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01 ANATOMY OF FLOWERING PLANTS

YOUR GATEWAY TO EXCELLENCE IN IIT-JEE, NEET AND CBSE EXAMS

# ANATOMY OF FLOWERING PLANTS

BIOLOGY

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# 01 INTRODUCTION TO TISSUES, MERISTEMATIC TISSUES, PERMANENT TISSUES (SIMPLE PERMANENT - PARENCHYMA, COLLENCHYMA, SCLERENCHYMA)

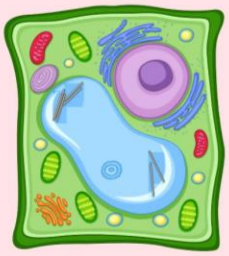
## Key Takeaways

- Cells and tissues
- Meristematic tissue
  - Promeristem
  - Primary meristem
    - Apical meristem
    - Intercalary meristem
  - Secondary meristem
  - Lateral meristem
- Permanent tissue
  - Parenchyma
  - Sclerenchyma
  - Collenchyma

## Cells and Tissues

### Cells

- The cell is the basic **structural** and **functional** unit of all living organisms.
- Every living organism is made up of cells.



Plant cell

### Tissues

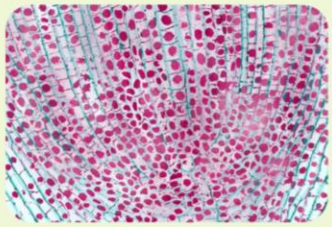
- Tissue is a group of cells that have a common:
  - Origin
  - Structure
  - Function
- Tissues come together to form an organ.

**Plant tissues**

- **Meristematic tissue** → Actively dividing cells
- **Permanent tissue** → Cells are not actively dividing

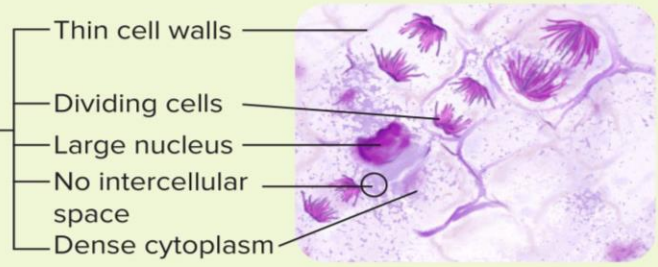
## Meristematic Tissue

- **Meristematic cells** are **unspecialized, actively dividing cells** that are present in the growing parts of the plant body.
- 'Meristem' comes from the Greek word 'meristos' which means 'to divide'.
- In plants, the growth is **limited to certain specialised regions**, where the meristematic cells are present, like the tips of roots, stems, and some other parts like leaves, flowers, and fruits.



Meristematic tissue under the microscope

**Features of meristematic cells**




### Types of meristematic tissues

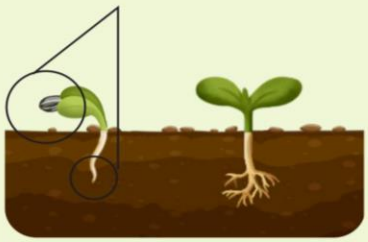
- There are different types of meristematic tissues based on different aspects.

#### Based on growth stage

**(i) Promeristems**

- The promeristems are responsible for **embryonic growth**.
- These are responsible for the growth of the embryonic roots and shoots during germination.
- They are **short-lived** and only exist until the seed germinates into a young plant.

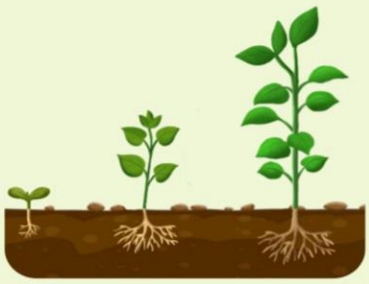
Location of the promeristems



Embryonic growth

**(ii) Primary meristems**

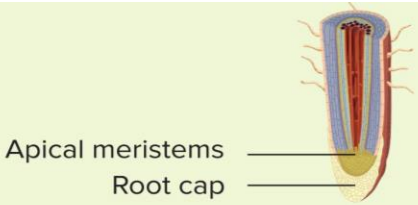
- Once the seedling grows into a young plant, the promeristems give rise to the **primary meristems**.
- They are responsible for **primary growth** and increase in the root and shoot length.
- **Apical meristem**
  - It is a type of primary meristem found at the **tips of the roots and the shoots**.
  - It gives **rise to primary tissues**.
  - **Shoot apical meristem**
    - Responsible for the growth of leaves and other aerial parts of the plants.



Primary growth


Shoot apical meristems

- **Axillary buds** are formed from leftover meristematic cells. New shoots or branches or even flowers can form from these buds.
- **Root apical meristem** - Responsible for the growth of the root.



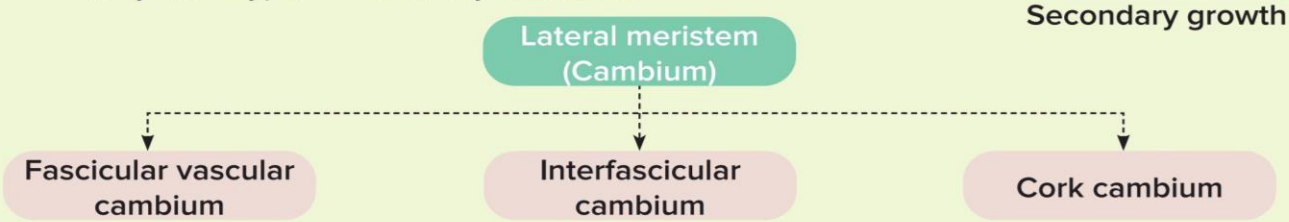
Root apical meristems

**(iii) Secondary meristems**

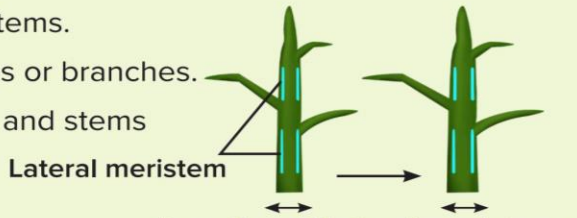
- The plant grows from a young tender plant to a thick, woody, hard tree because of **secondary meristems**.
- They are responsible for the formation of secondary tissues and increase in the girth of the plant.


Secondary growth

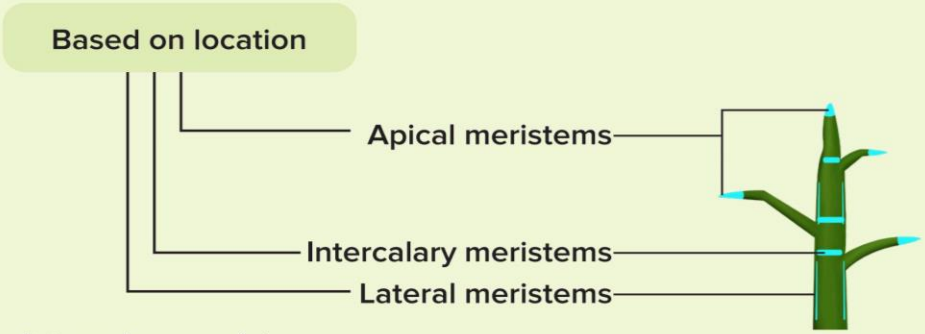
- **Lateral meristems (Cambium)**
  - They are a type of secondary meristem.



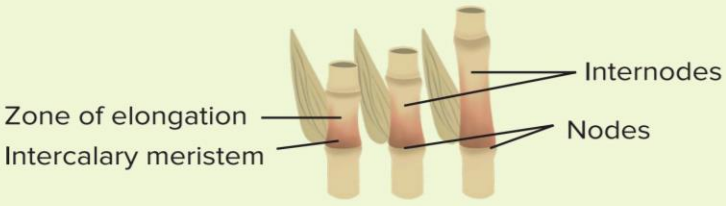

- These meristems **add girth** to the branches and stems.
- They are **cylindrical** or **parallel** to the side of stems or branches.
- They are found in the mature regions of the roots and stems and gives rise to the **woody axis** of the plants.
- They are present only in **dicot plants**.

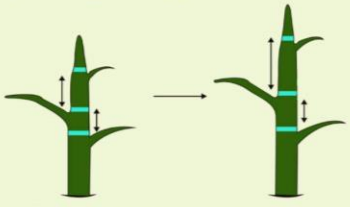


Location of lateral meristems




- **Intercalary meristem**
  - It is present **between mature tissues** at the nodes of the stem.
  - It is responsible for the **elongation of internodes** (Nodes are the parts of the stem from where branches/leaves arise. The internodes are the regions between two nodes).
  - It occurs in grasses and regenerates parts removed by the grazing herbivores.





Intercalary meristem

**Did you know?**

Meristematic cells are the only cells that are **not** affected by viruses.

## Permanent Tissue

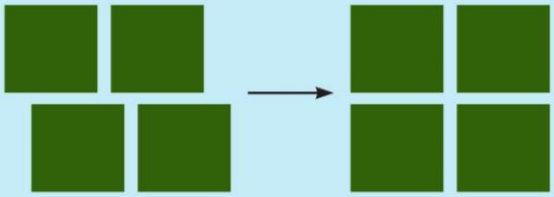
- The cells of the permanent tissues **lose the power of division** temporarily or permanently.

**Types of permanent tissues**

- **Simple** → Made up of only **one** type of cells
- **Complex** → Made up of **different** types of cells

### Simple permanent tissue

- Simple permanent tissue is composed of **only one type of cells** and is thus **homogeneous**.
- It is formed by primary meristems.

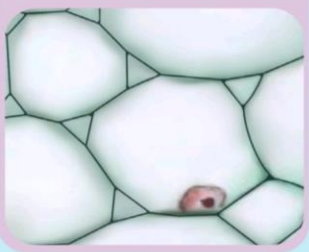


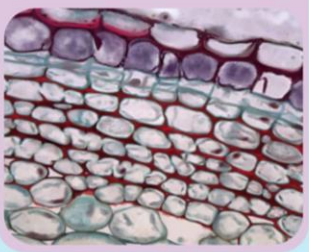
Identical cells → Simple tissue

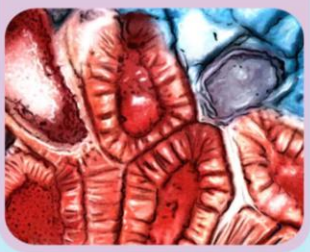
Formation of simple permanent tissue from identical cells

**Types of simple permanent tissues**

- Parenchyma
- Collenchyma
- Sclerenchyma







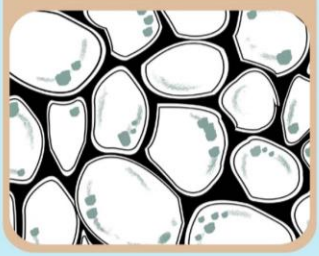
### (a) Parenchyma

- Parenchyma is derived from the Greek word '**para**' which means '**beside**'.
- It is a major part of all organs of the plant and is the most commonly found plant tissue.
- The cells of the parenchyma tissue are diverse and versatile.

- Characteristics of parenchyma are as:
  - The cells are generally **isodiametric** having equal diameters or axes.
  - The cells **vary in shape**.

**Shapes of parenchyma cells**

**Round**

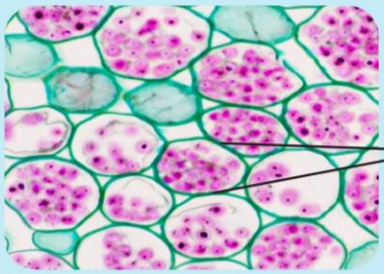


**Oval**

**Polygonal**

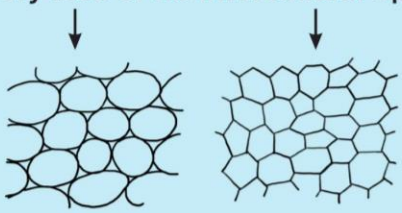
**Pillar-like**

- They have **thin cell walls** made up of cellulose and in some cases, pectin too.




Parenchyma tissue

- The cell walls have **very less** or **no intercellular spaces**.

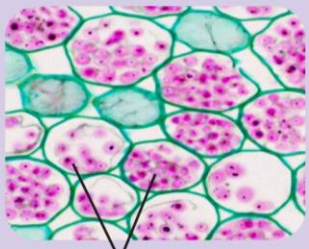


**Functions of parenchyma**

**Photosynthesis**

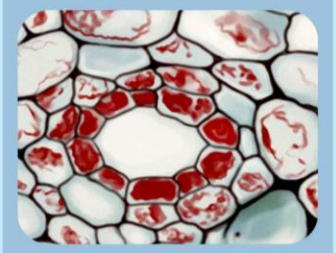
Parenchyma tissue which performs photosynthesis are known as **chlorenchyma**. The cells have abundant chloroplasts.

**Storage**



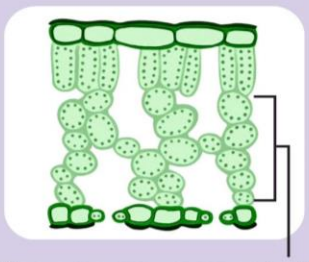
They help in the storage of reserve food like starch. E.g., Starch in potato

**Secretion**



Parenchymal cells with a secretory function line the insides of resin ducts.

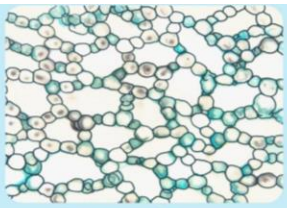
**Gaseous exchange**



The spongy mesophyll of leaves is made of parenchymal cells which have large intercellular spaces that help in exchange of gases.

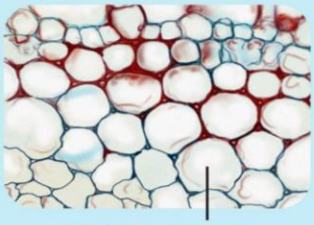
### Aerenchyma

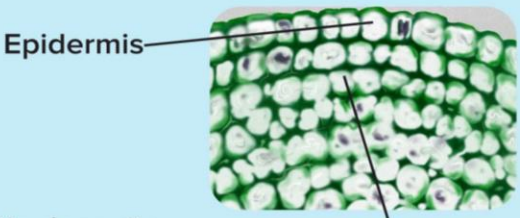
- Aerenchyma is a **modification of parenchyma**.
- It is a **spongy tissue** that is made up of cells with very large intercellular spaces. It is found in the leaves, stems, and roots of some plants and helps in buoyancy.


Aerenchyma

### (b) Collenchyma

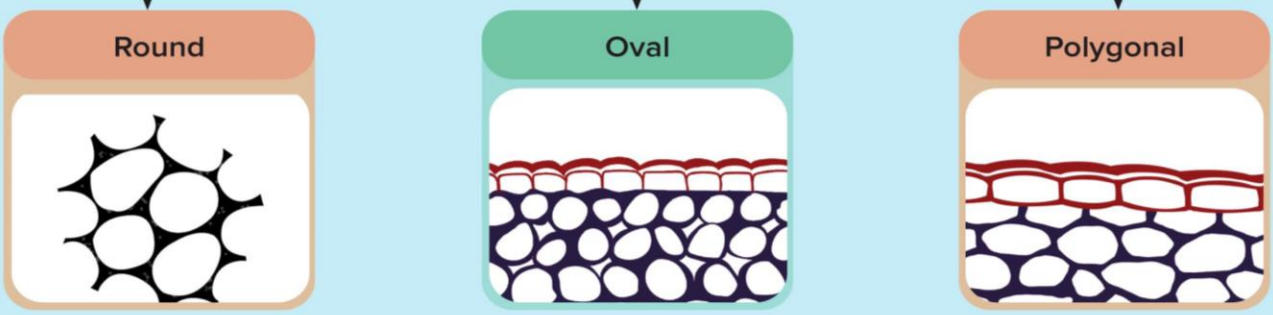
- Collenchyma is derived from the Greek word 'kolla' which means 'glue'.
- Collenchyma tissue is made up of **living cells filled with water**.
  - The pressure of the water against the cell walls creates a stiffness. (This stiffness gives rise to the crunchiness of a stalk of celery.)
- It is found either as a **homogeneous** layer or in **patches**.
- Collenchyma forms a layer under the epidermis in most herbaceous dicotyledon stems.
- **Cell wall** is made up of:
  - Cellulose
  - Hemicellulose
  - Pectin
- There are **no intercellular spaces** between cells due to pectin deposits.


Collenchyma



Collenchyma

**Shape of collenchyma cells**



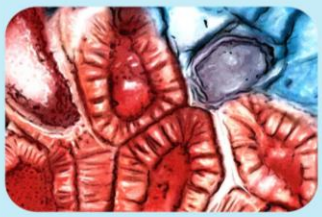

- Functions of collenchyma are as follows:
  - Help in photosynthesis.
  - Provide mechanical support (tensile strength).
  - Provide elasticity to plant parts such as a young stem and the petiole of a leaf. They help to resist the bending action of the wind.

**Did you know?**

Both parenchyma and collenchyma can become meristematic again. This occurs when repair of tissues is required.

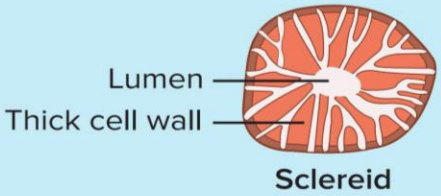
Meristem → Simple Permanent Tissue

## (c) Sclerenchyma



- Sclerenchyma consists of cells with **thick** and **lignified cell walls** having a few or numerous **pits**.
- They are usually **dead** and **without protoplasts**.
- These provide **mechanical support** to organs.
- **Cell wall** is made up of
  - Cellulose
  - Hemicellulose
  - Lignin
    - Lignin is a very complex organic substance and the second most commonly found substance (after cellulose).
    - It is insoluble in water and is impermeable to water.
    - It is found as a thick deposition on the cells
    - It provides rigidity.
- It is found in stems, leaves, seed coats, fruit pulp, and fruit wall.
- **Types of Sclerenchyma**
  - **Based on form, origin, structure, and development,** it is of two types:
    - **Sclereids** or sclerenchymatous cells
    - **Fibres**

### (a) Sclereids



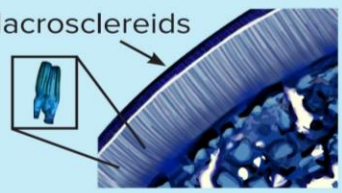
Sclereid

- They have **highly thickened walls**.
- They have a **narrow cavity (lumen)**.
- They are of different shapes.
- Based on the **different shapes**, sclereids can be classified into the following types:

#### (i) Astrosclereids

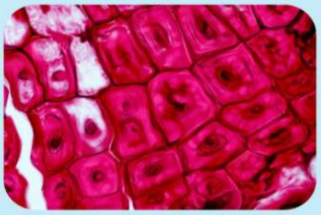
- Astrosclereids are rare sclereids found in specialised tissues (E.g., the floating leaves of water lily).
- They have an irregular shape with branches and pointed ends.
- Astrosclereids are not a common type of sclereid.

#### (ii) Macrosclereids



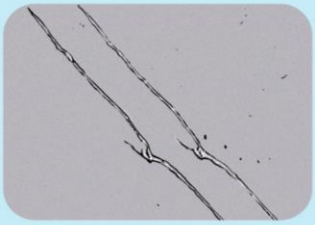

- They are **large rod-shaped** sclereids.
- They are a part of the outer layer of the seed coats of leguminous plants.

#### (iii) Brachysclereids



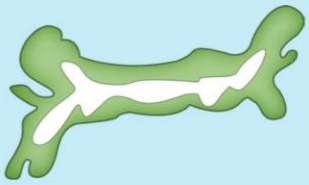
- They are **isodiametric cells** which resemble parenchyma cells in shape.
- The cells are **non-living** and have a **large secondary cell wall**.
- They are also known as **stone cells** because they form the **grit** in fruits like pear.

**(iv) Trichosclereids**



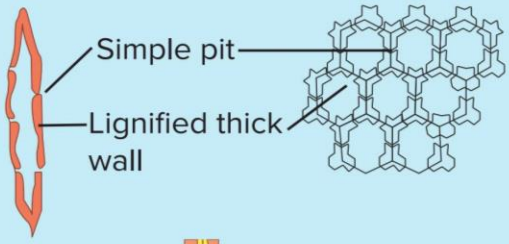
- They are **hard needle-like branched cells** found in some species of plants that serve the purpose of **protecting the plant** from herbivores. (E.g., Aerial roots of *Monstera*)
- They are **long** and **hair-shaped**.

**(v) Osteosclereids**

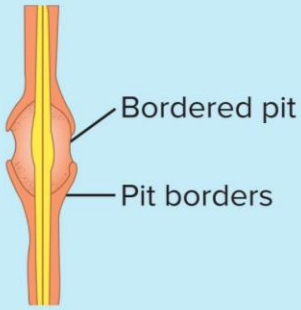


- Osteosclereids are also known as **bone cells** because of their characteristic shape like a bone.
- They form the **hypodermal layer** in seeds, fruits, and leaves of some plants (dicots).

**(b) Fibres**




- They are **elongated** cells.
  - Have **tapering ends**
  - Middle is **bulged**
- **Cell walls** are **thick** and have **lignin** deposits in them.
- They generally **occur in groups**.




- The cell wall has **pits** that help in **intercellular communication**. **Pits** are of two types:
  - **Simple pit** - Cavity has a uniform width.
  - **Bordered pit** - Cavity is broader towards the base and has a narrow opening.

## Summary Sheet

**Cells (basic building blocks of all living organisms)**

**Tissues (groups of cells)**

**Meristematic tissue** (actively dividing cells)

- **Promeristem** (responsible for embryonic growth)
- **Primary meristems** (responsible for primary growth and elongation of the roots and shoots)
- **Secondary meristems** (responsible for increase in the girth)
  - **Lateral Meristems** (present parallel or cylindrical to the side of the stems or branches)
  - **Apical Meristems** (present at the tips of the growing roots and shoots)
  - **Intercalary meristems** (responsible for growth of internodes)

**Permanent tissue** (cells which do not actively divide)

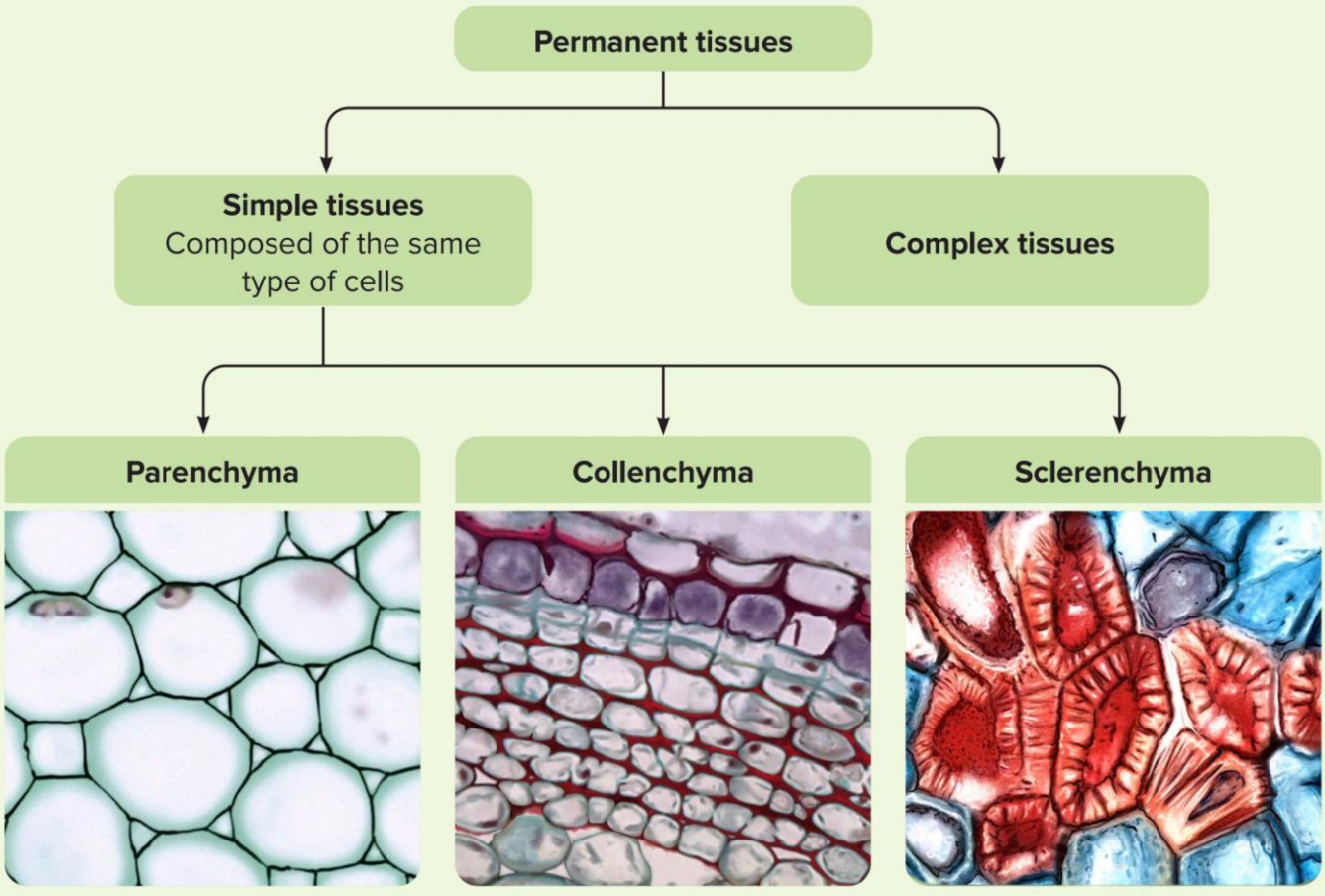
- **Simple** (made up of one type of cells)
  - **Parenchyma** (soft tissue found in softer parts of leaf, fruits, etc.)
  - **Collenchyma** (consist of cells thickened at corners and that provide mechanical support)
  - **Sclerenchyma** (dead mechanical tissue)
    - **Fibres** (elongated cells that provide support to plants)
    - **Sclereids** (cells with thickened walls and a narrow lumen)
      - **Astrosclereids** (branched, star- shaped, found in floating plants)
      - **Macrosclereids** (rod-shaped, found on outer layer of seed coats)
      - **Brachysclereids** (irregularly shaped, made entirely of secondary cell walls)
      - **Trichosclereids** (needle-like, branched, protects the plants from herbivores)
      - **Osteosclereids** (cells shaped like bones,form hypodermal layer in seeds, fruits, etc.)
- **Complex** (made up of different types of cells)
  - **Xylem**
  - **Phloem**

# 02 PERMANENT TISSUES (COMPLEX - XYLEM AND PHLOEM) TISSUE SYSTEMS: EPIDERMAL TISSUE SYSTEM, GROUND TISSUE SYSTEM, VASCULAR TISSUE SYSTEM

## Key Takeaways

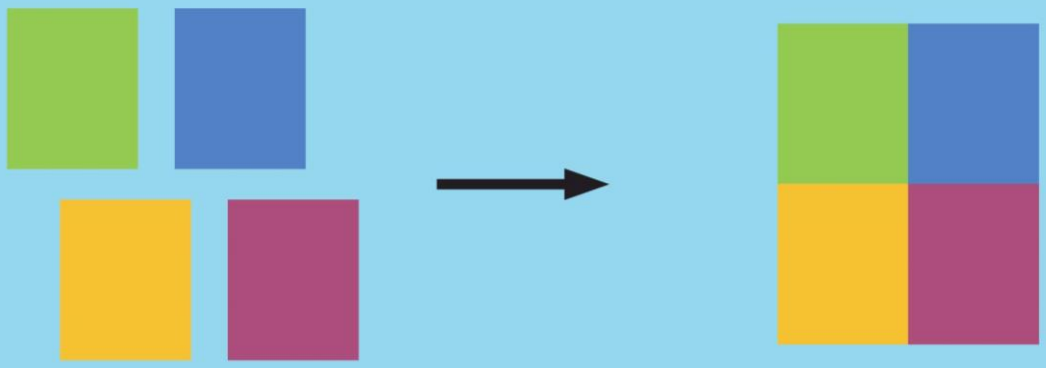
- Complex tissues
- Xylem
  - ➔ Types of xylem
  - ➔ Development of primary xylem
  - ➔ Components of xylem
- Phloem
  - ➔ Types of phloem
  - ➔ Elements of phloem
- Tissue systems

## Prerequisites



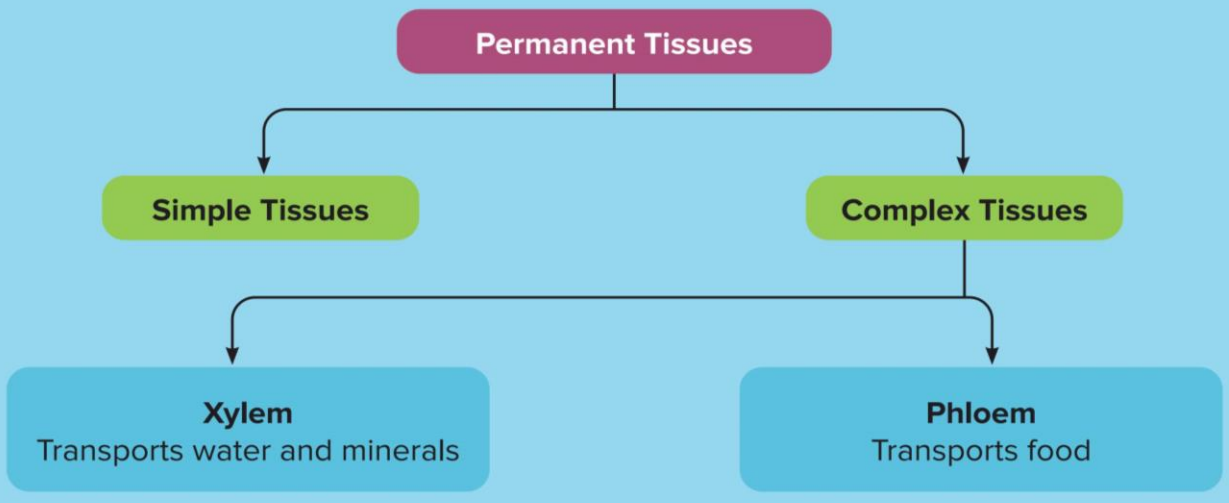
## Complex Tissues

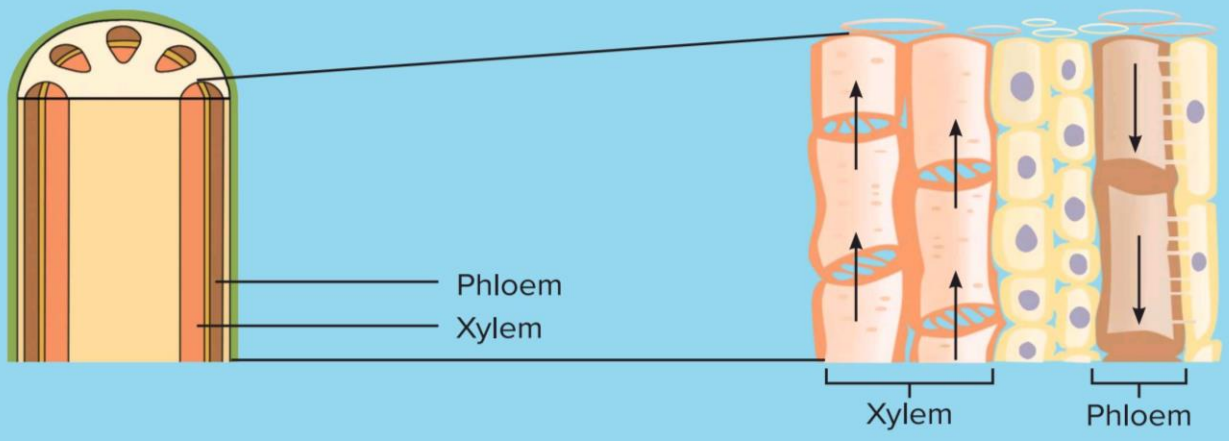
- **Complex tissues** are tissues that are composed of **more than one** type of cell.
- The complex tissues are **heterogenous**. They are composed of different types of cells that work as a **unit**.



**Different types of cells** **Complex tissue**

- The complex tissues are of two types:

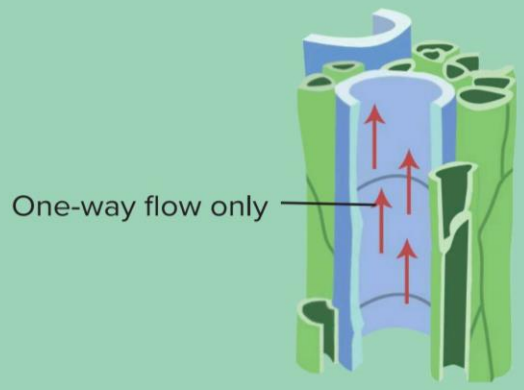



- The xylem and phloem are **conducting** or **vascular tissues**.

## Xylem

- It is a **conducting** tissue that consists of **living** and **non-living** cells.
- It conducts **water** and **minerals** from **roots** to all **other parts** of the plant.
- The movement in xylem is **unidirectional**.
- It has a thick-walled, semi-rigid tube that provides **mechanical support**.

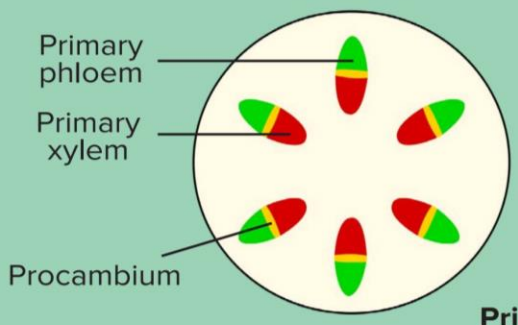



**Xylem**

## Xylem - Types
(Based on origin)

### Primary xylem

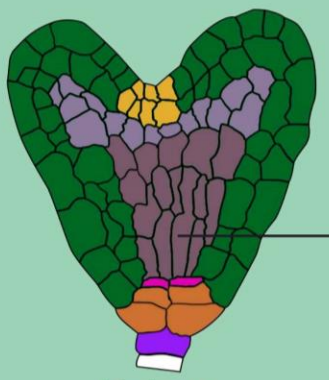
- It is formed during the **primary growth**
- The **increase** in the **length** of the **shoots** and **roots** is known as the **primary growth**



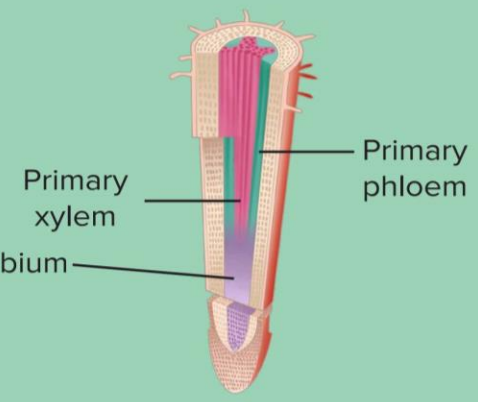

**Primary growth**

- The **procambium** (meristematic tissue) forms the **primary xylem** and **phloem (primary vascular system)**.
- The procambium is the **primary meristem**, first seen in embryos, and later seen in **root apex** and **shoot apex**.

## Primary xylem (contd.)



Embryo




Root apex

## Secondary xylem

- It is formed during the **secondary growth**.
- The increase in the **girth** of the **stem** and **roots** of **dicot** plants
- It is seen as **annual rings**. In some of the large plants, it is seen as **sapwood** or **heartwood**.

## Development of primary xylem

**Primary Xylem**
(Based on time of maturity)

- **Protoxylem**
- **Metaxylem**

| Protoxylem | Metaxylem |
|---|---|
| First formed xylem | Formed after protoxylem |
| Produced by procambium | Produced by fascicular cambium |
| Matures before plant tissues have finished elongation | Matures after plant tissues have finished elongation |

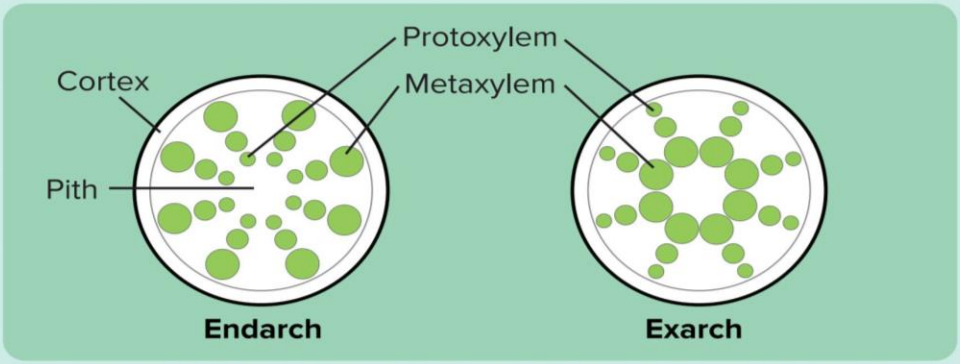
## Endarch vs Exarch

### Endarch (Observed in stems)

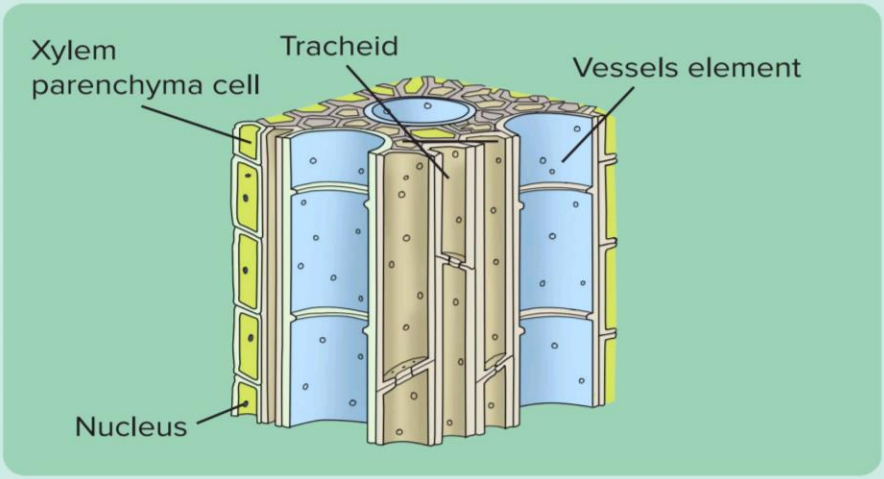
- The development is from **inside** to **outside**.
- The protoxylem is towards the **centre** (adjacent to **pith**).
- The metaxylem is towards the **periphery**.

### Exarch (Observed in roots)

- The development is from **outside** to **inside**.
- The protoxylem is towards the **periphery**.
- The metaxylem is towards the **centre**.




## Components of xylem




## Xylem Components

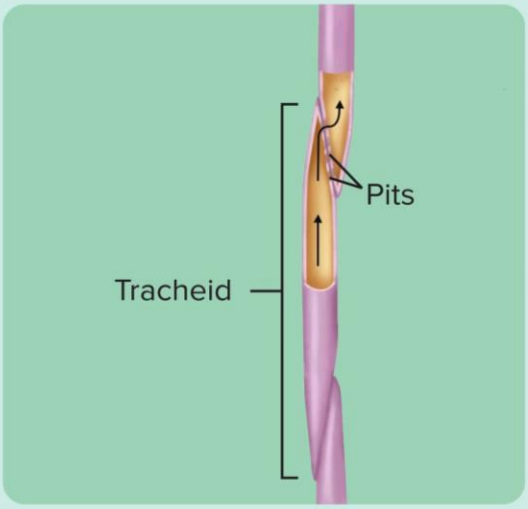
### Tracheids

- Tracheids are cells that are
  - → **Unicellular**
  - → **Elongated**
  - → **Tube-like**
  - → **Have tapering ends.**

## Tracheids (contd.)

**(a) Structure**

- The inner layers of the **cell walls** are **thick** and **lignified**.
- The tracheids are found **one above** the **other**, separated by a **cross wall/end wall**.
- Tracheid cells are **dead** and do **not** have a **protoplasm**.

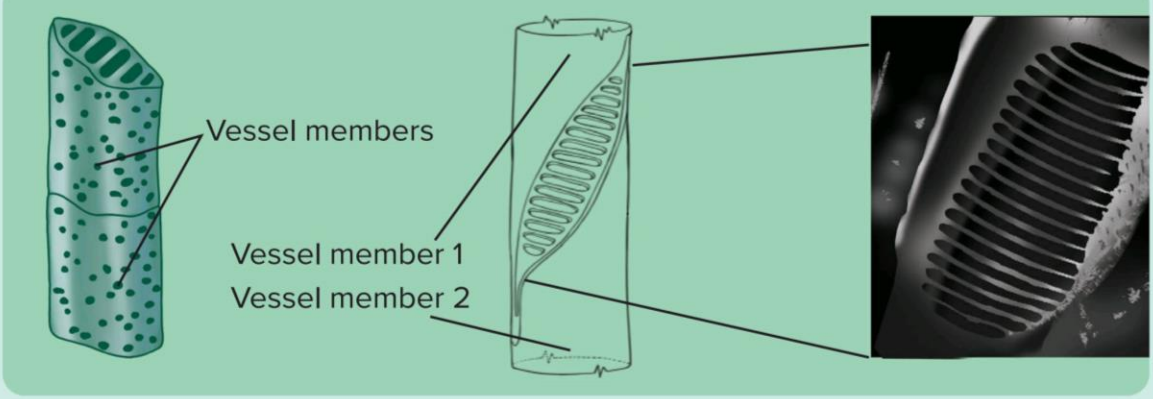



**(b) Function**

- This is one of the main **water transporting elements** of xylem.
- Tracheids transport water in all vascular plants.

## Vessels

- Vessels are
  - Long
  - Cylindrical
  - Multicellular



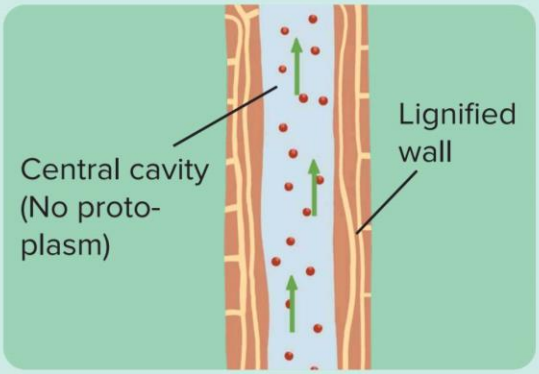
## Vessels (contd.)

**(a) Structure**

- Each cell or vessel member has cylindrical **lignified walls** that enclose a **large central cavity**.
- Adjacent vessel members are separated by a **perforated end plates**.
- The perforated end walls allow **vessel members to be stacked end to end** to form a larger conduit known as a **vessel**.
- Vessel members are devoid of protoplasm

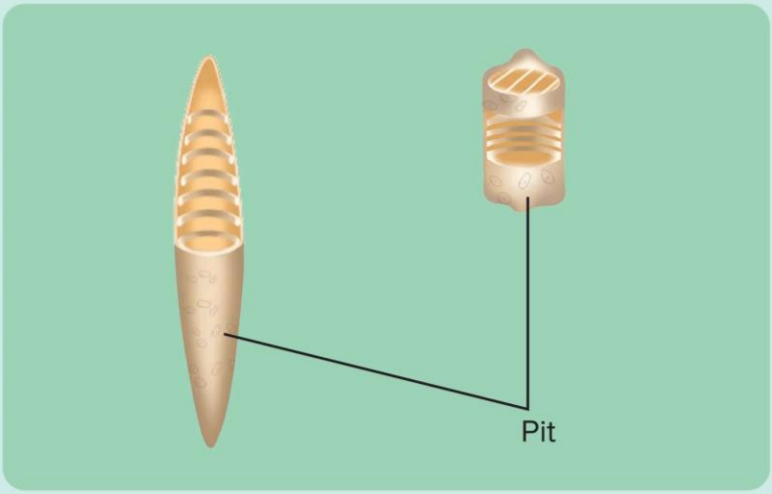
**(b) Function**

- The vessels are capable of conducting more water than tracheids.
- The open end walls of vessels provide a very efficient low resistance pathway for water movement.
- Vessels help transport water in Angiosperms only. They are absent in gymnosperms




## Similarities between tracheids and vessels

- They have **lignified walls**.
- They have **pores in the wall,** connecting the adjacent cells, i.e., **pits**.
- The pits are lined with pit membranes. They are composed of cellulose and pectins.
  - When pectins swell, the pores in the membranes are squeezed, slowing the water flow to a trickle.
  - When pectins shrink, the pores can open wide and allow the water flow.



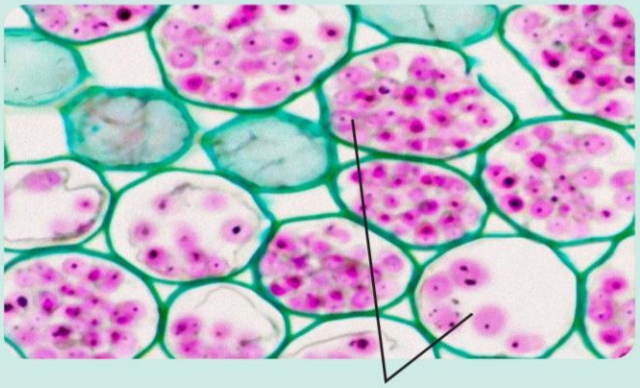
## Difference between tracheids and vessels

| Tracheids | Vessels |
|---|---|
| Present in all vascular plants | Present only in angiosperms |
| Narrow lumen | Wider lumen |
| Highly thickened | Less thickened than tracheids |
| Do not have end plates | Have perforated end plates |

## Xylem parenchyma

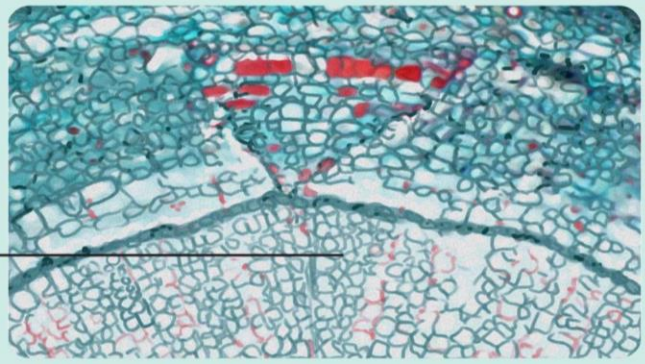
- They are **living cells** having **thin cell walls** made up of **cellulose**.
- They store secondary metabolites like **tannins** and food materials like **fats and starch.**

Thin cellulosic cell walls



Starch granules in parenchyma

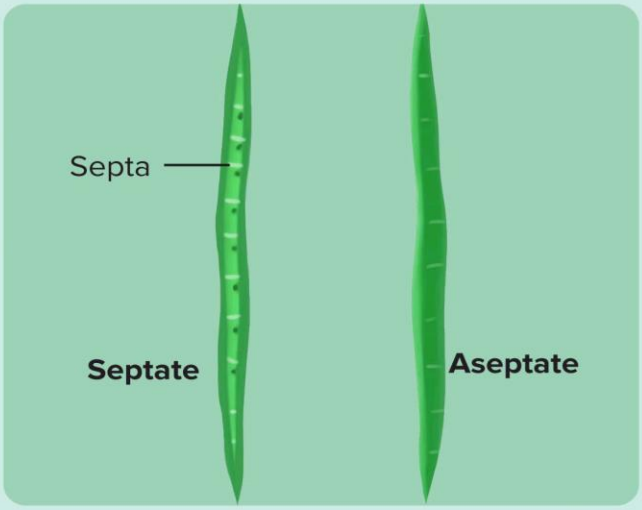
- **Radial conduction** of water performed by the **ray parenchymatous cells**.



Ray Parenchyma

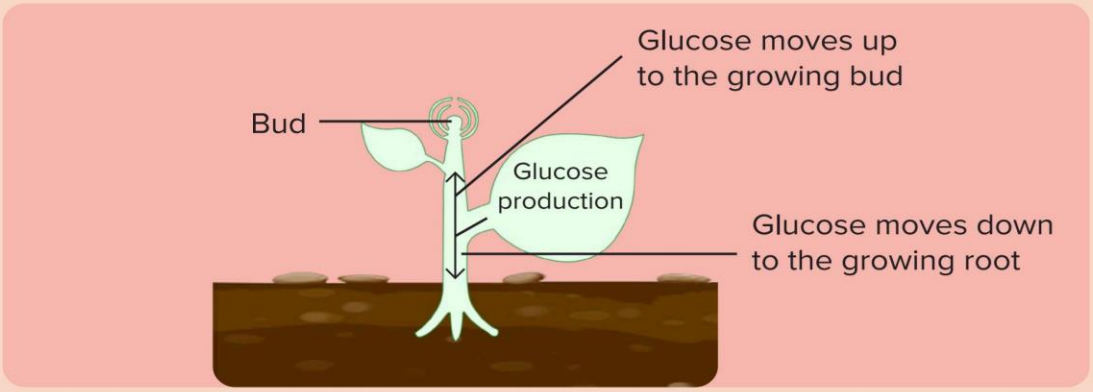
## Xylem fibres

- They provide **strength** to the tracheids and vessels.
- They have **highly thickened walls** and **indistinct** central **lumens**.
- These may either be **septate** or **aseptate**.




## Phloem

- It transports **food** (**glucose** produced by **photosynthesis** in leaves).
- It is a **bidirectional** transport.




## Types of phloem

**Phloem**

- **Primary**
  Develops from the procambium during **primary growth**
  - **Protophloem**
    First formed phloem
  - **Metaphloem**
    Later formed phloem
- **Secondary**
  Forms from vascular cambium during **secondary growth**

## Elements of phloem

### Angiosperms - Phloem

Angiosperms have the following phloem components:

- Sieve tube elements
- Phloem parenchyma
- Companion cells
- Phloem fibres

### Gymnosperms - Phloem

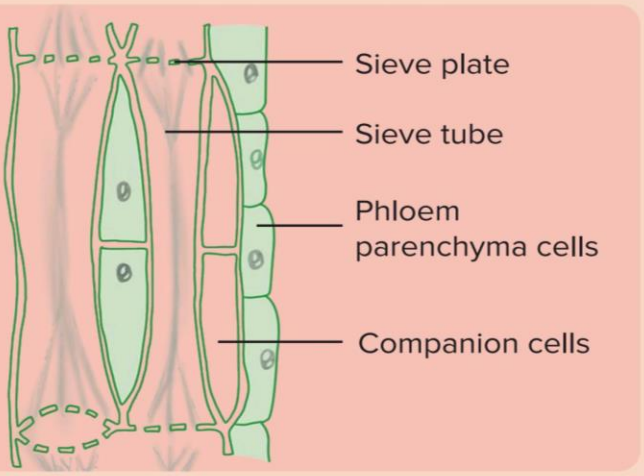
Gymnosperms have the following phloem components:

- Sieve cells
- Albuminous cells (specialised parenchyma)

Sieve tubes and companion cells are absent

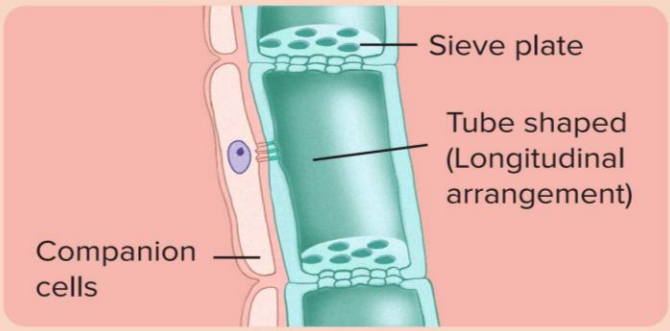
**Angiosperms Phloem Components**

- **Sieve tube elements**
  - **Sieve tube**
  - **Sieve plate**
- **Phloem parenchyma**
- **Companion cells**
- **Phloem fibres**




### Sieve tube

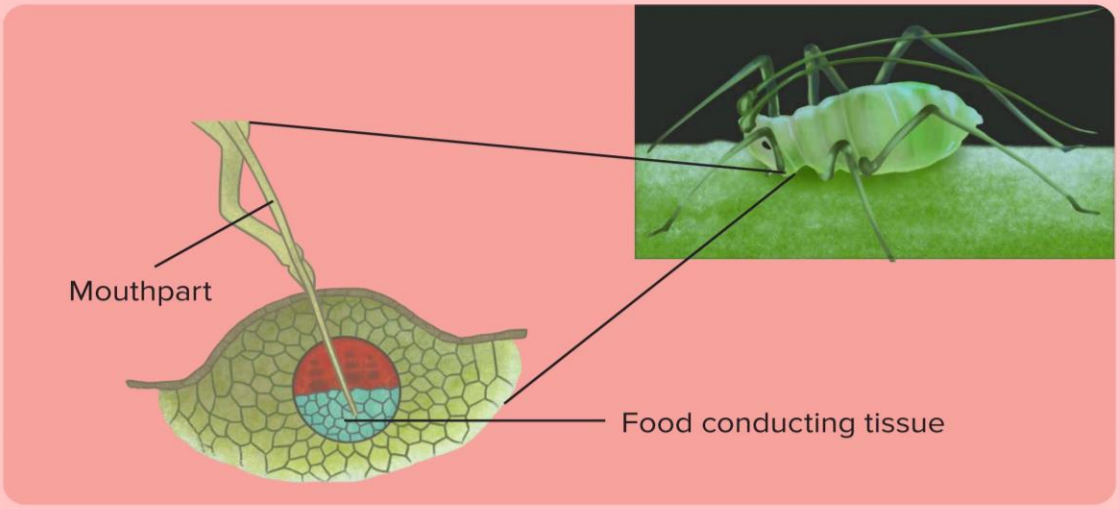
- Sieve tube elements are long, **tube-like** structures.
- They are arranged one below the other or **longitudinally**.
- It is associated with **companion cells**.
- **Sieve plate**: End walls are **perforated**



- Sieve tube elements are joined end to end with the sieve plates to form the **sieve tubes.**
- Immature sieve tube elements are living cells with all the organelles.
- As the sieve tube elements mature, they lose their nucleus and are left with only the cytoplasm at the edges of the cell and a large central vacuole.
- Function of the mature sieve tubes are controlled by the nucleus of the companion cells.

## Did you know?

Aphids are small insects which feed by inserting their very fine mouthparts (stylets) into plant tissue, where they feed on cell sap. When the stylets are withdrawn the stylet sheath remains in the tissues of the plant. The point where the sheath ends indicates the tissue on which the aphid has fed, and this proves to be the sieve tubes.

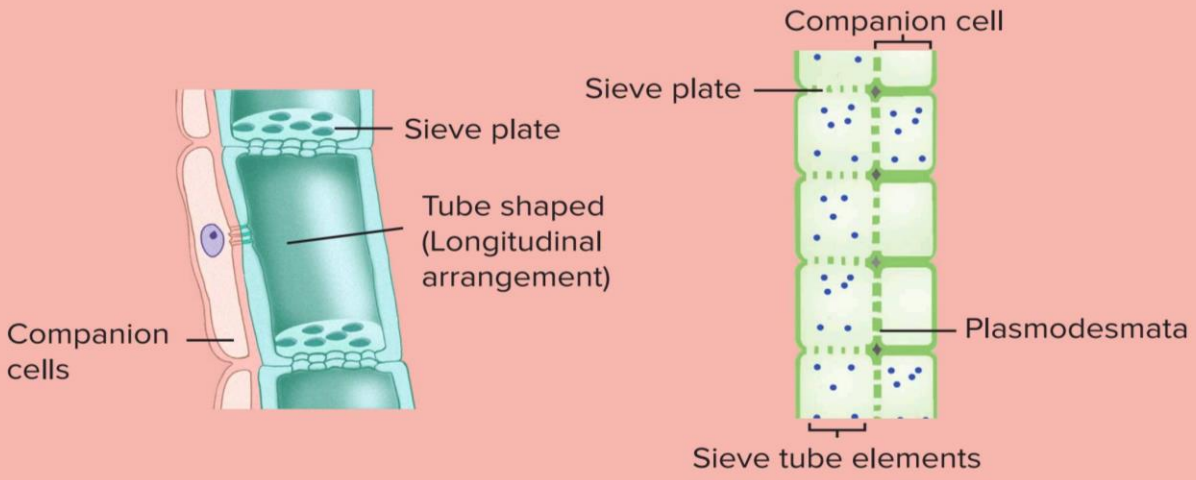



### Companion cells

- They are **living cells** with **large elongated nucleus** which **controls** the activity of the **sieve tube** element.
- They are specialised **parenchymatous** cells.
- They are **closely associated** with sieve tube elements.
- They are **non-conducting** cells.
- In gymnosperms, albuminous cells are present instead of companion cells.

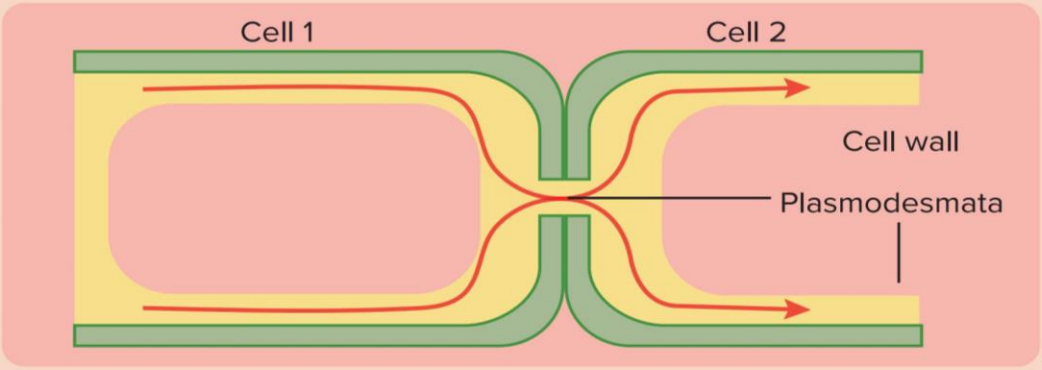
### Pit Fields (Plasmodesmata)

- The longitudinal walls between companion cells and sieve tubes are connected by **pit fields**.
- These pits are the plasmodesmata that connect the cells though channels in their cell walls.
- The **connection** maintains the **pressure gradient** in sieve tubes.



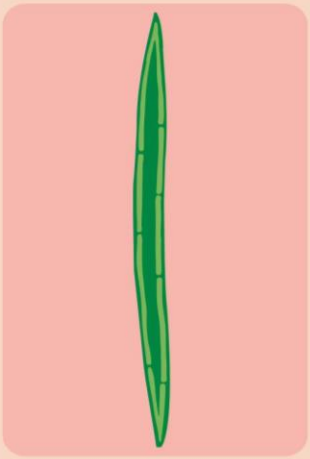

## Phloem Parenchyma

- They are **elongated, tapering cylindrical** cells.
- They have **dense** cytoplasm and a nucleus.
- They are **absent** in most **monocots**.
- They have **cellulosic cell wall, pits** and **plasmodesmata** connections between adjacent cells.
- They **store foods like resins, latex, and mucilage**




## Phloem fibres/Blast fibres

- They are **sclerenchymatous** cells.
- They are **absent in primary phloem** and are **found in secondary phloem**.
- These fibres provide **mechanical support** to sieve elements.
- They have an **elongated, unbranched** structure.
- They have a very thick cell wall with pointed, needle-like apices.
- At **maturity**, they have **loose protoplasm** and become **dead**.

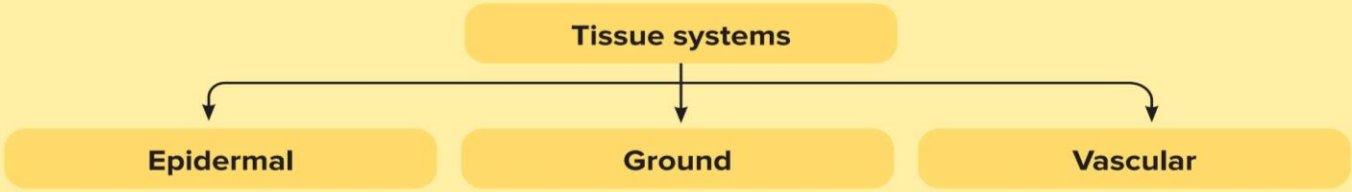


## Did you know?

Maple syrup from the sap of the sugar maple tree (Acer saccharum) is derived from the xylem and not from phloem.

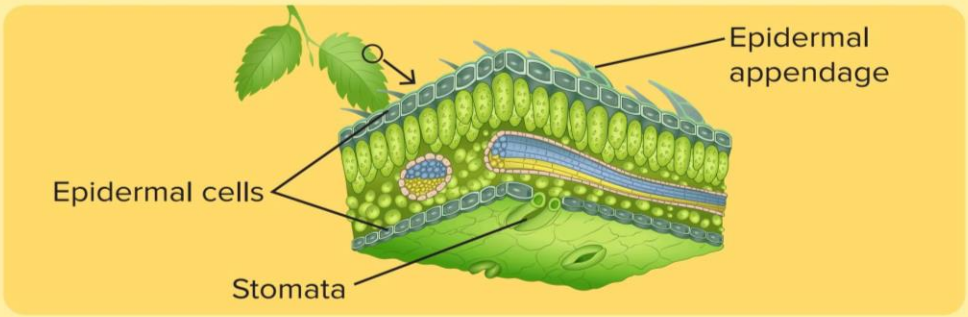
## Tissue systems

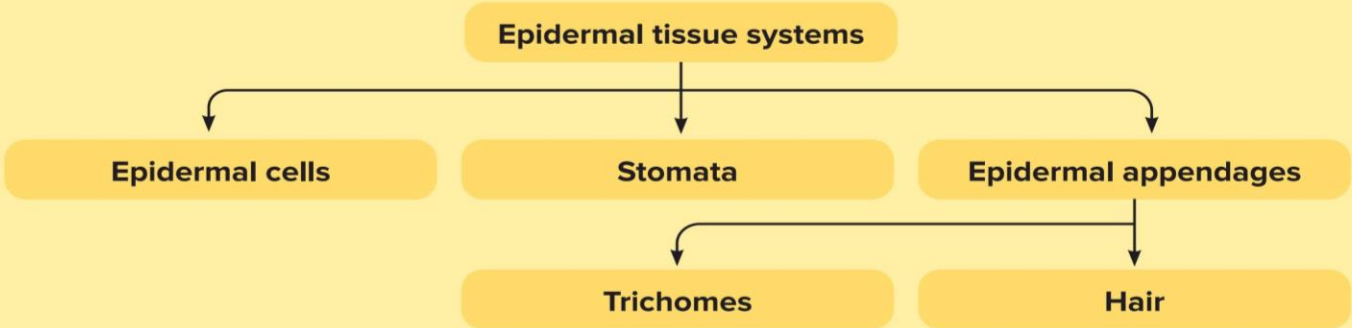
- The multicellular organisms have several tissues. The tissues which have the **same origin** combine to form a system that is known as a **tissue system**.
- Based on **structure** and **location**:




## Epidermal tissue system

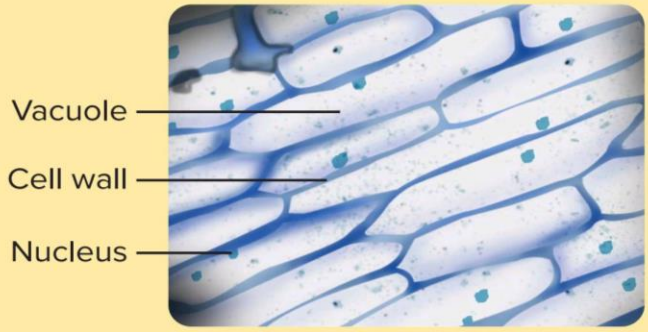
- It is the **outermost covering** of the whole plant body.
- The **outermost** covering of the plant body is the **epidermis**
- Epidermis is made of **elongated, compactly arranged** cells that form a **continuous layer** (usually a single layer)



## Epidermal cells

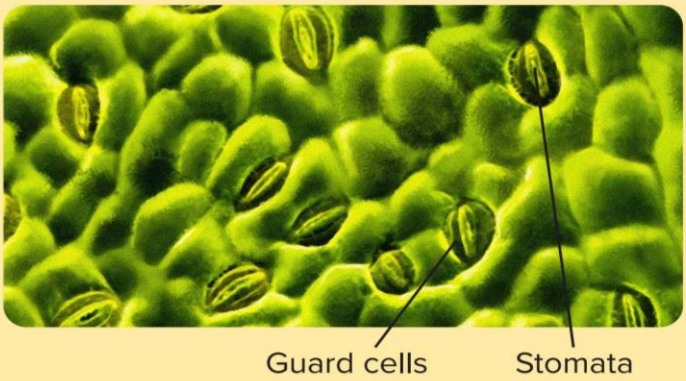
- They are **parenchymatous cells**.
- They have **large central vacuoles** with little space for the **cytoplasm** near the cell wall.



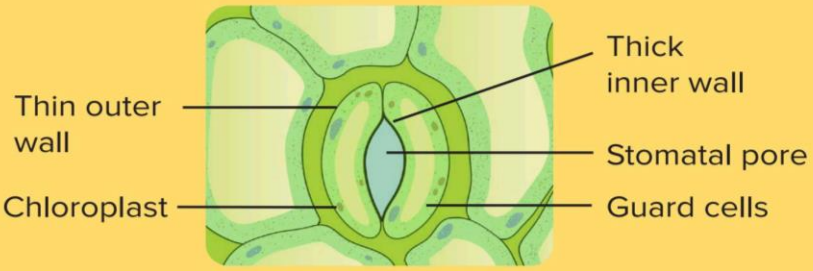

- **Cuticle**
  - ➝ It is a **waxy thick layer** present outside the epidermis.
  - ➝ It **prevents** the **loss** of **water**.
  - ➝ It is **absent** in **roots**.

## Stomata

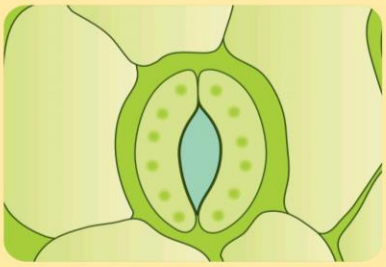
- They are small pores in the **epidermis** of leaves.
- They regulate **transpiration** and **gaseous exchange**.
- **Stomatal apparatus: Stomatal pore**, two **guard cells**, and **subsidiary cells**

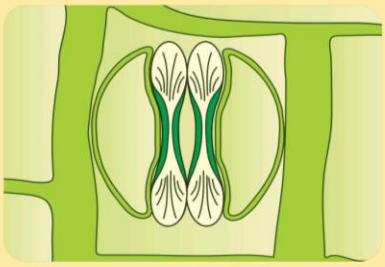



- **Guard cells**
  - ➝ They are **bean-shaped** or **dumb-bell shaped** and possess **chloroplasts**.
  - ➝ They **enclose** the stomatal pore.
  - ➝ They have a **thin outer wall** and a highly **thickened inner wall**.
  - ➝ They **regulate the opening** and **closing** of stomata.



**Bean shape (In dicots)**





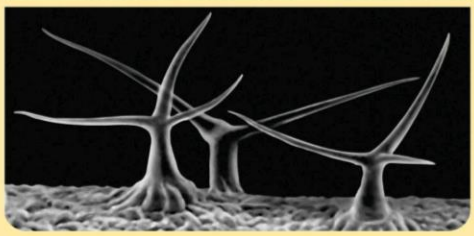
**Dumb-bell shape (In monocots)**

- **Subsidiary cells**
  - ➝ They are **specialised** epidermal cells.
  - ➝ They **surround** the guard cells.

## Epidermal appendages

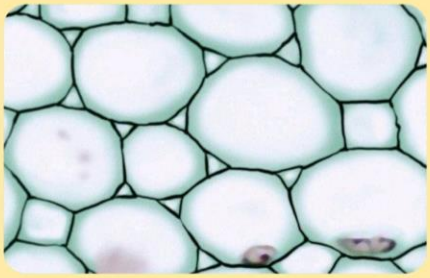
- They include root hairs and trichomes (multicellular stem hairs).
  - **Root hairs**
    - ➝ They are **unicellular elongations** of the epidermal cells of **roots**.
    - ➝ They help in the absorption of **water** and **minerals**.

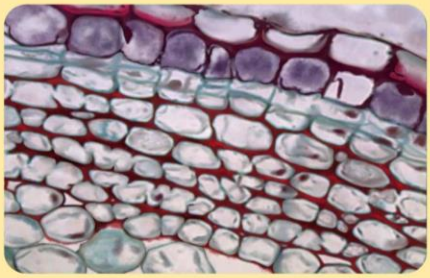
  - **Trichomes**
    - ➝ They are **epidermal hairs** on the **stem**.
    - ➝ They are usually **multicellular** in the shoot system.
    - ➝ They are **branched** or **unbranched.**
    - ➝ They are **soft** or **stiff**.
    - ➝ They may be **secretory**.
    - ➝ They **prevent** the **water loss** due to **transpiration**.

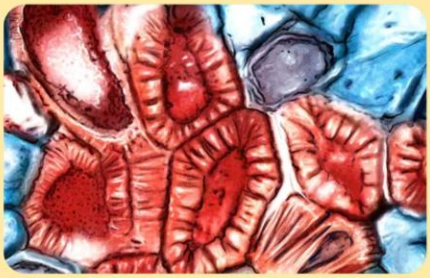


## Ground tissue system

- It includes all the tissues except epidermis and vascular bundles.
- It consists of **simple tissues:**
  - ➝ Parenchyma
  - ➝ Collenchyma
  - ➝ Sclerenchyma

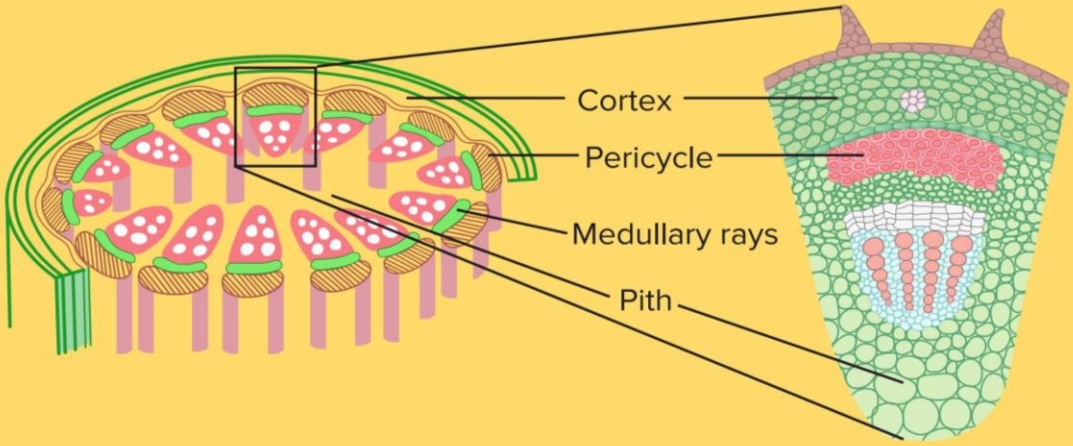






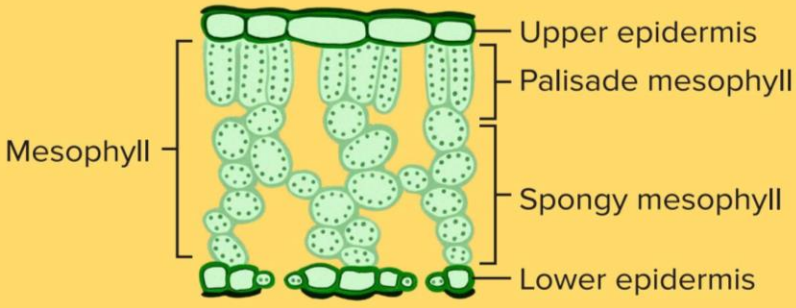
## In stems and roots

- Ground tissue is present in stems and roots as parenchyma cells.
- These parenchyma cells are present in the following parts of stems and roots:
  - **Cortex:** In plants, tissue of unspecialised cells lying between the epidermis (surface cells) and the vascular tissues is cortex.
  - **Pericycle:** It is a thin layer of plant tissue between the layer below the epidermis and the phloem.
  - **Pith:** It is composed of undifferentiated parenchyma cells, which function in storage of nutrients, found in young plants.
  - **Medullary rays:** Medullary rays are strips of parenchyma present between vascular bundles of dicot stem. They separate xylem and phloem bundles.




## In leaves

- **Mesophyll:** These are thin-walled chloroplast containing cells.
- It lies between the upper and the lower epidermis of the leaf.

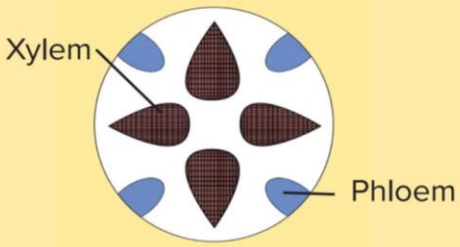


## Vascular tissue system

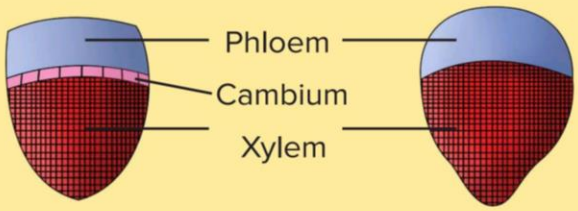
- Phloem and xylem are together known as **vascular bundles**.
- Based on arrangement of the vascular bundles, they are classified as follows:

**Vascular bundle**

| Radial | Conjoint |
|---|---|
| • Xylem and phloem alternate radially<br>• Found in stems and leaves | • Xylem and phloem are joined together<br>• Found in roots<br>• Phloem on the outer side |

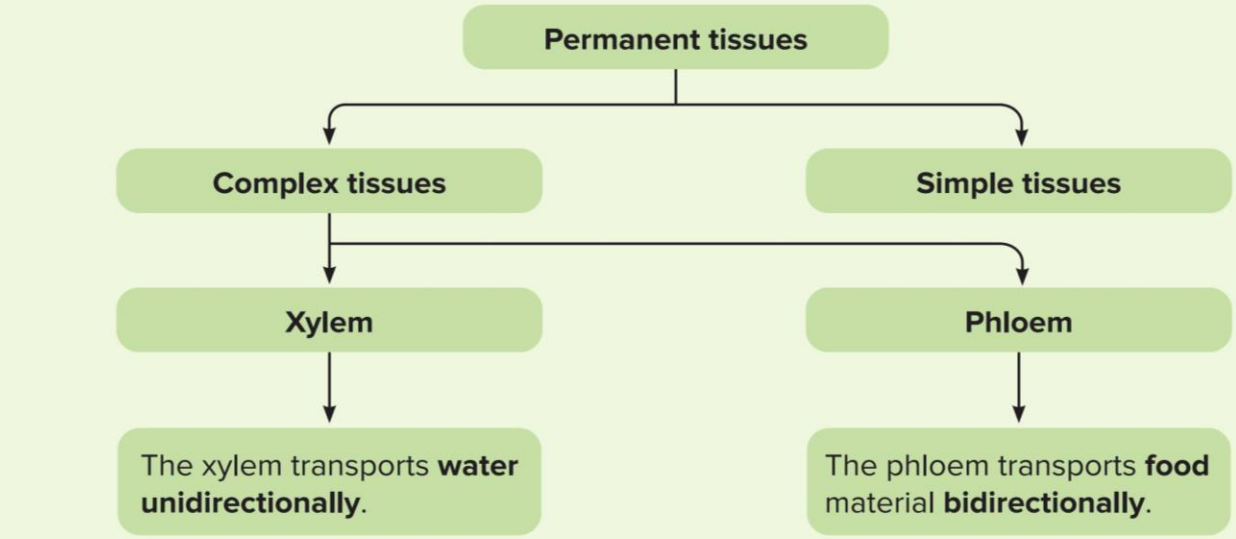


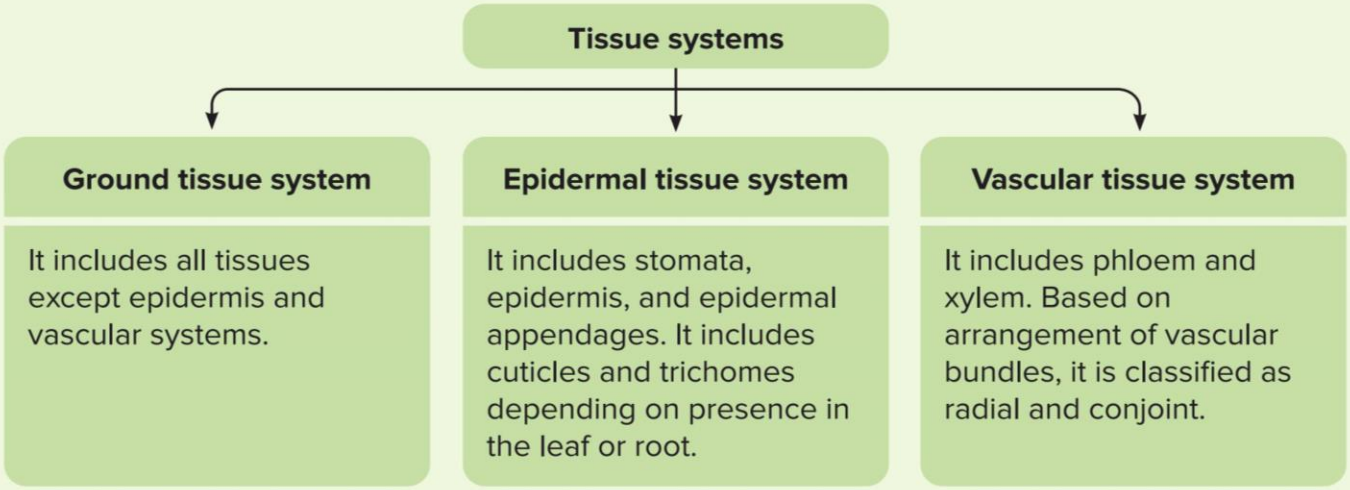

| Open | Closed |
|---|---|
| Cambium between xylem and phloem | No cambium between xylem and phloem |



## Summary Sheet

| | | |
|---|---|---|
| **Types of xylem** | **Primary xylem** | It develops during the **primary growth**. |
| | **Secondary xylem** | It develops during the **secondary growth**. |
| **Components of xylem** | **Tracheids** | They are unicellular, elongated tube-like cells with tapering ends. They are main water transporting elements. |
| | **Vessels** | They are long cylindrical, multicellular, lignified dead cells. |
| | **Xylem parenchyma** | They are living cells with a cell wall made of cellulose. |
| | **Xylem fibres** | They are thick-walled cells with a central lumen. They provide strength to tracheids and vessels. |
| **Development of xylem** | **Protoxylem** | Xylem develops as protoxylem and metaxylem. Metaxylem forms after the development of protoxylem. |
| | **Metaxylem** | It is formed after the protoxylem and has more tracheary elements and have a larger lumen. |
| **Types of phloem** | **Primary phloem** | It develops during the **primary growth** from **procambium**. |
| | **Secondary phloem** | It develops during the **secondary growth**. |
| **Elements of phloem** | **Sieve tubes** | They are longitudinal cells associated with companion cells and they are the main elements involved in the transport of food. |
| | **Companion cell** | hey are specialized parenchymatous cells which help in maintaining the pressure gradient in the sieve tubes. |
| | **Phloem parenchyma** | It is made up of elongated, tapering cylindrical cells which have dense cytoplasm and nucleus that help in storage of food in monocots. |
| | **Phloem fibres/Bast fibres** | They are made up of sclerenchymatous cells which are elongated,unbranched and have pointed, needle like apices and thick cell walls. |


Permanent tissues
Complex tissues
Simple tissues
Xylem
Phloem
The xylem transports **water unidirectionally**.
The phloem transports **food** material **bidirectionally**.


Tissue systems
Ground tissue system
It includes all tissues except epidermis and vascular systems.
Epidermal tissue system
It includes stomata, epidermis, and epidermal appendages. It includes cuticles and trichomes depending on presence in the leaf or root.
Vascular tissue system
It includes phloem and xylem. Based on arrangement of vascular bundles, it is classified as radial and conjoint.