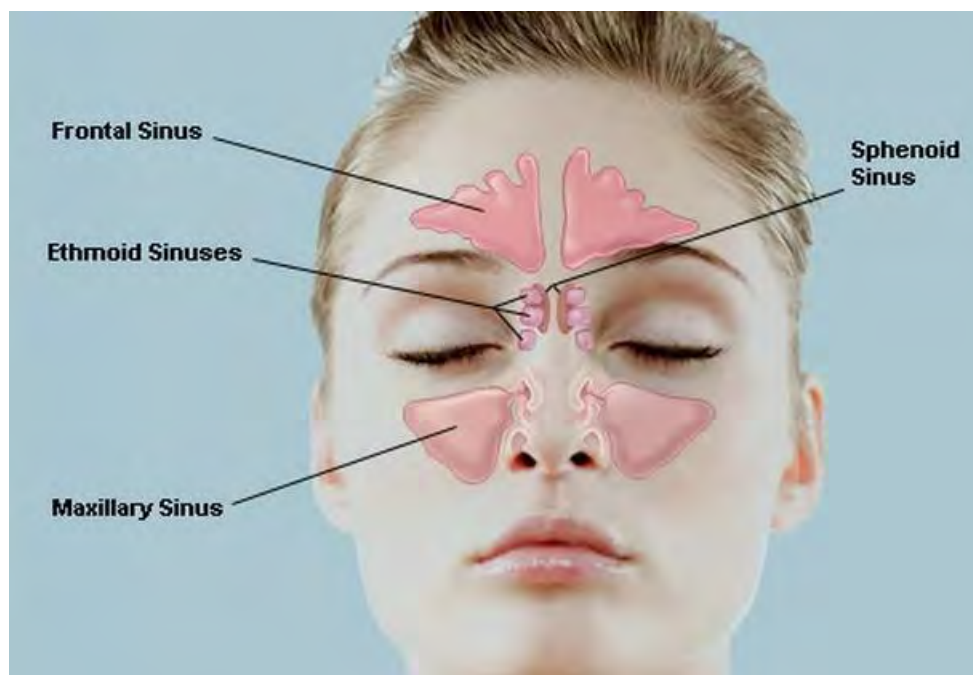


Human respiratory organs

1. Nose (nostrils and nasal chambers):

Nose is the first respiratory organ through which entry of fresh air and exit of CO_2 occurs. It is a triangular muscular structure supported by bones and cartilages. It opens externally by a paired oval or circular apertures called external nostrils and internally to pharynx by internal nostrils. A vertical septum divides the cavity of nose into right and left nasal chamber. Nasal cavity is lined internally by ciliated epithelium with goblet cells. Three main regions of the nasal cavity are: lower nasal vestibule (just inside nostrils), middle respiratory region and upper olfactory region. Respiratory region contains 3 pairs of convoluted scroll like bony projections called nasal conchae or nasal turbinates.

Air filled cavities within the skull are also connected with nasal cavities called paranasal sinuses. They are four in number namely frontal, ethmoidal, maxillary and sphenoid. These sinuses are lined by mucus cells; their secretion drain into nasal cavities.



Position of different paranasal sinuses

Functions of nose:

- i. It prevents the entry of dust and foreign particles into airways
- ii. Nasal cavity allows better filtration, humidification and warming of the air we breathe in
- iii. Olfactory region is beset with olfactory receptors which detect smell.
- iv. Vibrissae and mucus trap dust and micro-organism.
- v. Nasal cavity also contributes to the resonance of the voice

2. Pharynx:

It is a short, vertical tube behind buccal cavity which serves as the common passage for food and air. Pharynx is incompletely divisible into three regions: upper nasopharynx, middle oropharynx and lower laryngopharynx. Nasopharynx is located behind the nasal cavity. Internal nostrils and eustachian tube from middle ear open into nasopharynx. Oropharynx lies behind the oral cavity and this part is visible when a person opens mouth. Lowest region of pharynx is laryngopharynx and this region leads into two tubes; wind pipe or trachea at the front and food pipe or oesophagus at the back.

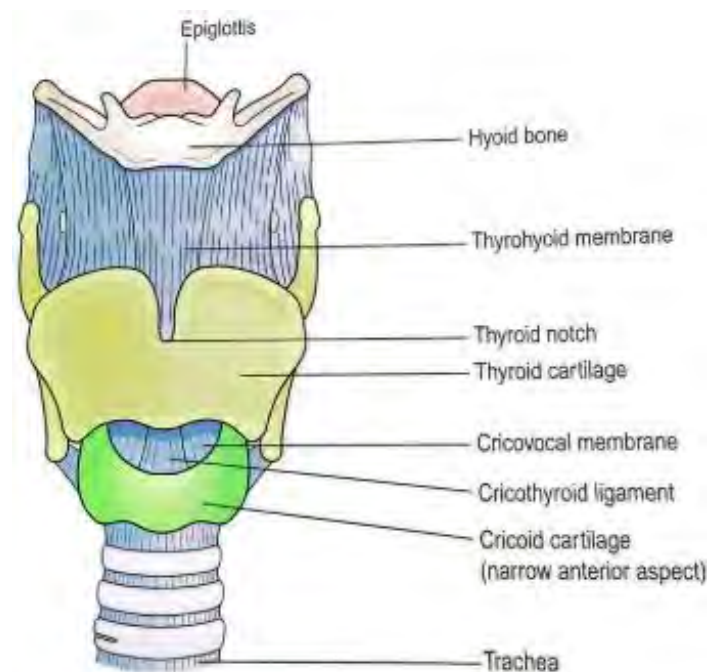
3. Larynx or voice box or Adam's apple

The hollow cartilaginous box lying at the top of trachea is larynx. In other words, larynx is occupying the region of neck i.e., 3rd cervical vertebrae to 6th cervical vertebrae (C3-C6). There are altogether nine cartilages found in larynx. These cartilages are grouped into three single cartilages and three paired cartilages. Single cartilages include thyroid cartilage, cricoid cartilage and epiglottis whereas paired cartilages are arytenoid, corniculate and cuneiform. These cartilages play a vital role in providing support to the larynx, protecting vocal cords and facilitating sound production. The largest cartilage is thyroid cartilage which gets enlarged due to the influence of testosterone during puberty in male and called Adam's apple. Epiglottis is a leaf-like fibro-elastic

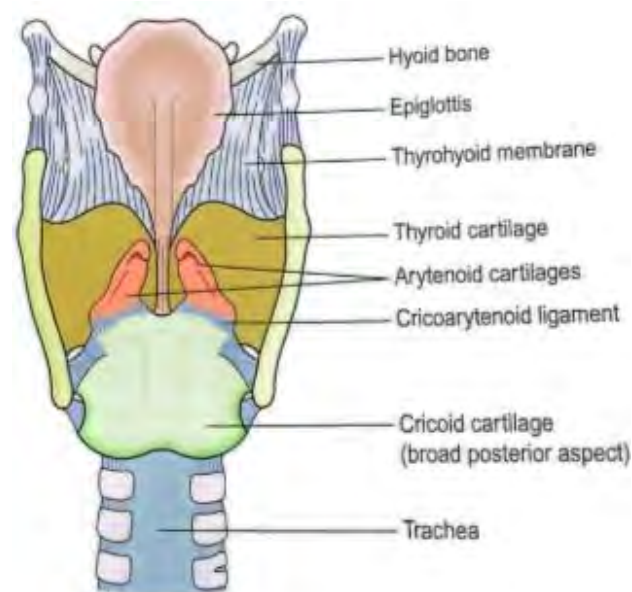
cartilage which closes glottis during swallowing. There are two pair of vocal cords; superior pair and inferior pair, extending from thyroid to arytenoid cartilage. Superior pair is false vocal cord having no role in producing sound whereas inferior pair is true vocal cord having main role in producing sound. When air is exhaled, true vocal cords vibrate and sound is produced.

Do you know?

Sometimes, while drinking water or eating food hurriedly, epiglottis may not close quickly enough over the larynx, causing the food or liquid particles being misdirected into the airway leading to aspiration.



Larynx (anterior view)



Larynx (posterior view)

4. Trachea or wind pipe

Trachea is a hollow tube that extends from the larynx to the upper part of thoracic cavity i.e., in the region from 6th cervical vertebrae to 5th thoracic vertebra. It is about 12 cm long and diameter is about 2.5 cm. It runs parallel and ventral to the oesophagus. Trachea is internally lined by ciliated pseudo-stratified epithelium bearing goblet cells. The wall of trachea is supported by 16-20 incomplete or C- shaped cartilaginous rings called tracheal rings. These tracheal rings prevent the trachea from being collapsed during forcible breathing.

5. Bronchi and Bronchioles

At the level of 5th thoracic vertebra, wind pipe or trachea divides into right bronchus and left bronchus in the thoracic cavity. Right bronchus is wider than left one. Length of right bronchus is 2.5 cm and that of left bronchus is about 5 cm. The right bronchus divides into 3 branches, each branch passes to each lobe of the lung. Similarly, Left bronchus divides into 2 branches, each passes to each lobe of lung. These lobar branches again subdivide to form tertiary branches, bronchioles, terminal bronchioles, respiratory bronchioles, alveolar duct and finally end at alveoli. Alveoli are richly vascularized. Bronchi are also supported by incomplete cartilaginous rings and internally lined by pseudo-stratified epithelium. Bronchioles are lined by ciliated columnar and cuboidal epithelium.

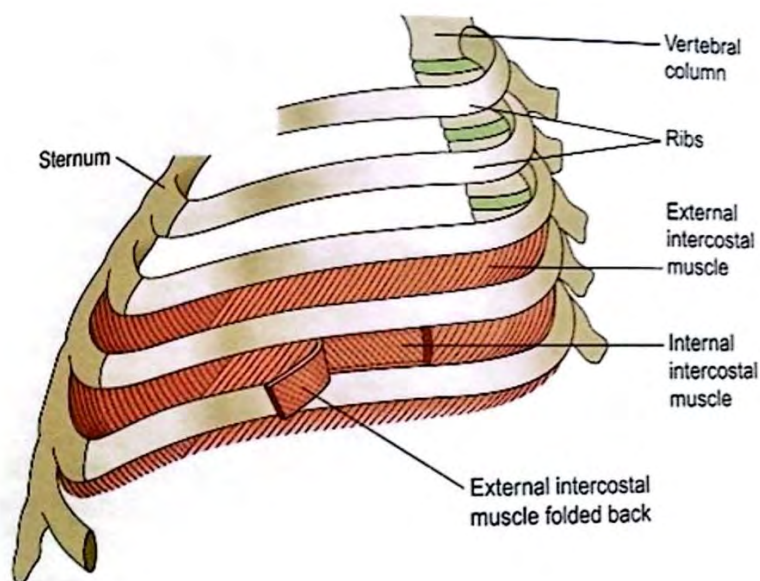
6. Lungs

Lungs in human are paired, soft, conical, spongy and pinkish organs. They occupy the greater part of thoracic cavity, on the either side of heart. Each lung consists of broad and concave basal part resting on diaphragm and narrower apex. Left lung is slightly smaller than right one and has cardiac notch. Each lung is enclosed within a double layered protective membrane called pleura. Inner membrane is visceral pleura covering lung and outer membrane is parietal pleura, lining the chest wall. These two membranes enclose a narrow space called the pleural space. The pleural space is filled with a small amount of pleural fluid. This fluid reduces friction between pleural membranes during breathing, allowing the lungs to expand and contract smoothly; and also act as cushion. Right lung is divided into 3 lobes but left lung is divided into 2 lobes by fissures. Internally, each lung contains tree of bronchi and bronchioles and numerous air sacs called alveoli. A total of about 300 million alveoli are found in lung, which are richly vascularized. Alveolar wall consists of squamous epithelial cells called pneumocytes which are of two types: type I pneumocytes for the gaseous exchange and the secretion of angiotensin converting enzyme (ACE) and type II pneumocytes which produce surfactants that reduce surface tension in alveoli and prevent from collapsing. Lungs receive both oxygenated and deoxygenated blood. Pulmonary arteries transport deoxygenated blood to lungs for oxygenation. Bronchial artery supplies oxygenated blood to the lungs.

7. Respiratory muscles

The chief muscles involved in breathing are diaphragm and intercostal muscles. Diaphragm is a thin muscular partition separating the thoracic cavity from abdominal cavity. Diaphragm becomes flat and straight during its contraction and become dome shaped during relaxation. Intercostal muscles occupy in between ribs. Intercostal muscles are of two types on the basis of their arrangement;

external intercostal and internal intercostal muscles. There are some other muscles too which aid in respiration which are muscles of neck, shoulder, abdomen etc. called accessory respiratory muscles



Activity

Divide the students of your classroom in to seven groups in such a way that each group will be responsible for researching and presenting different organ of respiratory system.

Physiology of respiration

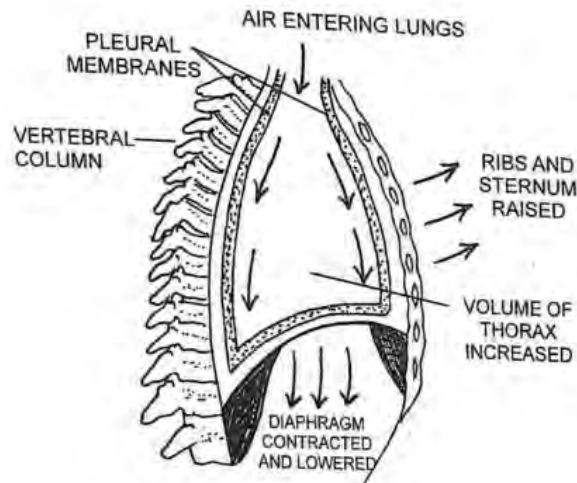
Physiology of respiration covers the biological processes and mechanisms involved in taking oxygen from the external environment, throwing out carbon-dioxide, transportation of these gases, oxidation of food exhaling carbon-dioxide, exchange of gases in between blood and lungs, blood and tissue. These all process can be described in following heads:

1. Pulmonary ventilation or breathing

Pulmonary ventilation can be defined as the process of inhaling oxygen from external environment into the lungs and throwing out carbon-dioxide in reverse direction. This process is brought about by the action of respiratory muscles such as diaphragm, intercostal muscles etc. an adult human normally breathe 12-16 times per minute. The two major steps of breathing are: Inspiration & Expiration

Inspiration:

It is the process of intaking of oxygen from outside into the lungs. It takes place when intrapulmonary air pressure is less than the atmospheric pressure. Entire process can be described in following points

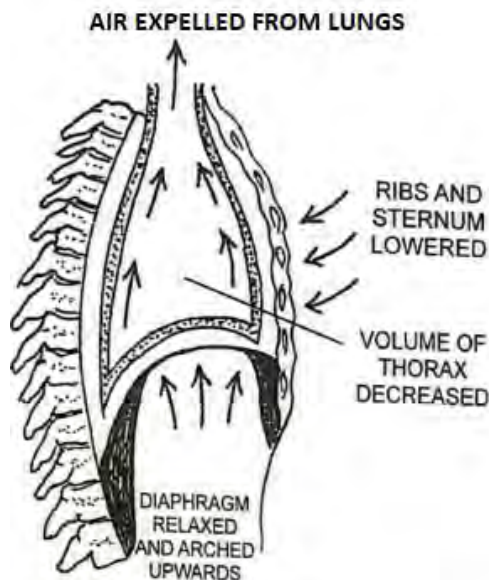


- External intercostal muscles contract and ribs are pulled outward and upward.
- Simultaneously, muscles of diaphragm also contract and becomes wide and straight.
- Such processes lead to the increase in size of thoracic cavity and lungs also expand.
- Air pressure decreases in the lungs because of increase in its volume.
- Now, the fresh air from atmosphere rushes towards the lung to equalize outer and inner air pressure.

Process of inspiration

Expiration:

The process of exhaling out CO₂ from lungs to the external environment is expiration or exhalation. It occurs when intrapulmonary air pressure become more than the atmospheric pressure. The entire process includes following sequential events:

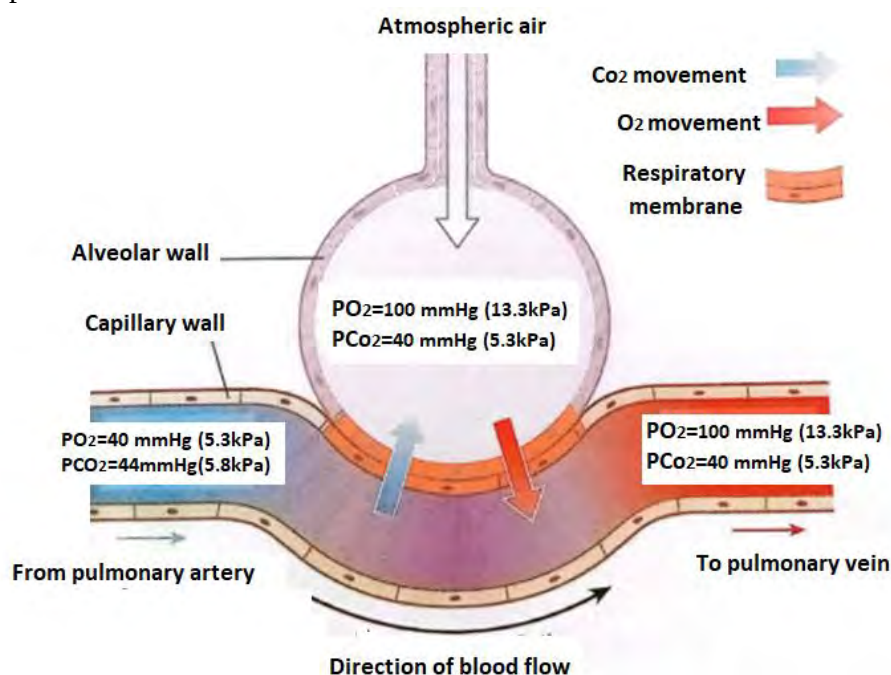


- Internal intercostal muscles contract and ribs move downward and inward.
- Diaphragm also relaxes and get its original dome shaped position.
- Now, lung surfaces are pulled inward and bases pulled upward resulting in decrease of lung size or volume along with thoracic cavity.
- Air pressure increase in lungs and air rushes forcefully to outside.

2. Exchange of gases

Alveoli are the primary sites of gaseous exchange. They are tiny, air-filled sacs, surrounded by capillaries and located at the ends of alveolar duct in the lungs. The fresh air inhaled, enters the lung and comes at the actual respiratory surfaces which are alveoli. Alveolar wall is extremely thin where blood also comes in close contact. The exchange of gases takes place in between blood and alveoli by simple diffusion method where diffusion occurs along the concentration gradient i.e., from higher partial pressure to lower partial pressure. Partial pressure of oxygen and that of carbon-dioxide in the venous blood are about 40 mmHg and 44 mmHg respectively. Similarly, partial pressure of oxygen (PO_2) and partial pressure of carbon-dioxide (PCO_2) in the alveolar air are about 100 mmHg and 40 mmHg respectively. Such differences in partial pressure facilitates the efficient exchange of gases.

Hence, O_2 diffuses into the blood capillaries from alveoli of lungs whereas CO_2 diffuses out from the blood capillaries into alveoli. From alveoli CO_2 is exhaled. The three layers which make up diffusion membrane are squamous epithelium of alveoli, endothelial wall of alveolar capillaries and the basement substances in between.



3. Transport of O_2

The oxygen diffused into the blood from alveoli is transported to the tissues. So, blood is the chief transporting medium and each 100 ml of arterial blood can carry about 20 ml of oxygen.

a. In solution form:

A small amount (About 1-3%) of oxygen is dissolved directly in the plasma or liquid component of blood and transported to the tissues.

b. As oxyhaemoglobin:

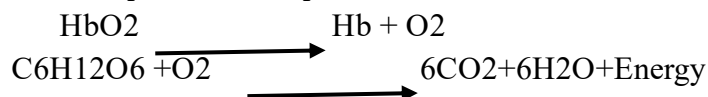
About 97-99% of oxygen is transported in the form of oxy-haemoglobin. Oxygen combines with hemoglobin (Hb) of RBC to form oxy-haemoglobin (HbO_2). Such condition is favored by some factors like decreased PCO_2 , temperature and high blood pH in lung. one molecule of Hb can carry

four molecules of oxygen. Oxy-haemoglobin is an unstable compound and under certain conditions, it readily dissociate and release O₂.



4. Internal respiration or Tissue respiration

The dissociation of oxy-haemoglobin near the cell takes place and oxygen is diffused into the cell where food burns with oxygen to release ATP or energy. The dissociation of oxy-haemoglobin is favored by high PCO₂ and temperature, low pH.



5. Transport of CO₂

Large amount of carbondioxide is produced as the byproduct in tissue respiration. It will be toxic if carbondioxide remains in the body for a long time. Hence, it should be transported to lungs for expulsion. Carbondioxide transport occurs by following method

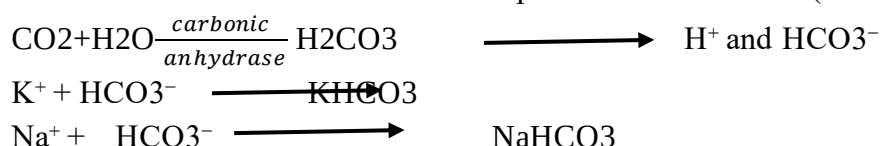
As carbonic acid:

A very small amount (about 7%) of CO₂ dissolves in water or plasma of blood to form carbonic acid in the presence of carbonic anhydrase which is transported to lungs



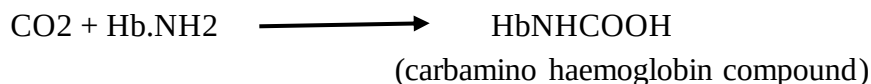
As bicarbonates:

Nearly about 70% of CO₂ is transported by blood in the form of bicarbonates. Most of CO₂ diffused into RBC combines with water to form carbonic acid in the presence of carbonic anhydrase. Carbonic acid is unstable and dissociates to form H⁺ and HCO₃⁻ ion. Most of bicarbonate ion HCO₃⁻ diffuse into the plasma from RBCs and combine with Na⁺ to form NaHCO₃. At that time, chloride ion (Cl⁻) diffuses into the RBCs from plasma to maintain ionic balance. This phenomenon is called chloride shift or Hamburger phenomenon. In RBCs, Bicarbonate ions combine with K⁺ ion to form potassium bicarbonate (KHCO₃).



iii. As Carbamino compound (Haemoglobin with Co₂)

About 23% of CO₂ is transported in the form of carbamino haemoglobin compound. CO₂ reacts directly with the amino group of protein i.e., haemoglobin to form carbamino haemoglobin compound.



Activity

Divide the students into four groups that each group will research and present on the topic pulmonary ventilation, gaseous exchange, internal respiration and transport of gases.

Project work

Prepare a model to demonstrate how oxygen and carbondioxide are exchanged between alveoli and capillaries during respiration.

Exercise

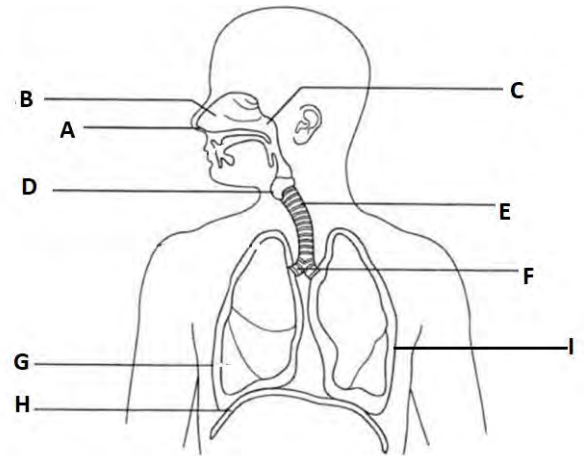
Choose the best alternative.

- Which of the following cartilage in larynx is unpaired?
a. Arytenoid b. corniculate c. cuneiform d. cricoid
- Which epithelium is found on the inner lining of trachea?
a. Cuboidal b. columnar c. pseudostratified d. squamous
- Pneumocytes are the modified epithelium.
a. Squamous b. cuboidal c. columnar d. compound
- What happens to the intercostal muscles during inspiration?
a. External intercostal muscles contract and internal intercostal muscle relax
b. External intercostal muscles relax and internal intercostal muscles contract
c. Both type muscles contract
d. Both type muscles relax
- Numerous and the narrowest tubes in lungs are
a. Hilum b. tracheae c. alveoli d. bronchioles
- Food and air pass ways are divided at
a. Larynx b. pharynx c. stomach d. oesophagus
- Which of the following statement is true?
a. Inspiration is passive process
b. Expiration is active process
c. Expiration is passive process
d. Expiration and inspiration are active process
- What happens to the diaphragm during expiration?
a. It becomes oblique
b. It becomes straight and wide
c. It becomes dome shaped
d. It contracts.
- In which of the following, bicarbonate ions are generated?
a. RBCs b. WBCs c. Platelets d. Plasma
- Into how many lobes Left lung of human is divided?
a. Two lobe b. three lobe c. four lobe d. five lobe
- Which of the following statement is the best that describes the surfactant role in the lungs?
a. It increases surface tension in the alveoli to prevent collapse.
b. Increases the resistance of the airway to infection
c. It helps in the exchange of gases
d. It reduces the surface tension in alveoli making it easier to expand during inhalation
- Which of the following best explains why oxygen moves from the alveoli into the blood and carbon dioxide moves from the blood into the alveoli during gas exchange?
a. Differences in the partial pressures of oxygen and carbon dioxide
b. Active transport mechanisms across the alveolar membrane
c. The solubility of oxygen in the blood
d. The temperature of the alveolar air

13. The open part of the "C-shaped" cartilage rings in the trachea is located on the:
- Anterior surface of the trachea
 - Lateral surface of the trachea
 - Posterior surface of the trachea
 - Inferior surface of the trachea

Short answer questions

- Describe the structure of larynx? what is the cause of a prominent Adams apple in neck of males?
- What do you mean by pulmonary ventilation? How does it occur in human body? Explain
- What is the primary respiratory organ in human body. Explain its morphology.
- What mechanism is mainly responsible for exchange of oxygen and carbondioxide in the alveoli of lung? Elaborate with diagram
- How oxygen and carbon dioxide are transported by blood? Describe briefly.
- Study the given diagram and answer the following questions.
 - Label A, B, C, D, E, F, G
 - What is the function of D and H.
 - Difference between G and I.



Long answer questions

- Inhaling oxygen and exhaling carbondioxide is called breathing or external respiration. What are the organs involved in this process? Describe briefly with a neat and labeled diagram of them.
- Explain the physiological process involved in respiration in terms of pulmonary ventilation, gaseous exchange, transport of gases and internal respiration.

Chapter 8.3

CIRCULATORY SYSTEM

Let's discuss few questions before starting this topic.

- i. What are the parts of blood vascular system? What role do they play in blood circulation?
- ii. When climbing a hilly or elevated road on foot, your heart rate increases and you begin to sweat. Why?
- iii. What are the chief functions of the blood circulations in your body?

The group of body organs working as a system, concerned with the transportation of essential and unwanted substances is circulatory system. Essential substances are oxygen, nutrients, hormones etc. which are carried to the tissues. Unwanted substances are metabolic wastes such as urea, carbon dioxide, toxins etc. transported to the excretory organs for the removal. Circulatory system is closed type in human. It consists of Blood vascular system and lymphatic system. Blood vascular system further consists of heart, blood vessels and blood.

Heart

Location and size

Human heart is red colored, hollow fibro-muscular organ of somewhat conical shape with upper broad base and lower narrow apex. It is located in the thoracic cavity between the two lungs; in the mediastinum. It is slightly angled to the left and size is approximately that of the owner's clenched fist. In adult, its length is about 12 cm and weighs about 300 grams. It is mesodermal in embryonic development.

Pericardium (Protective covering)

The heart is encased within a thin walled, double layered sac known as the pericardium, which also covers the bases of the large blood vessels connected to the heart. Two layers of pericardium are outer parietal layer (tough and fibrous) and inner visceral layer (serous layer). Parietal pericardium prevents the over distension of heart whereas visceral pericardium is made up of single layer of flattened epithelium and secrete pericardial fluid. The space between these two layers is called the pericardial cavity, which is filled with a small amount of pericardial fluid. This fluid facilitates smooth and frictionless movement of the heart. It also protects the heart from external shocks and injuries. Histologically, Wall of heart consists of 3 layers:

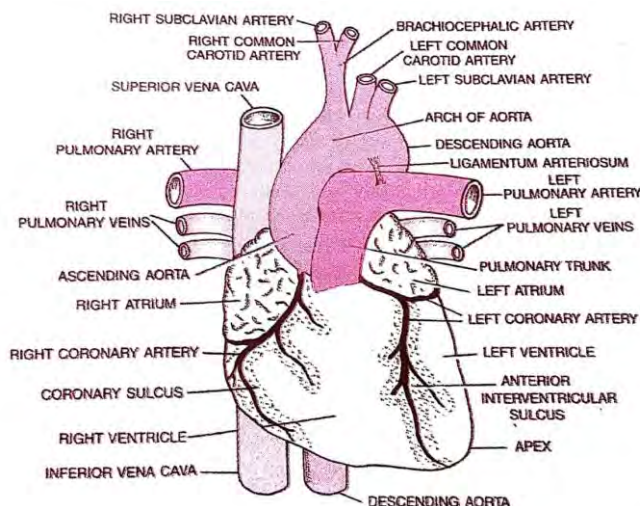
- i. outermost epicardium (visceral pericardium),
- ii. middle highly vascular thickest layer composed of cardiac muscle fibres called myocardium
- iii. innermost layer of endothelium or squamous epithelium on basement membrane called endocardium

External features

The human heart is four chambered divided into upper two atria (or auricles) and lower two ventricles. Its external structure can be studied under following points:

1. Sulci or grooves:

The two atria or auricles are separated externally by the inter-auricular (inter-atrial) sulcus. The atria are externally demarcated from the ventricles by an oblique and irregular groove known as the auriculo-ventricular groove or coronary sulcus. Coronary sulcus, anterior interventricular sulcus and posterior interventricular sulcus are present in the heart through which coronary arteries pass. The heart receives oxygenated blood through coronary arteries.

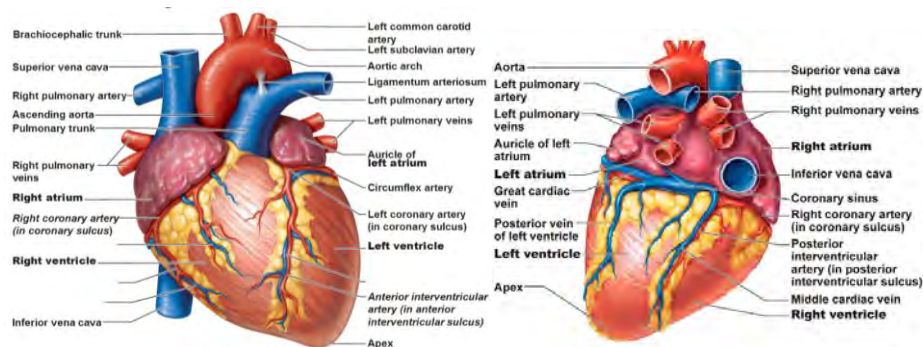


Atria or auricles:

The upper two thin-walled and receiving chambers of the heart are called atria. They are the right atrium and left atrium. The right atrium is larger than the left atrium and the former receives deoxygenated blood through the superior venacava, inferior venacava (larger) and coronary sinus. Superior venacava brings deoxygenated blood from upper body parts. Inferior venacava brings deoxygenated blood from lower body parts. Likewise, coronary sinus brings deoxygenated blood from the heart itself. The left atrium has a thicker wall and it receives oxygenated blood from the lungs through two pairs of pulmonary veins.

Ventricles

Ventricles are lower thick-walled pumping chambers. There are the right ventricle and left ventricle. The left ventricle is larger than the right ventricle. The wall of the left ventricle is three times more thicker than the right ventricle. The left ventricle pumps blood to various parts of the body but the right ventricle pumps blood only up to the lungs.



Pulmonary trunk and aorta

The pulmonary trunk originates from the right ventricle, divides into right and left pulmonary arteries. The aorta arises from the left ventricle and is divided into the ascending aorta, aortic arch, and descending aorta. From the ascending aorta arise the right and left coronary arteries which supply oxygenated blood to the

heart. Aortic arch gives off: brachiocephalic (innominate), left common carotid and left subclavian. Descending aorta runs downward through thorax and abdomen. Pulmonary trunk is connected with aorta by ligamentum arteriosum (=ductus arteriosus in embryo).

Internal structure

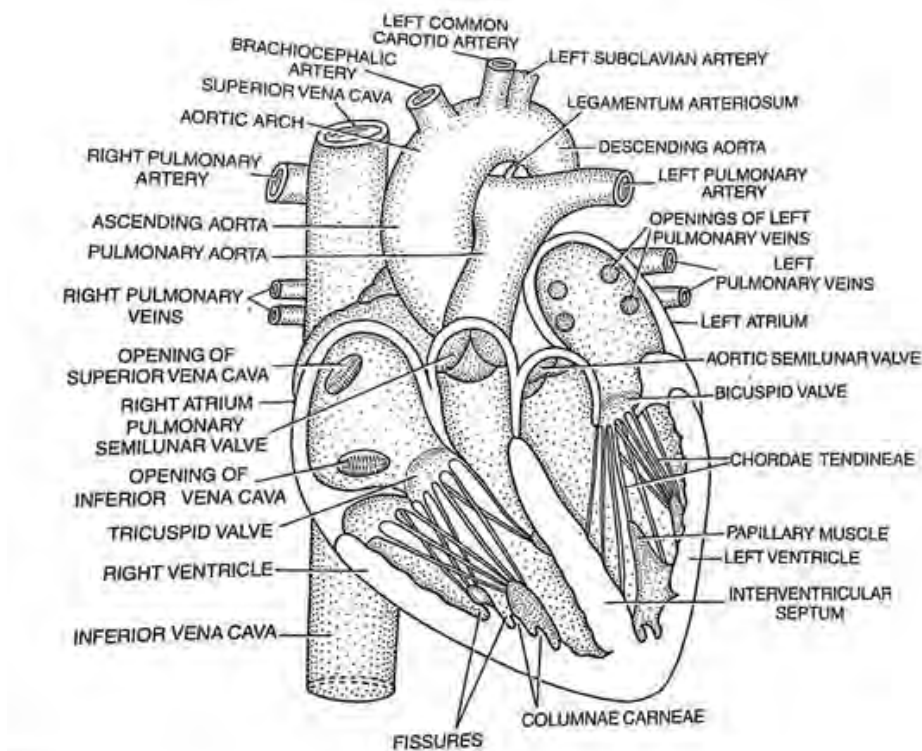
Internal structure of human heart can be studied in its longitudinal section or by the removal of its ventral side wall:

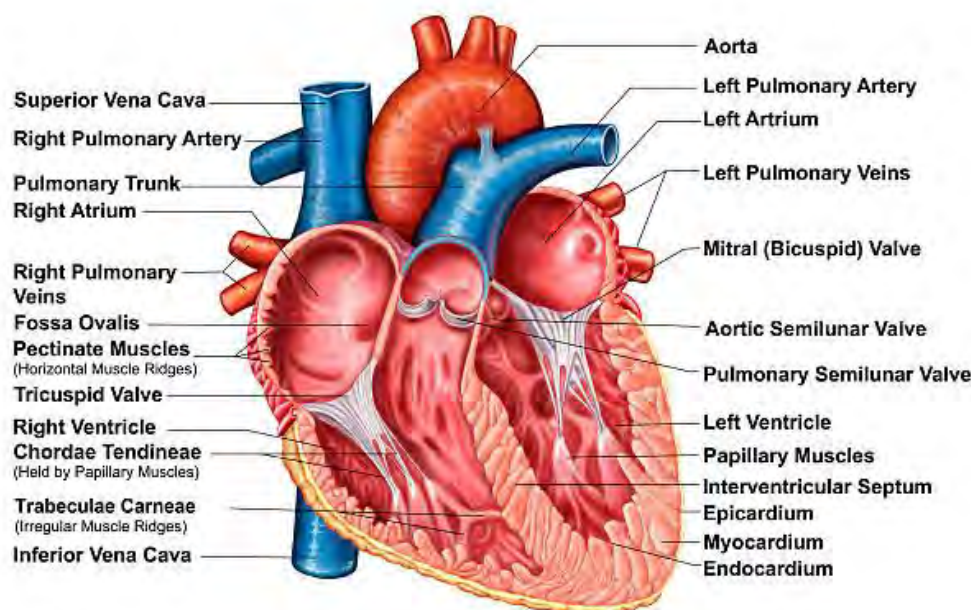
i. Atria:

Atria are thin-walled chambers and completely separated into two by a muscular vertical partition called inter-atrial septum. Right atrium receives the opening of superior vena cava, inferior vena cava and coronary sinus. Opening of inferior vena cava is guarded by rudimentary eustachian valve. Opening of coronary sinus guarded by thebesian or coronary valve. An oval depression in right atrium on interatrial septum is called fossa ovalis. Fossa ovalis marks an opening in fetus, called foramen ovale. Two atria communicate each other through this opening in fetus. Left atrium contains the opening of four pulmonary veins through which oxygenated blood from lungs is received.

ii. Valves:

The opening between right auricle and right ventricle (atrio-ventricular opening) is guarded by tricuspid valve which composed of three flaps or cusps like structure. Similarly, the left atrio-ventricular opening is also guarded by bicuspid valve or mitral valve consisting of two flaplike structure. Base of pulmonary trunk and aorta are provided with three half-moon shaped flaps called pulmonary valve (pulmonic valve) and aortic semilunar valves respectively. The function of these valves is to allow free and forward flow of blood but prevent backflow. The flaps of valve are supported by chordae tendineae connected with papillary muscle of ventricular wall.





iii. Ventricles

Atria open into a highly muscular thick-walled ventricles. Two ventricles are separated by a thick oblique and vertical interventricular septum and left ventricle is longer and thicker. The inner ventricular wall is provided with few conical muscles called papillary muscles. Flaps of tricuspid and bicuspid valves are supported by special fibrous cords called chordae tendinae. Chordae tendinae are further connected to the other ends with papillary muscles. Chordae tendinae prevent the valves from collapsing back into auricles during powerful ventricular contraction. Columnae carnea are the muscular ridges or projections on the wall of ventricles. Smaller spaces on the inner wall of ventricle; between the columnae carnea are fissures.

How is blood supplied to heart muscle itself?

For the continuous working of the heart, Heart needs continuous supply of oxygen and nutrients. Ascending aorta gives off right coronary artery and left coronary artery. These arteries supply oxygenated blood to heart muscle cells. Deoxygenated blood from the heart muscle is collected by coronary veins into the coronary sinus. From the coronary sinus, de-oxygenated or impure blood is poured into right auricle.

Activity

Objective: To study the structure of mammalian heart (Goat)

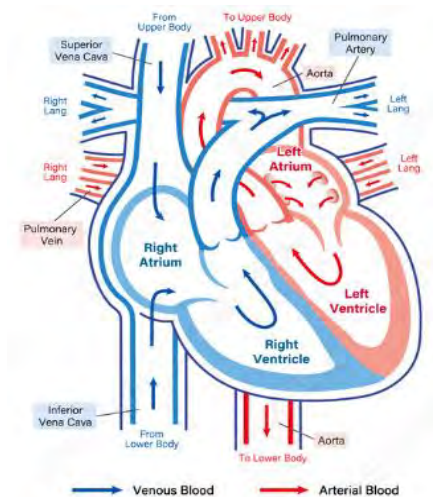
Apparatus required: dissecting tray, forceps, needle

Procedure:

- i. Take a fresh goat heart from nearby butcher shop
- ii. Keep it on dissecting tray.
- iii. Observe its external structure pointing out with the needle. (Take the help of your teacher if required)
- iv. Cut it longitudinally and observe its internal structure
- v. Note down all features on the chart paper, paste it and discuss.

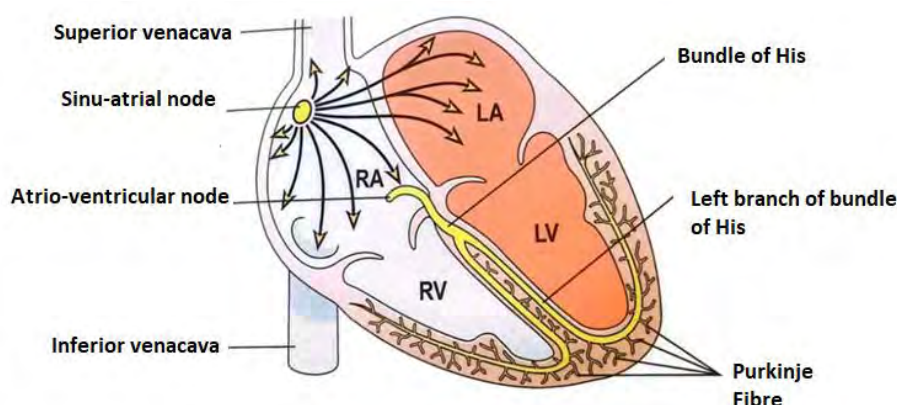
Course of blood circulation in the heart

Right auricle receives blood from upper body parts via superior venacava and lower body parts through inferior venacava, and from the heart through coronary sinus.



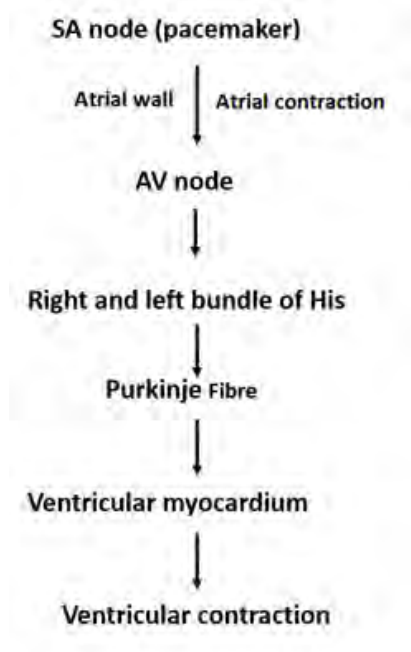
Right auricle contracts and impure blood is passed to right ventricle by opening tricuspid valve. Then, Right ventricle contracts and deoxygenated blood is pumped by opening pulmonic valves via pulmonary artery to the lungs for oxygenation. From lungs, oxygenated blood returns to left auricle through two pairs of pulmonary veins. Now, left auricle contracts and oxygenated blood flows into left ventricle by opening mitral or bicuspid valve. When the left ventricle contracts, aortic valve opens and oxygenated blood is forcefully pumped to different body parts through systemic aorta.

Origin and conduction of heart beat



Human heart is myogenic (myo-muscle, genic- migrating from) which means impulse of heart beat originates from heart muscle or specialized nodule tissue of heart itself. Heart beat is the rhythmic contraction and relaxation of the heart which includes a systole and a diastole phase. Healthy human heart beats 72 times per minute. The heart beat originates from the mass of neuromuscular tissue called sinu-atrial node (SA node) or pace maker. Pacemaker lies in the wall right auricle near the opening of superior venacava. Sometimes, S.A node may be defective which can be remedied by the surgical grafting of an artificial pacemaker in the chest. Another mass of neuromuscular tissue,

the atrioventricular node (AV node or pace setter) is situated in the wall of right auricle. From the AV node originates a mass of specialized fibre called Bundle of His. The bundle of His divides into two branches; left bundle of his and right bundle of his and each branch supplies to each ventricle. Within the muscle of ventricle each branch of bundle of His gives off a network of fine fibres called Purkinje fibres. The impulses of contraction are generated and spread by the SA node across the wall of atria. Such impulses or wave of contraction are picked up by AV node. From AV node excitatory impulses are rapidly transmitted through the bundle of His and Purkinje fibre to the myocardium of ventricles. These impulses stimulate the ventricles to contract simultaneously. The entire conducting system of the heart is summarized below:



Control of heart beat:

a. Neural or nervous control:

Cardiac centre lies in the medulla oblongata which is composed of cardio-inhibitor and cardio-accelerator. The function of cardio-inhibitor decreases rate of heartbeat but cardio-accelerator increases it. Cardio-inhibitor is connected with the heart through parasympathetic nerve fibres but cardioaccelrator is connected with sympathetic nerve fibres of autonomic nervous system.

b. Hormonal control:

Adrenal medulla secretes two hormones which are adrenaline (epinephrine) and nor-adrenaline (nor-epinephrine). Nor- adrenaline accelerates the heart beat during normal condition whereas adrenaline performs this function during emergency. Similarly, thyroxine hormone also has important role in increasing heartbeat rate by increasing basal metabolic rate (BMR).

Working mechanism of the human heart

Right atrium receives impure or deoxygenated blood from various parts of the body through superior venacava, inferior venacava and coronary sinus. Left atrium receives oxygenated blood form lungs through right and left pulmonary veins.

Human heart is myogenic. There is regular contraction (systole) and relaxation (diastole) of the atria and ventricles. The contraction and relaxation occur in the rhythmic manner. Contraction of atria is followed by the contraction of ventricles. Atria contract to pass blood into the corresponding ventricles.

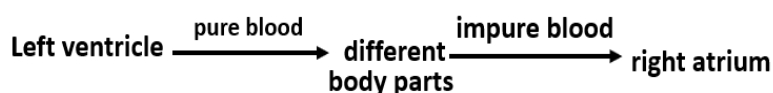
For the contraction of atrium, waves of contraction get originated from the SA node situated near superior venacava. These waves spread across the wall of atria; resulting atrial contraction at regular interval. The waves or impulses are picked up by the AV node situated at the wall of right atrium. The impulses or waves of contraction are rapidly transmitted from AV node to the entire wall of ventricle through bundle of His and purkinje fibres. Now, ventricles contract so that left ventricle pumps oxygenated blood to different parts of body through aorta and right ventricle pumps deoxygenated blood to lungs.

Concept of double circulation

Double circulation refers to the flow of blood through the heart twice: once through systemic circulation and once through pulmonary circulation.

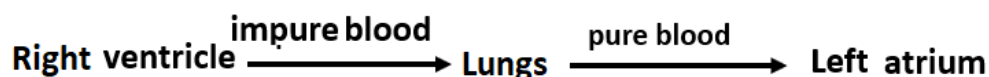
1. Systemic circulation:

The circulation of blood between heart and different parts of the body is called systemic circulation. In this, oxygenated blood from left ventricle is transported to all parts of body through aorta and deoxygenated blood is brought to right atrium from various body parts. Superior venacava, inferior venacava, coronary sinus brings impure blood into right atrium. Systemic circulation is also called greater circulation or peripheral circulation where blood flow is for a long distance.



2. Pulmonary circulation:

The circulation of blood between heart and lungs is called pulmonary circulation. In this, deoxygenated blood from right ventricle passes to the lungs and return of oxygenated blood from lungs to left atrium occurs. Blood pumped from right ventricle is passed through left and right pulmonary arteries to the lungs and oxygenated blood enters left atrium through pulmonary veins. Blood flow is for short distance.



Significance of double circulation:

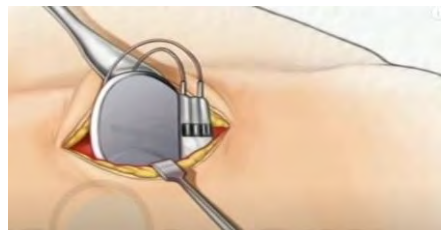
- It checks mixing of pure and impure blood.
- Oxygenated or pure blood carries more oxygen and deoxygenated blood carries more carbon dioxide

Pacemakers

Sinu atrial node is often referred to as the heart's natural pacemaker as it initiates or generates the electrical impulses that initiates the heartbeat. When the SA node fails to generate impulses properly or when impulse cannot be conducted to the ventricles because of various heart disorders, an artificial pacemaker is implanted in the heart.

Artificial pacemaker is a small medical device that can start electrical activity in heart to maintain its proper rhythm. It produces impulse for the cardiac contraction to normal. It was first implanted by Dr. Chardack in 1960. This device is placed under the collar bone below the skin by simple operation. The artificial pacemaker consists of a pulse generator, leads in the form of wire and electrodes. The pulse generator is a small, sealed and lithium battery powered device to generate

electrical impulses. The leads transmit the impulses and electrodes are connected at the ends of leads to deliver electrical impulses to the heart muscles.



Cardiac Cycle

The cardiac cycle consists of one heart beat or one cycle of contraction and relaxation of the cardiac muscle. During the heartbeat, there is regular contraction and relaxation of atria and ventricles. The contraction phase is called systole and the relaxation phase is diastole. The total duration of cardiac cycle is about 0.8sec in a healthy adult. There are three main phases of a cardiac cycle: atrial systole, ventricular systole and combined diastole.

- Atrial systole:** It is the simultaneous contraction of right and left atria to pump blood into the respective ventricles. Its duration is 0.1sec.
- Ventricular systole:** It is the simultaneous contraction of right and left ventricles to pump blood into pulmonary and systemic circulation respectively. It lasts for about 0.3sec.
- Combined diastole:** It is the stage of relaxation of both atria and ventricles. Blood returns to the heart at this stage. It lasts for about 0.4sec.

Cardiac output

Normally, Human heart beats about 72 times per minute which is called heart rate (HR). Heart rate increases during exercise, fever, fear, and anger. The amount of blood pumped out by each ventricle per beat is known as stroke volume (SV). It is about 70ml. The amount of blood pumped out by each ventricle per minute is called cardiac output. The mathematical product of heart rate and stroke volume is called cardiac output. Cardiac output is calculated by,

$$\text{Cardiac Output (CO)} = \text{HR} \times \text{SV} = 72 \times 70 = 5040 \text{ ml/min.}$$

Heart sounds and heart murmur

Beating of the heart produces characteristic sounds as the blood is pumped through the chambers and the valves. Such sounds or noises can be heard by placing the ear against the chest or by using stethoscope. The heart sounds are due to the flow of blood and closure of valves during cardiac cycle. Heart sounds are the crucial indicators that can help in assessing heart functions and detecting any underlying heart conditions. There are altogether four heart sounds: first, second, third and fourth but first and second heart sounds are normally heard in all person. Third and fourth sounds may be the sign abnormal condition of heart.

- First heart sound:** It is heard like 'lubb' due to the closure of Atrioventricular valves and contraction of the muscles of ventricles. It is of long duration (0.15 sec), low pitched, less loud.
- Second heart sound:** It is heard like 'dub' due to the closure of semilunar valves, marking the end of ventricular systole. It is of short duration (0.1 sec), high pitched, louder and sharper.

Third heart sound is the running water sound due to rapid ventricular filling whereas 4th heart sound is hissing sound produced by atrial contraction.

Heart murmur is the unusual heart sound, heard during heartbeat. It may be caused by turbulent blood flow through the valves chamber and blood vessels. Damage to the tricuspid and bicuspid valve affects the quality of first heart sounds. When the semilunar valves are injured, a soft hissing noise 'lubb shhh' is heard in the place of second sound called heart murmur. Such condition is due to some diseases like syphilis, rheumatic fever or other health complications which injure valves and affect their working, causing the back flow of blood.

Blood pressure

While blood flows through the blood vessels; particularly in arteries, it exerts some pressure on their inner wall. The pressure exerted by the blood on the wall of blood vessel through which it flows is called blood pressure. It is also called arterial blood pressure and measured by using a device called sphygmomanometer by the auscultatory method. Sphygmomanometer was invented by Karot koff in 1905. During the measurement of blood pressure, brachial artery is taken as reference as it is a major vessel that runs along the upper arm. In normal adult human, blood pressure is about 120/80 mmHg. Blood pressure rises and falls during a cardiac cycle giving systolic and diastolic blood pressure.

Systolic blood pressure: It is the pressure when the blood exerts pressure on the wall of blood vessels during ventricular systole. It is about 120mmHg (also called higher limit of arterial blood pressure) in a healthy adult.

Diastolic blood pressure: It is the pressure when the blood exerts pressure on the wall of arteries when the ventricles are relaxed. It is about 80mmHg (also called lower limit) in a healthy adult.

The difference between systolic and diastolic blood pressure is called pulse pressure. It is about 40mmHg. Blood pressure is affected by exercise, emotions of excitement, meals, sex, body posture etc.

Problems related to blood pressure:

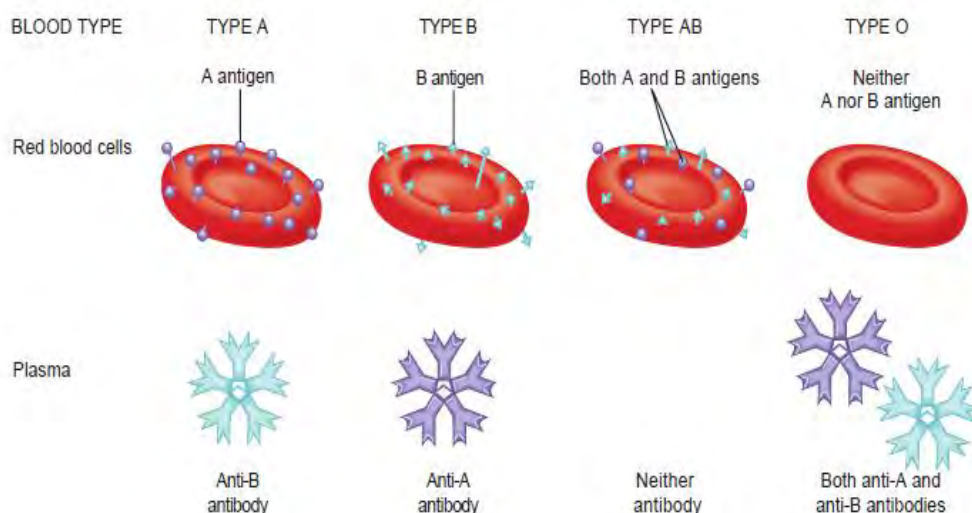
Hypertension or High Blood pressure: It is the condition in which a person has persistent high blood pressure beyond 140/90mmHg. It is caused due to tension, fear, obesity, taking fatty food, smoking, nephritis etc. leading to narrowing of artery's lumen. It harms brain, kidney, heart etc.

Hypotension or low blood pressure: It is the condition in which a person has persistent low blood pressure. The blood pressure is low as 90/50mmHg. Its causes are blood loss by hemorrhage, vomiting, diarrhea, heart problem, blood vessel dilation etc.

Divide the class into small groups, measure the blood pressure by using a sphygmomanometer, prepare a report on it and discuss in class.

Blood grouping

Blood grouping is the process of classifying human blood into different types based on the presence or absence of specific antigens and antibodies. The most commonly known blood grouping system are ABO system and Rh system. Karl Landsteiner is called the father of blood grouping who discovered 3 types of blood group (A, B, O). He got nobel prize in 1931. Blood group AB was later reported by de Castello and Steini.



ABO blood

grouping system is based on the presence or absence of specific protein molecules known as antigens (agglutino-gen) and antibodies (agglutinin). Antigens, if present, are A and B, located on the surface of RBCs and the corresponding antibodies are found in the blood plasma. Hence, four common blood groups are; A, B, AB and O.

Type or Group	Antigen on the surface of RBCs	Antibody in the plasma
A	A	b
B	B	a
AB	A and B	None
O	None	a and b

Blood transfusion

Blood transfusion is the medical procedure in which blood or blood components are transferred from one person (donor) to another person's (recipient) blood stream. Before a transfusion, blood grouping should be done to ensure that the donor's blood is compatible with the recipient's blood to reduce the risk of harmful reaction. Incompatible transfusions may lead to agglutination or clumping and lysis of donated red blood cells, intravascular clotting, circulatory failure and even death.

From the table given below, it is clear that

- Type A blood can be given only to those people which do not possess antibodies a which means only to A and AB
- Similarly, type B can donate to only B and AB
- AB blood group can be given to only AB group as other types are there with some antibody
- O type can be given to all types because it has no antigen.

Antigens \ Antibodies	A b	B a	AB —	O ab
A b				
B a				
AB —				
O ab				

 = Clumping
 = No Clumping

Blood group AB is called universal acceptor or recipient as its plasma is without antibodies. Blood group O is called universal donor as its RBCs lack antigens.

Inheritance of blood group

There are three alleles that determine the ABO blood group in human. They are i^a , i^b and i^o . Out of three alleles only two alleles can be present at a time in any human being. So, there are six genotype and four phenotype

Genotype of person	Blood group	Kind of antigen
$i^a \times i^a$	A	A
$i^a \times i^o$	A	A
$i^b \times i^b$	B	B
$i^b \times i^o$	B	B
$i^a \times i^b$	AB	A and B
$i^o \times i^o$	O	None

The blood types of the parents can help predict the possible blood types of their children:

Parents blood group	Blood groups of children	
	Possible	Impossible
O×O	O	A, B, AB
O×A	O, A	B, AB
A×A		
O×B	O, B	A, AB
B×B		
A×B	O, A, B, AB	-
O×AB	A, B	O, AB
A×AB	A, B, AB	B
B×AB		
AB×AB		

Rh grouping

Rh grouping is the classification of blood on the basis of presence or absence of specific antigen called Rhesus factor or Rh protein on the surface of RBC. Rh protein (Rh factor) was first isolated by Karl Landsteiner and Weiner in 1940 from the blood of Rhesus monkey. The person's blood with Rh antigen is called Rh-positive and the person's blood without Rh antigen is called Rh-negative. Rh-positive is dominant over Rh negative. About 85% people have Rh antigen on the surface of their RBC. Rh positive and Rh-negative blood are incompatible and cannot be mixed. If Rh positive blood is mixed with Rh negative it causes the production of Rh antibodies. These antibodies react with Rh antigen and agglutination takes place. First transfusion is a little dangerous but second transfusion is serious and even fatal.

Identifying blood groups

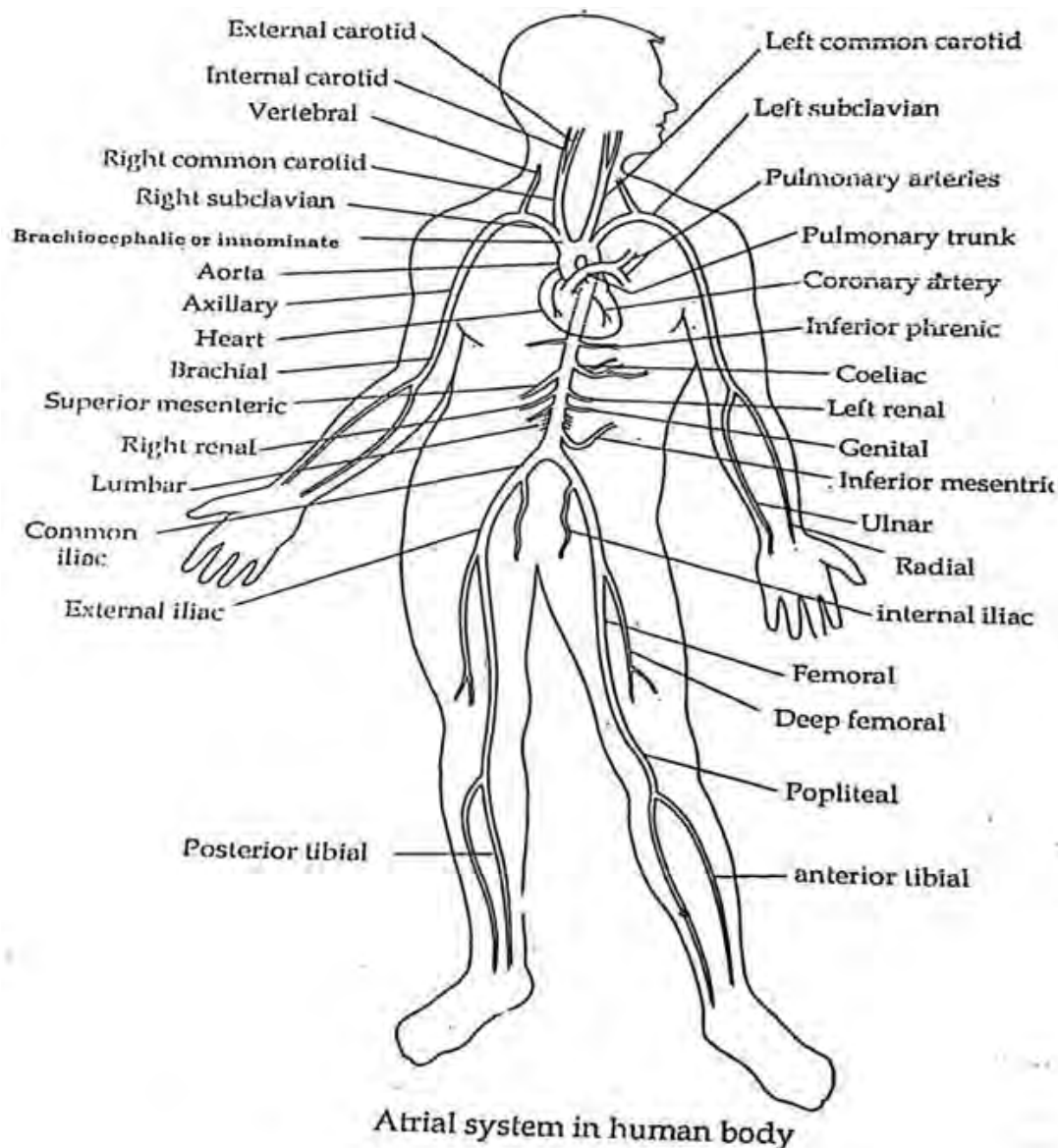
Blood group is detected by using antisera (Anti serum A, Antiserum B, Antiserum D). Antiserum is the serum containing antibodies.

Blood type	Anti-A	Anti-B	Anti-D
O +ve			
O -ve			
A +ve			
A -ve			
B +ve			
B -ve			
AB +ve			
AB -ve			



Arterial system

Arterial system is the system of arteries and their branches which transport pure blood (exception pulmonary artery which transport impure blood) to different body parts from the heart. It can be studied as:



- A. Pulmonary arteries: It transport deoxygenated blood from heart to the lungs.
- B. Systemic Aorta (largest artery): It consist of ascending aorta, aortic arch and descending aorta.
 Ascending aorta gives off coronary arteries; supply oxygenated blood to the heart muscle.
 Aortic arch gives off three branches: brachiocephalic, left common carotid, left subclavian.
1. Brachiocephalic further divides into: Right common carotid and right subclavian.
 - a. Right common carotid: It gives off 2 branches:
 - External carotid: supplies to right side of head, face, neck, jaw
 - Internal carotid: supplies to brain, eyes, forehead, nose.
 - b. Right subclavian: It gives off 3 branches:
 - Vertebral: supplies to head region
 - Right axillary: supplies to scapular region

- Right brachial: supplies blood to the arm by radial and ulnar
2. Left common carotid: It also gives off two branches:
 - External carotid: supplies to left side of head and face
 - Internal carotid: supplies to brain, eyes, forehead, nose etc. on the left side
 3. Left subclavian: it also gives off:
 - Vertebral: supplies to head region
 - Left axillary: supplies to scapular region
 - Left brachial: supplies blood to the arm by radial and ulnar

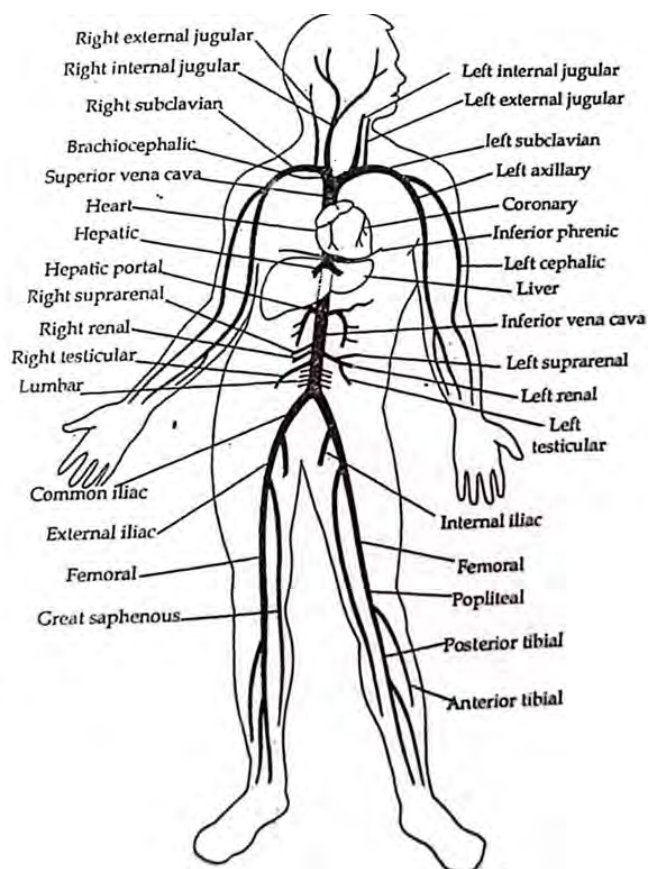
Similarly, descending aorta gives off following main branches:

1. Posterior intercostal: supplies to ribs and intercostal muscle
2. Oesophageal: supply to oesophagus
3. Phrenic: supplies to diaphragm
4. Coeliac: gives off 3 branches; left gastric, splenic and common hepatic
5. Left gastric: supplies stomach
6. Splenic: supplies pancreas and spleen
7. Common hepatic: supplies to liver, gall bladder, stomach duodenum pancreas, hepatic duct
8. Superior mesenteric: long unpaired branch, supplying small intestine, pancreas, caecum, transverse and ascending colon
9. Renal: supplies to kidney
10. Gonadal/genital: supplies to gonads
11. Lumbar: 4 pairs, supplying to body wall and vertebrae of posterior abdominal cavity
12. Inferior mesenteric: supplies to large intestine
13. Common iliac: divides into external and internal iliac supplying to leg.
 - Internal iliac: short and runs to supply organs of pelvic regions
 - External iliac: runs obliquely downward called femoral and further moves down bifurcates at the knee level and into anterior tibia and posterior tibia.

Do you know?

Circle of willis or circulus arteriosus is the circular network of arteries located at the base of brain; formed by two vertebral and two internal carotid.

Venous system



Veins and their branches which collect and transport deoxygenated blood (exception pulmonary vein) from various parts of the body to the heart. It consists of:

1. Pulmonary veins: Pulmonary veins (2 pairs) bring oxygenated blood from the lungs to the left atrium.
2. Coronary veins: these veins collect deoxygenated blood from heart muscle into the coronary sinus which open into right auricle.
3. Superior venacava (precaval): it collects impure blood from different veins and pour into the right atrium from upper body parts; head, neck, upper limbs.
Precaval is formed by the union of Right brachiocephalic and left brachiocephalic and each brachiocephalic is formed by the union of:
 - i. External jugular: Collects blood from mouth, face, jaw
 - ii. Internal jugular: Collects blood from brain, eye, ear
 - iii. Subclavian vein: collects from fore limb through axillary and cephalic
4. Inferior venacava (postcaval): it collects blood from posterior body parts and open into right auricle. It is formed by following veins:
 - a. Common iliac: it is formed of external iliac and internal iliac.
 - i. External iliac: collects from outer side of the leg, parts of pelvis through anterior and posterior tibial vein, saphenous vein (longest vein).
 - ii. Internal iliac (hypogastric): collects from rectum, urinary bladder, uterus, vagina, prostate gland, seminal vesicle, penis, scrotum etc.

- b. Lumbar veins: collect blood from lumbar region
- c. Genital vein: collects from gonads and inguinal region
- d. Renal vein: collect from kidney
- e. Supra renal/adrenal vein: drain venous blood from adrenal gland. Right one is shorter empties into venacava, left one is longer that empties into left renal vein
- f. Hepatic vein: collects from liver
- g. Inferior phrenic vein: from lower surface of diaphragm

5. Hepatic portal system/double capillary system

Hepatic portal vein collects blood from alimentary canal, pancreas and spleen. Hepatic portal vein is formed by:

- i. Cystic vein: collects from gall bladder
- ii. Splenic vein: collects from spleen, pancreas, and part of stomach
- iii. Gastric vein: collects from stomach and distal end of oesophagus
- iv. Duodenal veins: from Duodenum
- v. Mesenteric vein: from intestines

These veins pour nutrient rich deoxygenated blood into hepatic portal vein, which drains into liver but do not pass the blood into the heart directly and hence form hepatic portal system.

Significance of hepatic portal system

Nutrients absorbed in the intestine are transported to the liver, where they are processed and utilized for energy, storage, and various bodily functions.

Toxins absorbed, are detoxified, germs are destroyed by Kupffer cells, ammonia produced during protein metabolism is converted to urea which is removed by kidney.

Do you know?

Renal portal and hepatic portal system, both are found in frog.

Exercise

Choose the best alternative

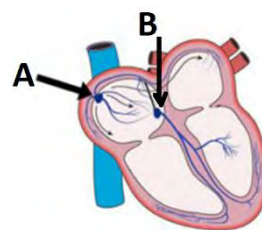
- Which of the following pericardium is closest to the heart?
 - Parietal pericardium
 - Endocardium
 - epicardium
 - fibrous pericardium
- Which of the following layer consist of cardiac muscles?
 - Epicardium
 - Endocardium
 - myocardium
 - pericardium
- What are the muscular ridges on the interior surface of atria called?
 - Chordae corneae
 - Musculipectinati
 - papillary muscle
 - endocardium
- Tricuspid valve is situated in between.....
 - Atria
 - Right atrium and right ventricles
 - Ventricles
 - Left atrium and left ventricle
- In embryo, Foramen ovale is the aperture lying in between right atrium and
 - Left atrium
 - Aorta
 - right ventricle
 - pulmonary artery
- Which of the following statements describes the best about the role of SA node in the heart beat?
 - It delays the electrical signal to allow complete atrial systole before ventricular systole
 - It initiates electrical impulse for heart beat
 - It is responsible for ventricular contraction only
 - It checks the backflow of blood
- Rashmi 's Grandfather is 65 years old who has been living with a dangerously slow heart beats. In this situation if he consults a cardiologist, he is possibly suggested to
 - Do heavy physical exercise everyday
 - Take less salty and spicy food
 - Implant an artificial pacemaker
 - Replace heart valves
- Which of the following event is responsible for hearing lubb dupp sound during heart beat?
 - Blood under pressure through aorta
 - Closure of bicuspid and tricuspid valve
 - Closing of semilunar valves
 - Closure of bicuspid and tricuspid valves followed by semilunar valves

9. To which of the following bundle of His transmits impulse of contraction?
 - a. Atrium
 - b. AV node
 - c. SA node
 - d. Purkinje fibre
10. Which of the following statement is incorrect?
 - a. Person having blood group A has antigen A in RBC and antibody b in plasma.
 - b. Person having blood group B has antigen A in RBC and antibody a in plasma.
 - c. Person having blood group AB has antigens A and B in RBC and no antibody in plasma.
 - d. Person having blood group O has no antigen in RBC and antibodies a b in plasma.
11. John was unknown about his blood group, falls in an accident. He immediately needs blood transfusion. One of his friend having valid certificate of his own blood type offers blood without delay. What was the blood group of the donor?
 - a. Blood group A
 - b. Blood group AB
 - c. Blood group B
 - d. Blood group O
12. Through which blood vessel does the left auricle receive pure blood?
 - a. Coronary vein
 - b. Pulmonary artery
 - c. pulmonary vein
 - d. coronary artery
13. Which of the following valve is present at the opening of the coronary sinus?
 - a. Mitral
 - b. Tricuspid
 - c. eustachian
 - d. tricuspid
14. From which of the following organ does the hepatic portal vein bring blood to the liver?
 - a. Kidney
 - b. Alimentary canal
 - c. heart
 - d. Gonad
15. Which of the following is associated with decreased cardiac output?
 - a. Parasympathetic signalling
 - b. Hormones of adrenal medulla
 - c. Pneumotactic centre
 - d. Sympathetic signalling
16. Which of the following chemical is used to detect the presence of absence of Rh antigen in RBC of blood?
 - a. Antiserum A
 - b. Antiserum D
 - c. Antiserum B
 - d. Antiserum A and Antiserum B
17. Which of the following artery supplies oxygenated blood to diaphragm?
 - a. Phrenic
 - b. pulmonary
 - c. carotid
 - d. vertebral
18. Which of the following vein is the longest vein in the human body?
 - a. Renal
 - b. Carotid
 - c. Gonadial
 - d. Saphenous

19. Which phase of the cardiac cycle involves flow of blood from ventricles to different body parts?
- Atrial systole
 - Isovolumetric contraction
 - ventricular systole
 - ventricular diastole
20. Mesenteric veins collect deoxygenated blood from
- Spleen
 - Intestines
 - stomach
 - gonad

Answer the following questions in brief.

- Describe the external structure of human heart.
- Draw well labeled diagram of internal structure of human heart.
- Describe the mechanism of origin and conduction of heart beat.
- What is blood pressure? Differentiate hypotension and hypertension ? what are the causes of hypertension?
- Observe the diagram given and answer the following questions.
 - Identify the part A and B.
 - What are their functions?
 - What is the remedy for the condition, when part A fails to work?
- Describe in brief about the arterial system of human.
- Write a brief note on human blood group.
- Draw neat and labeled diagram of venous system in human body.

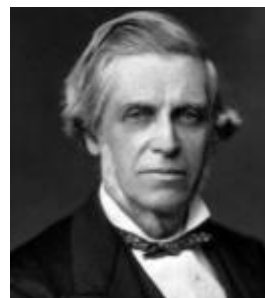


Long answer type questions

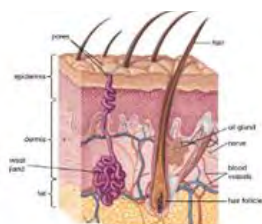
- What is myogenic heart? how is its structure and working mechanism in human? Explain.
- Describe the venous system in human body. Which type of portal system is found in human? explain

Chapter 8.4

Sir William Bowman (1816-1892) was an English surgeon, histologist, and anatomist, particularly regarding the kidney, eye, and striated muscle. He is famous for identifying the Bowman's capsule, a crucial part of the nephron in the kidney that filters blood. His research laid a foundation of knowledge for modern nephrology and histology. He also collaborated with Thomas Wharton Jones and made significant contributions in regard to the understanding of the eye and vision.



Observe the various organs shown in the pictures below and discuss on the following questions.



Skin



Lungs



Liver



Kidney



Intestine

- Are these organs excretory in function? If yes, how?
- Which organ among them is the major excretory organ in human body? Why?
- Which of them convert highly toxic ammonia to less toxic urea?

The group of organs involved in the elimination of metabolic wastes produced inside the body constitute excretory system. The metabolic wastes are nitrogenous compound, excess water, inorganic salts, CO₂, hormones etc. It is essential for maintaining homeostasis i.e. for regulating

the composition of body fluid and tissues. Nitrogenous wastes produced during protein metabolism, varies according to species.

Different types of nitrogenous excretory products in animals

Ammonia

It is highly toxic and highly soluble in water and its excretion needs large volume of water. Protozoans, sponges, coelenterates (*Hydra*), tapeworm, leech, most aquatic arthropods, most aquatic molluscs, freshwater bony fishes, tadpole of amphibian, tailed amphibian, etc. excrete ammonia. This is called ammonotelism or ammonotelic excretion.

Urea

Urea is less toxic and less soluble in water than ammonia and can stay in body for some time. Many land vertebrates like man, adult amphibians, mammals, elasmobranchs, marine bony fish, turtles etc. convert ammonia to urea for excretion. This is called ureotelism or ureotelic excretion.

C. Uric acid

Animals living in dry condition such as insects, land crustaceans (wood louse), gastropods, land reptiles (snakes and lizards), birds have to conserve water in their bodies. They synthesize crystals of uric acid from ammonia. Uric acid is least toxic, insoluble in water and can be retained in body for a considerable time. Uric acid is discharged in solid form and this type of excretion is called Uricotelism or uricotelic excretion.

D. Amino acid

Final product of protein digestion absorbed in small intestine. Animals cannot store amino acid in their body. So, the amino acids that the body cannot utilize are expelled by some animals. Some molluscan *Unio*, *Limnae* etc. and some echinoderms like *Asterias*. This is called aminotelism or aminotelic excretion.

Dual excretion:

Some animals such as earthworm, lung fishes, African toad, crocodiles etc. show dual excretion i.e., eliminate both ammonia and urea.

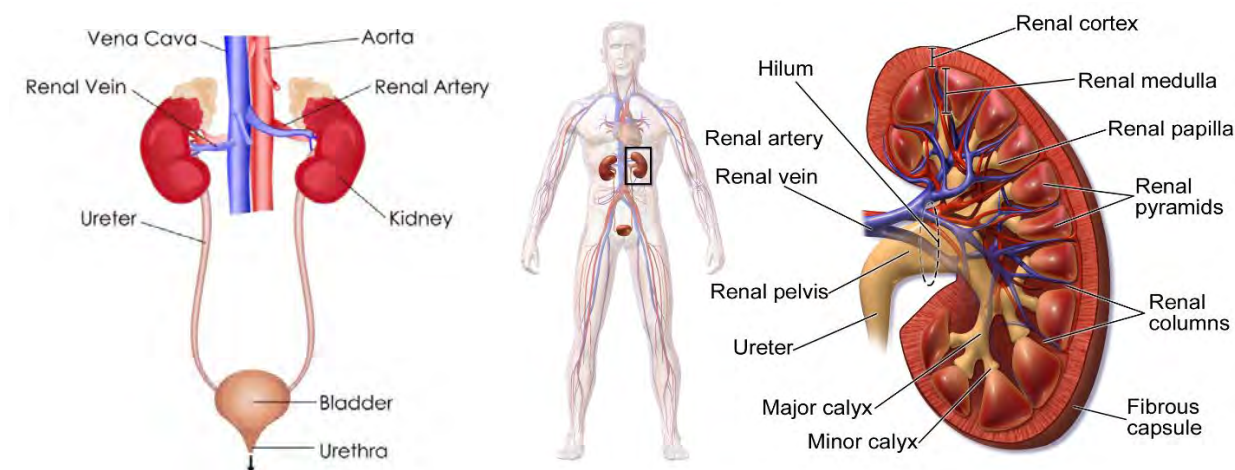
Activity

Visit your biology laboratory and examine the vertebrate specimen available (preserved specimens, models chart and fill in the table below.

S.N Vertebrate name

Mode of excretion

Excretory organs in the human body



Human major excretory organs consist of a pair of kidneys, a pair of ureters, a urinary bladder and a urethra.

Activity

Objective: To study the structure of mammalian kidney (Goat)

Apparatus required: dissecting tray, forceps, needle

Procedure:

- i. Take a fresh kidney of goat from nearby butcher shop
- ii. Keep it on dissecting tray.
- iii. Observe its external structure pointing out with the needle. (Take the help of your teacher if required)
- iv. Cut it longitudinally and observe its internal structure
- v. Note down all features on the white board and discuss.

Kidneys

External features

Kidneys are paired, dark red, bean shaped structures, situated on either side of the vertebral column at the level of T12 to L3. They remain attached to the anterior dorsal abdominal wall by a peritoneal fold. They are retroperitoneal in position; means they are located behind the peritoneal cavity. Right kidney lies slightly lower than left kidney to accommodate right lobe of liver. Each kidney typically measures about 11cm long, 5.5 cm wide, 3cm thick and weighs about 150 gram in male and 135 gram in female. However, these measurement can vary slightly depending on age body size and other factors. The kidney is metanephric (most advanced stage of embryonic development). Each kidney is enclosed within a three-layered protective coat:

- Innermost white, tough, and thin fibrous layer called renal capsule.
- middle layer of fat called adipose capsule.
- outermost covering of fibrous layer called renal fascia (attaches kidney to abdominal wall)

The kidney consists of outer convex surface and inner concave or notched surface. Inner concave surface is also called hilum or hilus. Hilum is the area from which ureter leaves the kidney and other structures, including renal vessels, lymphatic vessels and nerves etc. enter or leave kidneys.

Internal structure

Longitudinal section (L.S.) of the kidney shows two distinct regions: outer cortex and inner medulla. The cortex makes up about $\frac{1}{3}^{\text{rd}}$ of its tissue mass and is darker in color. The medulla is lighter region that comprises $\frac{2}{3}^{\text{rd}}$ part of the kidney, with striated appearance. In addition to this, Medulla is in the form of conical lobulated pyramids which are 15-16 in numbers. Cortex is continued or extended inwards between medullary pyramids to form renal column of Bertini. Medullary pyramids are connected with minor and major calyces. Major calyces lead into funnel shaped renal pelvis and renal pelvis leads into ureter. Internally, kidney contains millions of nephron or uriniferous tubule as the functional units, embedded in connective tissue. The cortex of the kidney contains parts of nephron such as Bowman's capsule, proximal convoluted tubule (PCT) and distal convoluted tubule (DCT) while the medulla contains loop of Henle, collecting duct and ducts of Bellini. Nephrons have chief role in the formation of urine.

2. Ureters

From the hilum or notched surface of the kidney, pelvis leads into whitish, narrow tube of 25-30 cm long called ureter. They run posteriorly on either side of vertebral column to open into urinary bladder. Openings of ureters into the urinary bladder are separate, but closely placed.

Histologically, the wall of ureter is composed of 3 layers- outermost fibrous layer, middle smooth muscle layer and the innermost mucosa. The mucosa layer is composed of transitional epithelium. There is a fold of mucous membrane serving as a valve like structure at the opening of ureter into urinary bladder. Such structure prevents backflow of urine from urinary bladder to urethra. The muscular layer creates peristalsis. Ureters transport urine from kidneys to the urinary bladder.

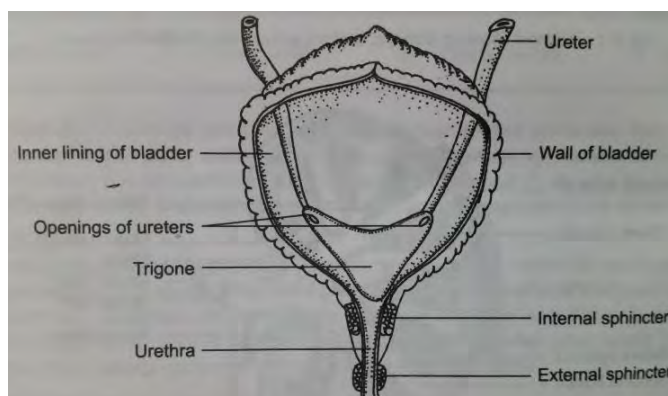
Urinary bladder

It is a thin walled, pear-shaped muscular bag lying on the floor of pelvic cavity. It serves as temporary storage of urine.

Histology of bladder wall shows the outermost fibrous layer, middle smooth muscle layer with loose connective tissue and the innermost transitional epithelium. The muscular layer is well developed called detrusor muscle (= muscle that can expel substance). Innermost layer of urinary bladder forms longitudinal folds called rugae, when bladder is empty. The urinary bladder is supplied with sympathetic and parasympathetic nerves. Internally the bladder has a triangular area called the trigone (trigonum vesicae). In the trigone, there are altogether three openings- two openings of ureter, one opening of urethra. In the normal adult, the bladder capacity is typically around 500 ml but it can sometime reach up to 1000 ml in fully stretched condition. Beyond this capacity can cause discomfort or may be harmful. The stimulation of urination or micturition starts, when bladder is filled with about 300ml urine.

Do you know

The transitional epithelium that forms innermost or mucosa layer of ureter, urinary bladder,



1. Urethra

It is a thick-walled tubular structure which discharges urine out from the urinary bladder. Urethra in female is relatively shorter, about 4 cm long and its opening lies between vaginal orifice and clitoris. In male, it is about 18 cm long and divisible into 3 parts: prostatic urethra (=2.5 cm, prostate gland covering part), membranous urethra (=0.5cm, middle short thinner part) and spongy urethra (=15 cm, last part passing through penis). Urethra is urinogenital duct in male as it carries urine and sperm but it serves as only urinary tract in female. Furthermore, it is provided with internal sphincter made from smooth muscle and external sphincter made from striated muscle. Internal sphincter lies near to the urinary bladder compresses urethra and retain urine in bladder, which is in involuntary control. External sphincter is under voluntary control. These sphincters relax to open the urethra for passing out urine.

Activity

Prepare a power point presentation on human excretory organ using internet research and reference books. Present your finding to the class.

Structure of Nephron (Uriniferous tubule)

As mentioned earlier, a kidney contains numerous, thin, much convoluted and long tubular units called nephron which produce very little amount of urine. So, a nephron is also known as the structural and functional unit of the kidney. About one million nephrons are embedded in the connective tissues of kidney along with blood vessel, lymph ducts, nerves and muscle fibres. The nephron measures about 3-5.5 cm in length. It consists of two parts: Malpighian body and Renal tubule

1. Malpighian body or renal corpuscle: It consists of Bowman's capsule and glomerulus.

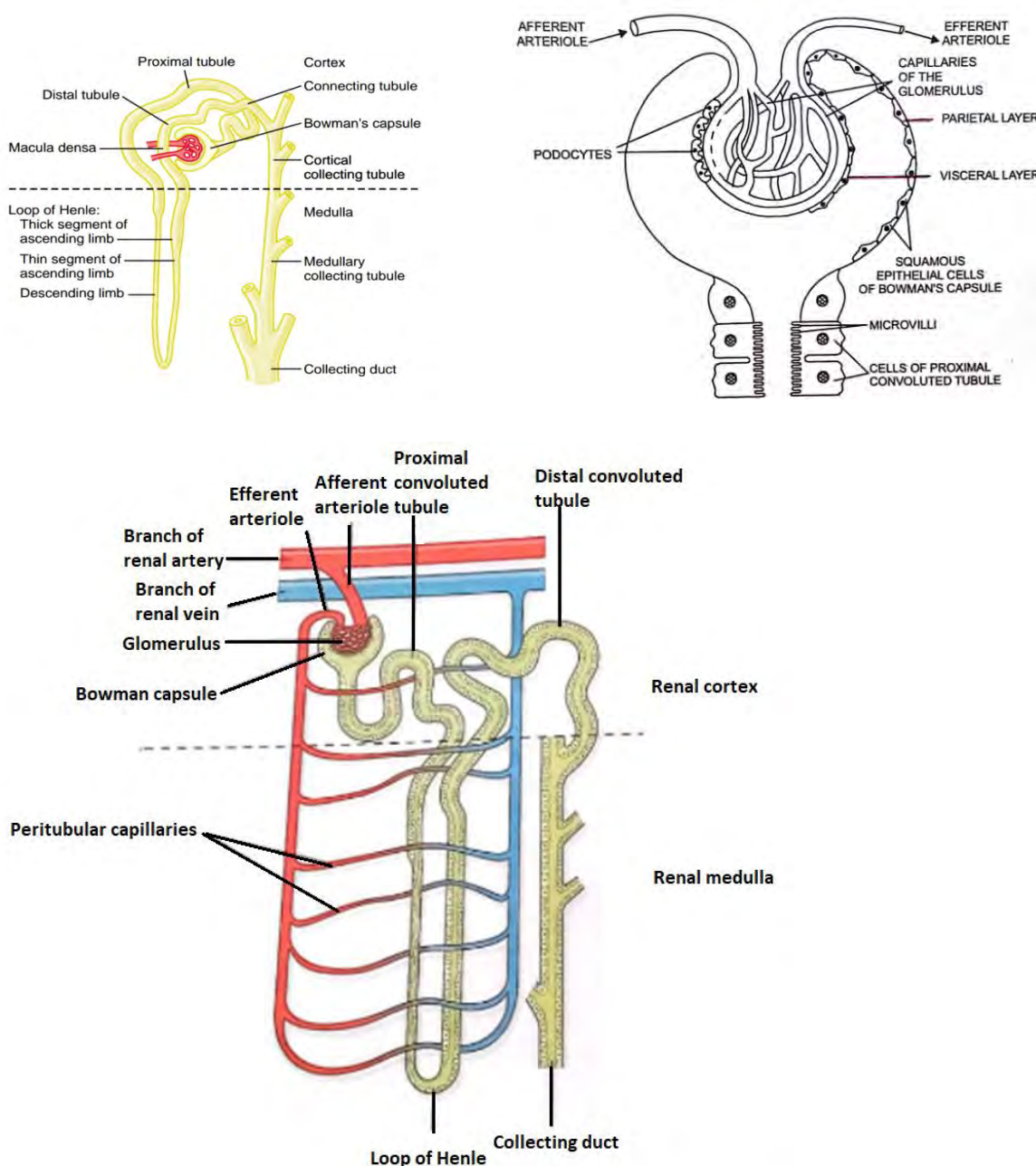
a. Bowman's capsule:

The name of bowman's capsule is based on a British physiologist sir William Bowman. It is an enlarged, proximal and double walled cup like structure. Two walls of Bowman's capsule are inner visceral layer and outer parietal layer. Inner layer is direct contact with capillary

endothelium and outer layer by squamous epithelium which surrounds an approximate spherical urinary space. Visceral layer cells are also called podocytes, having foot like cytoplasmic extensions (pedicels) which extend to glomerular capillaries network. Numerous micro-pores called filtration slits or slit pores are present between foot like processes which facilitate filtration.

b. Glomerulus

The Bowman's capsule is invaginated by a tuft of capillaries called the glomerulus. Afferent arteriole enters Bowman's capsule and break down into a fine capillaries network to form glomerulus which later come out as efferent arteriole. Capillary wall (endothelium) also has gaps or pores (fenestrae) of 0.1μ diameter to facilitate filtration of blood. Filtration of blood takes place in the glomerulus during the formation of urine under pressure.



2. Renal tubule:

It is the remaining tubular part of nephron behind the Malpighian body. It consists of following parts:

a. Proximal convoluted tubule (PCT)

Bowman's capsule is posteriorly continued into a convoluted tubular part called proximal convoluted tubule (PCT). It is internally lined by brush bordered cuboidal epithelial cells. The cells are brush bordered or having micro villi at their free edges to facilitate selective reabsorption during urine formation. These cells also have larger and numerous mitochondria for active transport in selective reabsorption. PCT lies in cortex region and it is the main site of selective reabsorption.

b. Loop of Henle (LOH)

PCT leads into a 'U' shaped tubular structure called Loop of Henle and its major part lies in medulla region. The loop of Henle has two limbs descending limb and ascending limb. Descending limb consists of a little thick segment and more thin segment. Thin part is lined by squamous epithelium and thick part is by cuboidal epithelium. Descending limb is permeable to water. The ascending limb also has both thin and thick part where thin part is lined by squamous epithelium and thick part is lined by cuboidal epithelium. Ascending limb is impermeable to water but permeable to NaCl by active transport only.

Do you know?

LOH is the longest in kangaroo rat.



c. Distal convoluted tubule (DCT)

It is the second convoluted tubular part after loop of Henle, which is lying in cortex region. DCT is internally lined by cuboidal epithelium. Absorption of Sodium ion and water but excretion of Potassium ion occurs in DCT. The terminal part of DCT is short and straight and is called connecting tubule or collecting tubule, joined with the collecting duct.

d. Collecting duct (CD)

Many DCT of number of nephrons lead into a bigger duct, through collecting tubules, called collecting duct. Collecting duct is lined by cuboidal and columnar epithelium. Collecting ducts unite to form larger ducts called ducts of Bellini and finally, large no. of duct of Bellini run through renal papillae to open into renal pelvis.

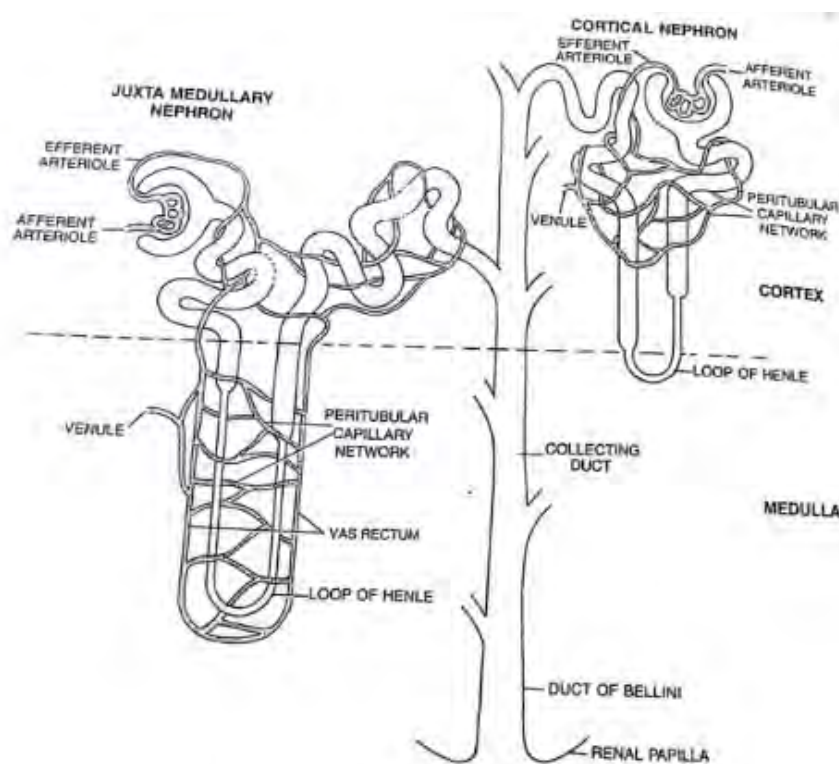
Types of nephron

Cortical nephron

Cortical nephrons are smaller in size and confined to cortex region. They form about 80-85% of total nephrons. They have short loop of Henle, not extended deep into the medulla. They are without vasa recta and they control plasma volume during normal water intake.

Juxta medullary nephron

These nephrons are larger in size occupying both cortex and medulla. They constitute about 15-20% of total nephrons. They have long loop of Henle, deeply seated up to medulla. Loop of Henle is provided with peritubular capillaries network called vasa recta. These nephrons have crucial role in controlling plasma volume during low water intake.



Prepare a chart to demonstrate the differences between cortical nephron and juxtamedullary nephron with diagram of each

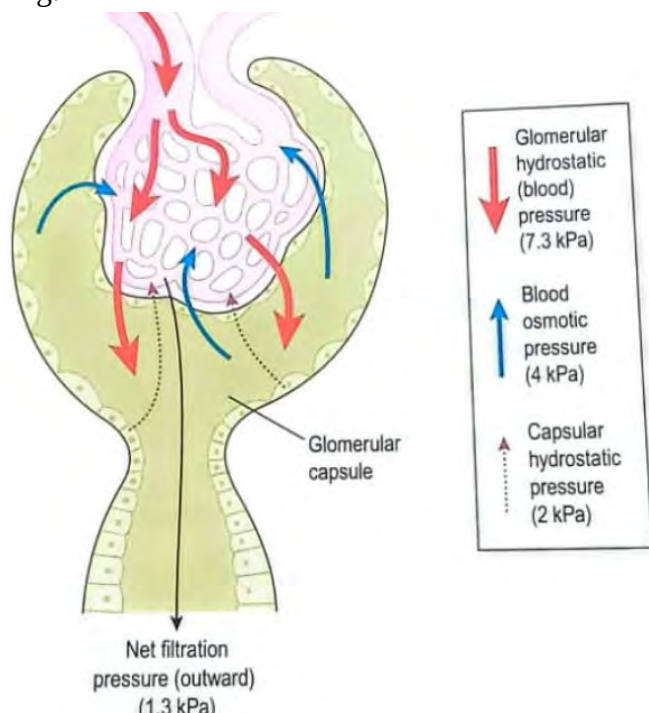
Mechanism (physiology) of urine formation

The entire process of urine formation can be summarized in following points:

1. Ultrafiltration or glomerular filtration

Ultrafiltration was first described by the Richard Bright in 19th century. It is purely a physical process in which filtration of blood under high pressure takes place. The substances dissolved in blood plasma are filtered out into Bowman's capsule due to the pressure of blood. During filtration, the barrier crossed by blood or filtration membrane is composed of capillary endothelium, basement

membrane of endothelial cells, visceral epithelium (layer of podocytes) of Bowman's capsule. during this, constituent of plasma passes except blood cells and some proteins. Diameter of afferent arteriole entering the Bowman's capsule is wider than that of efferent arteriole which escape out of capsule. So, more blood enters and less blood pass out from glomerulus. Hydrostatic pressure of blood in glomerular capillaries (GBHP=55mmHg) tend to promote filtration or drive the fluid downward. Whereas osmotic pressure of blood due to the presence of plasma protein (mainly albumen) opposes the filtration of fluid. (=30mmHg). Capsular hydrostatic pressure created by fluid in Bowman's capsule also opposes filtration (=15mmHg). Hence,net filtration pressure is about 10 mmHg.



Mathematically,

$$\begin{aligned}\text{Net filtration pressure} &= \text{Glomerular hydrostatic pressure} - (\text{osmotic pressure} + \text{Capsular hydrostatic pressure}) \\ &= 7.3 - (4 + 2) = 1.3 \text{ kPa}\end{aligned}$$

$$= 55 - (30 + 15) = 10 \text{ mmHg (may ranges from 8mmHg to 15 mmHg)}$$

Net filtration pressure is responsible for filtration of large amount of water, a number of small sized soluble substances, electrolytes. The filtrate so formed is called glomerular filtrate or nephric filtrate. Glomerular filtrate crosses capillary endothelium through the gaps and slits of podocytes down to the capsular space. Filtrate contains both the useful and harmful substances like glucose, amino acid, vitamin, urea, uric acid, ammonia, creatinine and large amounts of salts of low molecular weight. the amount of filtrate formed by both kidneys per minute in a normal adult is called glomerular filtration rate (GFR). It is about 125ml/min. (180l/day)

Selective reabsorption

In this process, selected substances, mainly useful substances are reabsorbed from the glomerular filtrate. The process of absorption occurs either by active or passive transport.

In PCT:

This is the main site of selective reabsorption where about 70% absorption of the filtrate occurs. Glomerular filtrate in PCT is isotonic to blood plasma. About 65% of Na^+ absorption takes place here by active transport. Glucose, amino acid, water soluble vitamins, lactic acid, HCO_3^- are also absorbed actively in PCT. About 80% of water is reabsorbed by osmosis, regardless of whether the person drinks a lot or a little water. This is called obligatory reabsorption. Various ions such as K^+ , Cl^- , Ca^{++} , Mg^{++} , are absorbed by diffusion. About 50% Urea is absorbed by diffusion

In loop of Henle

Descending limb of loop of Henle is highly permeable to water and impermeable to electrolytes. Water moves out the interstitial fluid and from this to the vasa recta. The filtrate in the descending limb becomes progressively hypertonic to blood plasma. Ascending limb of loop of Henle is impermeable to water and permeable to electrolytes like Na^+ , K^+ , and Cl^- ion which are actively transported to interstitial fluid. Such highly concentrated interstitial fluid also helps to draw out water from filtrate in the descending limb and collecting duct. Now the filtrate in tubule become progressively hypotonic to blood plasma.

In DCT

Reabsorption of Na^+ under the influence of aldosterone, Ca^{++} ion under the influence of parathormone. Water is absorbed (facultative reabsorption) under the influence of antidiuretic hormone (ADH). Filtrate is isotonic to plasma

In Collecting Duct

Further reabsorption of water occurs here. Water absorption under the influence of ADH, Na^+ ion under the influence of aldosterone. Some urea, Cl^- , HCO_3^- are also absorbed in collecting duct.

Tubular secretion

It is the process in which unwanted solutes, excess K^+ are actively secreted into the tubular fluid from the peritubular capillaries or blood. It helps controlling blood pH. Tubular secretion generally occurs in PCT, DCT, CD. Metabolic wastes such as creatinine, hippuric acid, foreign substances, pigments, drugs, penicillin, ammonia, H^+ are actively discharged into filtrate in PCT from the blood via interstitial fluid. Similarly, K^+ , H^+ , NH_4^+ are secreted into filtrate in DCT. Urea enters by diffusion into the thin segment of Loop of Henle.

This phenomenon has major role in marine fishes and desert amphibians which lack glomerulus and Bowman's capsule.

Finally, concentrated urine flows through collecting duct which reach to duct of Bellini and then to pelvis for the expulsion.

Activity

Design a poster showing different stages of urine formation. Display it around the class room and discuss.

Urine

Human urine is the liquid waste product formed by the kidneys. It is chiefly composed of water (95%) but it also contains a variety of dissolved substances (5%) such urea, creatinine, uric acid, electrolytes, ammonia hormones etc. About 1.5-2 litre urine is discharged per day by a healthy adult during normal water intake. Colour of urine is clear pale to deep yellow because of the presence of

urochrome (urobilin) pigment. Freshly discharged urine has aromatic odour but develops an ammonia odour if allowed to stand due to bacterial decomposition of urea. Urine is acidic around pH 6 but the value can vary from about 4.5 to 8. It has higher specific gravity (1.02-1.03) than the water due to the presence of solutes. Nitrogenous wastes constitute the largest solute fraction. The cause of characteristic aromatic odor of urine is due to the presence of a volatile substance called urinod.

Micturition

Urinary bladder contract to expel urine through the urethra is called micturition or urination. A kind of reflex action also called micturition reflex is followed by micturition. Collection of urine in the bladder is due to sympathetic and micturition is due to parasympathetic nervous system. When bladder is filled with about 300 ml urine, stretch receptor in the wall send afferent nerves impulses to the spinal cord and brain which activate micturition center of pons. Then, signaling of parasympathetic motor neuron take place and stimulate the contraction of detrusor muscle and relaxation of internal sphincter. Now external sphincter also relaxes and urine is discharged outside.

Role of other organs in excretion

There are some other accessory organs which help in the removal of wastes from the body.

1. Skin: Human skin consists of two types of glands: sweat gland and sebaceous gland. Sweat gland secrete sweat and sweat contains various wastes to be removed such as water, NaCl, urea, lactic acid amino acid. Similarly sebaceous gland secretes oily or wax like secretion called sebum which keeps the skin oily. Sebum contains various wastes like sterols waxes and other hydrocarbons.
2. Lungs: Lungs regularly remove CO₂ and less amount of water in the form of water vapor which are metabolic wasted produced during the oxidation of food inside the tissues.
3. Liver: Urea is formed in the liver which is removed by kidneys. Bile pigments Bilirubin, biliverdin, cholesterol, steroid hormones, vitamins, many drugs etc. are also expelled along with feces.
4. Intestine: Intestine excretes undigested food particle excess iron, calcium indole, skatole etc.

Project work

Prepare an anatomical model of human nephron using locally available materials.

Project work

Prepare a model of L.S of human kidney using locally available materials such as clay, thermocol etc. .

Exercise

Choose the best alternative

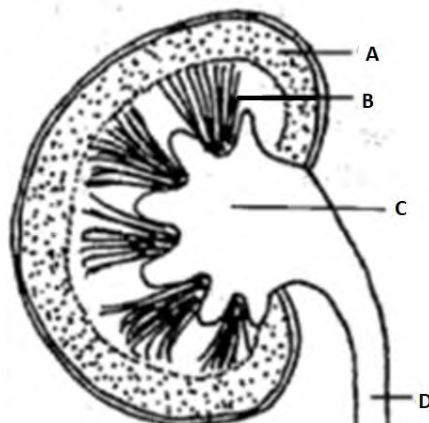
- Which of the following nitrogenous compound is most toxic?
a. Ammonia b. urea c. amino acid d. uric acid
- In the given animal, which one excrete amino acid without deamination?
a. Earthworm b. starfish c. human d. pigeon
- Frogs' tadpole is
a. Ureotelic b. amonotelic c. uerotelic d. aminotelic
- What are terrestrial insects?
a. Ureotelic b. uerotelic c. aminotelic d. ammonotelic
- Which of the following is the position of human kidney?
a. Intraperitoneal extraperitoneal
b. retroperitoneal interperitoneal
- Which is not correct with respect to human kidney?
a. Outer region is cortex and inner is medulla
b. Bowmans's capsule confined to cortex
c. Blood enters glomerulus through afferent venules
d. The concave part of kidney is hilum
- In which part, does the duct of Bellini open into?
a. Hilum renal pelvis
b. Ureter urinary bladder
- Which of the following part of nephron is responsible for obligatory reabsorption of water?
a. Proximal convoluted tubule Distal convoluted tubule
b. Loop of henle Glomerulus
- What is the cause of yellowish colour of urine?
a. Urochrome Indole
b. Skatole biliverdin
- Which of the following substance is most likely to be absorbed from glomerular filtrate during the process of urine formation?
a. Urea Glucose
b. Sodium Potassium
- Which of the following is a characteristic unique to juxtamedullary nephrons compared to cortical nephrons?
a. They have shorter loop of henle that stay within cortex
b. They are more abundant in the kidney than cortical nephron
c. They do not participate in the formation of concentrated urine
d. They have long loop of henle that extend deep into the medulla
- The muscular layer of urinary bladder responsible for the contraction during micturition is known as
a. Mucosa c. tunica adventitia
b. Detrusor muscle d. urethral sphincter

Answer the following questions in brief.

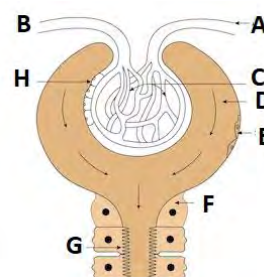
1. What is excretion? What are the types of animals on the basis of nitrogenous wastes they expel out?
2. Classify the following animals into different group in the table according to their mode of excretion.

Pigeon,	Lizard,	Rahu,	Shark,	earthworm,	<i>Lemnae</i>	crocodile,	crustacean,	woodlouse,	bat,	cow,	human,	snake,	dragonfly,	common carp,	tadpole,	frog,	lizard,	sparrow,	horse,	crab,	starfish,	Unio
Ammonotelic				Ureotelic																		aminotelic

3. Draw neat and labelled diagram of kidney.
4. Describe the structure of human kidney in brief.
5. What is ultrafiltration? in which part of the kidney does it occur? Describe the process in detail.
6. What is tubular secretion? Which type of animals are significantly more benefitted by this process?
7. Write short note on urine? By which process urine is discharged out? Describe the process in brief.
8. Observe the diagram give below and answer the following questions.
 - i. Label the parts A, B, C, D.
 - ii. What are the three difference between A and B?
 - iii. What are the function of C and D?



9. Observe the diagram give below and answer the following questions.
 - a. Label the parts A, B, C, D, E, F, G, H.
 - b. What are the two differences of A and B?
 - c. What is the function of C?
 - d. What is the significance of G?



Answer the following questions in detail.

1. Describe the human excretory organs with neat and labeled digram.
2. What is the functional unit of kidney called? How does it form urine? Describe the entire process?
3. Describe the structure of nephron? What are the differences between cortical nephron and juxtamedullary nephron?

Chapter 8.5

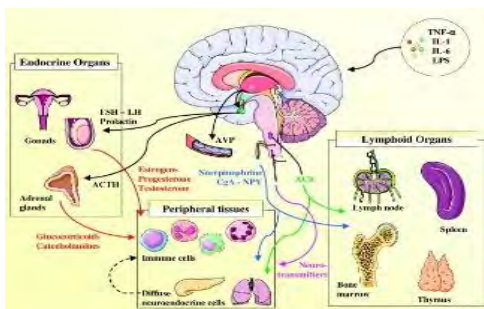
NERVOUS SYSTEM



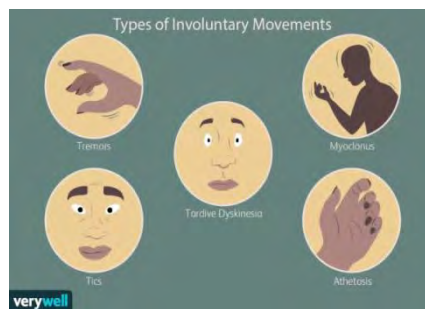
Santiago Ramon y Cajal (1852-1934) was a Spanish histologist and who along with **Camillo Golgi** jointly received **Nobel Prize** for **Physiology and Medicine** in **1906** for establishing the **nerve cell** or **neurone** as the basic structural unit of nervous system. The finding was instrumental in the recognition of neurone's fundamental role in nervous function and gaining a modern understanding of the **nerve impulse conduction**. He is considered the **father** of **modern neuroscience**.

See the figures given below and discuss following questions with your classmates.

1. How will you link nervous system with that endocrine system as shown figure A?
2. How will you connect the figures C, D, and E with one another in terms of control, coordination, integration, and regulation of one's own body through nerve impulse conduction due to nervous system?



A



B



C



D

Figure A reveals that there are two **integrative** or **communicative systems** in man – nervous system and endocrine system, both of which are collectively called **neuro-endocrine system**. The neuro-endocrine system is control of homeostatic processes in the body, including metabolism, energy balance, stress responsiveness, growth, and reproduction, etc. Hence, all sort of **integrative, communicative** or **homeostatic functions** of human body is controlled, coordinated, integrated, and regulated by the neuro-endocrine system. The neuro-endocrine system includes hypothalamus, pituitary gland and their connections to the brain, and other regions beyond the hypothalamus, e.g., inner layer of adrenal glands.

Neurology which is the study **nervous system** and treatment of the disorders of nervous system is one of the main important systems of the neuro-endocrine system.

The **involuntary muscle movements** (of man) shown in figure A, **thinking** (by man) shown in figure B, and **speaking** (by man) shown in figure C, reveals **control, coordination, integration, and regulation** of one's own body through **nerve impulse conduction** due to nervous system.

Nerve impulse conduction occurs via three types of the nervous systems: **central nervous system, peripheral nervous system, and autonomic nervous system** abbreviated as **CNS, PNS, and ANS**, respectively. The CNS, PNS, and ANS perform nerve impulse conduction by the exhibition of **sensitivity, sensibility** or **irritability**. The sensitivity, sensibility or irritability occurs through following steps: **excitability, reactivity, responsiveness, and behaviour**. The steps of excitability, reactivity, responsiveness, and behaviour are furnished by or inside **neurones**. The neurones which are originated from **ectoderm** are **structural and functional unit** of nervous system.

8.5.1 Types of nervous system

As mentioned above, there are three types of nervous system based on structure, function, and location: **central nervous system (CNS), peripheral nervous system (PNS), and autonomic nervous system (ANS)**.

1 Central nervous system

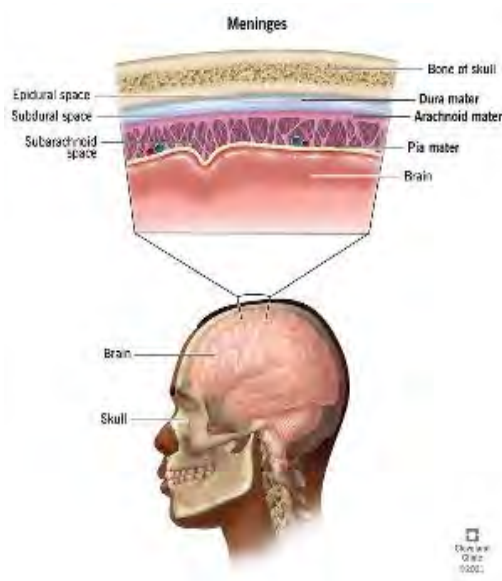
Central nervous system which is abbreviated as **CNS** and which is only formed of **association** or **inter neurones** carry nerve impulse from **receptors** of **sense organs**, e.g., eyes, nose, ears, etc. through **sensory neurones** and relay the required order for the desired work to the concerned **effectors**, e.g., muscles, bone, organ, system, etc. via **motor neurones**. CNS comprises two regions: **brain** and **spinal cord**.

Brain and spinal cord are covered by three consecutive layers of connective tissue. Each layer of connective tissue is known as **meninx** (plural – **meninges**). Three meninges (from outer to inner) are: **duramater, arachnoidmater, and piamater**.

Duramater (L., **dura**, tough mother) is outermost thick, tough, non-vascular, and double-layered meninx closely intact to cranial cavity of skull around brain and to neural canal of vertebral column around spinal cord. Duramater is followed by arachnoidmater.

Arachnoidmater (Gk., **arachnoid**, spider's web like) is middle thin, delicate, fine but webby, non-vascular, and fibrous meninx inner to duramater. Arachnoidmater is followed by piamater.

Piamater (L., **pia**, delicate mother) is innermost thinner, transparent, vascular, and closely intact to outer surface of brain and spinal cord.



V. S. of meninges

S. S. of brain

There is **epidural space** between skull and duramater, **subdural space** between duramater and arachnoid mater, and **sub-arachnoid space** between arachnoidmater and piamater. The spaces are filled up with cerebro-spinal fluid (CSF) secreted by two **choroid plexi** associated with piamater.

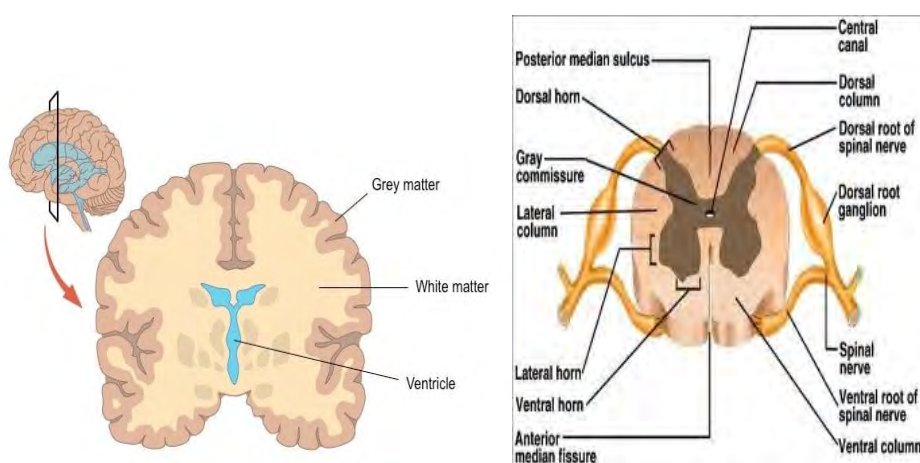
Do you know?

Inflammation of meninges due to the effect of certain species of bacteria is called **meningitis**. Out of many species of meningitis-causing bacteria, ***Neisseria meningitidis*** is one of them. Symptoms of the meningitis are: headache, vomiting, stiffness, and pain of neck.

I. Brain

Brain is the **most important** and **main organ** of human nervous system and is anterior most part of the CNS. Brain constitutes 98% of the total weight of CNS. It constitutes 2% of the total bodyweight of man, e.g., 1.4 kg in a 70 kg person. Brain reaches its full size in a child completing **six years**. It receives 15% of the total cardiac output and 20% of the total consumed oxygen.

Brain is that organ which is considered **main site** of **control, coordination, integration, and regulation** of one's own body through nerve impulse conduction. It is located in head and is completely protected inside brainbox called **cranium** of skull. Brain which possesses largest number of neurones (**86 billion**) has **graymater** outside on its outer surface due to aggregation of gray-coloured **soma**. It has **whitemater** inside on its inner surface due to aggregation of white-coloured myelinated **nerve fibres**. Therefore, outer surface of the brain looks gray and inner surface of the brain looks white. Neurones of the brain are embedded in and are closely associated with almost **85 billion neuroglia** which not only support them but also nourish. Neuroglia constitutes half the mass of brain and spinal cord. Brain is divided into three parts: forebrain, midbrain, and hindbrain.



Coronal or cross section (C. S.) of brain showing graymater and whitemater

T. S. of spinal cord showing graymater and whitemater

i. Forebrain

Forebrain, which is also known as **prosencephalon** is anterior most part of the brain. Forebrain has two parts: cerebrum and diencephalon.

A. Cerebrum

Cerebrum, which is also called **telencephalon** is largest part of the forebrain. It is also considered largest part of the brain.

Histologically, cerebrum has two layers: cerebral cortex and cerebral medulla.

a. Cerebral cortex

Cerebral cortex is surface layer on cerebral hemisphere (of cerebrum) measuring an average thickness of 1 to 4.5 (average 2.5) mm and constituting 82% of total mass of the brain. Out of the total mass, about 90% of cerebral cortex consists of six-layered tissues known as **neo-cortex**. There are numerous folds on cerebral cortex in the form of **sulci, fissures, and gyri**, all of which increase surface area of the cerebral hemisphere thus, making human more intelligent and wise along with high memory power. Cerebral cortex possesses two main types of cells – **stellate cells** and **pyramidal cells** which have sensory, motor, and integrative

signals in specific areas. **Sensory area** receives and interprets **sensory impulses**, **motor area** initiates **movements**, and **association area** commands more complex **integrative functions** like personality trait, intelligence, memory, reasoning, will, emotion, and judgement. There is an **anterior choroid plexus (ACP)** in close contact with cerebral cortex.

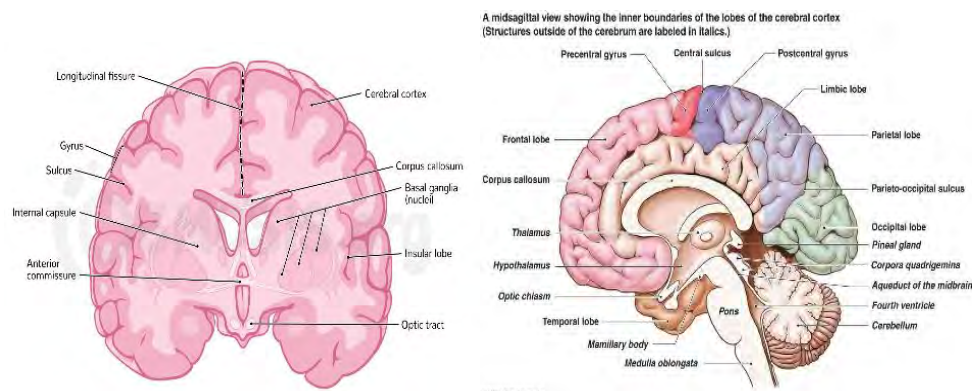
b. Cerebral medulla

Cerebral medulla is inner part of the cerebral hemisphere (of cerebrum) comprising basal ganglia and limbic system along with ventricles.

Structurally, cerebrum has three parts: cerebral hemispheres, basal ganglia, and limbic region.

a. Cerebral hemispheres

Cerebral hemisphere is the main and major part of cerebrum. It is equally but incompletely divided into two halves – **left cerebral hemisphere** and **right cerebral hemisphere** separated by median and deep **longitudinal fissure**. The left and right cerebral hemispheres are internally connected by a broad band of white matter called **corpus callosum** which contains nerve fibres and extends in between both hemispheres. The corpus callosum which is located below longitudinal fissure is arched from behind to forward and at both ends. Anterior curve of the cerebral hemisphere is called **genu** and posterior curve, **splenium**. **Fornix** is the central arch through which both genu and splenium are connected to cerebral hemispheres. Left cerebral hemisphere commands

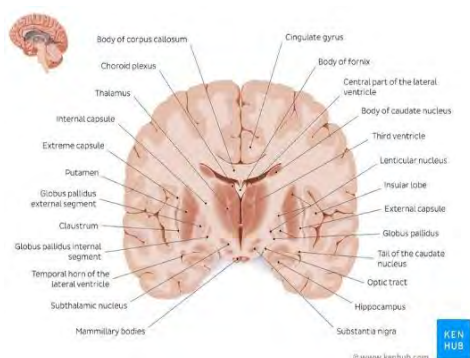


C. S. of brain showing cerebral cortex and cerebral medulla

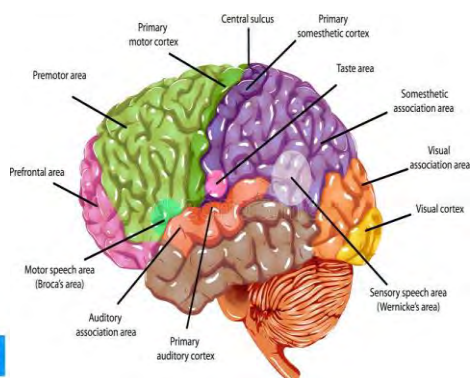
S. S. of human brain showing four lobes on left side

and controls **right side** of one's own body whereas right cerebral hemisphere commands and controls **left side**. Each of the cerebral hemisphere is divided into four lobes and each of the lobe is named after the name of the bones to which each one is connected – **frontal**, **parietal**, **temporal**, and **occipital**. Frontal lobe is separated from parietal lobe through **central sulcus**, frontal lobe is separated from temporal lobe through **lateral cerebral sulcus**, and parietal lobe is separated from occipital lobe through **parieto-occipital sulcus**. Each of the lobe performs

specialized functions. **Creative idea** occurs in frontal lobe. **Feelings** of hot, cold, touch, pain, etc., are registered in parietal lobe and



C. S. of brain showing cerebrum, basal ganglia, and limbic system



S. S. of cerebrum showing association/functional areas.

that the lobe exactly tends to **follow directions** on map, **reading time** in clock, **dressing** own-self, etc. Sound spoken by others is perceived through ears but **interpreted** and **understood** in temporal lobe. Vision of the objects is perceived through eyes but **marked** and **noted** in occipital lobe. In addition, **association areas** situated in these lobes are **functional areas**. There is one pair of solid olfactory bulbs, each of which is known as **rhinencephalon**. The left and right rhinencephalon are connected to **left** and **right arched cerebral hemisphere**, respectively through **left** and **right olfactory tract** just above **optic chiasma**. Two rhinencephalon which are the main site of olfaction are associated to amygdala of limbic system.

b. Basal ganglia

Basal ganglia are the group of **sub-cortical nuclei** lying deep within the cerebral hemispheres at the base of cortex. The basal ganglia are three in number: **caudate nucleus**, **putamen**, and **globus pallidus**. Three nuclei of the basal ganglia are collectively called **corpora striata**. The basal ganglia are functionally linked to the **sub-thalamic nuclei** of diencephalon and **substantia nigra** of midbrain. The basal ganglia help regulate initiation and termination of movements including control of subconscious contraction of voluntary muscles.

c. Limbic system

Limbic system possesses loop of cortical structures surrounding corpus callosum and thalamus at the medial border of temporal lobe. The limbic system comprises two nuclei – **amygdala** and **hippocampus** situated on median side of the temporal lobe, a tract called **fornix** leading to **mammillary bodies** of the hypothalamus, and a fold of cortex known as **cingulate gyrus** arching over the corpus callosum. The limbic system is designated as **emotional brain** because of its role in emotions like pain, pleasure, affection, and anger. Besides emotional role, the limbic system is also involved in **memory** and **olfaction**. When amygdala is removed, the person lacks **aggregation** and **fear**. Again, when amygdala is damaged, the person fails to recognize **fearful expressions** in others. The hippocampus is supposed to be

the **index for recall** of an event with its associated memory. Not only this, the cerebrum along with hippocampus help in memory.

Table: Association area in the lobes of cerebral hemispheres and their functions.

Lobe	Association area	Function/s
Frontal lobe	Pre-motor area	Highest centre of involuntary movements of muscles and ANS
	Motor area	Control of voluntary movements of muscles
	Broca's area	Speaking
Parietal lobe	Soma-aesthetic area	Perception of touch, hot, cold, pain, etc.
	Gustatory area	Sense of taste
Temporal lobe	Auditory area	Hearing
	Olfactory area	Sense of olfaction
	Wernicke's area	Understanding speech
Occipital lobe	Visual area	Sense of light

B. Diencephalon

Diencephalon is small or second part of the forebrain situated in between cerebrum and midbrain just below corpus callosum. **Anterior choroid plexus** (ACP) is present on its roof. The diencephalon has four main parts: epithalamus, thalamus, hypothalamus, and subthalamus.

Do you know?

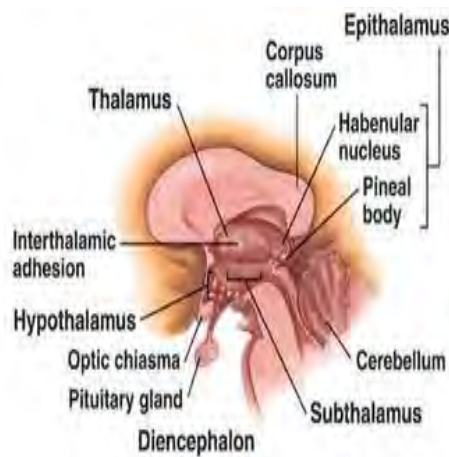
Nuclei are mass of soma in CNS and **ganglia** are mass of soma in PNS.

a. Epithalamus

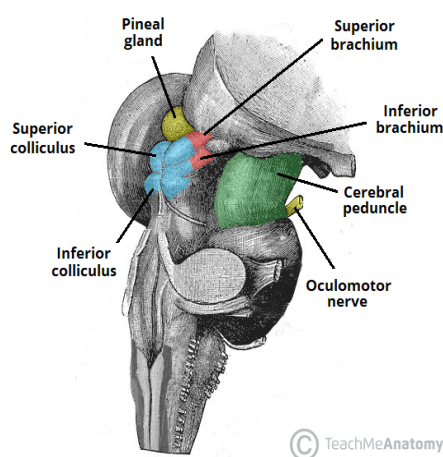
Epithalamus is narrow band of nervous tissue **superior** and **posterior** to thalamus on the roof of third ventricle and associated to **anterior choroid plexus** and anterior to **pineal gland** and **habenular nuclei**.

b. Thalamus

Thalamus is two oval mass of **gray matter** underlying cerebral hemispheres – **behind** corpus callosum, **above** hypothalamus, **superior to** midbrain in the lateral wall of third ventricle, and **near** optic chiasma. The thalamus tends to be **4/5th part** of diencephalon. The thalamus is interconnected to limbic system. The thalamus is **gateway** of the cerebral cortex because all sensory inputs pass through this gateway. The thalamus is involved in **memory** and **emotions**.



Diencephalon



Midbrain

c. Hypothalamus

Hypothalamus is sheltered at the base of thalamus on the floor of third ventricle supporting the pituitary body from below. The hypothalamus is **neuro-hormonal organ**.

Its **neural part** controls, coordinates, integrates, and regulates:

1. body temperature, homeostasis, internal body equilibrium, involuntary behaviour control, heartbeat, and respiration, and
2. eating, drinking, getting angry, keeping cool, making love, fighting, feeding, fleeing, and mating.

Its **hormonal part** secretes **releasing hormones** (RH), e.g., GH-RH, Gn-RH, etc. as well as hormones like **oxytocin** and **ADH**.

d. Subthalamus

Subthalamus is located below thalamus and dorso-ventrally to hypothalamus being continuous caudally with midbrain.

ii. Midbrain

Midbrain which is also known as **mesencephalon** is the middle part of brain situated in between diencephalon and hindbrain. **Cerebral aqueduct** which connects **third ventricle** with **fourth ventricle** passes from mid-brain. Out of several nuclei present in mid-brain, large and pigmented nuclei are left and right **substantia nigra** and richly blood supplied iron-containing left and right **red nuclei**. The substantia nigra release **dopamine** which is a **neurotransmitter**. There is **reticular formation** in mid-brain which is **gatekeeper** to consciousness and connects thalamus to major nerves in spinal cord. The midbrain has two parts: crura cerebri and corpora quadrigemina.

Do you know?

Deficiency of **dopamine**, a neurotransmitter released by **substantia nigra** of midbrain causes '**Parkinson's disease**'. The symptoms of **Parkinsonism** are: slow movement,

tremor, involuntary movement, rigidity, trouble walking, dementia, sleep disorders, pain, sensory disturbances, etc.

A. Crura cerebri

Crura cerebri which is also called **cerebral peduncle** is a pair of **tracts** lying ventrally in the anterior part of midbrain and relaying nerve impulses to and fro in all parts.

B. Corpora quadrigemina

Corpora quadrigemina which lies on **tectum** is the posterior part of midbrain containing two pairs of little lobes, each pair with paired colliculi: superior colliculi and inferior colliculi.

a. Superior colliculi

Superior colliculi which are **reflex centre** for certain **visual activities** are one pair rounded swellings lying dorsally but superiorly.

b. Inferior colliculi

Inferior colliculi which are **auditory pathway** relaying impulses from the receptors for **hearing in ear** to thalamus are one pair of rounded swellings lying dorsally but inferiorly.

iii. Hindbrain

Hindbrain which is also called **rhombencephalon** is situated in between midbrain and spinal cord. The hindbrain consists of three parts: cerebellum, pons varolli, and medulla oblongata.

A. Cerebellum

Cerebellum which is also known as **metencephalon** is the largest part of hindbrain and second largest part of the brain. The cerebellum is sometimes called **little brain** or **little cerebrum**. The cerebellum which lies inferior to cerebrum and located beneath fourth ventricle, is solid in consistency because no ventricles are inside it. The cerebellum constitutes about 10% of the brain but contains about 50% of neurons of the brain.

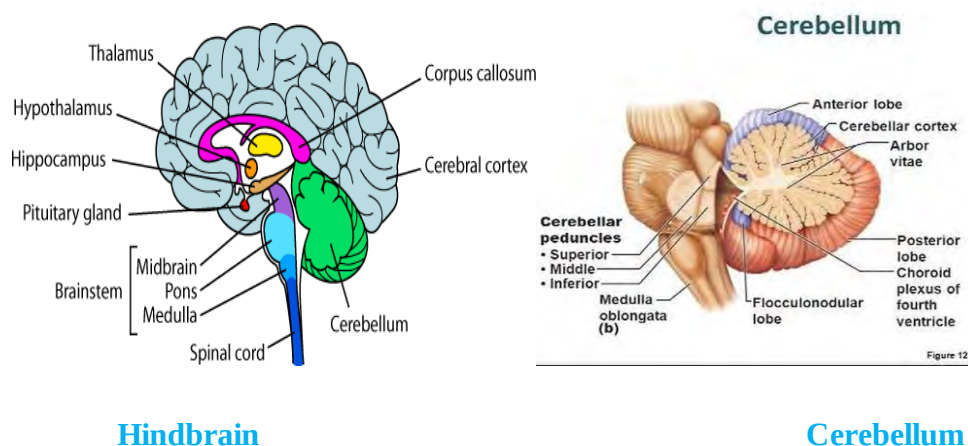
Histologically, cerebellum comprises two parts: cerebellar cortex and cerebellar medulla.

a. Cerebellar cortex

Cerebellar cortex is **three-layers of cells and fibres**.

b. Cerebellar medulla

Cerebellar medulla has tracts called **arbor vitae** resembling branches of tree.



Hindbrain

Cerebellum

Structurally, cerebellum comprises two parts: vermis and cerebellar hemispheres.

a. Vermis

The vermis (plural – **vermes**) is worm-like central constricted area in between two cerebellar hemispheres.

b. Cerebellar hemispheres

Cerebellar hemisphere is the main and major part of cerebellum. It is divided into two lateral wing-like lobes – **anterior cerebellar hemisphere** and **posterior cerebellar hemisphere**. The **flocculo-nodular lobe** on the inferior surface of cerebellar hemispheres contribute to equilibrium and balance. In cerebellar hemispheres, there are distinctive neurons called **Purkinje cells** and three paired bundles of myelinated nerve fibres. The first paired bundles are known as **superior cerebellar peduncles** which connect red nuclei of midbrain. The second paired bundles are called **middle cerebellar peduncles** which are largest among three cerebellar peduncles and communicate with pons. The third paired bundles are known as **inferior cerebellar peduncles** which are pathways to medulla oblongata and spinal cord. The cerebellar hemispheres **modulate** or **recognize** motor commands without initiation. Unconscious directions of the cerebellar hemispheres including conscious instructions of cerebrum determine when and how to move body parts. The cerebellar hemispheres control rapid muscular activities such as running, typing, talking, etc. and also perform involuntary activities involving learning in early stages.

Do you know?

Midbrain, pons, and medulla are collectively called **brainstem**.

B. Pons varolii

Pons varolii which is called **pons** in shortcut, is a bridge between midbrain and medulla. Pons forms floor of the **brainstem**. Pons is **neuronal link** between cerebral cortex and cerebellar cortex. Several of the **pontine nuclei** of pons are sites at which signals for voluntary movements which originate in cerebral cortex are relayed into cerebellum. **Pneumotaxic** and **apneustic** area are other nuclei present in pons.

Activity

Remember the dissection of general anatomy and alimentary canal of rat you did in class-XI. Now, with the permission of your biology teacher, take a preserved rat from your laboratory. Under the guidance of your biology teacher, dissect the rat so as to expose its CNS, i.e., brain and spinal cord. If possible, also expose PNS, i.e., cranial and spinal nerves. Try flag-labelling of the organs. If possible, take a photograph of the same.

C. Medulla oblongata

Medulla oblongata which is known as **medulla** in shortcut and which is also called **myelencephalon** is located in between pons and spinal cord. The medulla which is mainly made up of **white matter**, which has **posterior choroid plexus** (PCP) on its roof, and which has club-shaped ridges called **pyramids** on its anterior surface is continued into spinal cord. Some motor nuclei present in medulla are: cardiac, vaso-motor, and respiratory.

a. Cardiac centre

Cardiac centre adjusts diameter of blood vessels to adjust blood pressure.

b. Vasomotor centre

Vasomotor adjusts rate of heartbeat to force blood in blood vessels.

Activity

To be more clear about central nervous system (CNS) of man, **prepare a model of brain and spinal cord** with the help of mould by taking proper composition of plaster of Paris mixed with asbestos and other additives. Take the help of your biology teacher. Initiate this activity before her/him.

c. Respiratory centre

Respiratory centre controls rate and depth of breathing.

Table. Major parts of human brain and their main functions.

Part/s	Region of that part	Function/s
Forebrain	Cerebrum	Intelligence, thinking, knowledge, reasoning, will power, speech, learning from experience, skill, memory, consciousness, controls (defaecation, micturition, laughing, weeping, voluntary forced breathing, voluntary muscular contraction), etc.
	Rhinencephalon	Olfaction
	Diencephalon	Sensation of heat, cold, and pain; control centre of ANS; controls hunger, thirst, sweating, sleeping, sexual activities, etc.
	Hypothalamus	Regulate body temperature, maintain

		appetite, and fulfil satiety; controls emotion like love, anger, pleasure, satisfaction, etc.; controls metabolism of carbohydrate, lipid, and water.
Midbrain	Crura cerebri	To and fro conduction of nerve impulse in all parts
	Corpora quadrigemina	Reflex centre of visual and auditory sensation.
Hindbrain	Cerebellum	Involuntary muscular contraction; maintenance of posture, orientation, and equilibrium.
	Medulla	Regulate heartbeat and involuntary breathing; respiratory centres located; maintains blood pressure through vasodilation and vasoconstriction; maintains swallowing of food, gut peristalsis, vomiting, and glandular secretion.

Ventricles

Human brain and spinal cord are not solid from inside but hollow having cavities called **neurocoel**. The neurocoel present inside brain are called **cerebral ventricles** and that inside spinal cord known as **central canal**. The cerebral ventricles of brain and central canal of spinal cord are filled up by cerebrospinal fluid (CSF). The cerebral ventricles (singular – **ventricle**) which are called **ventricles** in shortcut are four in number: first, second, third, and fourth ventricle.

1. First ventricle

First ventricle which is also called **ventricle I** or **left lateral ventricle** or **left paracoel** is a large cavity inside left cerebral hemisphere.

2. Second ventricle

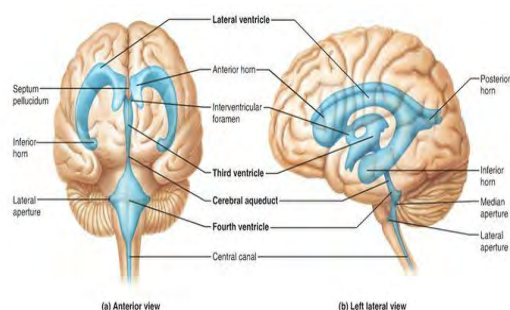
Second ventricle which is also known as **ventricle II** or **right lateral ventricle** or **right paracoel** is another large cavity in right cerebral hemisphere.

The first and second ventricle are collectively called **lateral ventricles** or **paracoels**. Anteriorly, both first and second ventricle are separated from one another by a thin membrane called **septum pellucidum**. The **foramen of Monro**, also known as **interventricular foramen** connect lateral ventricles with third ventricle.

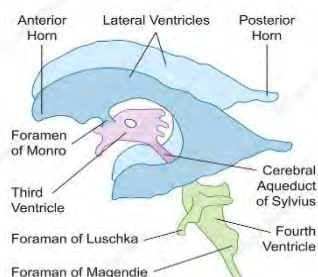
3. Third ventricle

Third ventricle which is also known as **ventricle III** or **diocoel** is a narrow cavity at the midline above hypothalamus and between left and right halves of thalamus. **Itter** which is also

called **cerebral aqueduct** or **aqueduct of Sylvius** is a narrow cavity in midbrain communicating diocoel with fourth ventricle.



Ventricular System of Brain



Ventricles of human brain

4. Fourth ventricle

Fourth ventricle which is also called **ventricle IV** or **metacoel** is a wide cavity lying between brainstem and cerebellum. There are three foramina (singular – **foramen**) present in fourth ventricle. Foramina refer to the apertures or holes. Out of the three apertures, an aperture present at the roof of fourth ventricle is known as **foramen of Magendie**. Similarly, two apertures present at the lateral wall of fourth ventricle are called **foramina of Luschka**. Out of the two foramina of Luschka, one is **left foramen of Luschka** and another is **right foramen of Luschka**.

The fourth ventricle extends inside spinal cord as **central canal**. Three holes present in the fourth ventricle (foramen of Magendie on the roof, left foramen of Luschka on the left wall, and the right foramen of Luschka on the right wall) maintain the flow of **cerebrospinal fluid (CSF)** out into subarchnoid space. The **blood supply in human brain** occurs mainly by **circle of Willis** which is formed at the base of brain by anastomoses of internal carotid and basilar artery.

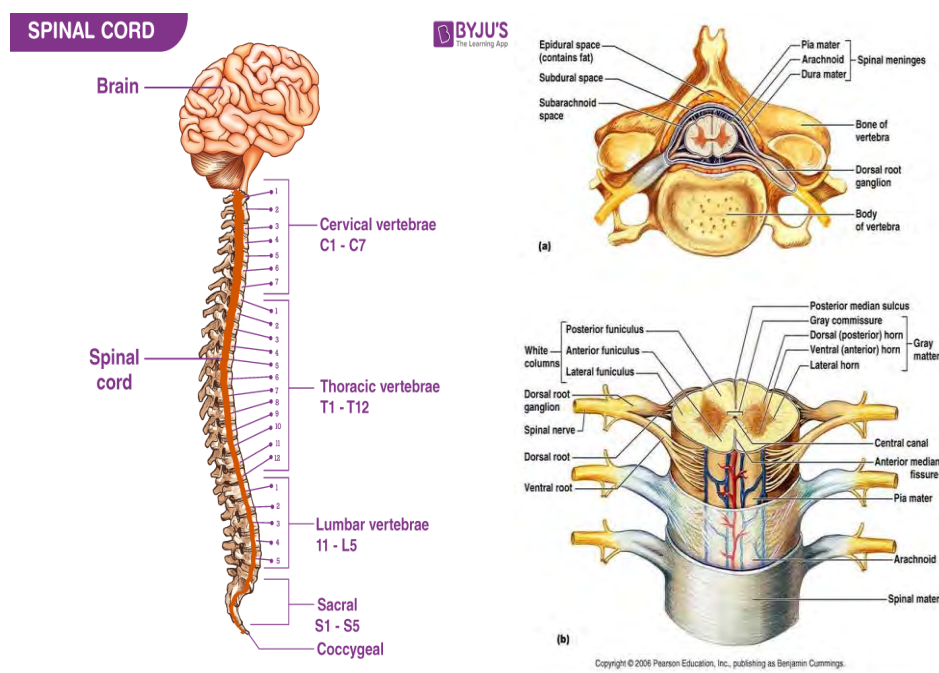
Activity

Human brain is not solid rather it is hollow from inside having cavities called ventricles which is filled up with cerebrospinal fluid (CSF). Take a white- or light-coloured chart- or sheet-paper and with the help of different colours, **draw ventricles**. Don't forget to mention proper labelling.

II. Spinal cord

Spinal cord is the second most important organ of human nervous system and is the posterior most part of CNS. It is inferior extension of the brain through medulla. The spinal cord is supposed to be the link between brain and nerves which stretch throughout the body. It stops growing at the age of 4-5 years. The spinal cord is located in vertebral column and protected inside cavity of the vertebral column called **neural canal**. It extends from cervical to first lumbar vertebra. The spinal cord is long, thin, cylindrical or tubular structure measuring 42-45

cm long, 2 cm thick in mid-thoracic region, somewhat larger in the lower cervical and mid lumbar region and smallest at the inferior tip. Its conical-shaped lower end is called **conus medullaris**. The terminal non- nervous part made up of pia-mater only extending from conus medullaris up to coccyx is called **filum terminale**. Tail-like gathering of roots of spinal nerves at the posterior end is known as **cauda equina** or horse-tail.



Spinal cord

Spinal cord is the accessory organ of brain of human body which controls, coordinates, integrates, and regulates one's own body through nerve impulse condition. Spinal cord is composed of about 69 million neurons and 1.6 billion neuroglia. Myelinated nerve fibres of the soma of neurons constitute white-coloured **white matter** outside encircling **gray matter** inside. Largest number of soma of neurons which constitute gray-coloured **gray matter** inside in the centre reveals **H-shaped** or **butterfly-shaped** structure having two horns. Closer to the front of spinal cord is **anterior** or **ventral gray horn** and closer to the back of spinal cord is **posterior** or **dorsal gray horn**, and between anterior and posterior lateral gray horns is **gray commissure**. Neurocoel of the brain called ventricles extends as neurocoel of spinal cord known as **central canal**. The central canal which is a hollow but narrow cavity is lined by ependymal cells and filled up with cerebrospinal fluid (CSF).

Cerebrospinal fluid (CSF)

Cerebro-spinal fluid (CSF) is secreted by two choroid plexi associated with ventricles – **anterior choroid plexus** (ACP) present on the roof of diencephalon and **posterior choroid plexus** (PCP) found on the roof of medulla. The **ACP** and **PCP** not only secrete CSF but also separate blood from CSF hence, constituting **blood-CSF barrier**. The CSF is filled up inside **cerebral ventricles** of brain and **central canal** of spinal cord. It is **colourless** but **clear watery fluid** without blood cells except few spinal cord lymphocytes. The CSF is similar to

blood plasma or **serum** containing glucose, proteins, cholesterol, lactic acid, urea, cations (Na^+ , K^+ , Ca^{2+} , Mg^{2+}) and anions (Cl^- and HCO_3^{3-}). It differs from plasma or serum in having lower concentration of Na^+ and higher concentration of Mg^{2+} and Cl^- . The CSF differs from blood in having $\frac{2}{3}$ rd of total glucose contained inside body, less proteins and cholesterol. It is present inside sub-arachnoid space entering through three apertures: first, foramen of Magendie, second, left foramen of Luschka, and the third, right foramen of Luschka. Total volume of CSF is **80-150 ml** in an adult human. The CSF functions to:

- a. protect brain and spinal cord from external shock and injury acting as shock-absorber,
- b. exchange nutrients and wastes, transport hormones, provide floating surface,
- c. give mechanical support, reduce internal friction, and reduce weight, and
- d. provide pressure equilibrium.

2 Peripheral nervous system

Peripheral nervous system which is abbreviated as **PNS** comprises peripheral nerves emerging from CNS, i.e., cranial nerves from brain and spinal nerves from spinal cord. The PNS comprises those peripheral nerves which interconnect CNS, i.e., brain and spinal cord with receptors (of sense organs) and effectors (of glands, muscles, bones, etc.) through cranial nerves and spinal nerves, respectively. Hence, the PNS has two types of nerves: **cranial** and **spinal nerves**.

I. Cranial nerves

Cranial nerves emerge from brain and interconnect receptors with effectors. The cranial nerves are present in **pairs** and in each pair – one left and one right. There are 12 pairs of cranial nerves. Each pair of cranial nerves are named in Latin, then expressed in ordinal numbers in English, and finally designated in Roman numerals indicating the order in which the nerves emerge from anterior to posterior of the brain. Out of the 12 pairs, first two pairs emerge from cerebrum and rest ten pairs emerge from brain stem. Again, out of 12 pairs, some pairs only contain sensory nerve fibres and thus, called **sensory nerves**, some pairs only contain motor nerve fibres and thus, known as **motor nerves**, whereas some pairs contain both sensory and motor nerve fibres and thus, called **mixed nerves**. The pairs of mixed nerves include both **somatic** and **autonomic efferent nerve fibres**. Twelve pairs of cranial nerves emerging from the brain are:

i. Olfactory nerves

Olfactory nerves are **first pair** of cranial nerves designated as **CN I**. They are one pair, **sensory** in nature, and emerge from bipolar neurons of olfactory epithelium on the roof of nasal cavity and projects centrally to olfactory bulbs. Because, they are distributed in nose, they transmit smell from nasal cavity to brain.

ii. Optic nerves

Optic nerves are **second pair** of cranial nerves designated as **CN II**. They are one pair, **sensory** in nature, and emerge from retina of eyes and projects through various tracts of primary visual cortex. Since, they are distributed in retina, they transmit visual signals from retina to brain.

iii. Oculomotor nerves

Oculomotor nerves are **third pair** of cranial nerves designated as **CN III**. They are one pair, **motor** in nature, and emerge from the junction between midbrain and pontine nucleus. Because, they are distributed in four eyeball muscles named **superior rectus**, **inferior rectus**, **internal rectus**, and **inferior oblique**, they carry signals from brain for eye movement.

iv. Trochlear nerves

Trochlear nerves, also called **pathetic nerves** are **fourth pair** of cranial nerves designated as **CN IV**. They are **smallest cranial nerves** having longest intra-cranial length. They are one pair, **motor** in nature, and emerge from posterior side of midbrain. Since, they are distributed in an extraocular muscles called **superior oblique**, they carry signals from brain for eye movement.

v. Trigeminal nerves

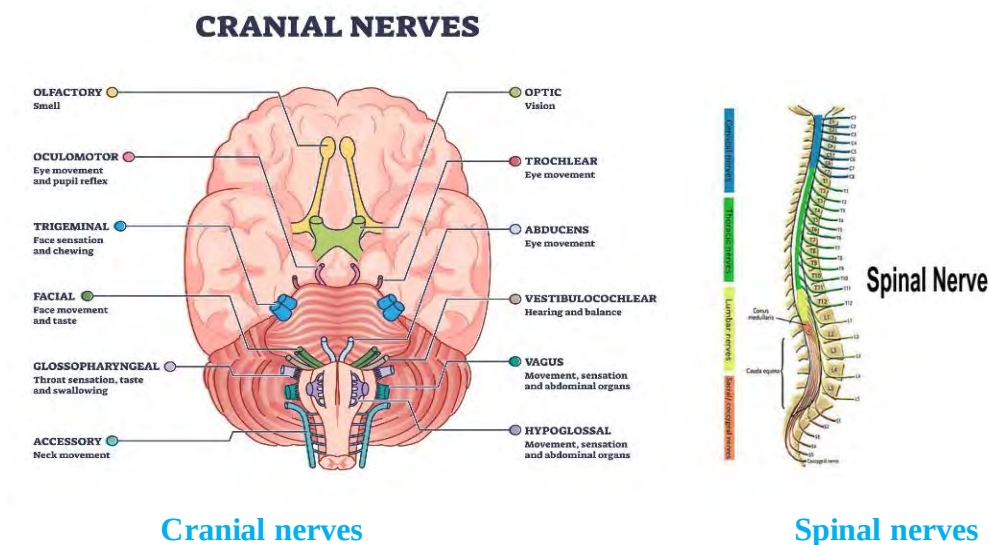
Trigeminal nerves are **fifth pair** of cranial nerves designated as **CN V**. They are **largest cranial nerves**. They are one pair, **mixed** in nature, and emerge from pons. Each **mixed nerve** of the trigeminal has two sensory and one motor nerves. First sensory nerves of both sides called **ophthalmic nerves** are distributed on snout, face, oral, and nasal cavity transmitting tactile, pain, and thermal sensation to brain. Another sensory nerves of both sides known as **maxillary nerves** are distributed on maxillary muscles transmitting above mentioned similar sensation to brain. Motor nerves of both sides called **mandibular nerves** are distributed on mandibular muscles carrying signals from brain for mastication or chewing.

Do you know?

There are six eyeball or extraocular muscles – **superior rectus**, **inferior rectus**, **external rectus**, **internal rectus**, **superior oblique**, and **inferior oblique**.

vi. Abducens nerves

Abducens nerves are **sixth pair** of cranial nerves designated as **CN VI**. They are one pair, **motor** in nature, and emerge from the junction between pontine nuclei and medulla oblongata. Because, they are distributed in an eyeball muscles known as **external rectus**, they carry signals from brain for eye movement.



vii. Facial nerves

Facial nerves are **seventh pair** of cranial nerves designated as **CN VII**. They are one pair, **mixed** in nature, and emerge from the junction between pontine nuclei and medulla oblongata. Each **mixed nerve** of facial has two motor and one sensory nerves. First motor nerves of both sides called **palatine nerves** distributed on palate and surroundings carry signals from brain for controlling facial expression. Sensory nerves of both sides known as **chorda tympani nerves** distributed on tongue, transmit signals of taste from tongue to brain. Another motor nerves of both sides called **hyo-mandibular nerves** distributed on lower jaw, neck, pinna, and hyoid carry signals from brain for helping in controlling facial expression.

viii. Auditory nerves

Auditory nerves also known as **acoustic** or **vestibulo-cochlear nerves** are **eighth pair** of cranial nerves designated as **CN VIII**. They are one pair, **sensory** in nature, and emerge from the junction between pontine nuclei and medulla oblongata. Since, they are distributed on internal ear, they transmit balancing and auditory signals from ear to brain.

ix. Glossopharyngeal nerves

Glossopharyngeal nerves are **ninth pair** of cranial nerves designated as **CN IX**. They are one pair, **mixed** in nature, and emerge from posterior to olive nuclei in medulla oblongata. Each **mixed nerve** of glossopharyngeal has one sensory and one motor nerves. Sensory nerves of both sides distributed on internal ear and tongue transmit balancing and taste signals, respectively to brain. Motor nerves of both sides distributed on pharynx carry signals from brain for swallowing of food.

x. Vagus nerves

Vagus nerves are **tenth pair** of cranial nerves designated as **CN X**. They are **longest cranial nerves**. They are one pair, **mixed** in nature, and emerge from posterior to olive nuclei in medulla oblongata. Each **mixed nerve** of vagus has one sensory and one motor nerves.

Sensory nerves of both sides distributed on pharynx, larynx, trachea, thoracic and abdominal viscera transmit signals to brain. Motor nerves of both sides distributed on pharynx and larynx carry signals from brain.

xi. Accessory nerves

Accessory nerves are **eleventh pair** of cranial nerves designated as **CN XI**. They are one pair, **motor** in nature, and emerge from posterior to olive nuclei in medulla oblongata. Because, they are distributed in neck, they carry signals from brain for turning of head.

Activity

Prepare a model of human cranial nerves with the help of mould by taking proper composition of plaster of Paris mixed with asbestos and other suitable additives. Take the help of your biology teacher. Start and furnish this activity before her/him.

xii. Hypoglossal nerves

Hypoglossal nerves are **twelfth pair** of cranial nerves designated as **CN XII**. They are one pair, **motor** in nature, and emerge from anterior to olive nuclei in medulla oblongata. Since, they are distributed in neck and tongue, they carry signals from brain for tongue movement.

Table. Cranial nerves, their branches, and their distribution

Name of the cranial nerves	Ordinal number	Roman numeral	Type of the nerves	Branches of the nerves	Distributed in/on
Olfactory	First	I	Sensory	—	Nose
Optic	Second	II	Sensory	—	Retina
Oculomotor	Third	III	Motor	—	Four eyeball muscles named superior rectus, inferior rectus, internal rectus, and inferior oblique
Trochlear	Fourth	IV	Motor	—	Eyeball muscle called superior oblique
Trigeminal	Fifth	V	Mixed	Ophthalmic	Snout
				Maxillary	Upper jaw
				Mandibular	Lower jaw
Abducens	Sixth	VI	Motor	—	External rectus eyeball muscle
Facial	Seventh	VII	Mixed	Palatine	Palate
				Chorda tympani	Tongue, taste bud.
				Hyo-mandibular	Lower jaw, neck, pinna, hyoid.
Auditory	Eighth	VIII	Sensory	—	Internal ear
Glossopharyngeal	Ninth	IX	Mixed	—	Tongue, pharynx.

Vagus	Tenth	X	Mixed	Anterior laryngeal	Larynx
				Recurrent laryngeal	Larynx muscles
				Cardiac depressor	Heart
				Pneumogastric	Lungs, oesophagus, stomach, and ileum.
Accessory	Eleventh	XI	Motor	–	Neck
Hypoglossal	Twelfth	XII	Moto	–	Neck and tongue.

Activity

Take a piece of white- or light-coloured thermocol and cut the thermocol in such a way so as to give the shape of human spinal nerves. **Paste** all the cuttings serially on a hard chart paper with the help of adhesive. Indicate the cutting with their proper labelling. Take the help of your biology teacher.

II. Spinal nerves

Spinal nerves emerge from gray matter of spinal cord and interconnect spinal cord receptors with effectors. The spinal nerves are found in **pairs** and in each pairs – one left and one right. There are 31 pairs of spinal nerves. Each pair of spinal nerves are named with the name of the corresponding vertebrae from where they emerge. All the spinal nerves are **mixed nerves** containing both sensory and motor nerve fibres. The spinal nerves, on each side possess two roots – **dorsal root** is **sensory** or **afferent** having ganglion and **ventral root** is **motor** or **efferent** without ganglion. There are eight pairs of **cervical spinal nerves** designated from **C₁** to **C₈** in cervical region corresponding to cervical vertebrae and distributed in upper limbs. There are twelve pairs of **thoracic spinal nerves** designated from **T₁** to **T₁₂** in thoracic region corresponding to thoracic vertebrae and distributed in trunk. There are five pairs of **lumbar spinal nerves** designated from **L₁** to **L₅** in lumbar region corresponding to lumbar vertebrae and distributed in lower limbs. There are five pairs of **sacral spinal nerves** designated from **S₁** to **S₅** in sacral region corresponding to sacral vertebrae and distributed in pelvis and lower limbs. There are one pair of **caudal spinal nerves** designated as **Cd₁** in coccygeal region corresponding to coccyx vertebrae and distributed in coccygeal region.

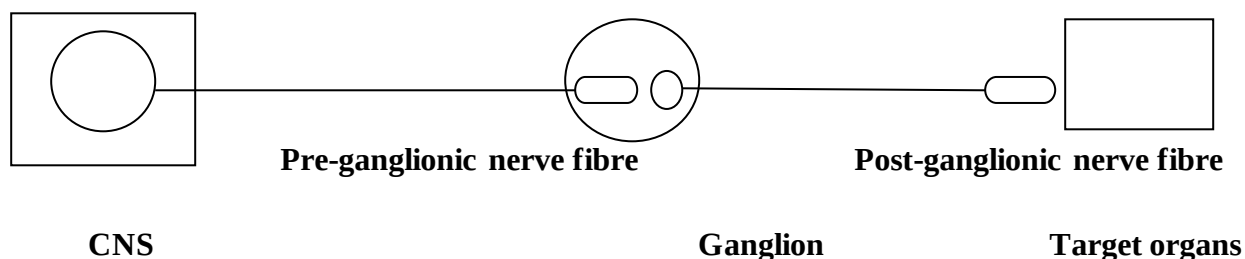
Do you know?

31 pairs of spinal nerves are expressed as: **C₈ T₁₂ L₅ S₅ Cd₁**.

3 Autonomic nervous system

Autonomic nervous system, also called **autonomous nervous system** or **automatic nervous system** and which is abbreviated as **ANS** comprises involuntary part of the nervous system serving to modulate those functions of human body which are not under voluntary control and

which are **self-occurring** or **self-perpetuating**. The ANS automatically regulates activities of unstriated muscles, cardiac muscles, and glands being regulated by centres in brain like cerebral cortex, hypothalamus, and medulla oblongata.



Autonomic efferent neurons are **pre-ganglionic** with **myelinated nerve fibres** and **post-ganglionic** with **unmyelinated nerve fibres** as shown in figure above.

The ANS, usually operates without conscious control as it is entirely motor hence, all **autonomic nerve fibres** are efferent. The autonomic nerve fibres which release **chemical** or **neurotransmitters** at **synapse** are two types: cholinergic and adrenergic.

I. Cholinergic nerve fibres

Cholinergic nerve fibres release **acetylcholine** which is used by pre-ganglionic and post-ganglionic neurons of parasympathetic nervous system and pre-ganglionic neurons of sympathetic nervous system.

II. Adrenergic nerve fibres

Adrenergic nerve fibres release **nor-epinephrine**, also called **nor-adrenaline** or **sympathetin** which is used by post-ganglionic neurons of sympathetic nervous system.

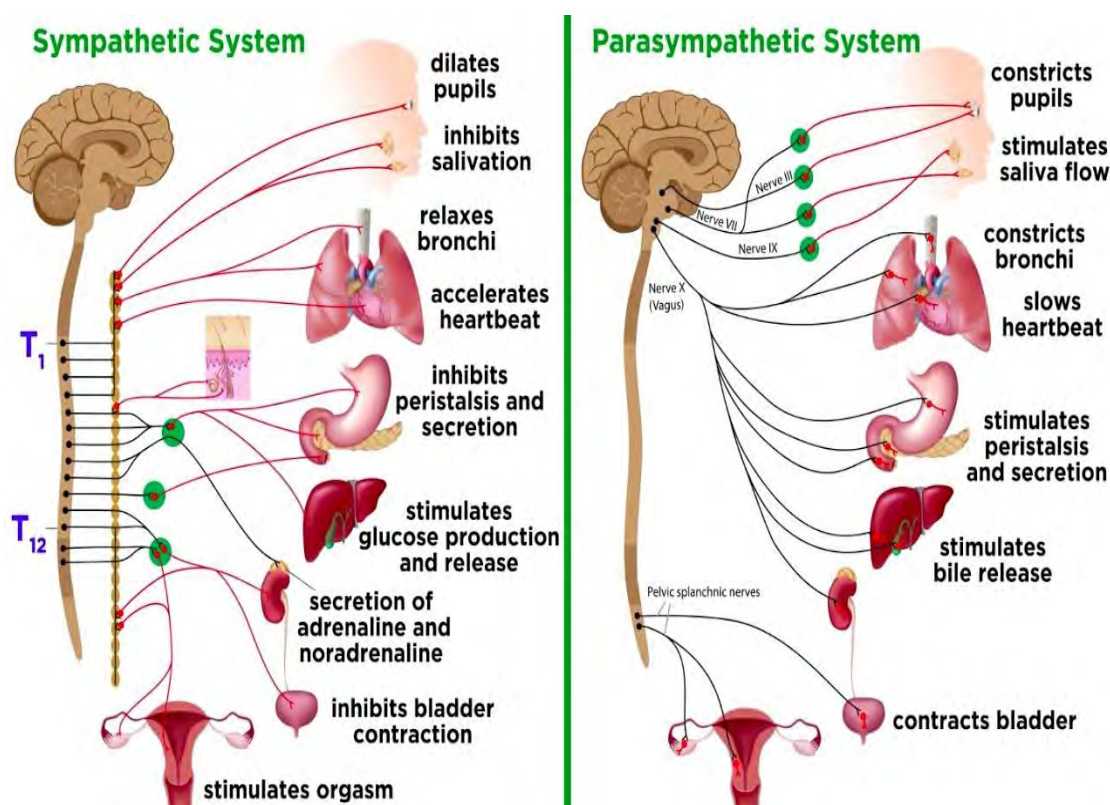
On the basis of outflow, the ANS is classified into two types: sympathetic and parasympathetic nervous system.

I. Sympathetic nervous system

Sympathetic nervous system abbreviated as **SNS** shows **thoraco-lumbar outflow** as sympathetic pre-ganglionic motor fibres occur in all pairs of thoracic spinal nerves and two pairs of lumbar spinal nerves from **T₁ to L₂** totaling 18 pairs of **sympathetic ganglia**. The sympathetic ganglia of each side are connected by a long sympathetic trunk. Each sympathetic ganglion is connected to the corresponding spinal nerves by **gray** and **white ramus communicans**. The SNS, which is an accelerator for the release of epinephrine or adrenaline increases defense of body against adverse conditions and is active in stress condition, pain, fear, and anger.

II. Parasympathetic nervous system

Parasympathetic nervous system abbreviated as **PaNS** exhibits **cranio-sacral outflow** as four cranial and three terminal ganglia from cranial (oculomotor, facial, glossopharyngeal, and vagus nerves) and sacral nerves (S₂, S₃, and S₄ spinal nerves), respectively forms it. The PaNS which becomes an inhibitor for the release of acetylcholine increases restoration and conservation of energy at the time of rest and is active in relaxed condition, comfort, and pleasure.



Sympathetic and parasympathetic nervous system

Activity

To show autonomic nervous system, take a white- or light-coloured chart- or sheet-paper and with the help of suitable colours, **draw** sympathetic and parasympathetic nervous system exhibiting antagonistic function. Maintain the proper labelling of both the system.

Hypothalamus which controls and integrates ANS is connected to both SNS and PaNS. SNS and PaNs exert opposite influence on the same organs or same set of organs. ANS regulates and coordinates involuntary activities like heartbeat, homeostasis, body temperature, breathing, gut peristalsis, and gland secretion but can't regulate learning and memory. Heartbeat is under the control of ANS however cutting the sympathetic and parasympathetic nerves from the heart will not stop it but the heart will beat without any nervous control.

Table. Human sympathetic nervous system

Emerge from	Site of synapse	Distributed in/on
Spinal nerves T ₁ to L ₂	Sympathetic chain ganglia or Para-vertebral ganglia	Unstriated muscles, cardiac muscles, and glands of head, limbs, and thoracic regions.
Thoracic-splanchnic nerves	Pre-vertebral ganglia	Unstriated muscles and glands of foregut and mid gut.
Lumbar-splanchnic nerves	Pre-vertebral ganglia	Unstriated muscles and glands of pelvic viscera and hindgut.

Table. Human parasympathetic nervous system

Emerge from	Site of synapse	Distributed in/on
CN III, VII, and IX	Four cranial ganglia	Unstriated muscles and glands of head
CN X		Viscera of neck, thorax, foregut, and mid gut.
Pelvic-splanchnic nerves (S ₂ , S ₃ , and S ₄)	Three terminal ganglia	Pelvic viscera and hindgut.

Table. Structural differences between SNS and PaNS

Structures	SNS	PaNS
Pre-ganglionic nerve fibres	Small	Long
	Come along with spinal nerves (thoraco-lumbar)	Emerge with cranial as well as spinal nerves (cranio-sacral)
	Branch and enter several ganglia (wide spread effect)	Don't branch and each enters a single ganglion (limited effect)
Post-ganglionic nerve fibres	Long	Small
	Adrenergic	Cholinergic
Ganglia	Sympathetic ganglia linked to form a chain of ganglia lying near spinal cord	Para-sympathetic ganglia remain isolated being present near of inside visceral organs
Neurons present in	Lateral funiculus of spinal cord	Midbrain, medulla oblongata, and lateral funiculus of spinal cord.

Table. Functional differences between SNS and PaNS

Organ or part of the organs	SNS	PaNS
Pupil of the eye	Dilation	Constriction
Ciliary muscles of the eye	Relaxes	Contracts
Salivary glands	Inhibits salivation	Stimulates salivation
Stomach	Inhibits peristalsis and digestion	Stimulates peristalsis and digestion
Pancreas	Inhibits activity	Stimulates activity
Liver	Stimulates glucose release	Stimulates bile release
Gallbladder	No significant effect	Stimulates activity
Intestine	Inhibits peristalsis and secretion	Stimulates peristalsis and secretion
Lungs	Relaxes bronchi	Constricts bronchi
Urinary bladder	Relaxes	Contracts
Heart	Accelerates contraction and heartbeat rate	Slows contraction and heartbeat rate
Blood vessels (below skin)	Constricts	No significant effect
Blood vessels (in skeletal muscles)	Vasodilation	No significant effect
Sex organs	Inhibits activity	Stimulates activity

8.5.2 Origin and conduction of nerve impulse

1. Nerve

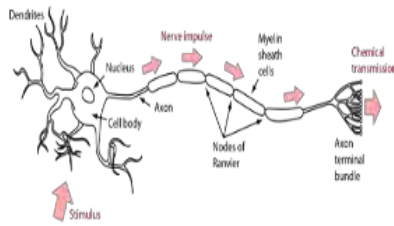
A **nerve** is that which receives and conducts nerve impulse to and from brain and spinal cord as well as from body. The nerve impulse occurs through nerve cell having fibre called **neurone**. Electro-chemical process is the **nature** of conduction of nerve impulse occurring through neurone.

2. Impulse

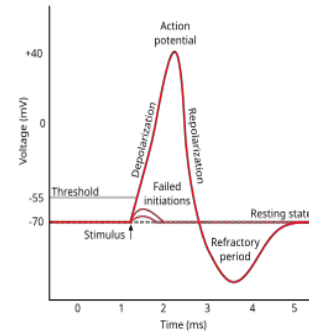
A **nerve impulse** also called **action potential** is wave of depolarization of membrane of the neurone through which it travels along itself, across its junction or synapse, between one neurone to another, between receptor to neurone or between neurone to effector.



Nerve



Impulse



Stimulus

3. Stimulus

A stimulus is **sudden change** in **environment** whether external (visual, sound, etc.) or internal (secretion of enzyme, hormone, etc.) and whether physical (temperature, light, etc.), chemical (oxygen, carbon dioxide, etc.) or biological (hunger, thirst, etc.) which is strong enough to **excite** a **nerve, muscle, gland** or **whole organism**. If stimulus is **capable** to excite a nerve, muscle, gland or whole organism to response then it is called **threshold stimulus** or **adequate stimulus** but if stimulus is not capable to excite a nerve, muscle, gland or whole organism to response then it is known as **subthreshold stimulus** or **inadequate stimulus**.

4. Neural summation

A neural summation is the series of subthreshold stimuli initiating an impulse or additive effect of several subthreshold stimuli.

5. All or none law

All or none law which is also known as **Bowditch's law** states that neurones, if conduct nerve impulse, then it will be at its **maximum** and if not transmit nerve impulse, then there will be **none**.

6. Neurones

Neurones which are main type of nervous tissue are **structural** and **functional unit** of nervous system. Each neurone possesses dendrites provided with endplates, soma containing Nissl's granules, and nerve fibre having synaptic knobs leading to nerve termination. The nerve fibre terminate in three ways as follows as:

- I.** Terminals of nerve fibre of one neurone connect endplates of the dendrites of another neurone through synaptic knob forming a junction called **synapse**.
- II.** Terminals of nerve fibre of a neurone terminate either on muscle fibre through motor end plate forming a junction called **neuromuscular junction** or in a gland cell forming a junction known as **neuro-glandular junction**.
- III.** Nerve fibres terminate and divide into fine branches called **sensory nerve endings** as in skin.

Neurones remain bathed in interstitial fluid (ISF) containing large amount of NaCl and HCO_3 including O_2 , CO_2 , and metabolic wastes whereas its intracellular fluid (ICF) contains large amount of K_3PO_4 and $\text{Mg}_3(\text{PO}_4)_2$ along with organic molecules including complex proteins. The solutes of ISF and ICF of neurones possess electrically charged particles called ions: positively charged cations (+) and negatively charged anions (–). The conduction of nerve impulse occurs electro-chemically.

Neurones exhibits two main properties: excitability and conductivity.

I. Excitability

Excitability is the ability of a neurone to enter into active state in response to a stimulus, e.g., touch, heat, etc., at the receptors.

II. Conductivity

Conductivity is the transmission of excitability in a particular direction through nerve fibre towards CNS, PNS or ANS.

7. Neural accommodation

A neural accommodation occurs when a neurone is depolarised by slowly **rising current** or **ramp depolarisation** in vitro as it adapts applied stimulus.

8. Speed of conduction of nerve impulse

Speed of conduction of nerve impulse depends on type of animals: low in invertebrates and high in vertebrates, type of vertebrates: low in lamprey and high in mammals, type of mammals: low in egg-laying mammals and high in human, type of nerve fibres: low in unmyelinated nerve fibre ($0.5\text{--}10\text{ m sec}^{-1}$) and high in myelinated nerve fibre (150 m sec^{-1}), and diameter of nerve fibre: low in small diameter and high in large diameter.

9. Refractory period

Refractory period is complete un-excitability between depolarization and repolarization. It is that period during which no threshold stimulus will create another nerve impulse or action potential.

The refractory period, on the basis of generation of nerve impulse, is two types: absolute and relative.

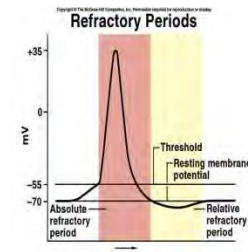
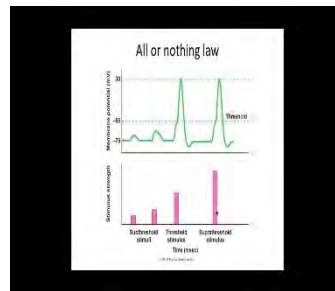
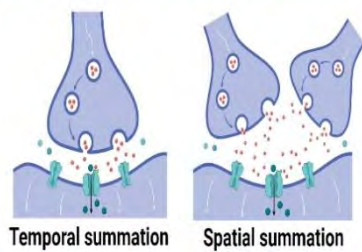
I. Absolute refractory period

Absolute refractory period is that during which, no matter how strong the stimulus is, can't produce another action potential.

II. Relative refractory period

Relative refractory period is that during which greater stimulus can produce another action potential.

Neural Integration: Temporal and Spatial Summation



Neural summation

All or none law

Refractory period

There are two ways of conduction of the nerve impulse: normal and saltatory.

I. Normal conduction of nerve impulse

Normal conduction of nerve impulse as mentioned above (resting potential or polarization, action potential or depolarization, refractory period, and repolarization) occurs through un-myelinated nerve fibre.

II. Saltatory conduction of nerve impulse

When nerve impulse travels along myelinated nerve fibre, depolarization occurs only at the nodes of Ranvier hence, impulse leaps over myelin sheath from one node to another using less energy than un-myelinated nerve fibre but being faster by 50 times.

10. Synapse

Synapse is an area of functional contact between one neurone and another for the purpose of transferring nerve impulse. Synapse is found between terminal branches of the nerve fibre of one neurone and dendrites of the soma of another and is called axo-dendrite synapse. Synapse consists of pre-synaptic knob (thickening of axon terminals) having mitochondria, SER, microfilaments, and numerous synaptic vesicles containing neurotransmitters (acetylcholine and noradrenaline) and post-synaptic membrane (thickening of dendrite ends) containing large protein molecules acting as receptor sites along with numerous channels and pores with gap junction or synaptic cleft (200 Å) in between.

Based on process of transmission of nerve impulse, the synapse is two types: electrical and chemical.

I. Electrical synapse

Electrical synapse is a gap junction in between pre-synaptic knob and post-synaptic membrane.

II. Chemical synapse

Chemical synapse is a synaptic cleft in between pre-synaptic knob and post-synaptic membrane.

Conduction of nerve impulse through synapse is two types: electrical and chemical.

I. Conduction of nerve impulse through electrical synapse

Nerve impulse which conduct through gap junctions (tubular proteins allowing free movements of ions) is faster than chemical but occurs rarely, e.g., cardiac muscles, un-stripped muscles of intestine, and epithelial cells of lens.

II. Conduction of nerve impulse through chemical synapse

Nerve impulse which conduct through synaptic cleft is slower than electrical but occurs mostly. When nerve impulse arrives at axon terminals, Ca^{2+} from the synaptic cleft enters the cytoplasm of pre-synaptic knob. The Ca^{2+} cause movement of synaptic vesicles to the surface of the knob. The synaptic vesicles fuse with post-synaptic membrane and get ruptured, i.e., exocytosis to discharge contents of the neurotransmitters into synaptic cleft. The synaptic vesicles then return to cytoplasm of synaptic knob where they are refilled with neurotransmitter. The neurotransmitter discharged in synaptic cleft binds with protein receptor molecules on the post-synaptic membrane. The binding action changes membrane potential of the post-synaptic membrane, opening channels in the membrane and allowing Na^+ to enter another soma causing action potential or depolarization and conducting nerve impulse. After changing permeability of the post-synaptic membrane, neurotransmitter is lost immediately from the synaptic cleft.

11. Neurotransmitter

Neurotransmitter is chemical substance which is released at the end of a nerve fibre by the arrival of a nerve [impulse](#) and, by [diffusing](#) across the [synapse](#) or junction, effects the transfer of impulse to another nerve fibre, a muscle fibre, or some other structure. The neurotransmitter are acetylcholine, norepinephrine, and gamma amino-butyric acid.

I. Acetylcholine

Acetylcholine is released in all neuromuscular junctions between motor neurons and striped muscles, at all synapses between pre- and post-ganglionic of ANS, and at certain synapses of CNS. It is excitatory in nature.

II. Norepinephrine

Norepinephrine is released by neurons of the SNS and few neurons of the CNS. It is excitatory in nature.

III. Gamma amino-butyric acid

Gamma amino-butyric acid abbreviated as GABA is released by some inter-neurons of CNS. It is inhibitory in nature.

12. Origin of nerve impulse

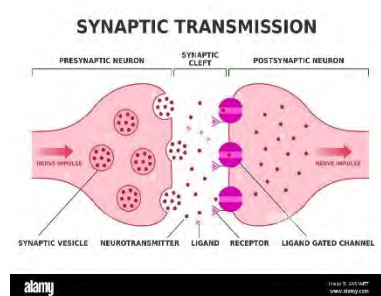
Origin of nerve impulse is guided by membrane or ionic theory of the conduction of nerve impulse.

I. Membrane or ionic theory of conduction of nerve impulse

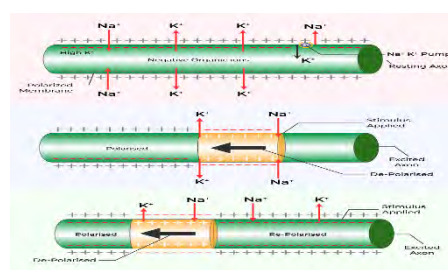
Membrane or ionic theory of conduction of nerve impulse is proposed by **Hodgkin and Huxley** (1930). This theory states that “**interaction of differential permeability and electric field across the membrane making critical threshold of charge is essential to excite nerve fibre**”. This theory is divisible into two main phases: resting and action membrane potential of nerve.

i. Resting membrane potential of nerve

Resting membrane potential of nerve, also called **polarization** refers to that in a **resting** or **non-conducting nerve fibre**, the **interstitial fluid** (ISF) contains low concentration of K^+ , high concentration of Na^+ (14 times more than **intracellular fluid** abbreviated as ICF), and negatively charged proteins whereas the ICF contains low concentration of Na^+ , high concentration of K^+ (28-30 times more than ISF), and negatively charged proteins, thus forming concentration gradients. Ionic gradients across the membrane are maintained by sodium-potassium pump in which active transport of 3 Na^+ from ICF to ISF (efflux) and 2 K^+ from the ISF to ICF (influx) occur resulting into net positive charge on outer axonal surface and net negative charge on inner axonal surface. **Potential difference** (PD) across the resting membrane is known as **resting potential** and the membrane is called to be **polarized**. The PD inside the membrane is -70 mV. If the PD inside the membrane is less than -70 mV then it is called hypo-polarization but if it is more than -70 mV then it is known as hyper-polarization.



Synapsis



Nerve impulse conduction

ii. Action membrane potential of nerve

Action membrane potential of nerve, also known as **depolarization** refers to that when **resting** or **non-conducting nerve fibre** is **excited** (because **excitability** is the first main property of neurone) by applying threshold stimulus, sodium-potassium pump stop operating and again due to active transport 3 Na^+ from ISF to ICF (influx) and 2 K^+ from the ICF to ISF (efflux) occur resulting into reverse in polarity in such a way that net negative charge occur on outer axonal surface and net positive charge on inner axonal surface. The potential difference (PD) across the excited membranes is called **nerve impulse** or **action potential** and the membranes are known to be **depolarized**. The PD inside the membrane is $+30$ mV. The

reverse in polarity (depolarization) and restoration of polarity (repolarization) successively and simultaneously from one location of axon to another **conduct** (because **conductivity** is the second main property of neurone) **impulse** with the help of **neural accommodation** at a speed of 130 m sec^{-1} in a fraction of second ($1\text{-}6 \text{ m sec}^{-1}$) during which no other impulse transmit called **refractory period** but after which the nerve fibre become responsive to another stimulus.

13. Process of conduction of nerve impulse

Everyone knows having two main properties of neurons – excitability and conductivity. Conduction of nerve impulse is guided and followed by “**All or none law**” proposed by Bowditch (1871). Further, conduction of nerve impulse is completely under the explanation of “**Membrane or ionic theory of nerve impulse**” proposed by Hodgkin and Huxley (1930). Furthermore, conduction of nerve impulse is supported by **neural accommodation** including **refractory period**. The process of conduction of nerve impulse is explained under – polarization, depolarization, repolarization, and hyperpolarization.

I. Polarization

In resting or non-conducting neurone of human body, due to active transport, sodium-potassium pump operates and there is efflux of 3 Na^+ for every influx of 2 K^+ resulting into polarization and resting potential of -70 mV .

II. Depolarization

When resting or non-conducting neurone of human body is excited (since, excitability is the first main property of neurones) having given threshold or adequate stimulus (either external or internal in terms of physical, chemical, or biological) through receptors like eye, ear, skin and glands (exocrine and endocrine) via PNS (cranial and spinal nerves) to CNS (brain and spinal cord) and the response of the same from CNS via PNS to effectors (muscles, glands, etc.) for conducting (since, conductivity is the second main property of neurones) nerve impulse to their respective locations as mentioned above then sodium-potassium pump stop operating and the axon membranes will not remain polarized and hence, action potential or nerve impulse is generated making the axon membranes depolarized. The threshold stimulus causes opening of voltage-gated Na^+ channels that open and close fast and the opening of Na^+ channels causes rapid influx of Na^+ and results in depolarization. At the same time K^+ channels open causing efflux of K^+ supporting the same depolarization. Excitatory impulses cause Na^+ influx and depolarization creating excitatory post-synaptic potential (EPSP). The inhibitory impulses open Cl^- channel and create inhibitory post-synaptic potential (IPSP). The neural summation of excitatory postsynaptic potential (EPSP) and inhibitory postsynaptic potential (IPSP) at the axon hillock determine generation of action potential or nerve impulse due to depolarization because of changing of the membrane potential hence, the threshold stimulus causes full-fledged action potential or nerve impulse exactly following Bowditch’s law. After action potential or nerve impulse, neural accommodation occurs in depolarised neurone by slowly rising current (ramp depolarisation) in vitro and the person adapts applied stimulus. Immediately after action potential or nerve impulse, absolute refractory period occurs followed by relative refractory period. The self-propagation of action potential or nerve

impulse is maintained by successive depolarization ahead in which the sequences move uninterrupted in an unmyelinated nerve fibre and is called normal propagation. In myelinated nerve fibre, rapid conduction (50 times more than normal conduction) of the action potential or nerve impulse occurs and is known as saltatory conduction. The action potential or nerve impulse of +35 mV that is an active process and doesn't show decrement with time, is further propagated as per direction mentioned below. The direction of action potential or nerve impulse, in sensory neurone, is from receptors to dendrite to soma to nerve fibre to synapse to dendrite of another neurone in PNS and CNS and in motor neurone, it is vice-versa, i.e., in CNS and PNS from dendrite to soma to nerve fibre to axon terminals to effectors.

Activity

Transmission of nerve impulse is the characteristic feature of neurones. To exhibit this, take a white- or light-coloured chart- or sheet-paper and with the help of different colours, **draw the diagram of nerve impulse conduction**. Mention the proper labelling of the same.

III. Repolarization

The action potential or nerve impulse is propagated along the axon membranes to synapse leading to the opening of voltage-gated calcium-channels in pre-synaptic membrane of the pre-synaptic knob. The Ca^{2+} influx leads to the release of neurotransmitter, e.g., acetylcholine by synaptic vesicles in synaptic cleft. The released neurotransmitter binds to receptors in post-synaptic membrane (of dendrite) leading to opening of chemically-gated ion-channels, the type of ion-channels being depending on neurotransmitter. If the action potential or nerve impulse is over and the impulse is relayed to its respective location, then membrane potential is again changed leading to the resting potential and repolarization.

IV. Hypo- or Hyperpolarization

The repolarization will have -70 mV as original or may be hypo-polarization being less or may be hyperpolarization being more. After repolarization, original ion gradients are established by Na/K ATPase pump that is a carrier mediated active transport in which hydrolysis of ATP drives this pump with the pumping of 3 Na^+ out for every 2 K^+ in. The route of nerve impulse is single-way traffic and is made clear for another message with the help of neurotransmitter.

Project work

Take into consideration seven mammals including man. Study and compare the brainwaves like alpha (α), beta (β), gamma (γ), delta (δ), and theta (θ) waves of man with that of mammals like dolphin, sea cow, dog, rabbit, elephant, and cow. Further, with the help of literature, either from standard book or online, **draw a conclusion to confirm brain activity** recorded through electroencephalography (EEG) and complete your project work.

Points to remember

Excitability (muscular): refers to the ability of muscle fibres to generate electrical impulses in response to stimuli, influencing muscle contraction.

Excitability (neuronal): refers to the magnitude of the response of neurones to stimulation.

Interneurones, also known as **association neurones**: receive nerve impulse from sensory neurones and relay the order to the effectors like muscles, bones, organs, glands, etc. through motor neurones.

Motor neurones, also called **efferent neurones**: carry nerve impulse from sensory neurones.

Reactivity (neuronal) refers to the readiness of the neurons to response to physiological response to stimuli.

Response or **responsiveness** (neuronal) refers to the arrangement of the internal change inside organism due to stimulus.

Sensitivity, **sensibility**, or **irritability** is the excitatory ability that living beings have to respond to changes in the environment, i.e., physiological reaction to stimuli.

Sensory neurones, also called **afferent neurones** carry nerve impulse from receptors/sense organs and relay to interneurones or directly to motor neurones

Glossary

Behaviour: refers to change inside an organism due to the response of stimuli.

Endocrine system: is the control, coordination, integration, and regulation of one's own body through chemical coordination via chemical messengers.

Nervous system: is the control, coordination, integration, and regulation of one's own body through nerve impulse conduction.

Neuroendocrine system: is a complex and well-integrated regulatory system that includes the hypothalamus, the pituitary gland and its connections to the brain, and other regions beyond the hypothalamus, e.g., inner layer of adrenal glands.

Neurology: is the study and treatment of disorders of nervous system.

Exercise

A. Tick the correct alternative.

1. Sensitivity or irritability is the characteristic feature of

- a. animals b. plants c. organisms d. protoplasm
2. How many meninges are found in man?
- a. One b. Two c. Three d. Four
3. Which one of the following layer of meninges closely adheres to the surface of brain?
- a. Duramater b. Arachnoid c. Piamater d. Cranium
4. Which one of the following is correct order of the meninges from inner to outer side?
- a. Duramater-arachnoid mater-piamater b. Duramater-piamater-arachnoidmater
c. Piamater-arachnoid mater-duramater d. Arachnoid mater-duramater-piamater
5. How many neurones are found in human brain?
- a. 5 billion b. 45 billion c. 85 billion d. 86 billion
6. The corpus callosum is not found in
- a. Man b. Rabbit c. Dog d. Duckbilled platypus
7. Which one of the following association areas of human brain functions in speaking?
- a. Broca's area b. Soma-aesthetic area c. Wernicke's area d. Visual area
8. If you are a right-handed person then which one of the following part of your brain tends to be active?
- a. Left cerebral hemisphere b. Right cerebral hemisphere
c. Left cerebellar hemisphere d. Right cerebellar hemisphere
9. Cerebral cortex of human forebrain contains many functional areas. What would happen, if the frontal lobe of cerebrum is accidentally damaged?
- a. Loss of memory and learning b. Loss of vision and hearing
c. Impaired respiration and circulation d. Impaired water balance and hunger
10. Which part of the brain is centre of intelligence?
- a. Cerebrum b. Cerebellum c. Pons varolli d. Medulla oblongata
11. Cerebellum is concerned with
- a. Intelligence b. Memory
c. Involuntary actions d. Coordination of muscle movement
12. The foramen of Monro connects
- a. first ventricle with second b. first ventricle with third
c. second ventricle with third d. first and second with third
13. All ventricles of brain are communicated with each other. Which one of the following connects third ventricle to lateral ventricles?

- a. Foramen of Monro b. Foramen magnum
- c. Cerebral aqueduct d. Foramen of Magendie

14. Which one of the following is auditory nerve?

- a. CN VI b. CN VII c. CN VIII d. CN IX

15. How many pairs of spinal nerves are found in man?

- a. 9 pairs b. 10 pairs c. 31 pairs d. 37 pairs

16. Ions responsible for the conduction of nerve impulse are

- a. S and P b. Na and K c. Fe and Cu d. Zn and Mg

17. Nerve impulse transmission occurs when the nerve is

- a. polarized b. depolarized c. repolarized d. in resting potential

18. Nerve impulse conduction is termed as

- a. wave of polarization along the nerve fibre
- b. wave of repolarization along the nerve fibre
- c. wave of no polarization along the nerve fibre
- d. wave of depolarization along the nerve fibre

19. If the cerebellum of a person gets injured, it will have effect on which of the physiological function?

- a. Memory function b. Smelling power
- c. Body movement d. Respiratory ability

20. Parasympathetic nervous system releases a hormone acetylcholine. Which one of the following is activated by this hormone?

- a. Increase myocardial contractility b. Decrease heartbeat rate
- c. Increase blood pressure d. Regulate involuntary response

21. Two systems having opposite actions on the same organ are

- a. Exocrine and endocrine systems b. Muscular and nervous systems
- c. Nervous and endocrine systems d. Sympathetic and parasympathetic systems

22. A part of our body where the axons may be more than a metre in length is

- a. cranial nerves b. spinal nerves c. autonomic nerves d. spinal cord

23. Human brain is divisible into fore-, mid-, and hind-brain. Which one of the following is not a part of forebrain?

- a. Rhinencephalon b. Telencephalon c. Diencephalon d. Rhombencephalon

24. Resting potential of the membrane of a nerve fibre is

a. +50 mV

b. -50 mV

c. +70 mV

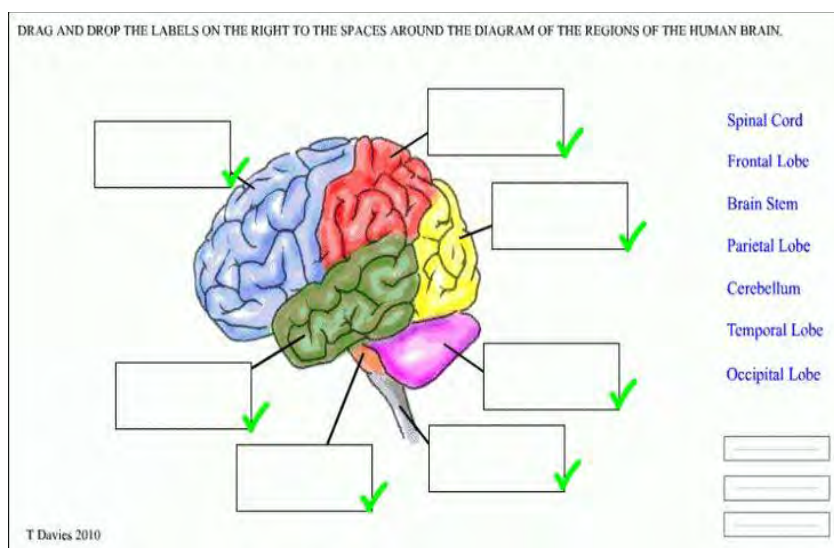
d. -70 mV

Answers.

1. d	2. c	3. c	4. a	5. d	6. d	7. a	8. a	9. a	10. a
11. d	12. d	13. c	14. c	15. c	16. b	17. b	18. d	19. c	20. b
21. d	22. b	23. d	24. d						

B. Short answer questions.

1. Compare and contrast nervous and endocrine system.
2. What do you mean by meninx? Describe meninges.
3. What is ventricle in brain? Discuss brain ventricles.
4. Label the diagram and write the association areas and their functions with respect to each lobe.



5. Explain human brain histologically.
6. Summarize the functions of hypothalamus.
7. Mention the functions of medulla oblongata.
8. Show the differences between sympathetic and parasympathetic nervous system.
9. Discuss about neurotransmitters used by sympathetic and parasympathetic nervous system.

10. What do you know about synapsis? Describe the synapses in between two neurones.

11. What is brainstem? Describe in brief the different parts of brainstem.

C. Long answer questions.

1. What is nervous system? How many types of nervous system are there? What are the parts of CNS? Illustrate the structure and functions of human brain.
2. What do you know about CNS? Describe in detail the medulla oblongata and spinal cord of man.
3. What is meant by PNS? Describe cranial nerves of man. Add an explanation of spinal nerves also.
4. How will you define ANS? Discuss the thoraco-lumbar and cranio-sacral outflow of sympathetic and parasympathetic nervous system, respectively.
5. What is nerve impulse conduction? Illustrate and describe in detail, how does a nerve impulse is transmitted through a nerve fibre? Do not forget to mention the role of neurotransmitters in the conduction of nerve impulse.

Chapter 8.6

SENSE ORGANS

8.6. Sense organs



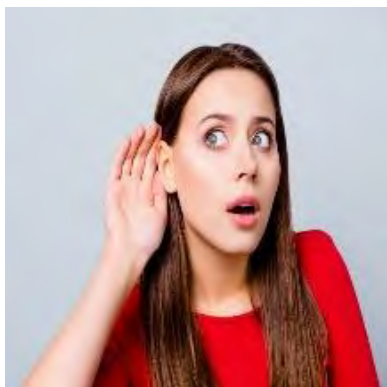
George Bartisch (1535-1607), a German physician was considered a highly skilled practitioner of **ocular medicine** and **surgery**. He discussed **ocular diseases**, **surgical techniques**, and **instruments**, and contained an **ophthalmic atlas**. He is also remembered for his work in **lithotomy** for the removal of **urinary calculi**. He wrote extensively on eye disease in the 16th century, and he was perhaps the most well-known **oculist** of his time and is considered by many to be the "**father of modern ophthalmology**".

Have a look at the figures given below and discuss following questions with your class friends.

1. How will you explain the figures A and B?
2. How can these figures be linked with sense organs and receptors?



A



B

Figure A exhibits a boy **observing** objects on sky through **eyes** with the help of binocular. Similarly, figure B indicates a girl **hearing** sound through **ears**. Both eyes and ears are **sense organs** which possess **receptors** of vision and hearing, respectively.

Sense organs, also known as **sensory organs** which possess receptors and which are connected to CNS through **sensory neurones** are **specialized organs** helping human beings to perceive and respond to surrounding environment. **Receptors**, also called **sensory receptors** which are **specialized cells** and which are situated in **sense organs** are part of the sense

organs. Receptors **receive** and **respond** to **stimuli** due to **change in energy**. They **detect stimuli** and **convert them** into **nerve impulses**, allowing a person to perceive surrounding environment. There are many types of receptors, e.g., photoreceptor in **eye**, stato-acoustic receptor in **ear**, chemoreceptor like olfacto- and gustato-receptor in **nose** and **tongue**, respectively and thigmo- or tactile-receptor in **skin**. Out of these receptors, the receptor of **vision** is situated in **eye** and the receptor of **mechanical balance** as well as **hearing** in **ear**.

Do you know?

Sense organs, possessing **receptors**, were seen for the first time in phylum-Cnidaria. The sense organs were **eye** and **statocyst**.

Following are the descriptions of two most important sense organs – eye and ear.

8.6.1 Eye

Eyes are **specialized sense organ** of **vision** or **sight** enabling man to see objects. Eyes are **extero-receptor** receiving stimuli from outside, **teloreceptor** receiving stimuli from distant object, and **special receptor** receiving stimuli to perform day to day activities. Eyes contain **photoreceptor** sensitive to light.

Eyes are **spherical** in shape, one pair in number (one left and another right), and each about 2.5 cm in diameter, 7.5 g in weight, and occupies a volume of 6.5 ml. Each eye is situated on either side (left and right) of face and each one located and protected inside spherical bony socket of the skull called **orbit**. Eyes are **simple**, provided with **clear**, **acute**, and **sharp vision**, and having **binocular** and **stereoscopic** or **3-D vision**.

Do you know?

Eyes, which were seen for the first time in phylum-Cnidaria are simple eyes possessing **photoreceptros**. The **simple eyes** of cnidarians, which are called **eyespots** or **ocellus** (plural – ocelli) are no image-forming eyes hence, photosensitive only. The **simple eyes**, which were image-forming with clear vision was seen for the first time in phylum-Arthropoda especially in arachnids like spider. The **compound eyes**, which were image-forming with mosaic vision was also seen for the first time in phylum-Arthropoda especially in insects like cockroach and honeybee.

Following are the structure and functions of eye.

1. Structure of eye

Eyes possess accessory structures, main structures, and content of the eyeball.

I. Accessory structures

i. Eyebrows

Eyebrows are small, arched-fringe of hairs on bony ridge just above eyelids protecting eyeball from dust, sweat, etc.

ii. Eyelids

Eyelids are transverse, muscular, and movable folds above and below the front of each eye called upper eyelid (larger) and lower eyelid (smaller) provided with eyelashes. Third eyelid also called **nictitating membrane** or **plica semilunaris** is vestigial being represented by swelling in the inner corner. The eyelids keep eyes moist.

iii. Eyelashes

Eyelashes are short, hard, and curved hairs present on the free edge of each eyelid to protect eyes from dust, foreign particles, etc.

iv. Conjunctiva

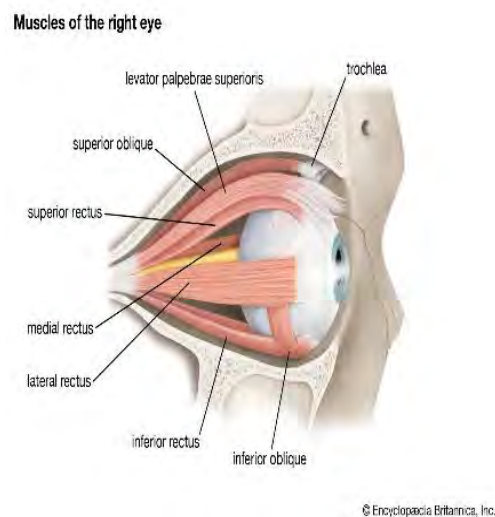
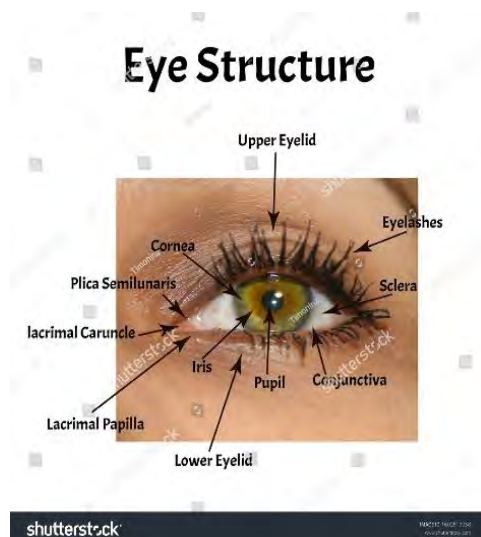
Conjunctiva is a **mucous membrane**, covering internal surface of upper eyelid, folding from upper to lower, continuing and covering on front surface of eyeball, and further folding from lower to upper, continuing and covering internal surface of lower eyelid. It keeps the eyeball moist. It is transparent.

v. Adipose tissue

Adipose tissue surrounds eyeball inside orbit so as to protect it from external shock and injury and to reduce internal friction.

vi. Extraocular muscles

Extraocular muscles, also called **extrinsic muscles** control eyeball movement inside orbit. These muscles are six in number.



External structure of eye

Extraocular muscles of eye

A. There are four **straight** or **rectus muscles** called internal or median rectus, external or lateral rectus, superior rectus, and inferior rectus.

B. There are two **oblique muscles** known as superior oblique and inferior oblique.

vii. Cranial nerves supplying to extra-ocular muscles

Oculomotor nerves which are third pair of cranial nerves designated as CN III and which are motor in nature supply to internal or median, superior, and inferior rectus and inferior oblique. Trochlear nerves which are fourth pair of cranial nerves designated as CN IV and which are motor in nature supply to superior oblique. Abducens nerves which are sixth pair of cranial nerves designated as CN VI and which are motor in nature supply to external or lateral rectus.

viii. Cranial nerves supplying to eyeball

Optic nerves which are second pair of cranial nerves designated as CN II and which are sensory in nature supply eyeball in which left one supplies to the right eyeball and the right one supplies to left eyeball.

ix. Glands: glands of Zeis, Meibomian or tarsal glands, glands of Moll, and tears- secreting lachrymal or lacrimal glands.

II. Main structures

Each eyeball, exposed part of which, out of the eyelids is called eye, is hollow and spherical structure. The eyeball is not empty rather it is filled up with liquid. The eyeball is ectodermal in origin except sclera and uvea which are mesodermal. The wall of each eyeball is made up of three **tunic** or **coats** in concentric layers from outer to inner called: fibrous, vascular, and nervous tunic.

i. Fibrous tunic

Fibrous tunic, also called **fibrous coat** is first, outermost, and covering layer of eyeball comprising two parts: sclera and cornea.

A. Sclera

Sclera, also known as **sclerotic** is larger most part having $\frac{5}{6}$ th of the eyeball and constituting white part of the outermost fibrous coat. The sclera is made up of white fibrous connective tissue with abundant collagen fibres. Sclera protects the eyeball and maintains its spherical shape.

B. Cornea

Cornea is small part having $\frac{1}{6}$ th of the eyeball and constituting the anterior or frontal and visible exposed part of the outermost fibrous tunic which is bulged on the frontal region and becomes convex. The cornea is modified or transformed part of sclera that is transparent so as to refract light waves to enter inside admitting them to fall on lens. Cornea is avascular and exchange gases from external environment. For this reason, cornea is considered most successful human organ for transplantation to others. At the junction of sclera and cornea, there is a structure called canal of Schlemm through which aqueous humour is drained into blood.

ii. Vascular tunic

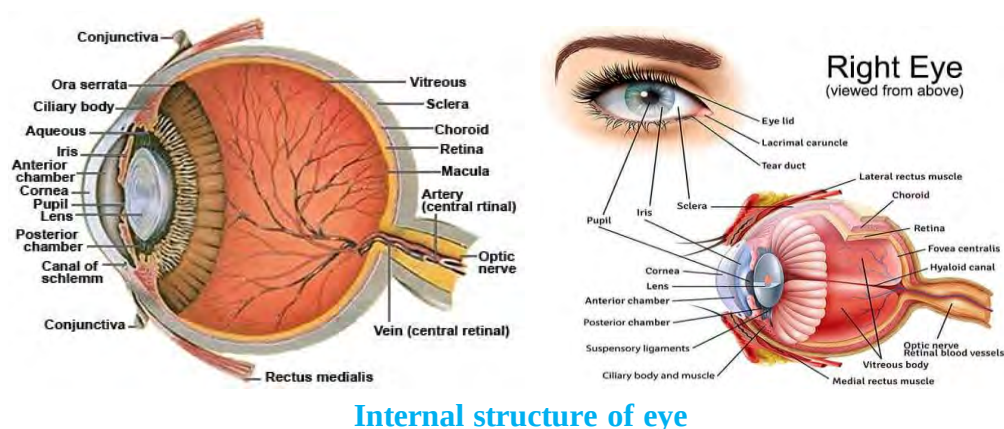
Vascular tunic, also called **vascular coat** or **uvea** is the second, middle, and supporting layer of eyeball consisting of three parts: choroid, ciliary body, and iris.

A. Choroid

Choroid is chocolate-brown coloured pigmented-layer lying posteriorly but adjacent to sclera preventing light to reflect back out of the eyeball by absorbing them. The choroid is made up of loose connective tissue with abundant blood vessels to supply nutrients and oxygen to surrounding tissues especially retina.

B. Ciliary body

Ciliary body is extension of choroid antero-backwardly being composed of ciliary processes or glands and ciliary muscles. The ciliary processes secrete aqueous humour. The ciliary muscles which are smooth muscles are two types: circular and meridional muscles. The ciliary body is attached to suspensory ligaments which are made up of yellow elastic fibres. The suspensory ligaments are attached to transparent and elastic capsule called **lens capsule**. The lens capsule completely surrounds lens. The ciliary body, along with suspensory ligaments and lens capsule hold the lens in its place.



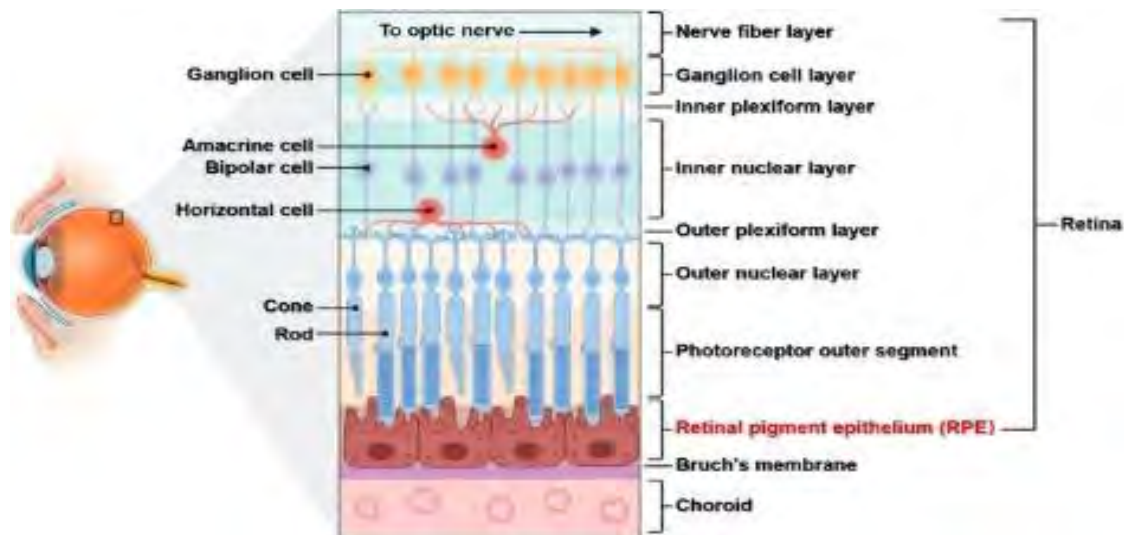
C. Iris

Iris is the extension of ciliary body antero-frontally forming bridge-like structure between cornea and lens. The iris is opaque and circular visible part having circular diaphragm and imparts colour to the eye. The iris is made up of two types of smooth muscles: outer circular functioning as sphincters and inner radial working as dialators. Central circular aperture in the iris is called pupil through which light passes. The iris separates aqueous chamber into anterior aqueous chamber and posterior aqueous chamber both filled up by aqueous humour.

iii. Nervous tunic

Nervous tunic, also known as **nervous coat** or **retina** is the third, innermost, and sensitive layer of eyeball. External or outer surface of nervous coat is in contact with choroid. Internal or inner layer of nervous tunic is in contact with vitreous humour. **Area centralis**, also called **macula lutea** or **yellow spot** lies in the centre, the central depression of which is called **fovea centralis** having cone cells only being centre of most distinct vision. **Blind spot** or **optic disc**

without rods and cones is that spot from where optic nerve and blood vessels pass. **Ora serrata**, also called **orra terminalis** demarcates retina from ciliary body. Retina comprises ten layers (from outer to inner): pigment cell layer, rods and cone layer, external limiting membrane, external nuclear layer, external plexiform layer, internal nuclear layer, internal plexiform layer, ganglionic cell layer, optic nerve fibre layer, and internal limiting membrane.



V. S. of retina showing ten layers of cells

A. Pigment cell layer

Pigment cell layer is single layer of pigmented epithelium or pigment-containing cells close to choroid.

B. Rods and cone layer

Rods and cone layer has rods with photosensitive pigment called **rhodopsin** or **visual purple** enabling to see in darkness and cones with three main photosensitive pigments like porphyropsin or erythropsin, iodopsin or chloropsin, and cyanopsin responding to red, green, and blue light, respectively.

C. External limiting membrane

External limiting membrane separates pigment cell layer and rods and cone layer from rest of the retinal layers.

D. External nuclear layer

External nuclear layer has soma of rods and cones.

E. External plexiform layer

External plexiform layer is network of nerve fibres forming synapses of rods and cones.

F. Internal nuclear layer

Internal nuclear layer has cell soma and nuclei of bipolar neurons, horizontal neurons, and amacrine cells.

G. Internal plexiform layer

Internal plexiform layer is network of nerve fibres forming synapses of bipolar neurons, ganglion cells, and amacrine cells.

H. Ganglion cell layer

Ganglion cell layer has soma of ganglion cells.

I. Optic nerve fibre layer

Optic nerve fibre layer has nerve fibre of ganglion cells.

J. Internal limiting membrane

Internal limiting membrane separates retinal layers from vitreous humour.

III. Content of eyeball

i. Lens

Lens is transparent, circular, biconvex, highly elastic, fibrous, and crystalline structure located behind iris having pupil and in front of vitreous humour. The lens which is large in size with a diameter of 8 mm and which is flexible in nature is made up of simple cuboidal epithelium on anterior surface in which cytoplasm of the epithelium cells lack nucleus but possesses fibres. Posterior surface of the lens is more convex than anterior. Lens focuses converged light on retina. Lens changes its shape or curvature depending on light, distance, etc. Lens separates aqueous humour with vitreous humour.

ii. Aqueous humour

Aqueous humour is thin, transparent, watery fluid possessed in compartment between cornea and lens secreted by processes or glands of the ciliary body. Aqueous humour maintains shape of the front part of eye and provides nutrients and oxygen to the associated parts. When required, aqueous humour is drained off into canal of Schlemm and then into blood. Aqueous humour acts as hydro-skeleton and produces intraocular pressure, i.e., pressure of the eye.

iii. Vitreous humour

Vitreous humour is thick, transparent, gel-like fluid possessed in compartment between lens and retina secreted by processes or glands of the ciliary body. Vitreous humour maintains shape of the back part of eye and also provides nutrients and oxygen to the associated parts. Vitreous humour also acts as hydro-skeleton and produces intraocular pressure, i.e., pressure inside the eye also.

2. Functions of eye

Vision, which refers to the ability to perceive and interpret the surrounding environment through light that enters the eyes, ultimately allowing man to see and process visual information. Vision that refers to see objects is the only function of eye. Human vision is binocular, clear, trichromatic, and stereoscopic or 3D. Following is the working mechanism of eye through accommodation and image formation.

Light rays refract through cornea, pass via aqueous humour, modify through lens, cross via vitreous humour, and focus on retina where they generate nerve impulse or action potential in rods and cones. Passing of the light is governed by pupil either by increasing or decreasing the size of its aperture by the help of iris muscles. Focusing of light to retina is maintained by the capacity of lens called **accommodation**. Potential differences (PDs) are generated in photoreceptor cells of retina causing nerve impulse or action potential. The nerve impulse or action potential is transmitted by optic nerve to visual cortex area in the occipital lobe of the cerebral hemispheres where it is analyzed and the image is recognized.

Defects of eye

Following are the defects of human eye: refractive errors, age-related conditions, and other eye conditions.

1. Refractive errors

I. Myopia

Also called **nearsightedness** or **shortsightedness**. It is difficulty in seeing distant objects clearly, while near objects remain in focus. This occurs when eyeball becomes elongated and the distance between lens and retina becomes too great or the lens becomes too thick and curved. In both condition, the light rays focus in front of retina instead of directly on it. The shortsightedness can be corrected by placing a **concave lens** in front of the eye in spectacle.

II. Hypermetropia

Also known as **hyperopia**, **farsightedness**, or **long-sightedness**. It is difficulty in seeing nearby objects clearly, while distant objects remain in focus. This happens when eyeball becomes too short and the distance between lens and retina becomes too small or the lens loss its elasticity to become thick as per requirement. In both condition, the light rays focus behind the retina instead of directly onto it. The long-sightedness can be corrected by putting a **convex lens** in front of the eye in spectacle.

III. Astigmatism

It is blurred or distorted vision at all distances due to an irregularly-shaped cornea or lens. It can be corrected by using special spherical **cylindrical lens**.

2. Age-related conditions

I. Presbyopia

Also called **old age long-sightedness**. It is age-related loss of the ability to focus on near objects, often occurring in middle age and beyond. This is caused by lens losing its flexibility. The old age long-sightedness can be corrected by providing **bifocal lens** (upper region with concave lens and lower region with convex lens) in front of eye in spectacle.

II. Cataracts

It is clouding of the lens, leading to blurred or hazy vision. It can be corrected by replacing opaque lens via surgery and placing **artificial lens** instead of it. It is the first leading cause of blindness in Nepal.

III. Macular degeneration

It is damage to the macula, the central part of retina, which can lead to vision loss.

IV. Floaters

Also called **eye floaters**. They are visible deposits of protein like collagen or cell debris within the eye's vitreous humour

3. Other eye conditions

I. Corneal opacity

It is the loss of transparency in the cornea due to various reasons, which may finally lead to blindness. It is the second leading cause of blindness in Nepal.

II. Glaucoma

It is due to increased intraocular pressure (IOP) in aqueous humour, ultimately damaging the optic nerve, which can lead to vision loss. If left untreated, can result in a permanent loss of vision. The glaucoma is the third leading cause of blindness in Nepal.

III. Diabetic retinopathy

Damage to the blood vessels in retina, which can lead to vision loss.

IV. Retinal detachment

When retina separates from the back of the eye, it can lead to vision loss.

V. Dry eye

It is due to negligible or less production of tears from lachrymal glands. The best treatment is washing with water and lubrication with eye drops.

VI. Diplopia

It is seeing two images of a single object one is looking at. It may be due to several reasons, e.g., drug addiction, alcoholism, smoking, etc.

VII. Colour blindness

It is an eye condition not to see colours. Men are more affected than women.

VIII. Amblyopia or lazy eye

It is reduced vision in one eye caused by abnormal visual development early in life.

Activity

Prepare a model of human eye with the help of mould mixed with asbestos and suitable additives. Try to colour it. If possible, label the organs. Take the help of your biology teacher if required.

8.6.1 Ear

Ears are **stato-acoustic organ** in which **stato** refers to the mechanical equilibrium or balance of one's own body and **acoustic** refers to the hearing of audible sound waves coming from speech and others. Hence, ears are **specialized sensory organs** enabling human beings to mechanically balance one's own body and to hear audible sound waves. In this way, ears possess two receptors – **stato-receptors** for mechanical balance and **acoustic- or phono-receptor** for hearing.

Do you know?

Statocysts, which were seen for the first time in phylum-Cnidaria contain dense particles to detect changes in animal's orientation. The **statocysts** possess **stato-receptors** that help cnidarians maintain balance and coordinate their movements.

Ability to perceive, hear, process, and respond sound was seen for the first time in **phylum-Arthropoda** especially in insects like mantis and katydids.

Ears are **extero-receptor** receiving stimuli from outside, **teloreceptor** receiving stimuli from distant object, and **special receptor** receiving stimuli to perform day to day activities. Ears are one pair in number, each situated postero-laterally on either lateral side (left and right) of head behind cheek and each continued from outer to middle to inner side of the bony skull called auditory capsule. Ears are connected to the brain through auditory nerves. Auditory nerves, which are sensory in nature are eighth cranial nerves and designated as CN VIII.

1. Structure of ear

Each ear is divided into three regions: external, middle, and internal ear.

I. External ear

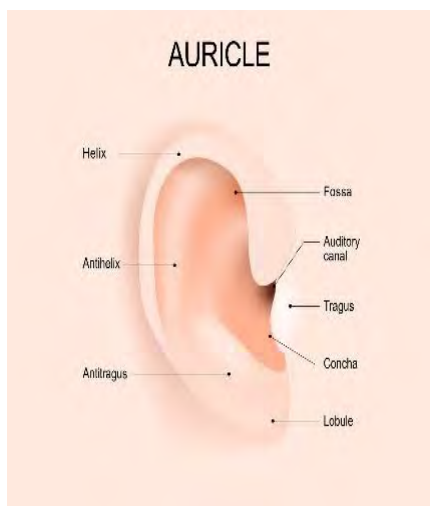
External ear which is located outside and which has most of its part exposed to outside comprises three parts: pinna, external auditory meatus, and tympanum.

i. Pinna

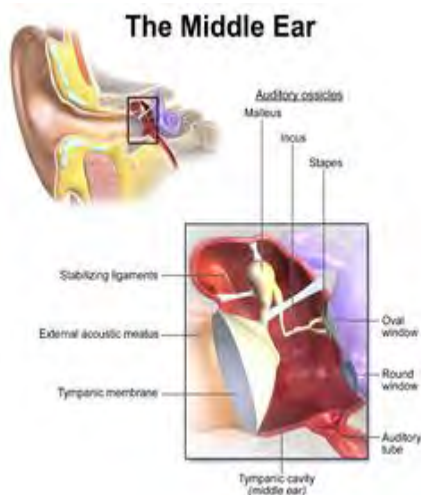
Pinna, also called **auricle** is elastic cartilage covered with skin, each projecting from lateral side (one left and another right) of head. Pinna is funnel-shaped being expanded outwardly. Most prominent outer ridge of pinna is called **helix**. The soft pliable part at its lower end of pinna is composed of fibrous and adipose tissue richly supplied with blood capillaries called **lobule**. Human pinna can't be moved, turned or rotated due to the presence of vestigial muscles. Pinna collects sound waves because of its natural architectural design.

ii. External auditory meatus

External auditory meatus, also known as **external auditory canal** or **external acoustic canal** is elongated tubular passage measuring about 2.5 cm in adult and is more or less ‘S-shaped’; supported by cartilage in its exterior part and by temporal bone in its interior.



External ear



Middle ear

The external auditory meatus is internally covered by hairy skin and modified sweat glands called **ceruminous glands** which secrete **cerumen** or **earwax**. External auditory meatus conducts sound waves to the middle ear. Hairs and earwax of the external auditory meatus prevent entry of foreign particles especially dust.

iii. Tympanum

Tympanum, also called **tympanic membrane** or **eardrum** is thin, semi-transparent, almost oval with a diameter of 1 cm though somewhat broader above than below. The central part of the tympanum is called umbo. The tympanum separates external auditory meatus, i.e., external ear from tympanic cavity, i.e., middle ear.

I.I Functions of external ear

Pinna directs sound waves towards tympanic membrane. Sound waves produce pressure changes on the tympanic membrane. The tympanic membrane vibrates acting as resonator that creates an impulse. The impulse is transmitted to middle ear. Pinna also prevents entry of any foreign particles like dust, bacteria, etc.

II. Middle ear

Middle ear which is located inside external ear and which is situated and protected inside temporal bone comprises four parts: tympanic cavity, ear ossicles, skeletal muscles, and openings.

i. Tympanic cavity

Tympanic cavity is irregular chamber in between tympanic membrane and internal ear and is filled up with air.

ii. Ear ossicles

Ear ossicles, also known as **auditory ossicles** or **chain of bones** are flexible chain of small bones inside tympanic cavity. The ear ossicles are three in number: malleus, incus, and stapes.

A. Malleus

Malleus is hammer-shaped, largest among the three ossicles, connected through its handle to tympanic membrane on one side, and through its head to the incus on another side.

B. Incus

Incus is anvil-shaped, moderate-sized among the three ossicles, and connected to stapes.

C. Stapes

Stapes is stirrup-shaped, smallest among the three ossicles, smallest bone among all the bones in human body, and connected to oval membrane covering oval window.

iii. Skeletal muscles

There are three skeletal muscles inside tympanic cavity: tensor palati, tympani, and stapedi.

A. Tensor palati

Tensor palate, also known as **palati muscles** closes and opens the Eustachian tube when required.

B. Tensor tympani

Tensor tympani, also called **tympanic muscle** is attached with malleus.

C. Tensor stapedii

Tensor stapedii, also known as **stapedius muscle** which is attached with stapes is smallest muscle of human body.

iv. Openings

Openings inside tympanic cavity are three in number: Eustachian tube, fenestra ovalis, and fenestra rotundus.

A. Eustachian tube

Eustachian tube, also called **auditory tube** is a large opening which connects tympanic cavity with naso-pharynx. The Eustachian tube is 4 cm long and is made up partially of cartilage and partially of temporal bone. The cartilage which occurs internally and the temporal bone which occurs externally are governed by tensor palati to close or open Eustachian tube. Eustachian tube serves to equalize air pressure of the cavity with that of outside environment.

B. Fenestra ovalis

Fenestra ovalis, also known as **fenestra vestibule** or **oval window** is small opening covered by foot-plate of stapes and closed by secondary tympanic membrane.

C. Fenestra rotundus

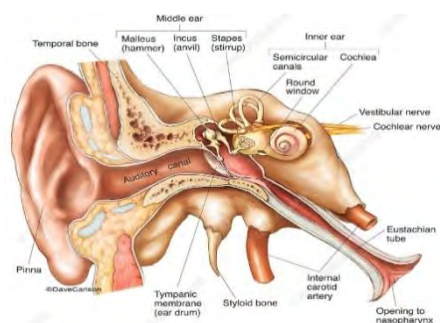
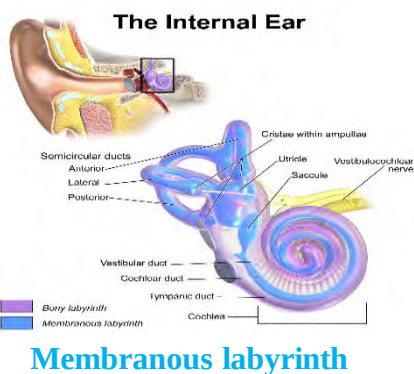
Fenestra rotundus, also called **fenestra cochlea** or **round window** is smallest opening above Eustachian tube being closed by secondary tympanic membrane and equalizing air pressure on either side of tympanic membrane.

II.I Functions of middle ear

Middle ear transmits sound waves from external to internal ear through chain of ossicles and finally through fenestra ovalis. Intensity of the sound is increased by 20 times by ear ossicles but frequency of the sound remains unchanged. Extra sound from tympanic cavity is carried to the naso-pharynx through Eustachian tube.

III. Internal ear

Internal ear, also called **labyrinth** which is located inside middle ear and which is situated and protected inside temporal bone consists of two parts: bony and membranous labyrinth.



i. Bony labyrinth

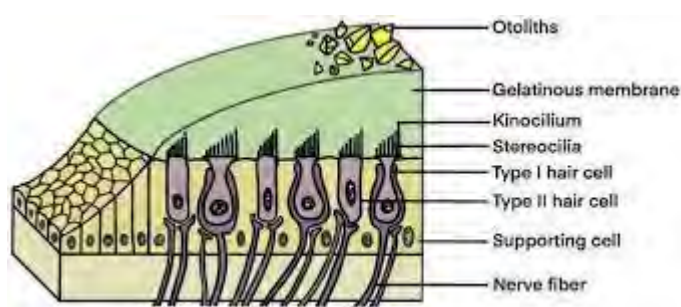
Bony labyrinth is bony cavity on each side enclosed in hard periotic bone which is filled up with perilymph akin to CSF.

ii. Membranous labyrinth

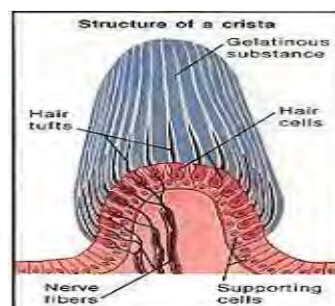
Membranous labyrinth which floats in perilymph, which contains fluid inside called endolymph, and which is stato-acoustic organ, in real sense, as it is concerned with both balancing and hearing is divided into three parts: vestibule, semi-circular canals, and cochlea.

A. Vestibule

Vestibule, also called **body proper** and which is sac-like structure comprises two parts: utricle and saccule. The utricle is larger, upper, and dorsal chamber to which all the three semi-circular canals are connected. The saccule is smaller, lower, and ventral chamber. The utricle is connected with saccule through a small, narrow **uticulo-saccular** or **sacculo-utricular** duct. From this duct, arises a long tube called ductus **endolymphaticus** which ends blindly as **sacculus endolymphaticus**. Both utricle and saccule have group of neuro-sensory cells called **macula**. The neuro-sensory cells of



Macula with otoliths



Cristae of internal ear

each macula has non-motile hair-tufts embedded in **gelatinous** or **otolith membrane** with small, fine crystals of CaCO_3 called **otoliths** or **otoconia** concerned with balance.

B. Semicircular canals

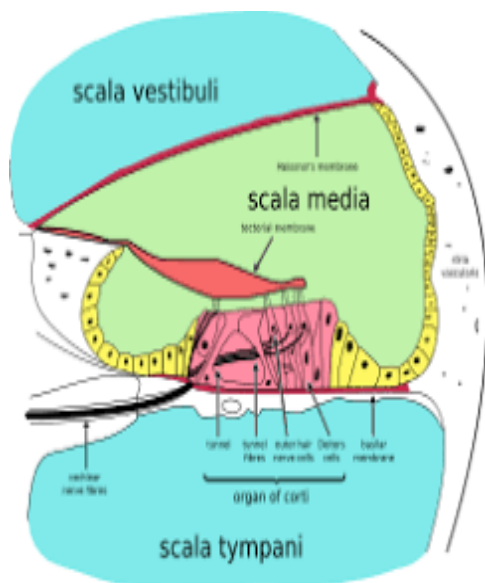
Semicircular canals are three in number: anterior vertical, posterior vertical, and horizontal or lateral. All the three semicircular canals arise from sacculus. The lower end of each semicircular canal has rounded swelling called ampulla. Each ampulla has group of neuro-sensory cells called **crista**. The cristae are covered by a mass of gelatinous material called **cupula**. The neuro-sensory cells of each crista has long, motile hairs concerned with balance but lack crystals of CaCO_3 called **otoliths** or **otoconia**. The maculae of vestibule and cristae of semi-circular canals resemble each other with slight difference.

C. Cochlea

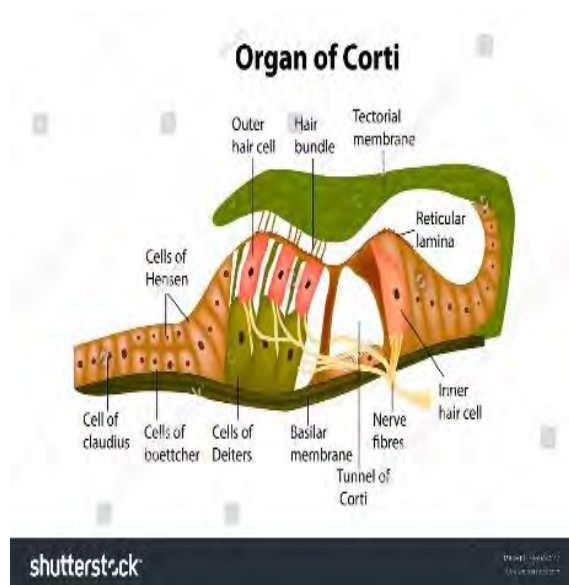
Cochlea, which is the main organ of hearing and which is connected to sacculus through **ductus reunions** is long, tubular, spirally coiled like snail's apex of the shell with two and three-fourth turns ($2\frac{3}{4}$), blindly-ending outgrowth of sacculus, and tapering from a broad base to an almost pointed apex. The cochlea internally consists of two partitions: **Reissner's** or **vestibular membrane** and **basilar membrane** along with three chambers or canals: **scala vestibuli**, **scala tympani**, and **scala media**.

a. Scala vestibuli

Scala vestibule, which is upper chamber or canal of cochlea is filled up with perilymph and partitioned below by Reissner's membrane. The scala vestibuli is connected with scala tympani at the apex by a small canal called **helicotrema**. At its base, the scala vestibuli comes in contact with fenestra ovalis.



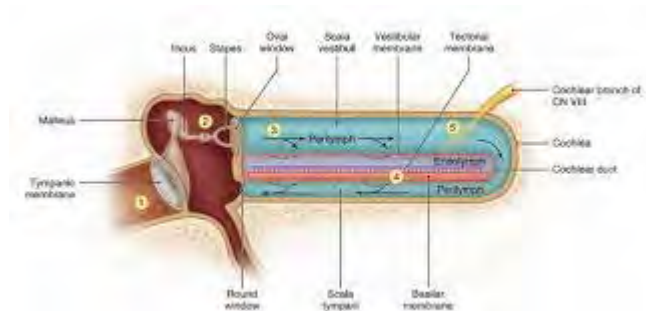
T. S. of cochlea



Organ of Corti

b. Scala tympani

Scala tympani which is lower chamber or canal is filled up with perilymph and partitioned above by **basilar membrane**. At the lower end of scala tympani lies fenestra rotundus.



Mechanism of hearing

c. Scala media

Scala media, also called **cochlear duct** and which is middle chamber or canal is most important chamber filled up with endolymph. The Reissner's membrane lies up on the roof and basilar membrane down on the floor. Lying on the basilar membrane is a sensory ridge called **organ of Corti** or **spiral organ** which is the main organ of hearing. The organ of Corti consists of outer hair cells, inner hair cells, inner pillar cells, outer pillar cells, tunnel of Corti, phalangeal cells or cells of Deiters, cells of Hensen, and cells of Claudius. Sensory hairs project from the outer ends of hair cells into scala media while from the lower ends of cells, nerve fibres arise that unite to form cochlear nerve. The tectorial membrane that overhangs sensory hairs determine patterns of vibrations of sound waves.

III.I Functions of internal ear

Vestibule and semicircular canals function in balance. Cochlea functions in hearing.

2. Functions of ear

There are two main functions of ear: equilibrium or balance and hearing.

I. Equilibrium or **balance** refers to the mechanical balance of the body which, based on orientation and maintenance of body, is two types: static and dynamic.

i. Static equilibrium

Static equilibrium is orientation of body, mainly head, relative to gravity.

ii. Dynamic equilibrium

Dynamic equilibrium is maintenance of body position in response to sudden movements.

I.I Mechanism of equilibrium

Vestibule (utricle, saccule, and semi-circular canals) called **vestibular apparatus** which maintains muscle position being **proprio-receptor** balances the orientation or position. When tilted or displaced, hair cells of maculae and cristae are stimulated by the movement of endolymph and otoliths. The stimulation is carried to brain through auditory nerves and change of the position is detected by medulla oblongata. The brain sends impulses to the concerned muscles to regain normal position.

Activity

Prepare a model of human ear with the help of mould mixed with asbestos and suitable additives. Try to colour it. If possible, label the organs. Take the help of your biology teacher if required.

II. Hearing

Hearing refers to the listening speech, audible sound, vibrations, etc.

Project work

Take the examples of nine mammals including man. Study the visual and hearing capacity of man, bat, cow, monkey, chimpanzee, gorilla, rabbit, elephant, and dog. The visual capacity should be compared in terms of minimum distance (in m.) of the recognition of object. Similarly, the audible capacity should be compared in case of minimum audability (in decibel). Take the help of standard or online literature for the study and comparison.

Conclude the project work.

II.I Mechanism of hearing

Sound waves are collected by external ear up to the maximum extent. The waves pass through external auditory meatus to tympanic membrane which is forced to vibrate. The vibrations are transmitted across the middle ear by ossicles. At the same time, the stapes fits into fenestra ovalis. The perilymph of internal ear receives vibrations through the membrane covering of fenestra ovalis. From perilymph, the vibrations are transferred to scala vestibuli (of cochlea) and then to scala media through Reissner's membrane. The movements of endolymph (of

scala media) and tectorial membrane stimulates sensory hairs of the organ of Corti. The impulses, thus, received by the hair cells are carried to the brain (temporal lobe of each cerebral hemispheres) through the auditory nerves where the sensation of hearing is recognized or felt.

Points to remember

Clear, acute, and sharp vision is that in which clear, acute, and sharp image of the object is formed in simple eye, e.g., spider, squid, and vertebrate.

Common sense organs or **common receptors** refer to such sense organs which have dual functions to do, e.g., stato-acoustic receptors for balance as well as for hearing.

General sense organs or **general receptors** refer to the sense organs like thigmoreceptor, e.g. skin.

Special sense organs or **special receptors** refer to four sense organs: vision (eyes), balance and hearing (ears), taste (tongue), and smell (nose).

Glossary

Binocular vision: is that in which both eyes are focused on the same object, e.g., primates.

Simple eye: is that which may be photosensitive only without forming image, e.g., fenestra of cockroach or it may be having vision by forming image through one lens in one eye, e.g., vertebrate eye.

Stereoscopic or **3-D vision:** is that in which vision occurs at every corners, e.g., anthropoids.

Trichromatic vision: is that in which colour vision of the object is formed, e.g., vertebrates.

Exercise

A. Tick the correct alternative.

1. Photoreceptor of the vertebrate is
a. eye b. ear c. nose d. tongue
2. An eye is extero-receptor, teloreceptor, special receptor, and
a. photoreceptor b. chemoreceptor c. stato-acoustic receptor d. thigmo-receptor
3. Human eye is
a. simple, monocular, and stereoscopic b. compound, binocular, and stereoscopic
c. compound, monocular, and stereoscopic d. simple, binocular, and stereoscopic
4. Nictitating membrane in man is
a. upper eyelid b. lower eyelid c. vestigial eyelid d. well-developed eyelid
5. How many extraocular muscles are there in an eye?
a. Two b. Four c. Six d. Eight
6. The aperture of the pupil of eye is controlled by
a. iris b. suspensory ligament c. ciliary body d. aqueous humour
7. In human eye, if rod cells contain the pigment rhodopsin then what type of pigment is found in cone cells?
a. Iodopsin b. Opsin c. Lysozyme d. Retinal
8. The sensory part of human eye is
a. cornea b. choroid c. lens d. retina
9. If a person sees an object, image is formed on retina. Which one of the following sequence describes the correct path for light entering the human eye?
a. Cornea – Lens – Pupil – retina b. Cornea – Iris – Pupil – Retina
c. Cornea – Pupil – Lens – Retina d. Cornea – Iris – Lens – Retina
10. Vitamin A deficiency causes night blindness in person. In a night blinded person, which of the following are not functioning in low intensity of light?
a. Lens b. Rods c. Cones d. Both rods and cones
11. If a person using biconcave lens to correct vision, does not use glasses. Where will be the image formed in such man?
a. Little behind retina b. Little in front of retina
c. On fovea centralis d. On blind spot

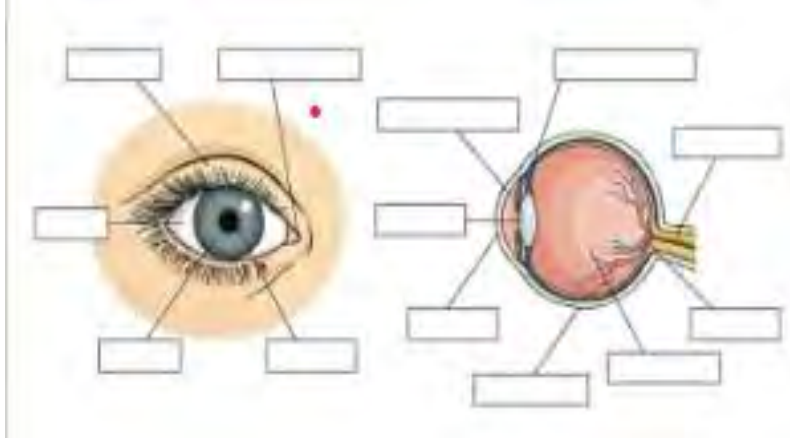
12. Person who can see near object but cannot see far object has a type of eye defects known as
 a. myopia b. hypermetropia c. presbyopia d. diplopia
13. Eustachian tube connects
 a. external ear with pharynx b. middle ear with pharynx
 c. internal ear with pharynx d. middle ear with internal ear
14. In the middle ear of man, there are three ear ossicles. Identify and choose which of the following ear ossicles are arranged in correct sequence?
 a. Malleus – Incus –Saccule b. Malleus – Incus – Stapes
 c. Malleus – Stapes – Incus d. Malleus – Incus - Cochlea
15. The auditory ossicles are situated in
 a. external auditory meatus b. tympanic cavity
 c. bony labyrinth d. membranous labyrinth
16. Which one of the following is associated with mechanical balance?
 a. Cochlea b. Cristae c. Tympanum d. Organ of Corti
17. The sensory auditory part of the human ear is/are
 a. utricle b. sacculus c. semicircular canals d. cochlea
18. The organ of hearing is
 a. cristae b. semicircular canals c. organ of Corti d. helicotrema
19. In which part of the human body, is the organ of Corti present?
 a. Nasal chamber b. Retina c. Middle ear d. Internal ear
20. The organ of Corti is situated in which part of the internal ear?
 a. Scala vestibule b. Scala media c. Scala tympani d. Macula and Cupula
21. Scala tympani is connected with scala vestibuli by
 a. Eustachian canal b. Scala media c. Helicotrema d. Fenestra ovalis
22. The function of human ear is
 a. Vision b. Hearing c. Balance d. Both b and c

Answers.

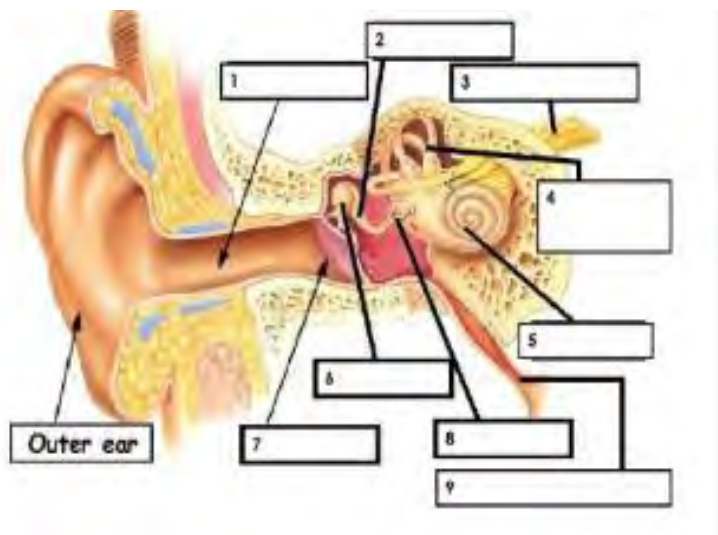
1. a	2.a	3. d	4. c	5. c	6. c	7. a	8. d	9. c	10. b
11. b	12. a	13. b	14. b	15. b	16. b	17. d	18. c	19. d	20. b
21. c	22. d								

B. Short answer questions.

1. Explain in brief, the main structures of human eye.
2. Label the diagram indicating function of each labelling.



3. Write down the defects of human eye.
4. Summarize briefly, the outer, middle, and internal ear of man.
5. Will you discuss the membranous labyrinth of man in brief.
6. Illustrate and describe in brief, the working mechanism of human ear.
7. Label the diagram and also write the function of the labelling.



C. Long answer questions.

1. Describe the structure and function of human eye. Discuss with the help of labelled and suitable diagrams.
2. Explain in detail along with illustration, the structure and function of human ear.

Chapter 8.7

ENDOCRINOLOGY

Thomas Addison (1793-1860) was a well known British physician and pioneer in the field of clinical endocrinology. He studied medicine at the university of Edinberg and graduated in 1815 he is best known for his discovery of Addisons disease, a serious disorder caused by the failure of adrenal gland to produce sufficient minerocorticoid and glucocorticoid. He also made significant contribution to the understanding of pernicious anemia, a condition later found to be linked to vitamin B12 deficiency. He is also called father of clinical endocrinology.



Observe the individual pictures given and discuss the following questions.





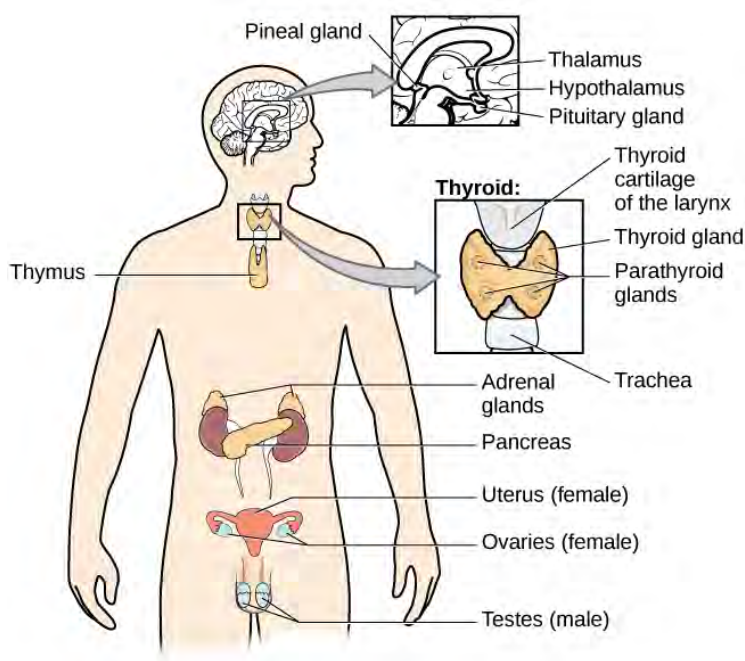
Fig: hormonal disorders

- i. You have noticed something unusual in these pictures. Can you mention name of these abnormalities?
- ii. Have you ever seen these kind of people in your neighborhood?
- iii. What could be the potential cause of these disorders?

A gland is a group of epithelial cells that secretes substances, such as enzymes or hormones or other fluids. Various glands in the human body form glandular system. Based on how and where they release their secretions, there are three types of glands:

- i. **Exocrine glands:** Ducted glands are called exocrine glands. They discharge their secretion via duct. Their secretions are called enzymes. Site of action of enzyme is nearer to the site of secretion. Example: Salivary gland, liver, sweat etc.
- ii. **Endocrine glands:** They are the glands without duct. Their secretions are called hormones. Hormones are directly discharged into the blood stream. The site of action of hormones is far away from the site of secretion. Example: Pituitary gland, thyroid gland etc. Excess or less secretion of hormones by endocrine glands cause various disorders in our body.
- iii. **Heterocrine gland:** The gland which functions as both exocrine and endocrine gland is called heterocrine gland. Example: Pancreas, gonads etc.

Study of endocrine system is called endocrinology. Thomas Addison is the father of endocrinology, reported the first endocrine disease (1855); Addison's disease caused by destruction of adrenal gland.



Hormone

The term hormone was introduced by Starling in 1905 it is derived from a Greek word which literally means to stimulate or arouse. Hormone is the special chemical substances or chemical messengers of the body secreted by endocrine or ductless glands in response to change in the environment inside or outside the body. English physiologists, William M. Bayliss and Ernest H. Starling discovered first hormone Secretin in 1903. This hormone is secreted by intestinal mucosa and stimulates the secretion of pancreatic juice.

Chemical nature of hormones

Chemically, hormones may be:

- i. **Steroid hormones:** The hormones secreted by the testes, adrenal cortex, placenta and ovaries are composed of steroids. E.g., testosterone, corticosterone, aldosterone, oestrogen and progesterone.
- ii. **Eicosanoids (lipid derivatives of arachidonic acid):** Prostaglandins.
- iii. **Proteinaceous hormones:** Hormones secreted by anterior lobe of the pituitary gland and hormones secreted by the pancreas are composed of proteins.
- iv. **Peptide hormones:** Peptide hormone includes: MSH, vasopressin (ADH), oxytocin, ACTH, parathormone, calcitonin.
- v. **Amino acid derivative hormones:** Amino acid derivative hormones include thyroxine, adrenaline and nonadrenaline.
- vi. **Glycoproteins:** TSH, LH and FSH (pituitary gland) are glycoproteins Erythropoietin (kidney) and inhibin (reproductive organs).

Properties of hormone

The various properties of hormones are listed in the points below:

- i. Hormones have low molecular weight so hormones can easily pass out through the capillaries.
- ii. Hormones are soluble in water, so hormones can be easily transported with blood stream.
- iii. Hormones are poured into venous blood.

- iv. Whenever their function is over, hormones are readily destroyed or inactivated or excreted.
- v. Hormones are non-antigenic.
- vi. Hormones are organic catalysts and act as coenzymes of the other enzymes in the body.
- vii. Hormones always act in very low concentration.
- viii. Many hormones are produced in an inactive form called pro-hormone.

Functions of hormones

- Metabolism
- Homeostasis
- Growth, maturation and regeneration
- Secondary sexual characters and reproductive activities
- Control of other endocrine glands
- Adaptations

Hormones

1. They are secreted by endocrine glands.
2. They are secreted at one site and carried by blood to another site.
3. They have low molecular weight.
4. Hormones may be steroids, proteins, peptides or aminoacid derivatives.
5. They are used up in their action
6. They act slowly or quickly
7. They may slow down or accelerate reactions.

Enzymes

1. They are secreted by exocrine glands.
2. Their site of action is generally nearer from the site of secretion.
3. They have very high molecular weight.
4. Enzymes are simple proteins.
5. They are not used up in their action
6. They act slowly
7. They speed up the reaction

Hypothalamus

Hypothalamus is the basal almond shaped region of diencephalon of forebrain. It develops from the ectoderm of embryo. The activity of pituitary gland is regulated by hypothalamus hence it is also called control centre or supreme commander of endocrine regulation. The hypothalamus consists of three main regions containing different nuclei. Nuclei are clusters of neurons that perform vital functions, such as secretion of releasing hormones and inhibiting hormones.

1. Anterior region

This area is also called the supra-optic region. Its major nuclei include the supra-optic and paraventricular nucleus. There are several other smaller nuclei in the anterior region as well. The nuclei in the anterior region are largely involved in the secretion of various hormones. Many of these hormones interact with the nearby pituitary gland to produce additional hormones. Some of the most important hormones produced in the anterior region include:

Corticotropin-releasing hormone (CRH): CRH signals the pituitary gland to produce a hormone called adrenocorticotrophic hormone (ACTH).

Thyrotropin-releasing hormone (TRH): TRH stimulates the anterior lobe of pituitary gland to produce thyroid-stimulating hormone (TSH).

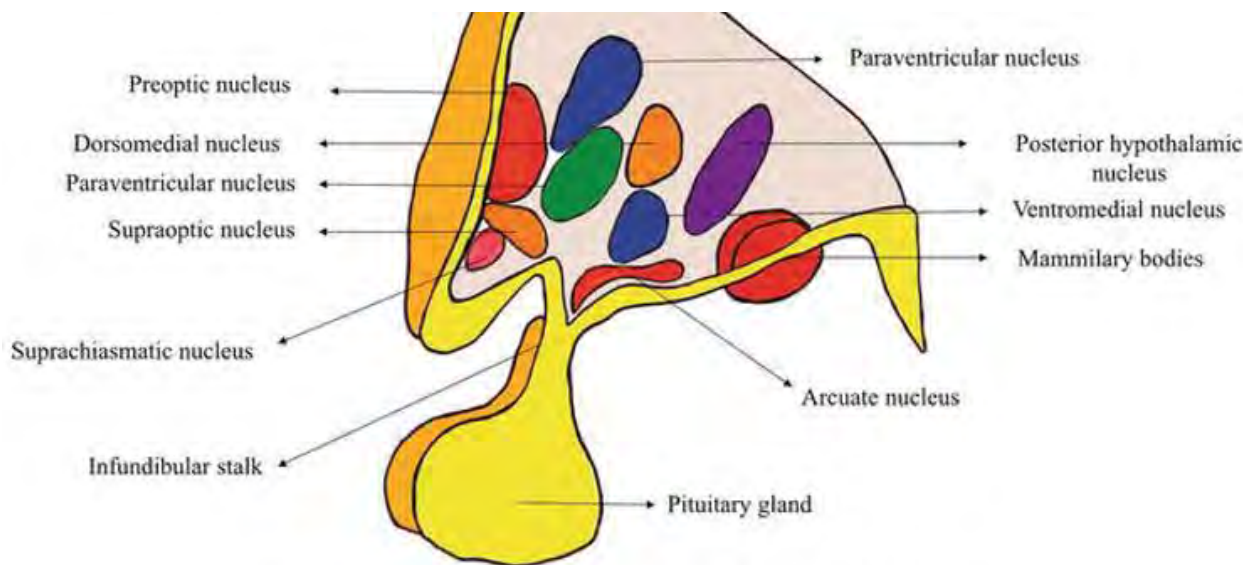
Gonadotropin-releasing hormone (GnRH): GnRH stimulates the anterior pituitary to release important reproductive hormones, such as follicle-stimulating hormone (FSH) and luteinizing hormone (LH).

Oxytocin: It is involved childbirth and lactation. It controls many important behaviors and emotions, such as sexual arousal, trust, recognition, and maternal behavior.

Vasopressin: Also called antidiuretic hormone (ADH), this hormone regulates water levels in the body.

Somatostatin: Somatostatin works to stop the pituitary gland from releasing certain hormones such as growth hormones and thyroid-stimulating hormones.

The anterior region of the hypothalamus also helps regulate body temperature through sweat and also maintains circadian rhythms



Schematic representation of hypothalamic nuclei (sagittal section).

Middle region

This area is also called the tuberal region. Its major nuclei are the ventromedial and arcuate nuclei. The ventromedial nucleus helps control appetite, while the arcuate nucleus is involved in releasing growth hormone-releasing hormone (GHRH). It stimulates the pituitary gland to secrete growth hormone.

4. Posterior region

This area is also called the mammillary region. The posterior hypothalamic nucleus and mammillary nuclei are its main nuclei. The posterior hypothalamic nucleus helps regulate body temperature by causing shivering and blocking sweat production. The role of the mammillary nuclei is less clear. Doctors believe it's involved in memory function.

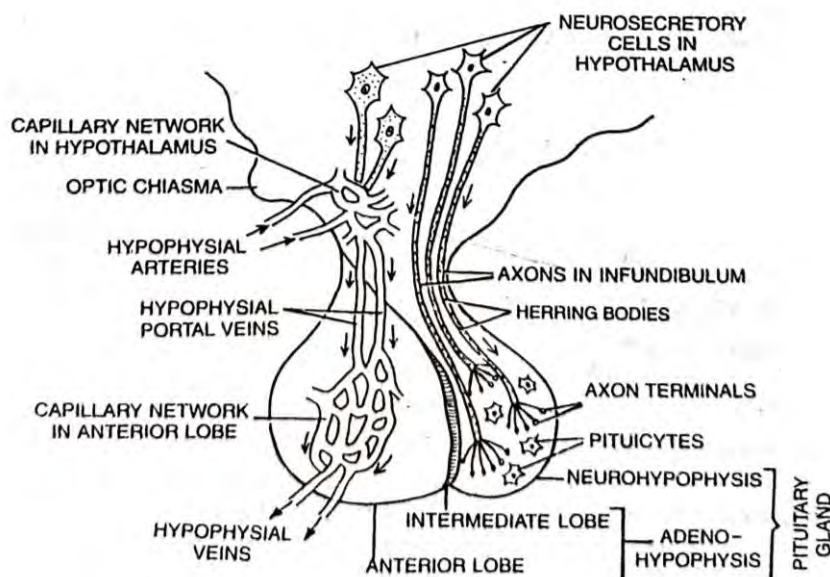
Pituitary gland (Hypophysis)



Pituitary gland is the smallest pea sized gland, lying just below the hypothalamus. It is often termed as master gland as it regulates the function of other endocrine glands, however its activity is further controlled by the hypothalamus. Pituitary gland and hypothalamus act as a unit regulating the most of the activities of other endocrine glands. It is developed from ectoderm of the embryo.

Structure

It is an oval or round shaped, reddish brown colored and smallest endocrine gland, situated in the depression (hypophyseal fossa) of sphenoid bone called sella turcica.



It typically measures about 1.3 cm in diameter and weighs about 500 mg. It is connected with the hypothalamus of brain by a stalk called infundibulum. There are three lobes of pituitary gland which are:

- i. Anterior lobe or pars distalis
- ii. Middle lobe or pars intermedium
- iii. Posterior lobe or pars nervosa

During the embryonic development, the adenohypophysis is derived from Rathke's pouch, an up growth of the glandular tissue from the roof of bucco-pharynx of the embryo. The neurohypophysis is derived from the downward growth of nervous tissue from brain. Thus, pituitary gland is dual in origin i.e from embryonic foregut and brain. There is a small, thin strip of tissue between the two lobe which is called middle lobe or intermediate lobe. Functionally, the anterior lobe and middle

lobe constitute adenohypophysis which comprises about 75% of pituitary gland. Hypophyseal portal veins carry blood containing neuro-hormones or releasing factor from hypothalamus to the adenohypophysis.

Histologically, adenohypophysis consists of 3 types of cells on the basis of their staining property: acidophils (somatotrophs, lactotrophs), basophils (thyrotrophs, corticotrophs and gonadotrophs) and chromophobes.

Posterior lobe comprises about 25% and the axons of neurosecretory cells extend into the posterior lobe where they terminate as axon terminals. These terminals are embedded in the neuroglial tissue formed by large and branched cells or pituicytes. No hormones are secreted by posterior lobe or neurohypophysis. Two hormones secreted by hypothalamic neurosecretory cells remain stored in vesicles called Herring bodies in axon and terminals.

A. Hormones secreted by adenohypophysis

The hormones secreted by adenohypophysis are chiefly trophic hormones, meaning they stimulate other glands except the growth hormone. Six different hormones secreted by adenohypophysis are:

1. Thyroid stimulating hormone (TSH) or thyrotropin: This hormone is secreted by specific cells; thyrotrophs of adenohypophysis and stimulates thyroid gland to secrete triiodothyronine (T3) and tetraiodothyronine (thyroxine or T4).
2. Adrenocorticotrophic hormone (ACTH): It is secreted by corticotrophs. This hormone stimulates the adrenal cortex to secrete steroid hormones such as mineralocorticoids, glucocorticoids and sexcorticoids.
3. Gonadotrophic hormones: These hormones are secreted by gonadotrophs which are follicle stimulating hormone (FSH) and luteinizing hormone (LH). FSH stimulates the development and maturation of ovarian follicles and secretion of oestrogen in female. In male, FSH is responsible for the development and maturation of seminiferous tubule to produce sperms. Likewise, LH stimulates ovulation and formation of corpus luteum in female to produce progesterone. In male, LH stimulates leydig or interstitial cells of testis to produce testosterone.
4. Prolactin or lactogenic or luteotrophic hormone (PRL or LTH): This hormone is secreted by lactotrophs. This hormone promotes the growth and development of mammary glands and stimulates milk production during pregnancy and after delivery.
 - i. Excessive secretion of this hormone causes galactorrhoea, infertility and amenorrhoea in female.
 - ii. Prolactin hypersecretion may also occur in male leading to gynecomastia (enlargement of breast) and sterility
5. Melanocyte stimulating hormone: This hormone is secreted by intermediate lobe of adenohypophysis and it regulates melanocytes
 - i. It stimulates darkened pigmentation of skin.
 - ii. Its role is found more in lower vertebrates (Pisces and amphibians) than in man.
6. Growth hormone: This hormone is secreted by somatotrophs it stimulates growth of body by cellular proliferation and differentiation.

Functions:

- i. It controls growth of muscle, bones and other tissues of entire body.
- ii. It also influences on the metabolism of carbohydrate, protein and fat.

Disorders due to hypo-secretion and hyper-secretion of growth hormone

- i. Dwarfism or ateliosis: hypo-secretion of GH in infants and children results retarded or stunted growth and become shorter called dwarfism. (with normal intelligence)
- ii. Simmond's disease: hypo-secretion of GH cause quite thin, early ageing, genitals become weak, retardation and degeneration of muscles and connective tissues.

Disorders due to hyper-secretion of growth hormone

- i. Gigantism: Hyper-secretion of GH in early age cause excessive growth of height and limbs which is called gigantism.
- ii. Acromegaly: Hyper-secretion of GH also cause abnormal growth of feet, hand and especially lower jaw called acromegaly (gorilla like appearance).

B. Hormones secreted by neurohypophysis.

Neurohypophysis does not synthesize any hormones of its own. Hypothalamic neurons secrete two hormones: oxytocin and vasopressin of proteinaceous nature which are stored and released by neurohypophysis.

Oxytocin (OT) or Pitocin (love hormone)

Oxytocin is also called birth hormone or milk ejecting hormone. This hormone promotes contraction of uterine wall inducing labor for parturition and stimulates mammary gland to produce milk after child birth. In male, oxytocin has role in sperm transport and ejection during sexual intercourse.

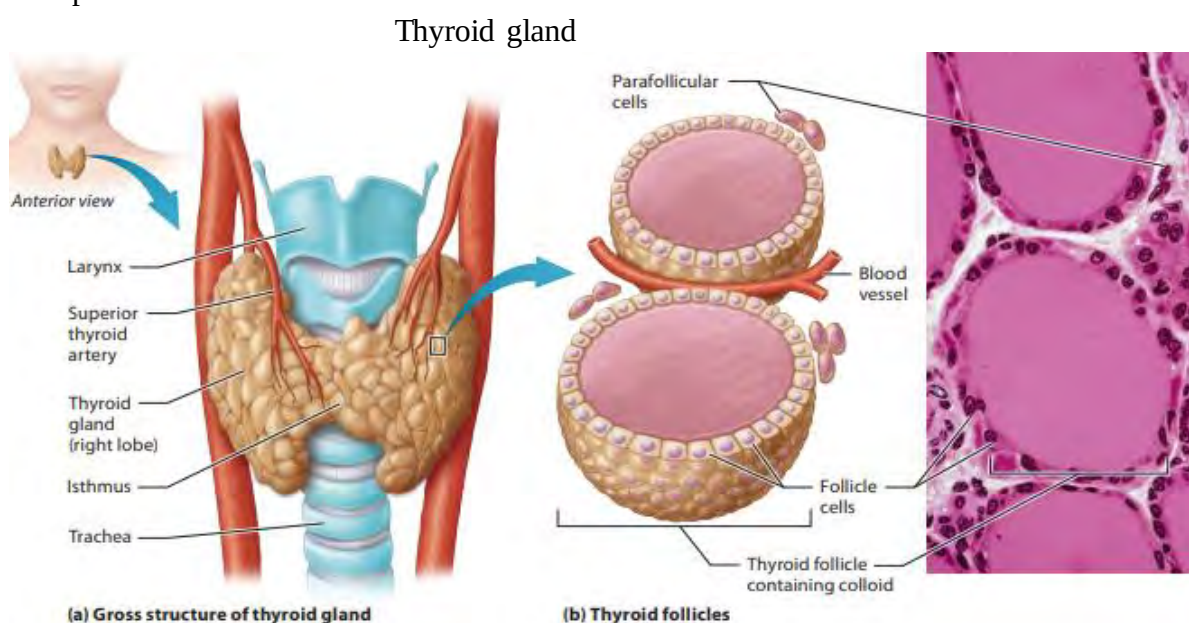
Vasopressin or Antidiuretic hormone (ADH) or pitressin

It regulates the absorption of water in DCT and CD of nephron in kidney. Release of ADH into blood is controlled by osmo-regulatory centre of hypothalamus. ADH also increase blood pressure by constricting blood vessels and hence called vasopressin.

Disorder due to hypo and hyper secretion of ADH

Hypo secretion of ADH results excretion of large volume of water in urine (diuresis) occurs, also called diabetes insipidus.

Hyper-secretion of ADH result anti-diuresis in which excretion of small volume of water in urine take place.



Thyroid gland is the largest endocrine gland of our body. It is butterfly or 'H' shaped gland, located in the neck region between C5 to T1 (5th cervical vertebra to 1st thoracic vertebra), just below the

larynx. The gland is highly vascular and hence, appears dark red than its surrounding tissues. It attains maximum weight during puberty. It is endodermal in origin.

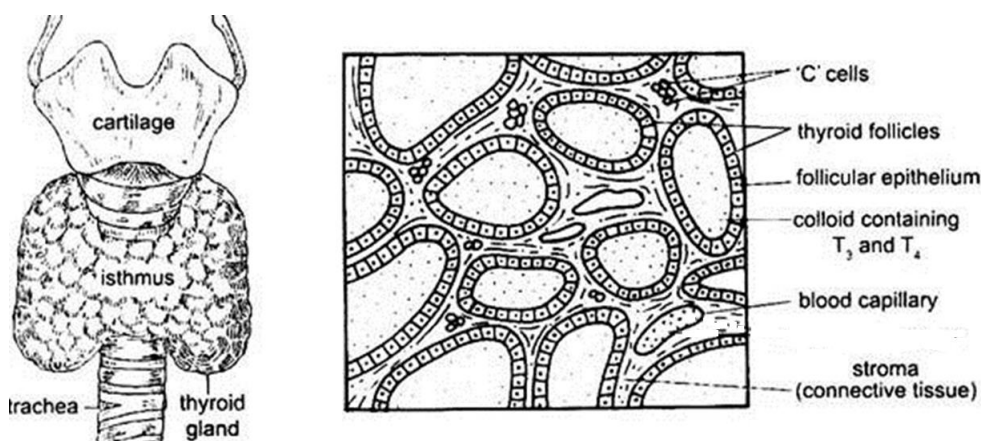
Question to think

What is the cause of increment in the size and development of thyroid gland during puberty?

Structure:

It is a bilobed gland and each lobe lying on the either side of trachea. The two lobes are connected by a narrow band of non-glandular connective tissue called isthmus. It typically measures 3-7 cm in length and weighs about 20-25 gram. The gland is enveloped within a fibrous capsule.

Histologically, thyroid gland consists of the thousands of thyroid follicles or acini and parafollicular cells or C-cells embedded in the connective tissue. Each thyroid follicle consists of a single layer of cuboidal epithelial cells called follicular cells or principal cells. The follicle is internally filled with a yellowish, jelly like iodinated colloidal substance called thyroglobulin. Thyroglobulin is a protein which contain thyroid hormone (Tri-iodothyronine (T₃) and Tetraiodothyronine(T₄) secreted by the cells of thyroid follicles. C-cells or parafollicular cells are found singly or in cluster between thyroid follicles. The function of parafollicular or C cells is to secrete non-iodinated hormone called calcitonin.



Hormones

Under the control of thyroid stimulating hormone secreted by pituitary gland, thyroid gland secretes:

Triiodothyronine (T₃), Tetra-iodothyronine(T₄) or thyroxine and Calcitonin.

T₃ is an iodine containing active hormone. T₄ is an iodine containing less active hormone and T₄ gets converted to T₃ by losing one iodine atom. Thyroxine is synthesized from iodine and an amino acid called tyrosine.

Do you know?

The greatest concentration of iodine is found in thyroid gland.

Function of T3 and T4

- i. These hormones maintain basal metabolic rate (BMR) as they control the rate of cellular respiration or energy production (calorigenic value). It maintains normal thermogenesis (heat production).
- ii. It regulates carbohydrate, protein and fat metabolism.
- iii. It plays a crucial role in tissue growth and development particularly in the childhood.
- iv. It also regulates the urine output by controlling the functions of renal tubules.
- v. This hormone is essential for metamorphosis in amphibians.

Disorders of T4 and T3

1. Hypothyroidism: Hypothyroidism is a disorder that occurs due to the less secretion of T4 and T3.

It is of following types:

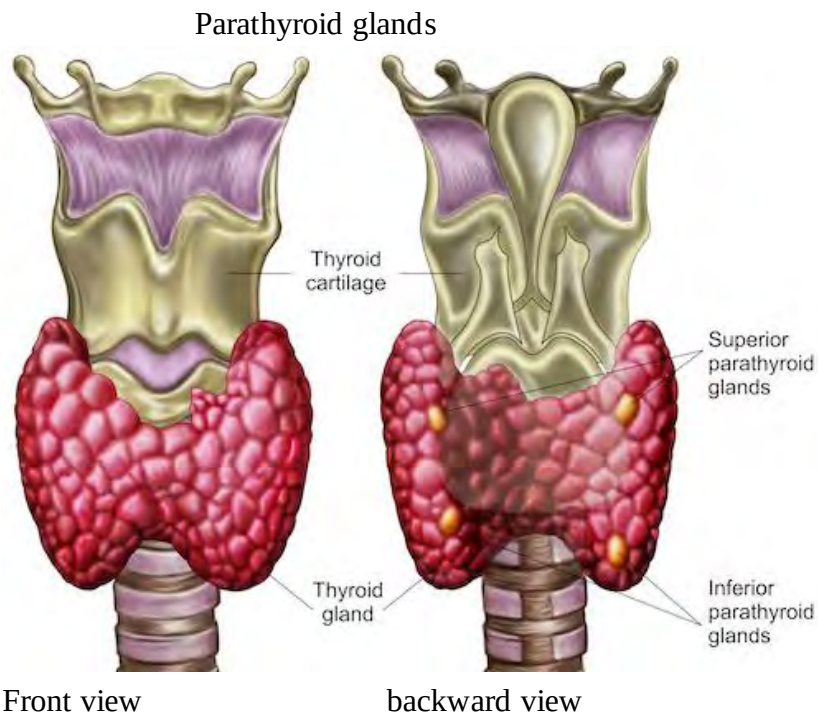
- a. Cretinism: Dwarfism, serious mental deficiency and undeveloped sex organ, low blood pressure, slow heartbeat, slow metabolic rate and low temperature in children. (Diseased person is called Cretin)



- b. Myxedema: it is particularly found in adults; characterized by fatty and sluggish appearance, face and hand become swollen, puffiness, person look dull, lack alertness and intelligence, skin dry and pale, retarded sexual development, Blood pressure, heart beat, basal metabolic rate and temperature are below the normal.
 - c. Simple goitre: Iodine deficiency in diet causes swelling and increase in the number of acinal cells of thyroid gland, leading to the formation of goitre in the neck region.
 - d. Hashimoto's disease: The disorder was first reported by Japanese physiologist Hakaru Hashimoto. It is an auto immune disease in which thyroid gland itself is progressively damaged over time due to less secretion of thyroxine
2. Hyperthyroidism or thyrotoxicosis: Excess or increased secretion of T4 and T3 causes hyperthyroidism.
- Exophthalmic goitre/Graves's disease/Basedow's disease/Parry's disease:
It is characterized by protruding eye ball, insomnia, weightless, physical and mental restlessness, abnormally high metabolic rate, heart beat and temperature, palpitation.

B. Function of calcitonin

Calcitonin has crucial role in reducing the concentration of calcium in blood when calcium level become high. Calcitonin lowers the Ca level in blood by increasing Calcium deposition in bones and by decreasing reabsorption of calcium from urine.

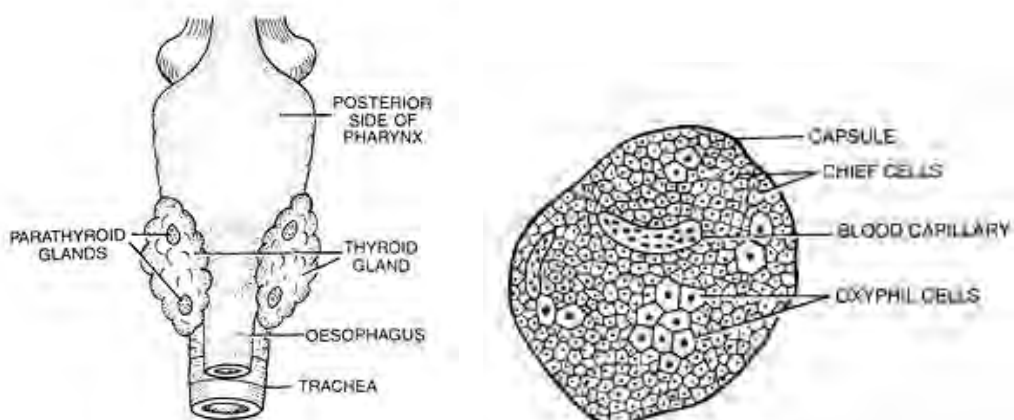


There are four rounded bodies, two each partially embedded on the dorsal surface of each lobe of thyroid gland called parathyroid glands. Each gland measures about 4-6 mm long and weight about 50 mg. They are surrounded by the connective tissue. They are endodermal origin.

Do you know?

Parathyroid glands are present in all vertebrates except fishes.

Histologically, parathyroid gland consists of two types of cells; chief cells and oxyphil cells. Chief cells are the smaller, cuboidal, and more numerous whereas oxyphil cells are polyhedral and less numerous.



Chief cells secrete parathormone or collip's hormone but function of oxyphil is unknown, they are believed to be modified or depleted chief cells that no longer secrete hormones.

Functions of parathormone

Parathormone regulates the calcium and phosphate level between blood and other tissues. Release of parathormone increases the blood calcium to normal by drawing calcium from bones to plasma,

increasing calcium absorption in alimentary canal and reducing the loss of calcium in the urine. In human body, balance of calcium and phosphate is essential for homeostasis, normal growth of bone and teeth.

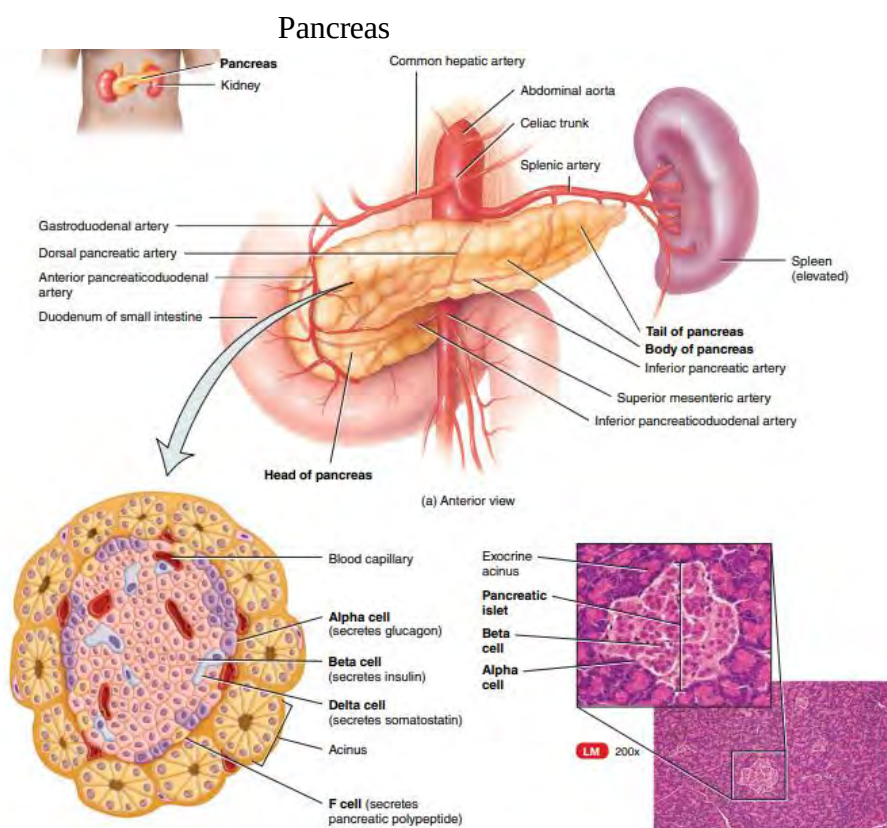
Normal calcium level is essential for muscle contraction, blood clotting and nerve impulse conduction.

Disorder

Tetany is the more serious disorder that occurs with hypoparathyroidism in which some skeletal muscles usually of hands and feet fail to relax after a contraction and remained in sustained contraction.

Low secretion of parathormone results fall of calcium level and rise of phosphate in extracellular fluid, leading to excessive perspiration, raising of hairs and prickly sensation of skin, cooling of hands and feet, muscular spasm, convulsion etc. Likewise, it also causes demineralization and softening of bones called osteoporosis.

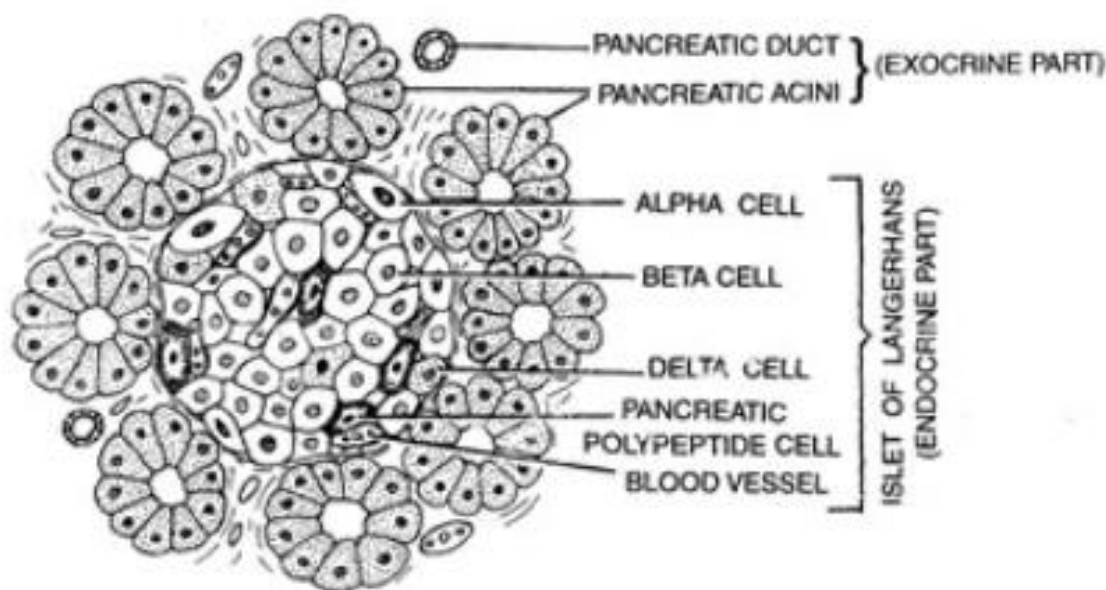
Excess secretion causes hyperparathyroidism that results in sharp rise of calcium level in blood (hypercalcemia) and hypercalciurea (rise in calcium level in urine). It may lead to the formation kidney stone.



Pancreas is a soft, spongy, and yellowish coloured gland located in the duodenum just behind the stomach. It is also called mixed or heterocrine gland because it has both exocrine and endocrine part. Exocrine part secretes digestive juice containing enzymes but endocrine part secretes hormones. The gland typically measures about 60 gram weight and 15 cm length. It is developed from endoderm of embryo.

Histologically, major portion of pancreas (99%) is formed by exocrine part composed of pancreatic lobules or acini. Acini are held together in position by connective tissue. Each acinus consists of a central lumen or pancreatic ductule surrounded by secretory epithelial cells.

These cells secrete pancreatic juice that contain various enzymes for digestion of food. Very small portion (1%) of pancreas is composed of endocrine part called islets of Langerhans. Islets of Langerhans consist of a cluster of specialized cells (about 1-2 million) innervated by nerve from ANS and surrounded by network of blood capillaries. Islet of Langerhans consist of 4 types of cell namely alpha cells, beta cells, delta cells and pp cells (f-cells). Beta cells constitute about 60% of islets and secrete insulin and Alpha cells constitute 25% of islets and secrete glucagon. Delta cells constitute about 10% and secrete somatostatin. F-cells secrete pancreatic polypeptide which regulate release of pancreatic digestive enzyme.



Functions of insulin

- It increases the rate of carbohydrate metabolism.
- It decreases the blood sugar by converting excess glucose into glycogen and store in liver and muscles.
- It converts excess glucose into fats.
- It increases the rate of protein and fat synthesis.
- Insulin has main role in functioning of growth hormone.

Insulin disorder

- Hypo-secretion of insulin leads to a disease, *Diabetes mellitus* characterized by high blood sugar level (hyper glycemia) and high sugar level in urine (glycosuria).
- Hypersecretion of insulin lead to insulinoma or hypo-glycaemia.

Function of glucagon

- This hormone increases blood sugar level by converting stored glycogen into glucose (glycogenolysis).
- It also Increases the uptake of amino acid in liver.

Disorder

- Deficiency of glucagon causes hypo-glycaemia.

iii. Function of somatostatin

- i. It regulates the secretion of insulin and glucagon.
- ii. It also inhibits the secretion of growth hormone.

Activity

Read the cases given below thoroughly and for each

- i. Identify the disorder and location of the gland involved.
- ii. Describe the structure of this gland and its function in brief.
- iii. Present your finding in the classroom

Case I

A 16-year-old boy is extremely tall and has large hand and feet. His facial features are also more pronounced than his friends. MRI showed enlarged.

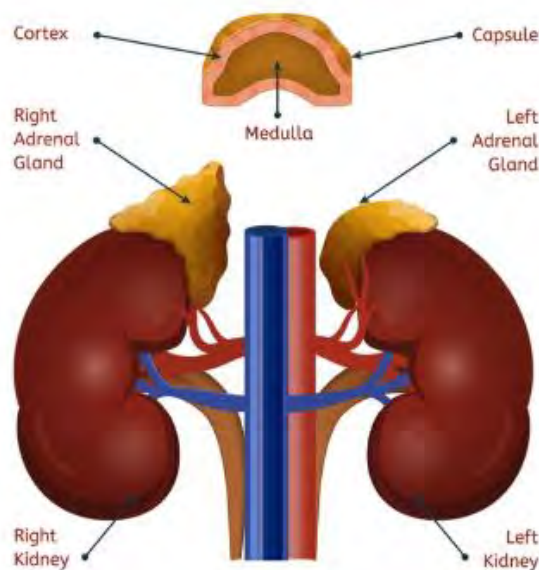
Case II

A man is experiencing increased thirst, frequent urination and fatigue. Blood test has revealed high glucose level and low insulin level.

Case III

A woman is experiencing weightless, physical and mental restlessness, abnormally high metabolic rate, protruding eye ball, increased heart beat and temperature, sleeplessness and excessive sweating. Blood test showed higher level of thyroxine.

Adrenal gland



Introduction

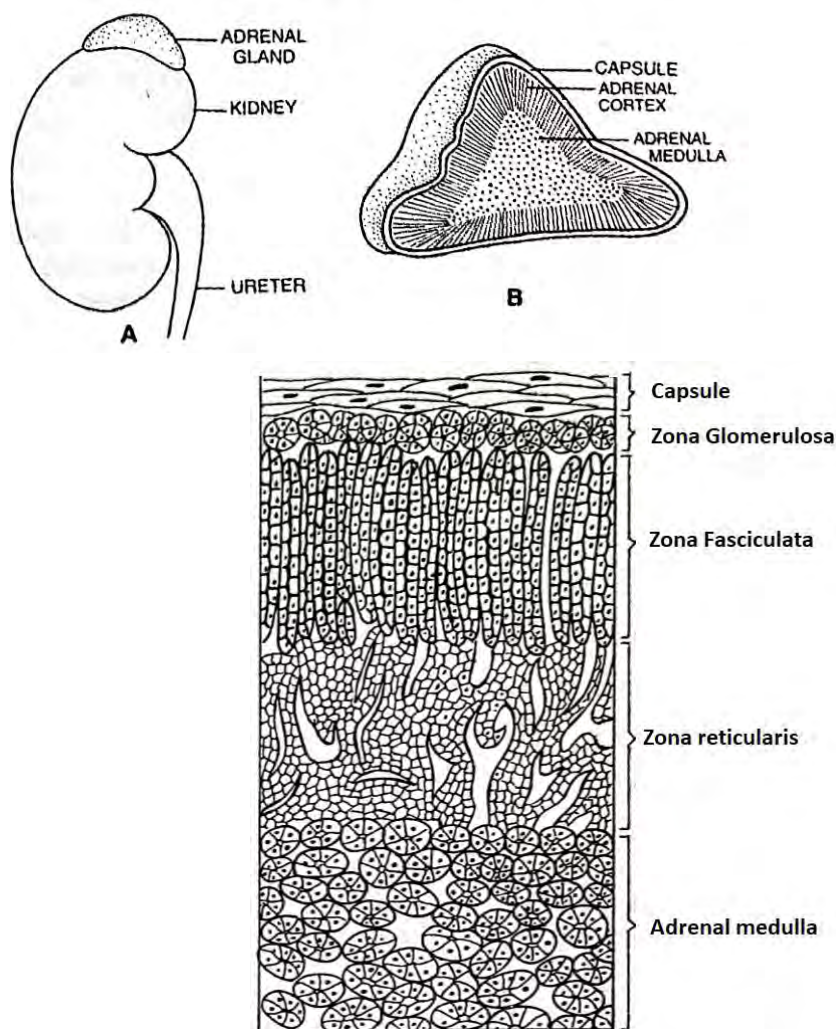
The adrenal glands are two, small, triangular and yellowish glands, each occupying the position on the top of kidney and hence called supra-renal glands. They are richly vascularized and each having the size of 5 cm length and 5-gram weight. They remain surrounded within a thin fibrous capsule.

Structure

L.S. of adrenal gland shows two distinct regions: Adrenal cortex developed from mesoderm and adrenal medulla developed from ectoderm in the embryonic stage.

a. Adrenal cortex

It is the outer portion of the adrenal gland which is composed of fatty and cholesterol rich cells. It makes up about 80% of the total gland. This portion is again differentiated into three layers: outer zona glomerulosa, middle thickest zona fasciculata and inner zona reticularis. Zona glomerulosa secretes mineralo-corticoid, zona fasciculata secretes gluco-corticoid and zona reticularis secretes sex-corticoid hormones. These, all hormones are steroid hormones. Adrenal cortex is stimulated by ACTH secreted by anterior lobe of pituitary gland.



Hormones secreted by adrenal cortex and their functions

a. Mineralocorticoids:

- i. Aldosterone is the principal mineralocorticoid which is concerned with the Na^+ and water absorption and K^+ excretion in the kidneys.

- ii. Secretion of mineralocorticoid is stimulated by a fall in Na^+ in plasma, rise of K^+ in the plasma.
- iii. Mineralocorticoid may also help to reduce sodium loss from sweat, bile etc.

b. Glucocorticoids

Glucocorticoids include: cortisol, corticosterone and cortisone.

- i. They are concerned with regulating the metabolism of carbohydrate, protein and fat.
- ii. Most abundant glucocorticoid is cortisol which stimulates the liver to synthesize glucose from amino acid and fatty acid; process is gluconeogenesis.
- iii. Cortisol is anti-inflammatory hormone, as it retards phagocytic activities of WBCs.
- iv. It is also called stress hormone as it mobilizes energy sources in illness, trauma, starvation etc.
- v. It also plays a role in maintaining blood pressure and are also the normal functioning of nervous system.

c. Sex-corticoids/gonadocorticoid

- i. They are also called sex hormones; both androgens and oestrogen are secreted in very small quantities by adrenal cortex.
- ii. These hormones are concerned with proper functioning of sex organs and development of secondary sexual characters in males and females.
- iii. Sufficient male sex hormones (androgens) are important in the development of normal male characteristics in fetus.

Hormonal disorder of adrenal cortex

1. Addison's disease:

The deficiency of mineralocorticoids and glucocorticoids cause Addison disease. It was first reported by Thomas Addison, a British physician. It is characterized by low Na^+ and high K^+ in plasma, nausea, vomiting, bronze like pigmentation, reduced blood pressure, nervous disorder, weakness, low resistance to infection, more urea in blood etc.

2. Cushing's disease:

It is caused due to the excess secretion of glucocorticoids or cortisol. This disease is characterized by the abdominal obesity and wasting of limb muscles, moon face, poor wound healing, high blood sugar, more glycogen in liver, high Na^+ and low K^+ in plasma.

3. Hyper-aldosteronism (Conn's syndrome):

Hyper aldosteronism is due to the hypersecretion of aldosterone. It is characterized by high Na^+ and low K^+ in plasma, rise in blood volume, high B.P, polyuria.

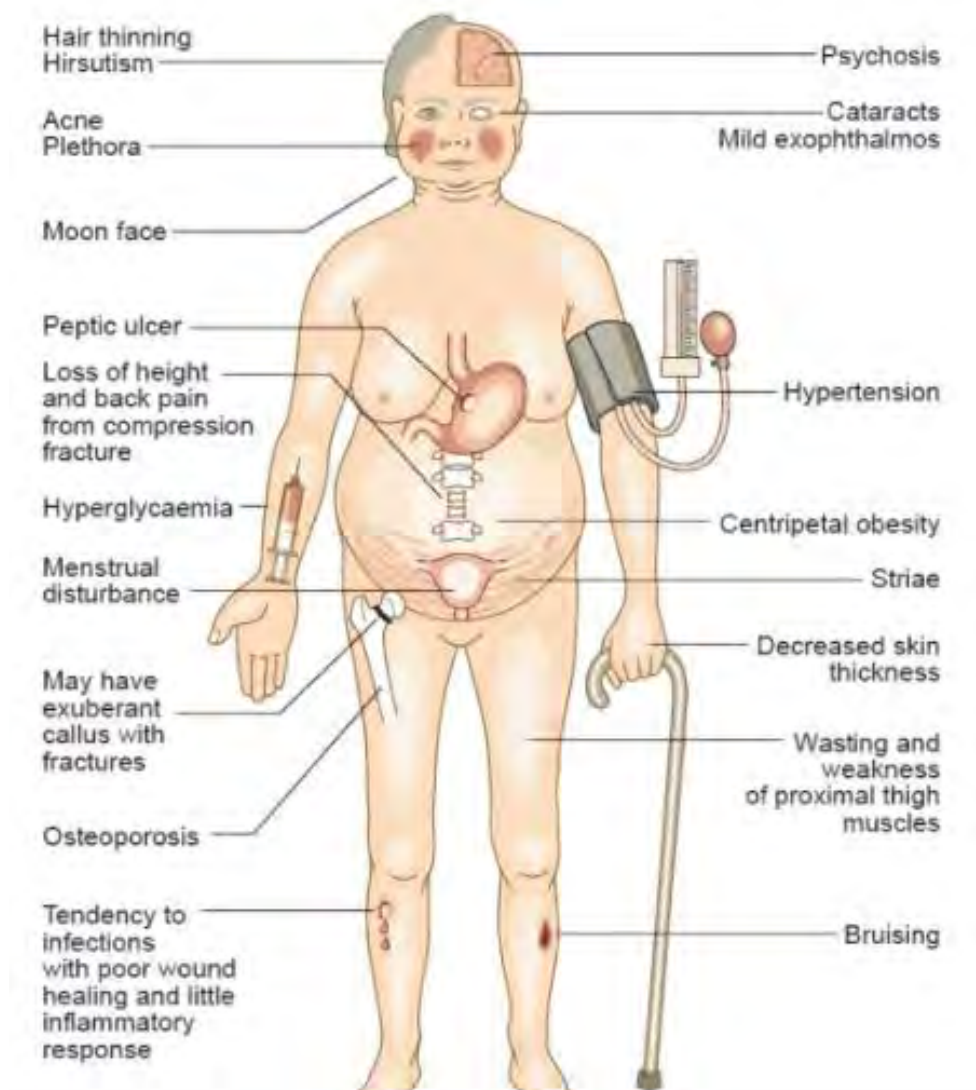


Fig: Cushing's syndrome

4. Hypo-aldosteronism:

It is due to the hypo-secretion of aldosterone which is characterized by low Na^+ and high K^+ in plasma, nervous disorder, dehydration, low B.P, low blood volume

5. Adrenal virilism:

Hypersecretion of androgen in females causes male type external sexual characters like beards and moustaches (hirsutism), male voice, uterus and ovaries degenerate, menstruation stops, clitoris enlarges and tend to change into male.

6. Gynaecomastia:

Oversecretion of oestrogen in male human results less developed facial hairs, female voice, enlarged breast (gynaecomastia).

b. Adrenal medulla

This is the second part of adrenal gland and consists of rounded group of relatively large granular cells called chromaffin cells. These cells secrete adrenaline (epinephrine 80%) and nor-

adrenaline (nor-epinephrine 20%) under the direct control of sympathetic nervous system (not under pituitary). Adrenaline and nor-adrenaline are collectively called catecholamines. These hormones help in 3F response: Flight, Fight and fright and hence called safety hormone.

Function of adrenaline

- i. Adrenaline secretion is greatly enhanced during the period of stress like anger, fright, heat, emotions cold etc.; hence called emergency hormone
- ii. It is a powerful vasoconstrictor hormone.
- iii. It stimulates contraction of heart muscles resulting rise in blood pressure and rise in cardiac output.
- iv. It stimulates rapid glycogenolysis in stress.
- v. It is used in asthma treatment and other allergic condition.
- vi. It also increases the breakdown of fat.

Function of nor-adrenaline

- i. It regulates blood circulation and make normal.
- ii. Nor adrenaline has more influence on blood vessels.

Gonad

The testes and ovaries are the primary male and female reproductive organs, or gonads. The gonads are responsible for the production of gametes—sperm in males and ova, or eggs, in females. In addition to these functions, the gonads produce the sex-steroid hormones, responsible for gamete production and have multiple other functions throughout the body.

The primary hormones of the ovaries are oestrogens and progesterone. Oestrogens: Group of female sex hormones important for reproduction and the development of female sex characteristics. Oestrogens are responsible for growth and maturation of the uterus and vagina; breast development; widening of the pelvis; greater fat distribution in the hips, thighs, and breast; uterus changes during the menstrual cycle; and increased growth of body hair. Progesterone hormone functions to prepare the uterus for conception; regulates uterus changes during the menstrual cycle; increases sexual desire; aids in ovulation; and stimulates gland development for milk production during pregnancy. Androgens are the hormones that primarily influence the development of the male reproductive system. Although found in much higher levels in men, androgens are also produced in women. Testosterone is the main androgen secreted by the testes.

Testosterone: It is important for the development of male sex organs and secondary sexual characteristics. Testosterone is responsible for increased muscle and bone mass; increased growth of body hair; development of broad shoulders; deepening of the voice; and growth of the penis.

Thymus Gland

The thymus gland is situated in the upper anterior portion of the chest cavity (mediastinum) behind the sternum, in front of the trachea. It lies below the thyroid gland and extends a little into the root of the neck. It is of a pinkish-gray color, soft, and lobulated on its surfaces. It is small at birth, enlarges during childhood, and atrophies at puberty. Hormone secreted from the thymus gland is thymosin.

Main function of thymosin is to promote the proliferation and maturation of T-lymphocytes.

Pineal gland

The pineal body or gland is a small endocrine gland (0.1g-0.2g). This gland is shaped like a tiny pine cone (hence its name), and is located near the center of the brain, between the two cerebral hemispheres. produces melatonin, also called 'sleep hormone' as it promotes sleep. This hormone plays a crucial role in regulating sleep and wake cycles or the circadian rhythm. Secretion increases in dim light and decreases in bright light. It possibly, inhibits growth and development of sex organs before puberty.

Using locally available materials such as clay, thermocol, cardboard, paper pulp etc. prepare a model of pituitary gland, thyroid gland, adrenal gland and pancreas

Exercise

Choose the best alternative.

- Which of the following is the endocrine gland?
 - Salivary gland
 - Sweat gland
 - thyroid
 - tear gland
- Who discovered the first hormone secretin?
 - William M. Bayliss and Ernest H. Starling
 - Addison
 - Cushing
 - Starling
- Which of the following is the common chemical nature of hormones and enzymes?
 - Protein
 - Steroid
 - carbohydrates
 - inorganic compound
- Where is the location of pituitary gland?
 - In cerebellum
 - below hypothalamus
 - above hypothalamus
 - in medulla oblongata
- Which of the following hormone is secreted by the posterior lobe of pituitary gland?
 - Somatostatin
 - Oxytocin
 - thyroid
 - prolactin
- Which of the following is the function of anti-diuretic hormone?
 - Stimulates milk secretion
 - Promotes the growth of muscle
 - regulates water balance
 - controls metabolism
- Which hormones stimulates the thyroid gland to secrete T₃ and T₄?
 - TSH
 - LH
 - ACTH
 - GH

8. Which part of the pituitary gland releases the hormone synthesized by the neurosecretory cells of hypothalamus?
 - a. Anterior
 - b. Posterior
 - c. middle
 - d. both anterior and middle

9. If a patient has a swollen thyroid gland, which test is commonly used to check whether the thyroid gland is over secreting or under secreting?
 - a. CT scan
 - b. Urine test
 - c. Stool test
 - d. Blood test for T3 and T4 and TSH

10. Which of the following function is carried out by calcitonin?
 - a. Increases the blood calcium level
 - b. Decreases the blood calcium level
 - c. Increases the blood sugar level
 - d. Stimulates production of erythrocytes

11. Which of the following disorder results from the over secretion of thyroid gland?
 - a. Myxoedema
 - b. Graves' disease
 - c. Cushing's syndrome
 - d. Acromegaly

12. Which of the following hormone is not produced by adrenal cortex?
 - a. Cortisol
 - b. Adrenaline
 - c. aldosterone
 - d. androgen

13. What is the main function of cortisol?
 - a. Regulating blood pressure
 - b. Control metabolism and stress response
 - c. Stimulating muscle growth
 - d. Lowering the blood pressure

14. Which two minerals are balanced by aldosterone in the body?
 - a. Calcium and phosphorus
 - b. Sodium and magnesium
 - c. sodium and potassium
 - d. calcium and potassium

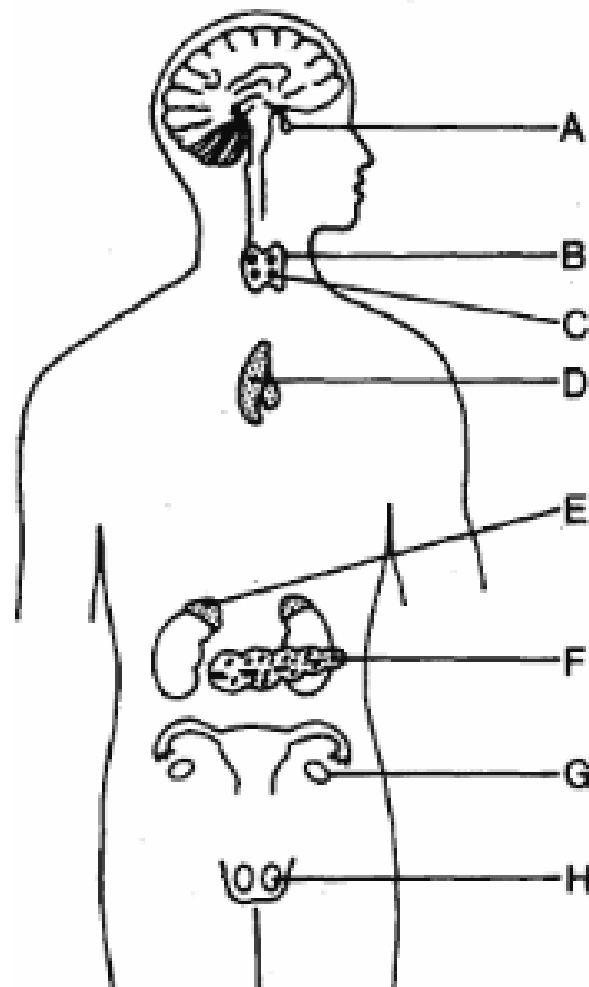
15. Addison's disease is caused by the deficiency of which hormone?
 - a. Adrenaline
 - b. Aldosterone
 - c. Cortisol
 - d. Aldosterone and cortisol

16. Which of the following condition causes the Grave's disease?

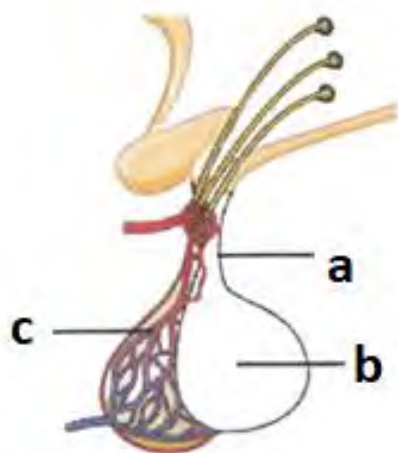
- a. Hyposecretion of adrenal gland
- b. Hypersecretion of thyroid gland
- c. Hyposecretion of thyroid gland
- d. Hypersecretion of adrenal gland

Answer the following questions in brief.

- 1. What are the differences between exocrine and endocrine glands?
- 2. Which part of pituitary is known as storage and releaser center? Briefly describe its structure and function?
- 3. Describe the causes and symptoms of hypothyroidism and hyperthyroidism.
- 4. Describe the structure and function of the heterocrine gland located in duodenum.
- 5. What is the function of parathyroid gland? How does it help maintain calcium balance in our body?
- 6. Describe briefly about the location and hormonal functions of gonads.
- 7. What are the differences between enzymes and hormones?
- 8. Describe the structure and function of adrenal medulla?
- 9. Describe about the gland situated in the region of brain which maintain sleep and wake cycle.
- 10. Observe the diagram and answer the following questions.
 - e.



- i. Label the parts A, B, C, D, E, F, G, H.
 - ii. Which of these part is also called gland of emergency?
 - iii. What is the function of D?
 - iv. What are the two differences between B and C?
- f.



- i. Identify the gland? Write its specific location in our body.
- ii. Label the parts a, b and c.
- iii. Write two secretions from part b and part c each.

Long answer type questions.

1. Name the part of brain which secretes neurohormones and also called supreme commander of endocrine regulation. Describe its structure and function of its secretion.
2. Why pituitary gland called master gland? Write its structure, function of different hormones and hormonal disorders.
3. Secretion of which gland controls basal metabolic rate of our body? Explain the structure, functions of hormone secreted by this gland and the various hormonal disorders.
4. Where is adrenal gland situated? Why is it called emergency gland? Describe its structure function and hormonal disorders.

Chapter 8.8

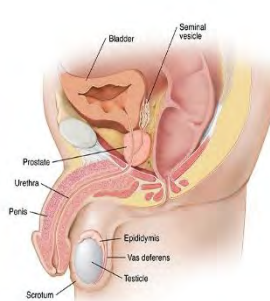
REPRODUCTIVE SYSTEM



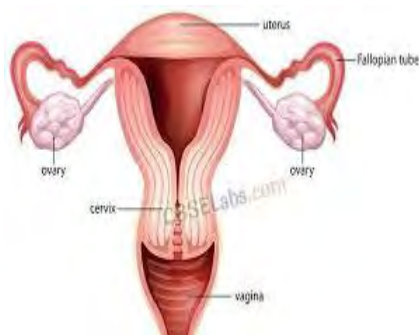
Regnier de Graaf (1641-1673) was a Dutch physician, physiologist, and anatomist who made **key discoveries** in **reproductive biology**. He is generally regarded as the '**father of modern reproductive biology**'. His name is associated with the corpus luteum, the Fallopian tubes, and the ovarian follicles which, in honour of his achievements, were named after him. In this context, ovarian follicles are named '**Graafian follicles**'.

Observe the figures given below and discuss following questions with your classmates.

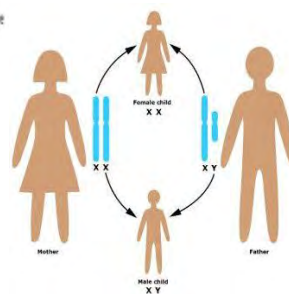
1. Out of the three figures A, B, and C, which one indicate sexual reproduction, which one male reproductive organs, and which one female reproductive organs?



A



B



C

Figure A indicates human male reproductive organs, figure B human female reproductive organs, and figure C human sexual reproduction to give rise to new progeny.

Reproductive system, also called **urino-genital** or **genital system** refers to the **sexual reproduction** involving **reproductive organs** to give rise to new progeny.

Do you know?

Reproductive system was seen for the first time in phylum-Cnidaria.

8.8.1 Sexual reproduction

There is no provision of asexual reproduction in human being hence, there is occurrence of **sexual reproduction** only. The sexual reproduction occurring in man is **anisogamy** or

oogamy. Human being is **viviparous** hence, fertilization is internal and the male inserts semen inside female through copulation to fertilize ovum or egg. The female, for the production of ovum or egg, operates **female reproductive cycles** known as **ovarian** and **menstrual cycle** closely related to one another and occurring at the same time.

Do you know?

Both man and kangaroo are **viviparous** but man gives birth to **baby** and kangaroo gives birth to **embryo** called **joeys**.

Human being is **unisexual** or **dioecious** because sexes are separate. **Sexual dimorphism** is well-marked. Secondary sexual characters in human male and female after attaining puberty and within and after adolescent are as follows as:

Table 8.8.1 Secondary sexual characters in human male and female

Human details	Male	Female
Face	Not smooth due to hairs	Smooth due to lack of hairs
Moustache and beard	Present	Absent
Neck	Prominent Adam's apple	Less prominent Adam's apple
Shoulder	Broad	Narrow
Hip	Narrow	Broad
Voice	Low-pitched	High-pitched

8.8.2 Reproductive organs

Reproductive organs, also called **urino-genital**, **genital**, or **sex organs** refer to male and female reproductive organs. The male and female reproductive organs possess **primary** and **secondary reproductive organs** as well as **reproductive glands**. The primary reproductive organs which are **main sex organs** are **gonads** – male gonads, **testes** and female gonads, **ovaries**. The secondary reproductive organs, which are also known as **accessory** or **helping sex organs** are **supporting sex organs**. The supportive sex organs are epididymis, vas deferens, urethra, penis, and scrotum **in male** and fallopian tubes, uterus, cervix, vagina, vestibule, clitoris, labia minora, labia majora, and mons pubis **in female**. The reproductive glands which are also called **accessory** or **helping sex glands** are **supporting sex glands**. The supportive sex glands are seminal vesicles, prostate glands, and Cowper's glands **in male** and Bartholin's glands, Skene's glands, and mammary glands **in female**. The Bartholin's glands and Skene glands help in copulation whereas mammary glands produce milk and antibodies after childbirth.

Do you know?

Urinary or excretory system and genital or reproductive system have some organs in common hence, reproductive system is also referred to as **urino-genital system** and the organs, **urino-genital organs**, e.g., human male urethra through which both urine and semen pass.

Not all parts of the genitalia are exposed outside but some are situated inside body. The exposed parts of reproductive organs which are seen from outside are **external genitalia** and those which are located inside the body are **internal genitalia**. The external genitalia are penis and scrotum **in male** and vestibule, clitoris, labia minora, labia majora, and mons pubis **in female**. The internal genitalia are testes, epididymis, vas deferens, and urethra **in male** and ovaries, fallopian tubes, uterus, cervix, vagina, and urethra **in female**. All the sex glands, e.g., seminal vesicles, prostate glands, and Cowper's glands **in male** and Bartholin's glands and Skene's glands **in female** are kept inside the body except **mammary glands** of female which are situated outside.

Following are the descriptions of male reproduction organs, female reproductive organs, and female reproductive cycles:

1. Male reproductive organs

Human male reproductive organs, which possess primary and secondary sex organs including accessory sex glands consist of testes, epididymis, vas deferens, seminal vesicles, prostate glands, Cowper's glands, urethra, penis, and scrotum.

Do you know?

Because, testes require 2-4 °C less temperature than body temperature hence, they are lodged inside scrotum.

I. Testes

Testes (singular – **testis**), also called **testicle** are **primary reproductive** or **main sex organs** because they form **sperms** and secrete **testosterone**. Testes are **internal genitalia** as they are located inside extra-abdominal sac known as **scrotal sac** or **scrotum**.

Do you know?

Non-descent of testes into scrotum is called **cryptorchidism** due to which a person becomes sterile.

Male Reproductive System: Testis

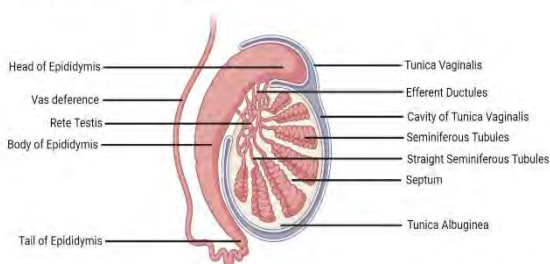
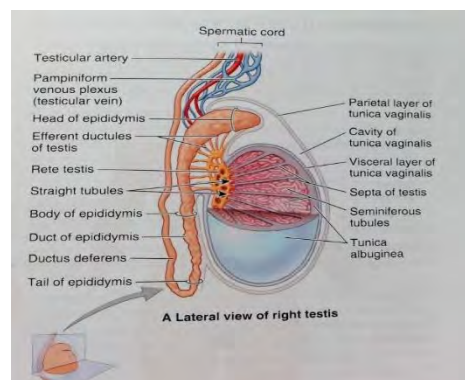


Figure: Structure of Testis

Designed By: Sagar Aryal. Created with biorender.com

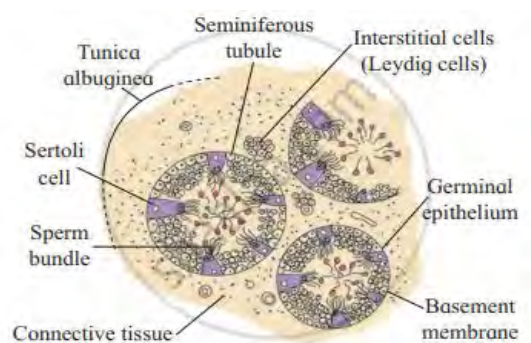


L. S. of right testis of man

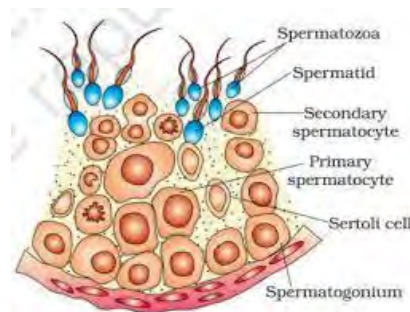
Testes are **oval-shaped**, **one pair** in number (one **left** and another **right**), and **yellow** in colour. Each testis is 4.5-5 cm long, 3 cm wide, and 2 cm high, with a weight of 15-30 g. The right testis is slightly larger and heavier than the left.

Structurally, each testis is covered by three layers: outer **tunica vaginalis**, middle **capsule** or **tunica albuginea**, and inner **tunica vasculosa**. The tunica albuginea further extends internally forming inner partitions called compartments or lobules. The lobules are embedded in network of capillaries called tunica vasculosa.

Histologically, each testis has 250 **compartments** or **lobules**. Each lobule has 1-4 convoluted **seminiferous tubules** each measuring 30-80 cm in length. The seminiferous tubules are separated from one another by **interstitial connective tissue**. The **interstitial cells** or **cells of Leydig's** which are distributed in the interstitial connective tissue secrete **testosterone**. The germinal epithelial lining the seminiferous tubules is made up of two types of cells – most numerous are smaller **primordial germ cells** which give rise to **spermatogonia** that form **sperms** and few supporting, larger and tall columnar cells which are **Sertoli sub-tencular cells** that help nourish sperms. Besides nourishing sperms, Sertoli cells also secrete the hormone, **inhibin**. All the seminiferous tubules in each testis open into a network called **rete testis** leading into fine ductules known as **vasa efferentia**. All the vasa efferentia conduct sperms into **epididymis**.



T. S. of human testis



Part of the T. S. of human testis

II. Epididymis

Epididymis (plural – **epididymides**) which is **secondary sex organ** and **internal genitalia** is modified **Wolffian duct** of the embryo in adult. The epididymides are one pair in number (one **left** and another **right**). Each epididymis is a whitish mass of irregular, narrow, and highly convoluted tubule found on the inner surface of respective testis. Each epididymis comprises three parts: anterior **caput**, middle **corpus**, and posterior **cauda**. The **vasa efferentia** enter into caput epididymis. Each caput epididymis is connected to the dorsal abdominal wall through **spermatic cord** that is made up of connective tissue, spermatic artery, and spermatic nerves, etc. In this way, each testis, through caput epididymis is also attached to the dorsal abdominal wall via spermatic duct. The maturity, motility, and

temporary storage of sperms occur in epididymis. The cauda epididymis continues into vas deferens.

Do you know?

Surgical removal of testes is known as **orchidectomy** or **castration**.

III. Vas deferens

Vas deferens, which is also called **ductus deferens** or **vasa differentia** or **sperm duct** are **secondary sex organs** and **internal genitalia**. The vas deferens are one pair in number (one **left** and another **right**). Each one arises from cauda epididymis, ascends to abdomen, passes over urinary bladder, turns in from ureter, and receives duct from seminal vesicle behind the urinary bladder forming **ejaculatory duct**. The ejaculatory duct passes through prostate to open into urethra shortly after its origin from the urinary bladder. The urethra which receives ducts from prostate and Cowper's gland pass through the penis to open outside.

IV. Seminal vesicles

Seminal vesicles, also known as **uterus masculinus** are **accessory sex glands** and **internal genitalia**. The seminal vesicles are one pair in number (one **left** and another **right**). Each seminal vesicle is narrow, long pouches with muscular tissue on their wall. Each vesicle is situated behind urinary bladder at the junction between vas deferens and prostate gland. About 70% of **semen** is composed of **seminal fluid**. The seminal fluid which has a pH of 7.4 contains fructose, ascorbic acid, citrate, prostaglandins, certain enzymes and H₂O. Fructose is the main source of energy for sperms in semen. Seminal vesicles are followed by **prostate gland**.

Do you know?

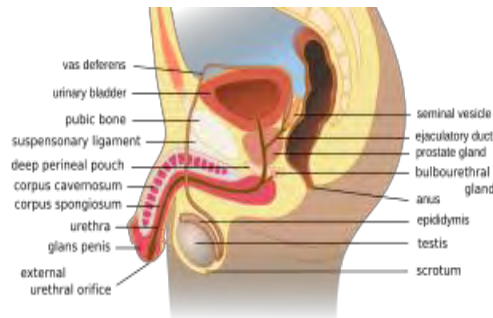
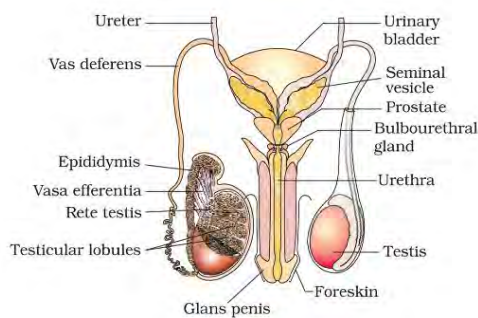
Semen, often called **seminal fluid**, is a greyish white bodily fluid containing 5% spermatozoa, 70% seminal fluid, and 20% prostatic fluid including 5% of the Cowper's fluid along with fructose.

V. Prostate gland

Prostate gland is **accessory sex gland** and **internal genitalia**. It is unpaired, single, large sac-like structure situated around the first part of urethra. The prostate gland possesses prostatic utricle and acini covered by a capsule. About 20% semen is composed of **prostatic fluid**. The prostatic fluid which has slightly acidic pH of 6.5 due to the presence of citric acid contains albumin, and proteolytic enzymes like fibrinolysin and fibrinogenase. The fibrinolysin and fibrinogenase are important for sperm-mobility. The prostate gland is followed by **Cowper's glands**.

Do you know?

Difficult or painful urination due to the enlargement of prostate gland is called **prostatitis**.



Male reproductive organs (front view)

Male reproductive organs (lateral view)

VI. Cowper's glands

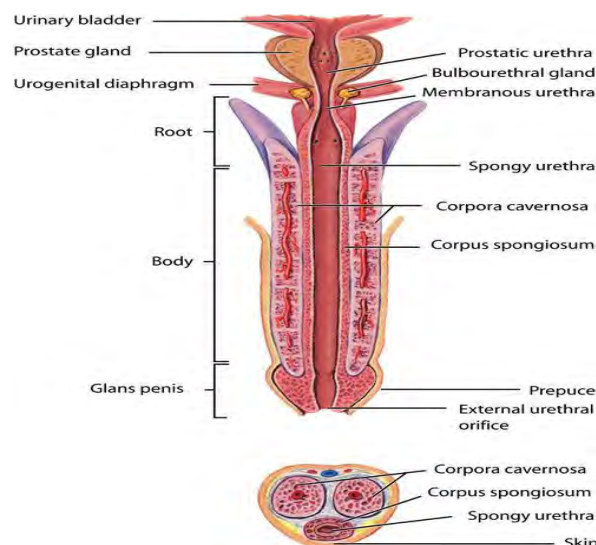
Cowper's glands, which are also known as **Bulbo-urethral glands** are **accessory sex glands** and **internal genitalia**. Cowper's glands which are **one pair** in number (one **left** and another **right**), small sac-like structure, and yellow in colour are situated beneath prostate gland and behind urethra. Each gland opens into urethra before entering into penis. The secretion of Cowper's glands is slightly alkaline and is produced during sexual stimulation. The secretion neutralizes urine in urethra and acts as lubricant for the glans penis.

VII. Urethra

Urethra, which is also known as **urino-genital duct** is **secondary sex organ** and **internal genitalia**. It is unpaired, single, long, thick-walled muscular duct being common passage for both urine and semen hence, it is called urino-genital duct. The urethra traverses from the inferior side of urinary bladder to the tip of penis where it opens through male genital aperture or urethral aperture.

VIII. Penis

Penis is **secondary sex organ** and **external genitalia**. It is unpaired, single, vascular, spongy, long, and erectile copulatory organ possessing **glans penis** at the tip covered by



L. S. (above) and T. S. (below) of human penis

a fold of skin called **prepuce**. The penis has three longitudinal columns of erectile and spongy tissue which tends to be filled up with blood during sexual excitement. Surrounding the urethra, is **corpus spongiosum** and above it lies two **corpora cavernosa**. The penis serves to transmit semen into the vagina of female during sexual intercourse.

IX. Scrotum

Scrotum, also called scrotal sac is **secondary sex organ** and **external genitalia**. The scrotum is unpaired and single. It communicates with abdominal cavity through **inguinal canal**. It is divided into **two compartments** by **scrotal septum**. Each testis is lodged in each compartment. Each testis is connected posteriorly or dorsally to each scrotal compartment of its side through **ligamentous connective cord** or **elastic cord** called **gubernaculum** which represents **mesorchium**.

Activity

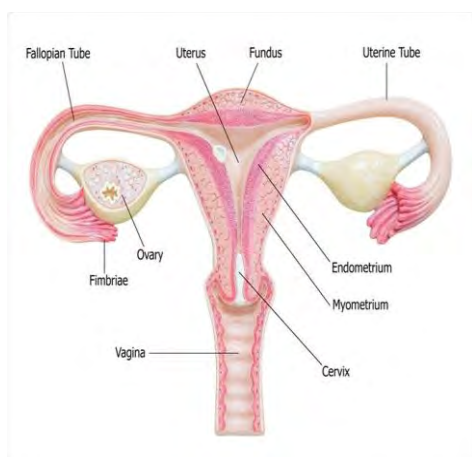
Take a white- or light-coloured sheet- or chart paper. **Draw** with the help of different colours, **human male reproductive organs** in frontal view and in lateral view. Mention the labelling of the organs you have drawn.

2. Female reproductive organs

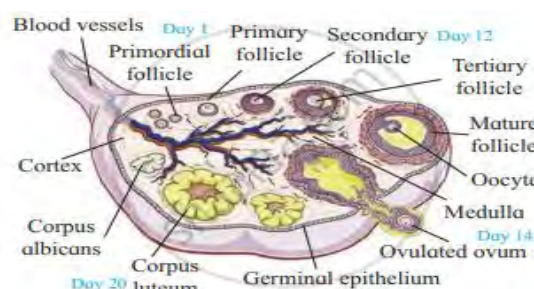
Human female reproductive organs, which possess primary and secondary sex organs including accessory sex glands comprise ovaries, fallopian tubes, uterus, cervix, vagina, vestibule, clitoris, labia minora, labia majora, mons pubis, Skene glands, Bartholin's glands, and mammary glands.

I. Ovaries

Ovaries (singular – **ovary**) are **primary** or **main sex organs** because they form **eggs** or **ova** and secrete **oestrogen** and **progesterone**. Ovaries are **internal genitalia** as they are located inside pelvic cavity.



Human female reproductive organ



Left ovary of human female

Ovaries are **almond-** or **oval-shaped** organ, each with **hilus** on one side, **one pair** in number (one **left** and another **right**), and light gray to white in colour. Each ovary is 4 cm long, 2 cm wide, and 1 cm thick with a weight of 2-4 g.

Structurally, each ovary is located on either side of **womb** or **uterus** against the wall of pelvis associated with hilus. Each ovary is attached posteriorly or dorsally to the abdominal wall with the help of a **ligamentous connective cord** or **elastic cord** called **mesovarium** just opposite to hilus. Each ovary is solid in which blood vessels and nerves enter through hilus. Ovaries are closely associated with fallopian tube.

Histologically, each ovary is covered by **germinal epithelium** comprising moderate-sized cuboidal cells which will give rise to **primordial germ cells**. The primordial cells will form **oogonia** and **egg**. Inside germinal epithelium, each ovary has stroma associated with connective tissue comprising – outer dense layer of **cortex** and inner loose layer of **medulla**. The cortex consists of numerous small and large, spherical and oval **ovarian follicles** (primary-, secondary-, tertiary-, and maturing), among which a fully matured one is called **Graafian follicle**. The Graafian follicle which contains a **primary oocyte** is covered with **theca** – outer **theca externa** and inner **theca interna**. The follicle cells lining the primary oocyte is called **membrane granulosa**. The **mass of cells** or **hillock** which surrounds and attaches primary oocyte to the follicle wall is known as **cumulus** or **discus proligerous**. The primary oocyte is covered by **zona pellucida**. Outer to zona pellucida and inner to discus proligerous, there is characteristic radial arrangement known as **corona raidata**. The Graafian follicle secretes **oestrogens**. Soon, after growth, primary oocyte becomes **secondary oocyte** and the Graafian follicle contains a large central **antrum** or **follicular cavity** filled up with liquid known as **liquor folliculi**. The discharge of secondary oocyte by rupturing Graafian follicle is called **ovulation**. After ovulation, the ruptured Graafian follicle, first of all, converts into **corpus haemorrhagicum**, and then turns into yellowish solid mass of cells called **corpus luteum** which starts secreting progesterone. The corpus luteum is a temporary structure and disappears leaving a whitish scar known as **corpus albicans**. The ovum from ovary drops and captured by **fallopian tubes**.

II. Fallopian tubes

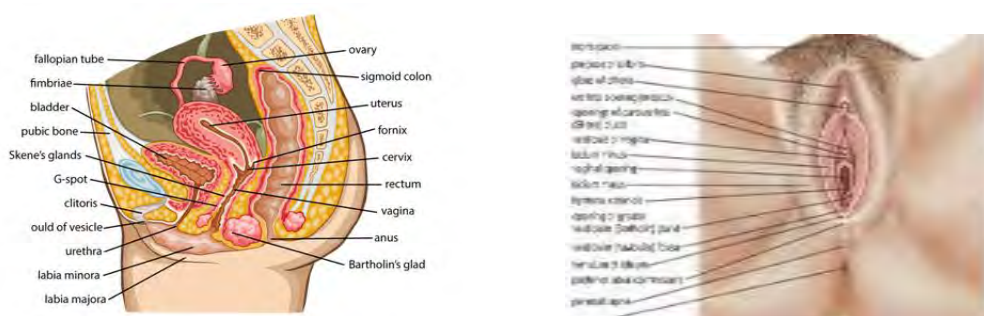
Fallopian tubes, also known as **uterine tubes** or **oviducts** are **secondary sex organs** and **internal genitalia**. Fallopian tubes are **one pair** in number (one **left** and another **right**). Each tube has a funnel-shaped **infundibulum** provided with an aperture called **ostium**. Infundibulum of each fallopian tube is closely associated with ovary of its respective side. The infundibulum has finger-like **fimbriae** having ciliated columnar epithelium. The part of the fallopian tube after fimbriae is **ampulla**. Internally, fallopian tube is also lined by **ciliated columnar epithelium**. Fertilization of the secondary oocyte which becomes ovum takes place in fallopian tube. Zygote takes development here in fallopian tube up to **blastocyst stage**. Each fallopian tube opens into **womb** or **uterus**.

III. Uterus

Uterus, also called **womb** is **secondary sex organ** and **internal genitalia**. It is unpaired, single, thick and strong muscular sac situated above and behind the urinary bladder. The uterus remains attached to body-wall through ligaments. Naturally, uterus is of the size of a lemon measuring 8 cm long, 5 cm across, and 4 cm thick and in which 80-200 ml fluid can occupy. The main part of the uterus is called **fundus**. Internally, uterus has wide cavity called **uterine cavity**. Histologically, wall of uterus is composed of smooth muscle fibres known as **myometrium**. The lumen of uterus is internally lined by **endometrium** which is highly vascular and rich in glands. The implantation of blastocyst occurs inside uterus. The uterus is followed by **cervix**.

IV. Cervix

Cervix is **secondary sex organ** and **internal genitalia**. It is unpaired, single cavity being situated on lower end of uterus. The internal part of cervix connected to uterus is **internal os** and the external part connected to the vagina is **external os**. The cervix is followed by **vagina**.



Human female reproductive organs (left: lateral view and right: front view)

V. Vagina

Vagina which is **secondary sex organ** and **internal genitalia** is unpaired, single, and elastic muscular tube. It is internally lined by non-keratinized epithelium without any glands. During reproductive life, human female vagina contains the **bacterium, *Lactobacillus acidophilus***, which keeps vaginal pH acidic in between 3.5-4.9 by producing lactic acid from glycogen. The vagina receives semen from male during copulation. The vagina conveys baby outside during delivery. The vagina opens through vaginal orifice in **vestibule**.

Do you know?

In rape case, presence of **fructose** in vaginal swab of the raped victim is considered **confirmatory test**.

VI. VESTIBULE

Vestibule which is also called **vulva** is **secondary sex organ** and **external genitalia**. It is a small space outside vagina. Because, it is opening to outside of vagina, it is also known as **urino-genital opening**. It possesses clitoris and is surrounded by labia minora, labia majora, and mons pubis. The Skene glands and Bartholin's glands are associated in this region.

VII. CLITORIS

The vestibule, on its superior side, has **clitoris**. The clitoris is **secondary sex organ** and **external genitalia**. It is single, small organ inside vestibule consisting of erectile tissue being homologous to penis of male. Superior to the clitoris lies **prepuce** or **glans clitoris** which is homologous to prepuce of male penis.

Inferior to clitoris, lies **urethral aperture**, **urethral orifice** or **urethral meatus** for voiding urine. Inferior to urethral meatus, lies **hymen**. The hymen is thin mucous membrane that stretches across the vaginal orifice. Normally, hymen is ruptured during female's first copulation. Inferior, posterior or dorsal to hymen lies **anus**.

VIII. Labia minora

Vestibule is covered laterally, on left side and right side, by thin fold of muscles called **labia minora**. The labia minora are **secondary sex organs** and **external genitalia**. They are two in number (one left and another right).

IX. Labia majora

Labia minora is externally and laterally covered, on the left side and right side, by thick fold of muscles covered by skin known as **labia majora** which is homologous to scrotum of male. The labia majora are **secondary sex organs** and **external genitalia**. They are two in number (one left and another right).

X. Mons pubis

The superior part of labia majora is called **mons pubis**. The mons pubis is **secondary sex organ** and **external genitalia**. It is unpaired and single. The mons pubis and remaining part of the labia majora is covered with hairs.

XI. Skene glands

Numerous minute accessory glands called Skene glands, **para-urethral glands** or **glands of Skene**, which are homologous to prostate gland of male, are present around the urethral orifice.

XII. Bartholin's glands

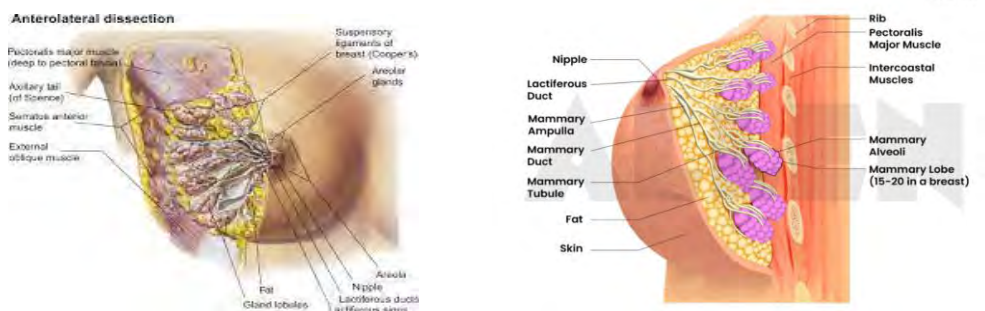
On either side of vaginal orifice lies accessory glands known as **Bartholin's**, **vulvo-vaginal**, or **greater vestibular glands** which are homologous to Cowper's glands of male helping to lubricate vestibule during copulation.

Activity

Take a white- or light-coloured sheet- or chart paper. **Draw** with the help of different colours, **human female reproductive organs** in frontal view and in lateral view. Mention the labelling of the organs you have drawn.

XIII. Mammary glands

Human female mammary glands are externally situated glands that ensure secondary sexual characteristic of a human female. They are one pair or two in number (one left and another right) and are located on the ventral thorax, especially in the breasts. They are specialized glands that produce and secrete milk and antibodies, essential for nourishing newly born baby immediately after delivery of the baby.



Human female mammary gland (left frontal view and right lateral view)

Mammary glands are complex structures composed of glandular, connective, and fatty tissues, with a network of milk-ducts and milk-producing alveoli. The glandular tissue, also called lobules, produces milk. In the connective tissue, are embedded glandular and fatty tissues. The fatty tissue fills the area between glandular and connective tissue and determine the breast size.

Do you know?

Mammary glands of both male and female monotremes like **duckbilled platypus** are functional, developed, and can secrete milk.

Pigmented area surrounding the nipple is areola. Nipple is central part of the breast beset with openings of milk ducts. The milk ducts, also called lactiferous ducts carry milk from lobules to nipple. The lobules are cluster of alveoli, and each lobule connects to a lobe. The alveoli are tiny, grape-like sacs that produce and store milk.

Mammary glands are developed during puberty due to the influence of oestrogen and progesterone. Mammary glands are sensitive to hormonal changes, particularly during pregnancy and lactation when they go significant growth and development.

3. Female reproductive cycles

Periodic or **rhythmic changes** which occur once at every lunar month of 28 days in female reproductive organs in ovary and inside uterus during **reproductive** or **fertile period** from **puberty** (10-14 yrs. of age) or from **menarche** (commencement of menstruation) until before or up to **menopause** (cessation of menstruation occurring at the age of 50-55 yrs.). The reproductive cycles include: ovarian and uterine cycle.

Activity

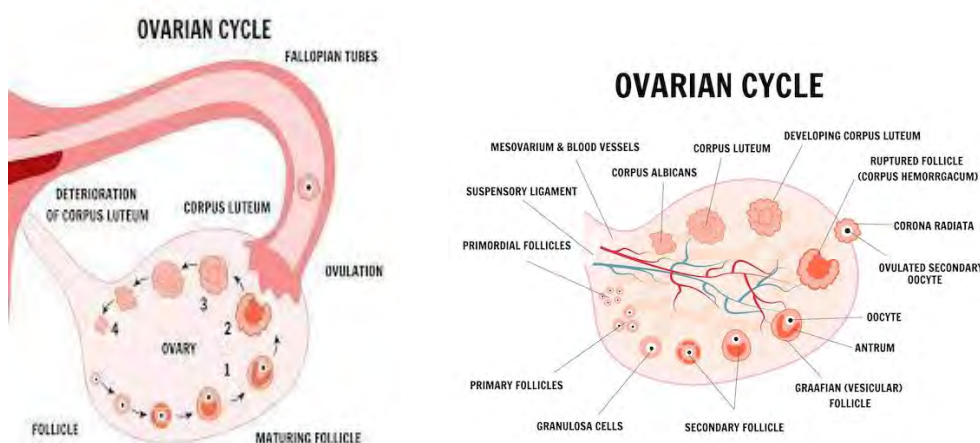
Compare and enlist homologous reproductive organs of human male and female. Get support from standard or online literature, if required. If available, you may consult "Encyclopedia Britannica", "Encyclopedia Americana", or "Grzimek's Encyclopedia".

I. Ovarian cycle

Ovarian cycle occurs in cortex of ovary, in alternate way or criss-cross fashion, one month in one ovary and another month in another, and so on. The cycle consists of three phases: follicular, ovulation, and luteal.

i. Follicular phase

Follicular phase, also called **pre-ovulatory** or **estrogenic phase** covers first half of the ovarian cycle and comprises maturation of ovarian follicle including secretion of estrogens. With the effect of FSH secreted by anterior pituitary, many primary follicles grow at the same time however, only one passes through secondary, tertiary, and maturing follicle, and reaches into a Graafian follicle. The rest of the primary follicles called **degenerating follicles** or **atretic follicles** undergo degeneration or atresia. The Graafian follicle which secretes estrogens in **liquor folliculi** is responsible for proliferative phase of menstrual cycle.



Human female ovarian cycle

ii. Ovulation phase

Ovulation phase tends to be the middle phase of ovarian cycle and refers to the rupture of Graafian follicle and release of mature secondary oocyte. Ovulation phase occurs once every lunar month of 28 days during fertile period of human female. Ovulation phase doesn't occur during pregnancy. Ovulation phase may, sometimes, occur during lactation period. The time of ovulation is variable but it usually occurs on 14th day of the ovarian cycle. This means, ovulation occurs at about 14 days (± 1 day) before beginning of the next menstruation. The cause of ovulation is attributed to inhibition of FSH by estrogens and stimulation of LH and LTH secretion by anterior pituitary leading to an increased salt concentration of the liquor folliculi resulting in an increase in its osmotic pressure and rupture of the Graafian follicle.

iii. Luteal phase

Luteal phase, also called **post-ovulatory** or **progestational phase** tends to be last half of the ovarian cycle and comprises the formation of corpus haemorrhagicum and corpus luteum along with inhibition and secretion of progesterone.

A. Corpus haemorrhagicum

After ovulation, wall of the Graafian follicle collapses and becomes folded due to sudden release of pressure inside it. Bleeding occurs inside follicle with the formation of blood clot. Corpus haemorrhagicum lasts for about three days before it changes into corpus luteum. With the stimulation of LH, corpus haemorrhagicum is gradually transformed into corpus luteum.

B. Corpus luteum

Cells of **membrane granulosa** enlarge, become polyhedral, and develop yellowish carotenoid pigment called **lutein**. Now, enlarged cells of the membrane granulosa are called **granulosa lutea cells**. At the same time, cells of the theca interna undergo similar changes like cells of the membrane granulosa and become **luteal cells**. Capillaries grow among **granulosa lutea cells** allowing gradual absorption of blood clot inside corpus luteum. With the stimulation of LTH, corpus luteum secretes progesterone and small amount of estrogens. The yellowish corpus luteum has two fates. If there is no fertilization, corpus luteum persists for 9-14 days becoming **corpus luteum of menstruation**, and then rapidly degenerates so as to give rise to **corpus albicans** or **fibrous body**. The progesterone inhibits secretion of LH and LTH leading to regression of corpus luteum. The decreased level of estrogens stimulates FSH secretion to start a new ovarian cycle. But, if fertilization occurs, corpus luteum persists for four months becoming **corpus luteum of pregnancy**, and then slowly degenerates. After degeneration, functions of corpus luteum of pregnancy, i.e., function of secretion of progesterone and secretion of small amount of estrogens is replaced by placenta. Persistence of corpus luteum of pregnancy up to four months is induced by human chorionic gonadotropin (HCG).

Do you know?

Menstrual cycle occurs in female anthropoids, i.e., monkeys, apes, and man whereas **oestrous cycle** is the reproductive cycle of female mammal without menstruation.

II. Menstrual cycle

Menstrual cycle, also known as **uterine** or **endometrial cycle** occurs in **endometrium** of uterus, in alternate way or criss-cross fashion, one month in one ovary and another month in another, and so on. The cycle duration extends from first day of one menstruation to the first day of next menstruation; in most typical cycle, it is about 28 days but it may normally vary from 21 to 40 days; the menstrual cycle consists of four phases: menstrual, regenerative, proliferative, and secretory.

Do you know?

Amenorrhea is no menstruation as in pregnancy; **menorrhoea** is increased menstrual flow; **oligomenorrhoea** is decreased menstrual flow; and **polymenorrhoea** is increased frequency of menstruation.

i. Menstrual phase

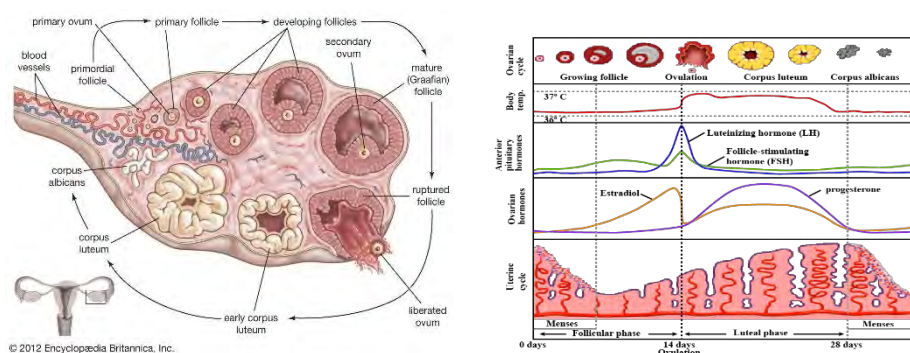
Menstrual phase, also called **menstruation** or **menses** in shortcut, is degeneration of corpus luteum at the end of luteal phase of the ovarian cycle leading to decreased level of progesterone and estrogens and resulting into **temporary spasm** of spiral arteries supplying superficially 2/3rd of the endometrium. At the same time, ischemia and necrosis of the endometrium and walls of the capillaries occur. When spasm is relieved, blood escapes from damaged capillaries and flows from the necrosed endometrium. The source of menstrual blood flow is from endometrium above the level of cervix because cervix and uterine tubes don't take part in menstrual blood flow. The menstrual flow contains epithelial cells and about 180 ml blood which doesn't clot due to the presence of anticoagulants. The superficial layers of endometrium like **stratum compactum** and **stratum spongiosum** are shaded off. The endometrium becomes thin. The duration of menstrual phase is 3-5 days.

Activity

Enlist different group of mammals so as to compare and show oestrous and menstrual cycle. Don't forget to mention the gestation period also of those mammals.

ii. Regenerative phase

Regenerative phase, which is also called **repair phase** and which starts from fourth to sixth day of menstrual cycle is the regeneration of endometrium and is carried out by



Human female menstrual cycle

stratum basale. The epithelium of the fundi (singular – **fundus**) of glands proliferates to complete epithelial lining of the denuded mucous membrane. Because the endometrial glands become straight and narrow and the endometrial stroma comprises spindle-shaped connective tissue and lymphocytes hence, the endometrium thickens.

iii. Proliferative phase

Proliferative phase, which is also known as **follicular**, **post-menstrual** or **estrogenic phase** and which starts from seventh to fifteenth day of the menstrual cycle is occurrence of proliferation of uterus. The proliferative phase corresponds to follicular phase of ovarian cycle. This phase is under the control of estrogens secreted by Graafian follicle. Endometrium

proliferates, increases in thickness with the lining of cuboidal epithelium. The uterine glands are straight, long, and widely separated with no or negligible secretion.

Activity

Remember the dissection of general anatomy and alimentary canal of rat you did in class-XI. Now, with the permission of your biology teacher, take a male and female preserved rat from your laboratory. Under the guidance of your biology teacher, dissect the rat so as to expose its male reproductive organs of male and female reproductive organs of the female. Make a flag-labelling of your dissection. If possible, take a photograph of the same.

iv. Secretory phase

Secretory phase, which is also called **luteal**, **pre-menstrual** or **progestational phase** and which starts from 16th to 28th day of menstrual cycle, is the occurrence of secretion. The secretory phase corresponds to the luteal phase of ovarian cycle. The secretory phase is under the control of progesterone secreted by corpus luteum. The endometrium is thick, soft, velvet-like with the lining of columnar epithelium and is loaded with water. The endometrium has (from superficial to deep) – **stratum compactum**, stratum spongiosum, and **stratum basale**.

Project work

Study and **compare** the reproductive behaviour and reproduction of man, apes, and monkeys.

Points to remember

Primary sex organs: are gonads, i.e., male gonads, testes and female gonads, ovaries.

Secondary sex organs: are also called **accessory** or **helping sex organs**, e.g., rest of the reproductive organs besides gonads.

Urino-genital system: occurring in vertebrates refers to the urinary or excretory system and genital or reproductive system.

Glossary

Adolescence: is transitional stage of physical and psychological development which generally occurs during the period of puberty to adulthood.

Puberty: is period of life when a boy or girl becomes sexually mature.

Sexual maturity: is period of life during which growth and maturation of the internal sex organs and external genitalia occur along with the development of secondary sexual characters.

Exercise

A. Tick the correct alternative.

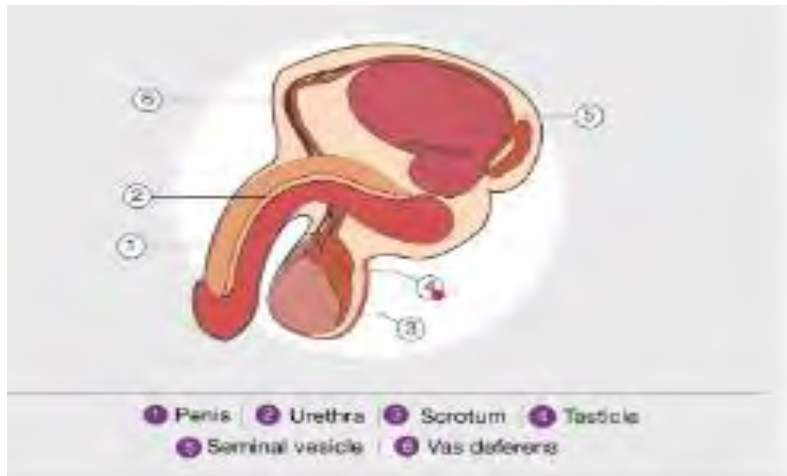
1. The main purpose of reproduction is to
 - a. produce one's own kind
 - b. make one's own copy
 - c. continue one's own race
 - d. all
2. Which one of the following is primary sex organs of human male?
 - a. Testes
 - b. Epididymides
 - c. Vas deferens
 - d. Seminal vesicles
3. The structural and functional unit of testes is
 - a. nephrons
 - b seminiferous tubules
 - c. uriniferous tubules
 - d. vasa differentia
4. Which organ of the male reproductive system releases male sex hormones?
 - a. Testes
 - b. Vas deferens
 - c. Ejaculatory duct
 - d. Urethra
5. The major volume of semen is from
 - a. seminal vesicles
 - b. prostate gland
 - c. Cowper's glands
 - d. Bartholin's glands
6. Which one of the following should be considered the urino-genital organ of man?
 - a. Male urethra
 - b. Female urethra
 - c. Male scrotum
 - d. Female labia majora
7. Which one of the following organ is homologous to scrotum?
 - a. clitoris
 - b. glans clitoris
 - c. labia minora
 - d. labia majora
8. The structural and functional unit of ovary is
 - a. vagina
 - b. uterus
 - c. fallopian tube
 - d. ovarian follicle
9. The menstrual cycle occurs in all of the following except
 - a. lemur
 - b. monkey
 - c. apes
 - d. man
10. At what time of menstrual cycle, ovulation takes place in adult female?
 - a. At the begging of proliferative phase
 - b. At the end of proliferative phase
 - c. At the beginning of menstrual phase
 - d. At the end of secretory phase
11. Hormones which regulate the menstrual cycle are
 - a. oestrogen and progesterone
 - b. insulin and glucagon
 - c. thyroxine and calcitonin
 - d. adrenaline and noradrenaline
12. Endometrium is found in
 - a. vagina
 - b. uterus
 - c. fallopian tube
 - d. ovary

Answers.

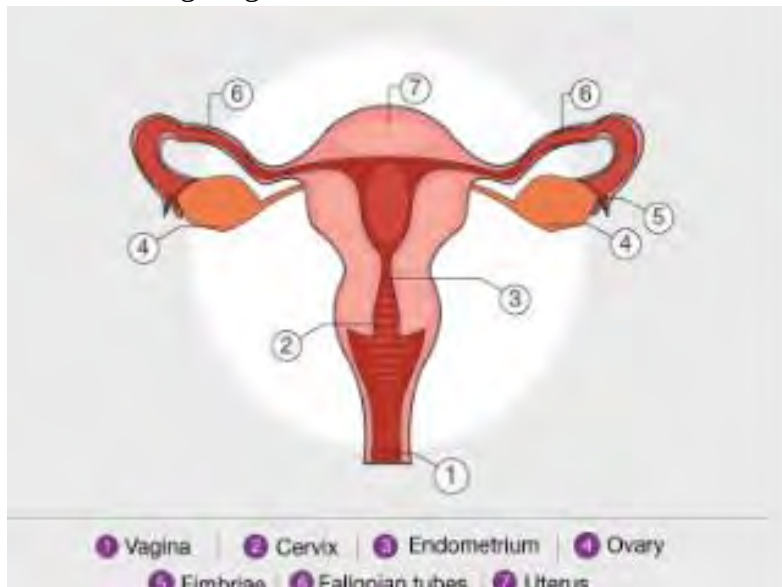
1. d	2. a	3. b	4. a	5. a	6. a	7. d	8. d	9. a	10. b
11. a	12. b								

B. Short answer questions.

1. Label the figure given below and also mention the function of the labelling.



2 Label the figure given below and also write the function of the labelling.



3. Explain in short the ovarian cycle of human female.

4. Describe in brief the menstrual cycle of woman.

5. Draw a well-labelled diagram of the T. S. of testis of human male (no description is required).

6. Write short note on ovaries of human female.

7. Summarize the accessory glands of human male.

C. Long answer questions.

1. Illustrate and describe in detail the human male reproductive organs.

2. Write a detailed account of human female reproductive cycles.

Unit 9

HUMAN POPULATION AND HEALTH DISORDER



Thomas Robert Malthus (1788-1834) was an English economist, cleric, and scholar, influential in the fields of political economy and **demography**. He is best known for his innovative work "**An Essay on the Principle of Population,**" published in 1798 in which he postulated "**Malthusian Theory of Population,**" and for which he is widely regarded as "**Father of Population.**"

Chapter 9.1

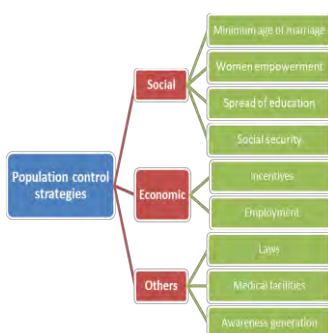
HUMAN POPULATION

Have a look at the figures given below and discuss following questions with your classmates.

1. How are the figures A, B, and C linked with human population?



A



B



C

Figure A indicates human population explosion and population growth problems. Figure B indicates control strategies of overpopulation of human beings. Figure C indicates the concept of demographic transition and demographic cycles.

Do you know?

Demography is the study of **human population growth** and prediction of future development whereas **demographer** is the one who studies human population trend and changes.

Population (L., **populous**, people) refers to the group of people living in a particular time occupying particular geographical area functioning as a unit. In this way, population comprises all the individual members of a species living at a given time in a specified location.

Biologically, population is considered self-regulating system (**Edwards, 1965**).

Ecologically, population is a group of individual organisms of the same species, or other groups, occurring in a specific time and inhabiting specified space, within which individuals may exchange genetics.

Do you know?

World's population day is observed on 11 July.

In shortcut, human population is the group of human beings living at a given time in a specified location.

Human population can be well understood when someone comes across: description of human population, human population growth problem and control strategies, and concept of demographic cycle.

Do you know?

Biological or **biotic community** is the combination of various populations of different types of organisms with one type in each which live together in a specific area and depend upon one another for food and shelter.

1. Description of human population

Human population comprises: population characteristics, population dynamics, population census, and population features.

I. Population characteristics

Population characteristics, generally refer to gender, race, ethnicity, education, household income, poverty, life expectancy, growth forms, and other aspects which are associated with the health of that community. However, following are the key population characteristics refer to natality, mortality, population distribution, population density, sex distribution, age distribution, and dispersal of the population:

i. Natality

Natality refers to the **birth rate**. Birth rate is the number of offspring reproduced per unit of population due to birth. It is the ratio of number of births in the size of any population. It is sometimes called **fertility**. It is expressed as:

Do you know?

Natality is affected by population size and time. The **population size** is the number of individual members of a species in a particular geographical area at a given time.

Natality rate = number of births per unit time in average population. It is number of births per 1000 individuals per year. It is sometimes known as **fertility rate**.

ii. Mortality

Mortality refers to the **death rate**. Death rate is the number of offspring reduced per unit of population due to death. It is the ratio of number of deaths in the size of any population. It is expressed as:

Mortality rate = number of deaths per unit time in average population. It is number of deaths per 1000 individuals per year.

Do you know?

Mortality rate varies among species but is correlated with natality rate. **Mortality** is affected by a number of factors like density, competition, predation, parasitism, antibiosis, disease, and environment. **Morbidity** is the state of being unhealthy for a particular disease or situation in a population.

iii. Population distribution

Population distribution is an arrangement of individuals of any population. There are three patterns of population distribution: random, uniform, and clumped.

A. Random distribution

Random distribution is the distribution of organisms of any population having no particular order.

B. Uniform distribution

Uniform distribution is the distribution of organisms of any population distributing evenly over an area.

C. Clumped distribution

Clumped distribution is the distribution of organisms of any population concentrated at some points throughout an area.

Do you know?

When **natality rate** equals **mortality rate**, population remains **stationary** or **constant** exhibiting '**zero (0) growth rate**'.

iv. Population density

Population density is number of individuals of a species of any population living in a particular area. Population density denotes the number of individuals per unit area or volume at a given time and space. Population density is expressed as:

$D = N \div S$ where D is the density of population, N is the total number of individuals, and S is the space occupied by the individuals.

Generally, population density is represented as the number of individual km^{-2} .

Do you know?

Vital index = **birth rate** – **death rate** or **natality ratio** – **mortality ratio**.

The vital index is expressed as: **number of births** $\div$ **number of deaths** $\times$ **100**.

v. Sex distribution

Sex distribution is a feature of population which influences natality and is represented by sex ratio. **Sex ratio** is ratio between males and females in a given population or it is the number of females per thousand males.

vi. Age distribution

Age distribution is a feature of population which influences both natality and mortality and is represented by age group. **Age group** refers to the different ages of individuals of a population. Age distribution is divided into three groups: pre-reproductive, reproductive and post-reproductive.

A. Pre-reproductive age group

Pre-reproductive age group refers to young individuals, e.g. human below 18 yrs.

B. Reproductive age group

Reproductive age group refers to mature individuals, e.g. human between 19-45 yrs.

C. Post-reproductive age group

Post-reproductive age group refers to old individuals, e.g. human above 45 yrs. of age unable to reproduce.

vii. Population dispersal

Population dispersal refers to the movement of individuals into and out of population.

Population dispersal occurs in three ways: emigration, immigration, and migration.

A. Emigration

Emigration is one-way movement of individuals out of its population. It decreases population.

B. Immigration

Immigration is one-way movement of individuals into a new population. It increases population.

C. Migration

Migration is two-way mass movement of entire population. It includes periodic departure and return. It occurs for food, shelter and breeding, e.g. fishes and birds. However, in case of **human population**, population dispersal itself is called migration occurring between individuals of two countries and is represented by emigration, i.e., going out of a country and immigration, i.e., coming inside a new country.

II. Population dynamics

Population dynamics is fluctuation in any population of a species in time due to population size and population density. Population dynamics includes: biotic potential, carrying capacity, and environmental resistance.

i. Biotic potential

The biotic potential, also known as **reproductive potential** refers to the maximum reproductive or physiological capacity of a population. It is, theoretically, maximum rate of reproduction.

ii. Carrying capacity

Carrying capacity which is represented by constant '**K**' refers to an average, i.e., in between maximum and minimum size of any population that can be maintained indefinitely

iii. Environmental resistance

Environmental resistance refers to the factors like food scarcity, shelter lacking, natural calamity, etc. which act against highest level of population growth.

III. Population census

Population census is the procedure of systematically acquiring, recording, and calculating population information like sex, age, education, household, industries, etc., about the members of a given population, usually displayed in the form of statistics. It occurs at an alternate period of 10 years and is conducted by the government. All factors of population characteristics including population dynamics are interpreted with the help of census.

Activity

Nepal, as a country exists from the last 313 years. If possible, try to compile, decade-wise population of Nepal from the beginning till date, with the help of standard or online literature.

IV. Population features

Two main population features or two main problems by which human beings are ever threatened are environmental pollution and population growth.

i. Environmental pollution

Environment pollution refers to adulteration of environment due to pollutants especially air, water, and soil.

ii. Population growth

Population growth is a dynamic feature of species of a population in which population size increases. It is the growth of a population which can be measured as it increases in its size over a period of time. Population growth is measured through population growth curve.

A. Population growth curve

When number of individuals of a population is plotted on Y-axis, and time on X-axis, a curve is obtained which indicates a trend in growth of population size in a given time. This is called growth curve. There are two types of growth curves: J- and S-shaped.

a. J-shaped curve

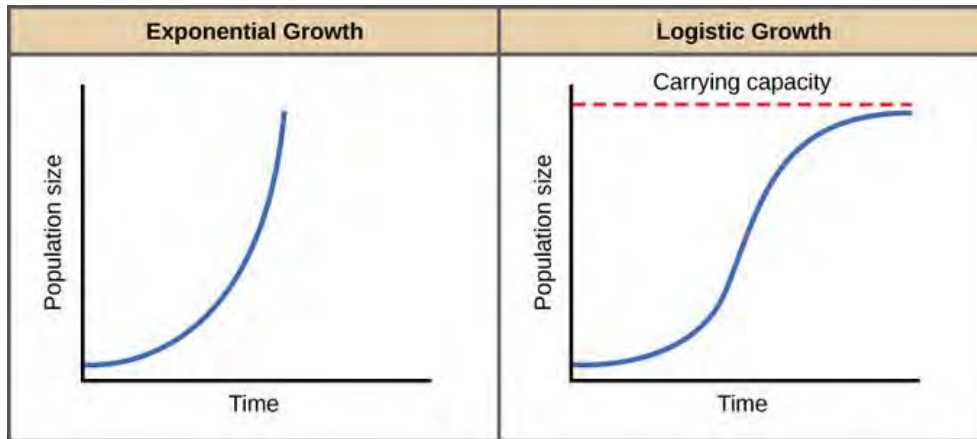
J-shaped curve, also called **exponential growth curve** shows two phases: lag and exponential phase.

1. Lag phase

In lag phase, which is also called **early phase**, because population has quite less of number of individuals, population, in its initial phase, increases slowly but gradually.

2. Log phase

In log phase, which is also known as **exponential phase**, because population has almost no environmental resistance, it increases rapidly in a geometric pattern.



J-shaped and S-shaped curve

J-shaped curve is a bio-potential curve when environmental resistance is zero. This curve occurs because larger population increases more rapidly than smaller one, e.g. insect population explosion occurs during rainy season followed by disappearance afterwards. This curve is not applicable in human population.

b. S-shaped curve

S-shaped curve, also known as **sigmoid curve** refers to the population approaching to an environmental carrying capacity and shows three phases: lag phase, log phase, and stationary phase.

1. Lag phase

In lag phase, also called **early phase** or **positive acceleration phase**, little growth in population size occurs due to small size of population and its incomplete adaptation to the environment.

2. Log phase

In log phase, also known as **middle phase** or **exponential phase**, sharp growth in geometric pattern occurs in population size due to abundance of food and related favourable conditions.

3. Stationary phase

In stationary phase, also called **zero growth**, **negative acceleration phase**, **saturation level**, or **plateau rate**, no growth in population size occurs due to natality equalizing mortality so that population stabilizes around the carrying capacity (**K**) of the environment.

The S-shaped curve is applicable in yeast and human population.

Table 9.1.1. Differences between J-shaped and S-shaped curve

Details	J-shaped curve	S-shaped curve
Also called	Exponential curve	Sigmoid curve
Pattern of curve	J-shaped	S-shaped
Phases of curve	Two: lag and log phase	Three: lag, log, and stationary phase
Lag phase	Also known as early phase which is slowly but gradually growing phase	Similar
Log phase	Also known as exponential phase which is rapidly growing phase in a geometric pattern.	Similar
Stationary phase	Absent	Also called zero growth phase in which natality equals mortality
Examples	Fruit flies, toad, rodents, etc.	Bacteria, yeast, man, etc.

2. Human population growth problem and control strategies

Human population growth problem and control strategies includes: human population growth, Malthus theory of human population growth, human population growth problem, and human population control strategies.

I. Human population growth

Human population growth, in three different periods of human civilization, are: hunter and gatherer, agriculture and industry.

i. Hunter and gatherer

Human beings were hunter and gatherer before 8000 BC hunting animals and gathering food. As estimated, human population at that time was 10 million.

ii. Agriculture

Agriculture practices by human started in 8000 BC. Agriculture increases environmental carrying capacity as a result of which the population became 500 million by 1650 AD.

iii. Industry

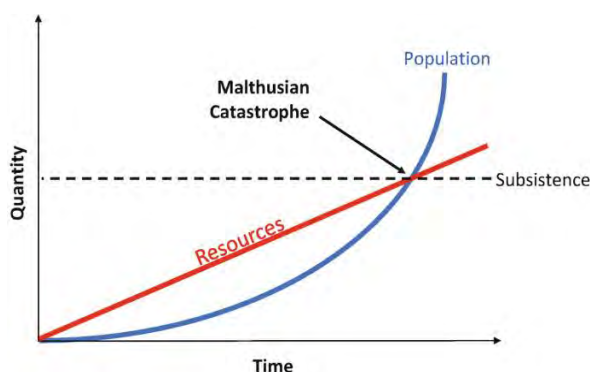
Industry by human beings started in 18th century by 1750 AD as result of which exponential phase in human population started in 1750 AD and is still continuing on.

Population dynamics theory fits in all species of living beings including man. Human being can govern so many factors which limit the size of human population. This is due to effort of human in agriculture, industry, medicine, and transportation, etc. Thus, impact of human population is directly related to food supply, proper housing, and medical facilities, etc.

Patterns of human population distribution and human population growth depend on several complex factors like geographical factors (climate, water, soil, minerals, energy resources, etc.), socio-economic factors (ethnicity, education, race, etc.), and demographic factors (demographic transition, demographic cycle, etc.).

II. Malthus theory of human population growth

T. R. Malthus was first to give the theory on human population. Malthus, in his book "**An Essay on the Principle of Population**" which was published in 1798 explained that "population tends to increase by geometric progression while food supply increase only in arithmetic progression".



Human population growth according to Malthus

III. Human population growth problem

Human population growth problem deals with: growth and features of world's population, growth and features of Nepal's population, human population pressure on human life, causes of increase in human population, and problems or consequences of overpopulation.

i. Growth and features of world's population

In between 1750 and 1850 AD, population increase in Asia was 50% far less than Europe. In 1850 AD, world's population was 1200 million, i.e. 1.2 billion. In between 1850 and 1950 AD, population of Asia, Africa and Europe doubled. The population of North America became six times and that of Latin America five times.

Table 9.1.2. Population of the world after every 50 yrs.

Year	Population (m)		Year	Population (m)
1650	500		1900	1600
1700	610		1950	2500
1750	791		2000	6100
1800	1000		2025	8092
1850	1200		2050	9800 (expected)

Population increase per annum in 20th century was 58 million. Population increase per annum in 21st century will be 70 million.

Table 9.1.3. Continent-wise human population at present

Continent	Population (m)	Population (%age)
Asia	4807	58.9
Africa	1515	18.6
Europe	743	9.1
North America	613	7.5
South America	436	5.3
Australia	47	0.6

Most of the human population growth is in Asia and Africa.

Table 9.1.4. Country-wise human population in 2025.

Country	Population (m)	Population (%age)
India	1450	17.78
China	1420	17.40
USA	345	4.23
Indonesia	284	3.47
Pakistan	251	3.8

Most of the human population growth is in India (1450 million) and China (1420 million).

Table 9.1.5. Trend of doubling population in the world

Year	Population (m)	Time taken to double
8000 BC	10	—
1 AD	250	—
1650 AD	500	1650 yrs.
1830 AD	1000	180 yrs.
1930 AD	2000	100 yrs.
1980 AD	4000	50 yrs.
2025 AD	8000	45yrs.

ii. Growth and features of Nepal's population

Present population of Nepal is approximately **2.97 million**.

Table 9.1.6. Trends of population growth in Nepal

Year (in AD)	Population (in number)	Difference (in number)	Population growth (percentage)	Annual growth rate (percentage)	Doubling time (in years)
1911	5638749	—	—	—	—
1920	5573788	−64961	−0.2	−0.13	—
1930	5532574	−41214	−0.7	−0.07	—
1941	6283649	751075	13.6	1.16	60
1952	8473478	1972976	34.9	2.30	31
1961	9412996	1156371	11.1	1.65	42

1971	11555983	2142987	22.8	2.07	34
1981	15020839	3466856	30	2.66	26
1991	18491097	3468258	22.89	2.10	33
1998	21843068	3351971	—	2.39	30
2001	23832106	1989038	—	2.41	29
2013	27380000	3547894	—	1.26	—
2025	29700000	2320000	—	1.08	—

iii. Human population pressure on human life

Human population pressure has affected human life in so many ways. Some of them are:

A. Population density

As population of a particular area increases, at the same time, the density of that area also increases and thus, creates all round pressure on human life.

B. Pressure on resources

With the increase in human population of a particular area, natural and man-made resources of that area tend to decrease posing unavailability of the resources for all.

C. Intensive agriculture

Due to increase in human population, to feed all, extensive method or semi-intensive method of agriculture is insufficient, so intensive culture is adopted which may exploit the land and soil more than it can.

D. Shifting to urban areas

Because of the increase in human population everywhere like country-side, sub-urban area, and urban area however, for getting opportunity, people from country-side and sub-urban area shift to urban area creating an extra pressure for everything.

E. More wastages production due to urbanization

As a result of urbanization, due to the use of day to day consumables, more wastages or pollutants are produced creating environmental hazards.

F. Over consumption of each and everything

With the increase in population, to feed and maintain all populace, there may be over consumption of each commodity and everything available at that time in that particular area.

G. Aggressive natural resources acquisition and colonization

Due to overpopulation in a particular area, there may be aggressive acquisition and colonization of natural resources.

Activity

Make a list of 15 most populace country of the world. Arrange them in order – from highest population to lowest. Compare their population of 20th century versus this century and inference.

iv. Causes or reasons of increase in human population

Following are the causes or reasons of increase in human population:

A. Agriculture development

Agriculture development produces enough food for the population maintaining the requirement to feed, sustain, and grow.

B. Control of natural calamity

If natural calamity like famine, earthquake, over raining, flooding, soil erosion, over drought, etc. are controlled, then there will be survival of more population and ceasing of mortality hence, increasing the population.

C. Better storage facility

There is better and longtime storage facility to overcome any famine, scarcity, no supply, etc., as a result of which day to day life of the people of a particular area becomes easy and normal so as to give rise and continue further generation increasing the population.

D. Control of diseases

Due to the control of diseases, especially epidemics, there is minimum mortality not from the diseases but from natural death only resulting into population increase.

E. Better health condition

Because of the advancement in medicine including medical biotechnology, health condition of the populace becomes better increasing human population.

F. Test tube baby

Test tube baby, a field of medical biotechnology has become boon for conceiving a child and giving the birth, adding in population.

G. Polygamy

If polygamy is noticed, then it is a reason of population increase because of many spouse of a single person giving birth to many individuals.

H. Marriage, divorce, and remarriage

The marriage and bearing children, then getting divorced, and getting remarriage again and bearing the children again, increases the population.

I. Desire of getting a son

The desire of getting a son is psychological weakness of the couple including their family and is also a religious weakness thus, aiding in population.

J. Increase in birth rate due to lack of education and awareness

Due to lack of education and social awareness there is no control in birth rate, thus increasing the population.

K. Decline in death rate

Due to development in medical science, death rate has been declined increasing the human population.

L. Decrease in child mortality

Child mortality which was quite high few years ago has totally been controlled increasing the population.

M. Better sanitary life

Better sanitary life has decreased the mortality rate and increased the population.

N. Increase in lifespan

Because of medical facilities, lifespan of the people has been increased hence, increasing the population.

v. Problems or consequences of overpopulation

Following are the problems or consequences of overpopulation:

A. Scarcity of food and potable water

The overpopulation of the world is struggling for food and potable water because they are beyond the reach of many more, especially those who are under poverty line.

B. Over exploitation of natural resources

To nurture, rear, and feed whole population, there will be over exploitation of the natural resources which may finish one day in the time to come

C. Excessive deposition of wastes

Because of overpopulation, there will be more use of resources – natural and manmade. As a result of such uses, excessive deposition of wastes or pollutants will be there.

D. Urbanization

To cope up overpopulation, there will be a cycle – the rural areas will be converted into suburban areas and suburban areas are converted into urban areas until all areas are converted into urban areas.

E. Unemployment

One of the major consequence of overpopulation is unemployment.

F. Pollution

Overpopulation and overcrowd will over-pollute the surrounding in its air, water, soil, etc.

G. Natural calamity

Natural calamity like famine, earthquake, heavy raining, flooding, erosion, etc. happen due to overpopulation.

H. Climate change

Indirectly, one of the major challenge due to overpopulation is climate change which is affecting human life in so many ways, especially change in temperature and rainfall pattern.

I. Deforestation

The first attack of overpopulation is on forest, to use its wood resources, required for the urbanization.

IV. Control strategy of overpopulation

Following are the control strategy of overpopulation:

A. Raising the age of marriage

Raising the age of marriage by at least four or five years will help control population to some extent. In this way, 18 yrs. for female will be 23 yrs. and 21 yrs. for male will be 26 yrs.

B. Education and awareness

Persons reaching marriage age should be educated and make aware of the benefit of small or planned family rather than large or haphazard family. The awareness should be raised further through magazine, radio, television, social media, 'sadak-natak', etc.

C. Medical termination of pregnancy (MTP)

The **MTP** is done in a female when childbirth is not expected or required. In certain cases, **amniocentesis** is done based on requirement like desire of a son or to know genetical status of the growing foetus, and then MTP is performed.

D. Family-planning leading to birth control

1. Birth control

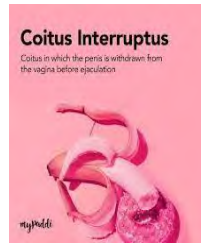
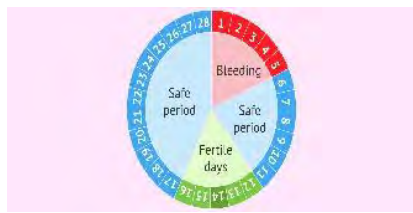
Following are the methods of birth control:

I. Natural method

- i. Safe period, calendar, or rhythm method
- ii. Coitus interruptus

II. Mechanical method

- i. Use of male condom, e.g., '**dhal**', '**panther**', or '**d'zire**' by males
- ii. Use of female condom by females
- ii. Use of intrauterine device (IUD), e.g., '**lippes loop**' (1st generation IUD); '**copper T**' (2nd generation IUD); '**progestasert**' (3rd generation IUD); diaphragm, cervical cap, or Norplant by females.



Safe period, coitus interruptus, male condom, and female condom



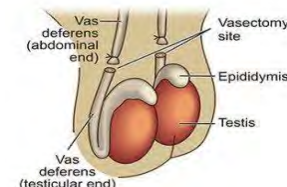
Lippes loop, Cooper T, Progestasert, Diaphragm, and Cervical cap

III. Chemical method

i. Use of spermicidal creams/foams/jellies, e.g., 'kamal chakki' by females



Norplant, Spermicidal cream, Oral pills, and Dipo provera



Injectable hormone, Tubectomy, and Vasectomy

IV. Hormonal method

i. Use of oral pills, e.g., 'neelokaan', 'sunaulo gulaf', 'nilocaan white', or 'kanchan' by females

ii. injectable contraceptive, e.g., 'dipo provera' and 'sangini' by females

V. Surgical or sterilization method

- i. Tubectomy in female
- ii. Vasectomy in male

Activity

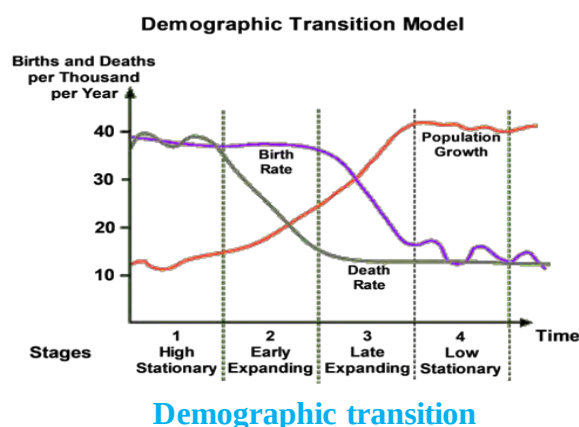
Make a list of different types of family planning done in Nepal. Take the help of your biology teacher. Support your activity by standard and online literature.

3. Concept of demographic cycle

Concept of demographic cycle includes: demographic transition and cycle.

I. Demographic transition

Demographic transition is a phenomenon and theory in social sciences referring to the historical shift from high birth rate and high death rate to low birth rate and low death rate as societies attain more technology, education, and economic development. This transition has occurred in most part of the world over the past two centuries, bringing the unprecedented population growth of the post-Malthusian period, then reducing birth rate and population significantly in all regions of the world.



II. Demographic cycle

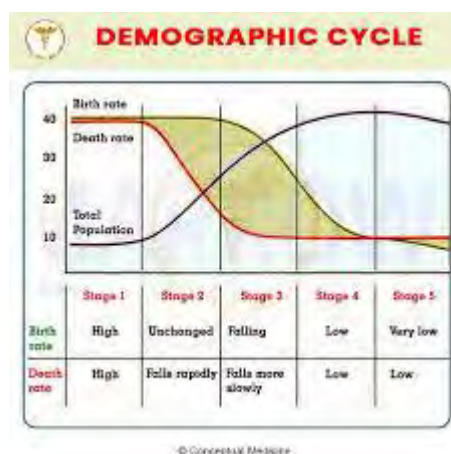
Demographic cycle, also called **population cycle** refers to population profile of the population evolution over time of a defined geographical area, region, country, continent or world. Population cycle theory has been postulated in terms of socio-economic history of industrialized countries. When one studies the world population since 1960, s/he could come into conclusion suggesting that **demographic transition** of a country involves five stages. These five stages of demographic transition constitute what is called demographic cycle. These stages are: first, second, third, fourth, and fifth stages.

i. First stage

First stage is referred to as **high stationary stage**. This stage is characterized by both high birth rate and high death rate, as a result of which the population remains stationary. This stage is observed in economically weak country, e.g., India till 1920 A.D.

Do you know?

Population explosion is rapid increase in **population size** over a relatively short period.



Demographic cycle

ii. Second stage

Second stage is denoted as **early expanding stage**. This stage shows high birth rate but decreasing death rate. The high birth rate is due to improved medical condition and shortening in breastfeeding time, as a result of which population increases. The low death rate is due to improvement in food and feeding, medical treatment, and healthy environment, as result of which, population increases. This stage is found in developing countries of Asia and Africa.

iii. Third stage

Third stage is mentioned as **late expanding stage**. The birth rate starts decreasing and the death rate decreases comparatively more than ever. Even though, there is use of contraceptive and women empowerment, birth rate still exceeds death rate, as a result of which population increases. This stage is seen in developing country like India. This stage in which the birth rate too has declined fast is seen in the developing countries like China and Singapore.

Activity

Enlist all the countries of the world associated with UNO. Categorize them as per the stages of demographic cycle. If possible, summarize.

iv. Fourth stage

Fourth stage is explained as **low stationary stage**. This stage is characterized by both low birth rate and low death rate, as a result of which consequently, population remains stationary with an ageing population as its main feature. This stage is marked in most of the industrialized countries like Belgium, Denmark, Japan, Sweden, and Switzerland. This stage in which demographic transition occurs from a high birth rate and high death rate to low birth rate and low death rate has been observed in most of the industrialized countries, e.g., zero population growth in Austria during 1980-85 and 0.1% growth rate in Belgium, Denmark, England, and Sweden during 1980-85.

Project work

Try to measure grasshopper population in the grassland of your school by quadrat method using a quadrat of $5\text{m} \times 5\text{m}$. In this context, take the help of your biology teacher. If possible, try to express your result through statistics tools.

v. Fifth stage

Fifth stage is forwarded as **declining stage**. This stage is marked by low birth rate than death rate, as a result of which population decreases. This stage prevails in east European countries like Germany and Hungary and north European countries like Norway and Sweden.

Do you know?

Population crash is **rapid decrease** in the **size of a population** caused by diseases, environmental stress like pollution or when the number of individuals surpass the carrying capacity of habitat.

Glossary

Ecological mortality: is the actual number of deaths under existing environmental condition and is always fluctuating.

Ecological natality: is the actual number of births occupying under existing environmental condition and is always less than potential natality.

Life expectancy: refers to the average number of years the members of a population have left to live.

Population ecology: is the study of the members of organisms including what determines their abundance and distribution.

Potential mortality: is the minimum (theoretical loss) deaths of individuals under ideal or non-limiting condition.

Potential natality: is the maximum number of births produced per individual under ideal condition of environment.

Exercise

A. Tick the correct alternative.

1. Study of human population is
a. geography b. phytogeography c. demography d. zoogeography
2. Human population is studied under
a. sociology b. anthropology c. census d. demography
3. Maximum number of individuals that an environment can support is known as
a. biotic potential b. carrying capacity
c. environmental resistance d. Physical potential
4. Which one of the following term indicate birth rate in human population?
a. Natality b. Mortality c. Morbidity d. Ethnicity
5. Natality is related to of an individual.
a. growth b. birth c. death d. ageing
6. Mortality refers to the of an individual.
a. growth b. birth c. death d. ageing
7. The S-shaped growth curve is applicable for which one of the following?
a. Insects b. Fish c. Rodents d. Human
8. Overpopulation causes adverse consequences in society. Highlight which of the following can control overpopulation?
a. Early marriage b. Food supply c. Polygamy d. Family planning
9. Which one of the following is control strategy of overpopulation of man?
a. Pollution control b. Agriculture control c. Birth control d. Health control
10. How many stages are there in demographic cycle?
a. Two stages b. Three stages c. Four stages d. Five stages
11. Vas deferens transport spermatozoa from cauda epididymis to ejaculatory duct. What happens when the vas deferens of male is surgically disconnected?
a. Sperms become non-motile b. Sperms lack nuclei
c. Seminal fluid is without sperms d. No spermatogenesis occurs

Answers.

1. c	2. d	3. b	4. a	5. b	6. c	7. d	8. d	9. c	10. d
11. c									

B. Short answer questions.

1. See the table A and B below. Fill up the human population in table-A. Answer as per required in table-B.

<u>Year</u>	<u>Human Population</u>
0 A.D.	
1000	
1800	
1927	
1960	
1974	
1987	
1999	
2050	

Population growth

Learning Objective – To see how the Human population has increased.

This data is from the United Nations.

1. Draw a graph of this data. (Use a sharp pencil and ruler. Care with scale on the x-axis.)
2. Plot the points (with a small cross) then draw a curved line of best-fit.

<u>Year</u>	<u>World population (billions)</u>
1750	0.8
1800	0.9
1850	1.1
1900	1.6
1950	2.5
1960	3.0
1970	3.7
1980	4.4
1990	5.3
2000	6.0
2010	6.8
2020	7.6
2030	8.5
2050	9.7
2100	11.2

3. Use the graph to estimate the population in 1955.
4. What is the difference between an estimate and a prediction?
5. It took approximately 90 years for the population to double from 1 - 2 billion. Use your graph to help you estimate how long it took to double again to 4 billion?
6. How has the increasing human population affected the Earth's resources?

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2. Illustrate and discuss in short human population growth curve.
3. State briefly problems of overpopulation.
4. Mention the causes of overpopulation.
5. Explain in brief control measures of human population growth.
6. Illustrate and describe in short Malthus theory of human population growth.
7. State in brief growth and features of world's human population.
8. Discuss in short growth and features of Nepal's human population.
9. Point out human population pressure on human life.

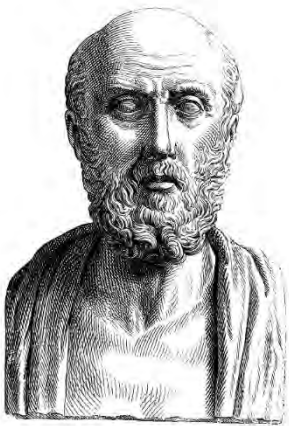
C. Long answer questions.

1. What is population? What is population census? Describe in detail human population characteristics.
2. When is "World's Population Day" observed? Give a detailed account of human population census and dynamics.

3. What is population growth curve? Illustrate and explain population growth curves with suitable examples when and where required.
4. What is Demography? Who is demographer? Write in detail, the reasons of human population growth, population growth problem, and control strategies of overpopulation.
2. What is demographic transition? What is demographic cycle? Explain in detail the human demographic cycle.
2. What is family planning? Write a detailed account of the family planning methods practiced in Nepal. Also add the comment on family planning association of Nepal (FPAN) and Nepal contraceptive retail sales (CRS) company devoted for family planning in Nepal.

Chapter 9.2

HEALTH DISORDERS



Hippocrates (460-370 BC) was a Greek physician and philosopher of the classical period who is considered one of the most outstanding figures in the history of medicine. He is traditionally referred to as the "**Father of Medicine**". His respect becomes live when a medical student takes "**Hippocratic oath**" after completing MBBS. He and his followers were the first to describe many diseases and medical conditions. He is given credit for the first description of clubbing of the fingers, an important diagnostic sign in chronic **lung disease**, **lung cancer**, and **cyanotic heart disease**.

Observe the figures given below and discuss following questions with your class friends.

1. Out of the five figures A, B, C, D, and E, which one shows disorder, which one condition, which one syndrome, which one substance abuse, and which one disease?



A



B



C



D



E

Figure A shows **condition** (i.e., health condition of a man), figure B **disease** (from which a man is suffering from), figure C **syndrome** (e.g., down's syndrome in an 8-year old boy), figure D **disorder** (e.g., cardiovascular disorder in a man), and figure E **substance abuse** (i.e., drug, alcohol, and smoking).

In medical terminology, **condition** broadly refers to the state of health, encompassing both **normal state** and **abnormal** or **pathological condition**. It can describe a person's overall health status, such as **good condition** or **serious condition**, or a **specific issue** like **disease**, **syndrome**, or **disorder**.

Do you know?

'**Condition**' as the medical term, dates back to **Hippocrates and his students**, since then it in continuous use.

According to World Health Organization (WHO), **health** is a state of complete physical, mental, and social wellbeing and not merely absence of disease, syndrome, or disorder.

In case, if the state of health of a person is bad, worse, or worst then the person may be suffering from disease, syndrome, or disorder. The disease, syndrome, or disorder are quite different from one another and variously affect health hence, they differ in their sense, causes, symptoms, and treatments. Following are the sense, causes, symptoms, and treatments of disease, syndrome, and disorder:

1. Disease

Disease is a **medical condition** with a **known** or **identifiable cause** which affects how the body functions. It is a biological or physiological illness which causes changes in the body's anatomy. Therefore, a disease usually has a known cause, distinct course, and established treatments.

2. Syndrome

Syndrome, on the other hand, possesses **group of signs and symptoms** which occur together, but do not have a clear cause, course, or treatment path.

3. Disorder

Disorder is quite different as it is a **collection of symptoms** which disrupts normal bodily functions. It is a disruption in the body's regular structure and function. It may be caused by disease, e.g., **arrhythmia**, an irregular heartbeat resulting from cardiovascular disease in which case, it is called **heart disorders**.

The disorder may also be caused due to **substance abuse** which is a **misuse of harmful substances** including illicit drugs, alcohol, or tobacco leading to physical, physiological, psychological, and social problems and in which case, it is known as **substance abuse disorder (SUD)**.

Do you know?

Tuberculosis was the **first disease** known to humankind, some 9000 yrs. ago.

'**Down syndrome**' also known as '**trisomy 21**' was the **first syndrome** brought into human notice by **John Langdon Down**, a British physician, in 1866.

Mental disorder was the **first disorder** known to human beings in 1100 B.C.

The **health disorders** are abnormal conditions which affect the body's normal functions or structure causing distress or disability but **may** or **may not have specific sign and symptoms**. They are group of symptoms which normally disrupt normal body functions but do not have known causes. Following are the characteristics, types, symptoms, and diagnosis of health disorders:

I. Characteristics of health disorders

Following are the characteristic of disorders:

i. Functional impairment

Health disorders disrupt the body's normal structure and function.

ii. Sign and symptoms

Health disorders may or may not have specific sign and symptoms.

iii. Distress

Health disorders may cause significant distress, damage, and /or suffering in day to day life of a person.

iv. Disability

Health disorders may create abnormality in a person's behaviour.

II. Types of health disorders

Health disorders are: physical, mental, genetic, or substance abuse.

i. Physical disorders

Physical disorders affect body's physical, physiological, and anatomical functions, such as cardiovascular, respiratory, and renal disorders.

ii. Mental disorders

Mental disorders affect mind, emotion and behaviour leading to anxiety, mood, or schizophrenia disorders.

iii. Genetic disorders

Genetic disorders are due to abnormalities in genetics, e.g., autoimmune disorders with symptoms ranging from fatigue, fever, swollen glands, digestive problems, and so on.

iv. Substance abuse disorders

Substance abuse disorders, also called **brain** or **mental health disorders** affect physical, mental, and social wellbeing of a person.

III. Symptoms of health disorders

Symptoms may include distress, disability, or anything which tends to be abnormal.

Symptoms may be physical, perceptual, sexual, or interpersonal. Symptoms may be temporary or long lasting.

Activity

Enlist different types of disease, syndrome, and disorders prevailing in the Himalayan country, Nepal. Indicate the major ones among each with their percentage.

IV. Diagnosis of health disorders

Health disorders may indicate that specific disease is present, but there is usually not enough evidence to make a diagnosis.

Health disorders has been discussed under: concept of cardiovascular, respiratory, and renal disorders and substance abuse disorder separately under substance abuse.

9.2.1 Concept of cardiovascular, respiratory, and renal disorders

See the figures given below and discuss the following questions with your classmates.

1. Out of the three figures A, B, and C, which one exhibits renal disorders, which one cardiac disorders, and which one respiratory disorders?

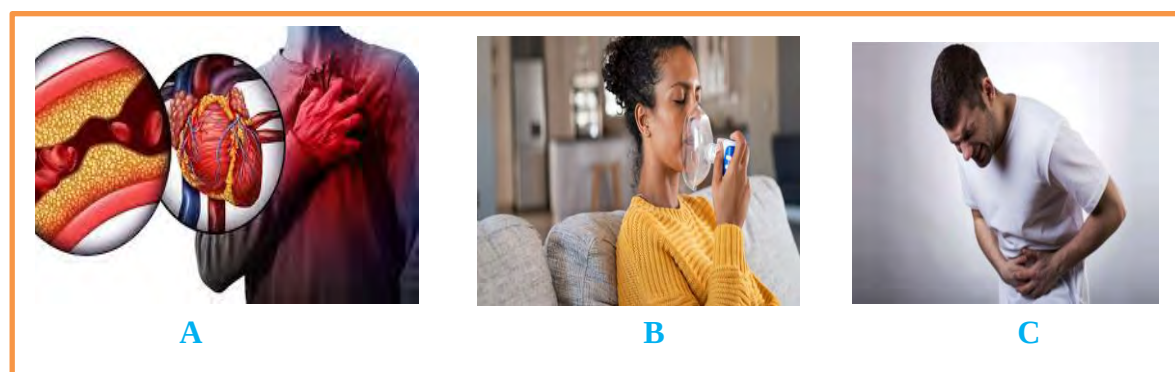


Figure A exhibits cardiovascular disorder, figure B respiratory disorder, and figure C renal disorder.

Cardiovascular, respiratory, and renal disorders may occur due to present day lifestyle, human population growth, community structure, anatomical and physiological disorders or so on. Following are the cardiovascular, respiratory, and renal disorders:

1. Cardiovascular disorders

Cardiovascular disorders, abbreviated as **CVDs** refer to physical, anatomical, and physiological disorders of the heart and blood vessels. These disorders cause about 18 million deaths every year.

I. Causes

Causes of the CVDs are **lifestyle choices** (unhealthy diet, excessive drinking and smoking, physical inactivity, and stress), **medical conditions** (diabetes, hyperlipidemia, hypertension, hypotension, stroke, arteriosclerosis, and atherosclerosis), **environmental factors** (air pollution), and **others** (age, sex, and obesity).

Do you know?

Cardiovascular disorders are **inheritable**, meaning they have a genetic component. **Hyperlipidemia** refers to the high lipid or cholesterol in blood.

II. Symptoms

Symptoms are **angina** (chest pain), **dyspnea** (shortness of breath), **fatigue** (exhaustion), and **dizziness** (loss of consciousness or fainting).

III. Complications

Complications are heart failure, heart attack, stroke, aneurysm, peripheral artery disease, and sudden cardiac arrest.

IV. Risk factors

Risk factors are diabetes, high blood lipids, obesity, smoking, excessive use of drugs, and excess use of alcohol.

V. Prevention

Prevention includes healthy diet eating, maintaining daily exercise, prohibition of tobacco and alcohol, reduction in salt intake, changing overall lifestyle, and public awareness campaigns.

VI. Treatment

Cardiovascular disorders are treated by the treatment of diabetes, high blood lipids, and high blood pressure, etc.

VII. Medication

Medicines to be used are aspirin, beta blockers, and blood thinners.

VIII. Some important cardiovascular disorders which attack most of the world populace including Nepalese are:

i. Cardiovascular disorders affecting heart:

A. Arrhythmia

Arrhythmia refers to the abnormal heart rates or rhythms due to improper impulse conduction. It is caused due to coronary heart disease, scarring of heart muscle, and genetics.

B. Congenital heart disease

Congenital heart disease refers to the defective heart by birth.

C. Heart failure

Heart failure refers to the improper pumping or relaxing of heart leading to fluid buildup and shortness of breath.

D. Myocardial infarction

Myocardial infarction, abbreviated as **MI** refers to the heart attack. It occurs when blood flow to the heart is reduced or stopped, which can damage or kill heart muscle. **Coronary heart disease** is the primary cause of MI.

E. Pericardial disease

Pericardial disease refers to the defect in pericardium leading to pericarditis or pericardial effusion.

F. Rheumatic heart disease

Rheumatic heart disease refers to the damage of heart muscles and valves due to rheumatic fever.

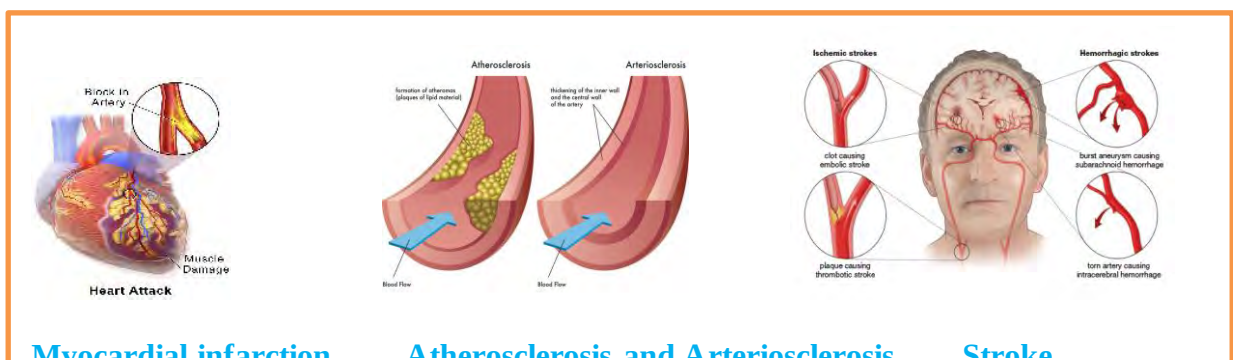
G. Valvular disease

Valvular disease, also known as **valve disease** refers to the leaking or tightening of heart valves.

ii. Cardiovascular disorders affecting blood vessels:

A. Aortic aneurysm

Aortic aneurysm, also called **aortic disease** refers to the dilation of large blood vessels or aorta which supply blood from heart to brain and rest of the body.



B. Arteriosclerosis

Arteriosclerosis refers to thickening of the wall of arteries due to deposition of plaque.

C. Atherosclerosis

Atherosclerosis refers to narrowing of the lumen of arteries due to deposition of lipid.

D. Cerebrovascular disease

Cerebrovascular disease refers to the narrowing or blockage of blood vessels which supply blood to the brain. Stroke is a type of cerebro-vascular disease.

E. Coronary artery disease

Coronary artery disease (CAD) or **coronary heart disease** (CHD), also called **ischemic heart disease** (IHD) refers to the blood flow obstruction due to blockage of coronary artery of the heart. It is caused due to **atherosclerosis**.

F. Deep vein thrombosis

Deep vein thrombosis, abbreviated as **DVT** is the blockage of veins.

G. Peripheral artery disease

Peripheral artery disease refers to the narrowing or blockage of blood vessels of arms, legs, or abdominal organs. It is caused due to atherosclerosis.

Do you know?

Cardiovascular disorders in Nepal is supposed to be one of the leading disorders that affected an estimated case of 12,50,000 persons in 2019 with coronary heart disease (CHD) being the most prevalent.

iii. Cardiovascular disorders affecting blood flow in blood vessels:

A. Hypertension

Hypertension which is also known as '**silent killer**' refers to the high blood pressure in arteries reaching about 180/120 mm Hg putting excessive pressure on blood vessels leading to heart attack and stroke.

B. Hypotension

Hypotension which is also called '**shock**' refers to the low blood pressure in arteries declining about 80/40 mm Hg caused by low blood volume, anemia, and heart problems, etc.

C. Stroke

Stroke, also called **cerebro-vascular accident**, **brain haemorrhage**, or **brain attack** refers to the stoppage of blood flow to the brain.

Activity

Make a list of life-style, physical activities, and diet to be taken (in Nepali context) to get rid of cardiovascular disorders (CVDs) in Nepal.

2. Respiratory disorders

Respiratory disorders, also called **lung** or **pulmonary disorders** refer to the conditions which affect the respiratory system including lung. These disorders make a person difficult to breathe and the disorders may become life threatening if left untreated. These disorders cause 3.5 million deaths every year.

I. Causes

Causes are **infection** (viral, bacterial, and fungal), **smoking**, and **environmental factors** (air pollution).

Do you know?

Kathmandu, the capital city of Nepal, because of its shape having a valley, i.e., bowl-shaped faces '**bowl effect**' which tends it to trap pollutants, leading to poor air quality, especially during winter. Kathmandu has been ranked as the **most polluted city** in the world, often holding first or second position due to high levels of air pollution, with **air quality indices (AQI)** frequently exceeding 200. This is the reason why most populace of Kathmandu is suffering from respiratory disorders.

II. Symptoms

Symptoms are shortness of breath, cough, and fatigue.

III. Complications

Complications are lung infection, chest infection, lung abscess, acute respiratory failure, pneumonia, and lung failure.

IV. Risk factors

Risk factors are **environmental factors** (air pollution), **genetics** (family history), and **lifestyle choices** (smoking), and **others** (age, asthma, and diabetes).

V. Prevention

Prevention includes reducing air pollution, maintaining daily exercise, prohibition of tobacco, changing overall lifestyle, and public awareness campaigns.

VI. Treatment

Respiratory disorders are treated by the treatment of diabetes, asthma, oxygen therapy, breathing exercise, etc.

VII. Medication

Medicines to be used are bronchodilators, inhaled steroids, and oral corticosteroids.

VIII. Some important respiratory disorders which attack most of the world populace including Nepal are

i. Respiratory disorders affecting respiratory passages:

A. Asthma

Asthma, sometimes called **bronchial asthma** refers to the difficulty in breathing due to inflammation and spasm of smooth muscles of bronchi and bronchioles causing wheezing and shortness of breath.

B. Bronchiectasis

Bronchiectasis refers to the trouble in breathing due to excessive secretion of mucous or phlegm caused by widening of the bronchi and their damage.

C. Bronchitis

Bronchitis refers to the trouble in breathing due to excessive secretion of mucous or phlegm caused by irritation, inflammation, and swelling of bronchi. It is two types: **acute bronchitis** referring to short term inflammation of about three weeks and **chronic bronchitis** referring to long term inflammation of about three months.

D. Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease, abbreviated as **COPD** refers to the trouble in breathing especially exhalation due to swelling and blockage of air passages.

E. Laryngitis

Laryngitis refers to the trouble in breathing due to infection in pharynx caused by inflammation of larynx or voice box.

F. Pharyngitis

Pharyngitis, also called **sore throat** refers to the trouble in breathing due to infection in pharynx caused by inflammation of pharynx, sinuses, and nose.

ii. Respiratory disorders affecting alveoli:

A. Lung cancer

Lung cancer, also called **bronchiogenic carcinoma** refers to the abnormal growth of pulmonary cells in lungs especially in alveoli.

B. Pneumonia

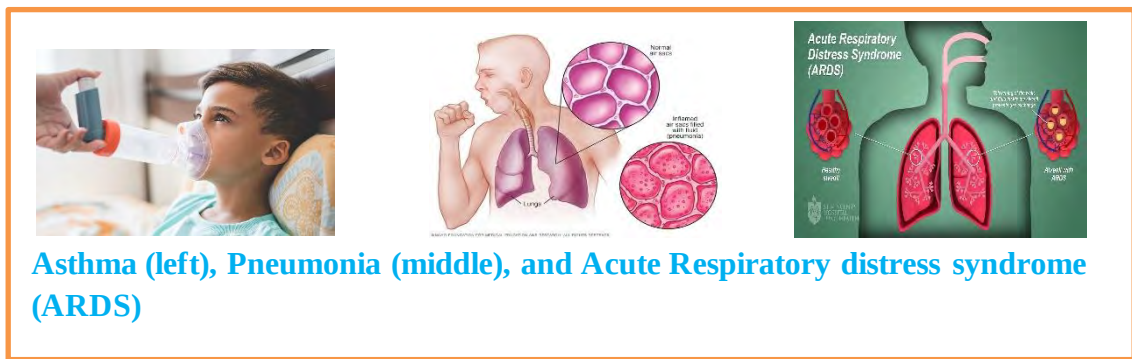
Pneumonia refers to the inflammation of alveoli and deposition of fluid inside them caused due to bacteria or virus including COVID-19 resulting into shortness of breathing. In acute cases, lung tissue thickens and alveoli are damaged.

C. Pulmonary edema

Pulmonary edema refers to the leaking of blood from blood vessels of lungs into alveoli due to heart failure or lung injury.

D. Tuberculosis

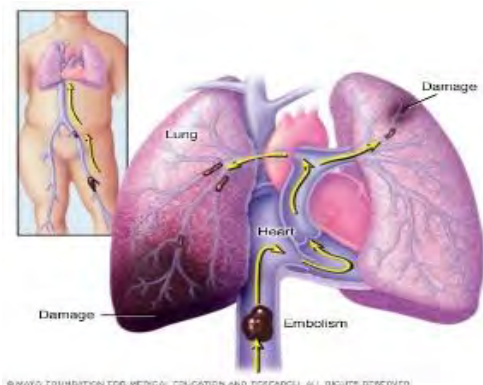
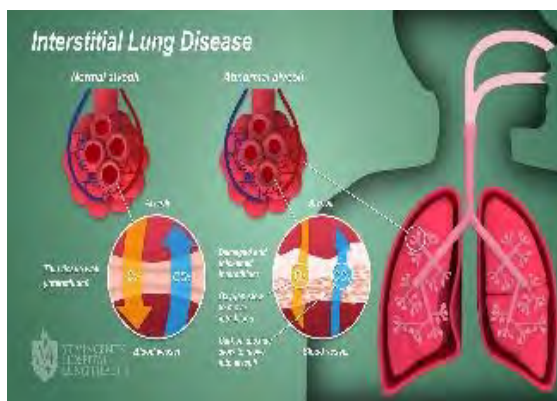
Tuberculosis refers to the inflammation of alveoli and deposition of fluid inside them caused due to bacteria, *Mycobacterium tuberculosis*.



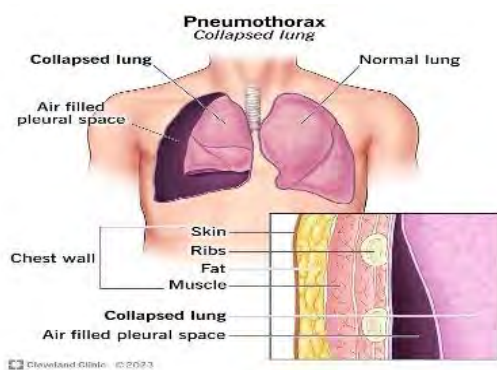
iii. Respiratory disorders affecting lungs:

A. Acute respiratory distress syndrome

Acute respiratory distress syndrome, abbreviated as **ARDS** refers to the sudden and severe injury of lungs due to serious illness, e.g., COVID-19 and others.



Interstitial lung disease and Pulmonary embolism



A. Interstitial lung disease

Interstitial lung disease, abbreviated as **ILD** refers to the affect in interstitium of alveoli.

Do you know?

Respiratory disorders in Nepal is supposed to be the most leading disorders affecting an estimated case of 35,00,000 persons in 2019 with chronic obstructive pulmonary disease (COPD) being the most prevalent.

v. Respiratory disorders affecting blood vessels:

A. Pulmonary embolism

Pulmonary embolism, abbreviated as **PE** refers to the blocking of pulmonary artery while a blood clot travels towards the lungs.

B. Pulmonary hypertension

Pulmonary hypertension, also called **pulmonary arterial hypertension** refers to the shortness of breath and angina due to high blood pressure in pulmonary artery.

VI. Respiratory disorders affecting pleura:

A. Pleural effusion

Pleural effusion refers to the hard to breathe due to collection of large pleural effusion or fluid between lung and chest wall caused by pneumonia or heart failure. pleural effusion needs to be drained.

B. Pleurisy

Pleurisy refers to the chest pain caused by the inflammation of pleura.

C. Pneumothorax

Pneumothorax refers to the collapsing of lung due to air getting into the space between chest wall and lung.

D. Mesothelioma

Mesothelioma refers to the rare form of cancer due to contact of asbestos.

VII. Respiratory disorders affecting lung:

A. Cystic fibrosis

Cystic fibrosis refers to the trouble in breathing due to trouble in mucous clearing caused by repeated lung infection. It may be a cause of bronchiectasis.

B. Pulmonary fibrosis

Pulmonary fibrosis refers to the scarring or weakening of the lung tissue.

C. Occupational lung disease

Occupational lung disease refers to the effect in lung due to silicosis and asbestosis caused by silica and asbestos, respectively.

Activity

Mention different types of respiratory disorders prevailing in Nepal. Get the support from standard or online literature. You can also see the online literature of WHO.

3. Renal disorders

Renal disorders, also known as kidney disorders refer to the conditions which damage kidneys or prevent them to filter blood. These disorders cause 0.25 million deaths every year.

Do you know?

Renal disorders in Nepal is supposed to be one of the leading disorders affecting an estimated case 19,00,000 persons in 2019 with chronic kidney disease (CKD) being the most prevalent.

I. Causes

Causes are **lifestyle choices** (unhealthy diet, excessive drinking, and physical inactivity), **medical conditions** (diabetes and high blood pressure), and **others** (age and sex).

II. Symptoms

Symptoms are changes in voiding urine, swelling in feet and ankles, high blood pressure, headache, loss of appetite, nausea and vomiting, and fatigue.

III. Complications

Complications are fluid retention (swelling in hand, feet, and ankles; high blood pressure; and pulmonary edema), heart disease (pericarditis, high blood calcium level, heart attack, and stroke), and kidney failure (dialysis and kidney transplant at the end stage).

IV. Risk factors

Risk factors are diabetes, high blood pressure, heart disease, obesity, and genetics (family history).

V. Prevention

Prevention includes managing diabetes, obesity, and blood pressure, changing overall lifestyle (prohibition of smoking and drinking), and public awareness campaigns.

VI. Treatment

Renal disorders are treated by medication however, dialysis and kidney transplant are done at the end stage.

VII. Medication

Medicines to be used are diuretics, aspirin, beta blockers, insulin, and metformin, etc.

VIII. Some important renal disorders which attack most of the world populace including Nepal are:

i. Renal disorders affecting kidneys:

A. End stage renal disease

End stage renal disease, abbreviated as **ESRD** refers to the final stage of chronic kidney disease (CKD) which may be life-threatening if left untreated.

B. Nephritis

Nephritis refers to the inflammation of kidney caused by pathogens, genetic disorders, and use of certain drugs.

C. Nephroptosis

Nephroptosis refers to the slight dropdown of kidneys into the pelvis caused by weight loss, pregnancy, child delivery, injury, etc.

D. Polycystic kidney disease

Polycystic kidney disease, abbreviated as **PKD** refers to the fluid-filled cysts growing on kidneys caused by genetic disorder.

E. Renal failure

Renal failure refers to the kidneys being non-functional.

F. Uremia

Uremia refers to the unnecessary retention of urea in blood due to improper function of kidneys. It is a type of renal failure.

ii. Renal disorders affecting nephrons and glomeruli:

A. Glomerulonephritis

Glomerulonephritis, also called '**Bright's disease**' refers to the inflammation of glomeruli caused by bacteria.

B. Nephrosis

Nephrosis refers to the damage of nephrons caused by infection, genetic disorders, and use of certain drugs.

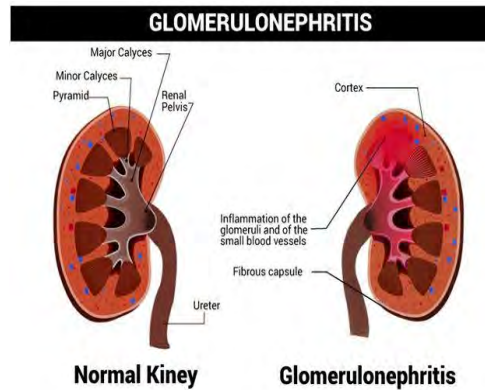
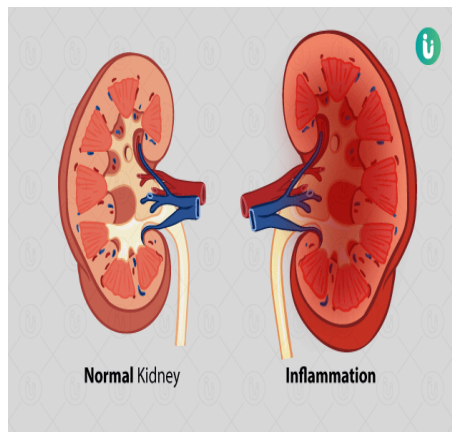
iii. Renal disorders affecting urinary tract:

A. Calculi

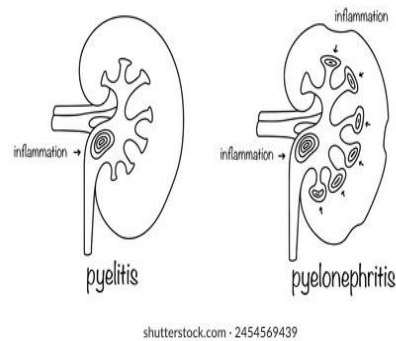
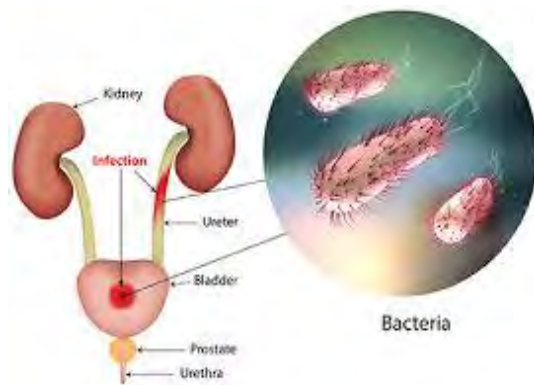
Calculi, also known as **renal calculi**, **kidney stone** or **nephrolithiasis** refers to the formation of stone in the urinary tract caused by crystallization of calcium oxalate and uric acid.

B. Cystitis

Cystitis refers to the inflammation of lining of urinary bladder starting from urethra caused by bacteria.



Nephritis and Glomerulonephritis



Urinary tract infection (UTI) and Pvelitis

C. Pyelonephritis

Pyelonephritis refers to the infection starting from urinary bladder or urethra up to the kidneys.

D. Urinary tract infection

Urinary tract infection, abbreviated as UTI refers to the infection of urethra and urinary bladder caused by bacteria mostly by *Escherichia coli*. Women are infected more than men due to their short-sized urethra.

Activity

Make a list of the prevalence of different types of renal disorders in Nepal. Do not forget to mention the deaths by chronic kidney disease (CKD).

iv. Renal disorders affecting renal pelvis:

A. PYELITIS

Pyelitis is the inflammation of renal pelvis caused by harmful bacteria. It may also be caused by *Escherichia coli*. It is considered a type of UTI.

Project work

Manage a sphygmomanometer and stethoscope along with an weighing machine from your laboratory where you learned to measure human blood pressure in practical classes. Now, make an assignment to measure blood pressure and weight of community peoples nearby your school taking into consideration their age, sex, education, and occupation, etc. Try to correlate blood pressure with body weight, if possible. For correlation take the help of statistical tools or your biology teacher.

9.2.2 Substance abuse

Have a look at the figures given below and discuss following questions with your class friends.

1. Out of the three figures A, B, and C, which one reveals smoking abuse, which one drug abuse, and which one alcohol abuse?



A



B



C

cumulative effect of any of the two or three at a time is known as **disease**. Disease may be physical, mental, physiological, or socially significant.

Any abnormal change that causes distress and discomfort to both concerned person and people around him/her is termed as **socially significant disease**.

Substance use disorder, also called **brain** or **mental health disorder** due to **substance abuse** is socially significant disease however, it is equally psychological, physiological, and physical disease.

Do you know?

Both **substance abuse** and **substance use** are interchangeably used however, **substance abuse** is often considered outdated or stigmatizing whereas **substance use** is generally preferred in modern usage, especially in scientific and medical contexts. **Substance abuse** refers to the harmful or problematic use of substances while **substance use** refers to the general consumption of substances, including drugs, alcohol, tobacco, and medications. **Substance use** is a neutral term used to describe both useful or harmful use.

Substance abuse refers to the excessive use of **psychoactive substances** like illicit drugs, alcohol, and tobacco in an excessive quantity in the way harmful, hazardous, or detrimental to the self, society, or both.

Substance abuse, according to "Diagnostic and Statistical Manual of Mental Disorders" (DSM) (5th edition) includes ten classes of drugs: **cannabis, alcohol, caffeine, hallucinogens, hypnotics, opioids, anxiolytics, inhalants, tobacco, and sedatives.**

Substance abuse leads to physical, mental, physiological, and social problems.

Substance abuse causes physical, physiological, and mental disorders and imposes physical, physiological, and mental dependence on them, respectively. Physical dependence caused due to prolonged use refers to an altered physiological state in which **withdrawal effects** and **withdrawal symptoms** are developed if substance use is not taken or discontinued. But if withdrawal effects and withdrawal symptoms are not developed because of physical dependence of the substance use then **mental dependence** of the substance use refers to a state of intense need of that substance taking continuously.

Following are the drug, alcohol, and smoking abuse:

1. Drug abuse

I. Introduction to drug abuse

According to WHO, **drug** is any substance or product which is used or intended to be



recipient. So, the drug taken by a person under the advice and/or supervision of a medical practitioner is called **drug use** as it is for the treatment and cure of a diagnosed disorder or disease of that person. However, if this is done for other purpose rather than treatment or cure then it is **drug abuse**.

Do you know?

Every year **26 June** is celebrated as the "**International Day against Drug Abuse**" or "**World Drug Day**".

Self-administration of a drug for non-medical reason, in quantity and frequencies which may impair an individual's ability to function effectively and which may result in social, physical, physiological, or emotional harm is called **drug abuse**. The person abusing drug has control over her/his life. However, regular abuse of drug to get its psychic effect is known as **drug**

addiction which is **neurological** and the person doing the same is called **drug addict**. The compulsion to take drug on a continuous or periodic basis in order to



experience its psychic effect and sometimes to avoid its absence is known as **drug dependence**. The drug dependence is physical and physiological. However, as a result of drug addiction and drug dependence, the person should have to face chronic and relapsing brain disorder called **drug use disorder** or **substance use disorder**. Therefore, if the person doesn't get drug at this stages then the person shows physical, psychological, and mental effects called **withdrawal effects** and the symptoms known as **withdrawal symptoms**.

Do you know?

In 2024 in Nepal, total number of drug addict was **1,57,000** out of which males were 93% and females 7% and 70% users were aged in between 20-29 years. With these figures, the Ministry of Home Affairs (MoHA) revealed that every year in Nepal, the percentage of drug addict is increasing by **5.06%**.

II. Types of abused drugs

Abused drugs, on the basis of nature and effects, are two major types: psychotropic and psychedelic.

i. Psychotropic drugs

Psychotropic drugs, also called **psychoactive**, **mind altering**, **consciousness altering**, or **mood altering drugs** are such drugs which affect how the person's brain works and cause changes in mood, consciousness, perception, cognition, awareness, thoughts, feelings, or behaviour. The psychotropic drugs are: narcotics, tranquilizers, sedatives, hypnotics, and stimulants.



Narcotics, e.g., red-flowered opium and white flowered opium



White-flowered opium boll, Latex in white-flowered opium boll, and Crude

A. Narcotics

Narcotics, also called **analgesics** or **opiates** are such drugs which in moderate doses dulls the senses, relieves pain, and induces profound sleep but in excessive doses causes stupor, coma, or convulsions. Narcotics include opium and its derivatives.

a. Opium

Opium (**afim**, vern.) is obtained from **unripe seed capsule** called **boll** of **red-** or **white-**



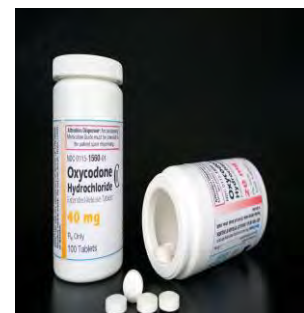
Morphine



Codeine



Heroin



Oxycodone

flowered poppy plant (*Papaver somniferum*). Incisions are made on boll through a process known as **lancing** when **latex** oozes out and sticks on the surface. On exposure to atmosphere, the latex turns brownish to black, gummy and resinous called **opium**. The quality opium is obtained from white-flowered poppy plant.

Do you know?

Depressants, also known as '**downing**' (colloq.) which reduce arousal and stimulation of a person affect CNS slowing down the messages between the brain and the body, e.g., opium, cannabis, and alcohol including tranquilizers and sedatives.

b. Semi-synthetic derivatives

Crude and natural opium is processed to form semi-synthetic derivative like **morphine**, **codeine**, and **heroin**.

c. Synthetic derivative

Semi-synthetic morphine is processed to form synthetic **oxycodone**.

B. Tranquilizers

Tranquilizers, also called **anxiolytics** are the drugs which bring about mental calmness by relieving anxiety and tension without affecting consciousness. Tranquilizers which have calming effect and eliminate both physical and psychological effects of anxiety or fear are **diazepam (valium®)**, **chlordiazepoxide (librium®)**, and **alprazolam (xanax®)**.

C. Sedatives

Sedatives are drugs which produce a calming effect, bring about a state of physical and mental comfort accompanied by a reduction or even suspension of mental activity and finally leading to complete suppression of consciousness. Sedatives are CNS depressants and vary widely in their potency. The lorazepam **barbiturates**, benzodiazepines, gamma-hydroxybutyrate (GBH), and sleep inducing zolpidem (**ambien®**) and eszopiclone (**lunesta®**) are sedatives.

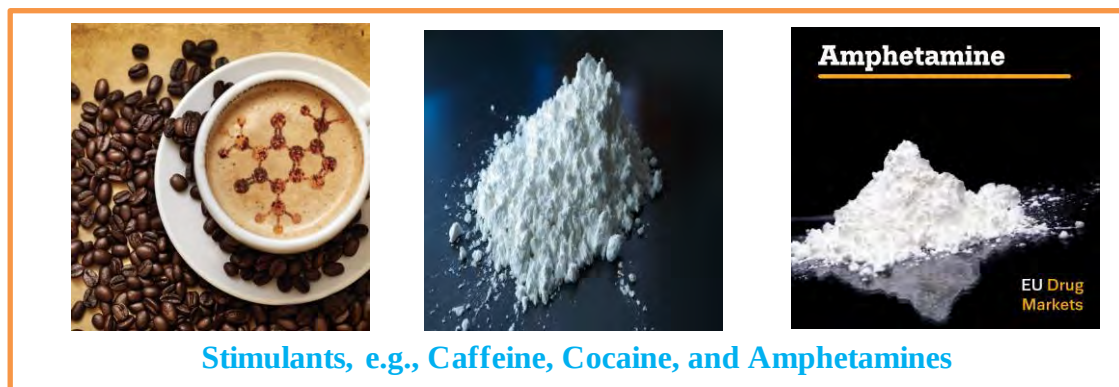


D. Hypnotics

Hypnotics, also known as **soporific drugs**, commonly called **sleeping pills** are a class of psychoactive drugs whose primary function is to induce sleep so as to treat insomnia or sleeplessness. **Luminal** and **saconal** are hypnotics.

E. Stimulants

Stimulants, also known as **mood elevators**, which increase alertness and enhance mood, attention, motivation, cognition, and physical performance. Stimulants increase activity of SNS, either directly or indirectly. stimulants are naturally occurring or synthetically prepared and mild or strong.



Naturally occurring stimulants are caffeine and cocaine.

a. Caffeine

Leaves of **tea plant** (*Thea sinensis*) is processed to get **tea**. Roasted seeds of coffee plant (*Coffea arabia*) is processed to obtain **coffee**. Roasted bean seeds called **cocoa** from the cacao beans of the cacao tree (*Theobroma cacao*) is processed to have **chocolate**. Beverages tea, coffee, and cocoa contain **caffeine**.

b. Cocaine

Coca leaves or **coca paste** is obtained from leaves and young twigs of **coca plant** (*Erythroxylum coca*), a shrub of South America. Crude and natural coca leaves or paste is processed to form semi-synthetic **cocaine**.

Do you know?

Pharmacologically, **coca** and **its derivatives** are not narcotics, they are **stimulants** however, due to law, they are included under narcotics.

Synthetically prepared stimulants are amphetamines.

a. Amphetamines

Amphetamines are CNS stimulant which are prescribed by the medical practitioners to treat depression. However, amphetamines are taken by those who want to continue their work without sleeping hence, they are also known as **anti-sleep drugs**. They are largely used by athletes to increase their physical strength including self-confidence.

Mild stimulants are tea, coffee, and chocolate whereas strong stimulants are cocaine and amphetamines.

ii. Psychedelic drugs

Psychedelic drugs are such drugs which act on CNS altering perception, feeling, and thought and causing auditory and optical illusion or hallucination. Psychedelic drugs are hallucinogens.

A. Hallucinogens

Hallucinogens are **hallucination-** or **illusion-causing drugs** which potentially change the way the people see, hear, feel or smell affecting mood and thought. Hallucinogens are cannabis and its products and LSD.



Hallucinogens: Bhang, Ganja, and Marijuana.



Hashish, Charas, and LSD

a. Cannabis and its products

Cannabis, also known as **hemp**, **Indian hemp**, or **marijuana** includes two subspecies – *Cannabis sativa sativa* and *Cannabis sativa indica*. The *Cannabis sativa sativa* is more invigorating and high energizing while *Cannabis sativa indica* is more relaxing and calming. Products of the cannabis are **bhang** (leaves and flowering shoots), **ganja** (unfertilized female inflorescence), **marijuana** (dried flowering plant), **hashish** (resin or trichomes from the flowers), and **charas** (concentrated resin or trichomes). Bhang is eaten in the form of crude paste directly or along with milk or sweet. Ganja, marijuana, hashish, and charas are smoked in pipe, hookah, or along with cigarette.

b. LSD

Lysergic acid diethylamide, abbreviated as LSD is obtained from ergot fungus (*Claviceps purpurea*), a parasite on wheat or rye plant. It is supposed to be the most powerful hallucinogens.

III. Ways of drug abuse

In drug abuse, drugs are taken through five methods – **swallowing, smoking, snorting, suppositories, and injecting.**

IV. Reasons of drug abuse

Drug abuse is not a new trend in the present world. It was started since time immemorial. Drug abuse and addiction seem to have been a part of human society since ancient times because there are evidences and reason to believe that evolution of human brain and psychotropic plants might be related to each other, connected by ancient drug use. Since it started, young generations of all the time were under its captivity due to its lucrative and fantastic outcome. From then till now, young generations are abusing the drugs.

Following are the reasons of drug abuse:

i. Curiosity and experimentation

Curiosity and desire for new experiences can drive individuals to experiment with drugs. The allure of the unknown, coupled with social portrayals of drug use in media, may spark curiosity which can lead to experimentation.

ii. Availability, accessibility, and environmental influences

Availability and accessibility of drugs in certain environment can play a significant role to influence in drug abuse. Exposure to drug-related cues and easy access to drugs may increase the likelihood of experimentation and ongoing use.

iii. Peer pressure and social influence

Influence of peer and social circles cannot be underestimated in the realm of drug abuse. The pressure to confirm, fit in, or seek acceptance can lead individuals to engage in drug abuse, especially in environments where drug use is normalized.

iv. Escaping pain and trauma

One of the primary drivers behind drug abuse is the desire to escape pain and trauma. Individuals grappling with emotional turmoil or past traumas often turn to drug as a coping mechanism, seeking temporary relief from their inner struggles.

v. Seeking pleasure and euphoria

The allure of euphoria and heightened pleasure is a powerful motivator for drug use. Many individuals experiment with drug in pursuit of intense sensations and altered states of consciousness, drawn by the promise of temporary bliss.

vi. Coping with mental health challenges

Individuals battling mental health challenges such as depression, anxiety, or mood disorders may turn to drugs as a form of self-medication. Temporary relief provided by drugs can seem preferable to confronting underlying mental health issues.

vii. Coping with stress and pressure

In present day superfast-paced world, many individuals use drugs as a way to cope with stress, pressure, and overwhelming responsibilities. The temporary escape provided by drugs can offer an escape from the demands of daily life.

viii. Genetic and biological factors

Genetic predispositions and underlying biological factors can contribute to an individual's susceptibility to drug abuse. Certain persons may have a higher risk due to genetic variations or neurochemical imbalances which influence their response to drugs.

ix. Coping with life transitions and changes

life transitions, such as major life changes, transitions, and challenges, can prompt individuals to turn drugs as a way of coping with uncertainty and upheaval. The desire for stability and control may drive some individuals towards drug use during these periods.

x. Role of family and society

Lack of proper family, healthy family environment, good relationship between and among family members, cent percent involvement of family members in guidance of junior members, and cooperative social environment may induce an individual towards drug abuse.

xi. Lack of education and awareness

Lack of education and awareness about the risks and consequences of drug abuse can contribute to its prevalence. Misconceptions, misinformation, and lack of understanding about addiction may lead individuals to understand the dangers of drug use.

In conclusion, reasons behind drug abuse are diverse and multifaceted, reflecting complex interplay of one's own self, family, genetic, environmental, social, and psychological factors. Understanding these reasons is crucial in developing effective prevention and intervention strategies to address the root causes of substance abuse and promote healthier lifestyles.

V. Sign and symptoms of drug abuse

Following are the five major sign and symptoms of drug abuse in drug addict due to drug addiction:

i. Physical changes

The physical changes are:

- A. Changes in physical appearance and hygiene
- B. Sudden changes in weight and skin colour
- C. Changes in appetite eating more or less than usual
- D. Changes in sleep patterns
- E. Drowsiness, running nose, and slurred speech
- F. Bloodshot eyes with enlarged or smaller pupil than usual
- G. Involuntary eye movements
- H. Lack of coordination and inhibition

ii. Changes in mood

When drugs take over the brain, there can be serious mood changes which are:

- A. Increased agitation, depression, anxiety, and irritability
- B. Short temper and paranoia
- C. Increased anger, bursts of energy, and nervousness.
- D. Problems concentrating or thinking clearly including memory problems

iii. Isolation and change in social circle

To take drugs, because isolation is required, there will be change in social circle which are:

- A. Distancing from family members, friends, and society
- B. Escaping from day to day routine and activities

iv. Drug seeking behaviours

For getting drugs, there may be drug seeking behaviours which are:

- A. Many prescriptions of the abused drugs from medical practitioners taken by the drug addict.
- B. Seeking the required drugs through whatever means will be available.

v. Financial and legal problems

For obtaining drugs, there may be financial loss including legal problems which are:

Do you know?

According to Nepal's "**Narcotic Drugs Control Act, 2033** and **National Drug Policy, 1995**", which is implemented by **Narcotic Drugs Control Bureau, Nepal**, **drug trafficking** (cultivation, production, preparation, manufacture, export, import, purchase, possession, sale, etc.) and **consumption** of most commonly abused drugs are illegal and reason of legal punishment. Fight Against Drug Abuse (FADA) is an **NGO** and Narconon, Nepal is a **rehabilitation centre** working in Nepal for drug addict.

- A. Maximum misuse of money
- B. Legal issues for getting drugs
- C. Extra financial burden for rehabilitation, if required
- D. Extra legal issues ending into jail

VI. Effects and consequences of drug abuse

Following are the effects of drug abuse on addict's health:

- A. Nausea and abdominal pain which can also lead to changes in appetite and weight loss.
- B. Increased strain on the liver, which puts the person at risk of significant liver damage or liver failure

- C. Seizures, stroke, mental confusion, and brain damage.
- D. Lung diseases, hepatitis, and HIV-AIDS
- E. Mental health problems, including depression, conduct problems, personality disorders, suicidal thoughts, attempted suicide, suicide, frustration and insecurity in life, neurosis, and psychosis.

Following are the effects of drug abuse on addict's life, his/her family and society:

- A. Violation of daily routine, dropping of school, loss of job, unhappy life, hospitalizations, and legal problems ending into jail.
- B. Decrease in family bonding and relationship,
- C. Increases social crime and violation, decreases personality and social reputation

Do you know?

Neurosis is a mild mental disorder not arising from organic diseases – instead, it can occur from stress, depression or anxiety. **Psychosis** is a major personality disorder characterized by mental and emotional disruptions. It is much more severe than neurosis – often more impairing and debilitating the affected individual.

VII. Control measures

The control measures of drug abuse include prevention and treatment:

i. Prevention of drug abuse

In case of drug addiction, control measures, first of all, to be followed by the drug addict is prevention. Following are the prevention or prophylaxis of drug abuse:

- A. Don't forget to take professional help
- B. Whatsoever may be, resist and deal with peer pressure and acceptance
- C. Totally abstain from drug use for which, self-help to develop self-confidence and strong values
- D. Don't miss to live a healthy and balanced lifestyle
- E. Completely foster strong family bonding and relationships
- F. Don't fail to take time for self-care
- G. Give full potential to learn healthy coping skills
- H. Don't slip to take only prescribed medicine
- I. Always encourage and indulge to practice healthy, mindful, and creative activities
- J. Don't leave opportunity to obtain education on the dangers of drug abuse
- K. Focusing on awareness at the family, social, and government levels

ii. Treatment of drug abuse

In case of drug addiction, when prevention becomes of no more use for the drug addict then treatment becomes necessary. Following are the treatment or cure of drug abuse:

A. Counselling

- B. Medicines to be selected as per abused drug, e.g., **methadone** administered in morphine addiction.
- C. Both counselling and medicines
- D. General cases are handled inside rehabilitation centre.
- E. Difficult cases are handled as per isolation of addicted person in jail called '**cold turkey method**'.

Activity

Locate a rehabilitation centre nearby your school if it is possible for you to survey it directly. If not, have a study of the same online. Whatsoever may be, make a table of the drug addict with their age, sex, education, reason of drug addiction, etc. Try to conclude drug addiction and drug addict.

2. Alcohol abuse

I. Introduction to alcohol

Alcohol is a class of organic compounds characterized by one or more hydroxyl ($-OH$)



Ethyl alcohol (as beverage), Alcohol abuse, and Alcohol addiction



Alcohol addict and Alcohol dependence

groups attached to a carbon atom of an alkyl group ($R-$), e.g., CH_3OH (methyl alcohol or methanol) C_2H_5OH (ethyl alcohol or ethanol), C_3H_7OH (propyl alcohol or propanol), C_3H_8O (isopropyl alcohol or isopropanol), etc. Alcohol which is prepared by fermentation of sugars using yeast is such a chemical substance that is found in drinks (beer, wine, and liquor),

medicine (mouthwash, cough syrup, and homeopathic), household products, and essential oils. Out of so many types of alcohols, **ethyl alcohol** has been consumed as **beverages** in **drinks** since its preparation and manufacture some 8000 years ago. 1 g or 1.27 ml of ethyl alcohol provides 7 Kcal energy but all the energy is lost in the form of heat. Absorption of ethyl alcohol starts from stomach. Ten percent of total ethyl alcohol metabolize in lung, skin, and kidney whereas 90% in liver.

II. Introduction to alcohol abuse

Alcohol abuse, also called **alcohol misuse** is heavy drinking of alcohol more than body can tolerate. **Ethyl alcohol** which is a **psychoactive**, **toxic**, and **dependence-producing substance** is the most commonly abused substance in the world. In alcohol abuse, whether taken in large or less volume, people can't stop drinking, even when drinking affects their health, puts their safety at risk and damages their personal relationships. Hence, alcohol abuse is associated with significant health risk and harms even when it is taken in quite less volume.

Do you know?

In Nepal, overall 24% peoples are drunkards out of which 39% are males and 11% females. Out of the 24% drinkers, 11.7% drinks daily; 6.8% (12.4% males and 1.7% females) are heavy episodic drinking, and between 1.5-25% adults have AUD.

Person abusing alcohol may have some control over her/his life for drinking. However, regular abuse of alcohol to get its psychic effect is known as **alcohol addiction** which is

Alcohol use disorder		Alcohol withdrawal	
Alcohol use disorder symptoms include:		Symptoms, ordered from mild to severe, include:	
 Craving alcohol.	 Drinking even though it affects relationships.	 Headache.	 Anxiety or irritability.
 Having a high tolerance for alcohol.	 Having alcohol withdrawal symptoms.	 Excessive sweating.	 Upset stomach.
 Trying and failing to quit drinking.	 Planning your life around the next drink.	 Increased blood pressure.	 Increased heart rate.
		 Difficulty walking.	
		 Tremors.	 Confusion.
		 Hallucinations.	
		 Seizures.	 Delirium.
Cleveland Clinic		Cleveland Clinic	

Alcohol use disorder
Alcohol withdrawal symptoms

neurological and the person doing the same is called **alcohol addict**. The compulsion to take alcohol on a continuous or periodic basis in order to experience its psychic effect and sometimes to avoid its absence is known as **alcohol dependence**. The alcohol dependence is physical and physiological. However, as a result of alcohol addiction and alcohol dependence, the person should have to face chronic and relapsing brain disorder called **alcohol use disorder (AUD)**, **alcohol abuse syndrome** or **alcoholism**. Therefore, if the person doesn't get alcohol at this stages then the person shows physical, psychological, and mental effects called **withdrawal effects** and the symptoms known as **withdrawal symptoms**.

Every year **2 October** is celebrated as "**World No Alcohol Day**".

III. Types of alcoholic beverages

Alcoholic beverages are basically two types: un-distilled and distilled.

i. Un-distilled alcoholic beverages are those which are prepared by fermentation of organic substrate by using yeasts and in which no more distillation of the fermented product is required. Following are un-distilled alcoholic beverages:

A. Beer

Beer is most popular alcoholic beverage worldwide. After water and tea, it is most commonly consumed drink in the world. It is prepared by brewing and fermentation of starches from cereal grain – most commonly malted barley, although wheat, maize, rice, and oats are also used. It has 4 to 6% of **alcohol by volume (ABV)**.

B. Wine

Wine is another popular and ancient alcoholic beverage. It is prepared by fermentation of grapes. It has 14% ABV.



Alcoholic beverages: Beer, Wine, Gin, and Brandy

ii. Distilled alcoholic beverages are those which are prepared by fermentation of organic substrate using yeasts and in which fermentation is followed by distillation of the fermented products. Following are the distilled alcoholic beverages:

A. Gin

Gin is a spirit typically made from a base of grain, such as wheat or barley, which is first fermented and then distilled. It has 35 to 55% ABV

B. Brandy

Brandy is liquor prepared by distilled wine. It has 35 to 60% ABV.



C. Whiskey

Whiskey is spirit made from fermented grain. It has 4- to 50% ABV.

D. Rum

Rum, a distilled drink made from fermented sugarcane or molasses, has a typical alcohol concentration of 40% ABV.

E. Tequila

Tequila is a type of liquor which is made by distillation of the fermented Mexican agave plant. It has 40% ABV.

F. Vodka

Vodka is a type of liquor which is made by distillation of the fermented grains (barley, corn, rye, and wheat) and potatoes. It has 40% ABV.

IV. Ways of alcohol abuse

Alcoholic beverages are drunk neat or diluted with water, soda, ice cubes, or cold drinks. Generally, alcohol addict drinks alcohol neat. Sometimes, it has been reported that alcohol addict heats alcohol and smell the hot vapour.

V. Condition of alcohol addicts after alcohol abuse

Condition of alcohol addict after alcohol abuse is diagnosed by healthcare providers doing a physical examination to look for symptoms of conditions that alcohol abuse may cause. Based on number of criteria for the symptoms of conditions, the condition of alcohol addict may be: mild, moderate, and severe.

i. Mild

Alcohol addict is said to be mild if symptoms of conditions match two to three criteria

ii. Moderate

Alcohol addict is said to be moderate if symptoms of conditions match four to five criteria

iii. Severe

Alcohol addict is said to be severe if symptoms of conditions match six or more criteria

VI. Reasons for alcohol abuse

Alcohol abuse is not a new trend in the nowadays world. Evidences show that alcohol use was started some 7000 BC in China. Since it started, generations of all the age and time were under its captivity due to its outcome of being happy and feeling pleasure. From then till now, generations of all the age are abusing the alcohols.

Following are the reasons of alcohol abuse:

- i. Curiosity and desire for new experiences force an individual first towards the normal alcohol use which may be followed by alcohol addiction.
- ii. Easy availability and accessibility of alcohol further followed by its intake due to promising environment.
- iii. Peer pressure and social influence for maintaining social status and society.
- iv. Mental health conditions like depression, post-traumatic stress disorder, etc., may increase risk of alcohol abuse.
- v. To feel pleasure moment again and again during and after alcohol consumption.
- vi. To temporarily subside daily life stress and pressure
- vii. People with family history of alcohol abuse have an increased risk of developing it.
- viii. Lack of education and awareness.

VII. Sign and symptoms of alcohol abuse

Following are the major sign and symptoms of alcohol abuse by alcohol addicts due to alcohol addiction:

- i. Withdrawal effects and symptoms.
- ii. Craving beverages containing alcohol.
- iii. Physical issues like pain, fever, or a cough won't go away.
- iv. Changes in mood and behaviour.
- v. Having high tolerance for alcohol.
- vi. Continuing the drinking even though it affects relationships with friends, colleagues, family, and society.
- vii. Drinking more or longer than intended.
- viii. Spending lots of time obtaining and drinking the alcoholic beverages or recovering from hangovers caused by drinking.
- ix. Resume drinking to cope up with hangovers.
- x. Failing to meet family obligations or professional work due to prolonged drinking.
- xi. Giving up important recreational, family, social, or professional work because of drinking.
- xii. Drinking even in physically hazardous conditions.

- xiii. Continue drinking even if suffering from medical condition or mental disorder making them more mischievous.
- xiv. Drinking to overcome withdrawal effects or symptoms.

VIII. Effects and consequences of alcohol abuse

Following are the effects of alcohol abuse on alcohol addicts:

- i. It acts as depressant as it decreases the activity of CNS.
- ii. It decreases activity of CNS especially cerebellum.
- iii. It decreases secretion of ADH hormone.
- iv. It acts on cerebellum leading to uncoordinated movement called **ataxia**.
- v. It acts as aphrodisiac increasing sexual excitement although it decreases performance.
- vi. It increases blood pressure and thus, increases the risk of heart disease.
- vii. The chronic alcohol intake leads to fatty change in liver known as **cirrhosis** of liver.
- viii. It increases the level of Gamma Glutamyl Transferase Enzyme (GGTE).
- ix. It hampers in the vitamin B (especially vitamin B₁, i.e., thiamine) metabolism which may lead to diseases like **Karsakoff psychoses** and **Wernicke's encephalopathy**.
- x. Hangovers and withdrawal symptoms are often noticed.
- xi. Because alcohol is a chemical carcinogen, heavy and long-term alcohol abuse increases the risk of oral, oesophageal, and gastric cancer.
- xii. Other complications are: alcohol-induced cardiomyopathy, alcohol-induced hepatitis, alcohol poisoning, cerebellar degeneration, and liver cirrhosis.

Do you know?

Alcohol may reduce one's own perception of cold and can also lessen some of the natural responses designed to help an individual to stay warm, like shivering.

IX. Control measures

Control measures of alcohol abuse include prevention and treatment:

i. Prevention of alcohol abuse

In case of alcohol addiction, control measures, first of all, to be followed by the alcohol addict is prevention. Following are the prevention or prophylaxis of alcohol abuse:

- A. Avoiding of high risk drinking, e.g., no more than 2 drinks day⁻¹ or 8 drinks week⁻¹ in women and 3 drinks day⁻¹ or 12 drinks week⁻¹ in men.
- B. Avoiding of stress in life by alcohol addict is distancing of relapsing drinking.

ii. Treatment of alcohol abuse

In case of alcohol addiction, when prevention becomes of no more use for the alcohol addict then treatment becomes necessary. The treatment depends on situation of the alcohol addict. Following are the treatment or cure of alcohol abuse:

A. In case of severe condition of the alcohol addict, **inpatient medical treatment** or **residential rehabilitation** is recommended.

B. **Behavioural treatment** focusing on counselling that changes the drinking behaviour.

C. **Support groups** who better know the situation of the alcohol addict are a way to connect with the addict.

D. **Medication** is an effective treatment of alcohol addict with the help of medicines like **naltrexone** and **acamprosate** however, medicines like **topiramate** and **gabapentin** decrease cravings.

Activity

Make a country-wise list of the adults suffering from alcohol use disorders (AUD). See where does Nepal stand in this context? Conclude.

3. Smoking abuse

Smoking abuse solely refers to tobacco abuse or misuse.

I. Introduction to tobacco

Various species of herbaceous plants of the nightshade family **Solanaceae** known as *Nicotiana* and commonly called **tobacco plants** are cultivated for ornamental purpose. Out of all the species of *Nicotiana*, dried leaves and dried stems of North American *N. tabacum* L. are commercially processed to prepare '**tobacco**' and **tobacco products** for human use to be used in smoke inhalation called **smoking**, smokeless purpose known as **sniffing** or **chewing**, and for aerosol or particulate suspension **inhalation**. South American species, *N. rustica* L. is another species of tobacco in human use. Tobacco smoke contains thousands of chemicals, out of which some are harmful like carbon monoxide, some are toxic like benzene, and more than 70 are cancer-causing chemicals referred to as carcinogens, e.g., tar (polycyclic aromatic hydrocarbon), hydrogen cyanide, formaldehyde, acetaldehyde, arsenic, cadmium, lead, nickel, etc., including remarkable **nicotine** for which smoking is done. Some of the chemicals can cause heart disease, lung disease, and even can damage developing foetus in a pregnant woman.



Nicotiana tabacum



N. rustica

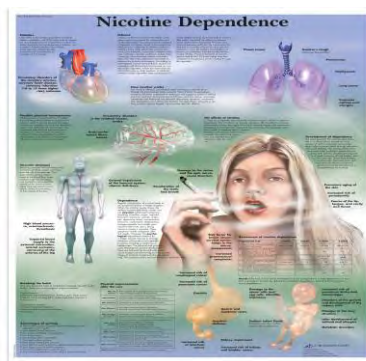


Tobacco abuse



Tobacco

Tobacco is one of the most widely abused substance in the world taking a toll of 6 million deaths per annum for which it is called leading cause of preventable disease. Predominant use of tobacco is by smoke inhalation popularly called **smoking**, smokeless purpose like **sniffing** or **chewing**, and aerosol or particulate suspension



Tobacco addict and Tobacco dependence



Tobacco use disorder and Tobacco abuse withdrawal symptoms

inhalation simply called **inhaling**. Out of so many harmful chemicals present in tobacco smoke, carbon monoxide is highly toxic substance whereas tar, formaldehyde, arsenic, and cadmium, etc., are carcinogenic agents, and **nicotine** is highly addictive drug. When absorbed in blood, nicotine causes rush of adrenaline giving quick boost to one's own mood. It also triggers an increase in dopamine – brain's happy chemical to stimulate area of the brain associated with pleasure and reward.

Tobacco abuse, also called **tobacco misuse** is habitual use of tobacco and its products. Person abusing tobacco may have some control over her/his life for smoking. However, regular abuse of tobacco to get its psychic effect is known as **tobacco** or **nicotine addiction** which is **neurological** and which is craving and willing to have tobacco containing nicotine again and again and the person doing same is called **tobacco** or **nicotine addict**. The compulsion to take tobacco on a continuous or periodic basis in order to experience its psychic effect and sometimes to avoid its absence is known as **tobacco** or **nicotine dependence**. The nicotine dependence is physical and physiological. However, as a result of tobacco addiction and tobacco dependence, the person should have to face chronic and relapsing brain disorder called **tobacco use disorder**. Therefore, if the person doesn't get tobacco at this stages then

the person shows physical, psychological, and mental effects called **withdrawal effects** and the symptoms known as **withdrawal symptoms**.

Tobacco abuse involves physical and psychological factors that make it difficult to stop using nicotine in tobacco, even if individual wants to quit. Nicotine which is **stimulant** as well as **depressant** releases a chemical called **dopamine** in the same region of brain as other addictive drugs. Nicotine causes mood-altering changes that make individual temporarily feel good. Inhaled smoke delivers nicotine to the brain within 20 seconds, which makes it very addictive comparable to – opioids, cocaine, and alcohols. This rush is a major part of addictive process. When individual stops using tobacco, nicotine levels in the brain drop. This change triggers processes that contribute to the cycle of cravings and urges that maintains addiction. Long-term changes in the brain caused by continued nicotine exposure result in nicotine dependence, and attempts to stop cause withdrawal symptoms that are relieve with renewed tobacco use.

Do you know?

In Nepal, overall tobacco smoker data: 22% in 2015, 34% in 2022, and 18% in 2025. Highest percentage of tobacco smoker data: males of Nauru and Myanmar and females of USA and Russia.

Every year, **May 31** is celebrated as "**World Anti-Tobacco Day**" or "**World No Tobacco Day**".

III. Introduction to tobacco abuse in Nepal

Tobacco abuse is most commonly abused substance in Nepal. One of the international brand of cigarette-making factory is situated in this country. Not only this, so many 'bidi-making' and 'khaini-making' factories are situated here and there in this country. To fulfill the supply of tobacco in these factories, tobacco is also produced inside the country.

IV. Types and ways of tobacco and its products abuse

Tobacco and its products abuse is basically done by three ways:



Smoking tobacco in: Cigarette, Cigar, and Pipe.

i. Smoke inhalation of fired tobacco

The standard way of **smoke inhalation** of tobacco is through cigarette, cigar, and pipe however, smoke inhalation of tobacco through '**bidi**' vern. (tobacco filled inside 'tendu leaf'),

'**churot**' vern. (instantly made in which tobacco is filled inside paper), '**chilam**' vern. (tubular earthen pipe to use tobacco at one end), '**gadgada**' vern. or '**locally made hookah**' (small-sized hookah made up of wood only in which tobacco is kept at the top) and **hookah** (metallic base supported by wooden top with an elongated rubber/plastic pipe for inhalation and in which tobacco is kept at the top) are indigenous way.



Smoking tobacco in: Bidi, Churot, and Cheelam

ii. Direct intake of tobacco called smokeless tobacco through:

A. Sniffing

Sniffing is inhalation of powdered tobacco through nose. '**Naswar**' (vern.) used in South-Asian countries is such type of tobacco.

B. Sucking or dipping

Sucking or **dipping** is keeping powdered tobacco inside lip/vestibule of mouth. '**Khaini**' (vern.) and '**snus**' (vern.) are such type of tobacco. '**Khaini**' (vern.) is limestone mixed rubbed tobacco used in South-Asian countries however, '**snus**' (vern.) is a Swedish tobacco product packed in a small pouch.



Smoking tobacco in: Locally made hookah called 'Gadgada', Classical hookah, and Modern hookah,

C. Brushing

Brushing is brushing of teeth by powdered tobacco instead of tooth powder or toothpaste. '**Gul**' (vern.) which is made from dried and roasted tobacco stem is such type of powdered tobacco.



Sniffing '**Naswar**', Sucking '**Khaini**', and Dipping '**Snus**'.



Brushing teeth with '**Gul**', Chewing '**Jarda**' or '**Patti**' in Betel, Chewing '**Gutkha**', and '**Aerosol Inhalation**' of heated tobacco.

D. Chewing of tobacco

Chewing is chewing of tobacco called '**jarda**' or '**patti**' in betel (locally called '**paan**') and '**gutkha**' (vern.) directly.

Do you know?

Betel, locally known as '**paan**' (colloq.) is prepared by betel leaf, limestone, nut, kattha or catechu, etc., and may be along with tobacco. '**Gutkha**' (vern.) is prepared by mixing limestone, nut, kattha or catechu, cardamom, etc., along with tobacco.

iii. Aerosol or particulate suspension inhalation of heated tobacco

Modern way of **aerosol** or **particulate suspension inhalation** of tobacco is by heating tobacco without inhalation of smoke.

V. Reasons of tobacco abuse

Tobacco abuse is not a new trend in nowadays world. Archeological evidences show that use of tobacco started since 12,300 years ago. Historical evidences exhibit that use of tobacco started from America some 5000 BC. There are various reasons of tobacco abuse and becoming nicotine dependence.

Following are the reasons of tobacco abuse:

i. Age at which the tobacco abuse started

The younger an individual is when s/he started abusing tobacco, greater the chance that s/he will continue developing nicotine use disorder.

ii. Friends and family

Youngsters with nicotine dependent friends are more likely to try tobacco abuse. Similarly, children with nicotine use disorders parents are more likely to eventually do tobacco abuse.

iii. Suffering from mental health problems

Individuals with mental health problems, such as depression, anxiety, and schizophrenia, have much higher rates of tobacco abuse.

iv. Other substance abuse

Individuals who abuse other substances like illegal drugs, cannabis, and alcohol have much higher rates of tobacco abuse.

v. Heredity and genetics

Heredity and genetics may determine how receptors in brain respond to high doses of nicotine delivered by tobacco products.

VI. Sign and symptoms

Following are the sign and symptoms of tobacco abuse in physical appearance and psychological condition:

i. Sign and symptoms in physical appearance:

- A. Feelings of pleasure and alertness seen on face of tobacco addict when tobacco is abused by him/her.
- B. If not, tobacco addict cannot stop tobacco abuse, despite attempts to quit for which s/he needs tobacco to feel normal.
- C. Gives up activities or won't attend event where tobacco use is not allowed.
- D. Continues to abuse tobacco despite health problems.

Withdrawal symptoms are shaky hands, sweating, irritability, or rapid heart rate including restlessness, anxiety, insomnia, difficulty concentrating, and fatigue.

ii. Sign and symptoms in psychological condition:

- A. Individuals develop conditioned signals, or **triggers** for tobacco abuse after breakfast or meal or when feel anxious because the triggers lead to behaviour patterns that can be difficult to change.

Do you know?

Drug and alcohol use along with **smoking** has nowadays become status symbol and way of the modernization in metros of Nepal also. What is your opinion?

VII. Effects and consequences of tobacco abuse

Following are the effects of tobacco abuse:

- A. Cardiovascular diseases like coronary artery disease (CRD), Burger's disease
- B. Respiratory diseases like chronic obstructive pulmonary disease (COPD), bronchitis, lung cancer, and emphysema
- C. Gastro-intestinal diseases like oral cancer, throat cancer, gastric cancer, and peptic ulcers
- D. Stroke

VIII. Diagnosis

Diagnosis of the addicted persons abusing tobacco can be done by health professionals through question-answers session.

Activity

Make a country-wise list of the adults suffering from tobacco use disorder. See where does Nepal stand in this context? Conclude.

IX. Control measures

Control measures against tobacco abuse include prevention and treatment:

i. Prevention of tobacco abuse

- A. Professional help should be taken.
- B. Completely resist to deal with friends and others.
- C. Once tobacco has been quit, beware of the upcoming of relapse.

ii. Treatment of tobacco abuse

- A. Combining behavioural counselling and medicine use is the most successful way to quit tobacco abuse.
- B. Behavioural counselling in case of tobacco abuse includes: individual face-to-face counselling, group face-to-face counselling, telephone quit-lines, and web-based programmes.
- C. Behavioural treatment in case of tobacco abuse includes: hypnotherapy, cognitive-behavioural therapy, and neuro-linguistic programming.
- D. Medicines to be used are two types: over-the-counter products containing nicotine and prescription without nicotine. Nicotine replacement therapy (NRT) uses nicotine through nicotine gum, spray, or inhaler whereas varenicline (chantix®), bupropion (wellburtin®), cytisine, nortriptyline, and clonidine are prescription medicine without nicotine.

Project work

Study and compare which one is the leading cause of cancer? Drug addiction, alcohol, or tobacco, or any of the two, or all three. Support your justification with the help of standard or online literature.

Exercise

A. Tick the correct alternative.

1. Which one of the following is collection of symptoms that disrupt the normal bodily functions?
a. Disease b. Disorder c. Syndrome d. Condition
2. Which one of the following disorder refers to the disorder of heart and related organs?
a. Cardiovascular disorders b. Respiratory disorders
c. Renal disorders d. Substance abuse disorders
3. Which one of the following is cardiovascular disorder affecting heart?
a. Myocardial infarction b. Arteriosclerosis
c. Atherosclerosis d. Hypertension
4. A condition in which the heart cannot pump enough blood to meet the body needs is known as
a. heart attack b. heart failure
c. cardiomyopathy d. aortic aneurisms
5. How can be most cardiovascular disease be prevented?
a. By addressing obesity b. By addressing alcohol abuse
c. By addressing tobacco abuse d. All of these
6. Stroke is
a. heart attack b. lungs attack c. kidney attack d. brain attack
7. Asthma is disorder.
a. cardiovascular b. respiratory c. nervous d. renal
8. What is the full form of COPD?
a. Congenital Obstructive Pulmonary Disease b. Cancer Obstructive Pulmonary Data
c. Chronic Obstructive Pulmonary Disease d. Conventional Obtaining Disease
9. A person is suffering from respiratory disorder. What would be the possible cause of chronic obstructive pulmonary disease (COPD)?
a. Using caffeine b. Exposure to pollutants
c. Inhalation of tranquilizers d. exposure to narcotics
10. Low oxygen supply to tissues is scientifically known as
a. asphyxia b. hypoxia c. emphysema d. asthma
11. Renal calculi is
a. urinary tract infection b. kidney stone
c. inflammation of renal pelvis d. inflammation of urethra
12. Which of the following mineral is not involved in the formation of renal calculi?
a. urea b. uric acid c. calcium carbonate d. calcium oxalate

13. What is glaucosauria?
 - a. Low amount sugar in urine
 - b. High amount of sugar in urine
 - c. Average amount of sugar in urine
 - d. Low amount of fat in urine
14. Haemodialysis is the treatment for renal disorders. It is the process of removal of in the blood by artificial means.
 - a. sodium ions
 - b. potassium ions
 - c. urea
 - d. ammonia
15. What is the inflammation of glomeruli of the kidney is referred to?
 - a. Cystitis
 - b. Nephritis
 - c. Glomerulonephritis
 - d. Pyelonephritis
16. The substance abuse shows
 - a. rhinorrhoea
 - b. diarrhoea
 - c. lacrimation
 - d. withdrawal symptoms
17. Which one of the following is referred to be the narcotics?
 - a. Diazepam
 - b. Caffeine
 - c. Opium
 - d. Cocaine
18. Dependency of mind and body on drug is known as
 - a. drug use
 - b. drug abuse
 - c. drug addict
 - d. drug addiction
19. Most dangerous hallucinogens are
 - a. cocaine
 - b. heroin
 - c. caffeine
 - d. lysergic acid diethylamide (LSD)
20. Performance enhancing drugs used by athletes are
 - a. amphetamines
 - b. sedatives
 - c. tranquilizers
 - d. nicotine
21. Which one of the following is undistilled alcoholic beverages?
 - a. Beer
 - b. Whiskey
 - c. Rum
 - d. Brandy
22. Drinking and driving do not go together. What could happen if a driver drinks?
 - a. It could affect judgement
 - b. It could affect liver
 - c. It could affect sugar level
 - d. It could affect body weight
23. Most severely affected organ due to alcoholism is
 - a. mouth
 - b. stomach
 - c. liver
 - d. kidney
24. The modern way of tobacco addiction is
 - a. smoking tobacco
 - b. chewing tobacco
 - c. aerosol inhalation of heated tobacco
 - d. sniffing tobacco
25. Main drug found in tobacco is
 - a. opium
 - b. caffeine
 - c. nicotine
 - d. LSD
26. Cigarette smoking causes
 - a. emphysema
 - b. asthma
 - c. fibrosis
 - d. bronchitis
27. Pneumonia is one of the harmful respiratory disease especially in children? All of the following are correct for the person during pneumonia but what happens first?
 - I. Alveoli are damaged
 - II. Alveoli are filled with liquid

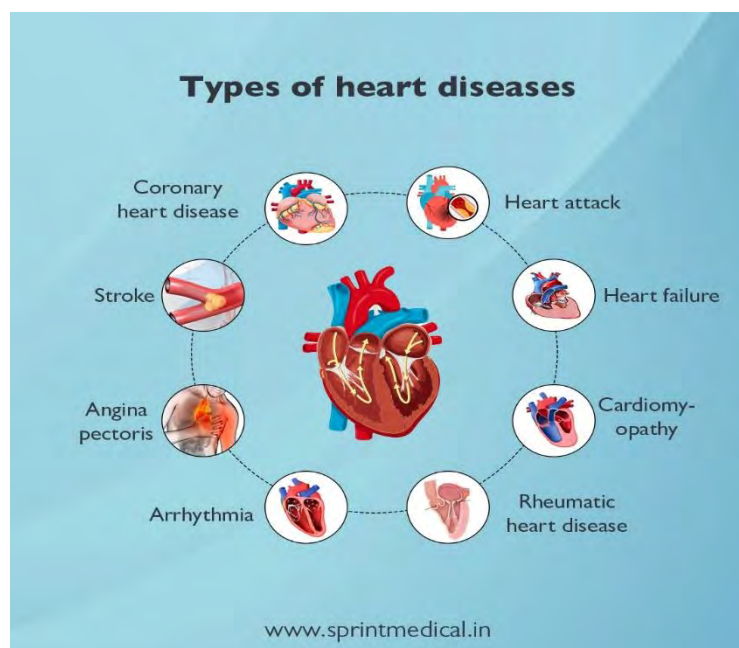
- III. Lung tissues are thickened IV. Shortness of breathing
- a. I, II, III, and IV b. II, III, IV, and I
- c. II, IV, I, and III d. I, III, II, and IV

28. A person suddenly falls down and becomes unconscious. A doctor checked and said that it is due to inadequate blood supply to brain. What would be the type of disorder?
- a. Asthama b. Heart attack c. Oedema d. Syncope
29. Which one of the following statement is correct in terms of a drunkard?
- a. The reaction time increases b. The reaction time decreases
- c. The reaction time equals d. The reaction time becomes fastest.
30. Most of the alcohol drunk is absorbed in
- a. buccal cavity b. oesophagus c. stomach d. intestine

Answers.

Short answer questions.

1. See the figure and comment on the disorders shown.



2. What is early warning or signs of pulmonary disease? Which respiratory diseases are more concerned with elderly and infants? Explain.
2. What is drug abuse? Describe in short the drug abuse.

3. How does alcohol affect the body? See the figure below and fill the blanks with affect of alcohol.

How Does Alcohol Affect the Body?

Name : _____ Date : _____

Directions: Fill the blanks with affect of alcohol

Brain		Head
Heart		Eyes
Liver		Tummy and gut
Waist		Bone

WORKSHEETSGO

4. Write short note on smoking.
5. 'Smoking is injurious to health'. Justify.

Long answer questions.

1. Write an essay on socially significant diseases.
2. Explain source and biological effects of different categories of abused drugs.
3. What is addiction? Discuss the symptoms, effects, and control measures of alcohol addiction.

Unit 10

APPLIED BIOLOGY

Chapter 10.1

APPLICATION OF ZOOLOGY

In vitro fertilization (Test tube baby)

In vitro fertilization is the assisted reproductive technology to solve the problem of infertility among the people. In this, fusion of egg and sperm is carried out in the laboratory glassware condition but not within the body of female. After fertilization the zygote is allowed to divide to form embryo. The embryo after forming eight blastomeres is transferred into the fallopian tube and this process also mimics the natural timing of embryo movement from fallopian tube to the uterus.

Do you know?

In Vivo fertilization is the fertilization that occurs inside the body of living organism typically within female reproductive tract.

Many people benefit from this technique as it helps the female who are unable to conceive naturally due to certain infertility problems in the male or the female or both. The first successful attempt to produce a test-tube baby was done by a British gynecologist Dr. Patrick Steptoe and a physiologist Dr Robert Edwards. The world's first test tube baby was Louise Joy brown born on July 25 1978. First test tube baby of Nepal was Om Mani Tamang born on March 3 2005.

Surrogate mother

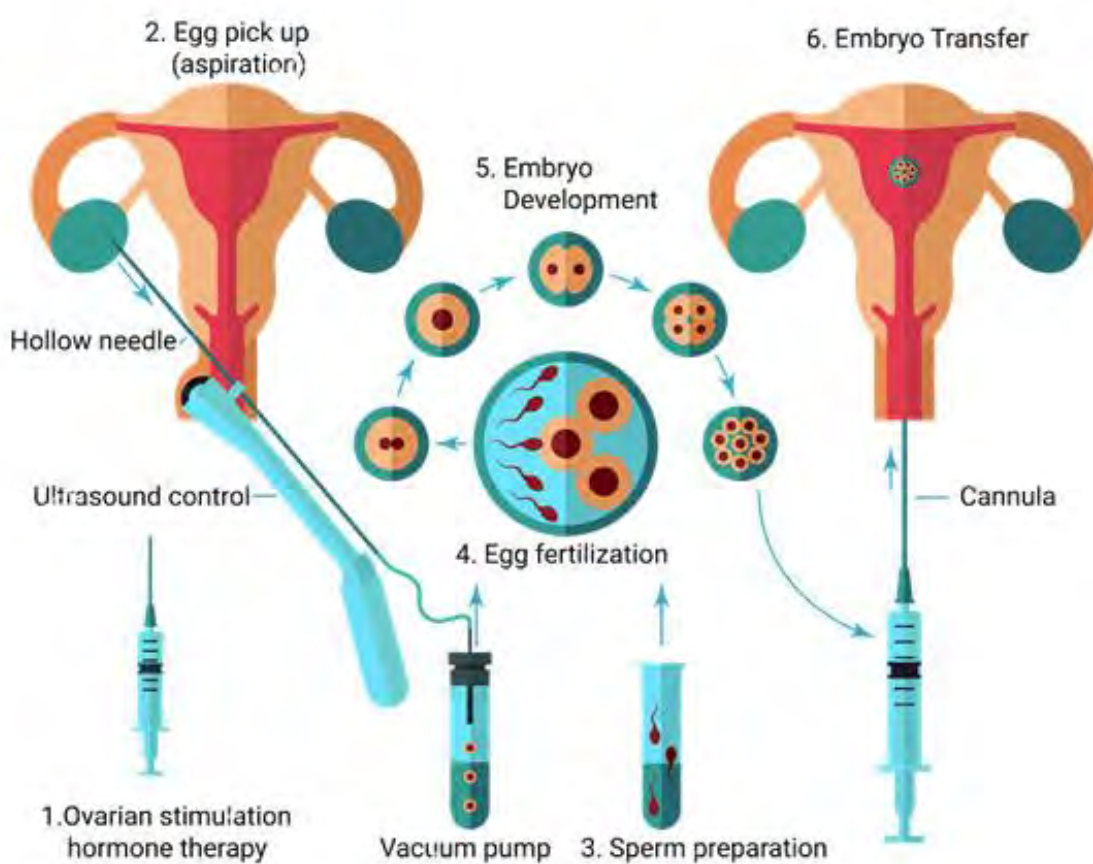
A female who carries and gives birth to a baby on behalf of another female or couple who are unable to do so is surrogate mother. In other words, A women who takes the position of real mother to nurse embryo is surrogate mother. She is also called substitute mother or second mother. She doesn't contribute genetically, to the baby.

Procedure of IVF

It involves the following steps:

1. Suppressing the natural menstrual cycle
The women receive the medications to suppress her natural menstrual cycle.
2. Super ovulation
this process involves stimulation of ovaries to produce multiple mature eggs. It is done by hormonal injection such as FSH and LH for about 2 weeks.
3. Egg retrieval
When ovarian follicles are matured and started producing mature eggs, eggs are retrieved using an ultrasound guided needle.
4. Sperm collection
Doners sperms are collected and best quality sperms are selected by a process called sperm washing.

5. Insemination and fertilization
Collected eggs are placed together with sperms in a controlled laboratory conditions for fertilization. Sometime a single sperm is directly injected into the egg called intra-cytoplasmic sperm injection.
6. Progesterone treatment
The woman is supplemented progesterone hormone or hCG to develop the lining wall of uterus.
7. Embryo culture and transfer
Zygote grow into embryo for about 3-6 days, then a thin catheter is used to transfer 1-2 embryos into the woman's womb.



Process of in-vitro fertilization

Do you Know?

Surrogate mother is used in the conditions such as:

Women with uterine issues (absence of uterus, recurrent miscarriages), women with medical conditions that makes pregnancy unsafe, same sex male couples or single man who want to have a biological child

Merits of IVF

- 1 This technique helps the infertile couple to conceive a baby.
- 2 It bypasses the problems regarding blocked fallopian tube in female and low sperm count in male.
- 3 In this technique, genetic disorder in embryo is detected, if present, before transferring to the womb of female. So, a healthy child will be borne.
- 4 Donor egg or sperm can be used if required.
- 5 If first attempt fails, frozen embryos are used to avoid repeated cycle of IVF.
- 6 It provides hope to the couple who failed other treatments.

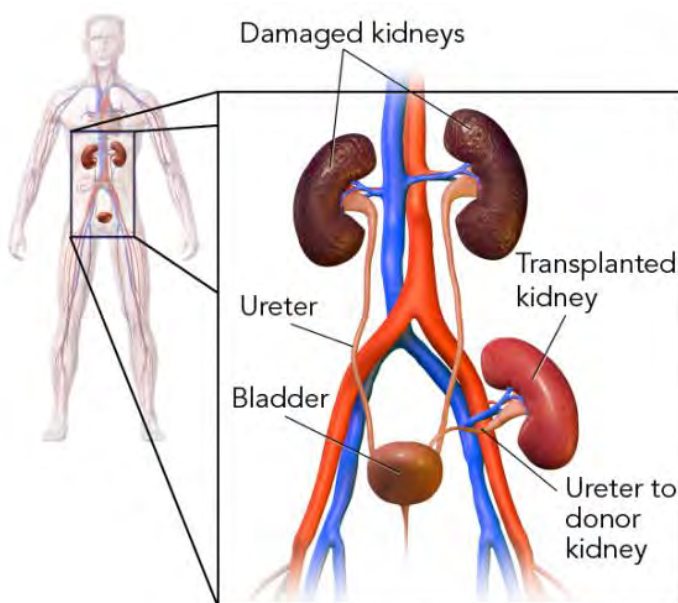
Demerits of IVF

- 1 This technology is costly and not affordable for all.
- 2 Success rate is not 100%
- 3 There is a risk of multiple birth i.e. twins and triplets
- 4 It gives physical and emotional stress due to hormone treatment.
- 5 Ethical and religious issues arise in IVF.

Ethical issues

- 1 Some religion opposes IVF as it separates conception from natural sexual intercourse.
- 2 Unused or extra-embryos are often discarded which raises the moral concern about the destruction of potential life.
- 3 Embryo may be selected on the basis of gender which is not a good practice.
- 4 This technique raises questions about child's identity, parental rights and family relationship.
- 5 Poor women may be financially exploited while using them as a surrogate mother.
- 6 IVF may turn reproduction, a biological life process, into the business.
- 7 It raises the questions about the child's right to know their genetic origin.

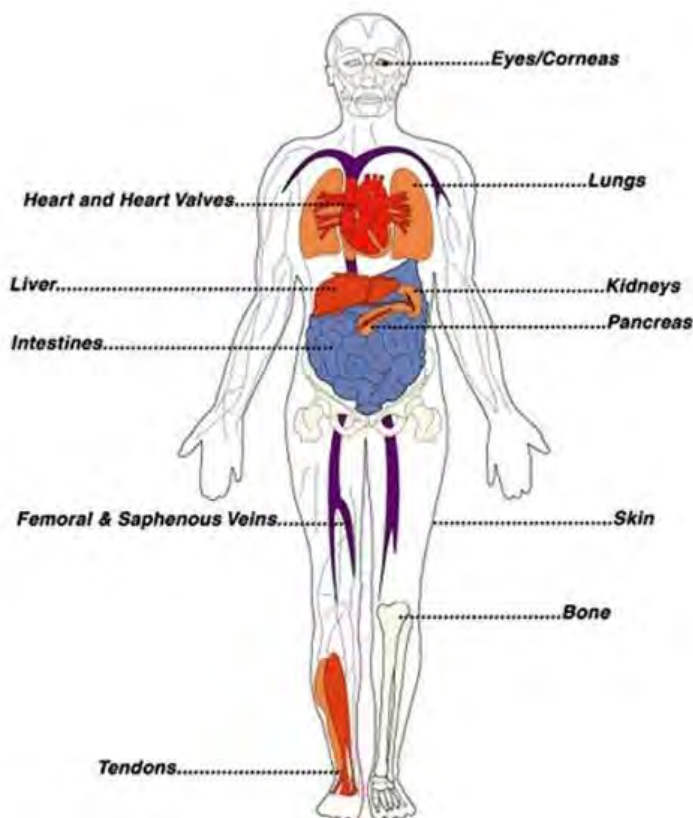
Organs and tissue transplantation



Organ transplantation is the medical procedure in which damaged or non-functional organ in an individual body is replaced by healthy organ from a donor. Donor is an individual who provides organ or tissue for transplantation. Donor may be living or deceased due to circulatory death or brain death. Recipient is a living individual who receives donated organ or tissue. Organ transplantation is used to dramatically improve or save life of people who are suffering from the end stage failure. This is the important field of medical endeavor where great advances have been made in the recent years. Common transplanted organs are brain, liver, kidney, heart, lungs, pancreas intestine. World's First successful human heart transplant was done in 1967 by a surgeon Dr. Christian Barnard.

Skin was the first tissue to be cultured and transplanted onto the patients with severe burns or skin loss. Skin and bone graft are most commonly and widely used form of tissue transplants which are successfully performed for several years in the case of burns fracture and reconstructive surgeries. In addition to them, blood transfusion is very common form of tissue transplantation which follows the same principle of donor-recipient compatibility. The increasing demand for tissues for the transplants has enforced the establishment of tissue banks which collect, screen, preserve and distribute human. Common tissues transplanted are bones, tendons which are referred as musculoskeletal graft, cornea, skin, heart valves, veins. Musculoskeletal graft refers to the transplant of tissues that are the part of the musculoskeletal system, which includes bones, cartilage, tendons, ligaments, and muscles. These grafts are commonly used in orthopedic, spinal, and reconstructive surgeries to repair, replace, or support damaged or diseased tissues.

For the successful transplantation organ or tissue of donor should be compatible or genetically similar to that of recipient.



Organs used in transplantation

Types

On the basis of relationship between donor and recipient, following are the type of transplant or graft:

Autograft: transplant of tissue from one part of an individual's body to another part of same individual. There is no risk of rejection in this type of transplant. Example: skin graft from thigh to the arm to treat a burn, coronary artery bypass surgery using the patient own leg vein (saphenous vein)

Isograft: A transplant between genetically identical individual such as identical twins (monozygous). There is no risk of immune rejection in this type. Example: Kidney transplant between identical twins, skin graft exchanged between identical twin

Allograft: A transplant between two genetically different individuals of the same species. Closer the relationship of donor and recipient, more successful will be transplant. There is a risk of immune rejection in this type. Example: heart, kidney transplant

Xenograft (heterograft): the transplant of tissue or organ between different species. There is a high risk of rejection in this graft. Example: Pig heart valve in human heart surgery, use of pig skin as a temporary wound cover for burns.

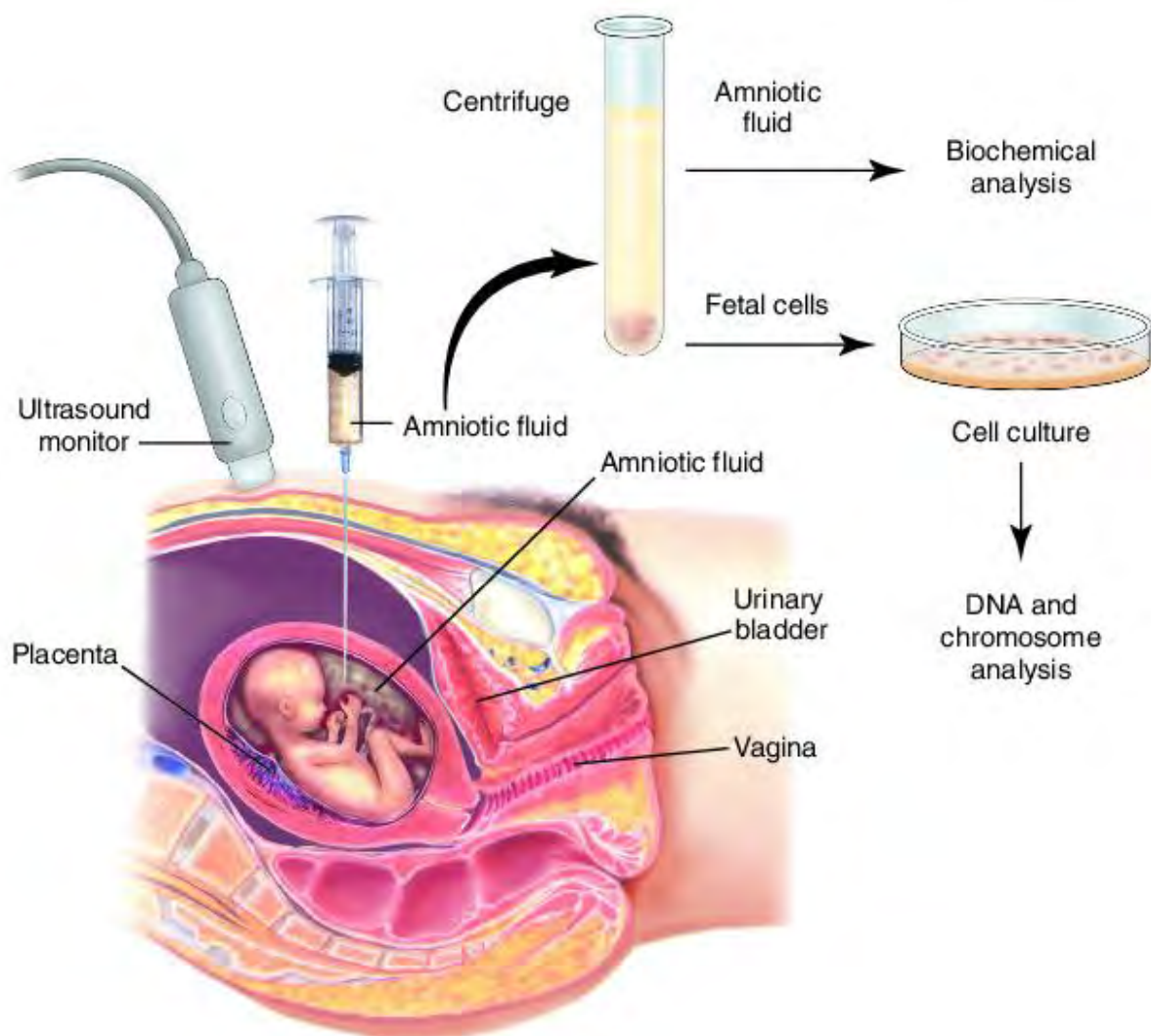
Challenges or risk of organ transplant

- 1 In organ transplantation, the main problem is that the recipient body recognizes transplanted organ as foreign body or antigen. As a result, the recipient body produces antibodies against a grafted organ and hence foreign organ/tissue graft will be rejected by the recipient's immune system. This is called rejection.
- 2 During transplant, immunosuppressant drugs are given to avoid rejection which reduce the immunity of recipient making more susceptible to infections.
- 3 Drugs used for long time, may affect kidney, blood pressure, bones cholesterol level.
- 4 This technique is costly which requires lifelong medications and follow up.
- 5 There is still a high risk of transmission of disease even though donors are screened.
- 6 Illegal activities such as organ trafficking may occur which violates human dignity and medical ethics.

Ways to prevent rejection

- 1 Use of Immunosuppressive drugs such as tacrolimus, cyclosporine, mycophenolate etc.
- 2 Tissue typing is the crucial process which involves matching of the donors and recipients tissue type for reducing the risk of rejection
- 3 Sibling or family members are recommended for transplants as there is a higher chance of genetic compatibility.
- 4 In bone marrow or stem cell transplant, high dose radiation treatment is done to destroy the recipient bone marrow and immune cells before introducing donor stem cells.
- 5 Researchers are actively working on the invention of such drugs which only avoid rejection but keep the person's immunity unaltered.
- 6 Various plastic based structures used in organ replacement and support are artificial blood vessels, trachea, heart valves, artificial skin, artificial cornea.
- 7 If artificial organs like liver, heart, wearable kidney can be invented, it will be one of the most transformative breakthrough in the medical field

To detect the developmental and genetic issues in fetus, amniocentesis is the safe and effective diagnostic procedure. It is the prenatal diagnostic test used to check for genetic chromosomal and certain developmental issues in fetus. In this technique, a small amount of amniotic fluid is taken out from the mother's womb at an early stage of fetal development (About 14th or 15th week of conception). Amniotic fluid surrounds the fetus in uterus. The fetal cells present in the fluid are used for detecting any possible chromosomal or metabolic disorder. If the developing fetus is suffered by serious non-curable and congenital defect the pregnancy is terminated but this technique has been widely misused so as to abort the female fetus. Hence it is banned in Nepal and there is no more legal right to use it.



Process of amniocentesis

Procedure:

1. Firstly, doctors use ultrasound to identify the position of fetus and amniotic sac.
2. A thin surgical needle is inserted through the abdomen into the mother's uterus.
3. About 20 ml of amniotic fluid is taken and sent to the lab for analysis.
4. The fluid containing fetal cells and chemicals is centrifuged to concentrate fetal cells and the cells are cultured for analysis.

5. Analysis mainly involves:

- a. Karyotype analysis: done for detecting chromosomal abnormalities and sex of fetus
- b. Biochemical test: to detect presence or absence of certain enzymes prenatal diseases such as haemophilia, sickle cell anemia

Purpose of amniocentesis

1. Genetic testing: test of fetus for various genetic disorders like down syndrome cystic fibrosis Tay-sach' s disease etc.
2. For identifying certain intra-uterine infections and also for evaluating the severity of anemia in babies having Rh sensitization.
3. Amnio-reduction, a technique similar to amniocentesis is done to drain excessive amniotic fluid if present from the uterus
4. For paternity testing by analyzing the DNA of the fetal cells in amniotic fluid
5. Neural tube defect testing

Risk/Complications

1. There is a rare but most serious risk of miscarriages in this process.
2. There may be the chance of infection into the uterus.
3. Amniotic fluid may continuously leak out through vagina after the amniocentesis is performed though it is rare.
4. The baby might move body parts such as arm leg into the path of needle and hence needle injury may occur.
5. If the mother has an infection such as hepatitis C, HIV AIDS, Toxoplasmosis, the infection may be transferred to the fetus.

Activity

Activity

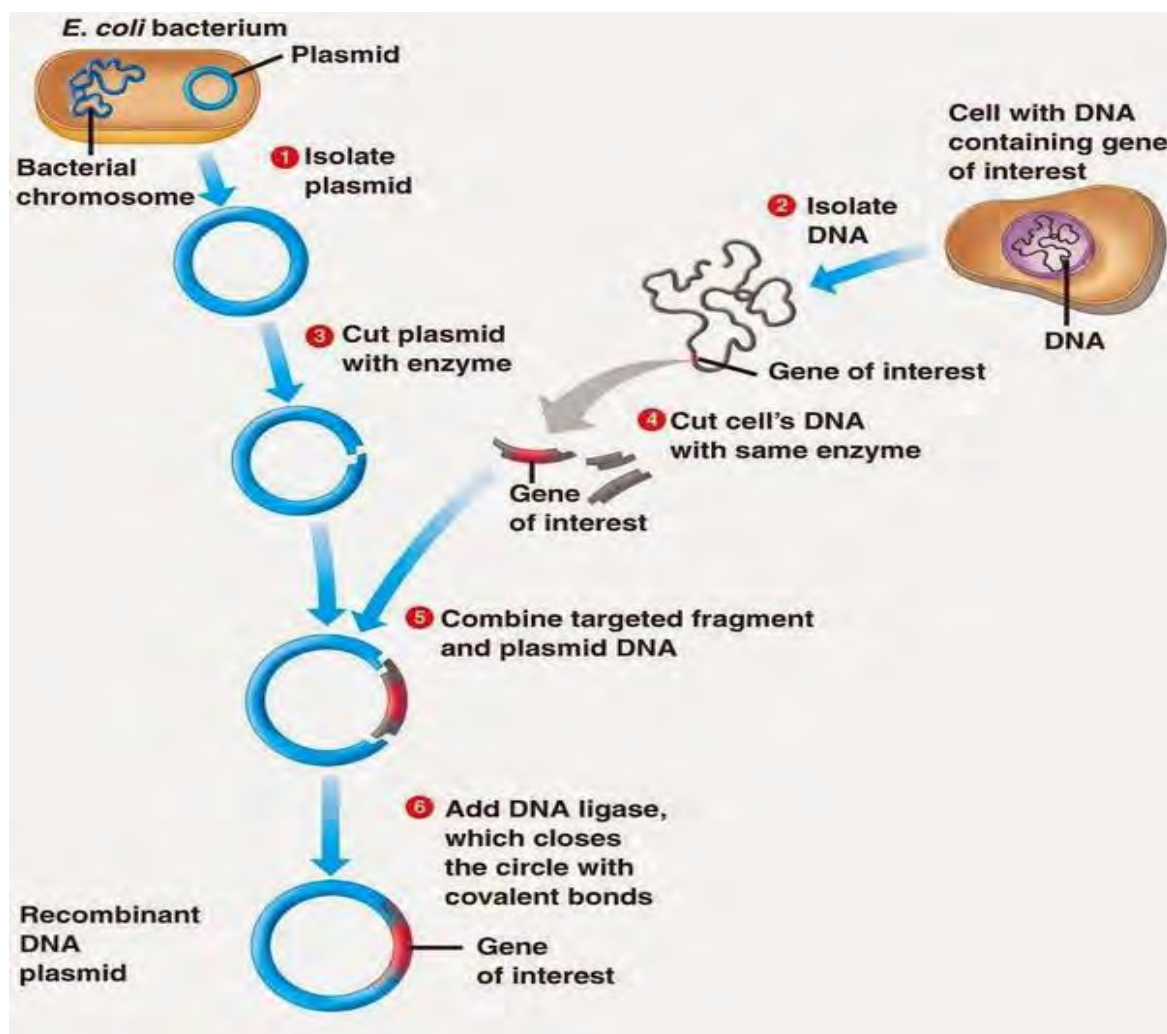
Read the cases given below thoroughly and do the task on chart paper based on questions given below.

Case

A couple in their early 40s is struggling with infertility. The male has a low sperm count and natural conception has not occurred after multiple attempts.

- Identify the reproductive issue.
- Suggest the technology to help the couple
- Mention its merits demerits and ethical consideration.

Concept of genetically modified organism (GMOs) (Transgenic animals)



Making recombinant DNA

The organism which carries foreign DNA is called genetically modified organism (GMOs). These organisms are also called transgenic organisms and the process is called transgenesis. The transferred gene or foreign DNA is also called transgene. Hence, the organisms such as plants, animals, or microorganisms whose **genetic material has been altered in a laboratory** using genetic engineering or biotechnology for various purposes. Unlike traditional crossbreeding or selective breeding, which involve choosing parents with desirable traits and waiting for results over generations, **genetic engineering allows scientists to make direct and specific changes to an organism's DNA.**

Genetically modified animals, known as transgenic animals, are engineered for desirable traits such as higher protein content in milk and improved meat quality and growth. Examples: Genetically modified goats that produce pharmaceutical proteins in their milk, used in the development of medical treatments. Dolly the sheep, the first cloned mammal, created by transferring the nucleus of an adult cell into an egg cell, marking a significant step in cloning and genetic research. Transgenic mice that carry human genes, which are widely used as models to study human diseases such as

cancer, diabetes, and neurodegenerative disorders. Transgenesis have been successfully done in variety of fishes such as common carp, rainbow trout, Atlantic salmon, catfish, goldfish, zebra fish. Transgenic salmon possess additional gene coding growth hormone which allows it to grow larger more rapidly. Disease resistant and rapidly growing to larger with more flesh variety of chicken are also produced by transgenesis. various human genes such as interleukin2, growth hormone, tissue plasminogen activator etc. have been transferred to rabbits which were expressed in mammary tissue and their proteins were harvested from milk.



Transgenic mice (larger) and normal mice

Similarly, genetically modified plants, often referred to as transgenic plants, are created using genetic engineering techniques. These plants are designed to have enhanced resistance to environmental stress and diseases. One notable advancement includes transferring nitrogen-fixing ability to non-leguminous plants by inserting *nif* genes from nitrogen-fixing bacteria. Other examples of genetically modified crops include slow-ripening tomatoes, Golden Rice enriched with vitamin A, and high-protein potatoes.

The major techniques used in the formation of genetically modified organisms is recombinant DNA technology: This technique involves cutting a gene from one organism and inserting into another organism. Production of transgenic animal involves following processes:

- i. Location identification and separation of desired gene
- ii. Selection of proper vector (plasmid, virus etc.) or direct transmission
- iii. Combining the desired gene with the vector
- iv. Introduction of recombinant vector in cells tissues embryos or mature individual
- v. Expression of foreign gene in transgenic tissue or animals



Transgenic animals

Advantages of transgenic animals:

- i. Biological product such as human protein α 1-antitrypsin, tissue plasminogen activator (from transgenic goat), lactoferrin from transgenic cow etc. can be produced. The first transgenic cow Rosie produced protein enriched milk (2.4 gram /litre)
- ii. Transgenic animals such as mice are used in testing the safety of vaccines before they are used in human.
- iii. **Transgenic animals** are increasingly used in **toxicity testing by exposing them to toxins** to evaluate the **safety of drugs, chemicals, and environmental toxins**
- iv. **Transgenic animals are used to study how genes are regulated and how they affect the normal functions of the body and its development.**
- v. **Transgenic animals are also produced to increase our understanding on how genes contribute to the development of disease and how treatment of such diseases is possible.**
- vi. **To produce spare parts in for organ transplants, transgenic animals are used.**
- vii. **Defective parts can be replaced by freshly grown parts from own body cells.**
- viii. **Clone of animals can be produced by transgenesis.**

Risk/challenges

- i. Genetically modified plants affect the non-target species by spreading their modified gene to wild plant varieties.
- ii. Only Single species farming with GMOs can reduce genetic diversity in animals and plants.
- iii. Superweeds and super pest resistant to herbicides and pesticides may be created in the future.
- iv. There is a chance of GMOs to introduce new allergens or toxins or unknown long term health effects.

- v. There is a risk of transfer of antibiotic resistance from GMOs to harmful bacteria.
- vi. Many people raise concern about the morality of altering animal's genes as the animals are suffered for human benefit.

Poultry farming

The term poultry is used for the birds which can be raised under domestication for economic purpose. This term applies to chicken, duck, turkey, swans, pigeon, quails, ostrich etc. The practice of raising domesticated birds, primarily chickens, turkeys, ducks, and geese, for the purpose of producing eggs, meat or both. In Nepal, it ranges from small-scale backyard operations to the large commercial farms. It is the important part of the country's agricultural sector which have been providing a significant source of protein and income for many families. Demand for poultry products, such as eggs and chicken meat, has been increasing steadily due to population growth and urbanization. Poultry farming can play a crucial role to solve the problem of malnutrition and poverty in the rural area in the developing country like us.

Breeds of Chicken

Both exotic and Indigenous breeds of chickens are reared in Nepal. Indigenous breeds are domesticated in the rural area under hygienic or semi hygienic system with less control and care resulting higher level of mortality and less production although these breeds have played a significant role in raising the livelihood of rural communities by providing meat egg and economic benefit. Some local or native breeds are Shakini, Dhobani, Hurra, Pwankh ultey, Giriraj etc.



Shakini



Pwankh ultey



Giriraj

Figure: Some indigenous breeds

In the recent years, mostly reared breeds are exotic breeds because of their high potential for producing meat and egg. Some of them are New Hampshire, Rhode Island Red, white leghorn, Australorp, Black Minorca and other synthetic breeds. They are domesticated under intensive management with good housing nutrition and medical care.

Most common breeds of chicken reared in Nepal are:

1. American breeds:
 - White leghorn: primarily egg layers.
 - Rhode Island red: for both meat and egg
 - White Plymouth rock (broiler): chiefly for meat

2. Other breeds: Asiatic breeds such as Brahma, Aseel, cochin and Indian breeds such as Basra, chittagong, Ghagus etc.



Rhode island red



White leghorn



Aseel



Broiler

Figure: Exoetic breeds

Poultry farm management includes the following components

Incubation:

Incubation is the process of developing chick embryo inside the egg. The eggs should be fertilized, cleaned, uncracked and obtained from healthy and vaccinated birds which are no older than a week. They are stored at a temperature of about 18°C. Eggs are kept inside the incubator for three weeks at about 37 °C for the incubation

Brooding:

Brooding is the process of caring young chicks or pullets, after they hatch, ensuring they are kept warm, well fed, and protected. It is often done in a controlled environment using brooder houses or equipment like heat lamps or heated floors for maintaining warmth.

Rearing

Healthy pullets are reared in the rearing rooms, provided with feed hoppers, water containers, laying boxes etc. Determining the sex of pullet by using optical device is sexing. Sex is also determined by observing feather color, presence or absence of spur. Before keeping into pen, they should be vaccinated against fowl pox.

Management:

Chicken house or poultry pen should be well ventilated, spacious, well lighted and fenced. Chicken of different ages are kept in different house. The cages where they are kept are called coops. The pen should be safe from rat, snake and other predators, with water drainage, free from noises, and parasitic infestations.

Feeding:

Feed refers to the formulated diet given to the poultry birds to meet their nutritional needs for growth, reproduction, egg production and overall health. Feeding is the practice or method of providing feed to the poultry. The type of feed provided depends on the age and strain of birds reared. Feeds are made by mixing different ingredients such as crushed grains of maize, wheat, rice, mustard cake, bone, shells, fish meal, salt, vitamins. Feeds rich in calcium, protein should be given to egg layers.

Pullet rearing system

Pullet are young female chicken under 1 year old. Their rearing system are:

1. Extensive or free range: It is the most traditional and common system chiefly practiced in rural areas for indigenous chickens. In this, birds are allowed to roam freely at the day time for foraging natural food such as insect seeds and household remains. They are imprisoned at night for protection. Benefits of this type of farming is that it needs little investment and the birds are hardy which can adapt easily against natural forces but there is still a high risk of predation and disease.
2. Semi-intensive: It is suitable for medium scale farming in which birds are let free in a small fenced area for foraging in day time and imprisoned at night. There is a low risk of disease and predation than the free range. This system requires moderate investment in housing and fencing.
3. Intensive system: This system is totally commercial based and large-scale production, done by keeping the birds in well managed and under controlled condition in poultry houses. The birds are well cared, and dependent upon formulate feed and water. There is a continuous provision of feeding watering and waste removal. It is of two types:
 - a. Battery or cage system: layers are kept in separate cage.



- b. Deep litter system: Many chickens or birds are kept in the floor-based housing system where the litter materials are rice husk saw dust straw dried leaves or grasses. The floor is made about 6-12 inches thick with the litters. The floor provided with litters or bedding materials absorb dropping and control moisture. Its main advantages are high productivity, efficient use of spaces and labor and easy to monitor.



4. Folding unit system:

A type of housing design where movable or folding platforms or panels are used to house the birds. This system combines the benefit of the free range and intensive system i.e., allows controlled grazing. Its advantages are chickens get new ground every day, reduces feed cost due to natural foraging, enhance the fertility of pasture land due to continuous manuring and protection from predators. It is appropriate for small organic farms, backyard and for hobby farmers and in area with sufficient pasture land but not for large number of birds.



Diseases of poultry

Poultry birds need protection against weather, predation and various infectious diseases. They may suffer from viral diseases (fowl pox, Avian influenza, dermitis, Newcastle disease or Ranikhet), bacterial diseases (tuberculosis, cholera diarrhoea), fungal diseases (Aspergilliosis) and other parasites such as worms, mites, lice etc. sometimes they also suffer from nutritional deficiency disease.

To prevent from such infections, poultry house should be cleaned regularly and properly. The house should be spacious, properly ventilated for the entry of air and light. There should be the provision of nutritive and hygienic feed and water. Farm should be free from ectoparasites such as tick, lice, flea and predators and birds should be regularly immunized.

Culling is the process of selectively removing infected or unproductive birds to maintain overall health, prevent the spread of disease and improve the productivity in the poultry.

Advantages of poultry farming

1. Poultry products such as eggs and meat are rich in high quality protein, some important vitamins and minerals required for our body.
2. It provides a reliable source of income for farmers by selling egg meat, chick and by-products such as manure and feather.
3. It creates employment opportunities for both skilled and unskilled labor across multiple fields such as hatchery operation, feed manufacture, veterinary service, marketing etc.
4. Poultry droppings is an excellent organic fertilizer rich in nitrogen, phosphorus and potassium which can be used in crop fields.
5. It provides quick return after the investment. For instance: broilers grow rapidly and marketed within 6-8 weeks, layers start to produce eggs in about 5 month
6. Feathers especially from ducks and chicken are used in the production of for clothing and home products, such as winter jacket, sleeping bags, quilts, pillow etc.
7. It is feasible within a limited or little space with a little investment

Fish farming

Fish farming is a branch of animal husbandry where fishes are commercially reared in natural or artificial water bodies. It is an industry devoted to the catching processing and selling of fish and fish products. Nepal holds vast and untapped potential of fish farming where more than 200 species of fishes thrive in the variety of freshwater resources. Our country has abundant natural freshwater bodies which consist of about 4 lakhs ha of river, 5 thousand ha of lakes, 1500 ha of reservoir, 6500 ha of village pond, 12500 ha of marginal swamps, about 4 lakhs ha or irrigated rice field. Many hill streams are occupied by highly valuable cold-water fishes like Asala (*Schizothorax spp*), Sahar (*Tor tor* and *Tor putitora*) and Katle (*Neolissochilus spp*) which need to be conserved. Fishes are found to be distributed from the lowlands of terai through the hills to the Himalayan mountains. Terai harbors warm water fishes whereas hills and mountains harbors cold water fishes. Hence, aquatic ecosystem of Nepal offers excellent habitat for fish farming. The demand of fish both locally and for export is increasing day by day. Fish farming creates opportunities for rural employment and entrepreneurship in different regions of the nation. It helps to uplift the rural economy by providing stable income sources.

- i. Aquaculture: It is the commercial rearing of aquatic organisms such as fish, prawn, crab, lobster, mollusks etc.
- ii. Pisciculture: Commercial rearing of fishes is called pisciculture.
- iii. Riverine fisheries: It is the practice of capturing fish in river.
- iv. Lacustrine fisheries: Fishing activities that occur in lake is called lacustrine fisheries.
- v. Inland fisheries: Fishing and aquaculture activities in freshwater bodies is called inland fisheries.
 - a. Capture fisheries: it is done in natural habitat
 - b. Culture fisheries: It is done in artificial freshwater bodies
- vi. Marine fisheries: It includes capture fisheries of oceans and seas.
- vii. Monoculture: It is the culture of single species of fish in a pond.
- viii. Polyculture or composite culture: It is the culture of more than a single species of fishes in a pond.

Native or indigenous fishes: The fish species which are naturally found in the specific geographical region, without human intervention are called native or indigenous fish. In other words, native fishes have evolved and adapted to the local environment over time. A total of about 187 indigenous fish species have been reported in Nepal. Some important native fishes are:

1. Rahu (*Labeo rohita*)
2. Naini (*Cirrhinus mrigala*)
3. Bhakura (*Catla catla*)
4. Asla (*Schizothorax*)
5. Sahar (*Tor putitora*)
6. Hile (*Channa punctatus*)
7. Mystus tengara



Rahu



Hile



Common carp



Trout

Do you know?

The largest fish found in Nepal is *Bagarius bagarius* and the smallest is *Danio rario*.

Exotic fishes: They are not native to a region or country but imported from foreign countries. Up to now, a total of 17 exotic fishes are found in Nepal where first known introduced species is common carp (*Cyprinus carpio*). Some well-known exoetic fishes are:

1. Common carp (*Cyprinus carpio*): From India and Israel
2. Grass carp (*Ctenopharyngodon Idella*): From India
3. Silver carp (*Hypophthalmichthys molitrix*): from Japan
4. Bighead carp (*Aristichthys nobilis*): from Hungary
5. Tilapia (*Oreochromis nilotica*): from thiland
6. Rainbow trout (*Oncorhynchus mykiss*): from England, India, Japan
7. Magur (*Clarius gariepinus*)

Types of pond

Ponds can be classified according their usage in the fish farm which are as follow:

1. Brood stock pond: Male and female fish are segregated and separately reared to prepare them sexually matured (brooder fishes) till the breeding season comes. The main purpose of this type of pond is to control reproduction timing for hatchery operations.
2. Spawning pond or breeding pond: In breeding pond, male and female brooders are released in the ratio 1:2 (however ratio varies with species) for spawning in breeding season (monsoon season). A gentle flow of water is maintained in the breeding pond to provide stimulation to the brooders. Once spawning occurs, the fertilized eggs are transferred to hatchery ponds for better control and survival rate during hatching.
3. Hatchery pond: Hatchery ponds are smaller and shallower tanks or ponds used for hatching the fertilized eggs. A continuous but slow flowing water is desirable for aerating the eggs. Fertilized eggs are hatched into fries and fries are kept for few days in hatchery pond.
4. Nursery pond: young fries are transferred from hatchery pond to grow into fingerling size. Nursery pond is a rectangular pond of about 90 cm depth. The fries are reared for about 3 month, up to about 40 gm weight i.e upto fingerlings.
5. Stocking pond: They are fairly large perennial ponds more than six feet depth for the growth and stocking of fishes. They are constructed larger to facilitate netting while harvesting fishes.

Construction and management of ponds

Following factors should be considered while constructing the fish pond:

1. Land topography: Land topography means the surface feature of the land which is important for both construction and maintenance of pond. Generally, a bowl-shaped land area with high land on three sides and narrow outlet on the fourth is considered initial landscape suitable for constructing pond which can be converted to a desired pond.
2. Soil: soil plays an important role in the fertility of fish pond which should have ability to hold water. For this clay soil is suitable. The soil should be rich in nutrients and with suitable pH (slightly alkaline).
3. Water supply: availability of adequate water supply is the important prerequisite for fish ponds. The quality and quantity of water required depends upon the type and number of fish raised in the pond. Different water sources required for pond are lakes, reservoirs, springs, rivers, canals, well, surface runoff etc.

4. Transportation: The **transportation** is also an important factor for smooth operations of overall fish farming. Proper roads are needed for vehicles during construction transportation of fish fries, feed, supplies and harvested fish.
5. Layout of the fish farm: Before starting the construction, the scientific layout plans have to be drawn for the location, design and number of various types of ponds. The size of ponds depends on the purpose of fish farm. There are two major types of farming:
 - a. Restricted farming: it consists of few ponds in which farmers buy the fry and fingerling from the hatchery and rear them to the marketable size.
 - b. Complete fish farming: it consists of many ponds where fish are bred, eggs are hatched, fry reared, fingerlings are raised to marketable size.

Fish pond should be well managed for better productivity which can be done in the following ways:

1. Controlling the aquatic vegetation: All undesirable plants, weeds must be removed regularly by using various method of weed control. The pond should be emptied, dried, cleaned in the regular interval after harvesting fishes.
2. Liming: After drying, Lime (Cao) is sprayed over the bottom of the pond which improve productivity as it has antiparasitic action, destroys unwanted weeds and improves pH of soil.
3. Manuring: this process increases the productivity of the pond by increasing the number of natural foods. Blooming of phytoplankton and heavy growth of zooplankton serve as the natural food for cultivated fish.
4. Artificial feeding: fish production can be greatly enhanced by artificial feeding and the feed should be simple and cheap. Feed ingredients include rice bran, oil cake, kitchen waste, fish meal, meat etc.
5. Controlling predatory and weed fishes: The fishes which feed on cultivated fishes are are called predatory fishes. Example: *Channa spp.* Similarly, those fishes which consume the food of pond and compete with the cultivated fishes are weed fishes. Example: *Puntius spp.* Such fishes should be eradicated or controlled.
6. Control of Physico-chemical parameter: Various physical and chemical parameter of the pond which influence on the productivity of fishes such as depth of the pond temperature, light penetration, turbidity, pH, dissolved oxygen by continuous aeration, soil nutrients etc. should be maintained optimal according to the species of fish reared.
7. Harvesting: Harvesting is done after the fishes attain marketable size which is by draining the water through outlet. This process also helps to eliminate predators.

Cage fish culture

Cage fish culture is the practice of raising fish in a large floating or submerged cages placed in pond, lake reservoirs etc. Cage culture can be practiced in areas like swamps where there is water not being used for any other purpose. The cages of various shape such as square, rectangular, circular, or boat shape are used in many countries. Size of cage varies greatly from 40-10000 m³. Cages of variable sizes are made from durable material such as nylon rope, steel frames. Generally, outer surface of cage remains above water surface.



Advantages

1. Possibility of using maximum use of all available water resources
2. Initial investment is relatively small and easy installation
3. Management and inspection easy
4. Easiness in control of predators, parasites and disease
5. Can be shifted to safe place at emergency
6. Fish harvesting is easy and flexible

Integrated fish farming:

Integrated fish farming is the technique where fish farming is integrated or combined with other types of agricultural activities. Such as paddy cum fish farming, pig cum fish farming, duck cum fish farming, livestock cum fish farming etc. This type of farming is beneficial for small scale and rural farmers as it promotes diversified income and resource efficiency.



Benefits

- i. Integrated fish farming combines the fish culture with crops or livestock farming which makes efficient use of resources.
- ii. It helps in recycling nutrients such as animal waste can be used to fertilize pond water, promoting plankton growth for fish.
- iii. Overall farm productivity can be increased such as fish, crops, and livestock on the same land.
- iv. This type of farming promotes sustainable agriculture by maintaining ecological balance and improving soil and water quality.
- v. Farmers are benefitted from diversified income which enhances food security and reduces financial risk.
- vi. It reduces production costs by minimizing the need of chemical fertilizers.

- vii. It also reduces environmental pollution by turning waste from one system into input for another.

Breeding techniques in fish farming

1. Natural breeding: During breeding season, Ripe female and ripe male fish in the ratio 1:2 is introduced into the breeding hapas in a breeding pond. The breeders spawn in the hapa when hapa is placed near the source of flowing water.
2. Semiartificial breeding:
It is done in cemented tanks provided with kakaban. The male and female fish are injected pituitary extract solution to make them sexually matured. After 12 hours of injection, breeders spawn on the kakaban.
3. Artificial or induced breeding:
The mature male fish is that which releases milt after applying gentle pressure around its genital opening. Similarly, mature female fish has extended and swollen belly with protruded and reddish genital opening. Injection of pituitary extract (hypophysation) is done to both (Female=3mg/kg, male= 1mg/Kg). After 12 hours of injection, each breeder fish is stripped. Ova are collected and mixed with the milt which is stirred immediately by feather. Equal volume of fertilizing solution (carbamide solution) is added to the mixture to prevent sticking of eggs. The mixture is stirred continuously for some time for fertilization and finally fertilized eggs are transferred into incubator.



Hapa



Stripping



Kakaban

Importance of fish farming

1. Fish farming has brought a lot of income to the farmers and contributed to the nation's economy.
2. Fish is a highly nutritious food, rich in proteins, vitamins (A and D), minerals, iodine and omega-3 fatty acids, which are essential for human health
3. Fish oil and liver are also rich in omega 3 fatty acid and vitamins
4. Fishmeal and manures and produced from waste part of fish used to feed poultry, pig, cattle etc.
5. Fish skin used to manufacture shoes, hand bags
6. Some fishing activities, like boating and angling, enrich people's lives with fun and recreation.
7. Fish farming drives research and innovation in areas such as fish breeding, genetic improvement, fish health management etc.

Project work

Write a comprehensive report on fish farming nearby your locality which includes its definition, various methods, operational process and benefits.

Exercise

Choose the best alternative.

1. Which of the following liquid is required for amniocentesis?
 - a. Blood
 - b. Amniotic fluid
 - c. lymph
 - d. urine

2. Process of forming testtube baby is also called
 - a. Artificial insemination
 - b. In-vivo fertilization
 - c. In-vitro fertilization
 - d. In-situ fertilization

3. A couple is performing Pre-implantation Genetic Testing during IVF. Which of the following is a valid reason?
 - a. To guarantee the child's intelligence
 - b. To ensure the baby has blue eyes
 - c. To screen for inherited genetic disorders
 - d. To increase the chance of having twins

4. In which time of pregnancy, amniocentesis is typically performed?
 - a. 14th -15 weeks
 - b. 8th – 10th weeks
 - c. 20th - 25th weeks
 - d. 4th week

5. Which of the following is a valid reason associated with the use of amniocentesis?
 - a. It is not accurate in detecting genetic conditions
 - b. It may influence decisions about continuing a pregnancy based on sex or disability.
 - c. It increases fertility

6. It is used to increase the chance of multiple births
 - a. Avoid natural conception
 - b. Infertility due to blocked fallopian tubes
 - c. Wanting twins
 - d. Gender selection

7. **Which type of transplant is called, between two genetically identical individuals?**
- a. Allograft
 - b. Autograft
 - c. Xenograft
 - d. Isograft
8. **A person with a transplanted heart is suggested to avoid crowds and sick individuals. What is this advice suggested?**
- a. To maintain stable heart rate
 - b. To prevent exposure to infections
 - c. To avoid low blood pressure
 - d. To reduce stress
9. **Which blood test is essential for matching organ donors and recipients?**
- a. Complete blood count (CBC)
 - b. Liver function test (LFT)
 - c. Tissue typing (HLA typing)
 - d. Glucose tolerance test
10. **Identify the term for the body's immune system attacking a transplanted organ**
- a. Infection
 - b. Intolerance
 - c. Rejection
 - d. Mutation
11. **A patient receives a kidney transplant and is medicated immunosuppressive drugs. What is the main reason for continuation of this medication long-term?**
- a. To increase urine output
 - b. To reduce the risk of organ rejection by the immune system
 - c. To promote faster healing of wound
 - d. To prevent the formation of kidney stones
12. **Which method is commonly used to create transgenic animals?**
- a. Mating of two different animal

- b. Microinjection of foreign DNA into a fertilized egg
- c. Feeding genetically modified food to the animal
- d. Using only natural selection

13. What is a transgenic animal?

- a. An animal that is cloned
- b. An animal containing a gene from another species
- c. An animal produced through selective breeding
- d. An animal which lives in multiple habitats

14. The first transgenic animal was produced in which species?

- a. Sheep
- b. Mouse
- c. Cow
- d. Pig

15. Which breed of chicken is commonly used for egg production?

- a. Broiler
- b. Leghorn
- c. Rhode Island Red
- d. Cornish

16. What is culling?

- a. Vaccinating all healthy birds
- b. Feeding birds special grains
- c. Eliminating sick, unproductive, or weak birds from the flock
- d. Allowing birds to roam freely

17. A farmer wants to reduce the use of antibiotics in poultry farming. What is the best alternative strategy to maintain flock health?

- a. Feeding birds only once a day
- b. Vaccinate birds
- c. Increase the stocking density
- d. Give birds untreated water

18. Which of the following is exoetic fish?

- a. Silver carp c. Rahu
- b. Naini d. Asala

19. Young female chicken under one year old is called?

- a. Pullet c. Chick
- b. Rooster d. Hen

20. What is the main purpose of liming in fish ponds?

- a. Increase water temperature
- b. Reduce oxygen levels
- c. Correct soil acidity and improve water quality
- d. feed the fish

21. In which animal farming system are movable enclosures used to rotate birds across grazing land?

- a. Intensive system
- b. Extensive system
- c. Folding unit system
- d. Backyard system

Answer the following questions in brief.

1. What fertility technology would you recommend for a same sex married couple who wishes to have a child using partners egg and doner's sperm? Explain this technology in brief.
2. Describe the various types of tissue and organ transplantation? What are the ways adopted to prevent rejection?
3. Briefly mention the pros, cons and ethical issues regarding in-vitro fertilization?
4. What is amniocentesis? How is it done? Describe its advantages and disadvantages?
5. Describe briefly about the scope and importance of poultry farming in the context of Nepal.
6. What is fish farming? Nepal has a great scope of fish farming. Justify
7. Write short note on transgenic animals with their advantages and disadvantages.

Chapter 10.2

MICROBIAL DISEASES AND APPLICATION OF MICROBIOLOGY



Henrietta Lacks (1920-1951), who was from Roanoke, Virginia, died of cervical cancer at the age of thirty-one. Upon her death, doctors discovered that cells from her body lived long lives and reproduced indefinitely in petri dishes. The cells were given the name "**HeLa cells**" in the name of Henrietta Lacks. These "**immortal**" HeLa cells, have since contributed to over 10,000 medical patents relating to polio, AIDS, Parkinson's disease, and other conditions. For this reason, she is considered the "**Mother of Modern Medicine**".

Observe the figures given below and discuss the following questions with your classmates?

1. Out of the six figures A, B, C, D, E, and F, which one shows patient suffering from elephantiasis and why, which one from HIV/AIDS and why, which one from candidiasis and why, which one from typhoid and why, which one from malaria and why, and which one from schistosomiasis and why?



A



B



C



Figure A shows microbial disease HIV/AIDS due to virus, figure B typhoid fever due to bacteria, figure C oral candidiasis due to fungi (yeast), figure D malaria due to protozoa, figure E schistosomiasis due to blood fluke, and figure F filaria due to filarial worm.

World Health Organization (WHO) declares **health** as a state of complete physical, mental, and social wellbeing and not merely absence of disease or infirmity. So, any deviation from normal state of health physically, physiologically, mentally or psychologically, and socially is called **disease**. Diseases may be caused due to various reasons. One of the main reasons is **microorganisms** or **microbes**. The disease caused by **microorganisms** or **microbes** is called **microbial diseases**.

Microbial disease is any disturbance from normal state that causes discomfort, disability or impairing of health due to the effect of microorganisms or microbes. Microorganisms or microbes may be non-pathogenic causing no diseases and useful, may be pathogenic causing diseases and harmful, and may be pathogenic causing diseases and deadly harmful. Hence, it becomes necessary to study **risk and hazard group of microorganisms** to assess their impact on living beings including man.

1. Risk and hazard group of microorganisms

Risk is chance, high or low, that any hazard will actually cause somebody harm, e.g., microorganisms whereas **hazard** is something that has potential to cause harm, e.g., pathogens.

Microorganisms or microbes, on the basis of whether they cause diseases or not, if cause diseases then treatable or untreatable and preventable or unpreventable, are classified into four risk groups:

I. Risk group 1

Risk group 1, abbreviated as **RG-1** includes such microorganisms which do not cause diseases in healthy adult humans, e.g., virus (influenza virus and rotavirus), bacteria (*Escherichia coli*, *Lactobacillus acidophilus*, and *Bacillus subtilis*), fungi (*Aspergillus niger*), and yeast (*Saccharomyces cerevisiae*).

II. Risk group 2

Risk group 2, abbreviated as **RG-2** includes such microorganisms which can cause diseases in humans, but diseases are treatable or preventable, e.g., virus (Herpes virus), bacteria (*Streptococcus pneumonia*), fungi (*Aspergillus flavus*), yeast (*Candida albicans*), protozoa (*Plasmodium vivax* and *Leishmania donovani*), and eggs and larvae of helminthes like flatworms (lung fluke, blood fluke, tapeworm, hydatid worm) and roundworms (filarial worm and eye-worm).

III. Risk group 3

Risk group 3, abbreviated as **RG-3** includes such microorganisms which cause serious diseases in humans, and treatment and vaccines for these diseases exist, e.g., virus (HBV, HCV, HIV, and SARS virus), bacteria (*Salmonella typhi*, *Mycobacterium tuberculosis*, and *Yersinia pestis*) and fungi (*Blastomyces dermatitidis*).

IV. Risk group 4

Risk group 4, abbreviated as **RG-4** includes such microorganisms which cause deadly diseases in humans, and they can easily travel from one person to another, and for which no treatment and vaccines exist, e.g., virus (Ebola virus, Marburg virus, and Lassa virus).

In contrast to risk groups (RGs), biosafety levels (BSLs) prescribe procedures and levels of containment for particular microorganisms. Primary risks that determine levels of containment are infectivity, severity of disease, transmissibility, and nature of the work conducted. There are four BSLs. Each level has specific controls for containment of microbes and biological agents. Four BSLs, on the basis of RGs are:

I. Biosafety level 1

Biosafety level 1, abbreviated as **BSL-1** is for RG-1 microbes.

II. Biosafety level 2

Biosafety level 2, abbreviated as **BSL-2** is for RG 2 microbes.

III. Biosafety level 3

Biosafety level 3, abbreviated as **BSL-3** is for RG 3 microbes.

IV. Biosafety level 4

Biosafety level 4, abbreviated as **BSL-4** is for RG 4 microbes.

Generally, there are six hazards in human life:

I. **Biological hazards**, e.g., microorganisms, blood, body fluids, harmful plants, sewage, dust, vermin, etc.

II. **Chemical hazards**, e.g., skin irritation, respiratory system irritation, blindness, corrosion, explosions, etc.

III. **Physical hazards**, e.g., altitude, noise, radiation, pressure, etc.

IV. **Safety hazards**, e.g., damaged furniture, exposed wire, etc.

V. **Ergonomic hazards**, e.g., poor office setup, poor posture, etc.

VI. **Psycho-social hazards**, e.g., sexual harassment, victimization, stress, workplace violence, etc.

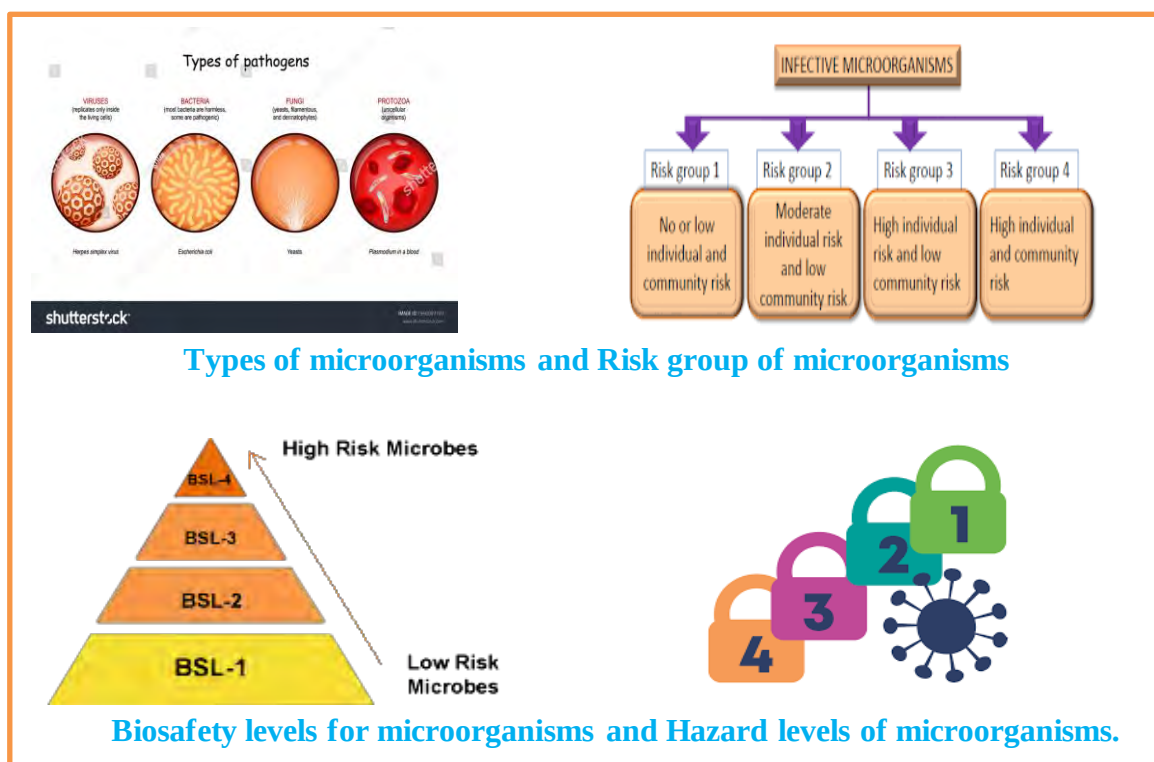
Out of the six hazards in human life, biological hazards are due to **biological agents**. It means biological hazards include biological agents. The biological agents may be toxins, allergens, carcinogens, or microbes. All types of microbes do not cause diseases. The microorganisms or microbes causing diseases are known as **pathogens** and the diseases called **pathogenic diseases**. The disease-causing microbes called pathogens are basically five types: **virus**, **bacteria**, **fungi**, **protozoa**, and **worms** (very few species of **flatworms** like blood fluke and **roundworms** like filarial and eye worm). Human pathogens, on the basis of ability to cause infection, severity of the disease that may result, risk that infection will spread to population, and availability of vaccines and effective treatment are classified into four hazard groups:

Do you know?

Not all worms are microorganisms or microbes however, some parasitic worms, especially those classified as helminthes (fluke and tapeworm under flatworms and filarial- and eye-worm under roundworms), are often kept within the field of microbiology due to their microscopic life-stages, particularly their eggs and larvae. Microorganisms are typically single-celled and microscopic, but helminthes, though multicellular, on the other hand, are included under microorganisms or microbes because of their parasitic and microscopic nature of their eggs and larvae.

I. Hazard group 1

Hazard group 1, abbreviated as **HG-1** is biological agent that is unlikely to cause human disease.



II. Hazard group 2

Hazard group 2, abbreviated as **HG-2** is biological agent that can cause human disease and may be a hazard but is likely to spread to community and there is usually effective prophylaxis or treatment available.

III. Hazard group 3

Hazard group 3, abbreviated as **HG-3** is biological agent that can cause severe human disease and may be a serious hazard and it may spread to community but there is usually effective prophylaxis or treatment available.

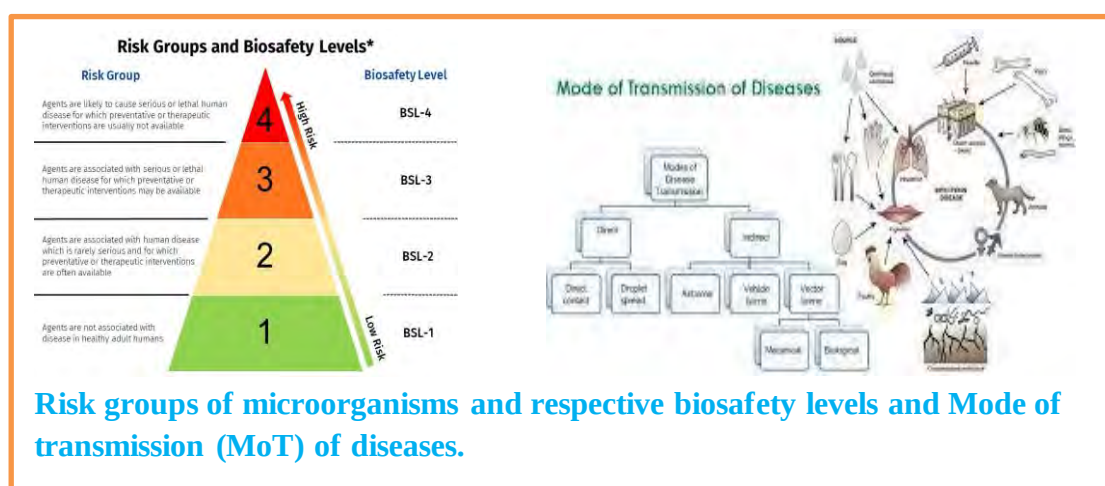
IV. Hazard group 4

Hazard group 4, abbreviated as **HG-4** is biological agent that causes severe human disease and is a serious hazard and it is likely to spread to community and there is usually no effective prophylaxis or treatment available.

When summarized, risk and hazard group of microorganisms/pathogens need biosafety levels as follows as:

I. **BSL-1** is for **RG-1** microorganisms or **HG-1** pathogens.

II. **BSL-2** is for **RG-2** microorganisms or **HG-2** pathogens.



III. **BSL-3** is for **RG-3** microorganisms or **HG-3** pathogens.

IV. **BSL-4** is for **RG-4** microorganisms or **HG-4** pathogens.

Activity

Point out which hazardous group of microorganisms or microbes causes diseases like influenza, hepatitis, HIV/AIDS, typhoid, tuberculosis, cholera, candidiasis, schistosomiasis, and filariasis. Support your activity with the help of which risk group of microbes are they included and which safety level do they require?

2. Human microbial diseases

Human microbial diseases are illness caused by pathogens that get into body. Most common pathogens causing diseases are virus, bacteria, fungi, and protozoa. **Mode of transmission (MoT)** is transmission of pathogens from reservoirs of infection to healthy persons. The MoT occurs through two ways: direct transmission (contact with infected person, droplet infection, etc.) and indirect transmission (through vectors).

Do you know?

Diseases caused by newly identified microbes are: COVID-19, MERS, SARS, smallpox, influenza, tick-borne diseases, West Nile fever, plague, fungal diseases, and schistosomiasis.

Human microbial diseases usually spread from person to person, through contaminated food or water and through contact. Some human microbial diseases are minor (influenza, typhoid, candidiasis, etc.) and some very serious (HIV, tuberculosis, cholera, hepatitis). Human microbial diseases are physical, acquired, and communicable (influenza, typhoid, candidiasis, etc.) or non-communicable (cancer). Some microbial diseases are epidemic (plague), some endemic (chickenpox), and some pandemic (malaria, cholera, etc.). Some human microbial diseases are epizootic (SARS, swine flu, etc.), some enzootic (influenza), and some zoonotic (Ebola virus). Some of the human microbial diseases are: influenza, hepatitis, HIV/AIDS, typhoid, tuberculosis, cholera, and candidiasis.

I. Influenza

i. Introduction

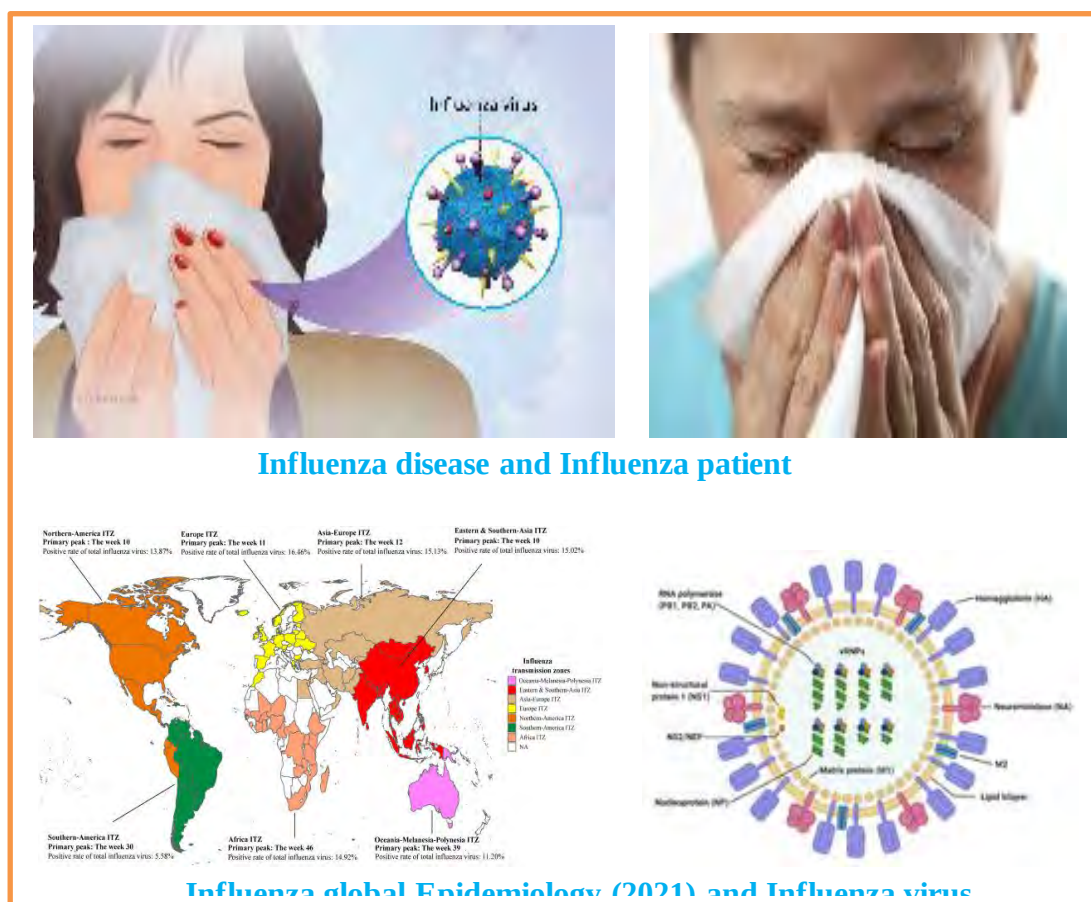
Influenza, also known as '**flu**' or '**grippe**' is an acute viral infection of the upper or lower respiratory tract that is marked by fever, chills, and a generalized feeling of weakness and pain in the muscles, together with varying degrees of soreness in head and abdomen.

It is contagious respiratory illness caused by influenza viruses that can infect nose, throat, and lungs, potentially causing mild to severe illness. In Nepal, influenza is known as '**rugha**' (vern.). Here, in this country Nepal, its season of huge contract is winter however, it may occur in any season.

ii. Description of influenza

Influenza is known as **physical disease** as it affects physical parts like upper and lower respiratory tract. This is a type of **acquired disease** because it tends to affect one's own body after getting birth. Influenza is considered **communicable disease** as it is spread from one human host to another. It is considered **endemic disease**, however, it may become **epidemic disease** and also **pandemic disease**. Influenza is considered **enzootic disease** because it contracts from one man to another. It is called **air-borne disease** as pathogens are transferred from one person to another through droplets.

November 1 is observed as "**World Influenza Day**".



iii. Epidemiology

Influenza may have been brought to the Americas as early as 1493, when an epidemic disease resembling influenza killed most of the population of the Antilles. The first convincing report of an influenza pandemic was recorded in 1510. It began in East Asia before spreading to North Africa and then Europe. Influenza is a seasonal epidemic disease and becomes pandemic after every 50 years of time.

Peoples of **high risk** are children under 5 years of age, especially those under 6 months of age, adults older than 65 years of age, residents of nursing homes and other long-term health care faculties, pregnant women and women up to two weeks after giving birth, people with weak immune system, people having chronic disease like heart, kidney, and liver disease, diabetes, asthma, etc. including highly obese-person

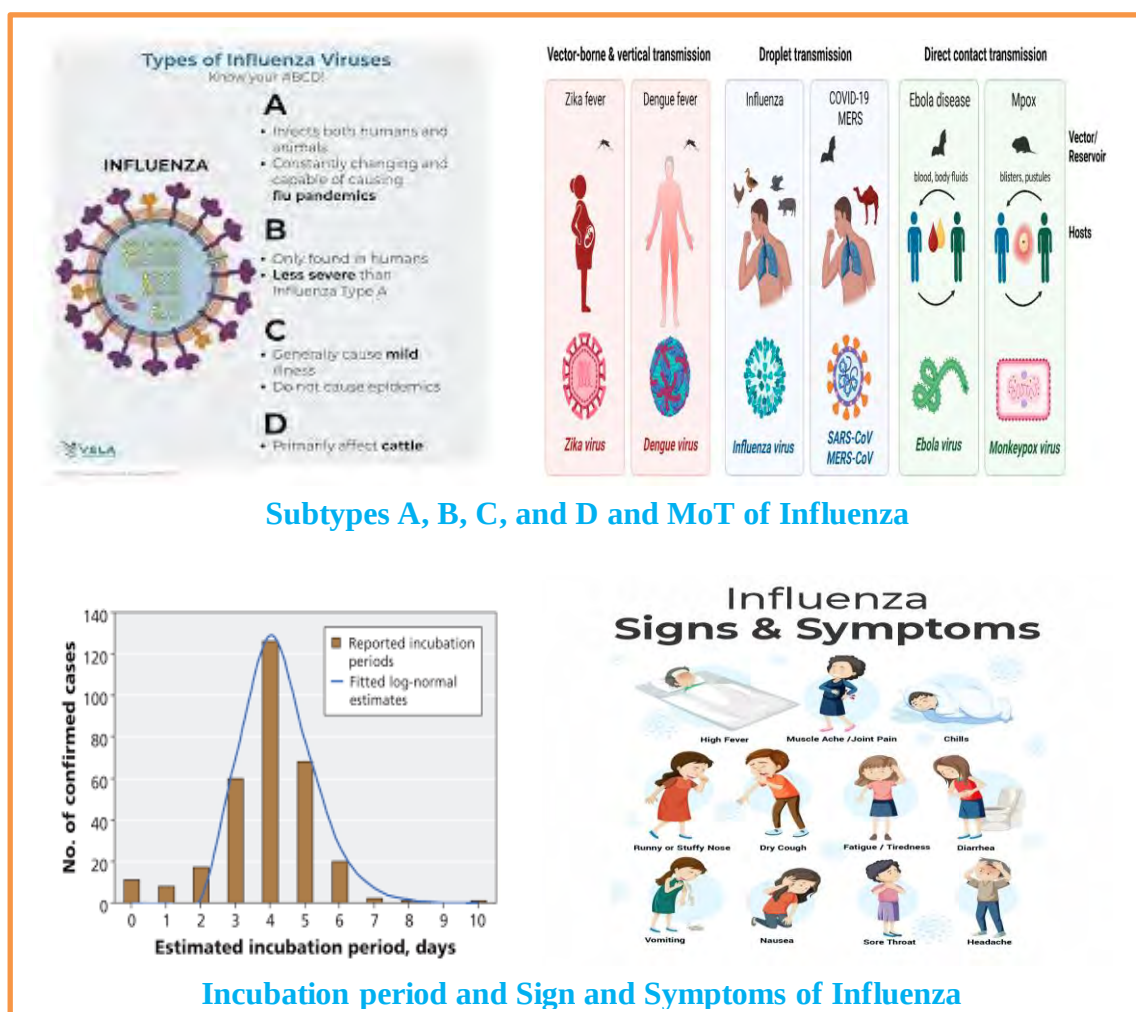
iv. Causative agent

Causative agent of the respiratory tract causing influenza is **influenza viruses**, which are **RNA viruses** of the genus *Orthomyxovirus*. The influenza viruses are classified into four types – A, B, C, and D. Only types A (sub-types H₁N₁ and H₃N₂) and B (sub-types B-Yamagata and B-Victoria) commonly cause illness to man.

Influenza viruses are four types – A, B, C, and D, out of which A and B viruses are the most common causes of seasonal epidemics in man especially in winter season.

v. Mode of transmission

Mode of transmission, abbreviated as **MoT** is **direct transmission** from person to person. People with flu can spread it to others up to about 2 m away. It spreads mainly by droplets made when people with flu cough, sneeze, or talk when these droplets can land in mouths or noses of people who are nearby or possibly be inhaled into the lungs.



vi. Incubation period

Incubation period is two days long on an average but may range from 1 to 4 days.

Do you know?

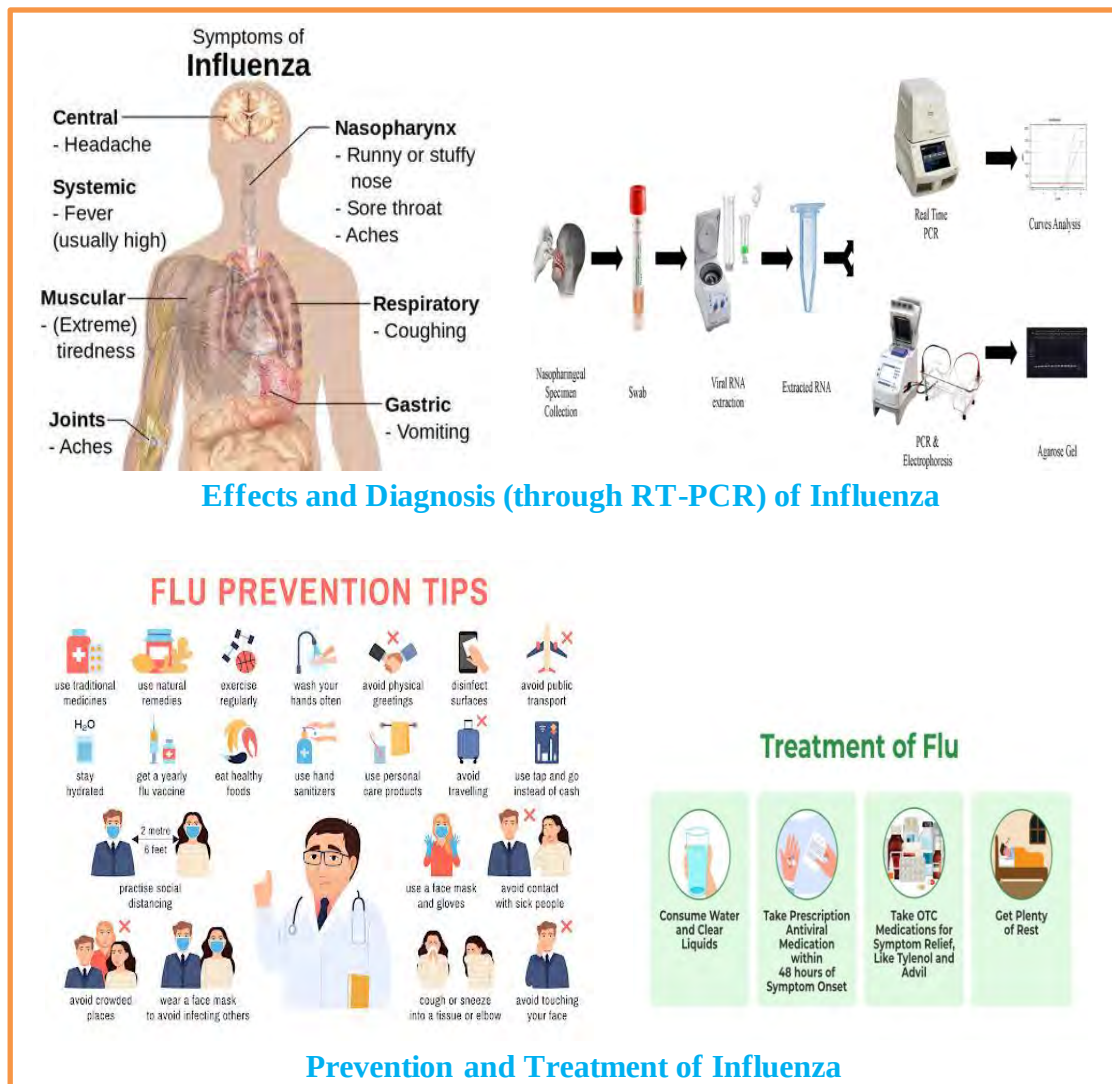
Sub-types of type A influenza virus like H₅N₁ and H₇N₉ (avian influenza viruses) and H₁N₁, H₁N₂, and H₃N₂ (swine influenza virus) may contract man.

vii. Sign, symptom, and clinical features

Generally, common cold with runny or stuffy nose, sneezing, and sore throat however, common signs and symptoms include: fever, aching muscles, chills and sweats, headache, dry and persistent cough, shortness of breath, tiredness and weakness, eye pain, and in children, vomiting and diarrhoea.

viii. Effects seen in patients

- Influenza affects nose, throat, and lungs followed by fever, chills, weakness and pain in muscles, and soreness in head and abdomen.



- **Complications** are pneumonia, bronchitis, asthma flare-ups, heart problems, ear infections, acute respiratory distress syndrome (ARDS), and sinus infections.

ix. Diagnosis

Diagnosis is through RT-PCR, viral culture, and immuno-fluorescence assays.

x. Prevention

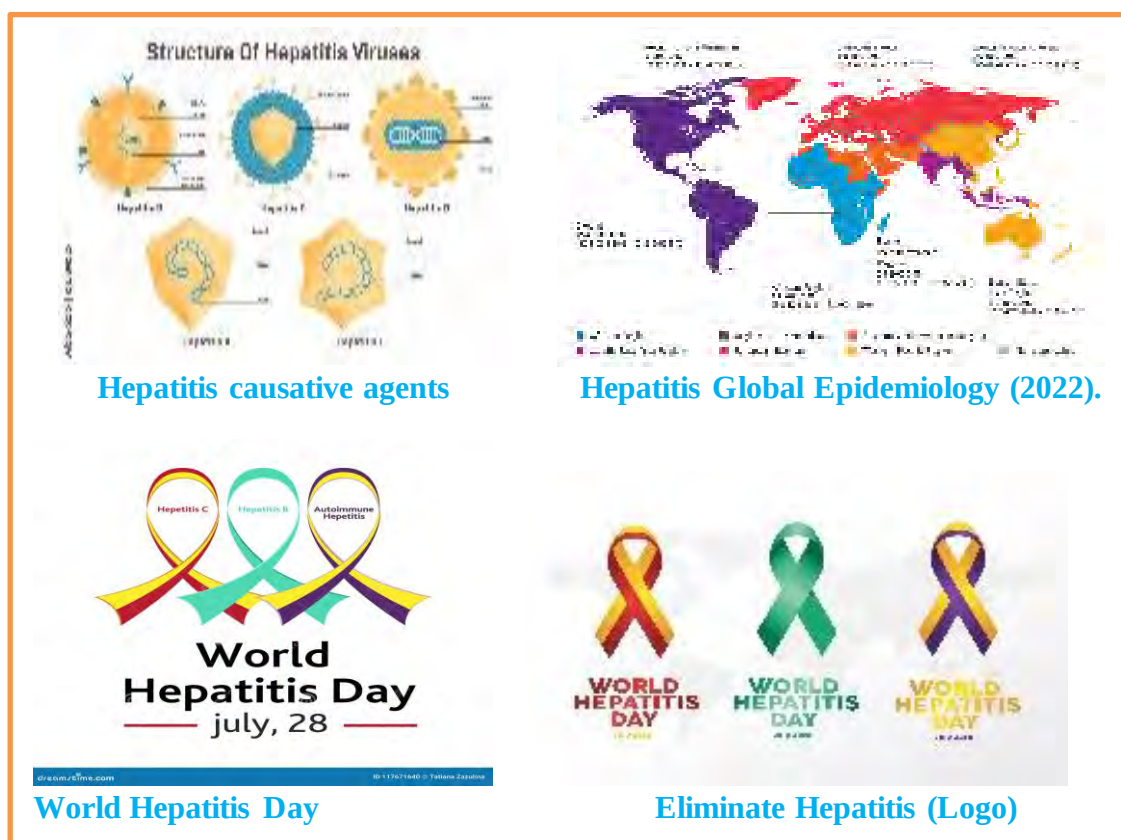
Following are the ways of prevention – washing of hands and feet, avoid touching face, covering of coughs and sneezes, clean surfaces, avoid crowds, use masks, and vaccination.

xi. Control measures/Treatment

Drugs like Tamiflu, Relenza, Rapivap, etc. as prescribed by the physician.

II. Hepatitis

Hepatitis, also called **inflammation of liver** is the inflammation of liver parenchyma caused by a variety of infectious viruses and noninfectious agents leading to a range of health problems, some of which can be fatal. In Nepal, hepatitis is called '**kalejo ko rog**' (vern.) or '**kamalpitta**' (colloq.) however, in Sanskrit, it is called '**yakritshodh**' which means 'inflammation of liver'.



July 28 is observed as "**World Hepatitis Day**".

According to WHO study, an estimated 4.5 million premature deaths could be prevented in low- and middle-income countries by 2030 through vaccination, diagnostic tests, medicines and education campaigns. Global hepatitis strategy set by WHO and endorsed by all WHO Member States, aims to reduce new hepatitis infections by 90% and deaths by 65% between 2016 and 2030.

There are five types of hepatitis – hepatitis A, hepatitis B, hepatitis C, hepatitis D, and hepatitis E caused by five main strains of hepatitis virus, referred to as types A, B, C, D, and E, respectively indicating as HAV, HBV, HCV, HDV, and HEV. While they all cause liver disease, they differ in epidemiology, causative agent, causes of contract, modes of transmission, incubation period, severity of illness, zoogeography, and preventive measures.

i. Hepatitis A

A. Introduction

Hepatitis A which is also called '**travelers' hepatitis**', **epidemic jaundice** or **infectious hepatitis** is a viral disease.

B. Description

Hepatitis A is designated as **physical disease** because it affects physical parts like liver. It is known as **acquired disease** as it occurs to affect one's own liver only after birth. Hepatitis is known as **communicable disease** as it contracts from person to person or spreads through contaminated water and food hence, it is contagious disease. It is **endemic**, **epidemic**, or **pandemic** depending on the location and specific context.



Hepatitis A disease



Hepatitis A causative agent

C. Epidemiology

HAV was reported in 1940 however, outbreaks of jaundice, probably hepatitis A, was reported in 17th and 18th centuries, particularly in association with military campaigns. Hepatitis A is preventable through vaccination. Hepatitis A is epidemic however, it is endemic in Kathmandu and is the most common type of hepatitis in Kathmandu.

The **risk factors** are poor sanitation, lack of safe water, living in a household with an infected person, being a sexual partner of someone with acute hepatitis A infection, use of recreational drugs, sex between men, and travelling to areas of high endemicity without being immunized.

D. Causative agent

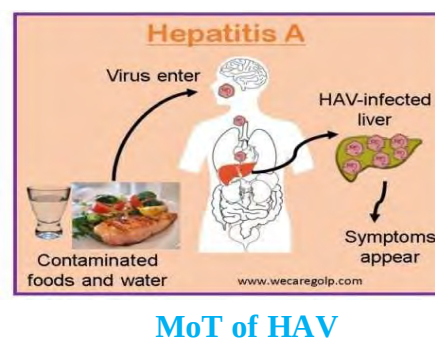
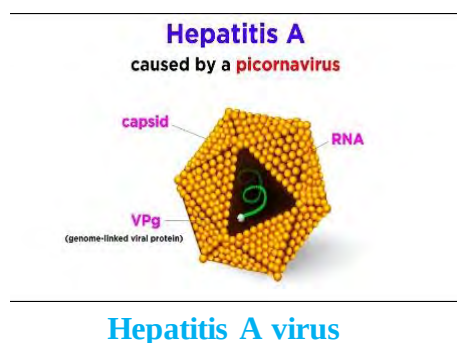
Hepatitis A is caused by **hepatitis A virus (HAV)**. HAV is a RNA virus.

E. Causes of contract

Causes of contract of hepatitis A are ingestion of contaminated food and water and personal contact with an infected person through sexual contact, sharing needles, or living in the same household.

F. Mode of transmission

Mode of transmission, abbreviated as **MoT** of HAV is **direct transmission** through faeco-oral route as well as through infected person via sexual contact, sharing needles, or living in the same household.

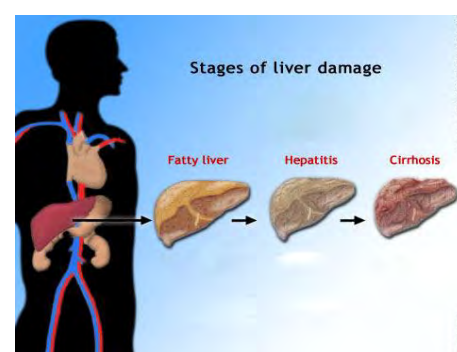
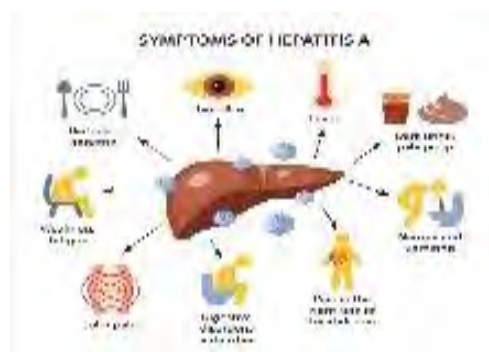


G. Incubation period

Incubation period of hepatitis A is 2-6 weeks (average 7-28 days).

H. Sign, symptom, and clinical features

Hepatitis A is mild to severe liver inflammation including fever, malaise, loss of appetite, diarrhoea, nausea, abdominal discomfort, dark-coloured urine, and jaundice (yellowing of the eyes and skin).



I. Effects seen in patients

Hepatitis mainly affects liver parenchymatous cells causing liver cirrhosis. Drinking alcohol increases the risk of liver cirrhosis.

J. Diagnosis

Hepatitis A: Blood test (IgM and IgG against HAV or anti-HAV test) and Molecular test (RT-PCR to detect RNA of HAV in blood or stool).

Hepatitis A - Diagnosis

- Three serologic markers available:
 1. Hepatitis A Total (IgG and IgM) antibody
 2. Hepatitis A IgM
 3. Hepatitis A IgG
- First tests available since 1978
- No antigen test
- Antibody response is similar following vaccination or wild type infection
- Incubation time is 7 to 28 days

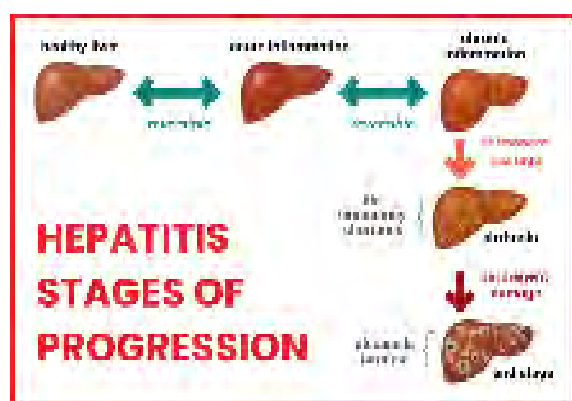
Diagnosis of HAV



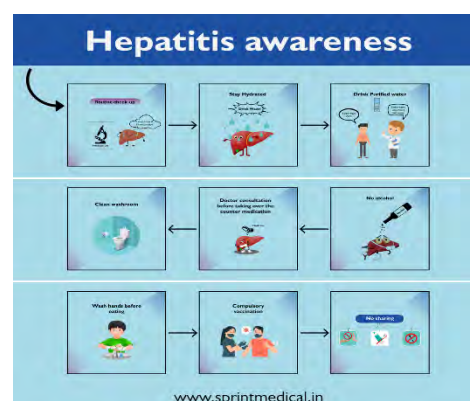
Prevention of HAV

K. Prevention

Hepatitis A can be prevented by vaccination as well as by personal hygiene and sanitation.



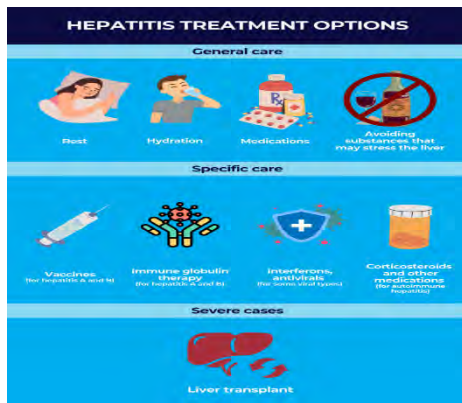
Hepatitis awareness for all types of hepatitis



Stages of Infection of all types of Hepatitis

L. Control measures/Treatment

Treatment can be done with the help of drugs prescribed by physicians.



Hepatitis treatment of all types of hepatitis

TREATMENT OF HEPATITIS A



HAV treatment

ii. Hepatitis-B

A. Introduction

Hepatitis B that is also called ‘**serum hepatitis**’ in which chances of transmission is 100 times more than that of HIV/AIDS is a viral disease.

B. Description

Hepatitis B is designated as **physical disease** because it affects physical parts like liver. It is known as **acquired disease** as it occurs to affect one's own liver only after birth. Hepatitis B is known as **communicable disease** as it contracts from person to person through infected blood, semen, or certain other body fluids hence, it is contagious disease. It is **endemic**, **epidemic**, or **pandemic** according to specific situations. Hepatitis B is spread through sexual contact, sharing needles or syringes, and from mother to child during birth.



Hepatitis-B Patient



Hepatitis B causative agent

C. Epidemiology

Outbreaks of jaundice, probably hepatitis B, were reported in 17th and 18th centuries, particularly in association with military campaigns. Hepatitis B started in North Africa and in the middle-east and then spread throughout the world. In 1940, HBV were reported.

In particular, type B lead to chronic disease in hundreds of millions of people and living together with infected persons are the most common cause of liver cirrhosis, liver cancer, and viral hepatitis-related deaths. An estimated 354 million people worldwide live with hepatitis B, and for most, testing and treatment remain beyond reach.

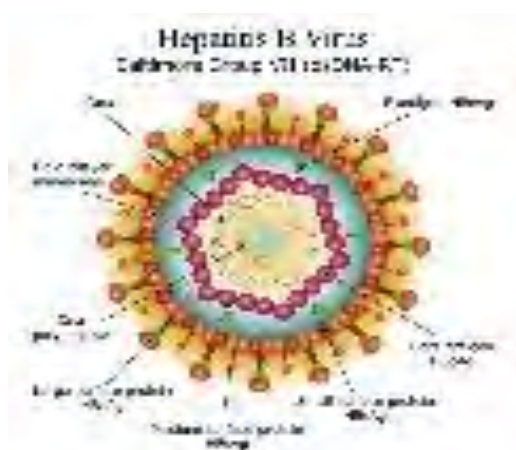
Some types of hepatitis are preventable through vaccination. According to WHO study, an estimated 4.5 million premature deaths could be prevented in low- and middle-income countries by 2030 through vaccination, diagnostic tests, medicines and education campaigns. Global hepatitis strategy set by WHO and endorsed by all WHO Member States, aims to reduce new hepatitis infections by 90% and deaths by 65% between 2016 and 2030.

Hepatitis B is considered both an epidemic and endemic. It becomes epidemic in certain regions or populations, when outbreaks occur and is endemic as a constant and widespread disease.

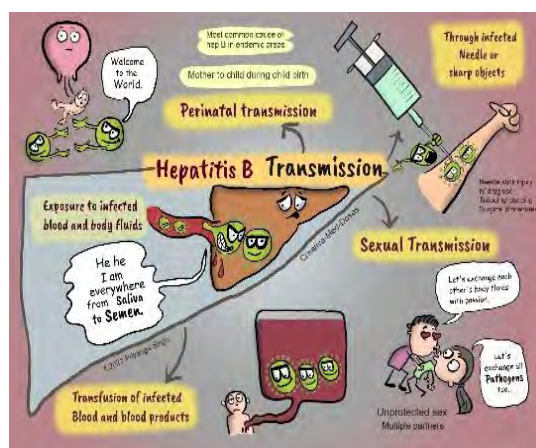
Risk factors are exposure to infected bodily fluids, such as blood and semen including sexual contact, sharing needles, or drug-injection equipment, or contact with contaminated medical instruments. Additionally, individuals born to mothers with hepatitis B, those with multiple sex partners, and those who live in areas where the virus is prevalence.

D. Causative agent

Hepatitis B is caused by **hepatitis B virus (HBV)**. HBV is a DNA virus. HBV has Dane's particles and has three antigens – surface antigen (HbsAg), core antigen and HbE antigen.



Hepatitis B virus



MoT of HBV

E. Causes of contract

Primarily, the causes of contract of hepatitis B are exposure to bodily fluids like blood, semen, and vaginal fluids from an infected person. It also can happen through sexual contact, sharing needles, or from mother to child during birth.

F. Mode of transmission

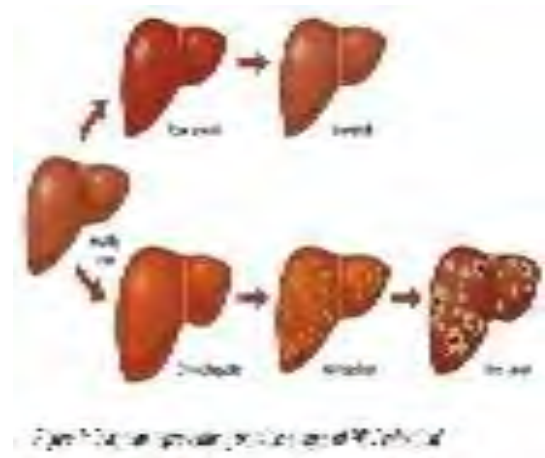
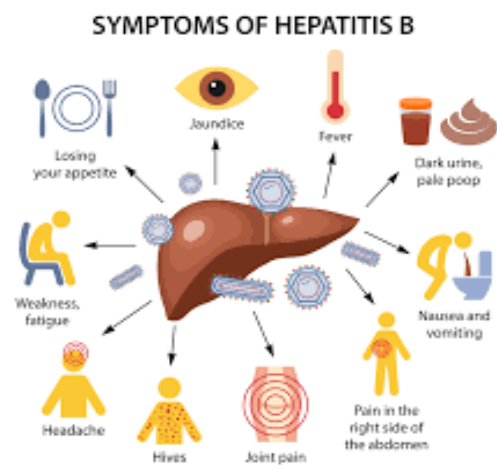
Mode of transmission, abbreviated as **MoT** of HBV is **direct transmission** through parental transmission or from unprotected sexual intercourse via blood, semen or other body fluids.

G. Incubation period

Incubation period of hepatitis B 2-26 weeks (average 8 weeks).

H. Sign, symptom, and clinical features

Hepatitis B shows fever, fatigue, loss of appetite, nausea, vomiting, abdominal pain, dark-urine, and clay-coloured bowel movements.



Sign, Symptoms, and Clinical features of HBV

Effects given by HBV

I. Effects seen in patients

Hepatitis mainly affects liver parenchymatous cells causing liver cirrhosis. Drinking alcohol increases the risk of liver cirrhosis.

J. Diagnosis

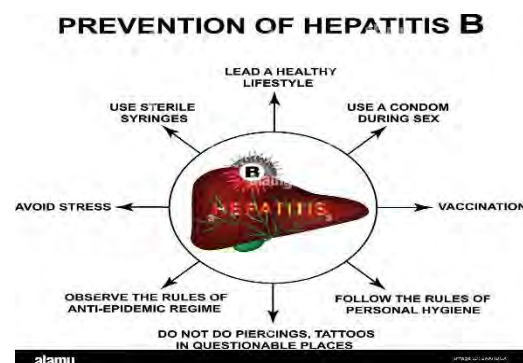
Hepatitis B: hepatitis B surface antigen test (HbsAg).

Hepatitis B – Laboratory Tests

Serologic markers:

- 1) HBsAg (Hepatitis B surface antigen):
 - if positive, person is infectious
- 2) HBsAb (Antibody to HBV surface antigen):
 - indicates immunity to HBV and protection from disease
- 3) HBcAb (Antibody to HBV core antigen):
 - Total - indicates past or active infection
 - IgM - early indicator of acute infection
- 4) HBeAg (Hepatitis B e antigen):
 - Selecting patients for therapy
- 5) Anti-HBe (Antibody to HBV e antigen):
 - prognostic for resolution of infection

Diagnosis of HBV Prevention of HBV



Prevention of HAV

K. Prevention

Hepatitis B is prevented by safe sex, screening of blood and blood products, etc.

iii. Hepatitis-C

A. Introduction

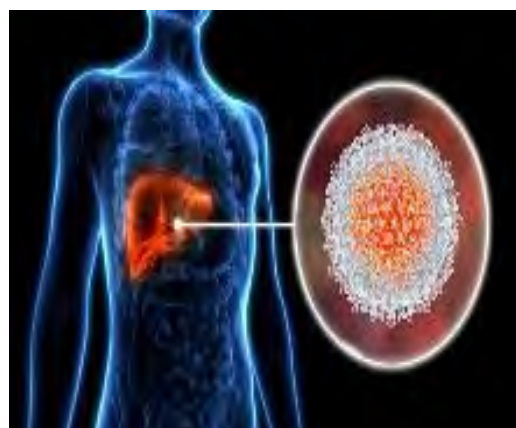
Hepatitis C which is also called ‘**silent killer**’ is a viral disease.

B. Description

Hepatitis C is designated as **physical disease** because it affects physical parts like liver. It is known as **acquired disease** as it occurs to affect one's own liver only after birth. It is **communicable disease** as it contracts from person to person or spreads through contaminated water and food. It is silent **epidemic** however it may be **pandemic** according to situation. Hepatitis is **human carrier disease** as it is transferred from one person to another through blood to blood contact or through sharing needles, razors, and toothbrushes including pregnant women to her baby in addition to unprotected sex, rarely.



Hepatitis-C Patient



Hepatitis C causative agent

C. Epidemiology

In particular, hepatitis C leads to chronic disease in hundreds of millions of people and together are the most common cause of liver cirrhosis, liver cancer, and viral hepatitis-related deaths. An estimated 354 million people worldwide live with hepatitis C, and for most, testing and treatment remain beyond reach.

Some types of hepatitis are preventable through vaccination. According to WHO study, an estimated 4.5 million premature deaths could be prevented in low- and middle-income countries by 2030 through vaccination, diagnostic tests, medicines and education campaigns. Global hepatitis strategy set by WHO and endorsed by all WHO Member States, aims to reduce new hepatitis infections by 90% and deaths by 65% between 2016 and 2030.

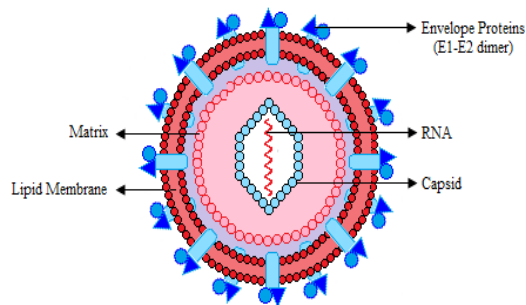
Risk factors are infected blood, sharing needles, making tattoos or piercings through unsterilized needles including certain sexual practices.

D. Causative agent

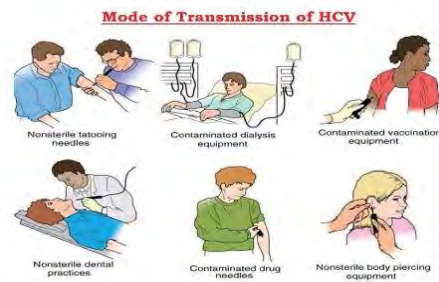
Hepatitis C is caused by **hepatitis C virus (HCV)**. HCV is a RNA virus.

E. Causes of contract

Causes of contract of hepatitis C are blood-to-blood contact with an infected individual through unsterilized needles, razors, toothbrushes, or from mother to baby during pregnancy, including sexual contact.



Hepatitis C virus



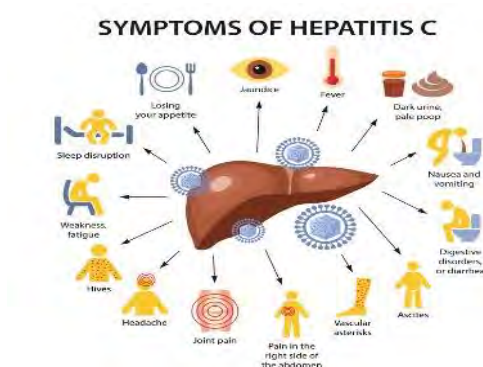
MoT of HCV

F. Mode of transmission

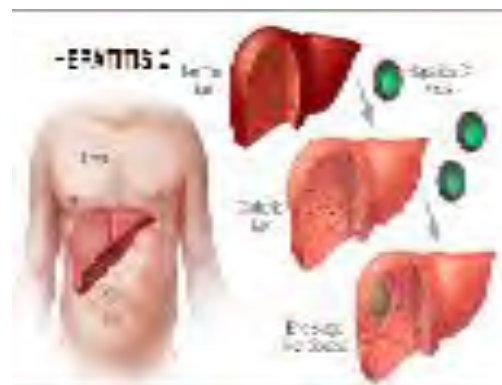
Mode of transmission, abbreviated as **MoT** of HCV is **direct transmission** through blood-to-blood contact of infected person including parental transmission or from unprotected sexual intercourse via blood, semen or other body fluids.

G. Incubation period

Incubation period of hepatitis C 2-26 weeks (average 9 weeks).



Sign, Symptoms, and Clinical features of HCV



Effects given by HCV

H. Sign, symptom, and clinical features

Hepatitis C exhibits bleeding easily, bruising easily, fatigue, poor appetite, jaundice (yellow colouration of eyes and skin), dark-coloured urine, itchy skin, and ascites (fluid build-up in abdomen).

I. Effects seen in patients

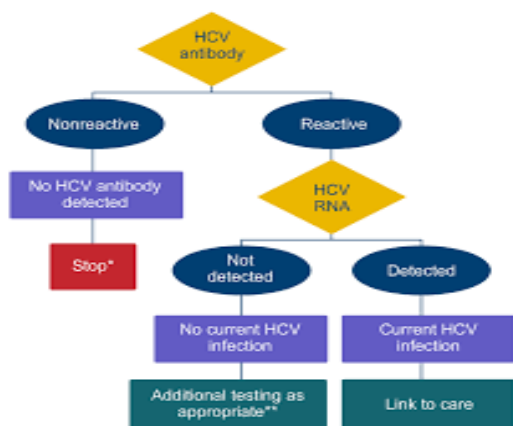
Hepatitis mainly affects liver parenchymatous cells causing liver cirrhosis. Drinking alcohol increases the risk of liver cirrhosis.

J. Diagnosis

Hepatitis C: Blood tests (anti-HCV test) and Molecular tests (RT-PCR to detect RNA of HCV).

K. Prevention

Hepatitis C is prevented by safe sex, screening of blood and blood products, etc.



Diagnosis of HCV



Prevention of HCV

L. Control measures/Treatment

Treatment can be done with the help of drugs prescribed by physicians.

iv. Hepatitis-D

A. Introduction

Hepatitis D that only affects those persons who have hepatitis B is a viral disease.

B. Description

Hepatitis D is designated as **physical disease** because it affects physical parts like liver. It is known as **acquired disease** as it occurs to affect one's own liver only after birth. It is known as **communicable disease** as it contracts from person to person. It is primarily **endemic**. It is **human carrier disease** as it is transferred from one person to another through blood-to-blood contact, sexual contact, and to those persons already suffering from hepatitis B.



Hepatitis-D Patient



Hepatitis D causative agent

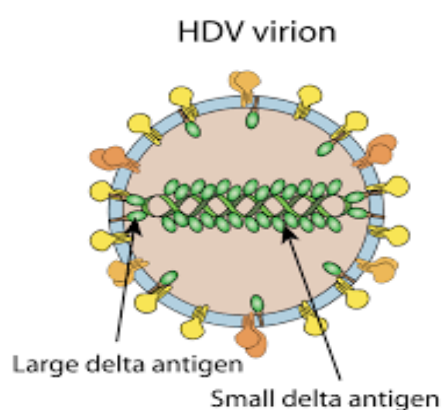
C. Epidemiology

Some types of hepatitis are preventable through vaccination. According to WHO study, an estimated 4.5 million premature deaths could be prevented in low- and middle-income countries by 2030 through vaccination, diagnostic tests, medicines and education campaigns. Global hepatitis strategy set by WHO and endorsed by all WHO Member States, aims to reduce new hepatitis infections by 90% and deaths by 65% between 2016 and 2030.

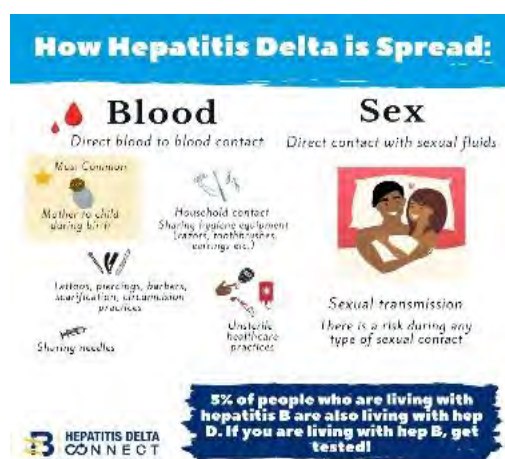
Risk factors are prior infection with hepatitis B and HIV/AIDS, poor sanitation, lack of safe water, living in a household with an infected person, being a sexual partner of someone with acute hepatitis A infection, use of recreational drugs, sex between men, and travelling to areas of high endemicity without being immunized.

D. Causative agent

Hepatitis D is caused by **hepatitis D virus (HDV)**. HDV is a RNA virus.



Hepatitis-D virus



MoT of HDV

E. Causes of contract

Causes of contract of hepatitis D: are blood and body fluids, sexual contact, and pre-natal transmission.

F. Mode of transmission

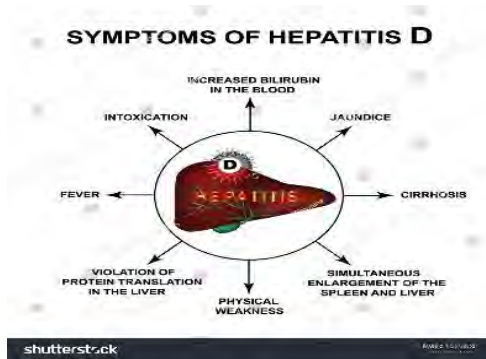
Mode of transmission, abbreviated as **MoT** of HDV is **direct transmission** through blood and other body fluids.

G. Incubation period

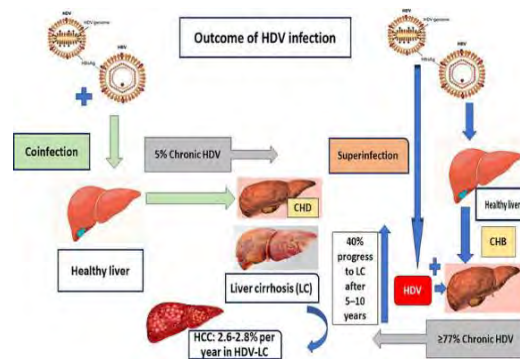
Incubation period of hepatitis D is 2-26.

H. Sign, symptom, and clinical features

Hepatitis D shows jaundice (yellow skin and eyes), stomach upset, belly-pain, throwing-up, fatigue, not feeling of hungry, joint pain, and dark-urine.



Sign, Symptoms, and Clinical features of HDV



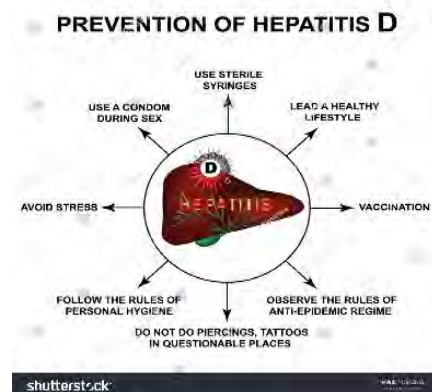
Effects given by HDV

I. Effects seen in patients

Hepatitis mainly affects liver parenchymatous cells causing liver cirrhosis. Drinking alcohol increases the risk of liver cirrhosis.



Diagnosis of HDV



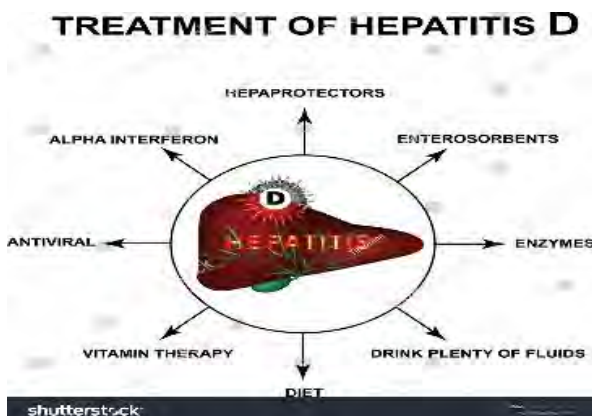
Prevention of HDV

J. Diagnosis

Hepatitis D: Blood tests (anti-HDV test) and Molecular tests (RT-PCR to detect RNA of HDV).

K. Prevention

Hepatitis D is prevented by safe sex, screening of blood and blood products, etc.



HDV treatment

L. Control measures/Treatment

Treatment can be done with the help of drugs prescribed by physicians.

v. Hepatitis-E

A. Introduction

Hepatitis E that is also known as ‘**infectious hepatitis**’ which especially affects pregnant ladies is a viral disease.

B. Description

Hepatitis E is designated as **physical disease** because it affects physical parts like liver. It is known as **acquired disease** as it occurs to affect one's own liver only after birth. It is known as **communicable disease** as it contracts from person to person or spreads through contaminated water and food especially raw or uncooked food. It is **endemic** and many become **epidemic**. Hepatitis is **human carrier disease** as it is transferred from one person to another through faeco-oral route.



Hepatitis-D Patient



Hepatitis E causative agent

C. Epidemiology

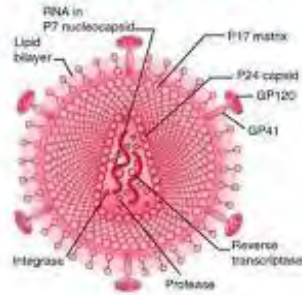
Some types of hepatitis are preventable through vaccination. According to WHO study, an estimated 4.5 million premature deaths could be prevented in low- and middle-income countries by 2030 through vaccination, diagnostic tests, medicines and education campaigns. Global hepatitis strategy set by WHO and endorsed by all WHO Member States, aims to reduce new hepatitis infections by 90% and deaths by 65% between 2016 and 2030.

Risk factors are poor sanitation, lack of safe water, consuming raw or uncooked food including certain medical conditions.

D. Causative agent

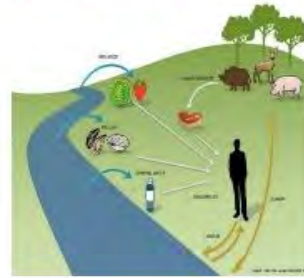
Hepatitis E is caused by **hepatitis E virus (HEV)**. HAE is a RNA virus.

HEV STRUCTURE



Hepatitis D virus

Large variety routes of HEV transmission



MoT of HEV

E. Causes of contract

Causes of contract of hepatitis E are: faeco-oral route, contaminated water and food, raw and uncooked food, and poor sanitation.

F. Mode of transmission

Mode of transmission, abbreviated as **MoT** of HEV is **direct transmission** through faeco-oral route including contaminated water and food especially raw and uncooked food.

G. Incubation period

Incubation period of hepatitis A is 2-6 weeks (average 7-28 days), hepatitis B 2-26 weeks (average 8 weeks), hepatitis C 2-26 weeks (average 9 weeks), hepatitis D 2-26 weeks, and hepatitis E 4 to 5 weeks.

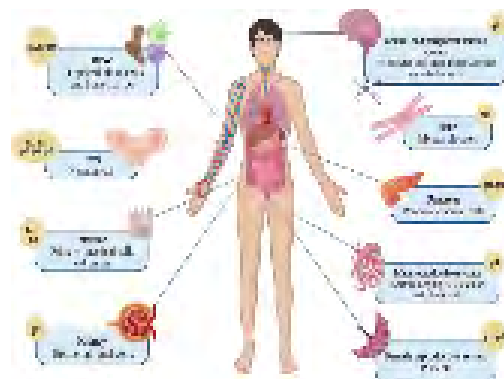
H. Sign, symptom, and clinical features

Hepatitis E exhibits fever, fatigue, loss of appetite, nausea, vomiting, abdominal pain, jaundice (yellowing of skin and eyes), and dark-urine.

SYMPTOMS OF HEPATITIS E



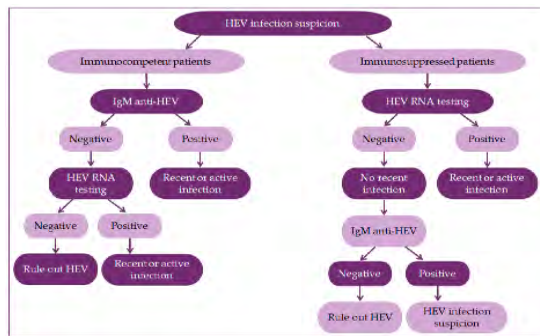
Sign, Symptoms, and Clinical features of HEV



Effects given by HEV

I. Effects seen in patients

Hepatitis mainly affects liver parenchymatous cells causing liver cirrhosis if infected by HBV and HCV. Drinking alcohol increases the risk of liver cirrhosis.



Diagnosis of HEV



Prevention of HEV

J. Diagnosis

Hepatitis E: Blood tests (anti-HEV test) and Molecular tests (RT-PCR to detect RNA of HEV in blood or stool).

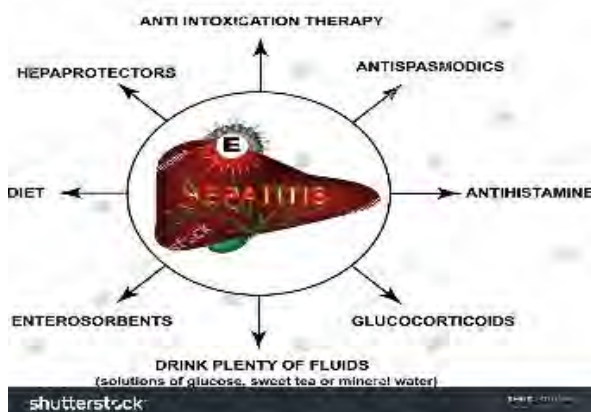
K. Prevention

Personal hygiene and sanitation can prevent Hepatitis E.

L. Control measures/Treatment

Treatment can be done with the help of drugs prescribed by physicians.

TREATMENT OF HEPATITIS E



HEV treatment

III. Human immune-deficiency virus/acquired immune-deficiency syndrome

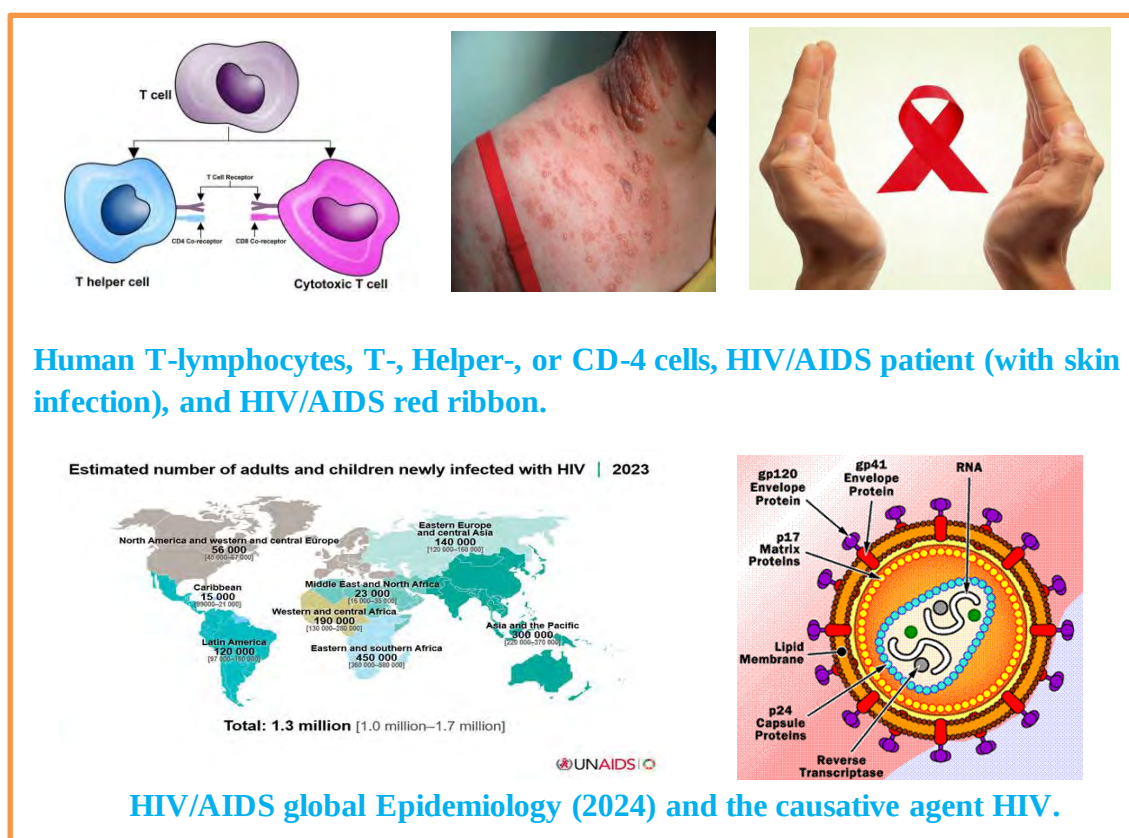
i. Introduction

Acquired immuno-deficiency syndrome, abbreviated as **AIDS**, which is caused by human immuno-deficiency virus, abbreviated as **HIV** is collectively called **HIV/AIDS** as it destroys helper T-cells or **CD₄** cells.

ii. Description of HIV-AIDS

HIV/AIDS may be **acquired disease** as it can affect one's own body after birth or may be **congenital** because of causative parents. It is a **communicable disease** as it spreads from one person to another. HIV/AIDS is a **pandemic disease** because it has captured whole world, especially through sexual contacts. It is a **human carrier disease** as its pathogens are transferred from one person to another through sexual contact, blood and its products, and through mother-baby. HIV/AIDS is an ongoing **physical disease** because it affects blood cells.

December 1 is observed as "**World AIDS Day**".



iii. Epidemiology

First case of HIV/AIDS was reported in USA in 1981. Pathogenic agent as virus was first detected in 1983. At first, the virus was named human T-cell Lymphotropic Virus (HTLV), then it was named Lymphadenopathy Associated Virus (LAV), and finally named by WHO in 1986 as Human Immuno Deficiency Virus (HIV) that causes the disease Acquired Immuno-Deficiency Syndrome (AIDS).

An estimated 630,000 people died of HIV-AIDS and 1.3 million people acquired this disease in 2023. It is a pandemic disease but in Nepal, it is considered **concentrated epidemic**. HIV antibody test was first introduced in Nepal in 1986. The first case of HIV-AIDS was diagnosed in Nepal in 1988. The estimated cases of HIV-AIDS in Nepal are 60,000.

Do you know?

Red ribbon is recognized worldwide as a symbol of solidarity with people living with HIV/AIDS, and as a symbol of awareness and support for those affected by the disease. The main function of 'Red Ribbon Foundation' founded in 1993 is education about prevention of HIV/AIDS and related ARC. However, red ribbon is also used in drug prevention and drunk driving.

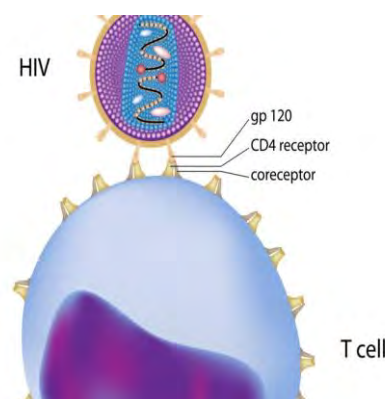
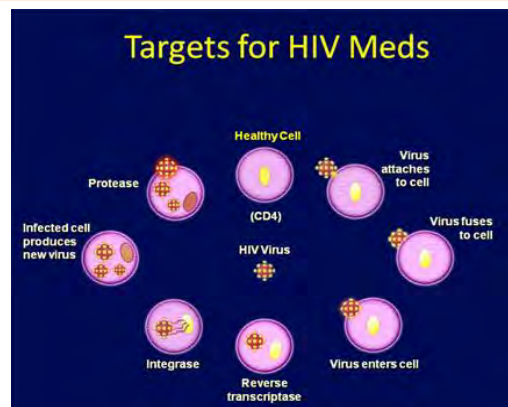
Risk factors are infected blood including blood products, unsafe sexual contact, and mother-baby contact.

Do you know?

Body fluids with **high concentrations of HIV** are blood, semen or vaginal fluids (as high as blood), breast milk, and pus from sores. **Low concentrations** of **HIV** are in CSF and amniotic fluid. It is **highly unlikely** that you will be **infected** if you come into **contact with** sweat, tears, urine, and saliva of infected person.

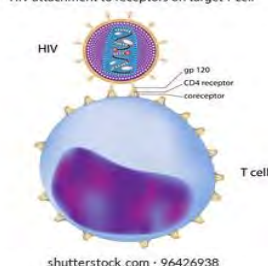
iv. Causative agent

Causative agent of HIV/AIDS is a **retrovirus** called **ssRNA virus** which contains **reverse transcriptase enzyme** that converts RNA to DNA. Its two varieties isolated are – HIV-1 and HIV-2, in which HIV-1 is more common.



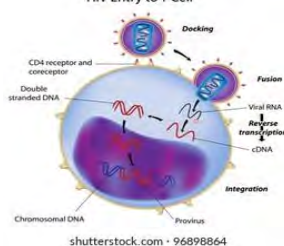
Steps in human T-cells affected by HIV: HIV comes near T-cells,

HIV attachment to receptors on target T cell



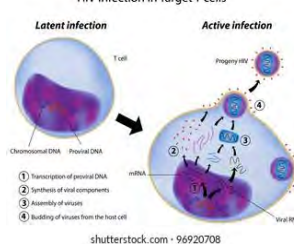
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HIV Entry to T Cell



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HIV Infection in Target T cells



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HIV attachment to receptors on target T-cell, HIV entry to T-cell, and HIV infection in T-cell

v. Mode of transmission

Mode of transmission, abbreviated as **MOT** of HIV/AIDS is **direct** through:

A. Sexual contact

Sexual contact is the most common route in which heterosexuality is the commonest route, however, homosexuals are always at greater risk. The risk of transmission through sexual contact is 0.08%.

B. Blood contact

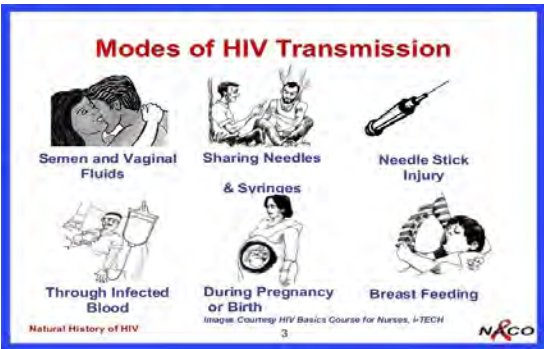
Blood contact through infected blood transfusion and intravenous drug users is the main route in which risk of transmission is more than 90%.

C. Mother-baby contact

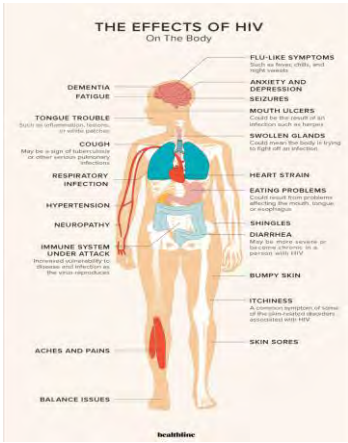
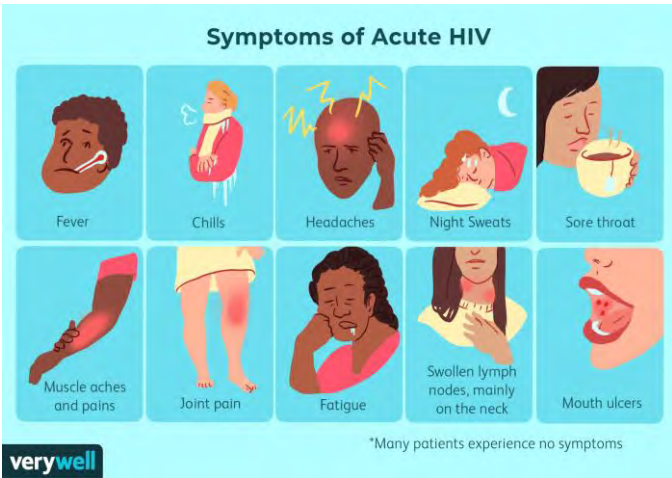
Mother to baby transmission, also called **vertical transmission** is during delivery and breast feeding in which risk of transmission is about 30%.

vi. Incubation period

Incubation period of HIV-AIDS is two to six weeks after exposure to HIV.



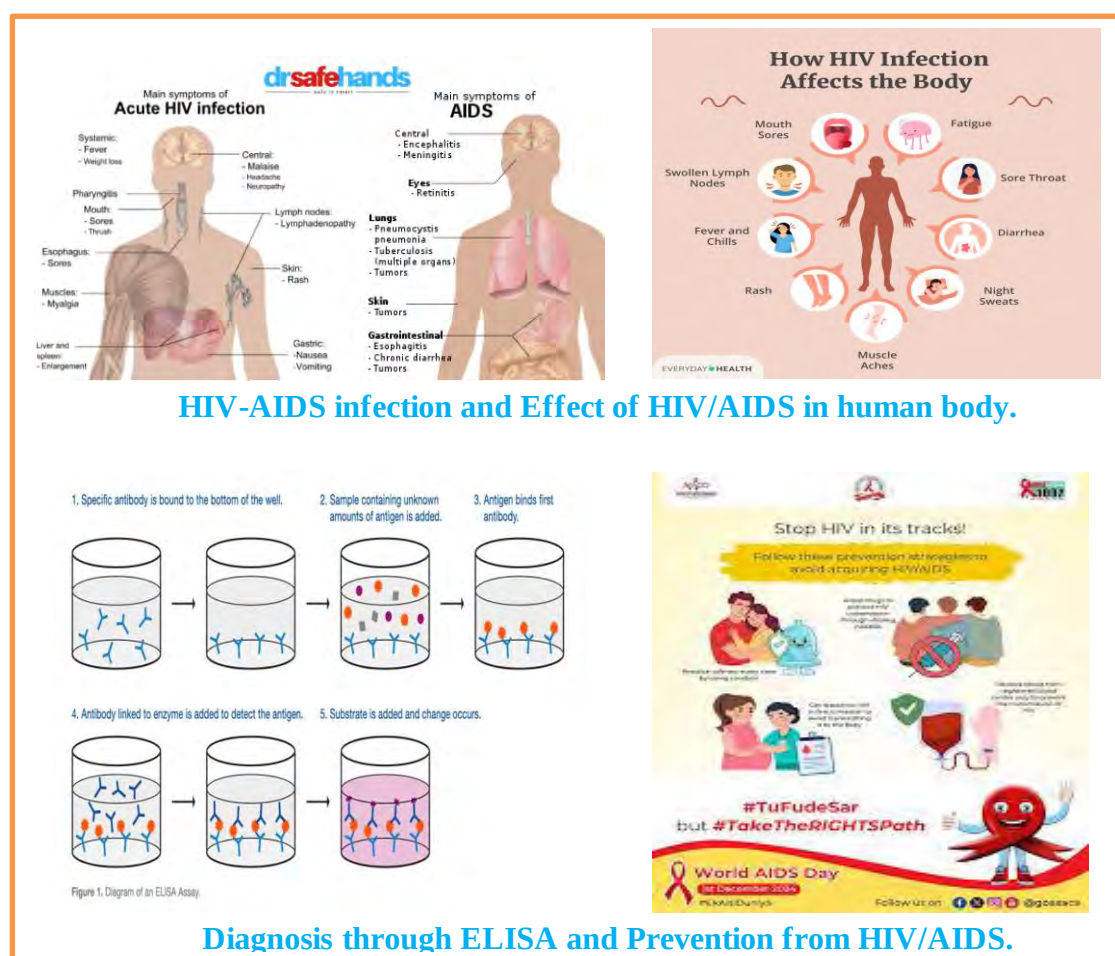
MoT and No transmission of HIV-AIDS from these activities.



Symptoms and Effects of HIV/AIDS

vii. Sign, symptom, and clinical features

Following are the sign, symptom, and clinical features of HIV-AIDS:



A. Window period (Acute viral stage)

Acute viral stage shows flu-like symptom, e.g., common cold, fever, headache, rash, sore throat, etc. with **window period** which is time interval between two weeks to two months during which antibody test is negative but patient can transmit the infection.

B. Asymptomatic stage

Asymptomatic stage shows no symptoms except generalized lymphadenopathy during which antibody test is positive.

C. AIDS-related complex

AIDS-related complex, abbreviated as **ARC** shows: **unknown fever** ≥ 1 month, **uncontrolled diarrhea** ≥ 1 month, and **weight loss** of about 10% of body weight, for which HIV-AIDS is also called **slim disease**.

D. full blown AIDS (End stage)

End stage or acquired immune-deficiency syndrome (AIDS) stage shows opportunistic infections, e.g., **tuberculosis** caused by *M. avium* being the major cause of death.

viii. Effects of HIV-AIDS seen in patients

Helper T-cells or CD4 cells are destroyed by HIV in AIDS which tends to weaken immune system of the patient and make him/her prone to diseases like TB, cancer, etc.

ix. Diagnosis of HIV infection

- Screening test like **enzyme-linked immunosorbent assay** (ELISA) and diagnostic test like **Western-blot test**.

x. Prevention

- Monogamy or safer sexual contact.
- Precaution in administration of blood and blood products.
- Precaution at the time of delivery of a child from HIV/AIDS mother.

xi. Control measures/Treatment

- **Highly Active Anti-Retroviral Therapy** (HAART)
- Other drugs used are zidovudine (AZT), saquinavir, nevirapine, etc.

IV. Typhoid

i. Introduction

Typhoid fever called **typhoid** in shortcut, is life-threatening bacterial infection usually spread through contaminated food or water. Once, typhoid fever-causing bacteria are ingested, they multiply and spread into blood stream and intestinal tract causing typhoid fever. In Nepal, typhoid is known by the name '**myadi jwaro**' (vern.).

ii. Description of typhoid fever

Typhoid fever is an **acquired disease** because it tends to affect one's own body after birth. It is a **communicable disease** as it spreads from one human host to another. Typhoid is **endemic** in Nepal because it is regularly found in a particular area where poor sanitation and hygiene leads to contaminated drinking water. It is a **human carrier disease** as pathogens are transferred from one person to another through contaminated food or water. Typhoid fever is a **physical disease** as it affects physical parts like intestine for the infection of which, it is known as an **enteric fever**.

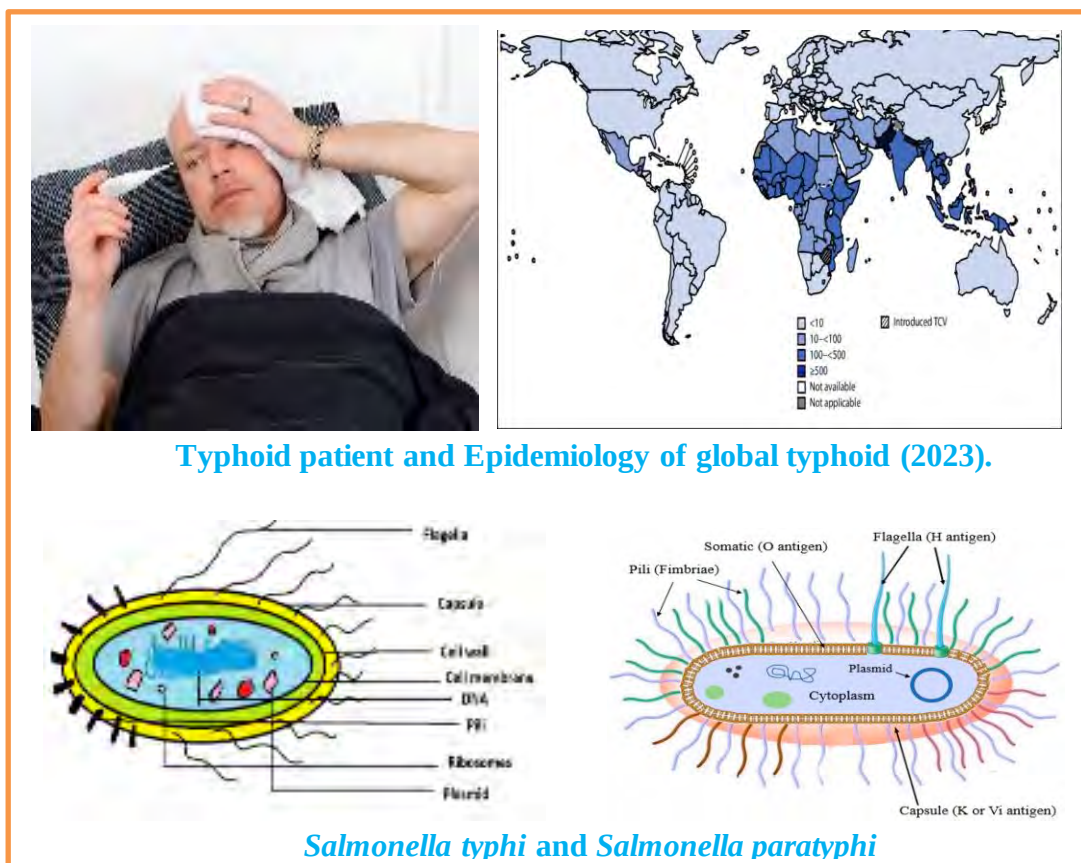
To raise awareness about typhoid fever and its prevention, unofficially, March 30 is celebrated as "**World Typhoid Day**" however, the date is not recognized by WHO.

iii. Epidemiology

Improved living conditions and introduction of antibiotics resulted in a drastic reduction of typhoid fever morbidity and mortality in industrialized countries. However, typhoid is most prevalent in regions with poor sanitation and access to clean water, particularly affecting young children in developing countries, where the fever is often transmitted through contaminated food and water due to inadequate hygiene practices, leading to higher incidence rates in these areas compared to regions with better sanitation.

Typhoid is more prevalent in tropical and subtropical regions, especially in South Asia, Southeast Asia, parts of Africa, Eastern Mediterranean, Western Pacific regions, and parts of South America.

According to WHO, as of the estimates of 2019, it is reported that every year, there are nine million cases of typhoid fever prevalence and 110,000 deaths in the world. It is also reported that every year, there are 82,000 cases of typhoid fever prevalence and 1,042 deaths in Nepal. This indicates poor hygienic condition of unavailability of potable water to most of the Nepali populace.



Urbanization and climate change have potential to increase the global burden of typhoid. In addition, increasing resistance to antibiotic treatment is making it easier for typhoid to spread in communities that lack access to safe drinking water or adequate sanitation. The **typhoid risk** is higher in populations that lack access to safe drinking water and adequate sanitation however, children are at highest risk.

iv. Causative agent

Causative agent of typhoid is a **rod-shaped bacterium** or **bacillus**, *Salmonella typhi*, which is **Gram -negative** and **monogenic**, and for which human being is the **final host**.

Do you know?

Salmonella paratyphi A, B, or C causes **paratyphoid fever** in insects, reptiles, birds, and mammals including man. The paratyphoid fever is mild than typhoid fever.

v. Mode of transmission

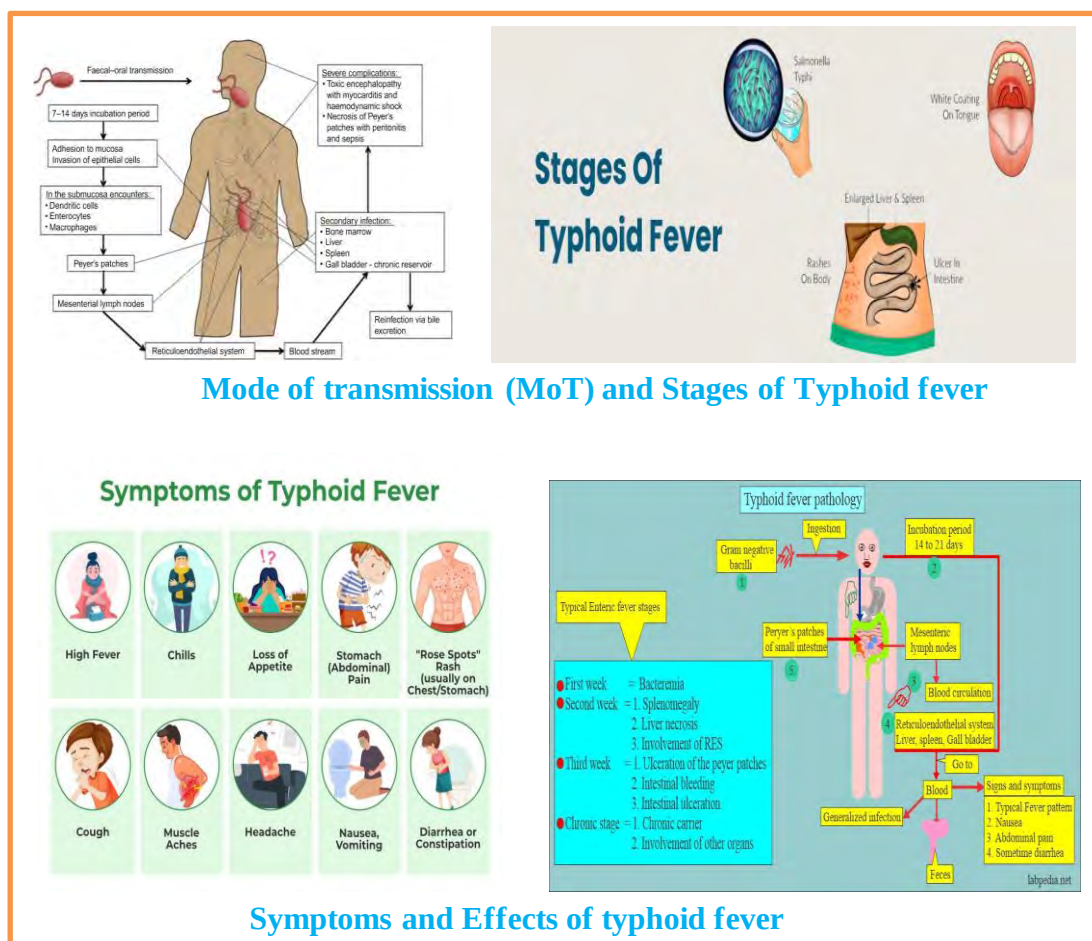
Mode of transmission, abbreviated as **MoT** of typhoid fever is **direct** and through **faeco-oral** or **urino-oral route** due to contaminated food or water containing the bacterium *S. typhi* coming from infected person's faeces or urine and mixing in food or water.

Do you know?

Long ago, due to lack of advanced medical technique, reddening of the intestine and liver came into existence only after postmortem of a dead patient who was severely suffering of typhoid.

vi. Incubation period

Incubation period of *S. typhi* that causes typhoid fever is 7-14 days, but ranges from 3 to 60 days.



vii. Sign, symptom, and clinical features

Sign, symptom, and clinical features of typhoid fever patient are intense headache, prolonged high grade fever (step ladder-type fever), stomach pain, abdominal pain, relative bradycardia, fatigue, nausea and vomiting, and constipation or diarrhea. Some patients may have rash or rose spot seen in trunk and chest after 1st week of infection. Severe cases may lead to serious complications or even death.

viii. Effects of typhoid seen in patients

- Severe cases can lead to serious complications like meningitis, sepsis, reddening of intestine and liver or intestinal perforation.

ix. Diagnosis

- Blood culture in 1st week
- Antigen-antibody detection in 2nd week (commonly known as **WIDAL** test)
- Stool culture in 3rd week
- Urine culture in 4th week

x. Prevention

- Safe drinking or potable water, proper or adequate sanitation, healthy food, health awareness and education, and immunization against typhoid.
- Typhoid conjugate vaccine in single injectable dose in children from six months of age and in adults up to 45 years or 65 years.

xi. Control measures/Treatment

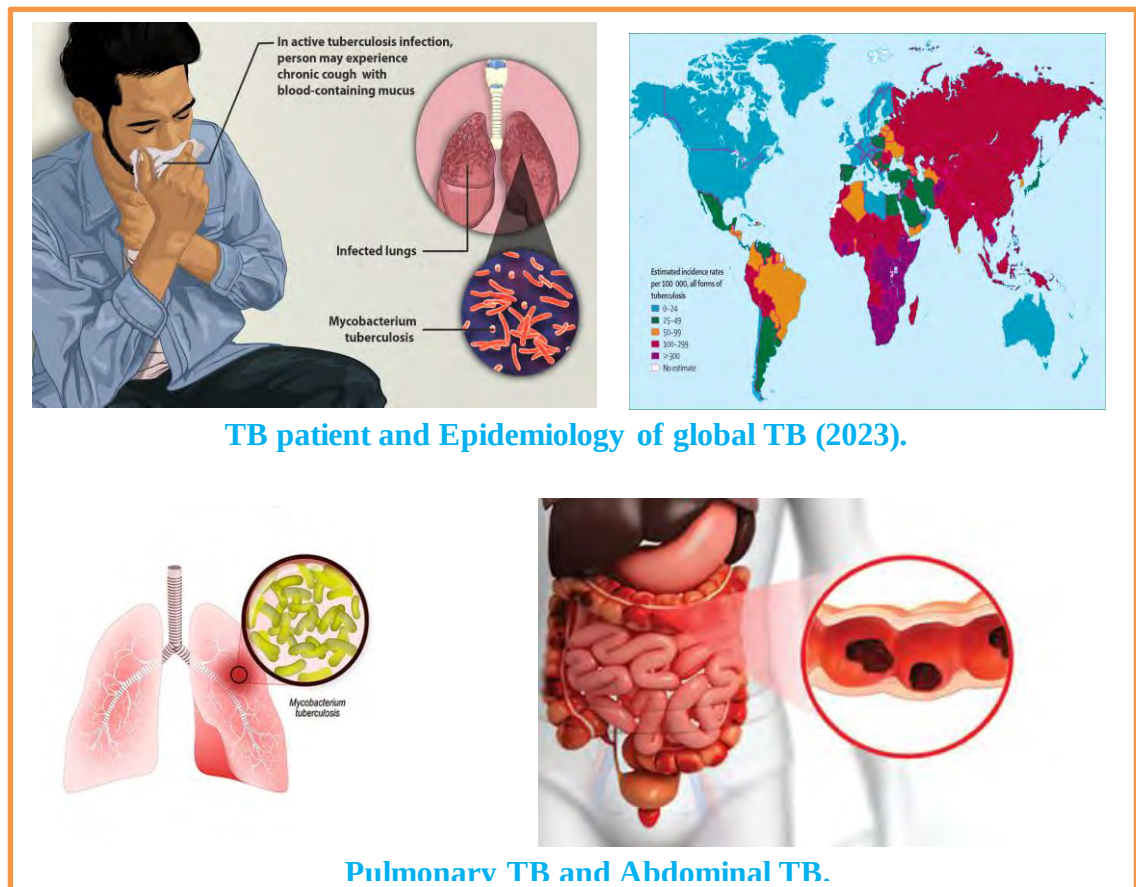
- Antibiotics like ciprofloxacin, chloramphenicol, etc.

V. Tuberculosis

i. Introduction

Tuberculosis, abbreviated as **TB** is also called **Koch's disease**. It is an illness caused by bacterial infection commonly affecting lungs however, other organs like intestine, spine, skin, brain or kidneys are also affected. Earlier, in Nepal, tuberculosis was known to be '**rajrog**' (colloq.) as its treatment was only possible to richest person. Nowadays, in Nepal, it is known by the name '**kshayarog**' (vern.).

Tuberculosis is an **acquired disease** as it can affect one's own body after birth however, in some cases, it may be **congenital** because of **family history**. It is a **communicable disease** as it spreads from an infected person to another through droplet infection. Tuberculosis was **pandemic** during 18th and 19th century however, it is **endemic** in the country like Nepal and India as it regularly occurs in a particular area where droplet infection is a major cause of the disease but it may be considered **epidemic** in India because of 25% of the global TB burden occurs here. It is an **air borne disease** as pathogens are transferred from one person to another through droplet infection. It is a **physical disease** because it affects physical parts such as lungs including spine, brain, or kidneys.



March 24 is celebrated as "**World Tuberculosis Day**".

Overcrowding, pollution, poverty, and people working in closed space, e. g., in case of carpet industry, garment industry, etc., are major **risk factors** of TB. In addition, conditions like diabetes, weakened immune system (e.g., from HIV-AIDS), malnourishment, and tobacco and alcohol abuse can increase **risk** for TB. Tuberculosis is a major cause of mortality and morbidity among the communicable diseases. Globally, an estimated 10.8 million people develop TB and over a million deaths occur annually.

India accounts for about 25% of global TB burden, with an estimated TB incidence of 2.77 million in 2022. It is a common disease infecting about 45% of the total population of Nepal. About 4,000-8,000 people die annually from this disease in Nepal

iv. Types of tuberculosis

TB, according to the site it affects, is three types: pulmonary, extra-pulmonary, and miliary.

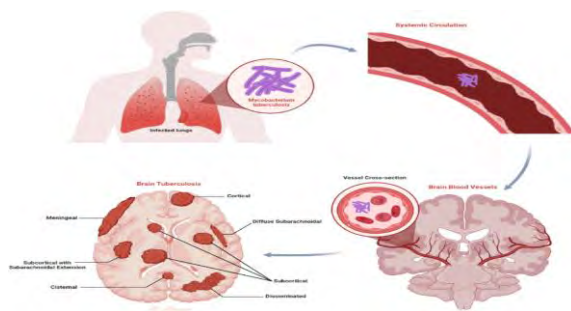
A. Pulmonary tuberculosis

Pulmonary tuberculosis affects lungs and pleura.

WHAT IS POTT'S DISEASE?



Pott's spine and Lupus vulgaris.



TB of tongue and TB of brain.

B. Extra-pulmonary tuberculosis

Extra-pulmonary tuberculosis affects extra-pulmonary area, e. g., abdominal TB, TB of vertebral column (**Pott's spine**), TB of skin (**Lupus vulgaris**), TB of tongue, TB of brain, and TB of kidney, etc.

C. Miliary tuberculosis

Miliary tuberculosis is so called as it is characterized by tiny, millet seed-like lesions. It is transmitted through blood and can affect multiple organs like lungs, liver, bone marrow, and even meninges and pericardium.

v. Causative agent

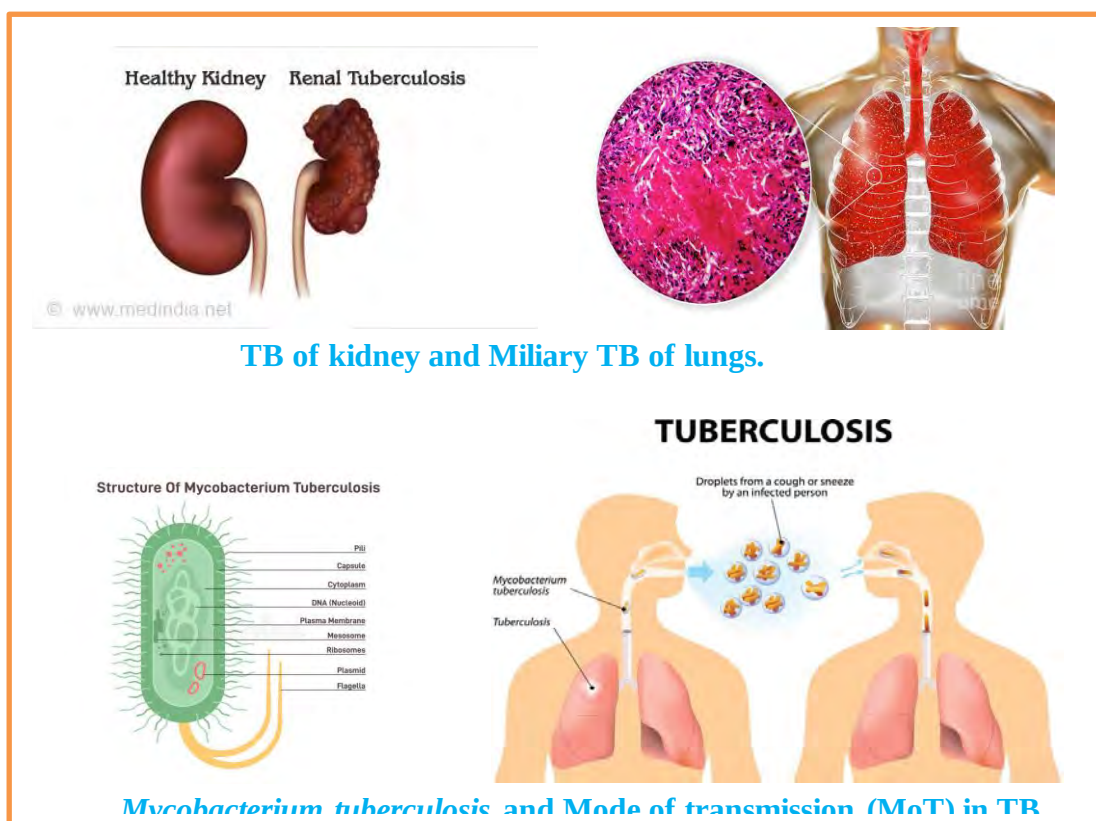
Causative agent of tuberculosis is a **rod-shaped bacterium** or **bacillus**, *Mycobacterium tuberculosis* which is **Gram-positive**, **large**, **slender**, **non-spore forming**, **non-motile**, **monogenic** (man is the final host), and **obligate aerobe** usually found in upper lobes of lungs.

Do you know?

Mycobacterium bovis causes TB in cattle and *Mycobacterium avium* causes TB in immune-compromised person, e. g., HIV-AIDS patient.

vi. Mode of transmission

Mode of transmission, abbreviated as **MoT** of tuberculosis is **direct** through **droplet infection, droplet nuclei, or infected cow-milk**.



vii. Incubation period

Incubation period of *M. tuberculosis* that causes TB is from 3 weeks to 3 months.

viii. Sign, symptom, and clinical features

Common sign and symptoms of tuberculosis are prolonged cough, blood in sputum (hemoptysis), weakness, fatigue, low grade fever, night sweating, loss of appetite (anorexia), chest pain, and weight loss.

ix. Effects seen in patients

M. tuberculosis usually affects lungs however, abdomen, tongue, skin, spine, kidneys or brain are also affected.

x. Diagnosis

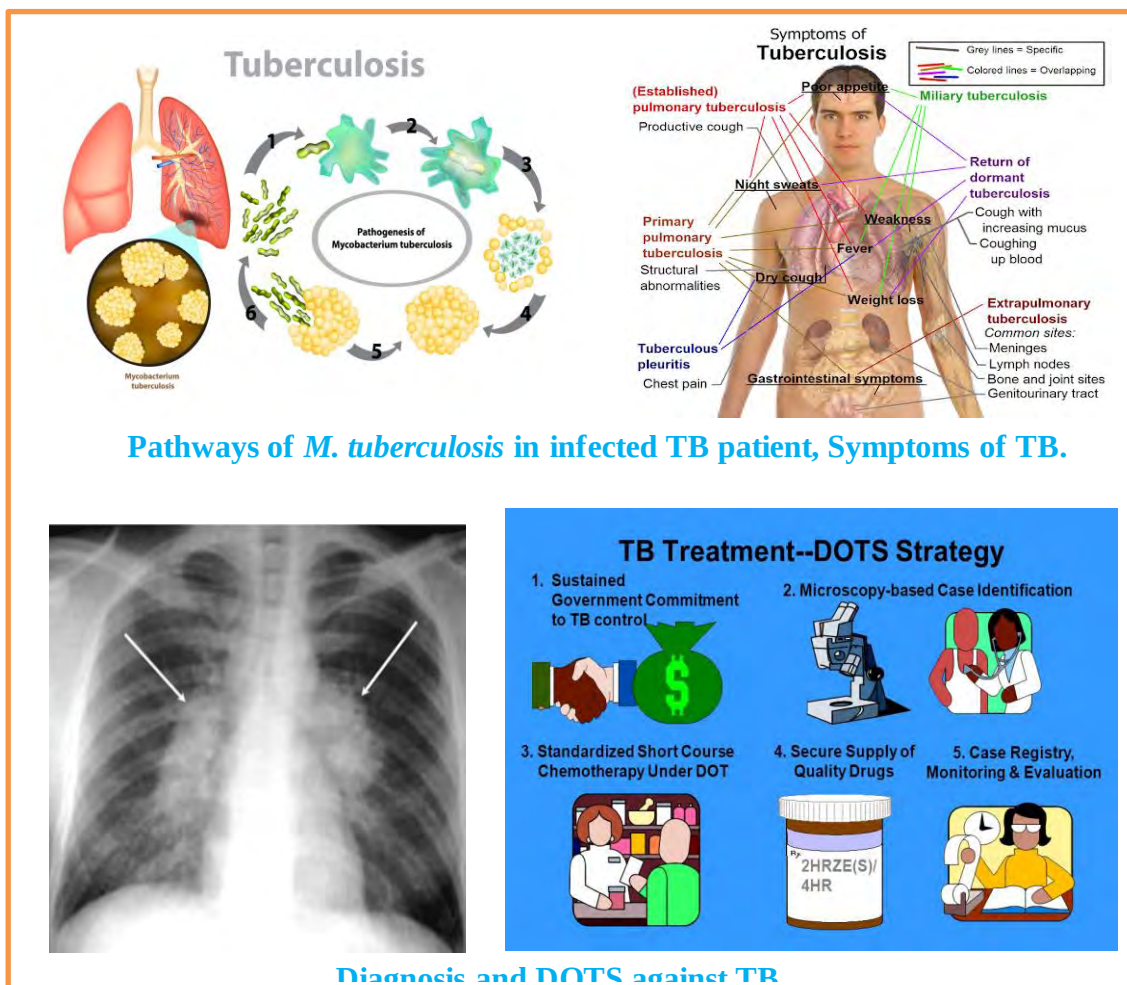
- Sputum culture (3 mornings sample taken)
- **Mantoux test** (tuberculin test)
- Chest X-ray

xi. Prevention

- Medical attention should be given when symptoms are seen.
- Well-ventilated room in such symptoms.
- Bacillus Calmette Guerin (BCG) vaccine should be given up to 4weeks at birth.

xii. Control measures

Control measures against TB includes treatment followed by DOTs.



xiii. Treatment

Treatment is through anti-tubercular therapy (ATT), also known as Multi Drug Regimen (MDR) therapy in which multiple drugs are given, e.g., pyrazinamide, rifampicine, isoniazide, streptomycine, ethambutole, etc. Among these drugs, ethambutole is the only bacteriostatic drugs and rest are bacteriocidal drugs. The rifampicine can make body secretion red, isoniazide hampers in the vitamin B₆ (Pyridoxine) absorption leading to the inflammation of peripheral nerve (peripheral neuritis). So, patient taking isoniazide should take vitamin B₆. The streptomycine is the only injectable drugs whereas rest are taken orally.

xiv. Directly observed treatment short-course

Directly observed treatment short-course, abbreviated as **DOTS** was launched in Nepal in April, 1996 AD and extended to all parts of the country by April, 2001 AD. The ATT drugs are given in two phase: intensive phase (for 2 months) and continuation phase (for 6 months).

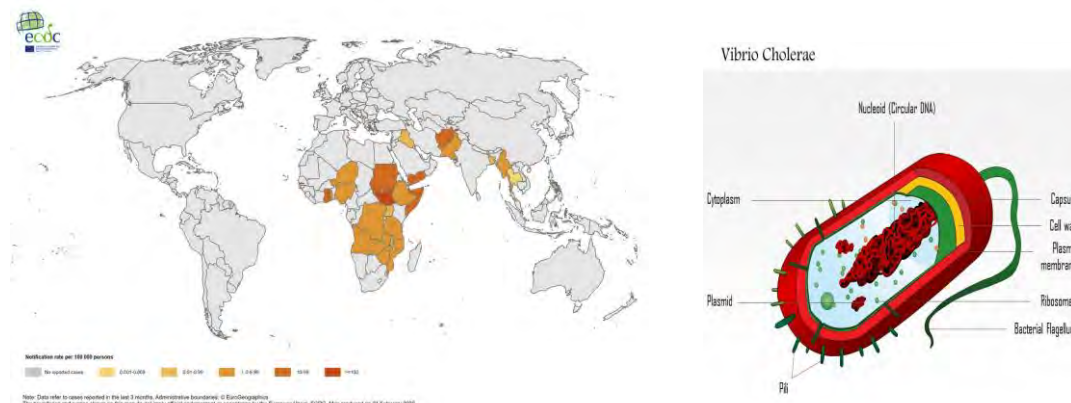
VI. Cholera

i. Introduction

Cholera is an infectious bacterial disease of intestine with severe diarrhoea and vomiting



Cholera disease and Cholera patient.



Global Epidemiology of Cholera (2025) and *Vibrio cholerae*.

ii. Description of cholera

at the same time leading to dehydration that may lead to death. In Nepal, cholera is known as 'haija' (colloq.).

Cholera is considered **physical disease** as it affects physical parts like intestine. It is a type of **acquired disease** as it tends to affect one's own body only after getting birth. Cholera is **communicable disease** because it spreads from one person to another person through contaminated water and food. It is a **pandemic disease** as it captures whole of the world at a time. It is known as **water borne disease** as its pathogens are transferred from one person to another through water and food.

March 22 is celebrated as "World Water Day" by the UNO to raise awareness and importance of water and sanitation, which directly impacts the prevention of waterborne diseases like cholera. Hence, March 22 is recognized by WHO and other related organizations to be celebrated as "**World Cholera Day**" for the acute diarrhoeal infection, and its prevention of the disease known as cholera.

iii. Epidemiology

During 19th century, cholera spread across the world from its original reservoir in the Ganges delta in India in 1817. Till then six subsequent pandemics killed millions of people across the continents. The seventh or latest pandemic started in South Asia in 1961, reached Africa in 1971, and occupied Americas in 1991. Cholera is **pandemic** causing 3-5 million people out of which 28,000-140,000 die every year however, it is less prevalent among the people of developed countries but more prevalent in the people of developing countries.

Some of the **risk factors** are improper sanitation and contaminated water, sick household members, low levels of HCl inside stomach, and eating raw food.

Do you know?

Persons with O-blood group are at higher risk for cholera than others.

iv. Causative agent

Causative agent is **rod-shaped bacterium** or bacillus, *Vibrio cholera* which is **curved**, **Gram-negative**, and **monogenic**, and for which man is the **final host**. First of all, the bacterium was isolated by **Robert Koch** in 1883.

v. Causes of contract

The main cause of contract is contaminated water and food. Other causes are eating raw and uncooked seafood like shellfish and raw fruits and vegetables.

vi. Mode of transmission

Mode of transmission, abbreviated as **MoT** is **direct transmission** and through faeco-oral route or faecal-oral route from contaminated water and food mixed with infected person's faeces or vomiting.

vii. Incubation period

Incubation period of cholera is 12 to 24 hours, however, it may be 5 hours to 5 days from the time of contact. The patient affected by cholera bacterium will discharge bacterium in his/her stool from 1 to 10 days.

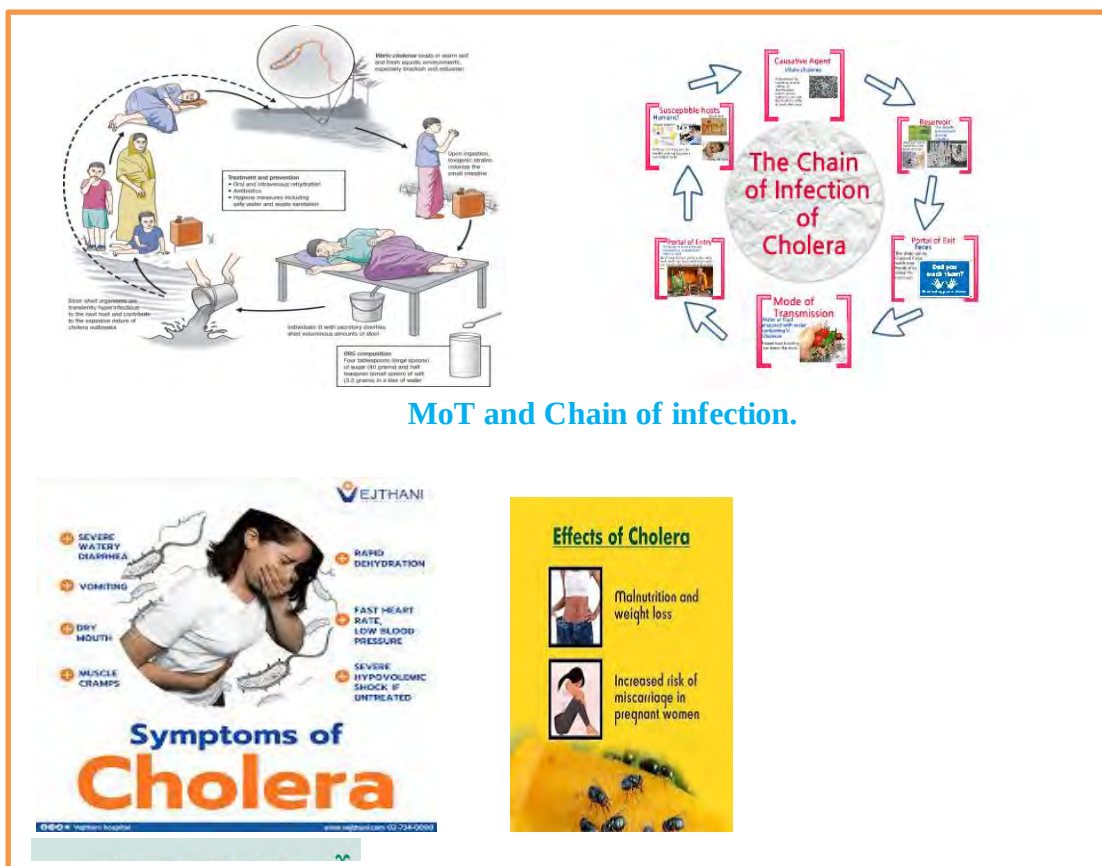
viii. Sign, symptom, and clinical features

- Most people with cholera have no or few symptoms, but some may experience severe diarrhoea and vomiting with dehydration however, its symptoms may include sudden onset of diarrhoea, nausea, vomiting, mild to severe dehydration.
- Dehydration associated with cholera is often severe and can cause signs and symptoms such as: tiredness, moodiness, sunken eyes, dry mouth, shriveled skin, extreme thirst, reduced urine output, irregular heartbeat rate, and low BP.
- Dehydration may also cause loss of minerals with the result of electrolyte imbalance followed by muscle cramps and shock.

- Children, besides showing above symptoms, also experience: severe drowsiness, fever, convulsions, and coma.

ix. Effects of cholera seen in the patient

Cholera bacterium, *V. cholerae* badly affects small intestine because of the strong toxin



produced by it called **cholera toxin (CTX)** causing watery diarrhoea and severe vomiting including dehydration.

x. Complications

Complications are low blood sugar, low K^+ level, and kidney failure.

xi. Diagnosis

- Stool test.

xi. Prevention

Following are the preventive measures against cholera:

- Proper sanitation, washing hands and feet, drinking potable water, eating healthy food, avoiding raw food eating, and vaccination.
- **Vaccine** is required for those who live or are going to the place of high transmission

but if, one is vaccinated but going to the place of active outbreak of cholera then the person needs a booster dose.

xii. Control measures/Treatment

- Oral rehydration salts mixed with water
- Other electrolyte solution as supplement.
- Intravenous (IV) fluid rehydration, if required.
- Zn supplements.
- Antibiotics

VII. Candidiasis

i. Introduction

Candidiasis is fungal infection caused by yeast (a type of fungus) of the genus *Candida*, some species of which can cause infection in people. Such species causing candidiasis in man are called invasive species. Most common species is *C. albicans*. The *Candida* normally lives on the skin and inside the body, in places such as mouth, throat, gut, and vagina, without causing any problems. In Nepal, candidiasis is called '**khameer sangkraman**' (vern.).

Do you know?

Candida auris, a multidrug-resistant yeast (a fungus), which survive on the skin and inside the body of human can cause infections, especially in those with weakened immune system. It spreads through direct or indirect contact. It is found resistant to many common antifungal medications.

ii. Description of candidiasis

Candidiasis is considered **physical disease** because it affects physical parts of the body such as skin including mouth, throat, gut, and vagina. It is a type of **acquired disease** which tends to affect one's own body after birth however, **congenital candidiasis** seems to be rare.

Candidiasis is **communicable disease** as it communicates from one person to another through contact. It may be **endemic** in some areas but **epidemic** in other areas. Candidiasis is human-carrier disease as the fungus is transferred from one people to another through physical contact.

There is no specific, globally recognized "World Candidiasis Day" however, Centres for Disease Control and Prevention (CDC) and other related organizations promote "**Fungal Disease Awareness Week (FDAW)**" including candidiasis, which is an infection caused by an overgrowth of the yeast, *Candida* from September 16-20.

iii. Epidemiology

Candidiasis dates back to 460-370 BC when white patches or vaginal discharge including itching were reported. It was first discovered in 1847.

Candidiasis is more prevalent in infancy and old age. Approximately, 9 per 100,000 people are suffering from this disease.

iv. Types of candidiasis

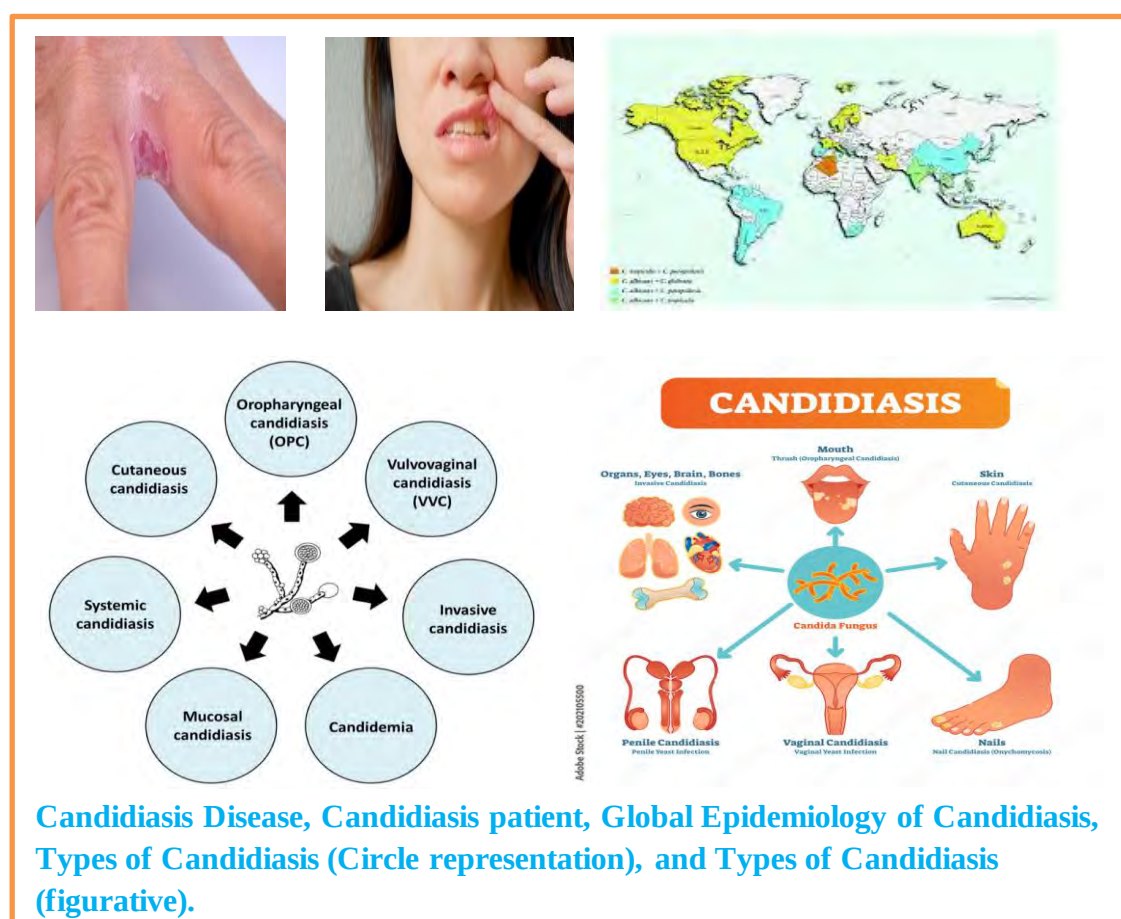
Following are different types of candidiasis, based on location of infection: cutaneous candidiasis, vaginal candidiasis, oral candidiasis, invasive candidiasis, and candida granuloma.

A. Cutaneous candidiasis

Cutaneous candidiasis is an infection of skin creating a raised, red patch with small, itchy bumps which form in folds of the skin like underarms, under breasts, and near buttocks (diaper rash) or groin.

B. Vaginal candidiasis

Vaginal candidiasis, also called **vaginitis** is a common infection which causes burning, itching, redness, and discharge from vagina.



C. Oral candidiasis

Oral candidiasis, also known as **thrush** is an infection which causes white sores of mouth, throat, oesophagus, and tongue.

D. Invasive candidiasis

Invasive candidiasis, also called **systemic candidiasis** is a serious infection that occurs throughout the body, often in bloodstream or on the membrane lining the heart or skull, as a result of an immune deficiency.

E. Candida granuloma

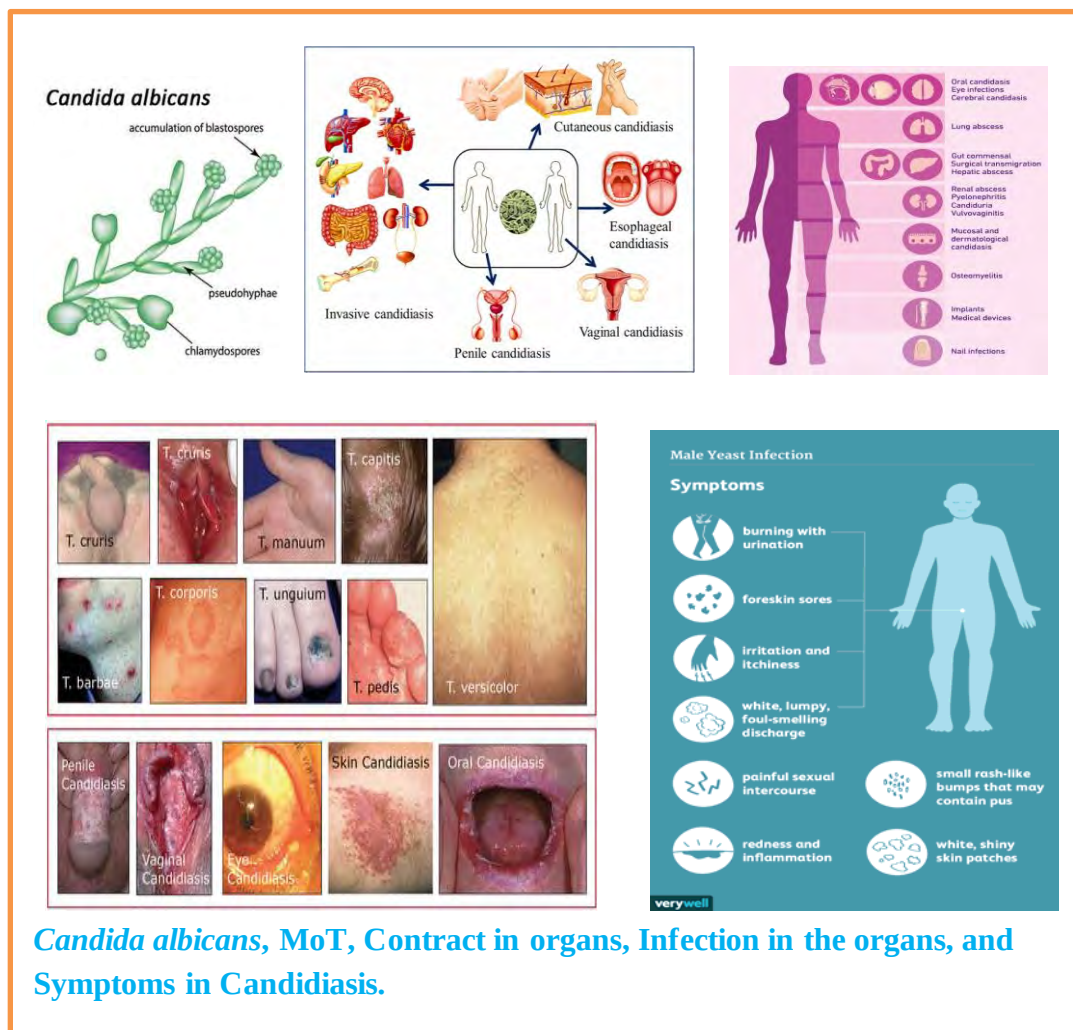
Candida granuloma is severe, chronic infection that targets skin, scalp, mouth, and fingernails.

v. Causative agent

Causative agent is *Candida albicans* causing **thrush** (in mouth), **vaginitis** (in vagina), skin-folds (in skin), and nail (in nail beds).

vi. Causes of contract

Main causes of contract are skin and inside the body, in places such as mouth, throat, gut, and vagina.



vii. Mode of transmission

Mode of transmission, abbreviated as **MoT** is **direct** or **indirect contact** with contaminated people or object.

viii. Incubation period

Incubation period is 2-4 weeks in adults but 2-5 days in children.

ix. Sign, symptom, and clinical features

Following are the sign, symptom, and clinical features of different types of candidiasis:

A. Cutaneous candidiasis

- Intense itching on skin.
- Red, growing skin rash.
- Rash on skin folds, genitals, middle of the body, buttocks, under the breasts, and other areas of skin.

B. Vaginal candidiasis

- Itching and irritation in vagina and vulva.
- Burning sensation, especially during intercourse or while urinating.
- Redness and swelling of vulva.
- Vaginal pain and soreness.
- Vaginal rash.
- Thick-white odour-free vaginal discharge with cottage cheese appearance.
- Watery vaginal discharge.

C. Oral candidiasis

- White patches on the inner cheeks, tongue, roof of the mouth, and throat.
- Redness or soreness.
- Cotton-like feeling in mouth.
- Loss of taste.
- Pain while eating or swallowing.
- Cracking and redness at the corners of the mouth.

D. Invasive candidiasis

- A serious infection in bloodstream, heart membrane, and skull.

E. Candida granuloma

It is a rare but severe form of chronic mucocutaneous candidiasis which may cause following:

- The nail (bed) becomes brittle, easily breakable, or splitting nails.
- White, brown, or yellow colouration
- Debris collecting under the nail
- Thinning nails with a dry, powdery surface
- Nail lifting up and becoming detached.



Infection, Effects, Diagnosis, Prevention, and Treatments in Candidiasis.

x. Effects seen in patients

Following are the mild to acute effects seen in patients:

Activity

Go to a nearby hospital or health centre in the surrounding vicinity in which you live. Request to get the hospital register so that you could record different types of diseases prevailing in your locality. Make a table of those diseases and explain your findings with conclusion.

- Infection in oral cavity basically tongue.
- Infection on skin, genitalia, nail, etc.
- Visceral infection in organs.

xi. Diagnosis

- Blood culture test
- Mannan antigen and anti-Mannan antibody.

xii. Prevention

- Proper sanitation.

xiii. Control measures/Treatment

- Anti-fungal drug like **fluconazole**.

Project work

Make a list of different types of diseases occurring in your province. Among them, point out major ones. Out of the major ones, select any five and describe their epidemiology.

3. Basic concepts of immunology – vaccines

Have a look on the figures given below and discuss following questions with your class friends.

1. Which one of the following figures indicate immunity, immune system, vaccine, and vaccination?

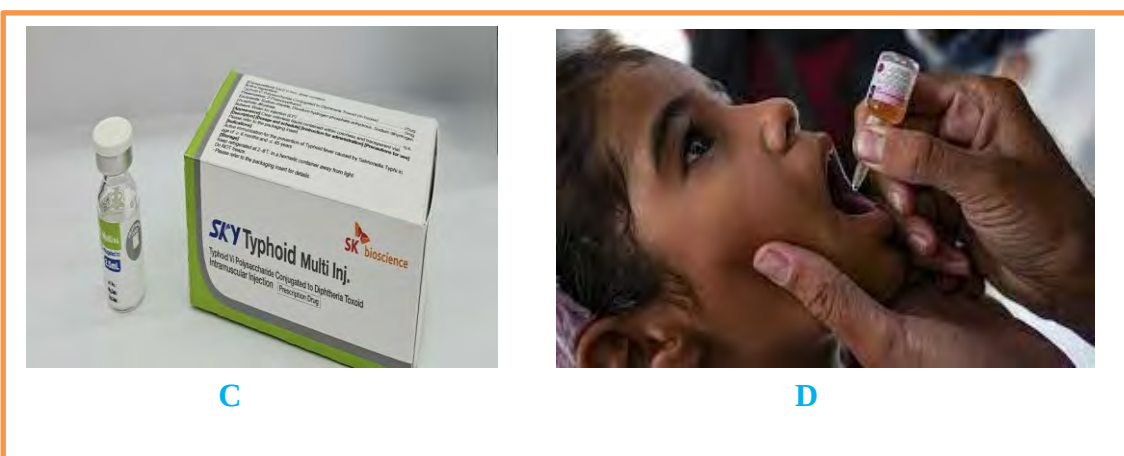
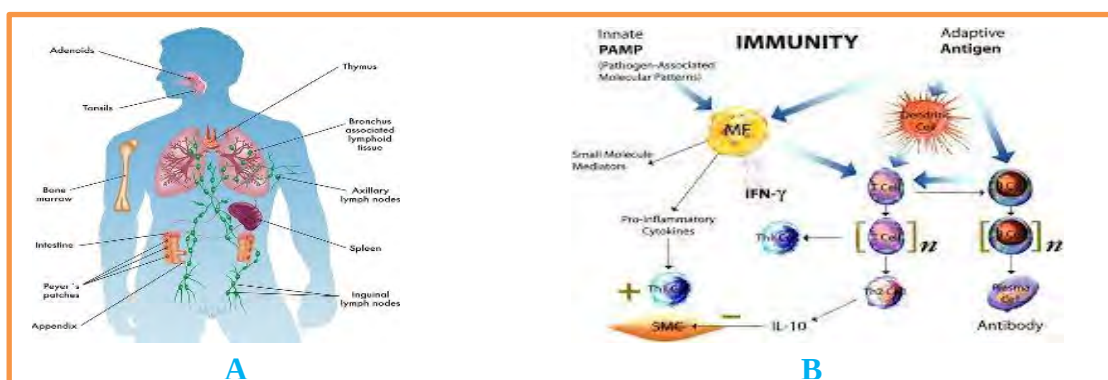


Figure A indicates immune system (of a man), B indicates immunity (occurring in man), C indicates vaccine (of typhoid), and D indicates vaccination (of polio vaccine through oral drop).

Immunology is the study of resistance towards any microbial disease hence, it is also the study of one's own immune system or immunity.

Immune system or immunity and the vaccines which can induce immunity will be discussed.

I. Immunity

Immunity (L., *immunis*, **exempt**) is the capacity and ability of human body to resist against foreign particles, including infectious organisms like viruses, bacteria, fungi, protozoa, and parasites along with their toxins.

Immunity or immune system, on the basis of being present before or after birth, is of two types: innate and acquired.

i. Innate immunity

Innate immunity, also known as **non-specific immunity** is obtained by birth. It comprises four types of defensive barriers: physical and anatomic, physiologic, phagocytic, and inflammatory.

A. Physical and anatomic barriers

Physical and anatomic barriers prevent entry of pathogens into body forming **first line of defense** against infection, e.g., skin, mucous membrane, sebum secreted by sebaceous glands.

B. Physiologic barriers

Physiologic barriers comprise temperature, low pH, and chemical mediators like lysozyme, interferon, and complement.

C. Phagocytic barriers

Phagocytic barriers perform phagocytosis by phagocytic cells like neutrophils and macrophages like monocytes.

D. Inflammatory barriers

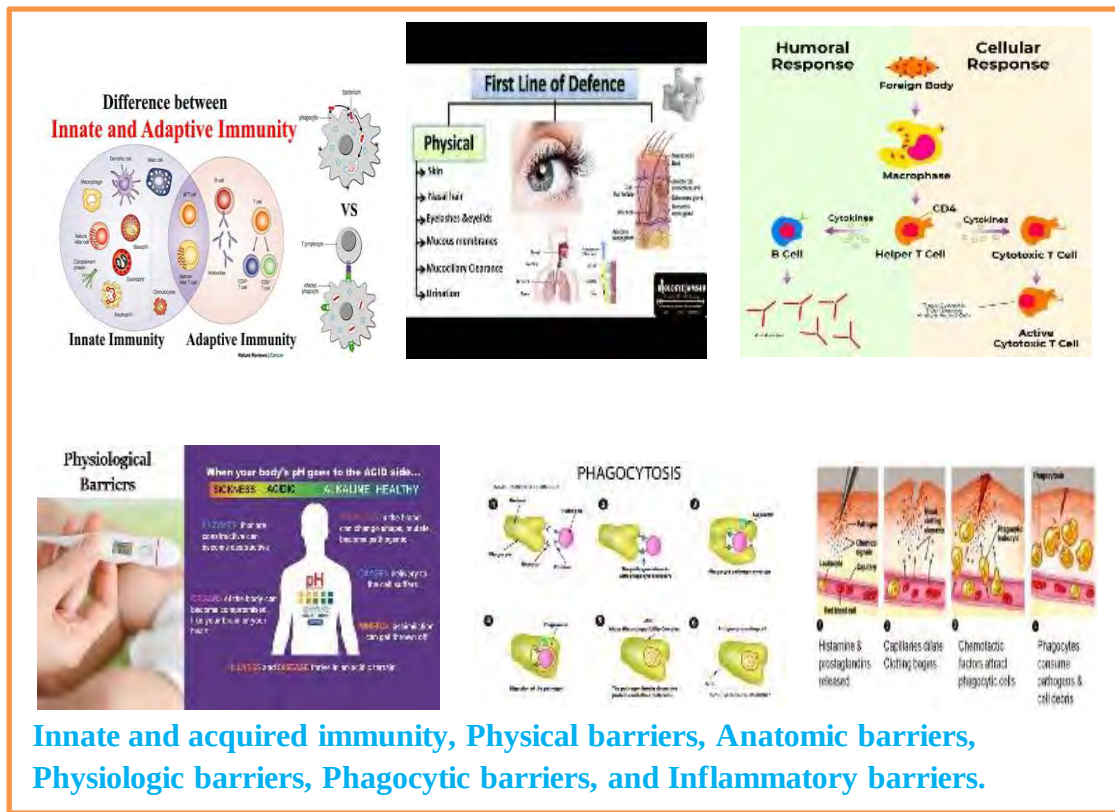
Inflammatory barriers perform inflammatory response due to histamine, kinin, and prostaglandins form oedema and influx phagocytic cells into the infected area.

ii. Acquired immunity

Acquired immunity, also called **adaptive** or **specific immunity** is the immunity obtained after birth.

Acquired immune responses are particular to specific antigens to secrete specific antigenic specificity, diversity, immunologic memory, and self or non-self-recognition. antibody (IgM,

IgG, IgD, IgE, and IgA). Characteristics of the acquired immunity are: Major group of cells of immune system are two types: lymphocytes and antigen-presenting cells.



Acquired immunity is of two types: humoral and cell-mediated immunity.

A. Humoural immunity

Humoural immunity in which **humour** refers to plasma and lymph and that is also called **antibody mediated immunity** defends against viruses and bacteria in body fluids.

B. Cell-mediated immunity

Cell-mediated immunity, also known as **cellular immunity** secrete antigen-specific antibody.

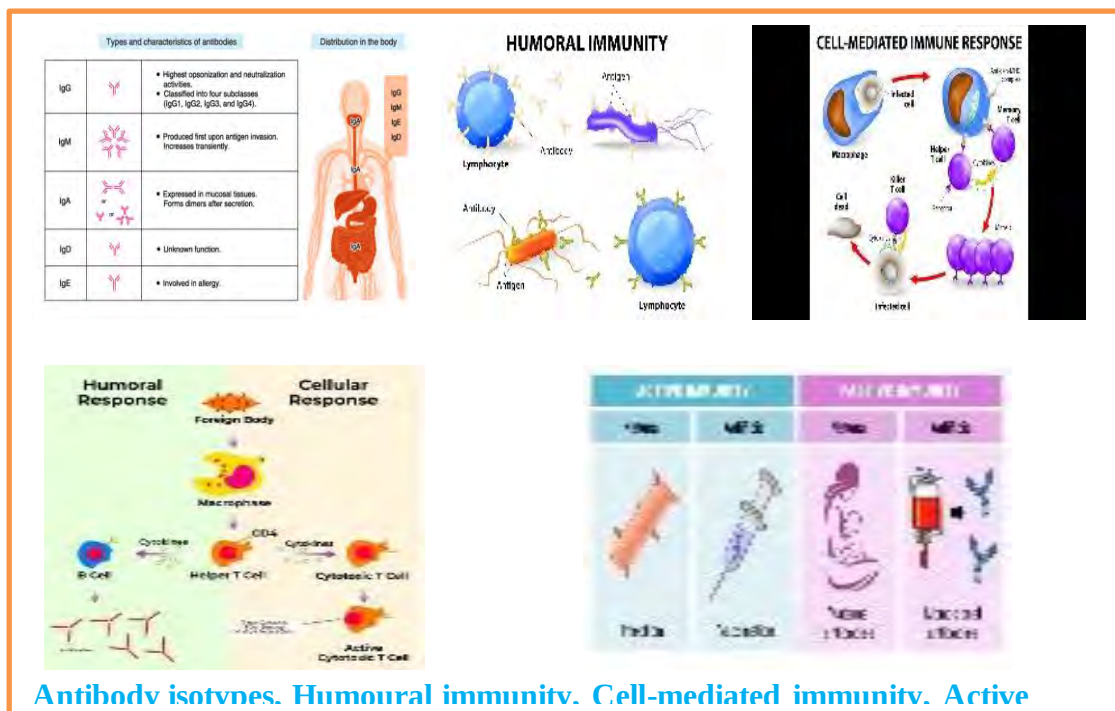
Immunity or immune system, based on activity, is of two types: active and passive.

i. Active immunity

Active immunity is obtained after a disease (infection of germs) or vaccination after which the body builds up antibodies.

ii. Passive immunity

Passive immunity is one which is obtained by injecting antibodies. It is also the transfer of antibodies from one individual to another.



Differences between humoral immunity and cell-mediated immunity

Humoural immunity	Cell-mediated immunity
B-lymphocytes secrete antibodies that circulate in blood as a soluble protein	Mediated by activated, antigen-specific T-lymphocytes
Mediated by B-lymphocytes	Mediated by T-lymphocytes
Mediated by B-lymphocytes, T-lymphocytes, and macrophages	Mediated by helper T-cells, cytotoxic T-cells, suppressor T-cells, natural killer (NK) cells, and macrophages
Acts on extracellular microbes and their toxins	Acts on intracellular microbes like viruses, bacteria, parasites, and tumour cells
Recognizes unprocessed antigens	Antigens are processed and presented by major histocompatibility complex (MHC)
Plasma cells (memory B-cells and effector B - cells) secrete antibodies	T-cells secrete cytokinins
Rapid	Delayed type of hypersensitivity
Doesn't act on tumour cells and transplant	Acts on tumour cells and transplant

II. Vaccines

Vaccines are **preparations/suspensions** of **killed, dead, modified, weakened, inactivated**, or **attenuated** pathogenic **microorganisms**, **part of microorganisms**, or **toxoids**, which when **injected, inoculated**, or **entered** into an animal including man, produce **immunity** to a particular disease.



Vaccine, Vaccination, Edward Jenner, Louis Pasteur, World Immunization Day, and World Immunization Week.

Process of administration of vaccine is called vaccination.

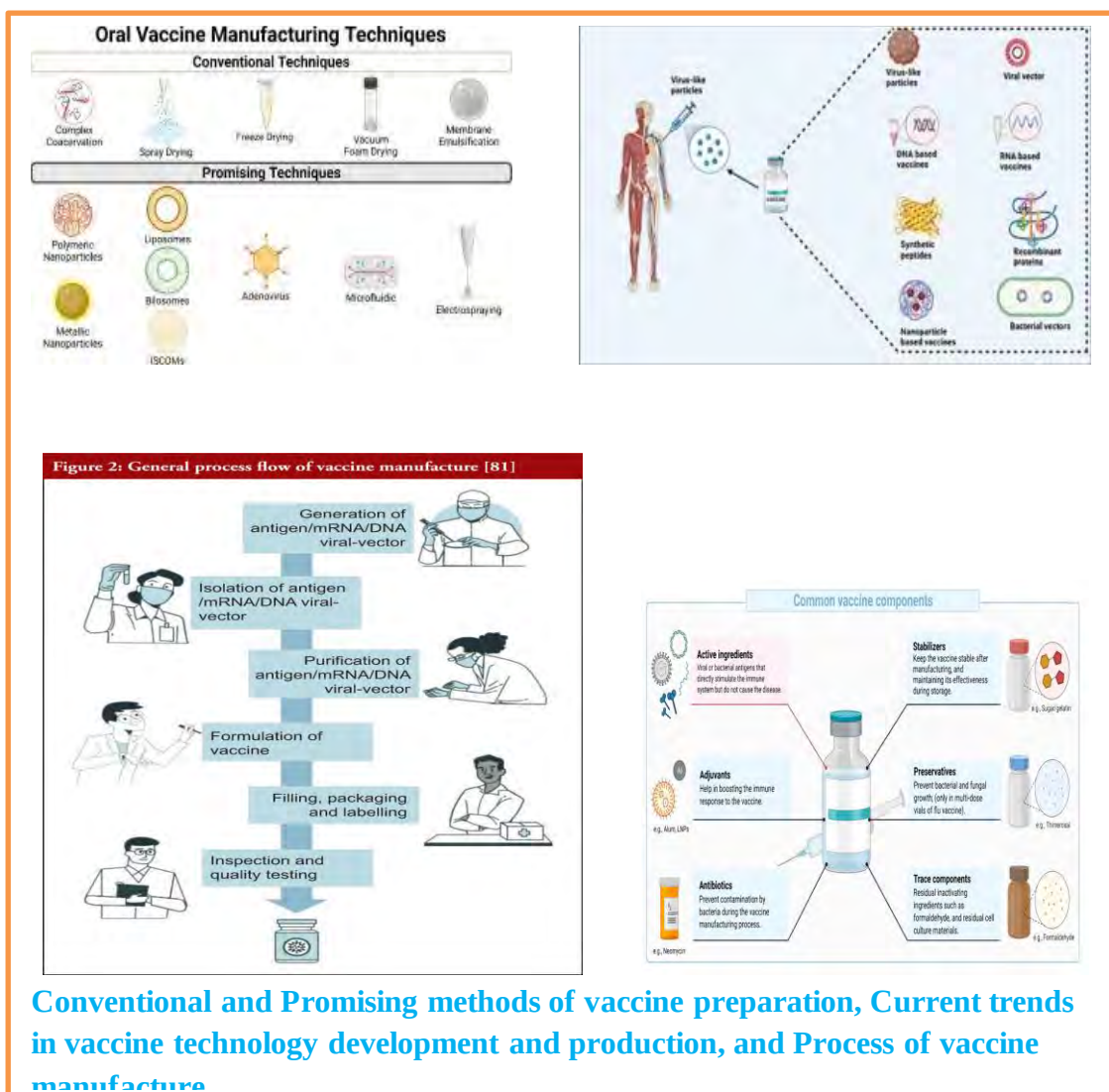
i. Vaccination

Vaccination is the process of inoculation/injection/entry/administration of killed, dead, modified, weakened, inactivated, or attenuated pathogen to stimulate antibody production. It is a process conferring immunity by administering a vaccine. Vaccination is used against measles, mumps, chickenpox, yellow fever, polio, and many other viral diseases by inoculating live attenuated viruses. Similarly, it is used against typhoid, diphtheria, whooping cough, and many other bacterial diseases by introducing dead germs.

ii. History

Edward Jenner (1749-1823), an English physician, could develop smallpox vaccine by observing that the dairymaids infected with milder cowpox are safer from infection of smallpox. In 1796, Jenner inoculated an eight-year old boy, James Phipps with fluid obtained from cowpox blisters, which were on the hand of a dairymaid, Sarah Nelmes'. Then, he, further, inoculated the same boy with fluid from smallpox blisters. To Jenner's surprise, the boy had become immune to smallpox. That experiment demonstrated the effectiveness of cowpox inoculation against smallpox. Hence, the technique of inducing immunity inside body came to be known as vaccination (L., **vacca**, **cow**). The first true vaccine consisting of weakened or attenuated microorganisms against chicken cholera was developed in 1879 by Louis Pasteur (1822-1895). In this way, the scientific basis of vaccination was established by Louis Pasteur. An inactivated exotoxin called toxoid is used to induce active immunity to toxin-caused disease. The toxoid is used in vaccinating against tetanus, botulism, diphtheria, and other diseases. The weakened or attenuated germs are used to protect against poliomyelitis, yellow fever, measles, smallpox and many other viral diseases. For their

contributions, Jenner is honoured as 'father of immunology' or 'father of vaccination' whereas Pasteur is considered 'father of microbiology'.



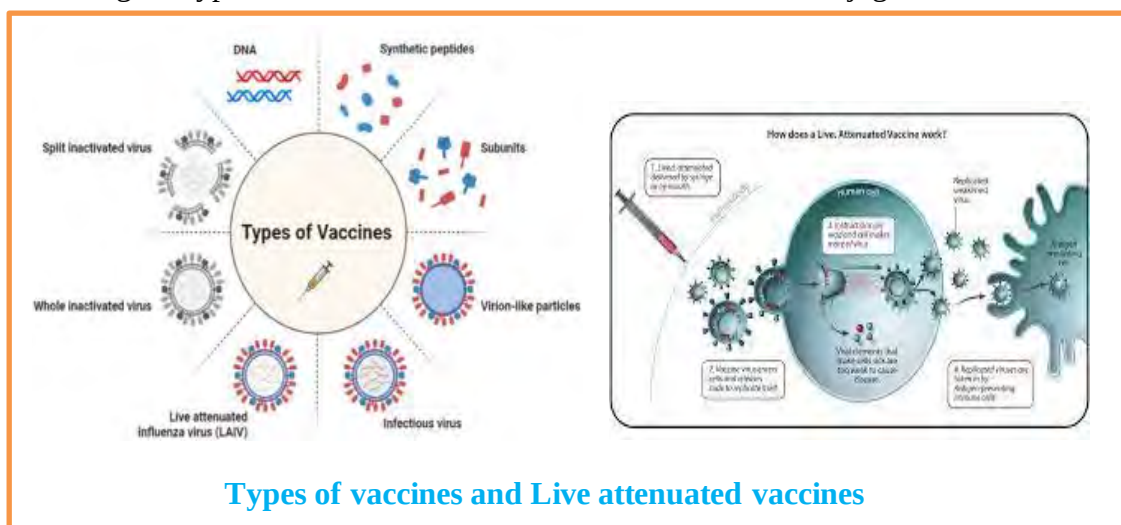
November 10 is celebrated as "**World Immunization Day**". The "**World Immunization Week**", observed annually from April 24 to 30, aims to raise global awareness and encourage action on immunization, with the goal of protecting people from vaccine-preventable diseases.

iii. Vaccine preparation

Earlier, vaccines were prepared by classical or traditional methods called **conventional methods**. Nowadays, vaccines are prepared by modern or advanced methods called **promising methods**. For the promising methods, biotechnology has proven successful in the development of recombinant vaccines. The vaccines produced by genetic engineering are prepared faster than conventional methods. The vaccines produced by genetic engineering are safer, more reproducible, and can be administered in high doses without the fear of any side effects.

iv. Types of vaccines

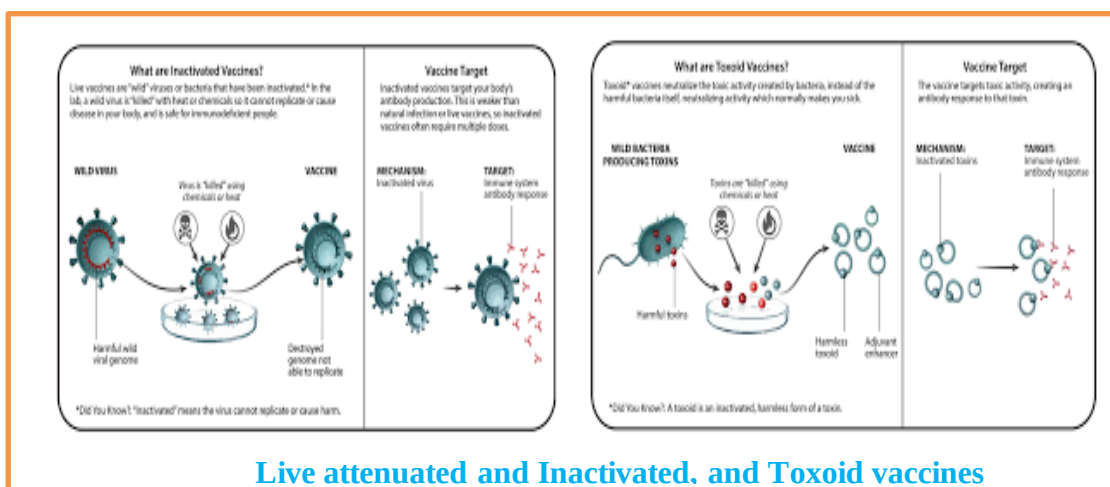
On the basis of pathogens procured or their toxic chemicals included, vaccines are of following six types: attenuated, inactivated, toxoids, subunit, conjugated, and nucleic acid.



Types of vaccines and Live attenuated vaccines

A. Attenuated whole-agent vaccines

Attenuated whole-agent vaccines refer to such vaccines which use live but attenuated microbes, e.g., oral polio, measles, mumps, rubella (MMR), cowpox, yellow fever, influenza, intranasal, etc.



Live attenuated and Inactivated, and Toxoid vaccines

B. Inactivated whole-agent vaccines

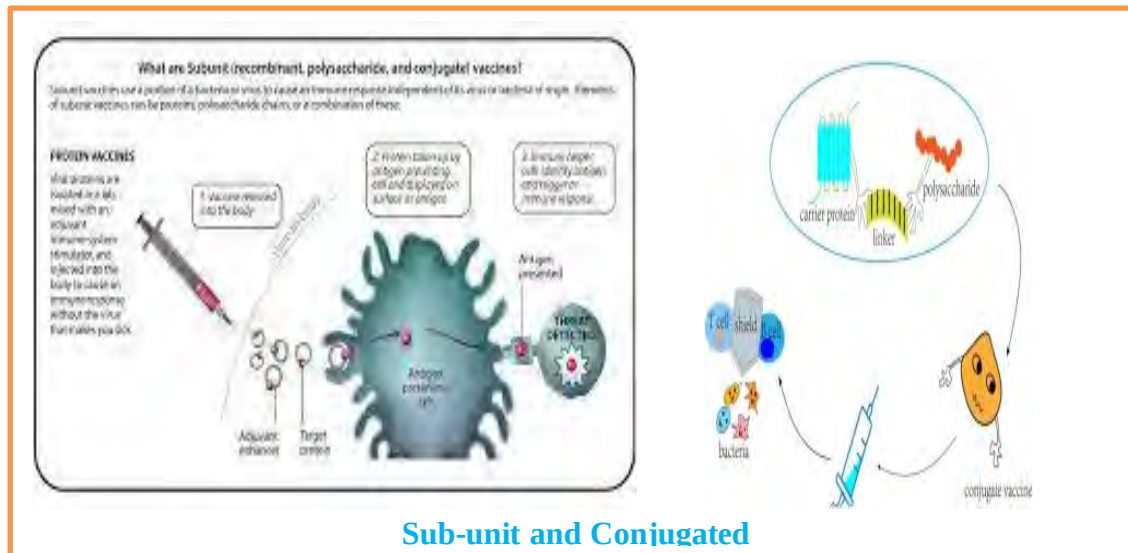
Inactivated whole-agent vaccines refer to such vaccines which use killed microbes (killed usually by formalin or phenol), e.g., inactivated polio (IPV), whole cell pertussis (whooping cough), rabies, hepatitis A, etc.

C. Toxoids

Toxins are produced by pathogens and the toxoids refers to such vaccines which use inactivated toxins, e.g., diphtheria, tetanus, etc.

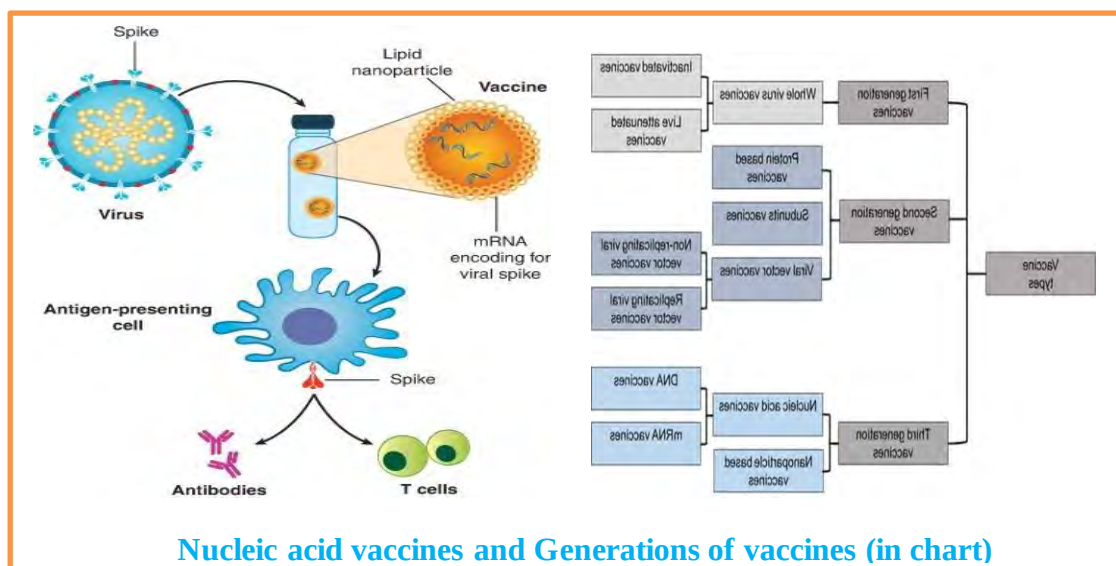
D. Subunit vaccines

Subunit vaccines refer to such vaccines which use only those antigenic fragments of microorganisms that best stimulate an immune response, e.g., hepatitis B, acellular pertussis, etc.



E. Conjugated vaccines

Conjugated vaccines refer to such vaccines which use polysaccharides combined with proteins, e.g., haemophilus influenza (Hib), pneumococcal, etc.



F. Nucleic acid vaccines

Nucleic acid vaccines which is also known as DNA vaccines refer to such vaccines which use naked DNA, e.g., malaria, HIV/AIDS, influenza, Ebola, herpes virus, etc.

Based on way or method of their preparation, vaccines are following four types: first, second, third, fourth, and fifth generation.

A. First generation vaccines

First generation vaccines refer to such vaccines which are prepared by conventional methods with the help of live-attenuated, inactivated, or killed microorganisms, e.g., influenza, measles, mumps, polio, rabies, rotavirus, rubella, tuberculosis, typhoid, varicella, yellow fever, zoster, cholera, hepatitis A, pertussis, and plague.

B. Second generation vaccines

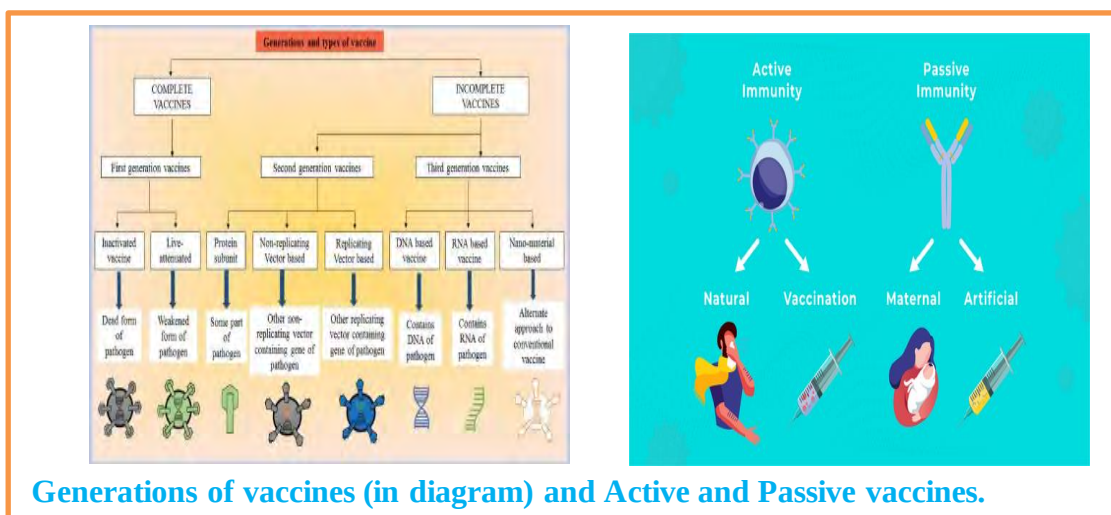
Second generation vaccines, also called **recombinant vaccines** refer to such vaccines which are prepared by biotechnology/genetic engineering, e.g., hepatitis B.

C. Third generation vaccines

Third generation vaccines, also known as **synthetic vaccines** refer to such vaccines which are prepared by biotechnology/genetic engineering by taking the help of DNA or m-RNA, e.g., tumour, cancer, etc.

D. Fourth generation vaccines

Fourth generation vaccines are receptor-legend binding as it is biochemically and artificially prepared to neutralize the infectious agent, e.g., CoV,



On the basis of inoculation of pathogens, their products or other products, vaccines are classified into two types – active and passive.

A. Active vaccines

Active vaccines refer to such vaccines which are prepared by keeping whole pathogens, e.g., oral polio,

B. Passive vaccines

Passive vaccines refer to such vaccines which are prepared by keeping toxoids, antigenic fragments, biomolecules like polysaccharides and proteins, naked DNA, and biochemically prepared, e.g., anti-snake venom (ASV),

Activity

Enlist different types of vaccines administered to the citizens from year of a baby to the 65 years of adults in your locality.

Below mentioned table is the list of vaccines required for man in developing countries.

Vaccines required for man in developing countries

S. No.	Pathogen	Disease	Includes	Type of vaccine	Name of vaccine	Remarks
1.	Rubeola virus	Measles	Whole microorganism	Live attenuated	Measles	Virus
2.	Mumps virus	Mumps	Whole microorganism	Live attenuated	Mumps	Virus
3.	Varecella-zoster virus	Chickenpox or Vacicella-zoster	Whole microorganism	Live attenuated	Chickenpox	Virus
4.	Yellow fever virus	Yellow fever	Whole microorganism	Live attenuated	Yellow fever	Virus
5.	Poliovirus	Poliomyelitis or Polio	Whole microorganism	Live attenuated	Polio (sabin)	Oral vaccine
				Inactivated	Polio (salk)	Injectable
6.	Rubella virus	Rubella	Whole microorganism	Inactivated	Rubella	Also called German measles virus
7.	Influenza virus	Influenza	Whole microorganism	Inactivated	Influenza	Types A, B, C, and D.
8.	Virus	Hepatitis A	Whole microorganism	Inactivated	Hepatitis A	Virus
9.	Virus	Hepatitis B	Surface antigen (purified macromolecule), e.g., HBsAg	Recombinant	Hepatitis B	Virus
10.	<i>Corynebacterium diphtheriae</i>	Diphtheria	Toxoids (purified macromolecule)	Inactivated exotoxin	DPT (Diphtheria, Pertussis, and Tetanus) (a combination vaccine)	Bacterium
11.	<i>Bordetella pertussis</i>	Pertussis	Whole microorganism	Inactivated		Bacterium
12.	<i>Clostridium tetani</i>	Tetanus	Toxoids (purified macromolecule)	Inactivated exotoxin		Bacterium
13.	<i>Mycobacterium tuberculosis</i>	Tuberculosis	Whole microorganism	Live attenuated	BCG (Bacillus Calmette-Guerin)	Bacterium
14.	<i>Salmonella typhi</i>	Typhoid	Whole microorganism	Live attenuated	Typhoid	Bacterium
15.	<i>Bacillus anthracis</i>	Anthrax	Whole microorganism	Inactivated	Anthrax	Bacterium
16.	<i>Vibrio cholerae</i>	Cholera	Whole microorganism	Inactivated	Cholera	Bacterium
17.	<i>Yersinia pestis</i>	Plague	Whole microorganism	Inactivated	Plague	Bacterium
18.	<i>Plasmodium falciparum</i>	Fatal malaria	Proteins (surface antigen, i.e., purified macromolecule)	Recombinant	RTS, S ('Mosquirix') and R21	Protozoa

Below mentioned table is the list of vaccines managed by the National Immunization Scheme, Ministry of Health and Population, Government of Nepal. The vaccines are managed to be administered to the people of Nepal.

List of vaccines for Nepalese populace (updated on 2024)

S. No.	To whom and at what age?	Vaccine	Against which disease/s?	Way and Site of administration
1.	Pregnant lady	TD (Tetanus and Diptheria): two doses in first pregnancy at an alternate of one month and single dose in second pregnancy and onwards.	Tetanus and Diptheria for both mother and embryo/foetus.	Intramuscular injection at the outer middle of the left arm.
2.	Immediately born Neo-natus	BCG	Tuberculosis (TB)	Intradermal injection at the outer upper part of the right arm.
		Hepatitis-B	Hepatitis-B	Intramuscular injection at the outer middle of the left thigh.
		OVOP (Oral Polio Vaccine)	Polio	Oral drop (two drops inside mouth)
3.	Six week Baby	DTwP/DTaP	Diptheria, Pertussis, and Tetanus	Intramuscular injection at the outer middle of the left thigh.
		Hib	Haemophilus Influenza Type B	
		Hepatitis-B	Hepatitis-B	
		IPV-1 (Inactivated Polio)	Polio	Intradermal injection at the outer upper part of the right arm.
		PCV-1 (Pneumococcal conjugate vaccine)	Pneumonia and Pneumococcal diseases, Meningitis, and Blood infections	Intramuscular injection at the outer middle of the right thigh.
		Rotavirus-1	Diarrohoea	Oral drop (inside cheek)
4.	Ten week Baby	DTwP/DTaP	Diptheria, Pertussis, and Tetanus	Intramuscular injection at the outer middle of the right thigh.
		Hib	Haemophilus Influenza Type B	
		Hepatitis-B	Hepatitis-B	
		IPV-2	Polio	Intradermal injection at the outer upper part of the right arm.

		PCV-2	Pneumonia and Pneumococcal diseases, Meningitis, and Blood infections	Intramuscular injection at the outer middle of the right thigh.
		Rotavirus-2	Diarrohoea	Oral drop (inside cheek)
5.	Fourteen week Baby	DTwP/DTaP	Diphtheria, Pertussis, and Tetanus	Intramuscular injection at the outer middle of the right thigh.
		Hib	Haemophilus Influenza Type B	
		Hepatitis-B	Hepatitis-B	
		IPV-3	Polio	Intradermal injection at the outer upper part of the right arm.
		PCV-3	Pneumonia and Pneumococcal diseases, Meningitis, and Blood infections	Intramuscular injection at the outer middle of the right thigh.
		Rotavirus-3	Diarrohoea	Oral drop (inside cheek)
6.	Six month Baby	TCV (Typhoid Conjugate Vaccine)	Typhoid	Intramuscular injection at the outer middle of the left thigh.
		Influenza-1	Influenza	Subcutaneous injection at the outer upper part of right arm.
7.	Seven month Baby	Influenza-2	Influenza	Subcutaneous injection at the outer upper part of right arm.
8.	Nine month Baby	MMR-1 (Measles, Mumps, and Rubella)	Measles, Mumps, and Rubella	Subcutaneous injection at the outer upper part of left arm.
9.	Twelve month Child	Hepatitis-A1	Hepatitis-A	Intramuscular injection at the outer middle of the right thigh.
		JE	JE(Japanese Encephalitis)	Subcutaneous injection at the outer upper part of right thigh.
10.	Fifteen month Child	MMR-2	Measles, Mumps, and Rubella	Subcutaneous injection at the outer upper part of left arm.
		Varicella-1	Chickenpox	
11.	Eighteen month Child	DTwP/DTaP	Diphtheria, Pertussis, and Tetanus	Intramuscular injection at the outer middle of the right thigh.
		Hib	Haemophilus Influenza Type B	
		IPV-B1 (Inactivated Polio)	Polio	Intradermal injection at the outer upper part of the right

		Vaccine- Booster 1)		arm.
		PCV-4	Pneumonia and Pneumococcal diseases, Meningitis, and Blood infections	Intramuscular injection at the outer middle of the right thigh.
		Hepatitis-A2	Hepatitis-A	Intramuscular injection at the outer middle of the right thigh.
12.	Four to Six years Child	DTwP/DTaP	Diphtheria, Pertussis, and Tetanus	Intramuscular injection at the outer middle of the right thigh.
		IPV-B2	Polio	Intradermal injection at the outer upper part of the right arm.
		MMR-3	Measles, Mumps, and Rubella	Subcutaneous injection at the outer upper part of left arm.
		Varicella-2	Chickenpox	
13.	Ten years Child	TCV (Typhoid Conjugate Vaccine)	Typhoid	Intramuscular injection at the outer middle of the left thigh.
14.	Ten to Thirteen years girls	HPV (Human Papilloma Virus Vaccine)	Cervical cancer	Intramuscular injection at the outer middle part of left arm.

Project work

Record the different types of vaccines administered in your province and find out the percentage so as to know their succession rate.

Below mentioned table (represented in vernacular language) is the list of vaccines managed by the National Immunization Scheme, Ministry of Health and Population, Government of Nepal to be necessarily administered to the people of Nepal.



विशाल स्वास्थ्य
संरक्षण तथा जनसंख्या योजना
संरक्षण तथा विकास
परिवार कल्याण महाशाखा

राष्ट्रिय खोप तालिका



पूर्ण खोप, सुरक्षित भविष्य

पटक/भेट	कुन उमेरमा	कुन खोप	सुई लगाउने स्थान र माध्यम	कुन रोगबाट बचाउँछ
	गर्भवति महिला	टि.डी. पहिलो गर्भमा कमिमा एक महिनाको अन्तरमा २ पटक र त्यसपछिको प्रत्येक गर्भमा १ पटक	बायाँ पाखुराको बिच बाहिरी भाग मासुमा (Intramuscular)	मातृ तथा नवजात शिशु धनुषकार र भ्यागुते रोग
१	 जन्मने वित्तिकै सकेसम्म छिटो	बि.सि.जी. 	दायाँ पाखुराको माथिल्लो भाग छालाभित्र (Intradermal)	क्षयरोग
२	 ६ हप्तामा	रोटा (दाहिने माया) पोलियो (दाहिने माया) पि.सि.भी (दाहिने माया) डि.पि.टी. हेप-बी हिब (दाहिने माया)	 • मुखमा (गालाको भित्री भागमा) • मुखमा दुई थोपा • दायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular) • बायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular)	• रोटा भाइरसबाट हुने भगडापखाला • पोलियो • निमोनिया (न्यूमोकोकल रोगहरु) • भ्यागुते रोग, लहरे खोकी, धनुषकार, हेपाटाइटिस-बी, हेमोफिलस इन्फ्लुएन्जा-बी,
३	 १० हप्तामा	रोटा (दोस्रो माया) पोलियो (दोस्रो माया) पि.सि.भी (दोस्रो माया) डि.पि.टी. हेप-बी हिब (दोस्रो माया)	 • मुखमा (गालाको भित्री भागमा) • मुखमा दुई थोपा • दायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular) • बायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular)	• रोटा भाइरसबाट हुने भगडापखाला • पोलियो • निमोनिया (न्यूमोकोकल रोगहरु) • भ्यागुते रोग, लहरे खोकी, धनुषकार, हेपाटाइटिस-बी, हेमोफिलस इन्फ्लुएन्जा-बी,
४	 १४ हप्तामा	पोलियो (तेस्रो माया) एफ.आई.पि.भी. (दाहिने माया) डि.पि.टी. हेप-बी हिब (तेस्रो माया)	 • मुखमा दुई थोपा • दायाँ पाखुराको माथिल्लो भाग छालाभित्र (Intradermal) • बायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular)	• पोलियो • पोलियो • भ्यागुते रोग, लहरे खोकी, धनुषकार, हेपाटाइटिस-बी, हेमोफिलस इन्फ्लुएन्जा-बी,
५	 ९ महिनामा	एफ.आई.पि.भी. (दोस्रो माया) दादुरा-रुवेला (दाहिने माया) पि.सि.भी (तेस्रो माया)	 • दायाँ पाखुराको माथिल्लो भाग छालाभित्र (Intradermal) • बायाँ पाखुराको माथिल्लो भाग छाला र मासु बीच (Subcutaneous) • दायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular)	• पोलियो • दादुरा र रुवेला • निमोनिया (न्यूमोकोकल रोगहरु)
६	 १२ महिनामा	जापानिज इन्सेफलाइटिस 	दायाँ तिघ्राको माथिल्लो बाहिरी भाग छाला र मासु बीच (Subcutaneous)	• जापानिज इन्सेफलाइटिस
७	 १५ महिनामा	दादुरा-रुवेला (दोस्रो माया) टाइफाइड 	• बायाँ पाखुराको माथिल्लो भाग छाला र मासु बीच (Subcutaneous) • दायाँ तिघ्राको बिच बाहिरी भाग मासुमा (Intramuscular)	• दादुरा र रुवेला • टाइफाइड
८	 कक्षा ६ की छात्रा र विद्यालय नजाने १० वर्षकी किशोरी	एच.पि.भी. 	बायाँ पाखुराको बिच बाहिरी भाग मासुमा (Intramuscular)	पाठेघरको मुखको क्यान्सर

10.2.2 Application of microbiology

Application of microbiology, a part of biotechnology refers to the use of microorganisms in industrial process for the benefit of humankind. Here, application of microorganisms in dairy and beverage industries, microbial contamination of water, sewage and drinking water treatment, and biocontrol agents and bio-fertilizers will be discussed.



1. Application of microorganisms in dairy and beverage industries

From the time immemorial, microorganisms are used in human food and drink to make them more nutritious, tasty, and cheap. Here, microorganisms applied in dairy and beverage industries are discussed.

I. Application of microorganisms in dairy industries

Dairy refers to milk and its products. Since 6000 years, dairy products have become part of human diet as these contain proteins, vitamins, calcium, etc. Various dairy products are prepared in dairy industries by the process of fermentation by applying microbes, some of them are:

i. Curd

Curd (**dahi**, vern.) is obtained by coagulating milk in a sequential process called **curdling**. Coagulation can be caused by adding **starter culture**, **rennet** or **edible acidic substances** such as lemon juice, lactic acid, or vinegar, and then allowing it to coagulate. First of all, composition of milk and its blending ingredients are adjusted. Milk is then pasteurized (heat

treatment), homogenized, cooled, and inoculated with starter culture, rennet, lemon juice, lactic acid, or vinegar. Starter culture contains *Lactobacillus acidophilus*, *L. lactis*, and *L. lactiscremoris* that converts lactose of milk into lactic acid. Lactic acid imparts sour taste to curd. Milk is then held and cooled. Curd is prepared after 10-12 hrs.



ii. Yoghurt

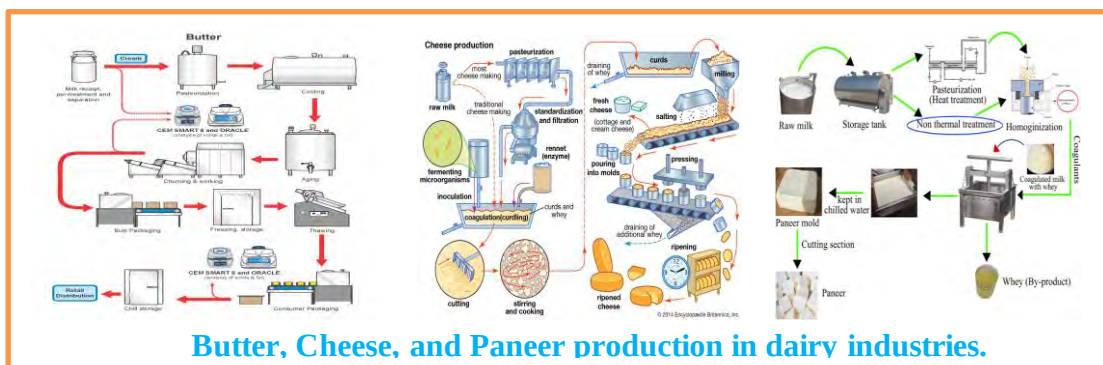
Yoghurt (**guliyo dahi**, vern.), also called **yogurt** like curd is also obtained by coagulating milk in sequential process called curdling. At first, composition of milk and its blending ingredients are adjusted. Milk is then pasteurized (heat treatment), homogenized, cooled, and fermented using **starter culture** containing *Lactobacillus bulgaricus*, *Streptococcus lactis*, and *S. thermophiles*. Flavours and additives are added. Yoghurt is prepared after 10-12 hrs.

iii. Butter

Butter (**nauni**, vern.) is obtained from milk in the form of cream following sequential process. First of all, milk is standardized, pasteurized (heat treatment), cooled, and is then put under cream separator. Cream is separated from the milk leaving skimmed milk. Skimmed-milk is pasteurized, processed, and packed for drinking purpose. Cream is pasteurized (heat treatment). Pasteurized cream is mixed with culture containing *Lactococcus lactis* and is then put under vacuum aeration for ripening. Ripened cream is put under ageing when butterfat crystallized. Crystallized butterfat is put under churning when butter granules are seen. Butter granules are put under draining and washing when raw butter and buttermilk is separated. Buttermilk is pasteurized, processed, and packed for drinking purpose. Raw butter is put under salting and temperature treatment. Finished butter is packed and stored.

iv. Cheese

Cheese is obtained from milk in the form of solid following sequential process. At first, milk is standardized, pasteurized (heat treatment), cooled, and is then inoculated with starter culture containing *Lactococcus lactis* and non-starter mesophilic bacteria, already present in milk to ripen the milk. Ripened-milk is further added with rennet to form curd which is allowed to ferment further. Curd is cut and heated to separate the whey which is then drained from the vat and the curd forms the mat. Curd mats are cut into sections and piled up on top of each other and flipped periodically when this step is called **cheddaring**. Cheddared curd mats are treated with dry salt/brine or put into salt/brine solution. Cheese, thus, prepared is put under storing and ageing.



v. Paneer

Like curd and yoghurt, paneer is also obtained by coagulating milk in a sequential process called curdling. First of all, composition of milk and its blending ingredients are adjusted. Milk is then pasteurized (heat treatment), homogenized, cooled, inoculated with starter culture (containing *Lactobacillus acidophilus*, *L. lactis*, and *L. lactiscremoris* that converts lactose of milk into lactic acid imparting sour taste to curd), rennet, lemon juice, or vinegar, and left for coagulation. Coagulated milk is then separated from whey. Coagulated milk is put under hooping. Hooped-milk is pressed and dipped in chilled water when paneer is prepared.

Do you know?

Biotechnology, in this century, has become boon for the human beings in all possible sectors including food and beverages in industrial process, purification of water, and all types of agriculture – extensive, semi-intensive, and intensive.

II. Application of microorganisms in beverages industries

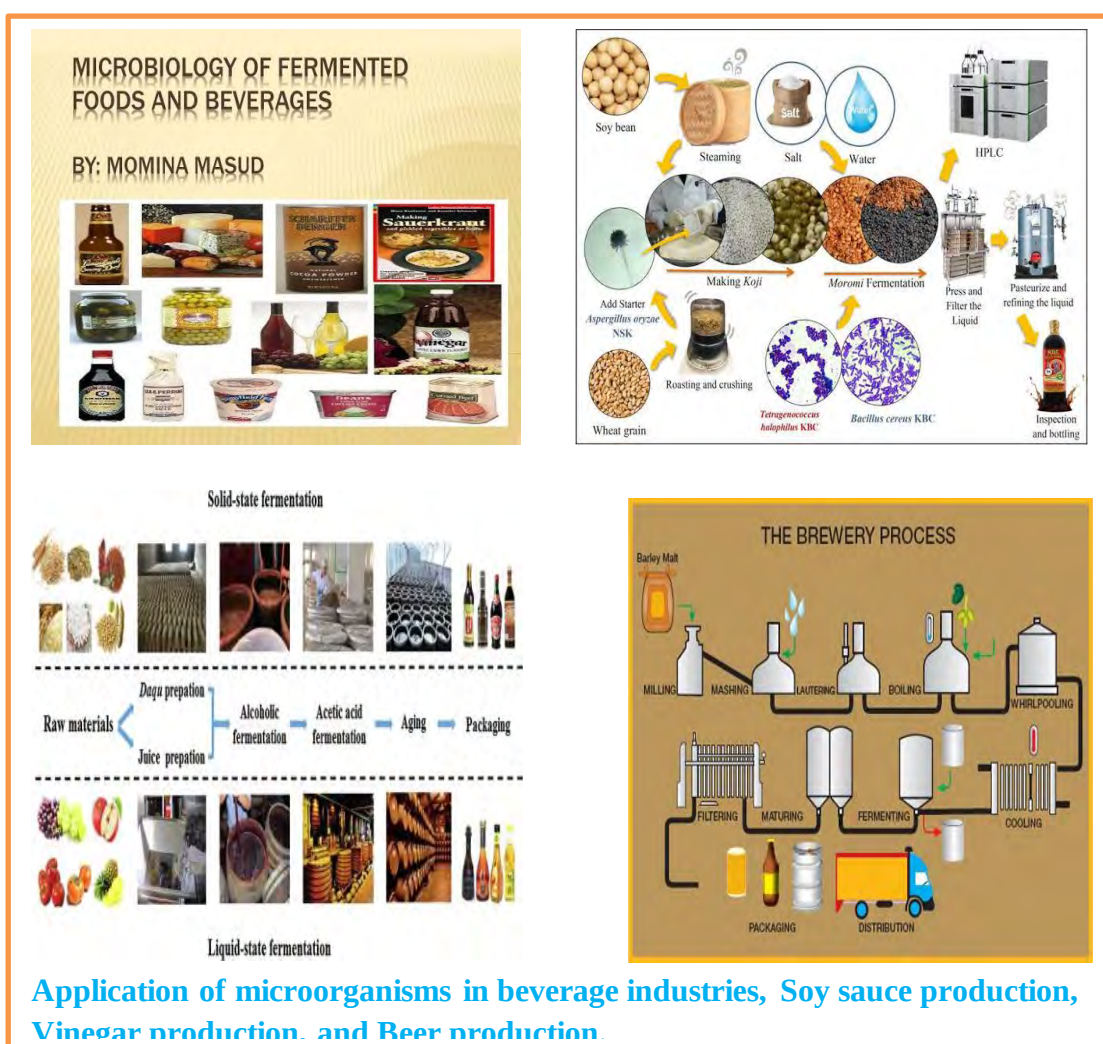
Beverage (in commercial use) refers to drink other than water. Since, 2500 years, alcoholic beverages are prepared. Here, some of the beverages that are prepared in beverage industries by the application of microorganisms are discussed.

i. Soy sauce

Soy sauce is an increasingly popular oriental fermented condiment. It is made from soybeans, wheat, salt, and fermenting agent like **fungus** *Aspergillus sojae* or *A. oryzae*, or **bacterium** *Enterococcus faecum*. Traditional brewing method to make soy sauce involves moistening and soaking 60% soybeans (defatted soy meal) in water dissolved with salt for several hours, draining the soybeans, and steaming them. Forty percent wheat is then roasted, ground into flour, and mashed into the steamed soybeans. Soybean and wheat mixture is added with any of the above mentioned fermenting agent and then incubated for 24 hours. In the solid-state, i.e., **koji-state**, ferment brine is added and the liquid ferment, i.e., **moromi state** is fermented at 40-50°C. Brine is further added in ferment and the ferment is treated at 80°C. Afterwards, ferment is centrifuged. Liquid part, thus, obtained is soy sauce which is mixed with benzoic acid, and is then clarified and bottled.

ii. Vinegar

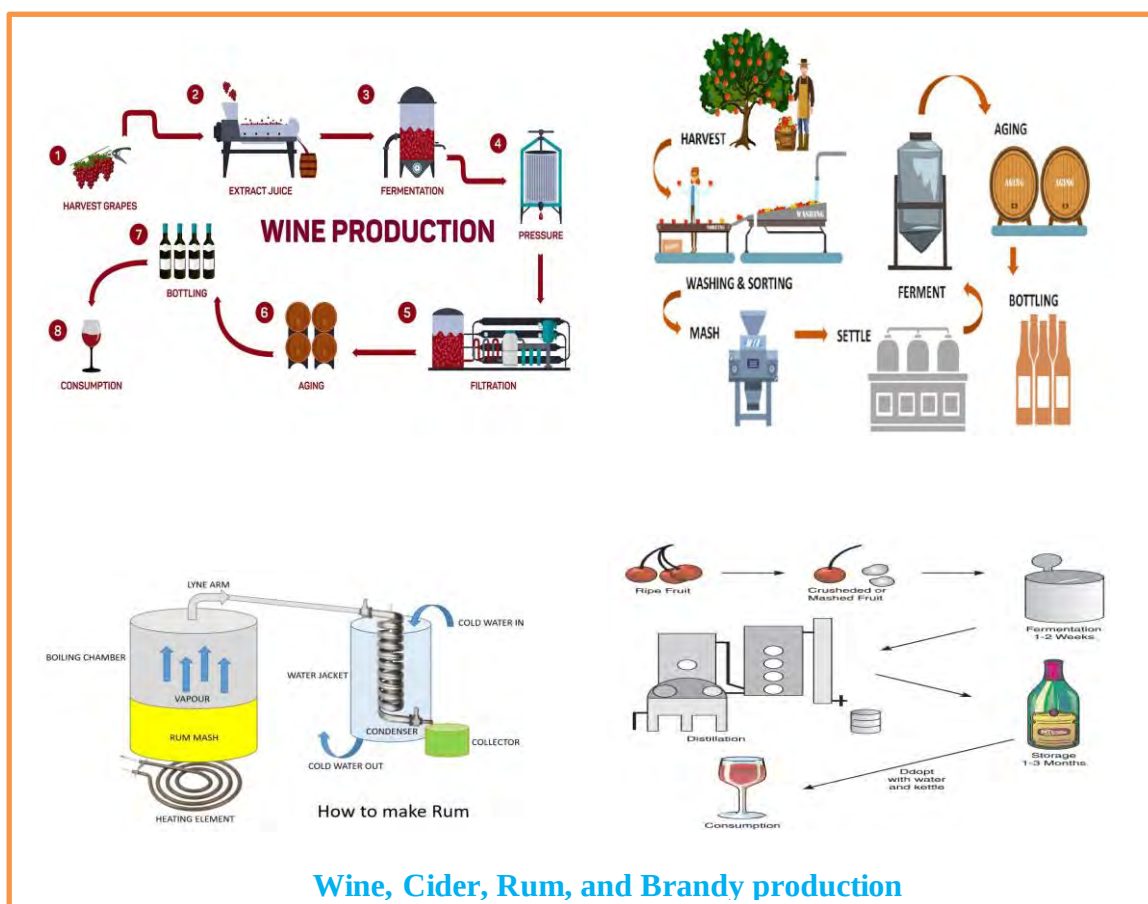
Vinegar is an alcoholic liquid that has further been allowed to sour. It is primarily used to flavor and preserve foods and as ingredient in salad dressings and marinades. It is also used as a cleaning agent. Ten kilograms of peelings of sugar-containing fruits like grape, apple, etc., is taken. Five litre hot water at 100 °C is added when saccharine is extracted. The product is put under pressing when raw juice is separated from waste. Waste is thrown. Fifty part per million (ppm) **sulfit** is added to eliminate tannin. Tannin-eliminated juice is put under heating when juice concentrates by 20 brix. Concentrated juice is put under alcohol fermentation by the help of alcohol fermenting bacteria. When product becomes wine then wine is put under acetic fermentation by the help of **bacterium** *Acetobacter aceti*, *A. malorum*, *A. pasteurianus*, *A. pomorum*, *Gluconacetobacter europaeus*, or *G. hansenii* when alcohol is converted into sour vinegar.



iii. Beer

Beer is one of the oldest and most widely consumed alcoholic drinks in the world, and is the third most popular drink overall after water and tea. It is prepared by cereal grains, most popularly by barley. First of all, required quantity of barley is taken and is put under screening for obtaining good quality barley. Screened barley is passed through first process called **malting** with **three steps** to make barley ready for brewing – **first step** of malting is **steeping**

when barley is added to a vat with water and allowed to soak for approximately 40 hours, **second step** of malting is **germination** when soaked-barley is spread out on the floor of the germination room for around five days, and the **third step** of malting is **kilning** when germinated barley is passed through high temperature drying in a kiln. After kilning the barley is called **malt**. Malt is put under second process called **milling** when malt is milled or crushed. Crushed malt is passed through third process called **mashing** when it is mashed or mixed with some other grains such as corn, sorghum, rye, wheat, etc., along with water. Mashed-malt is put under fourth process known as **lautering** when liquid wort is separated from solid. Liquid wort is put under fifth process called **boiling** when liquid wort is boiled along with hops cone to make the wort bitter. Liquid wort is then cooled and put under sixth process **fermenting** by the addition of **yeast** (fungus) *Saccharomyces cerevisiae* (for ale), *S. pastorianus* (for lager), *S. caribergensis*, or **bacterium** *Acetobacter cerevisiae*. Liquid wort is then passed through clarification to separate any precipitate. Afterwards, it is passed through cleaning agent like isinglass to make it clear. Now, liquid wort is called beer. Beer is put under seventh process called **conditioning** in which it is put under ageing for about 3-4 weeks. Beer is then passed through filtering that provides flavour to it. After filtering, packaging is done.



IV. WINE

Wine is an alcoholic drink typically made from fermented grapes. Yeast consumes sugar in grapes and converts it to ethanol and carbon dioxide, releasing heat in the process. **Harvesting** or **picking** of required quantity of grapes is certainly first step in the actual wine making process. **Crushing and pressing** of harvested grapes mechanically so as to obtain grape juice is considered second step of wine making process. Grape juice, thus, obtained is put under third step of wine making process called fermentation by the help of anyone **yeast** (fungus)

like *Saccharomyces bayanus*, *S. cerevisiae*, *Cyberindnera mrakii*, or **bacterium** like *Lactobacillus hilgardi*, *L. kunkeei*, *L. mali*, *L. nagelli*, *L. oeni*, *L. pentosus*, *L. yamanashiensis*, *Leuconostoc*, *Oenococcus oeni*, *Pichia fermentans*, *Leuconostoc palmae*. Wine thus prepared is put under fourth process of wine making known as **clarification** so as to clarify any of the precipitate. Wine is then put under ageing and bottling.

v. Cider

Cider is an alcoholic beverage made from fermented juice of apple. Required quantity of apple is taken. Crushing and pressing of the apple is done mechanically so as to obtain apple juice. Apple juice is allowed to ferment with the help of **bacterium** like *Lactobacillus collinoides*, *L. mali*, or *L. yamanashiensis*. Cider, thus, obtained is packed.

vi. Rum

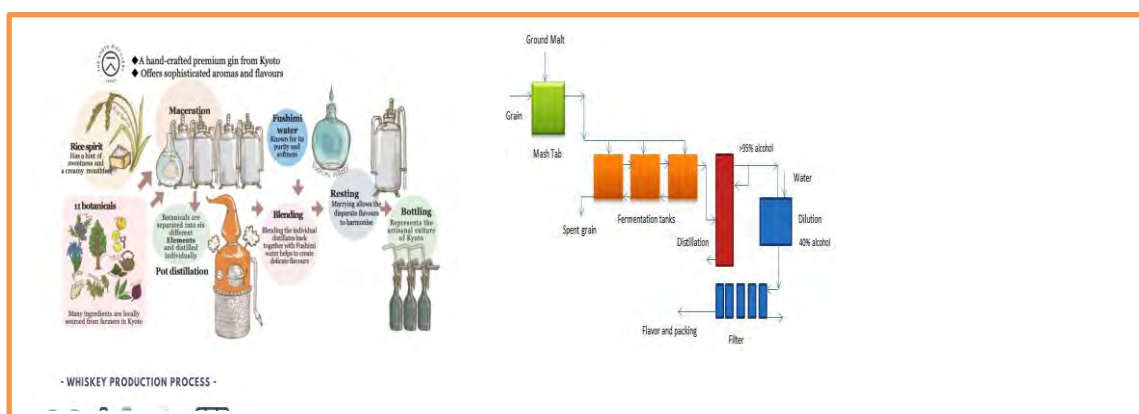
Rum is a liquor made by fermenting then distilling sugarcane molasses or sugarcane juice. It is a distillate, clear liquid, aged in oak barrels. Required quantity of molasses is taken, mixed with water, and allowed to fermentation for 1.5-2.0 days by the help of **bacterium** like *Lactobacillus mali* or *L. similis*. Ferment is further put under distillation. Liquid obtained after distillation called rum is further passed through ageing and blending to increase its taste and flavor. Prepared rum is then bottled.

vii. Brandy

Brandy is liquor produced by distilling wine. It contains 35-60% alcohol by volume (70-120 US °proof) and is typically consumed as an after dinner digestive.

viii. Gin

Gin is a juniper-flavoured spirit made not via re-distillation of final alcohol product but by simply adding approved natural flavouring substance to a neutral spirit. It contains 35-60% alcohol by volume (70-140 US °proof).



It is made by distilling liquid from fermented cereal grains. Sometimes with traces of impurities and flavourings.

x. Whisky

Whisky, also written as **whiskey** is a type of distilled alcoholic beverage made from fermented grain mash including barley, corn, rye, and wheat. It is typically aged in wooden casks made from oak.

Activity

Locate any of the dairy and alcohol manufacturing industries situated in your locality. Represent your observation of that industry/industries in the form of description.

2. Microbial contamination of water

I. Introduction

Non-desirable mixing of any physical (dust, silt, sand, etc.), chemical (CH_4 , NH_3 , CuSO_4 , etc.), or biological (plants, animals, microorganisms, etc.) components in water is known as **contamination of water**.



Contamination of water



Microbial contamination of water and Microbial pollution of water

Unwanted, unnecessary, unintentional, or undesirable inhabitation of any type of microorganisms including pathogenic microorganisms in water is termed as **microbial contamination**, e.g., microbial pollution.

Microbial pollution in aquatic environment is one of the crucial issues with regard to sanitary state of water bodies used for drinking water supply, recreational activities, and harvesting aquatic food due to potential contamination by pathogenic viruses, bacteria, or protozoa. The issue is directly related to human health in terms of gastroenteritis. Generally, turbidity test of water to be used has been carried out.



II. Sources of contamination of water

Discharges of water treatment plants, decontamination stations, hospitals, industries, etc., along with sediments and submerged aquatic vegetation (SAV) are major sources of contamination of water.

III. Causes of contamination of water

Diffuse sources (faecal matter, slurry, manure, sludge, etc.) are causes of contamination of water.

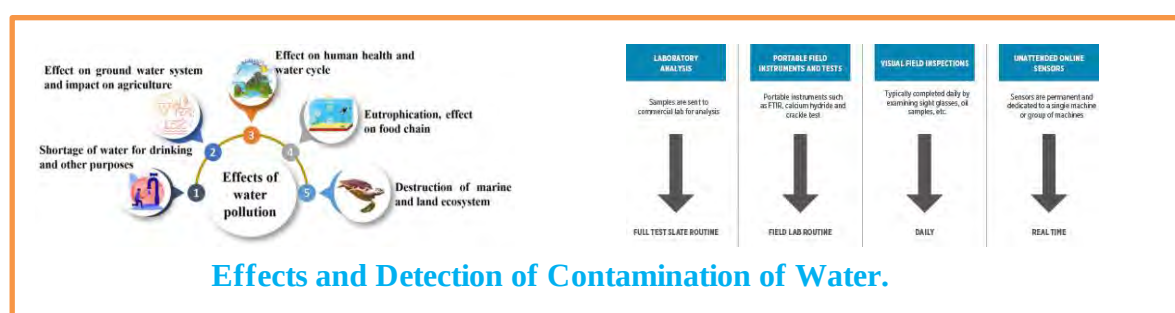
IV. Microorganisms responsible for contamination of water

Contagious microbes like viruses (rotavirus, noro virus, etc.), bacteria (*Shigella*, *Escherichia coli*, **faecal coliforms**, *Vibrio*, *Salmonella*, etc.), fungi, yeasts, moulds, and protozoa (*Entamoeba*, *Cryptosporidium*, *Giardia*, etc.) including their toxins are responsible for microbial contamination.



V. Effects of contamination of water

Problems with processing, safety concerns, human health including health of the cattle which human domesticate.



VI. Detection of contamination of water

Recently, nucleic acid amplification methods, such as PCR and nucleic acid identification and characterization methods, such as hybridization (gene probe), RFLP analysis, and nucleotide sequencing, have been applied to the detection of microbes in water.

Activity

Do you think, the locality in which you live has water contaminated with microbes? If so, point out the causative microbes through which water becomes contaminated. What remedies are you people doing to alleviate the microbial contamination of water and to make that water drinkable.

VII. Prevention of contamination of water

Physico-chemical and biological parameters test of the contaminated water.



3. Sewage and drinking water treatment

Life depends on/in water, so, it becomes necessary to keep water safe and clean in its healthy condition. To keep water in its healthy condition and to get potable water, i.e., water suitable for human consumption in drinking and cooking, it is necessary for sewage and drinking water treatment.

I. Sewage treatment

Sewage treatment is nowadays called **wastewater treatment**. It is a type of wastewater treatment that aims to remove contaminants from sewage to produce an effluent that is suitable for discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. Sewage is collected at a particular place through channels or pipes. Sewage comprises wastewater from household waste, industrial waste, and surface runoff, and is supposed to be the part of sanitation. Treatment is done in wastewater treatment plant (WWTP).

i. Treatment processes

Wastewater treatment processes are generally two types: low tech, extensive or nature-based processes and high tech, intensive or mechanized processes.



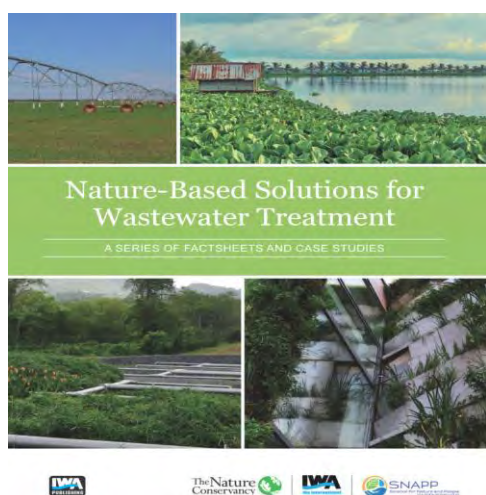
Life depends on/in water and the 'Tips' keeping water safe and clean in its healthy condition.



Potable water for human consumption and Sewage treatment

A. Low tech, extensive, or nature-based processes

It is less expensive with no or little energy use with treatment of the part of sewage, e.g., stabilization/holding sewage in large area.



Sewage or wastewater treatment: Low tech, extensive, or nature-based process

B. High tech, intensive or mechanized processes

It is expensive with more energy use with treatment of the whole sewage, e.g., treatment plants.

ii. Disposal or treatment options

Application of sewage to land as a form of final disposal or treatment, e.g., application of sludge, irrigation, soak pit, leach field, fish pond, floating plant pond, etc.

iii. Treatment steps

There are three main steps in wastewater treatment: primary, secondary, and tertiary including disinfection to sludge treatment however, preliminary treatment is must before starting primary and other treatments.

iv. Preliminary treatment

Preliminary treatment, also called **pre-treatment** so as to remove coarse materials from the sewage comprises:

A. Screening

Screening is that in which sewage is passed through **bar-screen** to remove all large objects like cans, rags, sticks, plastics, etc.

B. Grit removal

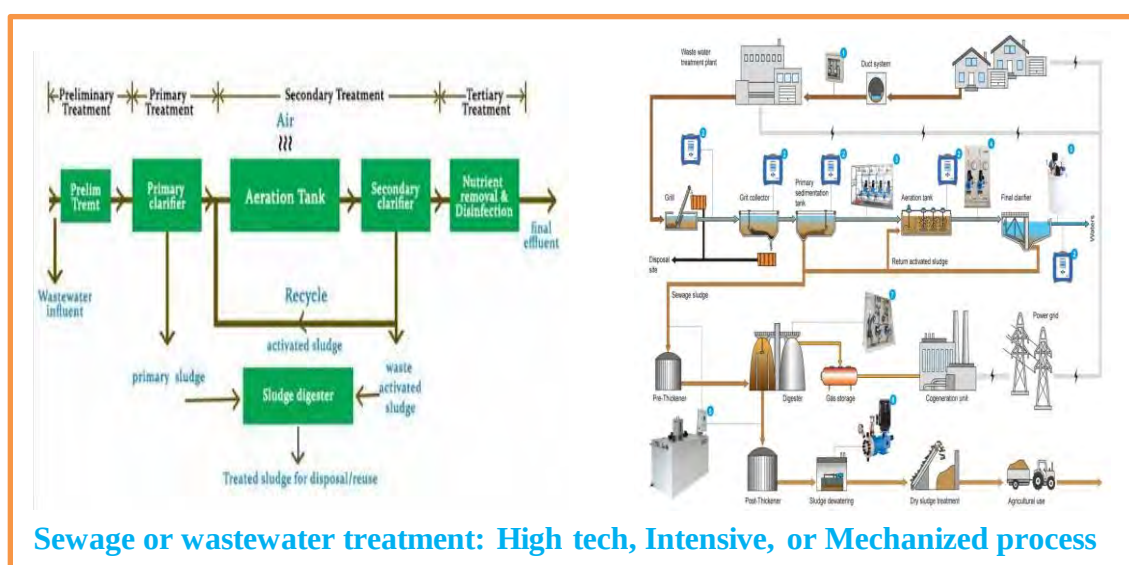
Grit removal comprises removal of sand, gravel, rocks, and other heavy materials from sewage.

C. Flow equalization

Flow equalization is for balance in flow of sewage.

D. Fat and grease removal

Fat and grease removal is through skimmers that collect fat and grease floating on surface.



v. After preliminary treatment, the three main steps of wastewater treatments are:

A. Primary treatment

Primary treatment is the removal of portion of suspended solids and organic matter from sewage. This treatment removes 50-70% suspended solids and 25-40% BOD.

B. Secondary treatment

Secondary treatment is to remove as much as solid materials as possible by the help of biological processes of biological digestion and organic fraction (**suspended-growth** and **bio-film processes**) in which most of the solids are removed.

C. Tertiary treatment

Tertiary treatment is an advance treatment ending in polishing of sewage or wastewater.

vi. After three steps of wastewater treatment, disinfection and removal of biological nutrients are performed.

A. Disinfection

Disinfection is to kill pathogens from the treated sewage.

B. Removal of biological nutrients

Removal of biological nutrients is the removal of N, P, K, NH_3 , etc.

vii. After completion of all sort of processes mentioned above, sewage is then disposed on land and water is reused in agriculture, irrigation, etc.

Activity

Do you have sewage treatment facility in your locality? If so, summarize the sewage treatment process. If not, how you and your neighbours are managing the sewage or garbage so that it never mixes with water.

II. Drinking water treatment

Drinking water, also called **potable water** which is safe to drink is the water that is used in drinking, drink or food preparation.

Drinking water treatment is any process that improves the quality of water to make it appropriate for specific end-use. The end-use may be drinking, industrial water supply, irrigation, etc.

Drinking water supplies should be safe and safe drinking water should come from hygienic drinking water sources. Because drinking water sources are subject to contamination hence, most of the drinking water sources are contaminated, causing disease and sickness from

water-borne microbes like *E. coli*, *Giardia intestinalis*, *Cryptosporidium*, HAV, etc. therefore, require appropriate treatment to remove pathogenic microorganisms. Public drinking water systems use various methods of water treatment to supply potable water. Most common steps in water treatment include:

Do you know?

Mineral water which is collected from spring and contains various minerals, such as salts and sulphur compounds is usually still, but may be sparkling water. **Purified water** which is processed to remove impurities and contaminants, through processes like microfiltration, reverse osmosis (RO), and advanced oxidation, is water for drinking and other usable purposes. **Unhygienic** or **impure water** is contaminated water with pathogens like viruses, bacteria, protozoa including animal faeces and certain chemicals, etc.

i. Coagulation and flocculation

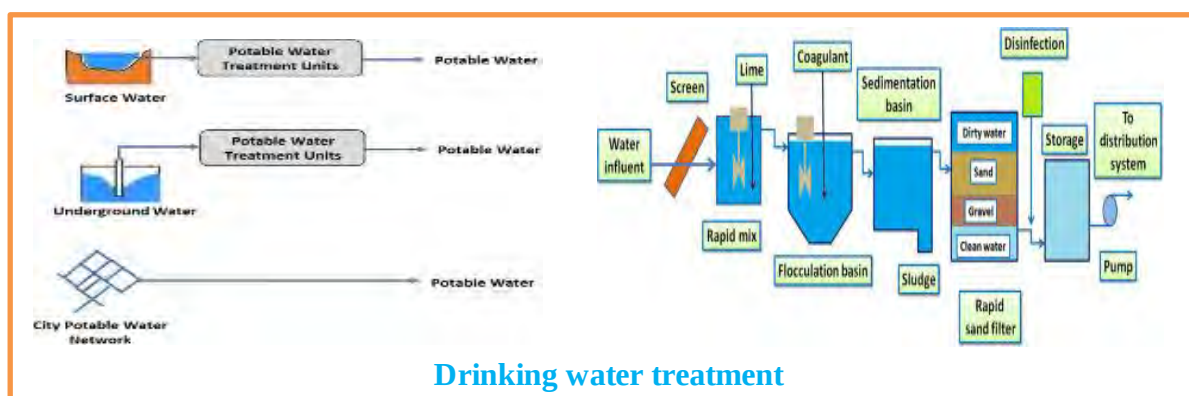
Coagulation and flocculation is considered to be the first step in drinking water treatment. Chemicals with positive charge are added to water. Positive charge of these chemicals neutralizes negative charge of dirt and other dissolved particles in water. When this occurs, particles bind with chemicals and form larger particles known as ‘floc’.

ii. Sedimentation

Sedimentation is self-occurring process in which floc settles to the bottom of water supply, due to its weight.

iii. Filtration

Once, floc has settled to the bottom of water supply, clear water on top will pass through filters of varying compositions (sand, gravel, and charcoal) and pore sizes, in order to remove dissolved particles, such as dust, chemicals, parasites, viruses, bacteria, etc.



iv. Disinfection

After filtration, disinfectant like chlorine or chloramines may be added in order to kill any viruses, bacteria, parasites, that remained in drinking water, thus, protecting drinking water from microbes and then finally piped to its destination.

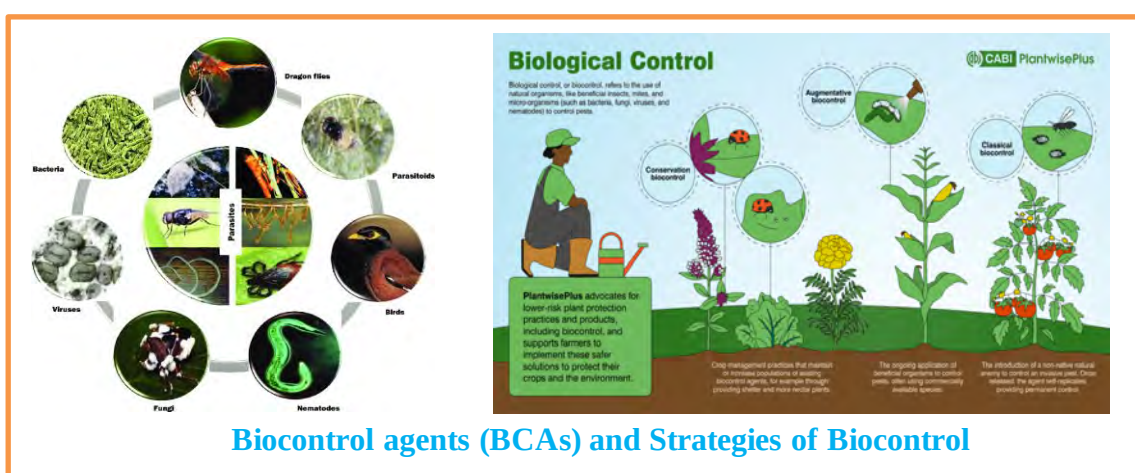
Activity

Make a list of the families that have an excess to drink what type of water – drinking water, purified water, or unhygienic water? Also mention, the waterborne diseases in your locality.

4. Bio-control agents and bio-fertilizers

I. Bio-control agents

Controlling of pests (insects, ticks, mites), weeds (narrow-leaf, broad-leaf), or plant diseases in a sustainable and environmentally friendly way by the utilization of organisms, like predators, parasitoids, pathogens, and competitors including certain plants, is known as biological control agent or bio-control agent (BCA).



Biocontrol agents (BCAs) and Strategies of Biocontrol

BCA is natural efficient strains of any microorganisms, modified organisms, animals, or plants that reduce the incidence or severity.

BCA relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role and can be an important component of integrated pest management (IMP). There are three basic strategies of IMP:

i. Importation

Importation is introduction of natural enemy of a pest in the hope of achieving control.

ii. Augmentation

Augmentation is that in which a large population of natural enemies are administered for quick pest control.

iii. Inoculation

Inoculation, also called **conservation** is to maintain natural enemies through regular establishment.

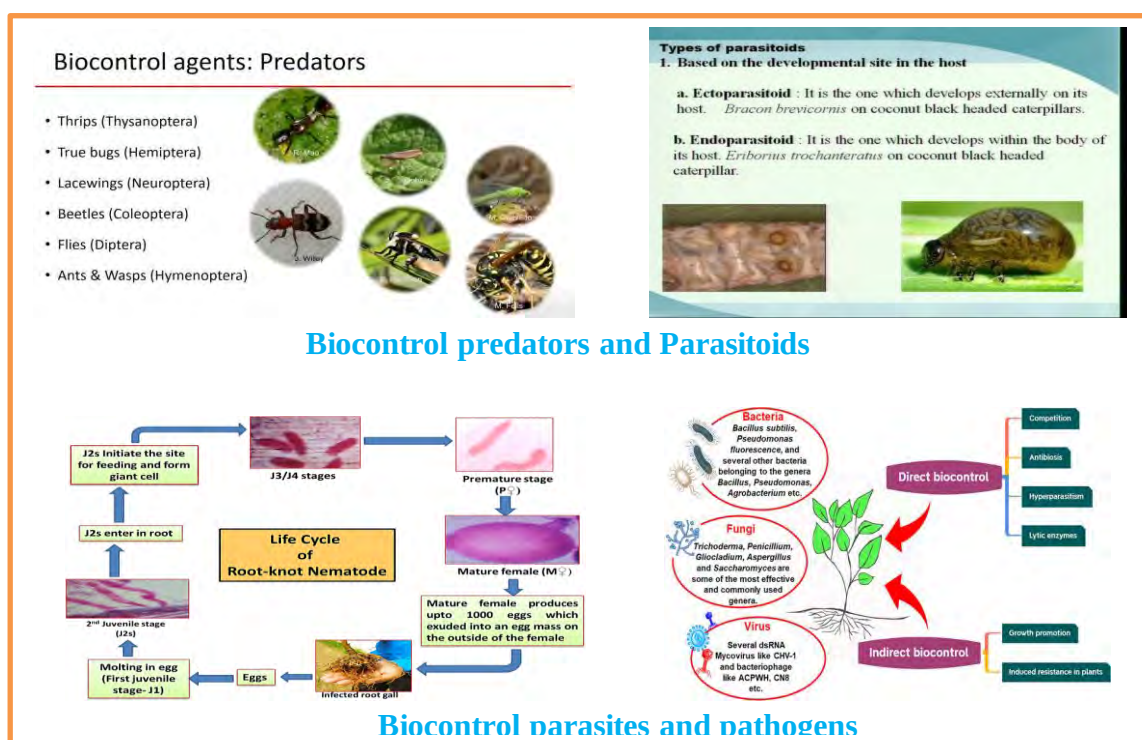
Biological control agents (BCAs) are: predators, parasites, parasitoids, and plants.

i. Predators

Predators are mainly free-living species that directly consume a large number of prey during their whole lifetime, e.g., lady beetles and their larvae are voracious in eating aphids, mites, scale insects, and caterpillars, etc., of cultivated crops.

ii. Parasitoids

Parasitoids lay their eggs on the body of an insect host, which is then used as food for developing larvae, killing host, e.g., wasps laying eggs on caterpillar, adult of which is parasitic on crops.



iii. Pathogens

Pathogens like viruses, bacteria, and fungi are used in killing pest through disease.

iv. Plants

Plants like **neem** (*Azadirachta indica*), **tobacco** (*Nicotiana tabacum*), and **lemon** (*Citrus limon*), etc. containing azadirachtin (insecticide), nicotine (alkaloid), and lemon extract (fungicide), respectively act as biopesticides in controlling pests.

II. Bio-fertilizers

Bio-fertilizer is a substance that contains living micro-organisms which, when applied to seeds, plant surface, or soil, colonize rhizosphere or interior of the plant and promotes growth by increasing supply or availability of primary nutrients to the host plants.



Bio-fertilizers

Bio-fertilizers add nutrients through natural processes of nitrogen-fixation, solubilizing phosphorus, and stimulating plant growth via synthesis of growth-promoting substances. There are many groups of bio-fertilizers, out of which some important groups are: bacteria, cyanobacteria, fungi, green manure, and unigrow.

i. Bacteria

Bacteria like *Rhizobium* and *Azobacter* help in nitrogen-fixation.

A. *Rhizobium*

Rhizobium is nitrogen-fixing bacteria found in root nodules and also in shoot nodules of leguminous plants like **dhaincha** (root nodules of *Sesbania rostrata* and root and shoot nodules of *S. aculeate*). Dhaincha, with the help of *Rhizobium*, fixes atmospheric nitrogen in soil. Inoculation of *Rhizobium* in agronomic practice has supplied adequate nitrogen.

B. *Azobacter*

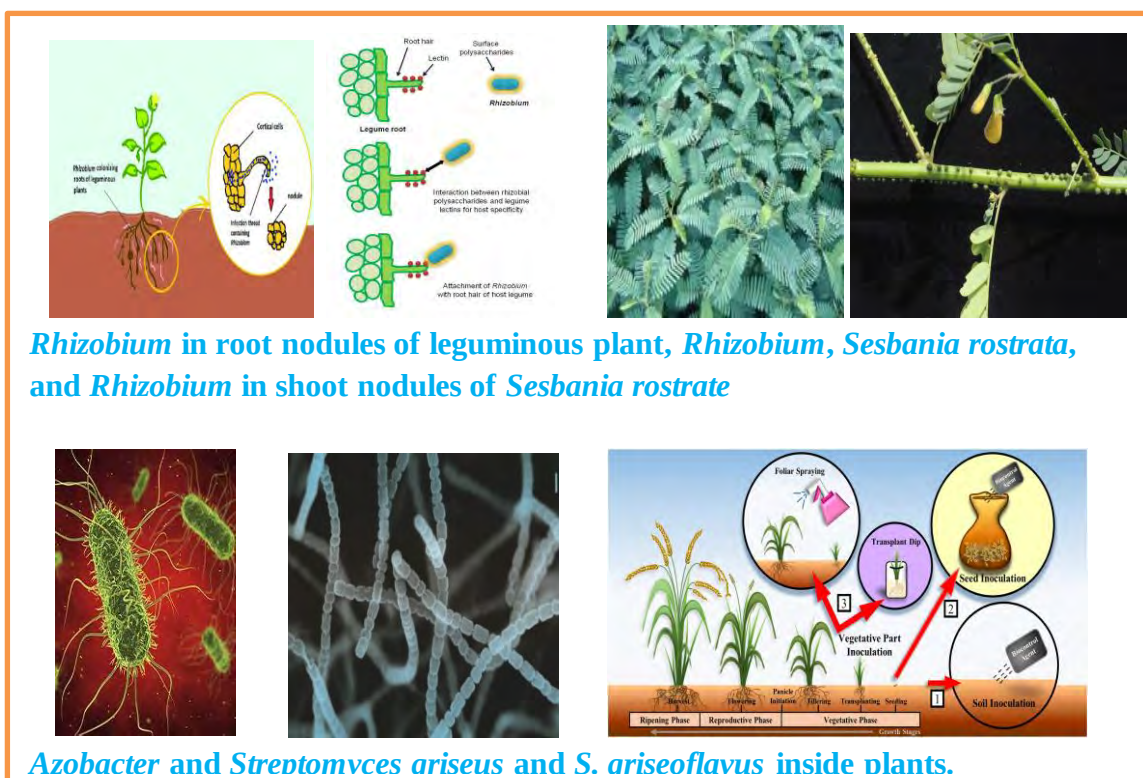
Azobacter like *Rhizobium* is nitrogen-fixing bacteria and fixes atmospheric nitrogen in soil.

C. *Streptomyces*

Streptomyces griseoflavus and *S. griseus* are bacteria that are isolated from garden soil produce antibiotics like **bicozamycin** and **streptomycin**, respectively.

ii. Cyanobacteria

Cyanobacteria, also called **blue green algae** (BGA) like *Anabaena*, *Nostoc*, and *Spirulina* fixes atmospheric nitrogen in soil.



A. *Azolla-Anabaena* mutualism

Azolla is a small, eukaryotic, aquatic fern and *Anabaena azollae* is a prokaryotic nitrogen fixing cyanobacteria or BGA residing in the leaves of *Azolla* performing mutualism – a type of positive symbiosis. Instead of using chemical fertilizers, this relationship has long been used in agriculture.

B. *Nostoc*

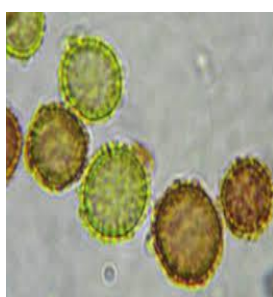
Nostoc is filamentous nitrogen-fixing cyanobacteria or BGA that form colonies and is common in both aquatic and terrestrial environments. It also occurs in mutual association with liverworts, ferns, and few angiosperms.

C. *Spirulina*

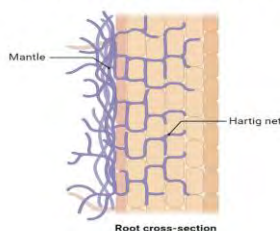
Spirulina is a type of nitrogen-fixing cyanobacteria or BGA and used in soil in the form of powder, capsule, or tablet.



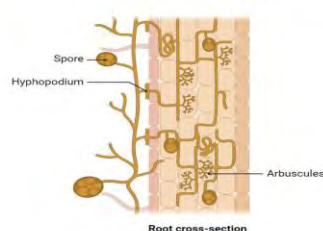
Azolla with Azolla-Anabaena mutualism, Anabaena, Nostoc, and Spirulina.



Ectomycorrhiza



Arbuscular Mycorrhiza



Pisolithus albus, Ectomycorrhiza (Pisolithus albus), and Endomycorrhiza called arbuscular mycorrhiza (Glomeromycota).

iii. Fungi

Certain fungi that make mutualistic association with seed-bearing plants by converting barren soil into fertile soil is called mycorrhiza. This association is two types: ectomycorrhiza and endomycorrhiza.

A. Ectomycorrhiza

The association in which the fungus (*Pisolithus albus*) lives outside the root of peach, oak, pine, etc.

B. Endomycorrhiza

The association in which the fungus called arbuscular mycorrhiza or AM (*Glomeromycota*) lives between and inside cells of cortex of orchids and woody plants.

Do you know?

Probiotics are microorganisms, primarily bacteria and yeasts, which, when ingested or applied to the body, confer a health benefit on the host. They are good bacteria used to improve or restore the balance of the gut microbiota in animals and plant bio-fertilizer in agriculture. Nowadays, **probiotics** are used in agriculture as bio-fertilizer.

iv. Green manure

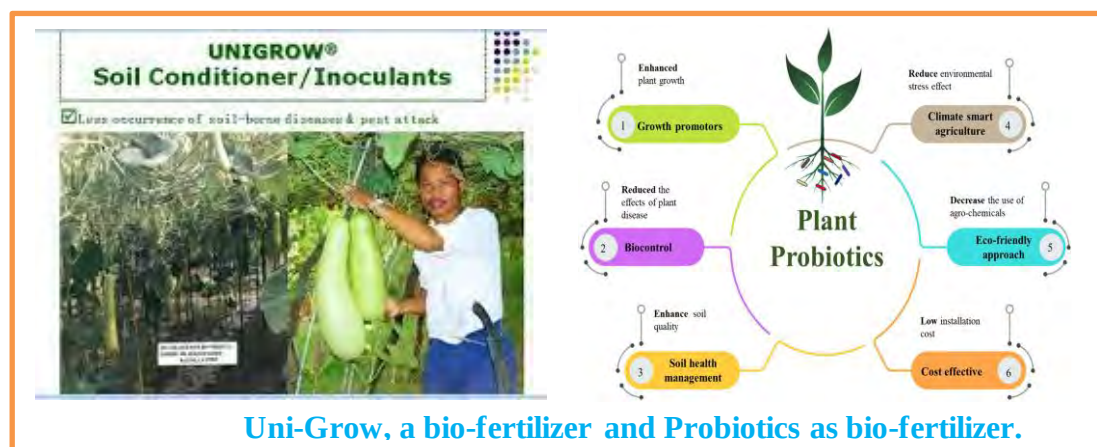
Plants like legumes (e.g., dhaincha, peas, beans, and clover), grasses (berseem, para, and napier), and cereals (paddy, wheat, millet, and oat) are grown in the agriculture field and their whole or left harvested part are ploughed in soil and let them decay for a while so as to form green manure.

Do you know?

Green manure is bio-fertilizer but not the organic manure. Bio-fertilizer possesses living microorganisms that enhance nutrient availability in the soil. Organic manure support microbial activity however, it is decomposed wastes of the origin of plant, animal, or both providing nutrition directly to the soil.

v. Unigrow

Unigrow, also written as **Uni-Grow** is a commercial bio-fertilizer is currently in use. It contains microbes and is prepared from by-product of palm.



Activity

What type of biocontrol agent (BCA) and bio-fertilizers are utilized in your locality in the agricultural practices? Make a list of them and compare with the agriculture practices of developed countries?

Points to remember

Vernacular language written in shortcut as **vern.** is one's own language of one's own nation, e.g., Nepali name for Nepal.

Colloquial name written in shortcut as **vern.** is is one's own language of one's own nation, e.g., Nepali name for Nepal.

Exercise

Tick the correct alternative.

1. Microbial diseases refer to diseases caused by
a. microorganisms b. microbes c. harmful microbes d. pathogens
2. Which one of the following risk group (RG) of microorganisms does not cause disease?
a. RG-1 b. RG-2 c. RG-3 d. RG-4
3. Which one of the following virus is included under RG-4?
a. Ebola virus b. Influenza virus c. SARS virus d. Herpes virus
4. Biosafety level 2 (BSL-2) is for which one of the following risk group (RG)?
a. RG-1 b. RG-2 c. RG-3 d. RG-4
5. Risk group 3 (RG-3) microorganisms fall under which one of the following hazard group (HG)?
a. HG-1 b. HG-2 c. HG-3 d. HG-4
6. Which biosafety level (BSL) is required for RG-2 microorganisms or HG-2 pathogens?
a. RG-1 and HG-1 b. RG-2 and HG-2 c. RG-3 and HG-3 d. RG-4 and HG-4
- 7.. Disease are grouped as non-communicable and communicable? Which one of the following groups of disease is communicable?
a. Typhoid, tuberculosis, and alcoholism b. Tuberculosis, alcoholism, and smoking
c. Alcoholism, smoking, and ascariasis d. Ascariasis, typhoid, and tuberculosis
8. Which one of the following sets contains the bacterial diseases only?
a. Tuberculosis, cholera, and candidiasis b. Tuberculosis, typhoid, and cholera
c. Hepatitis, cholera, and influenza d. Cholera, typhoid, and candidiasis
9. Which one of the following disease is caused by a virus?
a. Tuberculosis b. Cholera c. Influenza d. Candidiasis
10. Which one of the following hepatitis is deadly and severe?
a. Hepatitis A b. Hepatitis B c. Hepatitis D d. Hepatitis E
11. In HIV/AIDS patient, which one of the following happens?
a. Immune system is upgraded b. Immune system is lowered
c. Immune system is destroyed d. Immune system is neither upgraded nor destroyed.

12. Incorrect statement about HIV/AIDS is
- risk of transmission from mother to foetus is about 30%.
 - HIV affects CD4 cells
 - confirmatory test is usually 'western blot test'.
 - persons appear well till two years of infection.
13. What is the causative agent of typhoid?
- Human immunodeficiency virus (HIV)
 - Leishmania donovani*
 - Salmonella typhi*
 - Mycobacterium tuberculosis*
14. Which one of the following is very common air-borne disease?
- Typhoid
 - Tuberculosis
 - HIV/AIDS
 - Cancer
15. Mention the causative agent of tuberculosis.
- Leishmania donovani*
 - Plasmodium vivax*
 - Salmonella typhi*
 - Mycobacterium tuberculosis*
16. Which one of the following is serious microbial disease?
- Influenza
 - Typhoid
 - Candidiasis
 - Tuberculosis
17. Diarrhoea and vomiting are the symptoms of
- amoebiasis
 - typhoid
 - tuberculosis
 - cholera
18. Which one of the following disease is caused by kissing and sexual contact?
- Tuberculosis
 - Cholera
 - Influenza
 - Candidiasis
19. Which one of the following drug is specifically used in candidiasis?
- Metronidazole
 - Albendazole
 - Fluconazole
 - Secnidazole
20. Vaccines are generally administered in human body in order to
- maintain growth of the body
 - diagnose the disease
 - cure the disease
 - prevent future viral and bacterial infection
21. Which one of the following is second generation vaccines?
- Smallpox vaccine
 - Salk's polio vaccine
 - Hepatitis-B vaccine
 - Toxoids
22. Which one of the following is prepared by *Lactobacillus bulgaricus*?
- Curd
 - Yoghurt
 - Butter
 - Cheese
23. Soy sauce is prepared by
- Lactobacillus lactis*
 - Aspergillus sojae*
 - Acetobacter aceti*
 - Lactococcus lactis*

24. Which one of the following alcoholic product is prepared by distillation of wine?
a. Beer b. Rum c. Brandy d. Gin
25. Microbial contamination of water is due to
a. rotavirus b. *Escherichia coli* c. *Giardia* d. all of these
26. Which one of the following is final step in drinking water treatment?
a. Coagulation and flocculation b. Sedimentation
c. Filtration d. Disinfection
27. Which one of the following biological control agent (BCA) is utilized in tricho-card for killing the insect pest in insect pest management (IMP)?
a. Virus b. Bacteria c. Predator d. Parasitoid
28. In biofertilizer treatment, *Azolla-Anabaena* association is
a. commensalism b. mutualism c. antibiosis d. parasitism
29. Which one of the following is latest biofertilizer?
a. *Azolla-Anabaena* b. *Rhizobium*
c. *Streptomyces griseoflavus* d. Probiotics
30. Which one of the following is green manure?
a. Organic compost b. Urea c. DAP d. Dhaincha

Short-answer questions.

1. Summarize risk group, biosafety level, and hazard group of microbes or pathogens.
2. Mention epidemiology of influenza including incidence, distribution, risk factors, and control.
3. Write short note on Hepatitis-B.
4. Sum up in brief candidiasis occurring in human being.
5. What is immunity? Explain its types.
6. What is vaccine and vaccination? Describe various types of vaccines.
7. Are microorganisms applied in dairy and beverage industries? Describe industrial production of yoghurt and cheese.

8. What are alcoholic beverages? Discuss the industrial production of beer.
9. What is microbial contamination of water? What are the sources, causes, effects, detection, and prevention of contamination of water?
10. What is sewage? Describe in brief the treatment process of sewage.
11. What is drinking water? Discuss in short the steps of drinking water treatment.
12. Write short note on biological control agents (BCA).
13. Nowadays, even in the country like Nepal, inorganic fertilizers like urea, DAP, TSP, etc., are being slowly replaced by organic compost or manure. Organic compost or manure are further supplemented by bio-fertilizers. Make a list of the bio-fertilizers utilized in Nepal. Explain all the listed bio-fertilizers.
14. Write short note on *Azolla-Anabaena* mutualism.

Long-answer questions.

1. What is disease? What is microbial disease? What is risk, hazard, and safety levels in terms of microorganisms or microbes? Discuss risk and hazard groups of microorganisms/microbes/pathogens including biosafety levels.
2. Mention the causative agent of HIV/AIDS. Why is it prevalence among intravenous drug users? Which part or organs of the human body are badly affected? Describe mode of transmission, symptoms, and preventive measures of HIV/AIDS.
3. Name the causative agent of typhoid. Explain its mode of transmission, symptoms, and control measures. Do not forget to mention the name of the part or organs badly affected by typhoid in severe cases.
4. Discuss causes, causative agent, mode of transmission, effects, symptoms, and control measures of tuberculosis. Correlate DOTS with it.
5. Why is cholera called microbial, physical, acquired, communicable, pandemic, and water-borne disease? Describe its epidemiology, causative agent, causes of contract, mode of transmission, incubation period, sign and symptoms, effects, diagnosis, and prevention and control.