Aakash + BYJU'S NOTES

Anatomy of Flowering Plants

Key Takeaway

1. Meristematic cells
2. Types of meristematic tissue
3. Permanent tissue
4. Simple permanent tissue
   - Parenchyma
   - Collenchyma
   - Sclerenchyma
5. Complex permanent tissue
   - Xylem
   - Phloem

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Different parts of dicot root 9

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Different parts of monocot stem 13

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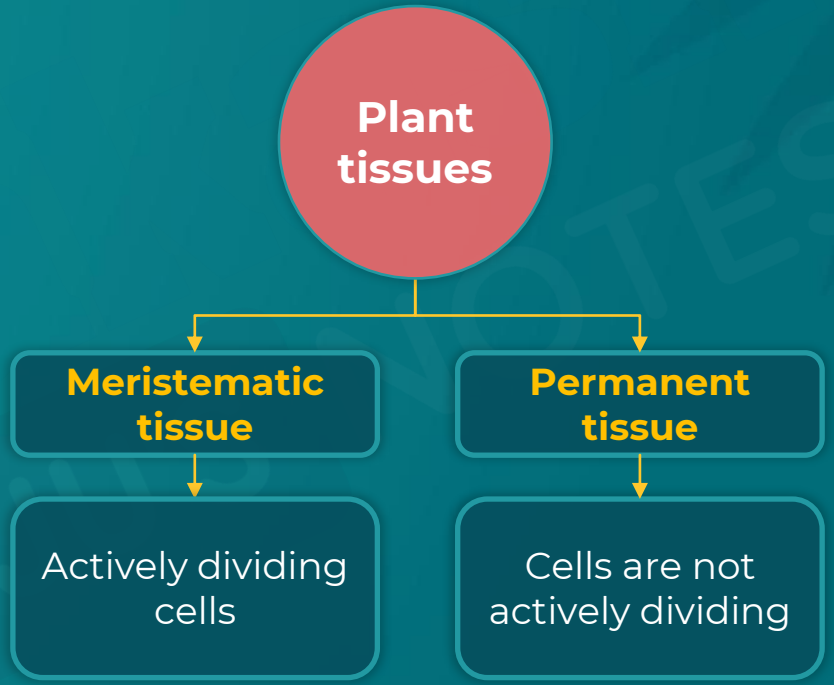
Secondary growth 15

16 Bark

Summary

Cells and Tissues

- The cell is the basic structural and functional unit of all living organisms.
- Every living organism is made up of cells.
- In plants, humans and other animals, cells come together to **form a tissue**.
- Tissues come together to **form an organ**.
- Tissue is a group of cells that has a common:
  - Origin
  - Structure
  - Function



Meristematic Cells

- Meristematic cells are **actively dividing cells** that are present in the growing parts of the plant body.
- ‘Meristos’ in Greek means ‘divided/divisible’.
- In plants, the growth is **limited to certain specialised regions**, like the tips of roots, stems and some other parts like leaves, flowers and fruits.
- The growth in the plants is because of the actively dividing meristematic cells.
- The meristems are **unspecialised** cells that supply new cells for growth and formation of tissue.

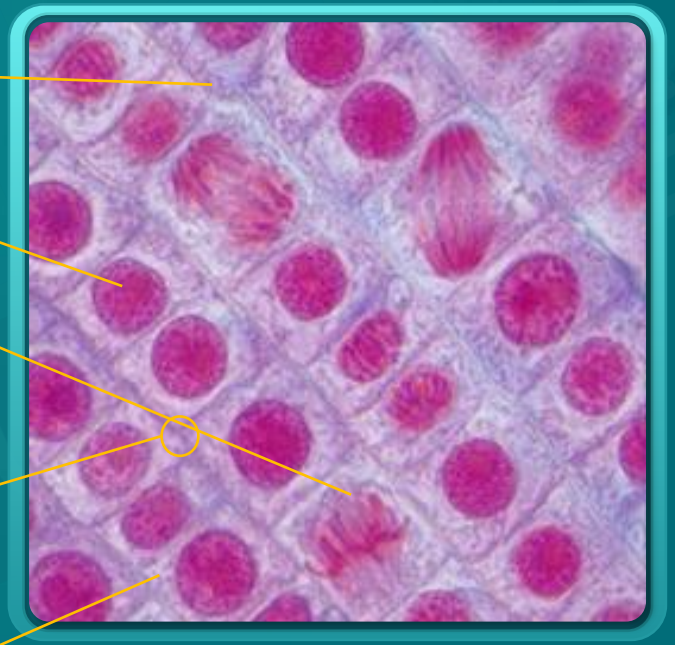
Regions of actively dividing cells such as tip of root and stem, leaves, flowers and fruits.

Meristematic Cells

Features

Features of meristematic cells

- Thin cell walls
- Large nucleus
- Dividing cells
- No intercellular space
- Dense cytoplasm



Types of Meristematic Tissue

Based on growth stage

Promeristem

- Growth of **embryonic root and shoot** is due to promeristems.
- They are **short-lived** and only exist until the seed germinates into a young plant.
- The promeristems are responsible for **embryonic growth**.

Primary meristem

- Apical meristem
  - Root apical meristem
  - Shoot apical meristem
- Intercalary meristem

Secondary meristem

- Lateral meristem
  - Intrafascicular vascular cambium
  - Interfascicular cambium
  - Cork cambium

Types of Meristematic Tissue

Primary meristem

Once the plant has grown from being a seed to a young plant, the promeristem gives rise to the primary meristems that are responsible for the growth in the next stage.

Apical meristem

- Found at the **tips of the roots and the shoots**
- They give **rise to primary tissues**

Shoot apical meristem

- Responsible for the leaves and other aerial parts of the plants
- **Axillary buds** are formed from leftover meristematic cells. New shoots or branches or even flowers can form from these buds.

Root apical system

- Responsible for the **growth of the roots**

Intercalary meristem

- Present between mature tissues at the nodes of the stem
- Responsible for the **elongation of internodes**
- Occurs in **grasses** and regenerates parts removed by the grazing herbivores

Types of Meristematic Tissue

Secondary meristem

- The plant grows from a young tender plant to a thick, woody, hard tree because of secondary meristems.
- The **increase in height or length of the tree shoots or roots** is still because of primary growth or primary meristems.
- The **increase in girth** is a result of secondary meristems and the tissues that are formed are known as the **secondary tissues**.

Lateral meristem

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

Permanent Tissue

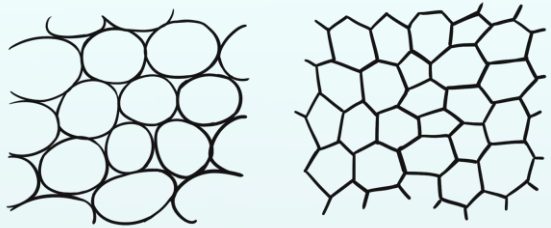
Permanent tissue consists of cells which mostly do not divide further.

- **Simple**
  - Made up of cells **similar in structure and function**
    - Parenchyma
    - Collenchyma
    - Sclerenchyma
- **Complex**
  - Made up of **different** cell types
    - Xylem
    - Phloem

Simple Permanent Tissue

Parenchyma

- It is derived from the Greek word **'para'** which means **'beside'**.
- It is a major part of all organs of the plant.
- It is the most **commonly found tissue**.
- It is the most **diverse** and **versatile cell**.
- They have thin walls and very less or **no intercellular spaces**.
- Characteristics of parenchyma are as follows:
  - The cells are generally **isodiametric** (roughly spherical).
  - The cells **vary in shape**.



No/less intercellular spaces in parenchyma

- **Round**
- **Oval**
- **Polygonal**
- **Pillar-like**

Simple Permanent Tissue

Functions of parenchyma

Photosynthesis

Performs photosynthesis and cells haave abundant chloroplasts in the chlorenchyma. Chlorenchyma makes up the mesophyll of plant leaves.

Storage

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

Secretion

Parenchymal cells line the insides of resin ducts.

Buoyancy

Aerenchyma is a modification of parenchyma. It is made up of cells with very large intercellular spaces. It helps to maintain buoyancy.

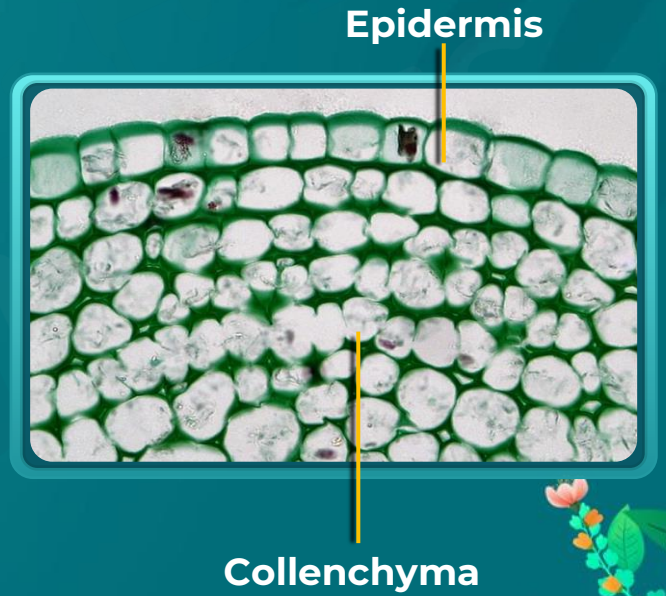
Gaseous exchange

Spongy mesophyll, in parenchyma have large intercellular spaces which help in exchange of gases.

Simple Permanent Tissue

Collenchyma

- Collenchyma tissue is made up of **living cells**.
- It is found either as a homogeneous layer or **in patches**.
- Collenchyma forms a **layer under the epidermis** in most dicotyledon stems.
- Cell wall is made up of:
  - Cellulose
  - Hemicellulose
  - Pectin
- There are no intercellular spaces between cells as they are filled with pectin.



Simple Permanent Tissue

Collenchyma

Shapes

- Spherical
- Oval
- Polygonal

Functions

- Provides **mechanical support** (tensile strength)
- Provides **elasticity** to plant parts such as a young stem and the petiole of a leaf
- Helps to resist the bending action of the wind
- Assimilates food when cells contain chloroplasts

Simple Permanent Tissue

Sclerenchyma

- Sclerenchyma consists of cells with **thick** and **lignified cell walls** having a few or numerous **pits**. They are usually **dead** and **without protoplasts**.
- **Lignin** is a very complex organic substance and the second most commonly found natural organic polymer after cellulose.
  - It is insoluble in water. Hence, it is impermeable to water.
  - It is found as a thick deposition in the cell walls.
- **Sclerenchyma** provides **mechanical support** to organs.
- Cell wall is made up of:
  - Cellulose
  - Hemicellulose
  - Lignin
- They are found in stems, leaves, seed coats, fruit pulp and wall.

Sclerenchyma

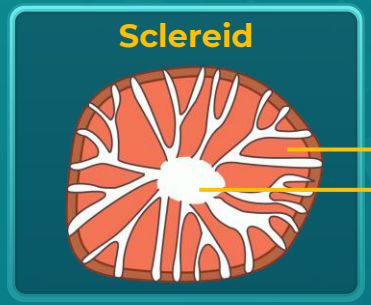
Simple Permanent Tissue

Types of sclerenchyma

Based on form, origin, structure and development, they are of two types.

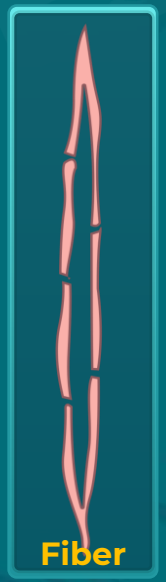
Sclereids

- They have **highly thickened walls**.
- They have a **narrow cavity** (lumen).
- They are of different shapes.
- They are commonly found in pulp of fruits like guava etc.



Fibers

- They are elongated in shape.
  - 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**.



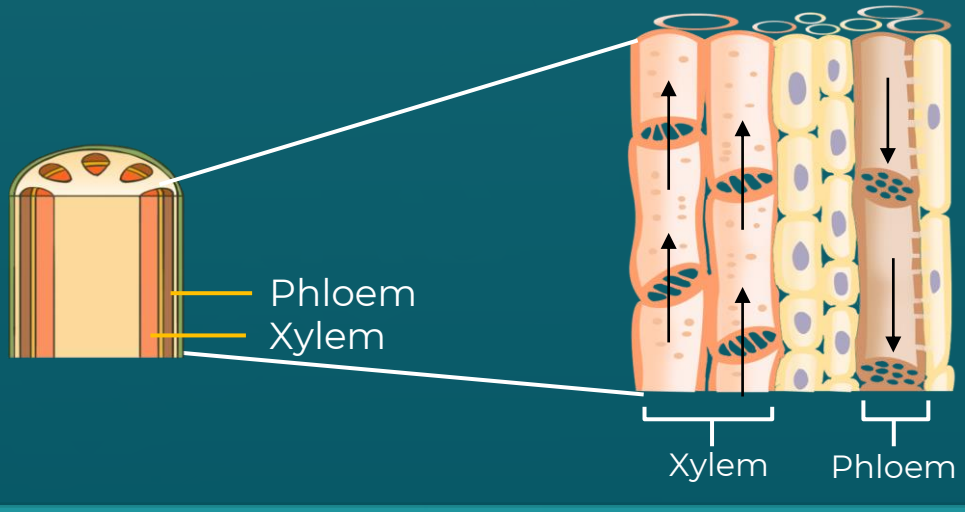
Complex Permanent Tissue

- In photosynthesis occurs in leaves and roots absorb water as well as minerals.
- The plants transport water from the soil to the leaves and food synthesised in the leaves reaches all the parts of the plants through **complex tissues**.
- There is an unidirectional movement in transport of water and a bidirectional movement in transport of the synthesised food**.**
- The complex tissues are **heterogenous**. They are composed of different types of cells that work as a **unit**.

Complex Permanent Tissue

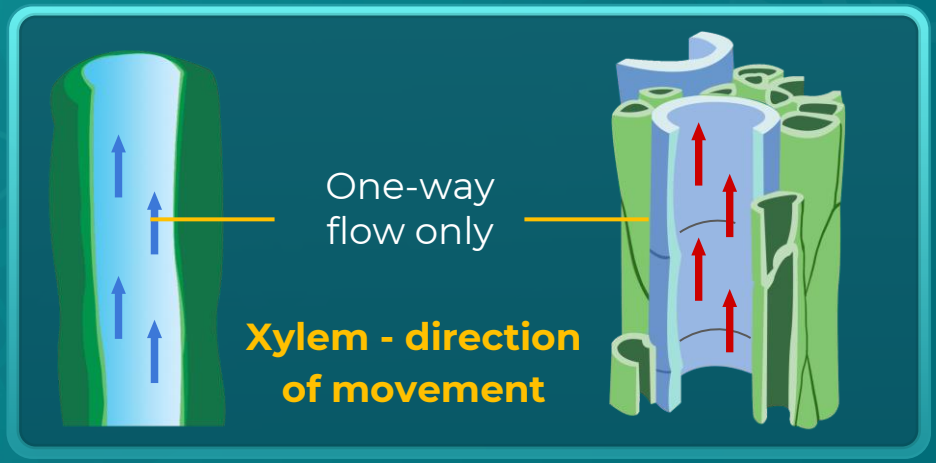
- Xylem
- Phloem

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



Xylem

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



Types of Xylem

Primary

Protoxylem

- Part of the primary xylem that **forms first**
- In stem, it lies towards the center

Metaxylem

- Part of the primary xylem that **forms after the protoxylem** is formed
- In stem, it lies towards the periphery

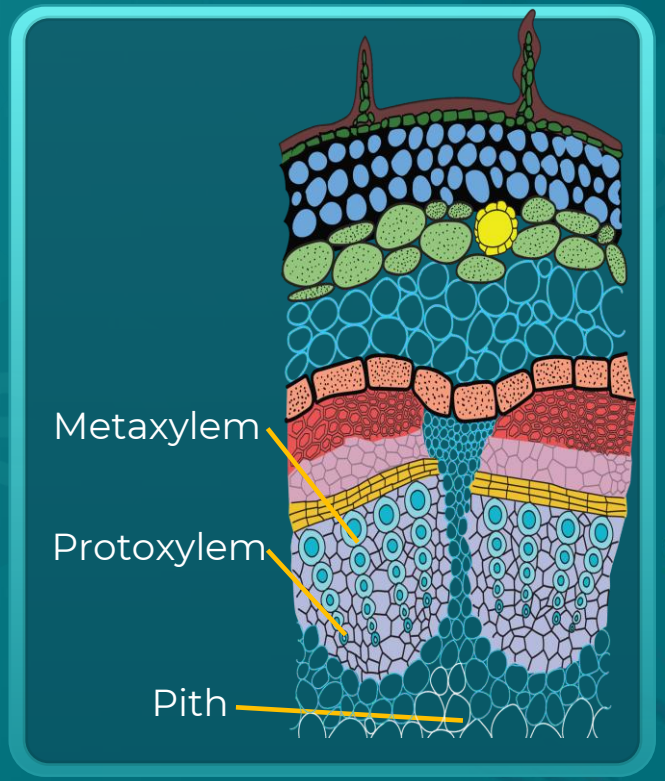
Secondary

- It is formed during the secondary growth of plants.
- It is **seen as annual rings**. In some of the **large plants**, it is seen as **sapwood** or **heartwood.**

Types of Xylem

Endarch

- The protoxylem is found inner to the metaxylem.
  - The protoxylem is towards the centre (adjacent to **pith**).
  - The metaxylem is towards the **periphery**.
- Endarch arrangement is seen in **stem**.

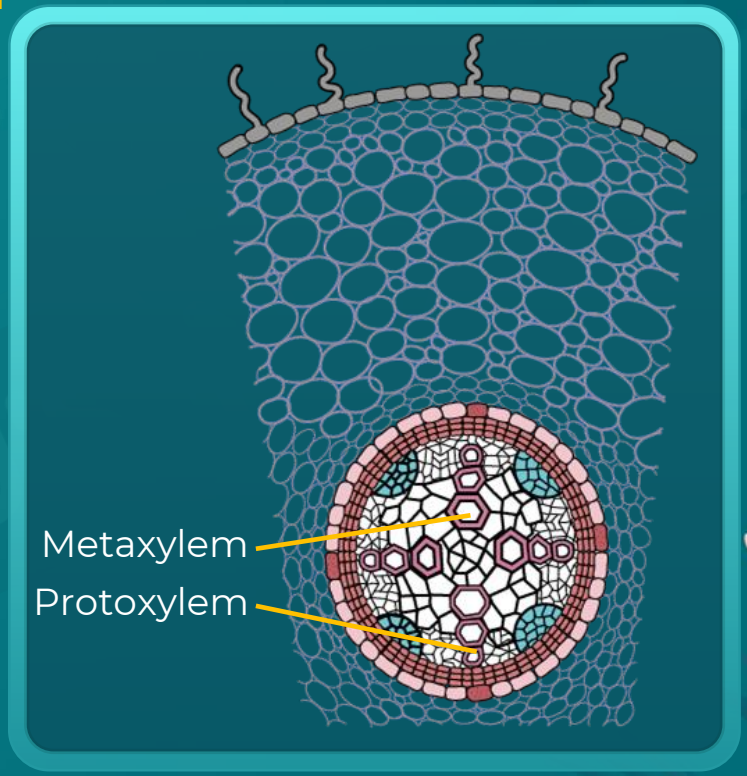


T.S of dicot stem

Types of Xylem

Exarch

- The **protoxylem is found outer to the metaxylem**.
  - The protoxylem is towards the **periphery**.
  - The metaxylem is towards the **centre**.
- Exarch arrangement is seen in **roots**.

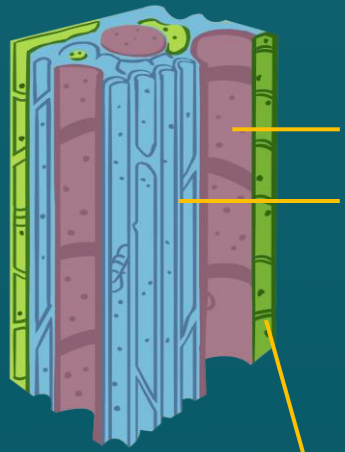


T.S of dicot root

Components of Xylem

Xylem

- Tracheids
- Vessels
- Xylem parenchyma
- Xylem fibres



Components of Xylem

Tracheids

They are **unicellular, elongated tube-like cells with tapering ends**.

Structure

- The inner layers of the **cell walls have varying thickness and are lignified**.
- Cells are elongated with **tapering ends**.
- The tracheids are found one above the other, separated by a cross wall/end wall that bears bordered pits.
- The cells are **dead or without protoplasm**.

Function

- The secondary cell wall helps in long-distance transport.
- This is one of the main **water transporting elements** of xylem in angiosperms.

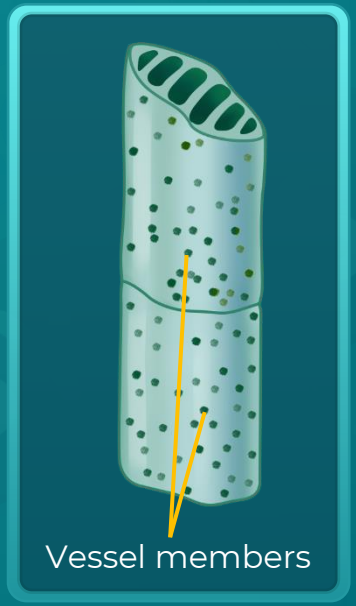
Components of Xylem

Vessels

- Each vessel consists of broad, lignified dead cells, joined end to end forming a **tubular structure**.
- They are **long, cylindrical** and a characteristic features of angiosperms.

Structure

- Each cell or vessel member has **lignified walls** and a **large central cavity**.
- The end wall is **perforated**. Hence, the vessels work as a pipeline.
- The perforated end walls allow **vessel members to be stacked end to end** to form a larger conduit known as a **vessel**.



Vessel members

Function

- The vessels are **more capable for the conduction of water** than tracheids.
- The open-end walls of vessels provide a very efficient low resistance pathway for water movement.

Components of Xylem

Xylem parenchyma

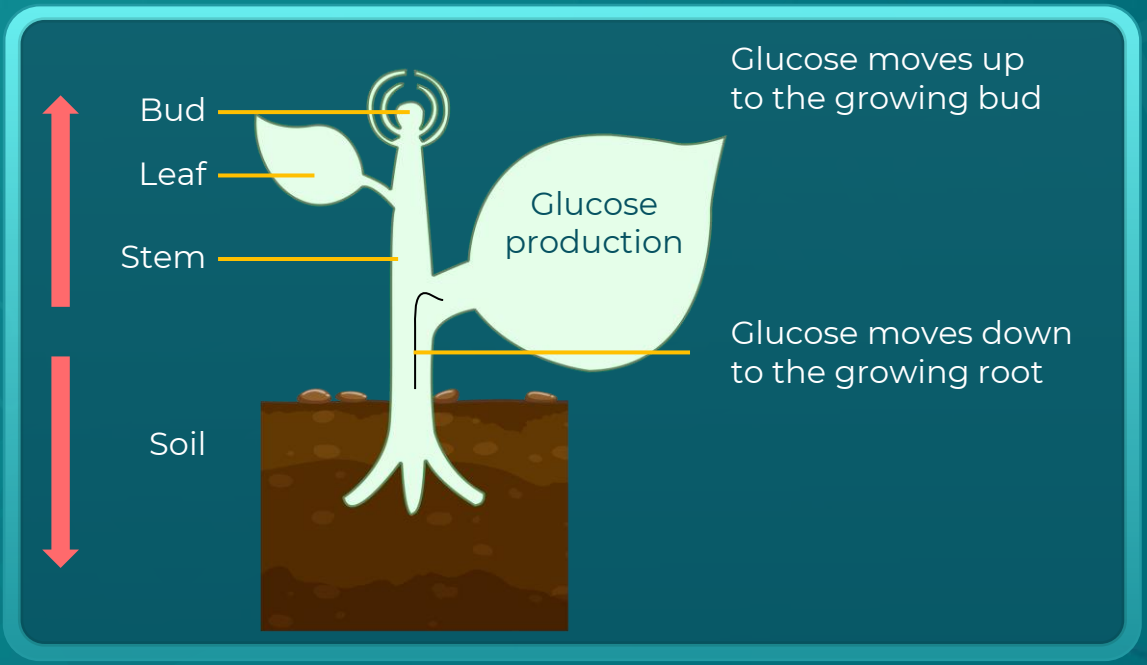
- They are **living cells** having **thin cell walls** made up of **cellulose**.
- They store secondary metabolites like **tannins** and food materials like **fats and starch**.
- **Radial conduction** of water is performed by the **ray parenchymatous cells**.

Xylem fibres

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

Phloem

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



Phloem

- Primary
  - Protophloem — First formed phloem
  - Metaphloem — Later formed phloem
- Secondary

- **The primary phloem** is divided into **protophloem** and **metaphloem**, based on the development.

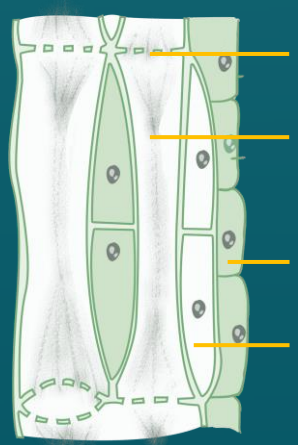
- The secondary phloem forms from the **vascular cambium** during the secondary growth.

Elements of Phloem

Phloem components

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

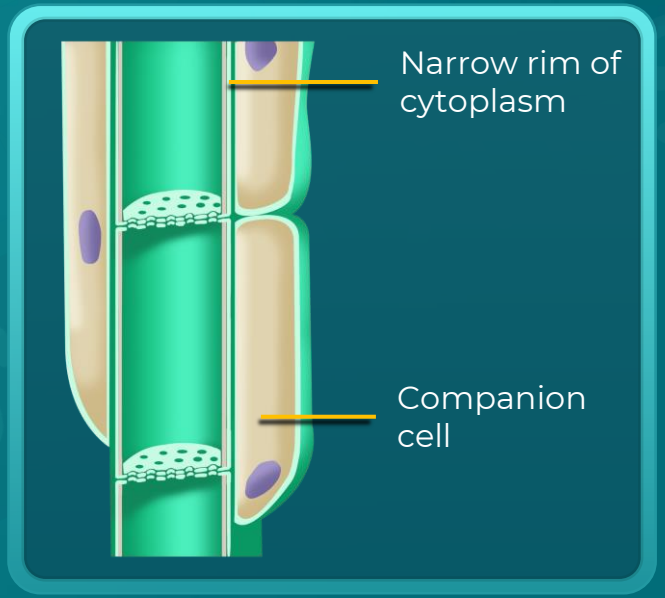
- The gymnosperms have **albuminous cells** and **sieve cells**.
- The gymnosperms lack companion cells and sieve tubes.



Elements of Phloem

Mature sieve elements

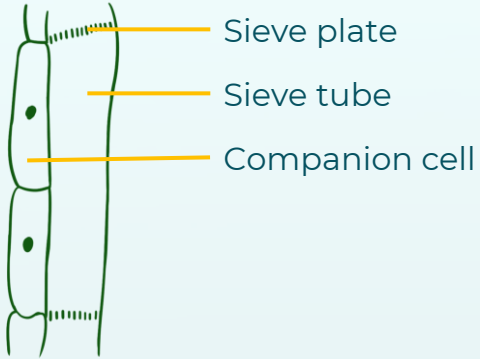
- **Sieve elements** are joined end to end with pore filled **sieve plates** between to make a **sieve tube**.
- They have a **peripheral cytoplasm**.
- They have a functional plasma membrane.
- They have a **large vacuole**.
- Tonoplast and nucleus are lost generally.



Elements of Phloem

Companion cells

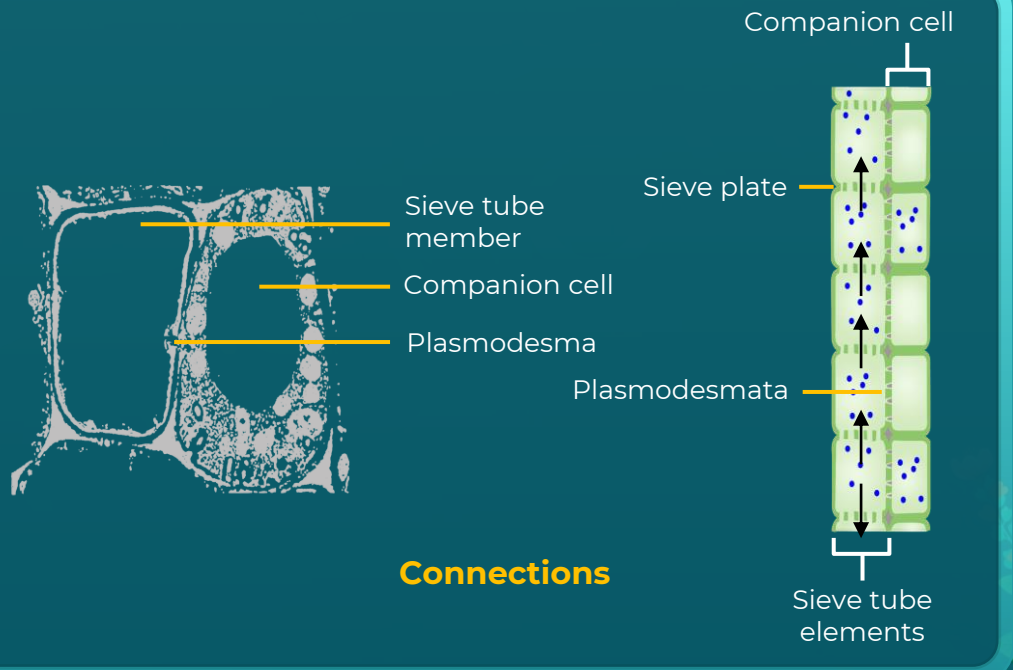
- They have a nucleus along with dense cytoplasm.
- They can perform metabolic and cellular functions.
- The companion cell is a living cell with **a large elongated nucleus**. This nucleus also controls the activity of the sieve tube element.
- **Features:**
  - They are specialised **parenchymatous** cells.
  - **They are closely associated** with sieve tube elements.
  - **They are non-conducting** cells.
  - In gymnosperms, albuminous cells are present instead of companion cells.



Elements of Phloem

Companion cells

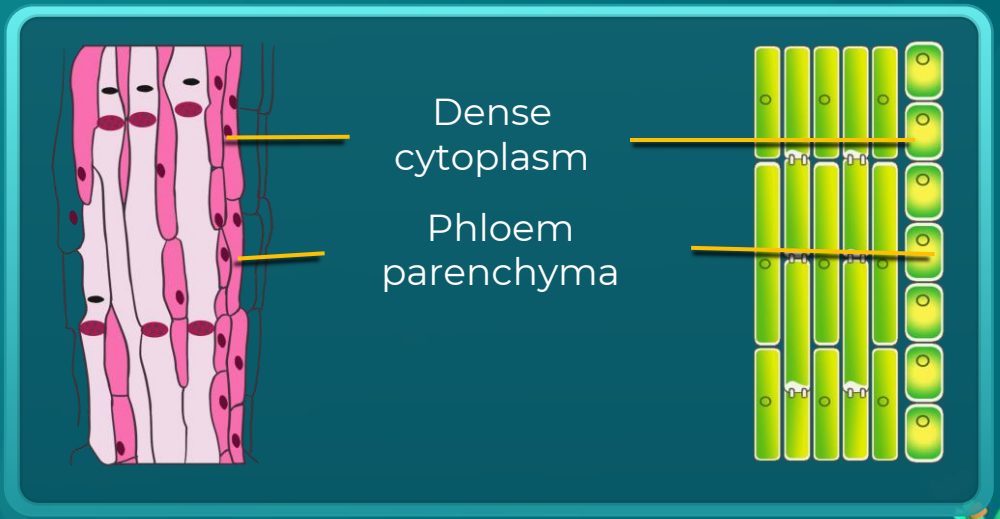
- The longitudinal walls between companion cells and sieve tubes are connected by **pit fields**.
- The companion cells and sieve tube elements maintain close cytoplasmic connections with each other through **plasmodesmata**.
- **The connection** maintains the **pressure gradient** in sieve tubes.



Elements of Phloem

Phloem parenchyma

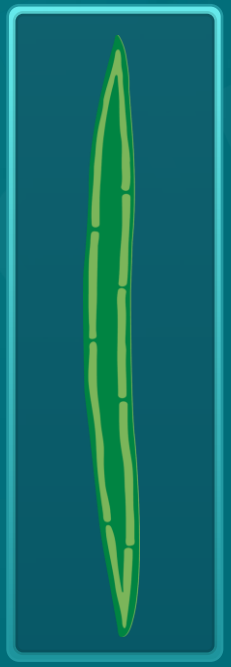
- They are **elongated, tapering cylindrical** cells.
- They have dense cytoplasm and a nucleus.
- They are **absent** in most **monocots**.
- They have **cellulosic cell wall, pits** and **plasmodesmata** connections between adjacent cells.
- They **store foods like resins, latex, and mucilage**.



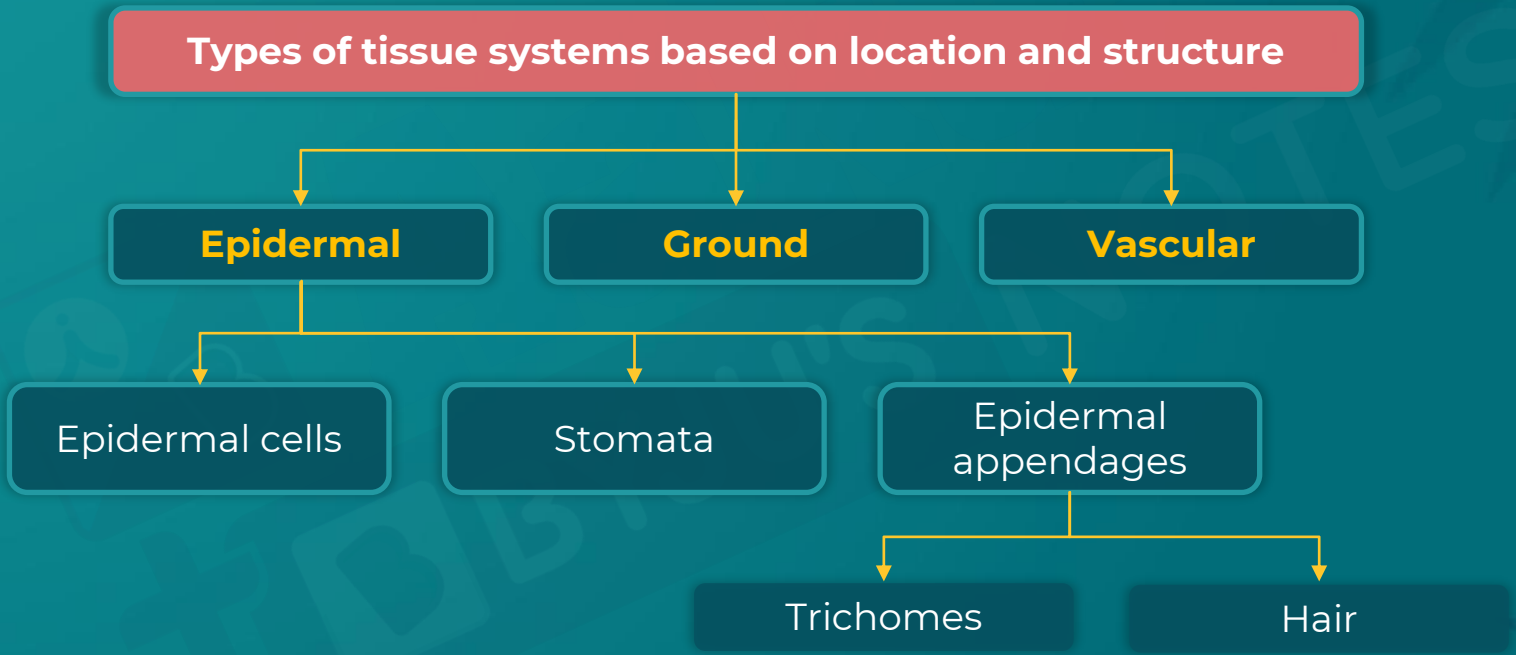
Elements of Phloem

Phloem fibres (bast 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**.
- Phloem fibres of jute, flax and hemp are commercially useful.



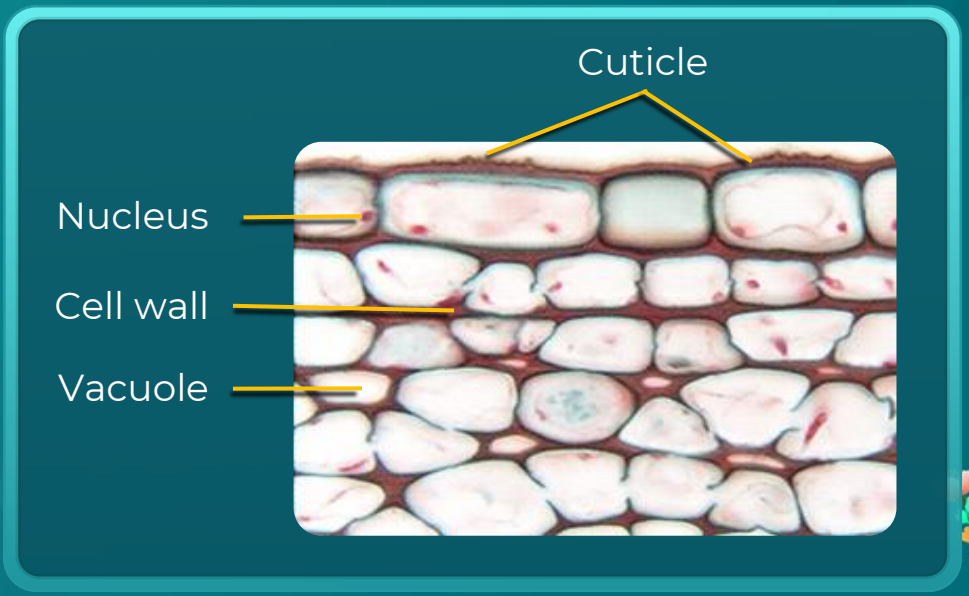
Tissue Systems



Epidermal Tissue System

- **They are parenchymatous.**
- They have a little **cytoplasm** lining the cell wall.
- They have a **large** vacuole.
- Cells are lined by cuticle.
  - It is a **waxy thick layer present outside** the epidermis.
  - It **prevents** the loss of water.
  - It is absent in roots.

Epidermal cells



Epidermal Tissue System

Stomata

- They are small pores in the **epidermis** of leaves.
- They regulate the **transpiration** and **gaseous exchange**.

Stomatal apparatus consists of

- **Stomatal pore**
- **Guard cells**
- **Subsidiary cells**

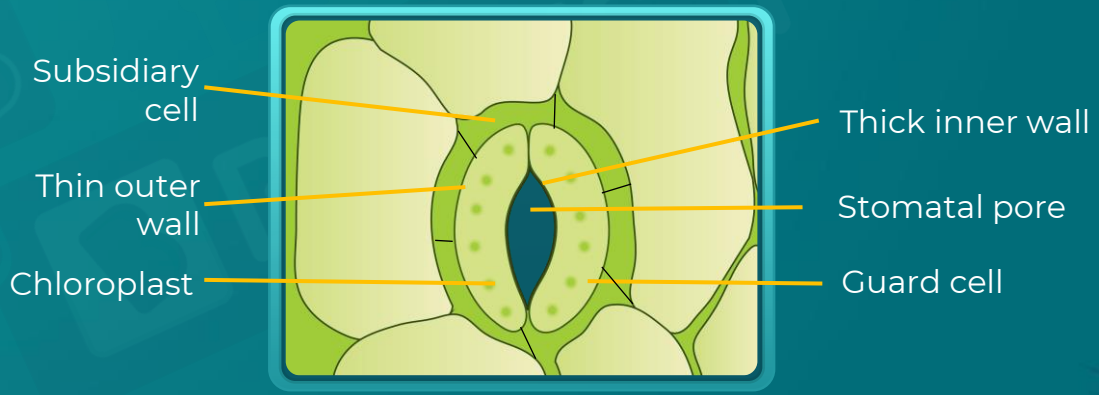
Epidermal Tissue System

Guard cells of stomata

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

Subsidiary cells of stomata

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



Epidermal Tissue System

Epidermal appendages

Root hair

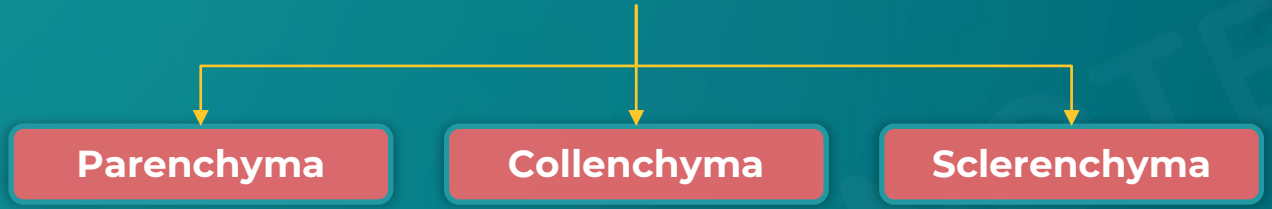
- **They are unicellular elongations** of the epidermal cells.
- They help in the absorption of **water** and **minerals**.

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 usually consists of simple tissues.



Ground Tissue System

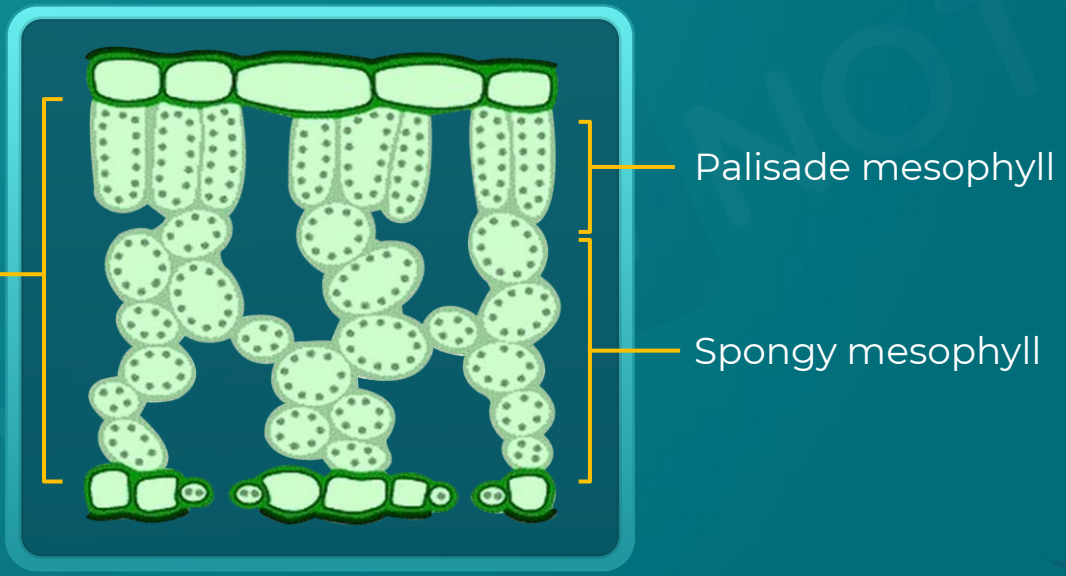
Parenchymatous tissue is found in stem and roots.

- **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 thick-walled parenchymatous cells just below the endodermis.
- **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.

Ground Tissue System

In leaves

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



Vascular Tissue System

Phloem and xylem together form the vascular bundles or vascular system.

In monocots

- They have **closed vascular bundles**.
  - The **cambium** is **absent**.
  - The secondary tissues are not formed.

In dicots

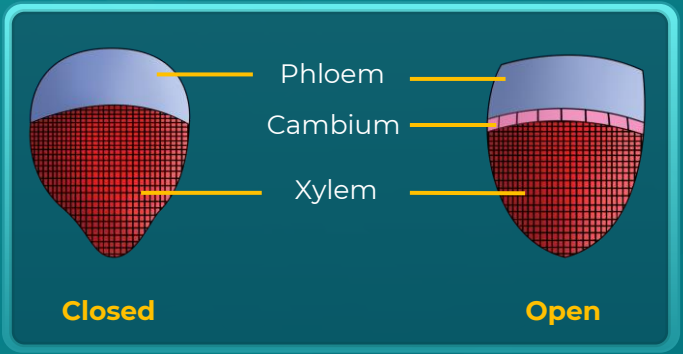
- **They have open** vascular bundles.
  - The **cambium** is **present** in between the phloem and xylem.
  - The cambial activity gives rise to the **secondary** xylem and phloem tissues.

Vascular Tissue System

Based on arrangement, vascular bundles are of 2 types

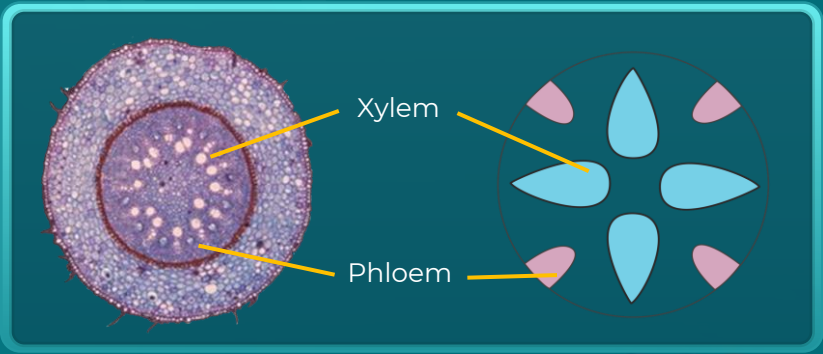
Radial

- Alternate arrangement along different radii
- Found in roots



Conjoint

- Arranged **together along the same radius**
- Found in **stems** and **leaves**
- Phloem usually on the **outer** side of xylem



Different Parts of Dicot Root

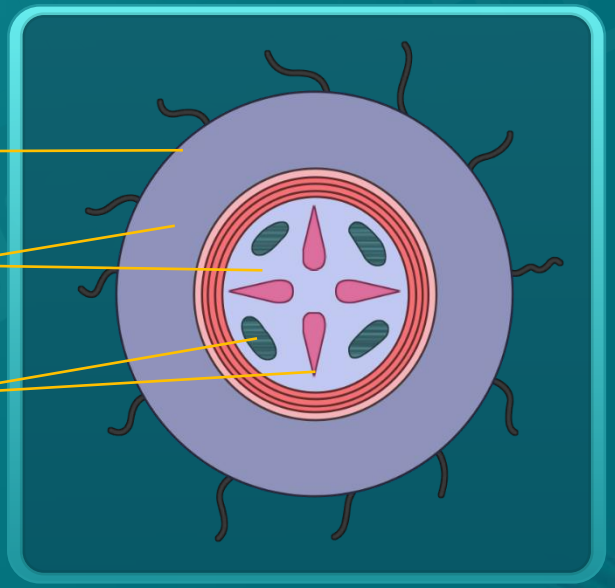
- **The dicot roots have a taproot system.**
  - A taproot system is made of a central, large root that is known as the **primary root**.
  - The primary root is larger in diameter than the **lateral roots**.

Transverse section of dicot root

Epidermal tissue

Ground tissue

Vascular tissue



T.S of dicot root

Different Parts of Dicot Root

a) Epidermis

- Also known as **epiblema/rhizodermis**
- Protective in function
- Some epidermal cells protrude to form root hairs

b) Cortex

- It is a multilayered thin-walled structure, made up of a mass of **parenchymatous cells** with intercellular spaces between them.
- The innermost layer is of **barrel-shaped cells** without any intercellular space is called **endodermis**.

c) Casparian strips

- The tangential and radial walls of endodermal cells have **suberin** deposition in the form of strips known as **casparian strips**.

Different Parts of Dicot Root

d) Pericycle and conjunctive tissue

- A few layers of thick-walled parenchymatous cells known as **pericycles** (beneath the endodermis) help in the formation of lateral roots and secondary growth by forming **cambium**.
- Parenchymatous cells that lie between the xylem and the phloem are known as **conjunctive tissue**.

e) Pith

- Pith is small and inconspicuous, made up of **parenchymal cells**.

f) Vascular tissues

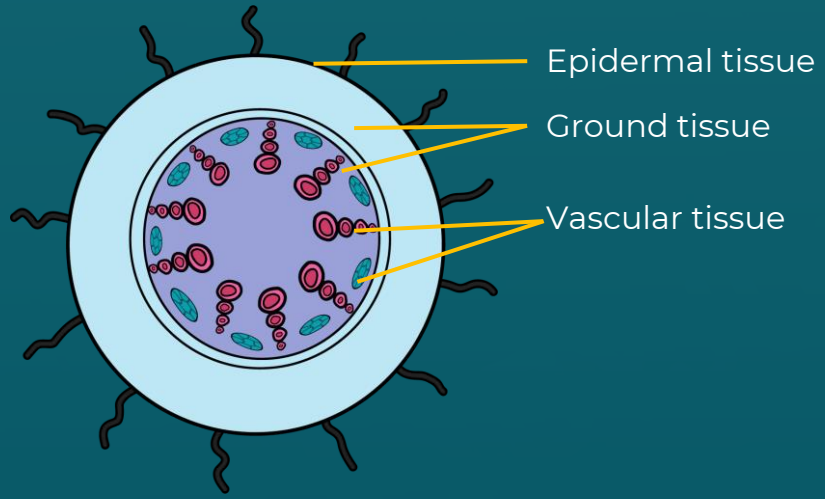
- **2-4** phloem and xylem patches are present.

g) Stele

- All tissues on inner side of endodermis constitute the stele.

Different Parts of Monocot Root

- They have a **fibrous root system**.
- The monocot roots and dicot roots are similar in their internal structure except for few differences.

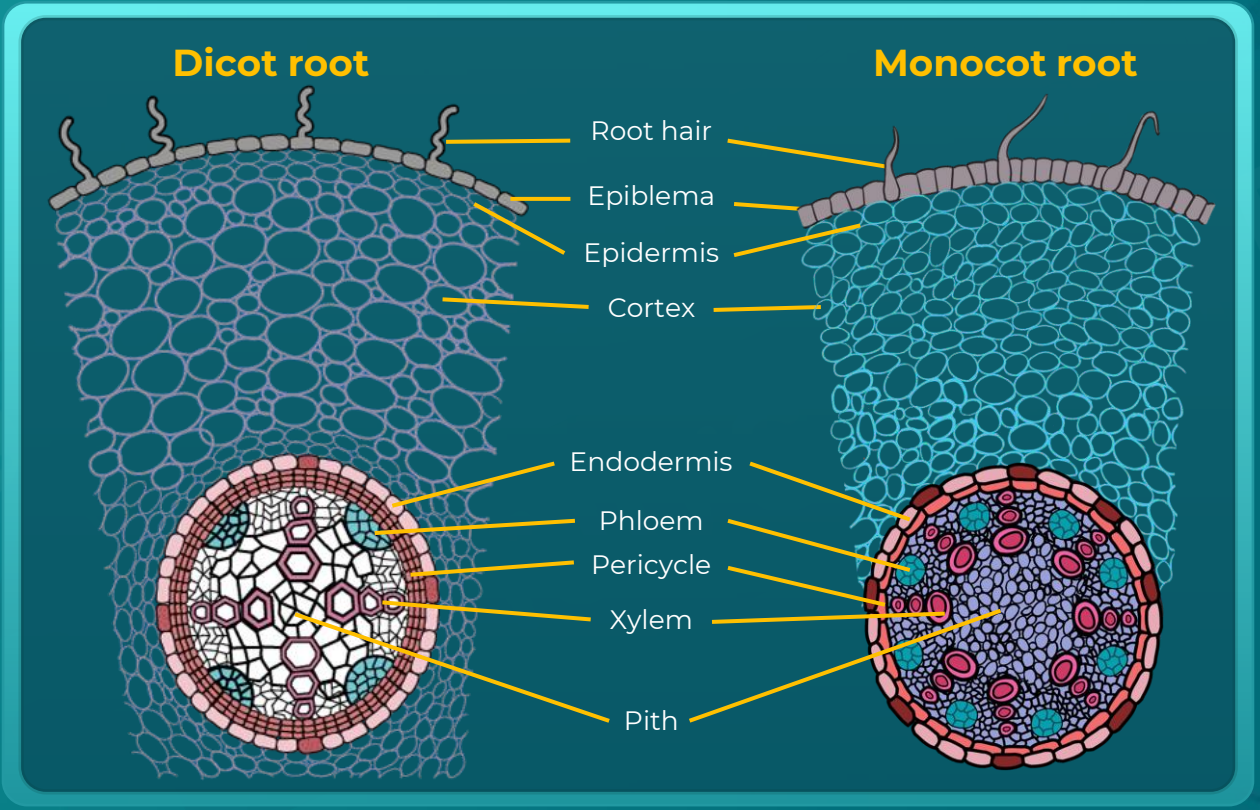


Section of monocot root

Difference Between Monocot and Dicot Root

Features	Dicot root	Monocot root
Xylem and Phloem	**Diarch to tetrarch:** There are 2 to 4 xylem and phloem bundles.	**Polyarch:** There are more than 6 bundles of xylem and phloem.
Pith	It is **small** or inconspicuous.	It is **large** and well developed.
Secondary growth	From the pericycle of dicot roots, **vascular cambium is formed** at a later part of plant life that helps in the **secondary growth**.	From the pericycle of monocot roots, there is **no vascular cambium formation**. Therefore, there is **no secondary growth**.

Difference Between Monocot and Dicot Root

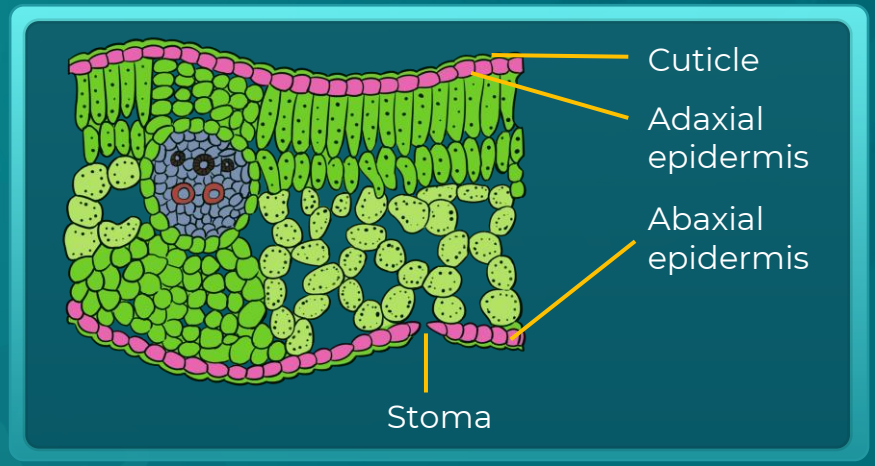


Different Parts of Dicot Leaf

- It has **reticulate venation**.
- It has **dorsal and ventral** surfaces.

Epidermal tissue system

- The epidermis on the upper surface of a leaf is known as **adaxial** epidermis.
- The epidermis on the lower surface of a leaf is known as **abaxial** epidermis.
- The conspicuous cuticle is present on epidermis.
- The stomata is present on the epidermis of the leaf.
- The abaxial epidermis has more number of stomata, hence it is known as **hypostomatic leaf**.
- **Guard cells** in dicot leaves are **bean shaped**.



T.S of dicot leaf

Different Parts of Dicot Leaf

Ground tissue system

- The tissue between the upper and the lower epidermis is known as the **mesophyll**.
- The mesophyll cells that possess **chlorophyll** carry out **photosynthesis**.

Mesophyll

Palisade parenchyma

- Present **near** the **adaxial** surface.
- The elongated cells are arranged **vertically** and are **parallel** to each other.

Spongy parenchyma

- Present **below palisade parenchyma** and extend to lower epidermis.
- Cells are oval/round and **loosely arranged**.
- The intercellular spaces are filled with air cavities.

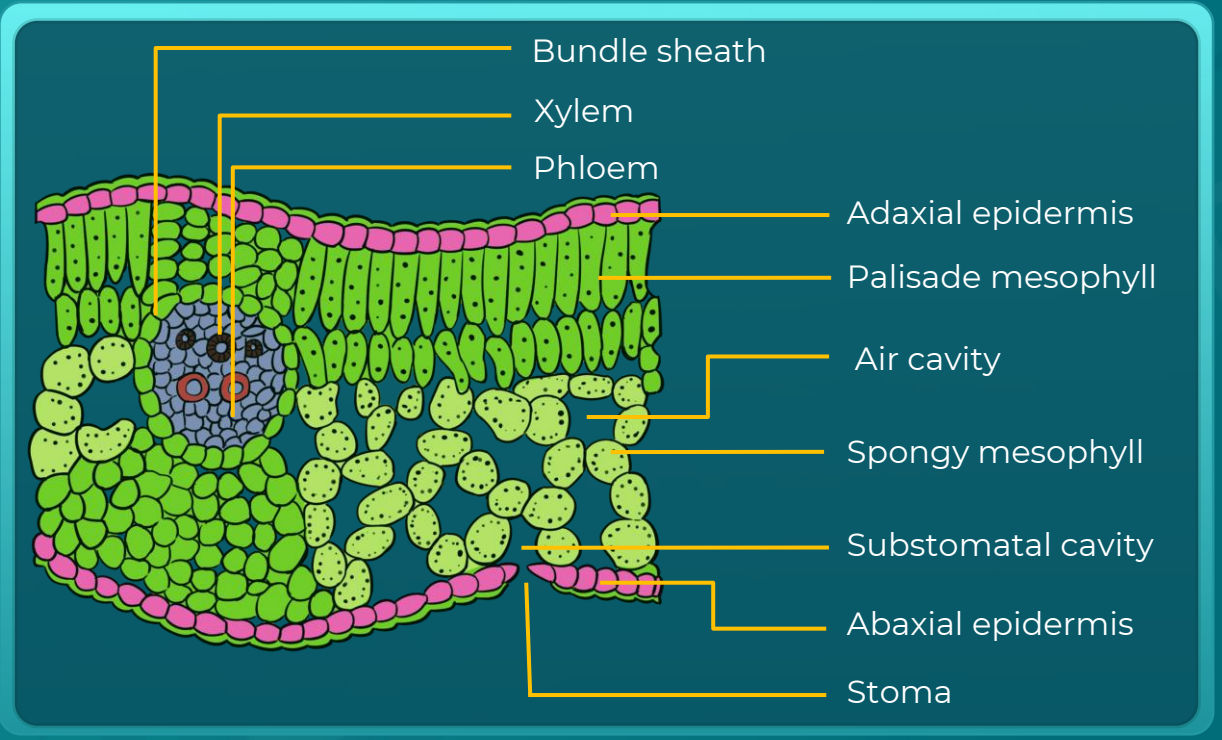
Different Parts of Dicot Leaf

Vascular bundles

- The vascular tissues are present in midrib and veins.
- The size of vascular bundles varies due to variation in thickness of veins.
- The vascular bundles are **surrounded by thick-walled bundle sheath cells**.
- The **xylem** is on the **upper side** and the **phloem** is on the **lower side**.

Dicot leaves are known as **dorsiventral leaves** as the upper and lower regions have distinct features.

Transverse Section of Dicot Leaf

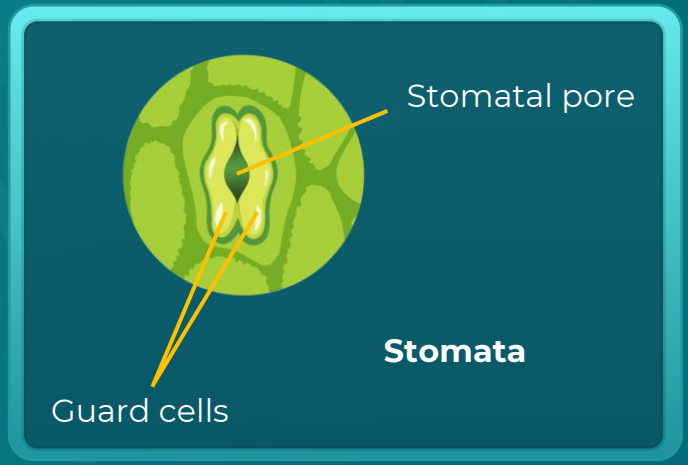


Different Parts of Monocot Leaf

- It has parallel venation.
- The monocot leaves are also known as **isobilateral leaves** as both of its surfaces are similar.

Epidermal tissue system

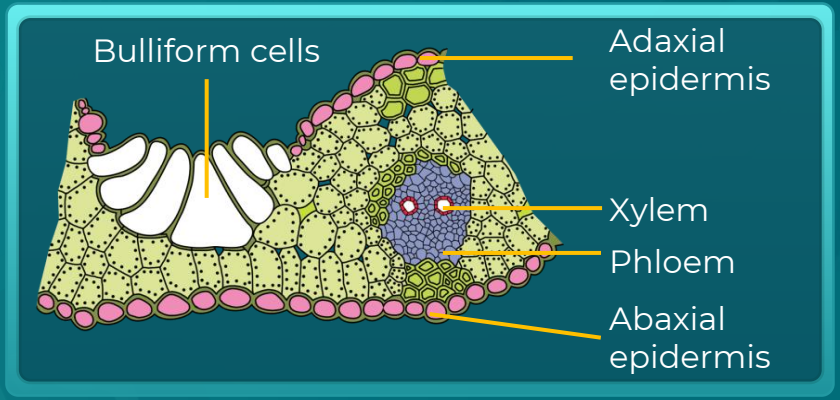
- Equal number of stomata are present in the epidermis on both sides of the leaf, hence it is known as an **amphistomatic leaf**.
- **Guard cells** in monocot leaves are **dumbbell shaped**.



Different Parts of Monocot Leaf

Epidermal tissue system

- **The bulliform cells** are large, empty, and colourless cells present in adaxial epidermis that absorb water and become turgid when the leaf surface is exposed.
- They help in rolling and unrolling of leaves due to change/variations in turgidity.
- The **mesophyll** is present between upper and lower epidermis.
- The mesophyll is **not differentiated** into palisade and spongy parenchyma.
- They consist of chlorenchyma cells.

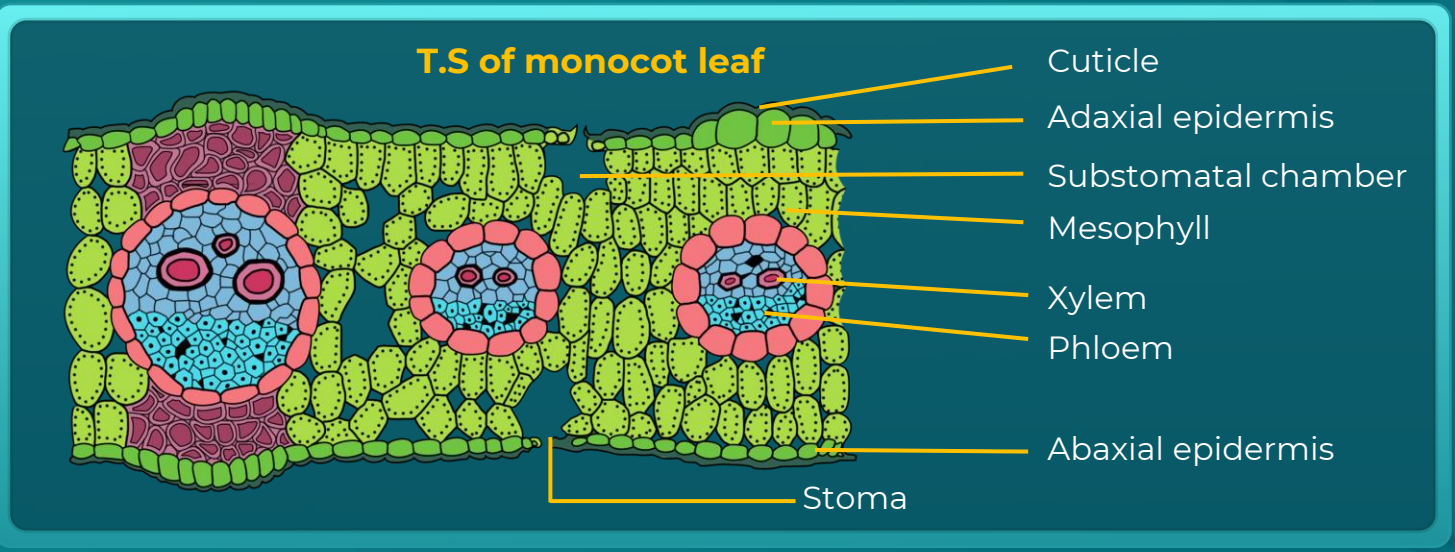


T.S of monocot leaf showing bulliform cells

Different Parts of Monocot Leaf

Vascular tissue system

- The vascular bundles are **surrounded by bundle sheath cells**.
- The **xylem** is on the **upper side** and the **phloem** is on the **lower side**.



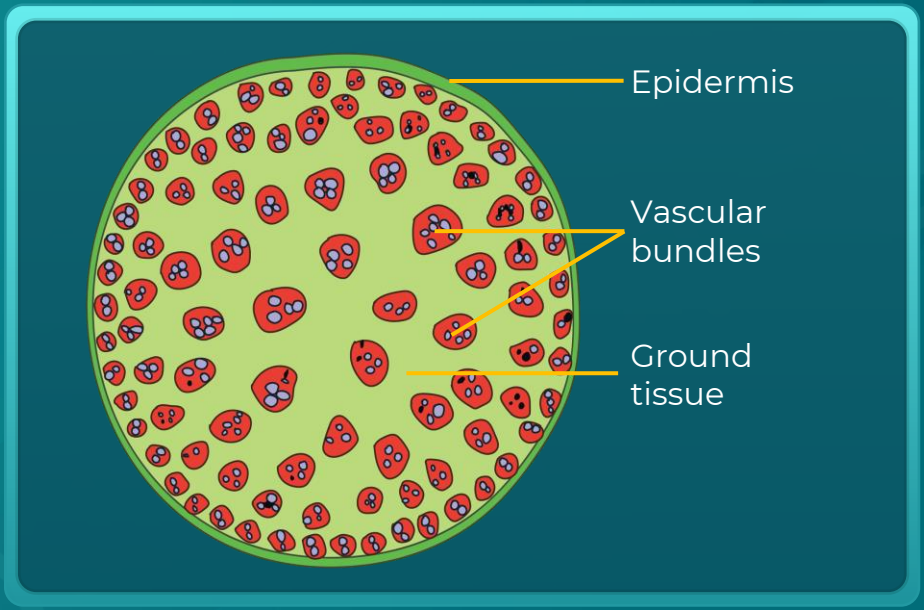
Different Parts of Monocot Stem

Epidermal tissue system

- The epidermis is made up of **monolayered**. **parenchymatous cells**.
- The **hypodermis** is made up of **sclerenchyma cells**.

Ground tissue system

- The ground tissue is **large and parenchymatous**.



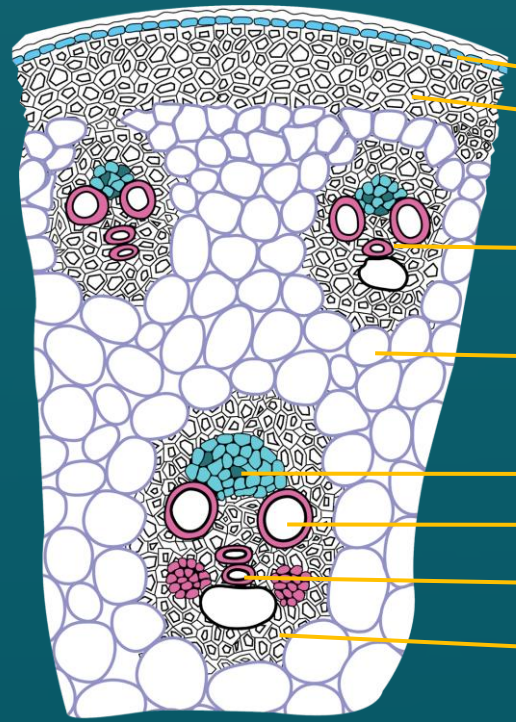
T.S of monocot stem

Different Parts of Monocot Stem

Vascular tissue system

- The vascular bundles are **scattered** in ground tissue.
- **The peripheral vascular bundles** are generally smaller than the centrally located vascular bundles.
- **The pith and pericycle** are absent.
- The vascular bundles are **conjoint** and **closed** due to the absence of cambium.
- **There is no secondary growth.**
- **The sclerenchymatous bundle sheath** surrounds the vascular bundles.
- The phloem parenchyma is **absent**.
- Vascular bundles have water containing cavities.

Anatomy of Monocot Stem



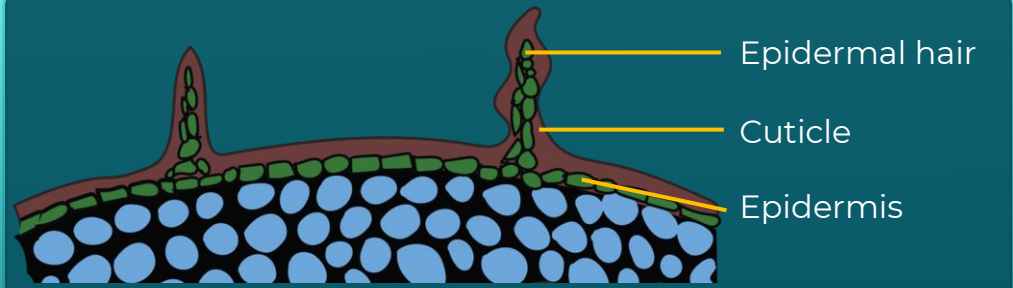
Monocot stem

- **Epidermis**
- **Hypodermis**
- **Scattered vascular bundles in ground tissue**

Different Parts of Dicot Stem

Epidermis

- It is the outermost layer that is protective in function.
- It comprises of
  1. **Trichomes:** They are unbranched multicellular hair that arise from the epidermal layer.
  2. **Stomata:** They are present on leaves, young green stems, and other green parts of the plants. They usually help in gas exchange.
  3. **Cuticle:** It is a thin, waxy layer that protects the plants. It prevents the loss of water from the epidermal cells.



Epidermis (dicot stem)

Different Parts of Dicot Stem

Outer-Hypodermis

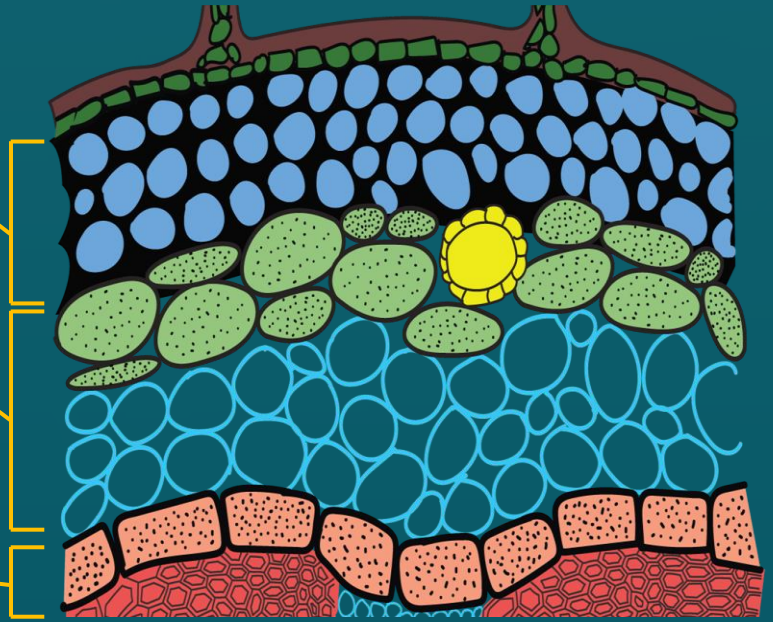
- Has **collenchyma** cells which provide mechanical strength.

Middle-General cortex

- Has **parenchymal cells**.
- The parenchymatous cells are thin-walled and provide cushioning. They are round with intercellular spaces.

Inner-Endodermis

- It is also known as **starch sheath** because the cells store starch.

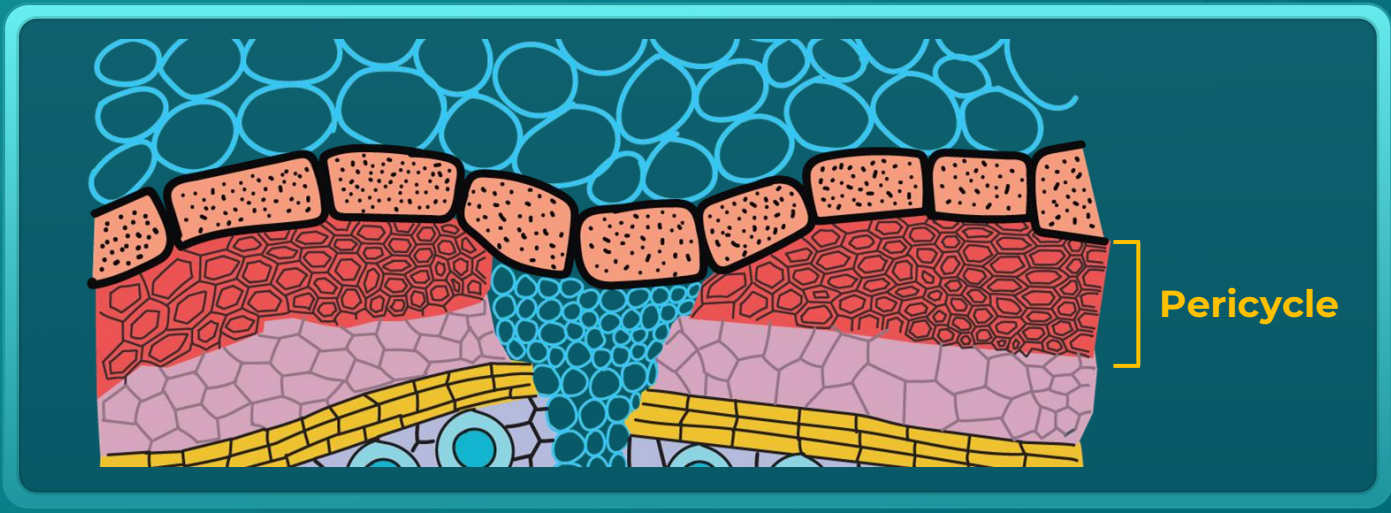


Layers of cortex

Different Parts of Dicot Stem

Pericycle

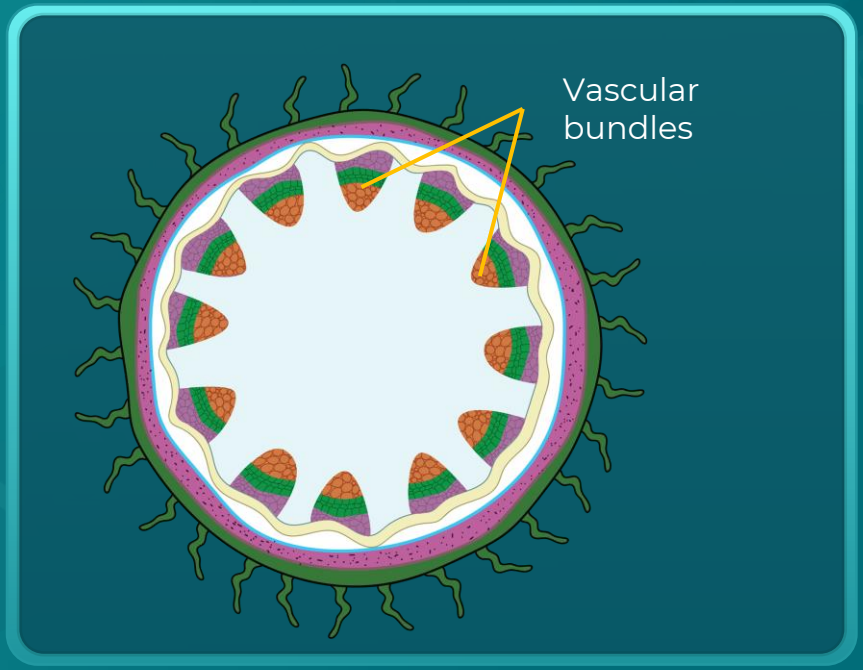
- Present below the starch sheath (endodermis)
- Made of **sclerenchyma cells**
- Found as **semilunar patches**



Different Parts of Dicot Stem

- They are arranged like a **ring**.
- They are **open**, **conjoint** and **endarch**.
- **Conjoint:** Xylem and phloem are arranged in the **same radius.**
- **Open: Cambium is present** between the xylem and phloem.
- **Endarch:** Protoxylem lies towards the centre or the pith, and the metaxylem lies towards the periphery of the stem.
- Parenchymal cells between the vascular bundles are called **medullary rays**.

Vascular bundles



T.S of dicot stem

Secondary Growth

Promeristems
During embryonic growth, the promeristems drive the growth.

Embryonic growth

Primary meristems
As seeds germinate, primary meristem divides and plant grows to form primary tissues.

Primary growth

Primary tissue
Apical meristems form shoots and roots. The tissues formed are primary tissues.
E.g. Primary vascular bundles.

Secondary meristems
Meristems that take part in secondary growth.

Secondary growth
It drives the increase in girth of the stem/root with help of the secondary lateral meristems. It is only seen in dicots.

Secondary tissue
E.g. Secondary xylem and phloem.

Secondary Growth

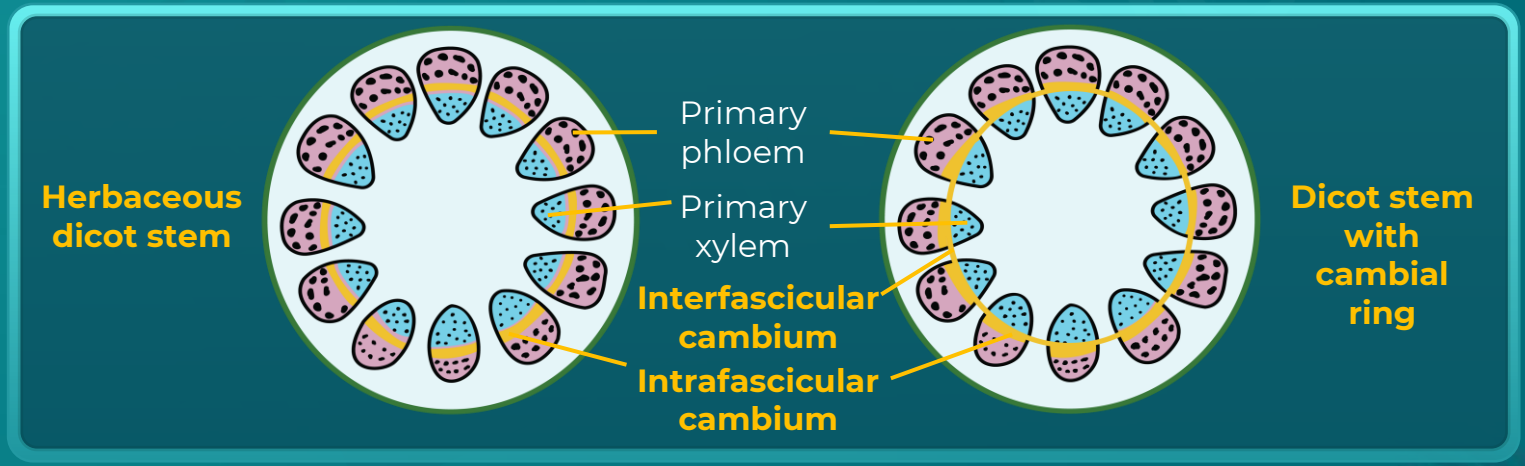
Vascular cambium

Intrafascicular cambium

- **The patchy** or non-continuous **cambium** between **primary xylem** and **primary phloem** is **known as the intrafascicular cambium**.

Interfascicular cambium

- The cells of medullary rays, adjoining these intrafascicular cambium, become meristematic and form the **interfascicular cambium**.



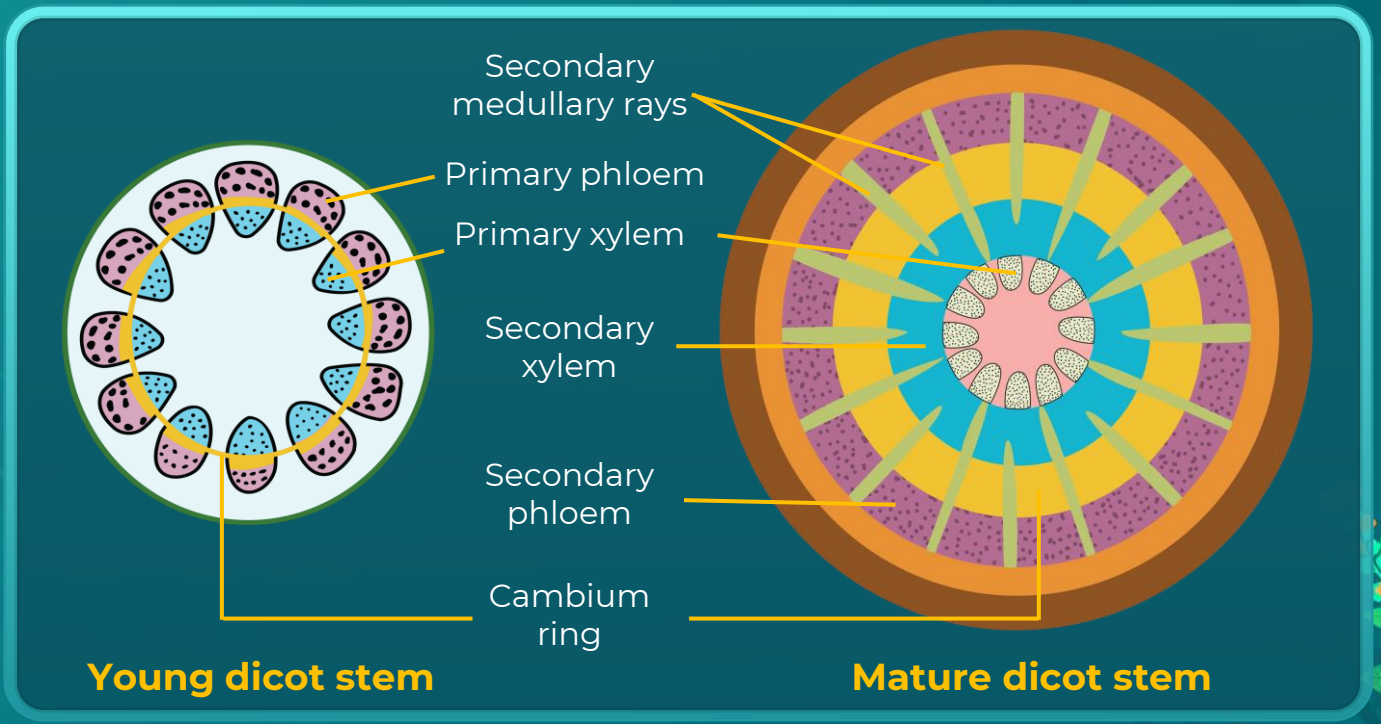
Secondary Growth

Cambial ring

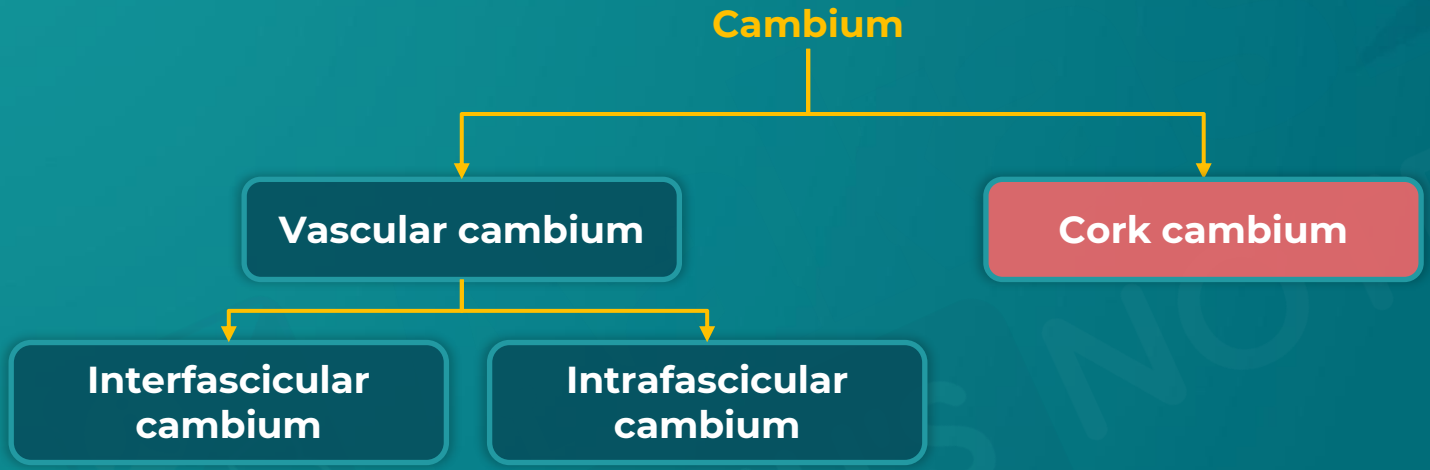
- The **interfascicular cambium** and the **intrafascicular cambium** together form the **cambial ring**.
- The cambial ring becomes active and cuts off cells on both the sides.
- On the **outer side** or towards the periphery, it leads to the formation of **secondary phloem**.
- Towards the **inner side** or (pith) it gives rise to the **secondary xylem**.
- The secondary xylem layers formed inside accumulate inwards. The different primary xylems from different vascular bundles merge together.
- Since the monocots lack cambium unlike dicots, secondary growth that results in increased girth is not observed in them.

Secondary Growth

The cambium forms a narrow band of parenchyma, which passes through the secondary xylem and the secondary phloem in the radial directions forming the **secondary medullary rays**.



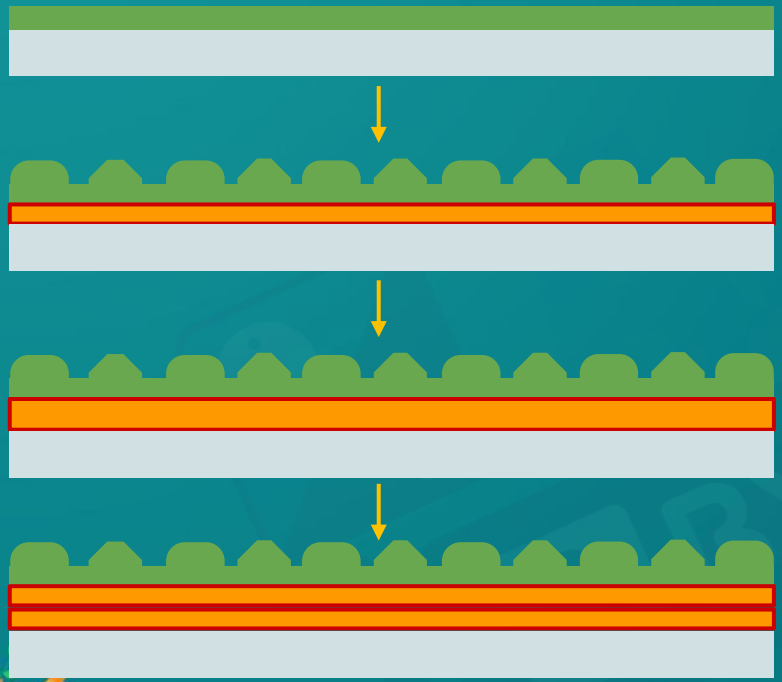
Secondary Growth



- Due to the secondary growth of the vascular cambiums, the epidermis bursts.
- The epidermis is replaced by a **protective layer** known as the **cork**, which is formed by the **cork cambium**.
- **Cork cambiums** are the meristematic tissues formed in the **cortex**.

Secondary Growth

Cork development

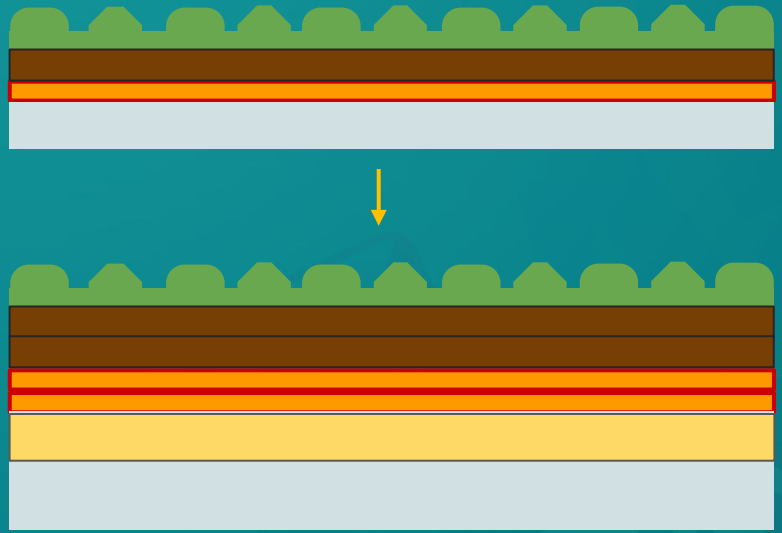


As the secondary growth occurs due to vascular cambial activity, the **epidermis eventually breaks**.

The damaged epidermis is replaced by a new protective layer. A new layer of secondary meristem or cambium called **cork cambium** or **phellogen** appears.

The cork cambium expands. Cork cambium cells are **narrow, thin-walled and rectangular**.

Secondary Growth



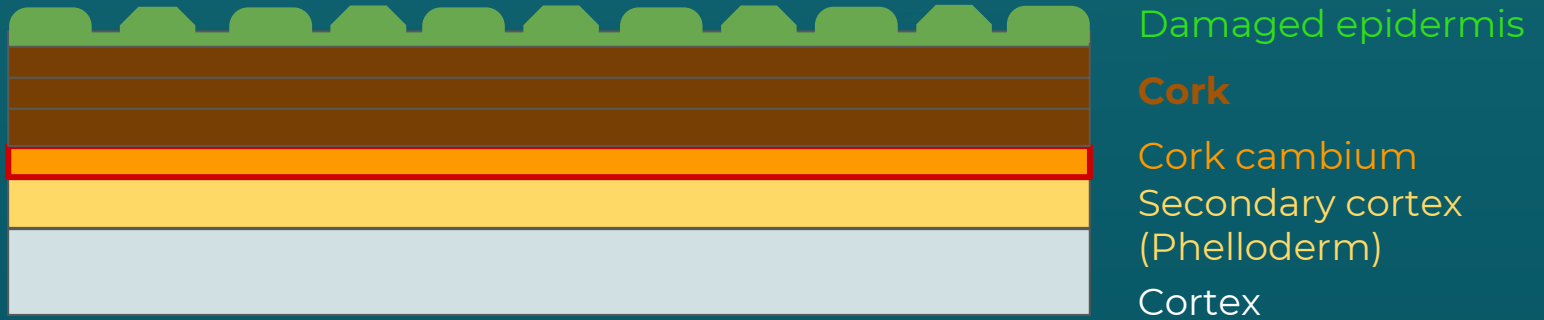
The **cork** layer is formed towards the **periphery**.

Secondary cortex is formed towards the **inner side** of cork cambium.

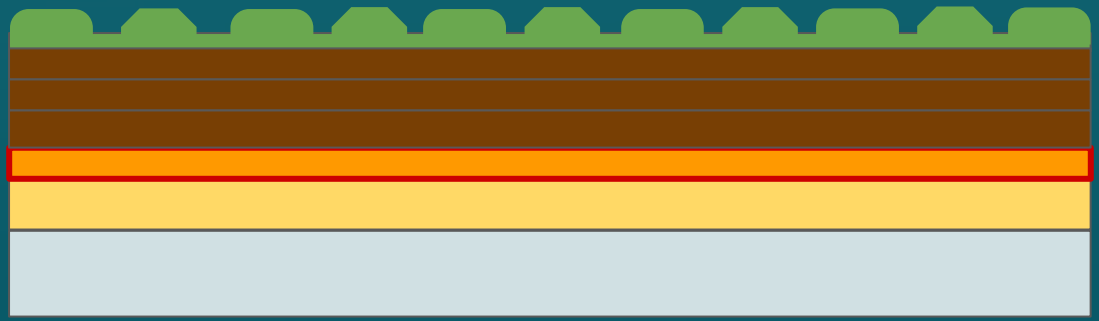
Secondary Growth

Cork development

- The **outer cells** differentiate into the **cork** or the **phellem.**
- The **inner cells** differentiate into the **secondary cortex** or the **phelloderm.**
- **The cork is** impervious to water due to the **suberin** deposition in the cell wall of the cork cells.



Secondary Growth

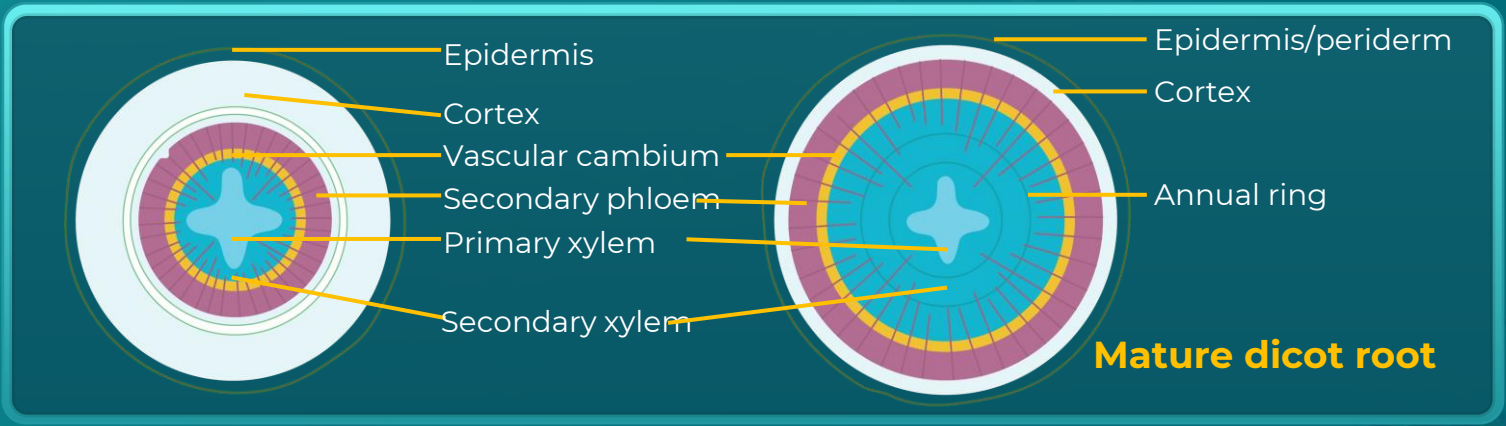


- Together, the three layers (phellem, phellogen and phelloderm) form the **periderm**.

Secondary Growth

Root

- The vascular cambium is formed during secondary growth.
- It starts off as a complete and **continuous wavy ring** that later becomes **circular**.
- The vascular cambium originates from the tissue located just below the phloem bundles, a portion of pericycle tissue, above the protoxylem.
- Further development occurs as in dicot stem.



Bark

- Layers beyond vascular cambium are termed as the **bark**.
- It is a non-technical term.
- It includes the following:
  - Secondary phloem
  - Phelloderm
  - Phellogen
  - Phellem (Cork)

Phelloderm, Phellogen, Phellem (Cork) → Periderm

Secondary phloem, Periderm → Bark

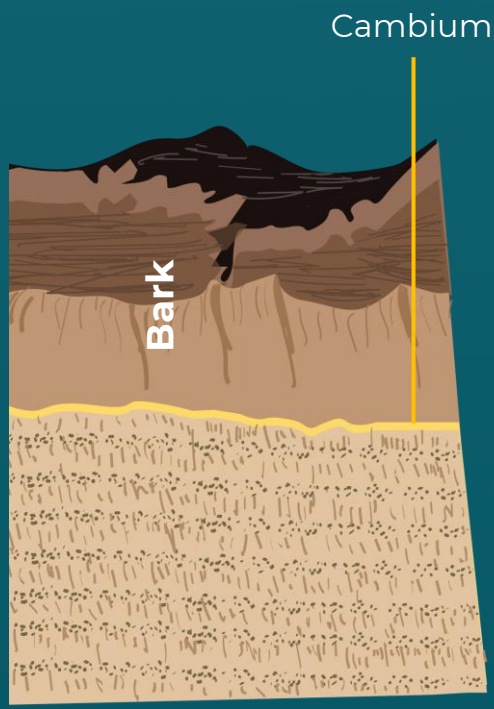
Cork cambial activity → Due to cork cambial activity, pressure builds up on phellem or cork

→ These outer layers die and slough off

Bark

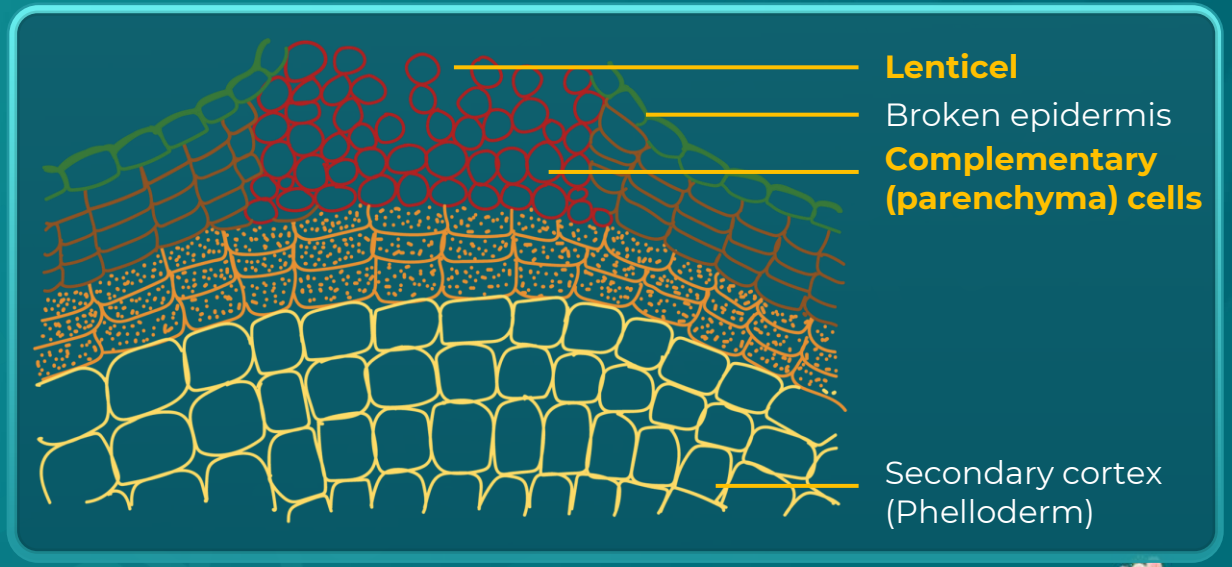
Bark

- **Early or soft bark**
  - Formed **early** in the season
- **Late or hard bark**
  - Formed in the **end** of the season



Lenticels

- The **lens-shaped** openings that are known as **lenticels** are created when the epidermis ruptures.
- They **exchange gases** between the outer atmosphere and the internal tissue.
- They are found as raised circular, oval, or elongated parts on the surface of the bark.
- Phellogen or cork cambium in this region gives rise to **complementary cells** instead of cork or phellem.
- Complementary cells are closely arranged parenchyma cells.



Annual Ring

Dendrochronology

- When cutting a dicot tree, the tree trunk has a characteristic **ring-like pattern**.
- Each ring actually signifies one year of the tree's growth.
- Counting all the rings, one can tell the age of the tree.
- This science is known as **dendrochronology**.

Formation of annual rings

1 **light** band + 1 **dark** band = 1 **annual** ring

- The tree produces an annual ring that represents its growth during the year.
- The light and dark bands are due to the **different seasons**.

Spring Wood & Autumn Wood

Spring wood	Autumn wood
• Also known as the early wood	• Also known as the late wood
• Formed when **nutrients** are **easy to access**	• Develops in autumn when **nutrients** are **scarce in cold**
• Xylary elements grow quickly and are **large in number**	• Fewer xylary elements
• Xylary elements have **wider cavities**	• Xylary elements have **narrow vessels**
• **Cambium is very active**	• **Cambium is less active**

Sapwood & Heartwood

Sapwood	Heartwood
• Sapwood is the **light brown** secondary xylem	• Heartwood is the **dark brown secondary** xylem
• Present in the peripheral region of the secondary xylem	• It gives **mechanical** support and is hard and durable • It has deposits of tannins, resins, oils, gums, aromatic substances, and essential oils • It is resistant to microorganisms and insects
• **Living** tissues conduct **water** and **minerals**	• It is a **dead** tissue that has highly **lignified** walls • They **do not conduct water**
• Present in young trees/plants	• Present in older trees

Summary

Cells (basic building blocks of all living organisms)

Tissues (groups of cells)

Meristematic tissue (actively dividing cells)

Permanent tissue (Do not actively divide)

Promeristem (young meristematic cells in early embryonic stage)

Primary meristems (responsible for primary growth)

Secondary meristems (responsible for girth increment)

Intercalary meristems (responsible for growth of internodes)

Apical Meristems (found at the root and shoot tips)

Lateral Meristems (add girth to stem)

Interfascicular cambium (formed between two vascular bundles)

Intrafascicular cambium (present between xylem and phloem of the vascular bundle)

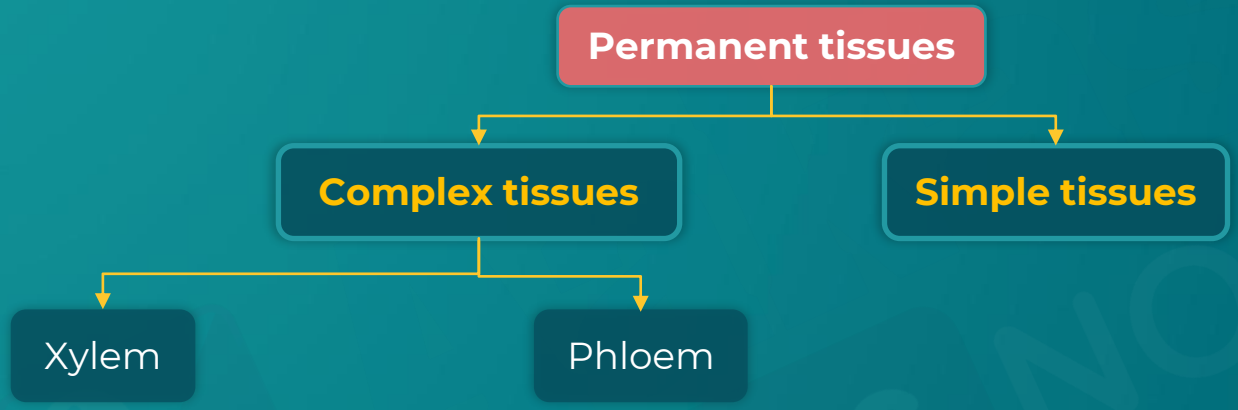
Cork cambium (produces secondary tissue that replaces the epidermis in roots and stems)

Summary

Cells (basic building blocks of all living organisms)

- **Tissues (groups of cells)**
  - **Meristematic tissue** (actively dividing cells)
  - **Permanent tissue** (Do not divide actively)
    - **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 provide mechanical support)
      - **Sclerenchyma** (dead mechanical tissue)
        - **Fibres** (elongated cells that provide support to plants)
        - **Sclereids** (spherical, oval or cylindrical, highly thickened dead cells)
    - **Complex** (made up of different types of cells)
      - **Xylem**
      - **Phloem**

Summary



The xylem transports water **unidirectionally**.

The phloem transports food material **bidirectionally.**

Summary

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 elongated tube-like cells with tapering ends. They are main water transporting elements.
	Vessels	They are long cylindrical, lignified dead cells.
	Xylem parenchyma	They are living cells with a cell wall made of cellulose.
	Xylem fibres	They provide strength to tracheids and vessels.
Development of xylem	**Protoxylem**	It is the first formed xylem consisting of small cells.
	Metaxylem	It is formed after the protoxylem and has a larger lumen.

Summary

Types of phloem	Primary	It develops during the **primary growth**.
	Secondary	It develops during the **secondary growth**.
Elements of phloem	**Sieve tubes**	They are long longitudinal cells associated with companion cells.
	Companion cell	It has a large nucleus and is present in angiosperms.
	Phloem parenchyma	It is an elongated, taper ended cell that stores food in angiosperms.
	Phloem fibres/Bast fibres	They are unbranched, needle-like cells with thick cell walls.

Summary

Tissue systems

Ground tissue system

It includes **all tissues** except epidermis and vascular bundles.

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**.

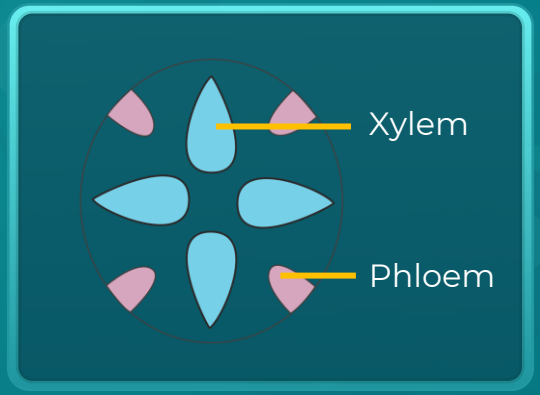
Summary

Vascular Bundles

Radial

Xylem and phloem alternate radially

Found in roots



Conjoint

Xylem and phloem are joined together

Found in stem and leaf

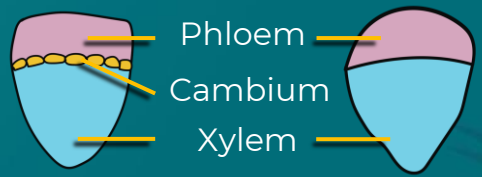
Phloem on the outer side

Open

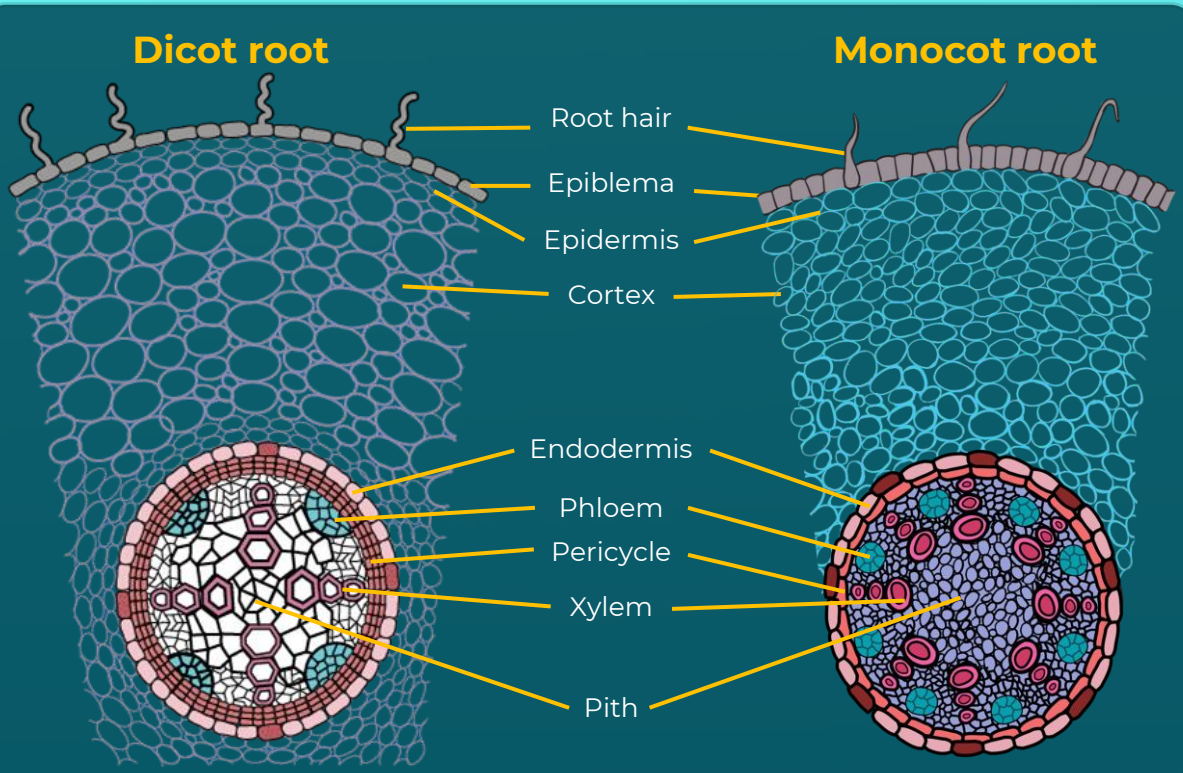
Cambium is present between xylem and phloem

Closed

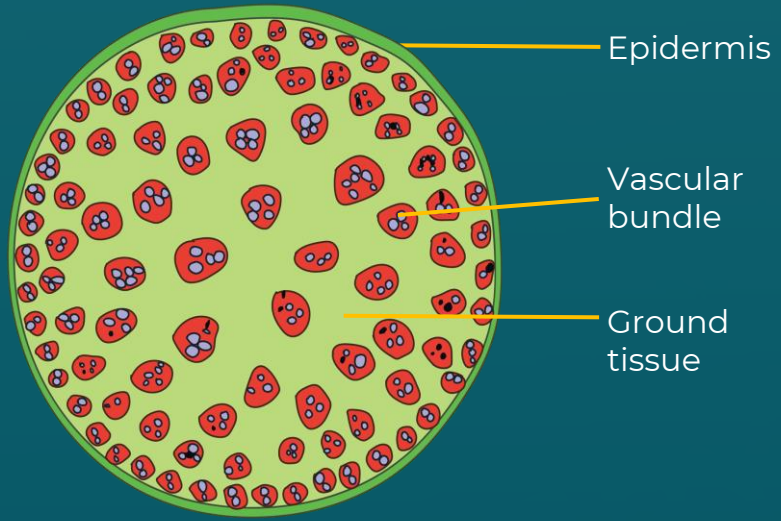
No cambium between xylem and phloem



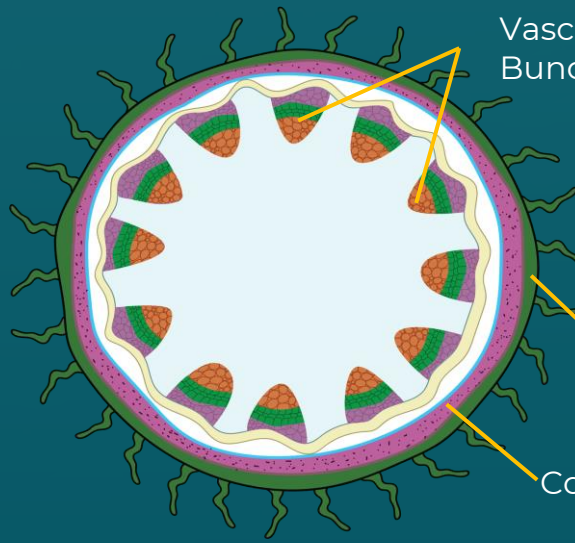
Summary



Summary

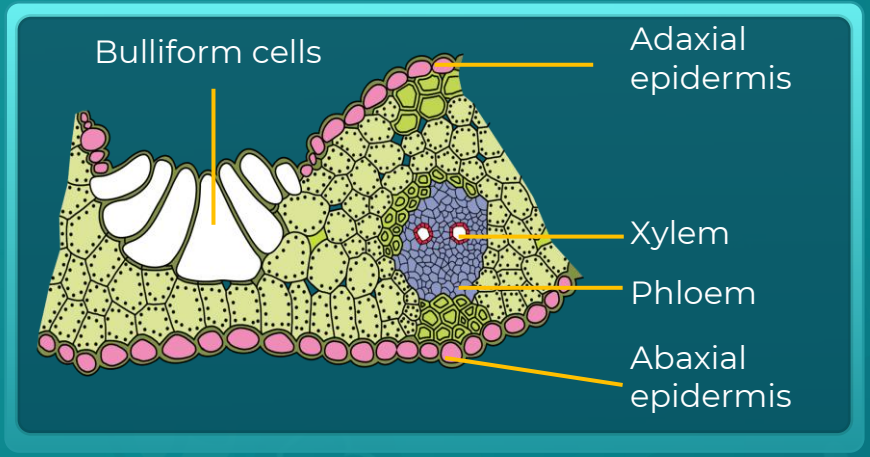


T.S of monocot stem

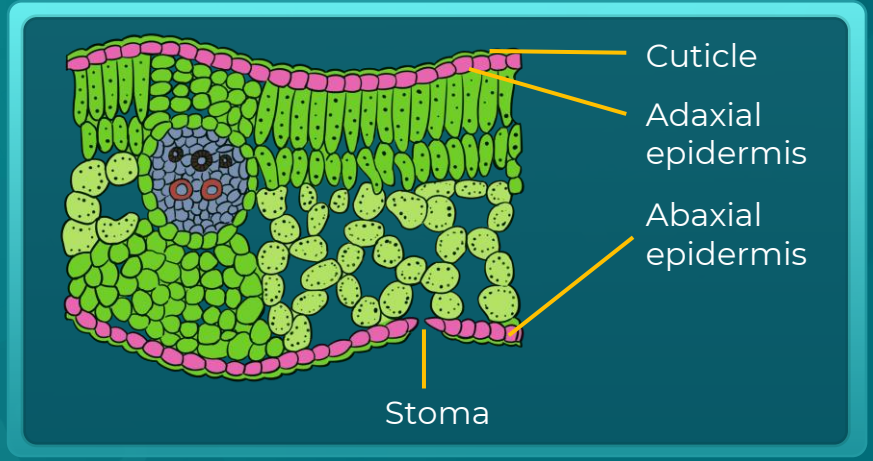


T.S of dicot stem

Summary



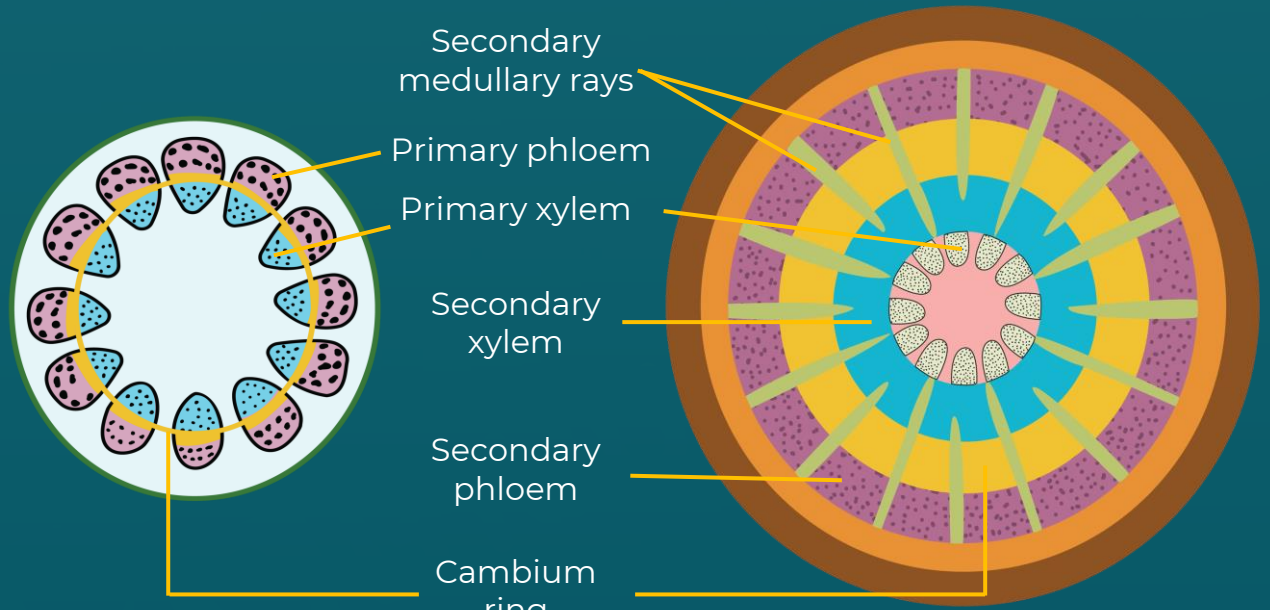
T.S of monocot leaf showing bulliform cells



T.S of dicot leaf

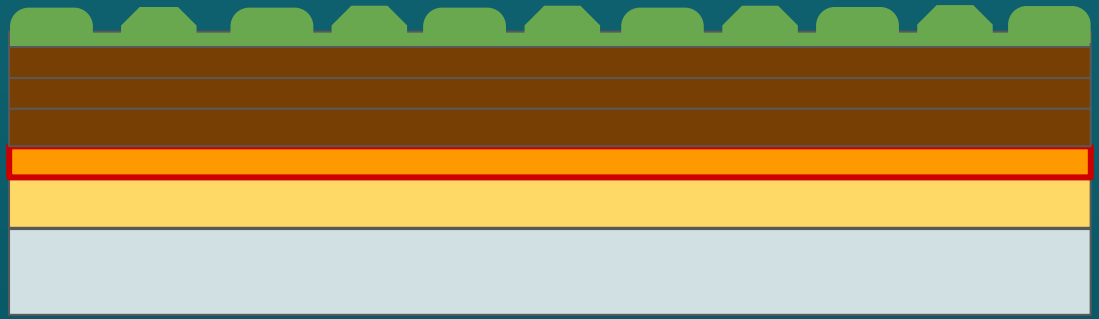
Summary

Intrastelar secondary growth in dicot stem



Summary

Extrastelar secondary growth in dicot stem



Mature dicot stem

The three layers (phellem, phellogen and phelloderm) form the **periderm**.