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02 ANATOMY OF FLOWERING PLANTS

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ANATOMY OF FLOWERING PLANTS

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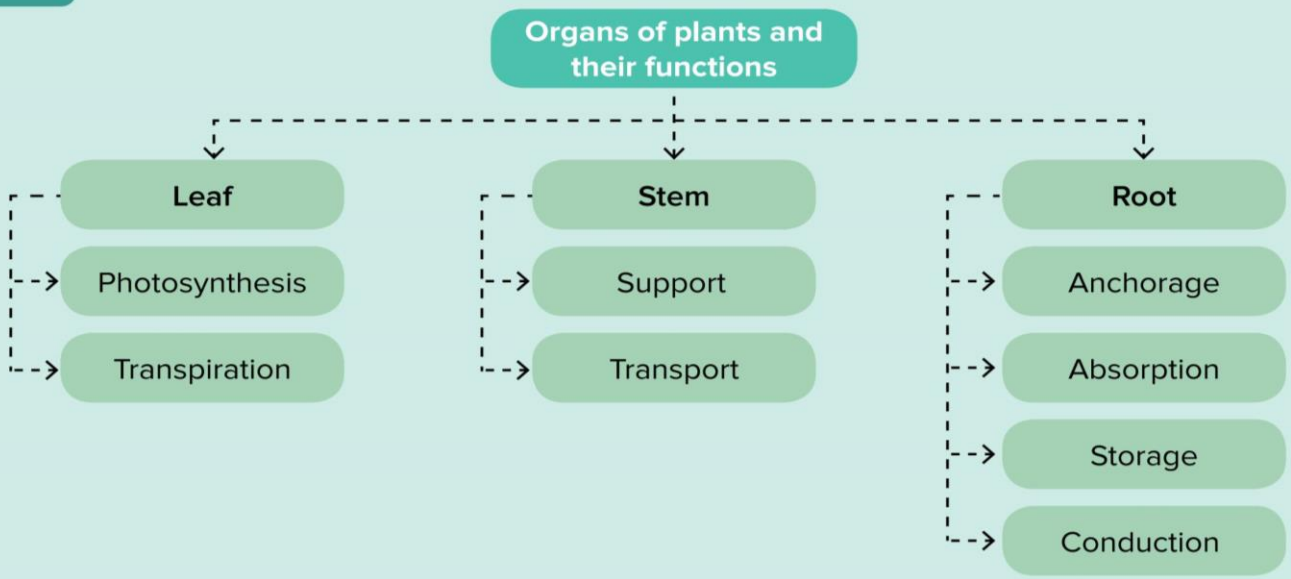
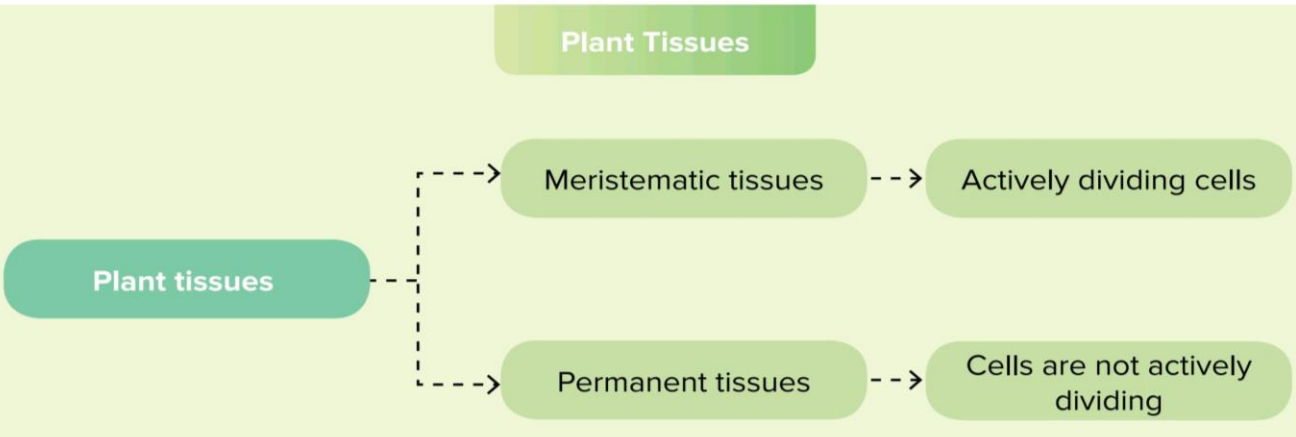
13 ANATOMY OF - DICOT AND MONOCOT ROOT, DICOT AND MONOCOT LEAF, MONOCOT STEM

Key Takeaways

- Anatomy of:
  - Dicot root
  - Monocot root
  - Dicot leaf
  - Monocot leaf
  - Monocot stem

Prerequisites





Types of tissue systems

Epidermal tissue

Epidermal tissue is the outermost layer of the plant body.

Ground tissue

Tissues that are neither dermal nor vascular are termed as ground tissue. They consist of simple tissues like parenchyma, collenchyma and sclerenchyma.

Vascular tissue

Vascular tissues consist of two conducting tissues - **xylem and phloem**.

Anatomy

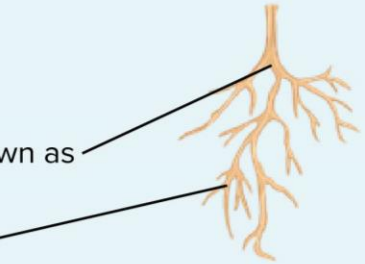
- The study of internal structure is known as **anatomy**.
- Anatomy is a Greek word that means 'cutting up'.
- Plant **anatomy or phytotomy** is a branch of science that deals with study of plant tissues, tissue systems and internal structure of plant organs. This study helps us to have a better understanding of plants.
- **Nehemiah Grew** is considered as the **Father of Plant Anatomy**. He and **Marcello Malpighi** are prominent scientists in the field of plant anatomy.
- Grew wrote a book on plant anatomy and described the internal structure of the plant organs (root, stems and leaves).
- **Anatomical sections:**
  - A **transverse section** is defined as a cross section that is obtained by slicing the body or any part of the body structure along a horizontal plane or along a plane that intersects the longitudinal axis at a right angle.
  - A **longitudinal section** is defined as a section that is obtained by slicing the body or any part of the body structure in the direction parallel to the length of structure.

Transverse section

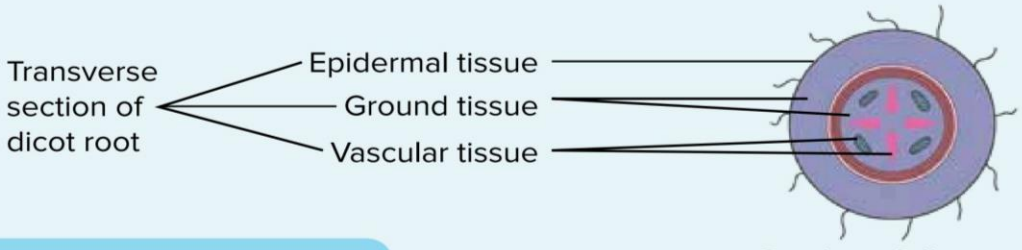
Longitudinal section

Dicot Root

- **Dicots 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**.



Taproot



Section of dicot root

Epidermal tissue system

(a) Epidermis (also known as epibelma or rhizodermis)

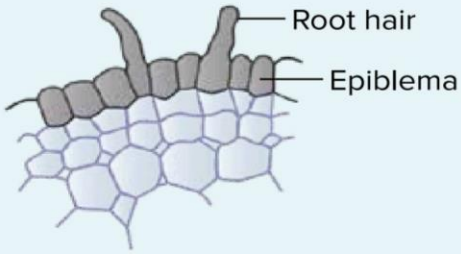
- It is the **outermost**, single-layered structure, consisting of compactly arranged **parenchymatous** cells. It is **protective** in function
- Some epidermal cells protrude to form **root hairs**.
- **The root hairs** help to increase the surface of exchange between the root system and soil and facilitate the uptake of water and nutrients.

(b) Stomata

- Stomata is **absent** in the roots as they are under the ground.

(c) Cuticle

- It is a water-impervious protective layer covering the epidermal cells of leaves and other parts. It helps in limiting the water loss.
- Cuticle is **absent** in the root to facilitate the entry of water into the single and multi-layered cells.



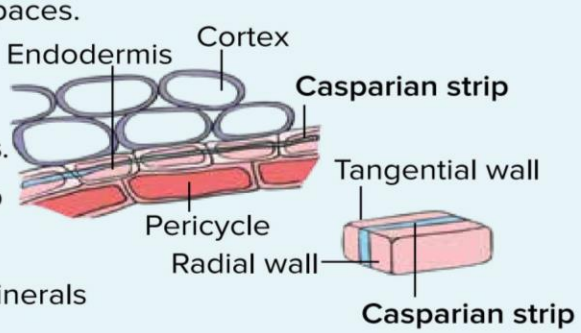
Ground tissue system

(a) Cortex

- It is a **multilayered** structure, made up of a mass of thin-walled **parenchymatous cells** with intercellular spaces between them.
- This system is responsible for the **transport of water and salts** from the root hairs to the centre of the roots.
- The cortical cells have **no chloroplast** but may **contain leucoplasts** for the storage of starch grains.
- The innermost layer of the cortex consists of a single layer of barrel-shaped cells known as the **endodermis**.
- The cells of endodermis do not have any intercellular spaces.

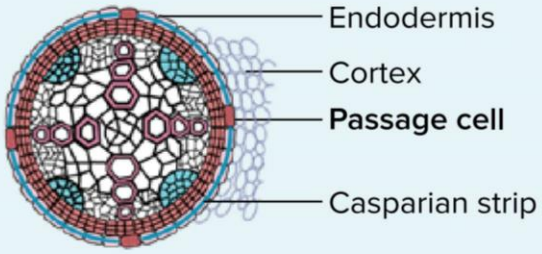
(b) Casparian strips

- The tangential and radial walls of endodermal cells have **suberin deposition** in the form of **casparian strips**.
- Suberin is a waxy deposit and hence the casparian strip is **impermeable to water**.
- It allows the plant to control the amount of water and minerals it absorbs from the soil.



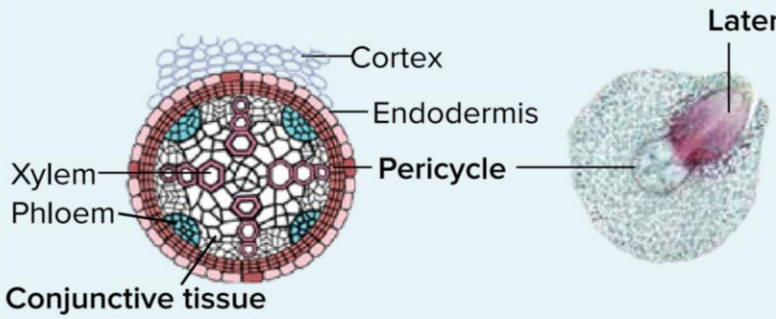
(c) Passage cells

- Some endodermal cells have **no casparian strips** (no suberin deposition) and are known as **passage cells** or **transfusion cells**.
- These cells allow radial diffusion of water and minerals through the endodermis.

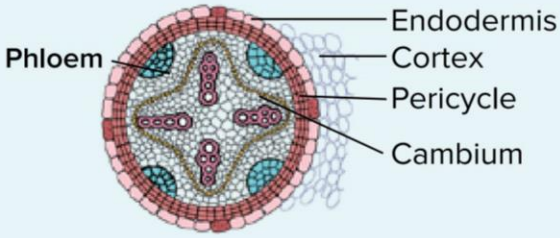


(d) Pericycle and Conjunctive tissue

- A few layers of thick-walled parenchymatous cells known as pericycle 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**.



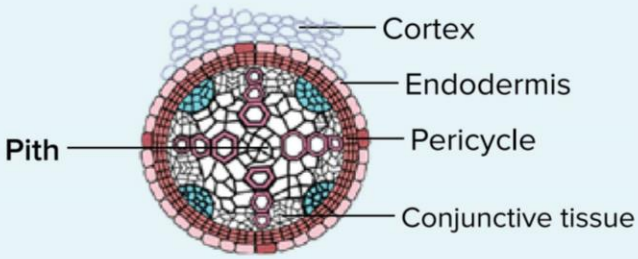
Location of pericycle and conjunctive tissue



Vascular cambium formed from the pericycle

(e) Pith

- It is small, inconspicuous and made up of parenchymatous cells.
- It is located at the centre of the root.
- It helps in storage and transport of nutrients.



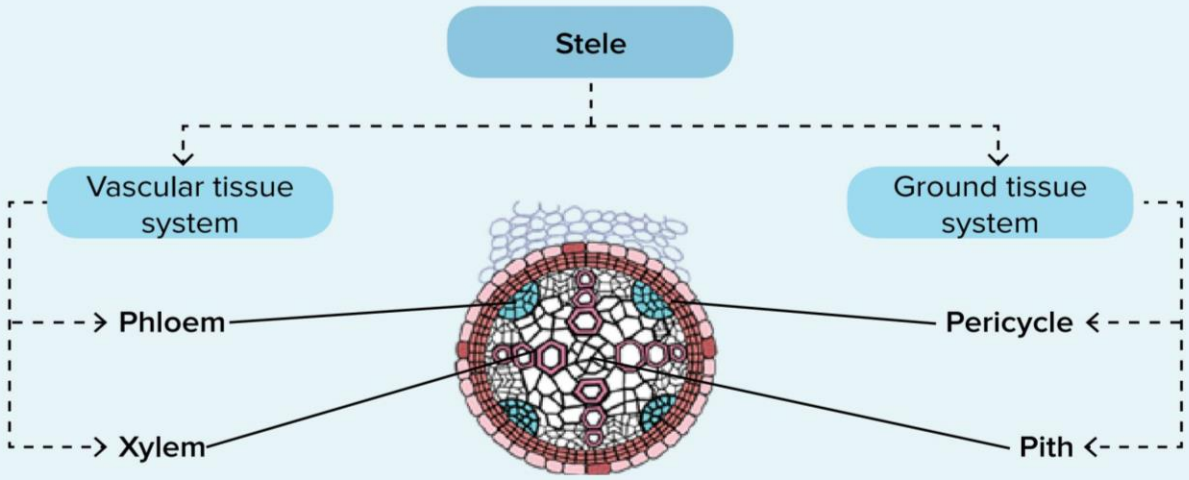
Location of pith

Vascular tissue system

- It consists of **xylem** and **phloem**.
- Characteristics:
  - **Radial**: Xylem and phloem arranged in an alternate manner along different radii.
  - **Open**: Presence of cambium.
  - **Diarch** to **tetrarch**: Presence of two to four xylem and phloem bundles.
  - **Xylem is exarch**: Protoxylem towards periphery, metaxylem towards centre.

(a) Stele

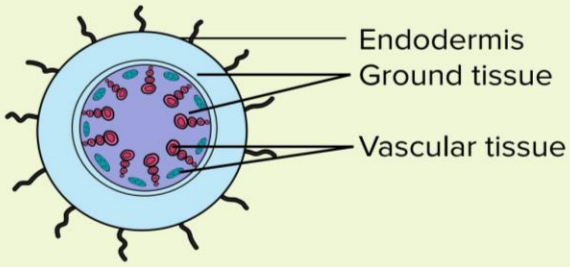
- It constitutes parts of the ground tissue and the vascular tissue systems.
- It is covered by the endodermis.



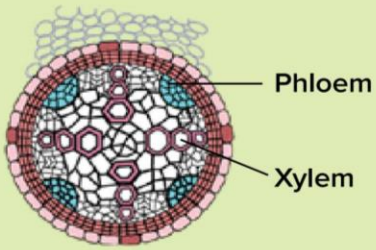
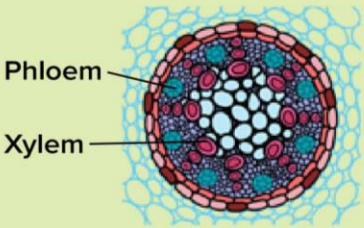
Monocot Root

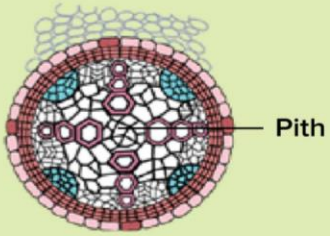
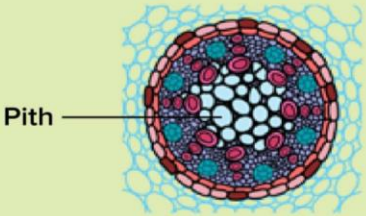
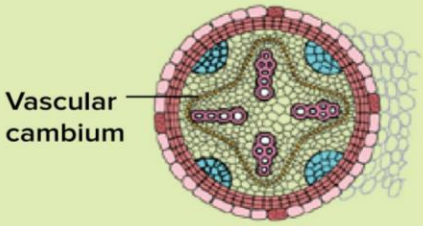
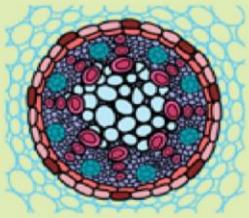
- They have a **fibrous root system**.

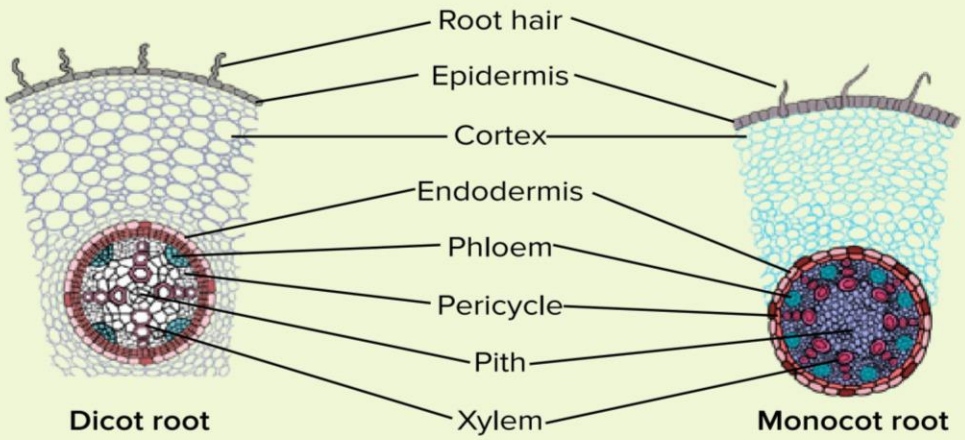
- The monocot roots and dicot roots are similar in their internal structure except for few differences.



Differences between monocot and dicot root

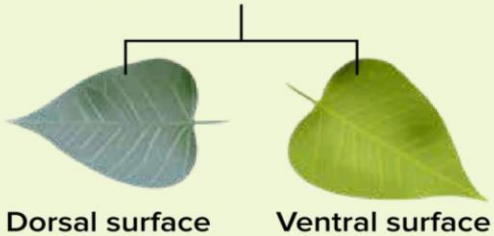
Features	Dicot root	Monocot root
Xylem and phloem	**Diarch to tetrarch:** There are two to four xylem and phloem bundles. 	**Polyarch:** There are more than six bundles of xylem and phloem. 

Pith	They are **small** or **inconspicuous**.  	They are **large** and **well developed**. 
Secondary growth	In the pericycle of dicot roots, **vascular cambium is seen** at a later part of plant life that helps in the secondary growth.  	In the pericycle of monocot roots, there is **no vascular cambium**. Therefore, there is **no secondary development**. 

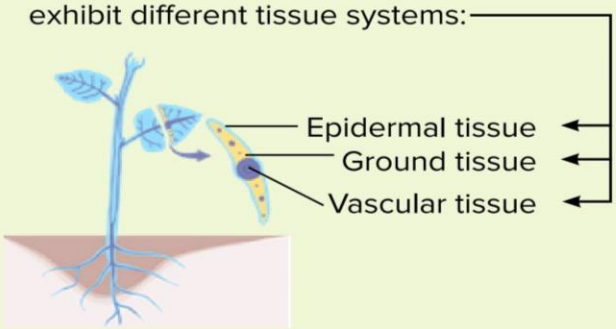


Dicot Leaf

- It has **reticulate venation**.
- It has two surfaces:

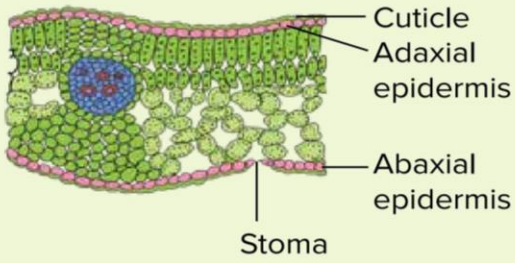


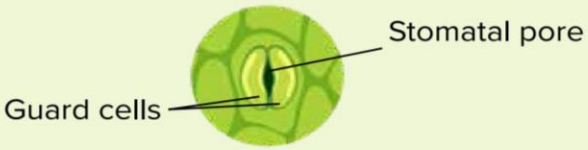
- The transverse sections of the leaf exhibit different tissue systems:



Epidermal tissue system

- Epidermis:
  - On the upper surface - Adaxial epidermis
  - On the lower surface - Abaxial epidermis
- A conspicuous **cuticle** is present on the adaxial and abaxial 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**.
  - **The guard cells** in dicot leaves are bean-shaped.



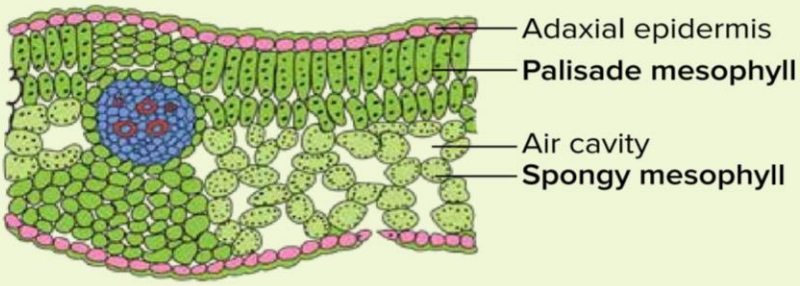


Ground tissue system

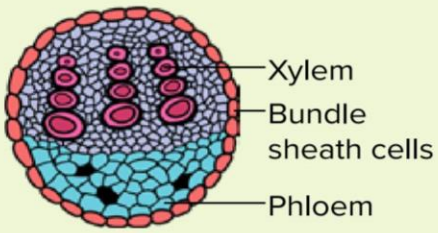
- The tissue between the upper and the lower epidermis is known as the **mesophyll**.
- Parenchymatous cells of the mesophyll that contain chloroplasts and perform photosynthesis are known as **chlorenchyma**.

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.



Vascular tissue system



- **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.

Monocot Leaf

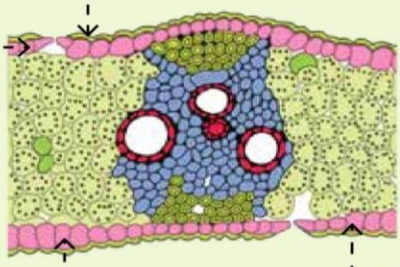
- It has **parallel venation**.

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

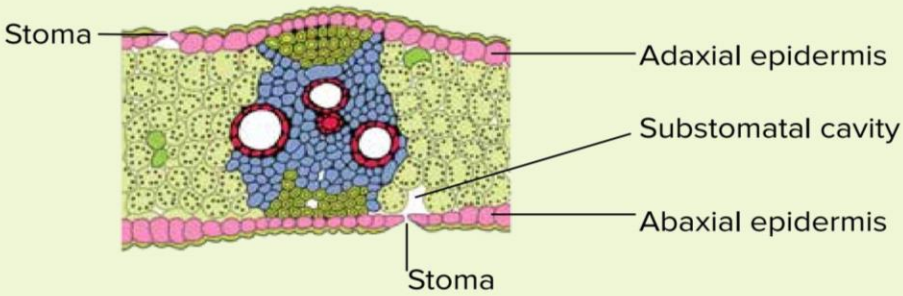
Epidermal tissue system

Epidermis

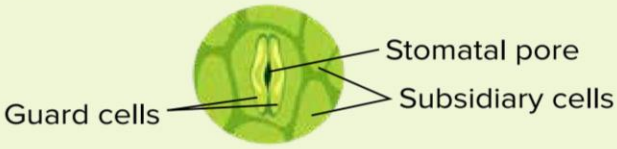
- **Cuticle** (conspicuous and present on both surfaces)
- **Adaxial epidermis**
- **Abaxial epidermis**



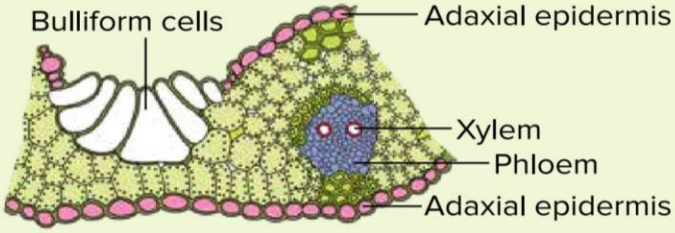
- Equal number of stomata is present on the adaxial and abaxial epidermis of the leaf, hence it is known as an **amphistomatic leaf**.



- **The guard cells** are dumbbell-shaped.

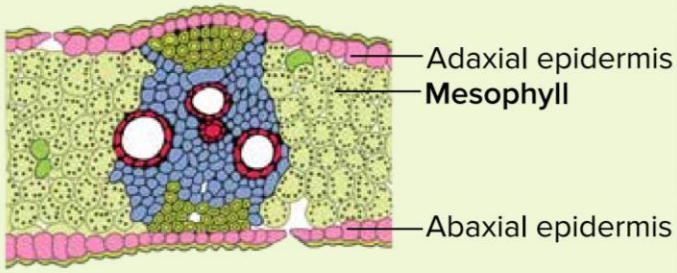


- **The bulliform cells** are large, empty and colourless cells present in adaxial epidermis that absorb water and become turgid when the leaf surface is exposed.
  - They help in rolling and unrolling of leaves due to change/variations in turgidity.



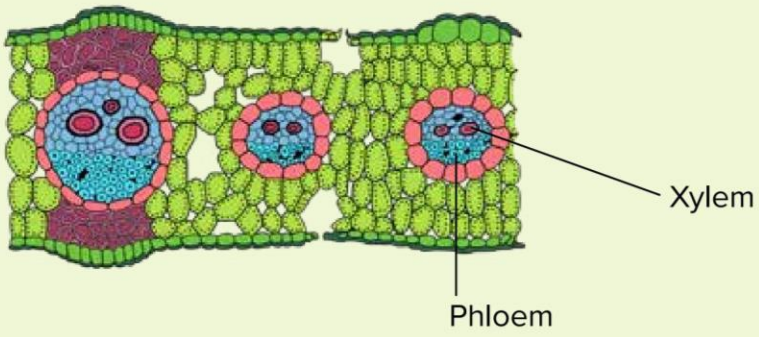
Ground tissue system

- The **mesophyll** is present between upper and lower epidermis.
- The mesophyll is **not differentiated** into palisade and spongy parenchyma.
- They consist of **chlorenchyma cells**.

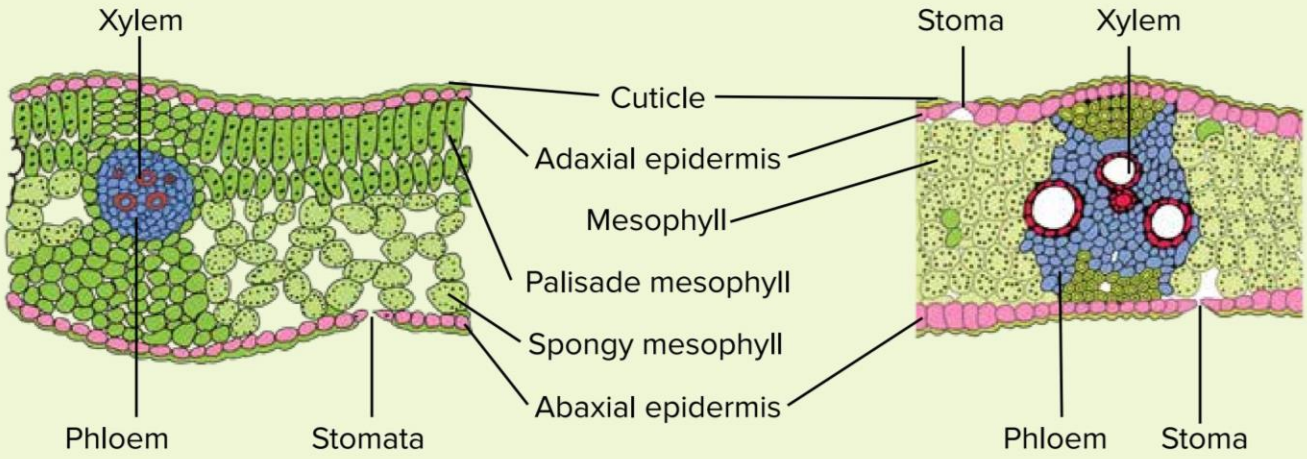


Vascular tissue system

- **Vascular bundles**
  - The vascular tissues are present in **midrib** and **veins**.
  - The size of vascular bundles are nearly similar except in main veins.
  - The vascular bundles are surrounded by **bundle sheath cells**.
  - The **xylem is on the upper side** and the **phloem is on the lower side**.



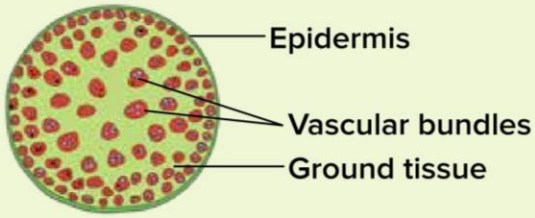
Anatomy of monocot and dicot leaf



Dicot leaf **Monocot leaf**

Monocot Stem

- The monocot consists of the following tissue systems:



Transverse section of monocot stem

Epidermal tissue system

- The epidermis is made up of **monolayered parenchymatous cells**.
- It is covered by **cuticles**.
- A layer of sclerenchymatous cells lies below the epidermis that is known as the hypodermis.

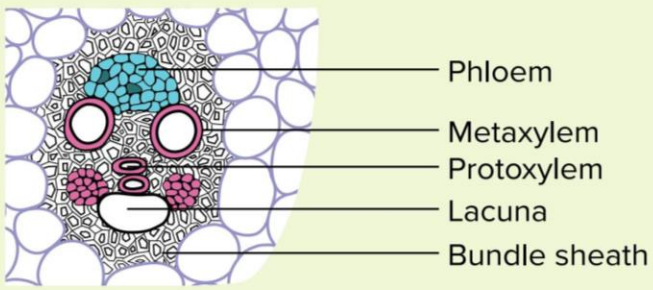
Ground tissue system

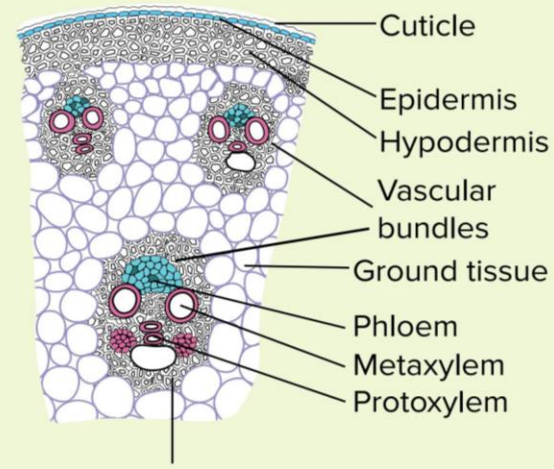
- The ground tissue is **large and parenchymatous**.

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 **endarch** and **closed** due to the absence of cambium.
- **There is no secondary growth**.
- **It is conjoint** (the xylem and phloem are on the same radius.)
- **The sclerenchymatous bundle sheath** surrounds the vascular bundles.

- The **phloem** parenchyma is **absent**.
- The xylem vessels are arranged in **V or Y shape**.
- **The protoxylem** disintegrates forming **protoxylem lacuna** that transforms into water filled cavities. Hence, the vascular bundle appears skull-shaped.





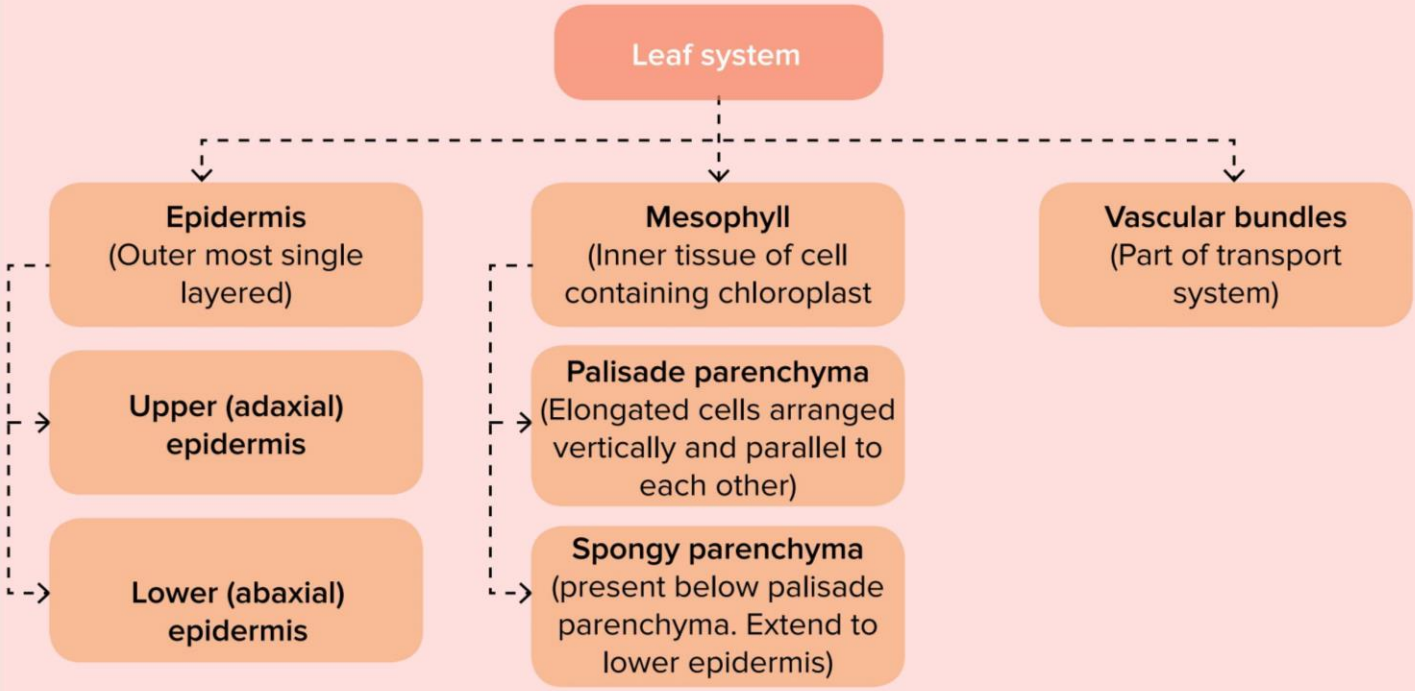
Anatomy of monocot stem

Summary Sheet

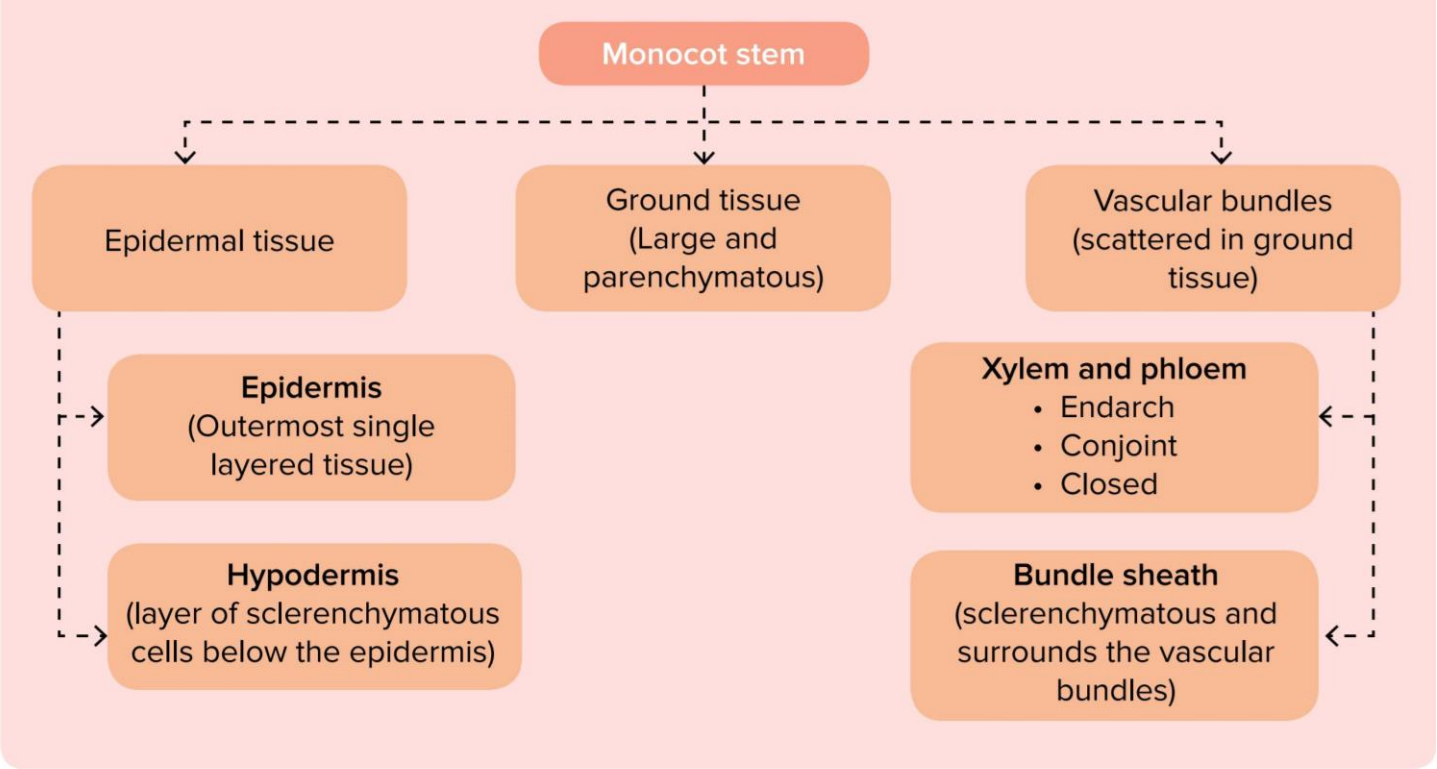
Root system

- **Epidermis** (Outermost single layered)
- **Cortex** (Outer layer lying below epidermis)
  - **General cortex**
  - **Endodermis** (Inner layer of cells in cortex)
- **Stele** (Central part of root or stem)
  - **Pericycle** (Few layer of thick walled parenchymatous cells)
  - **Vascular bundles** (Part of transport system)
  - **Pith** (Helps to store and transport nutrients)

Features	Dicot root	Monocot root
Xylem and phloem	Diarch to tetrarch	Polyarch
Pith	Small and inconspicuous	Large and well developed
Secondary growth	Vascular cambium seen at later part of plant life	No vascular cambium hence, no secondary growth
Passage cells	Present	Present



Features	Dicot leaf	Monocot leaf
Stomata	More on lower surface	Equally distributed on both surfaces
Shape of guard cells	Bean-shaped	Dumbbell-shaped
Mesophyll	Differentiated into palisade and spongy parenchyma	Undifferentiated
Size of vascular bundles	Size depends on the size of veins, hence, it is dissimilar	Size is similar due to similar size of veins in parallel venation


Monocot stem
Epidermal tissue
Ground tissue (Large and parenchymatous)
Vascular bundles (scattered in ground tissue)
Epidermis (Outermost single layered tissue)
Hypodermis (layer of sclerenchymatous cells below the epidermis)
Xylem and phloem
• Endarch
• Conjoint
• Closed
Bundle sheath (sclerenchymatous and surrounds the vascular bundles)

C4 ANATOMY OF DICOT STEM, DIFFERENCE BETWEEN DICOT AND MONOCOT STEM, SECONDARY GROWTH

Key Takeaways

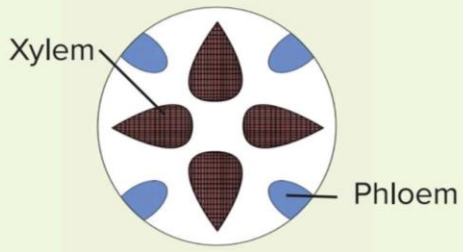
- Anatomy of dicot stem
- Monocot stem vs dicot stem
- Secondary growth in dicot stem
- Bark and its types
- Lenticels
- Secondary growth in dicot root
- Annual rings: Spring wood and autumn wood
- Heartwood and sapwood

Prerequisites

Vascular bundle

Radial

- Xylem and phloem alternate radially
- Found in stems and leaves



Conjoint

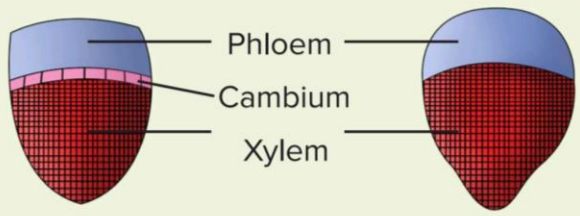
- Xylem and phloem are joined together
- Found in roots
- Phloem on the outer side

Open

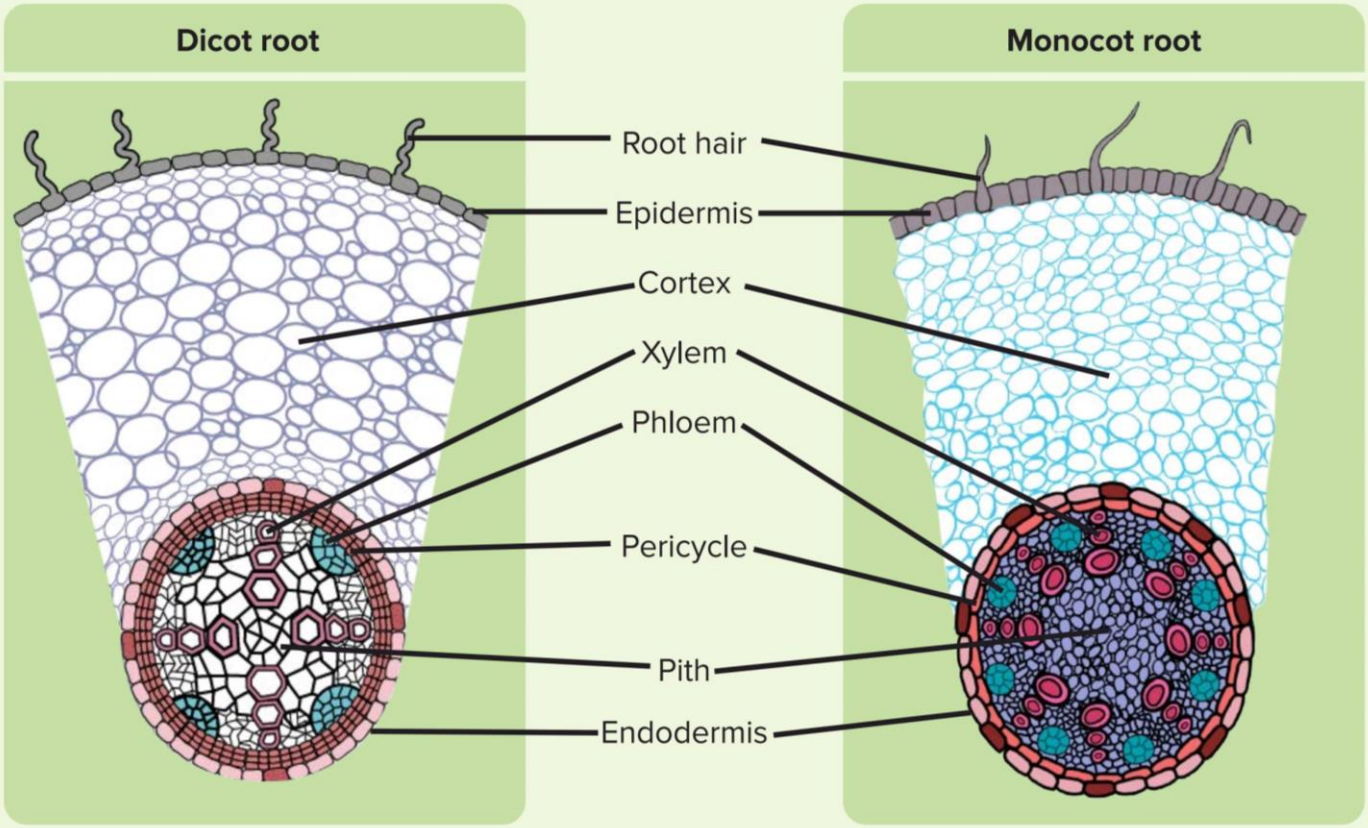
Cambium between xylem and phloem

Closed

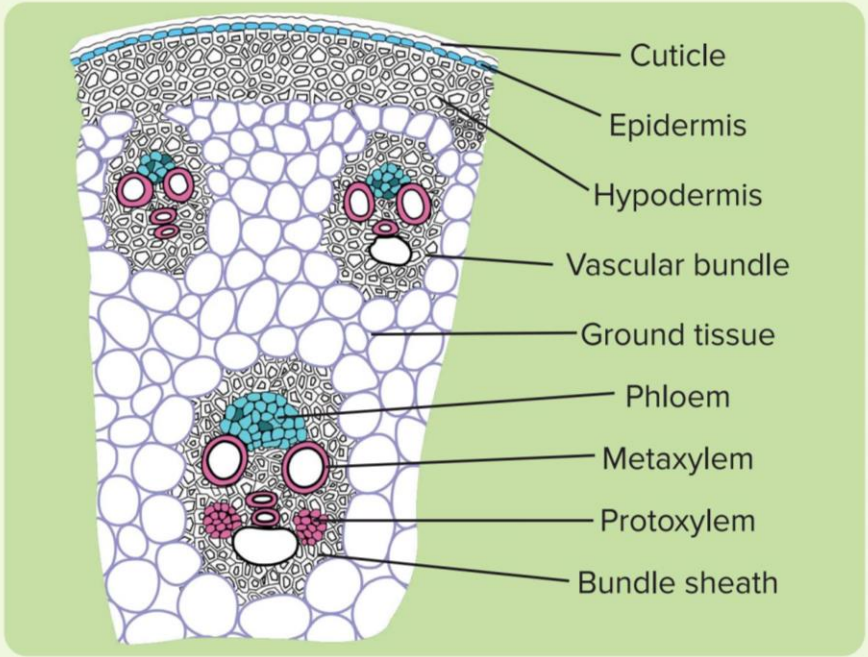
No cambium between xylem and phloem



Dicot root and monocot root

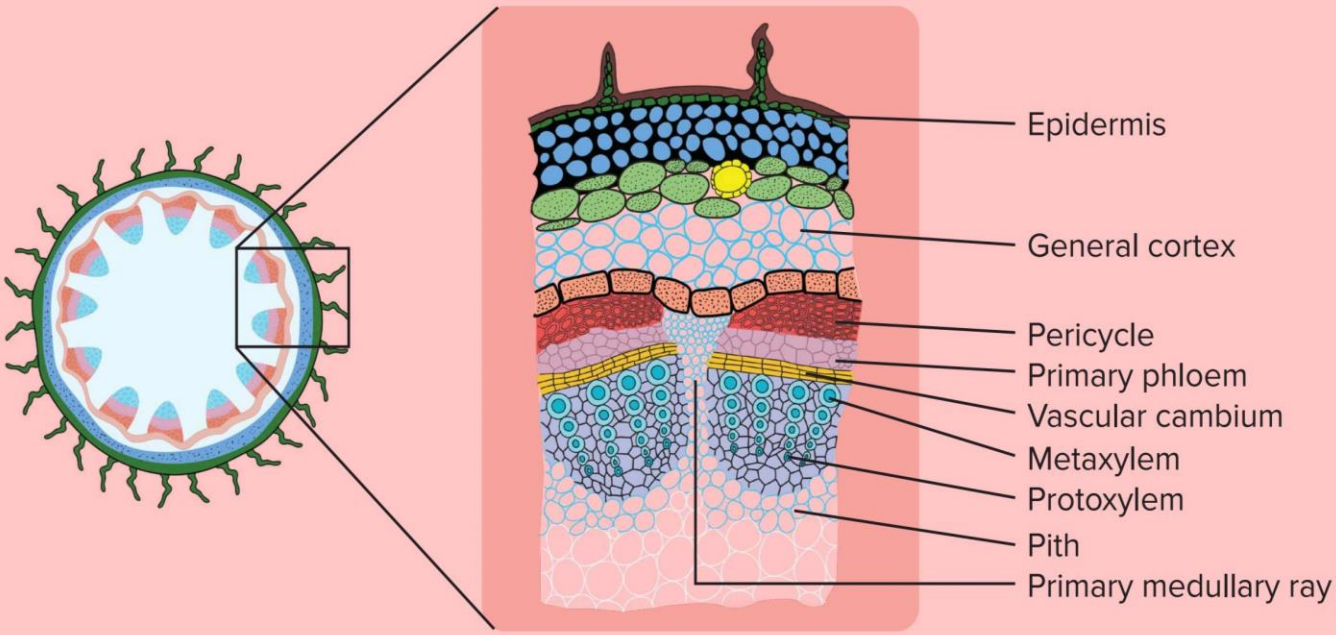


Monocot stem



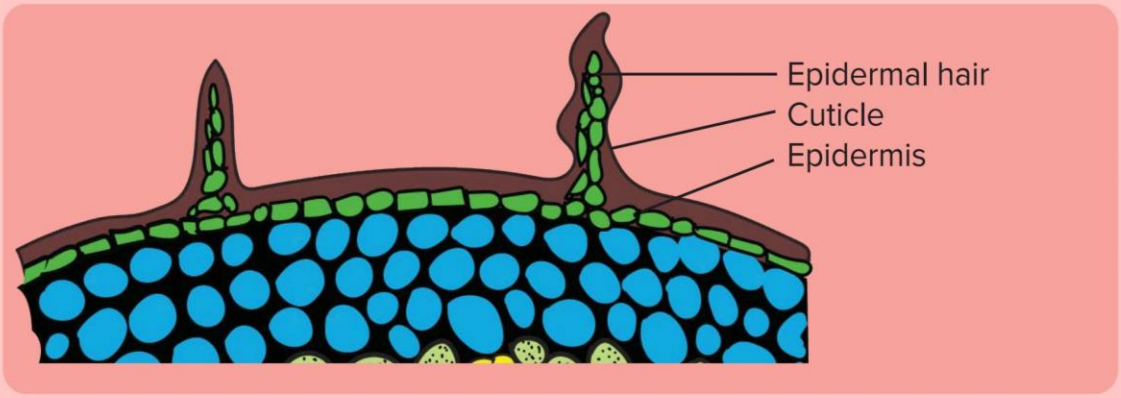
Anatomy of the Dicot Stem

- Different layers of cells can be seen in the transverse section of the 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 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.



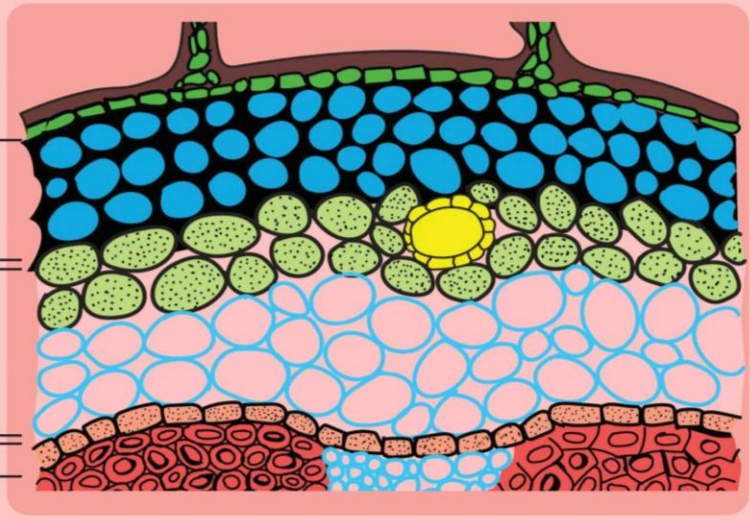
Cortex

- The cortex is divided into three layers:

Outer - Hypodermis
Consists of collenchyma cells with no intercellular space. Provides mechanical strength.

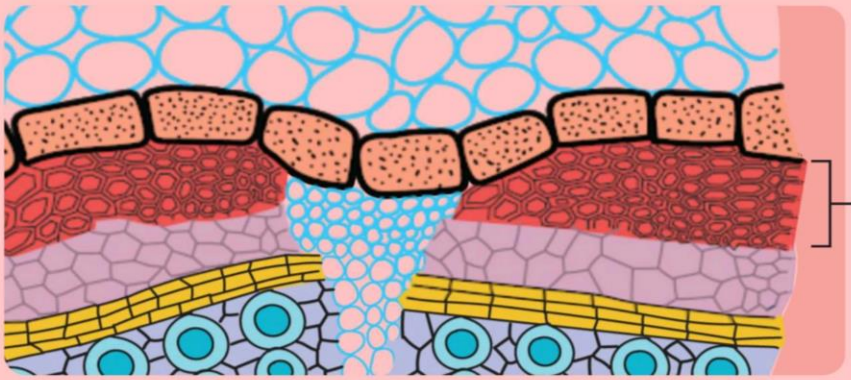
Middle - General cortex
Consists of round, thin-walled parenchymatous cells with intercellular spaces.
Parenchymal cells with chloroplast (chlorenchyma) are also present.

Inner - Endodermis
Cells rich in starch (food storage)
Also called starch sheath



Layers of cortex

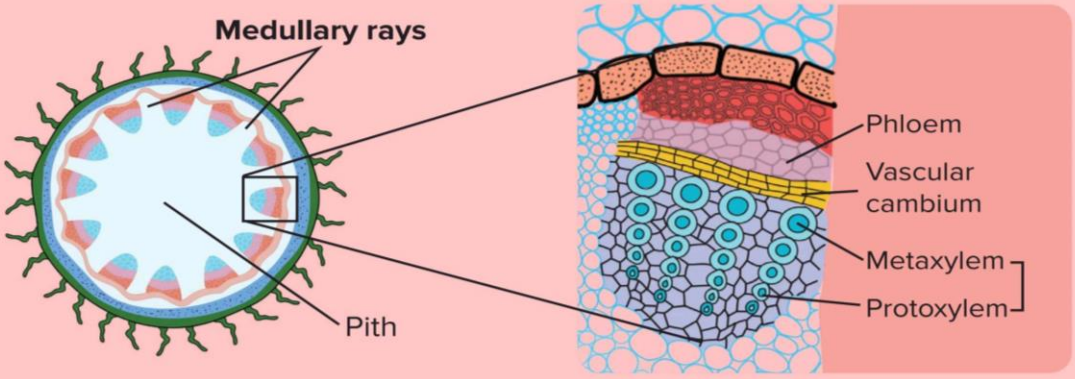
Pericycle



Pericycle
- Pericycle is below the starch sheath of endodermis
- Made of sclerenchyma cells
- Has semilunar patches

Vascular bundles

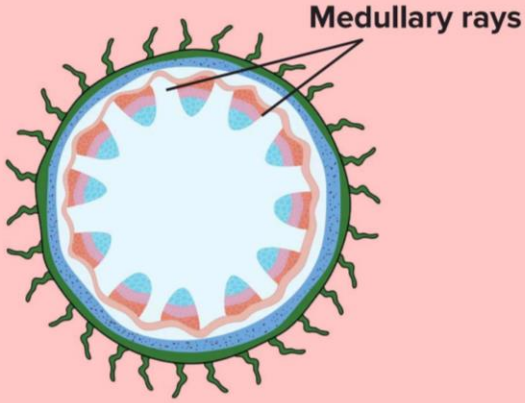
- They are arranged like a **ring**.
- **Conjoint, open vascular bundles and endarch condition of xylem**

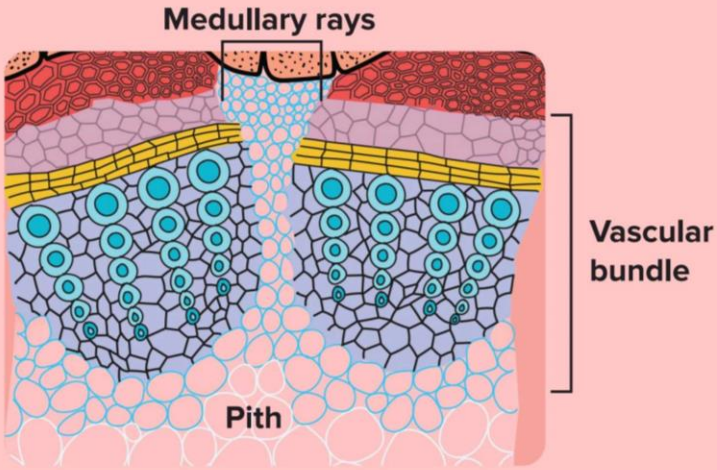


- **Conjoint**: Xylem and phloem arranged together in the same radius
- **Open**: Cambium in between xylem and phloem
- **Endarch**: Protoxylem lies towards the centre or the pith, and the metaxylem lies towards the periphery of the stem

Medullary rays

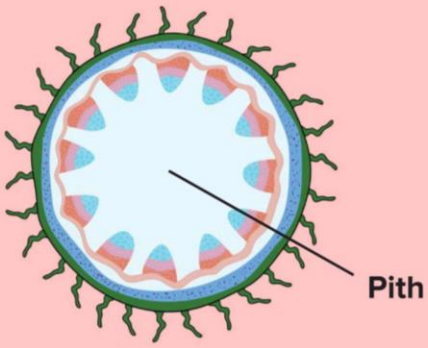
- Radially arranged parenchymatous cells in between the vascular bundles

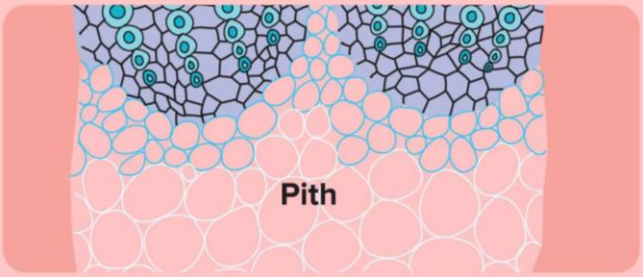




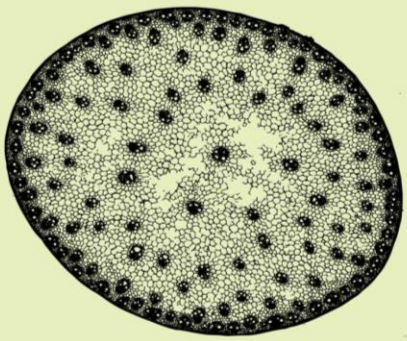
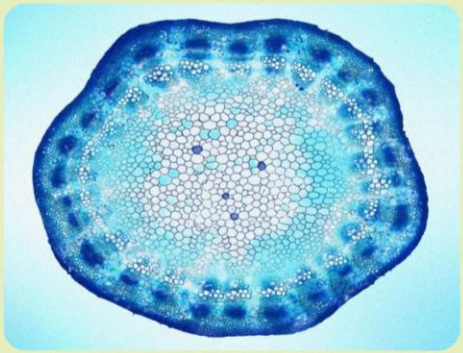
Pith

- Centremost part: Large number of **parenchymatous** cells with large intercellular spaces



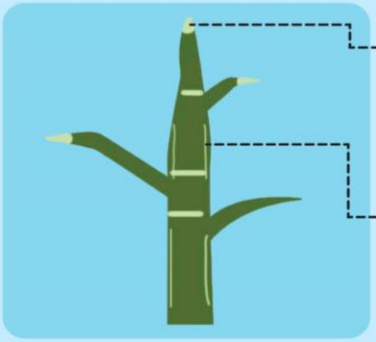


Monocot stem vs Dicot stem

Character	Monocot stem	Dicot stem
Hypodermis	Sclerenchymatous	Collenchymatous
Ground tissue	Not differentiated but is a continuous mass of parenchyma	Differentiated into cortex, endodermis, pericycle and pith
Starch sheath	Absent	Present
Medullary rays	Absent	Present
Vascular bundles	• Closed • Scattered in the ground tissue • Secondary growth usually does not occur	• Open • Arranged in a ring • Secondary growth occurs
	 TS of a monocot stem	 TS of a dicot stem

Secondary Growth

- Plants show both **primary** and **secondary growth**.
- **Secondary growth** is seen only in **dicots**.



→ Apical meristems **(Primary growth)**
Growth of the shoots and roots in length

→ Lateral meristems **(Secondary growth)**
Increase in girth of the stem

Promeristems
During embryonic growth, the promeristems drive the growth

Embryonic growth

Primary meristems
As seeds germinate, primary meristems divide and grow 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 developed from mature or differentiated tissue system.

Secondary growth
It drives the increase of girth of the stem with help of the secondary lateral meristems.

Secondary tissue
E.g. Secondary xylem and phloem

Vascular cambium

- Secondary vascular bundles develop from the lateral meristem.
- They are of two types:

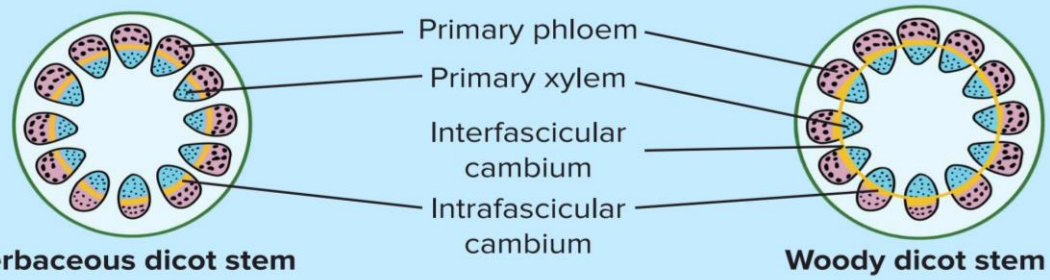
Vascular cambium

Intrafascicular cambium

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

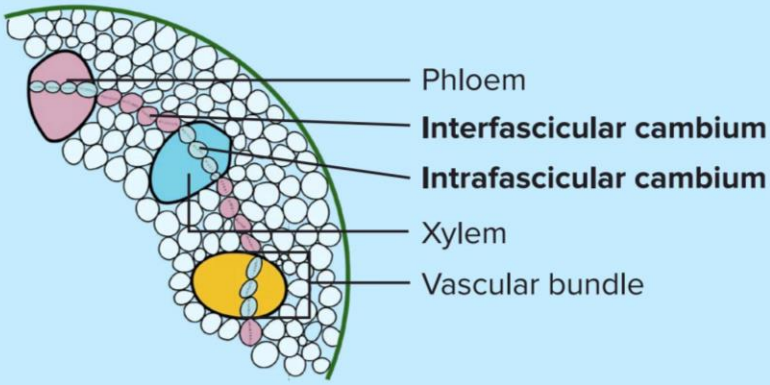
Interfascicular cambium

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



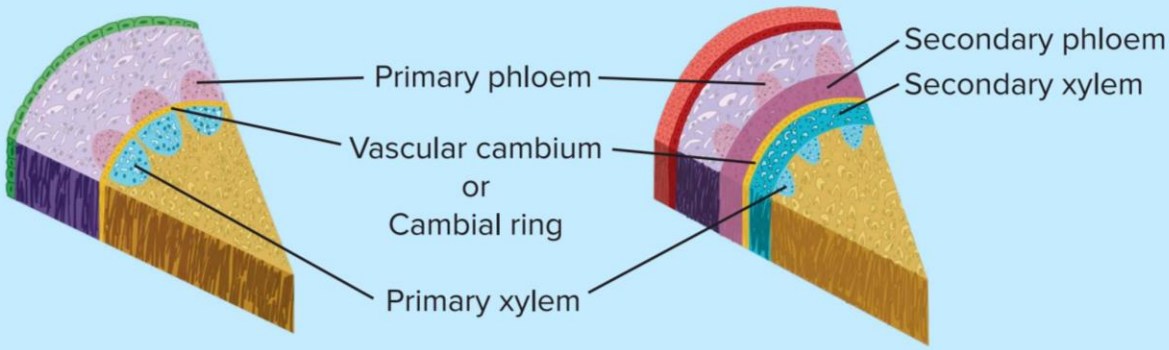
Cambial ring

- The interfascicular cambium and intrafascicular cambium together form the **cambial ring**.



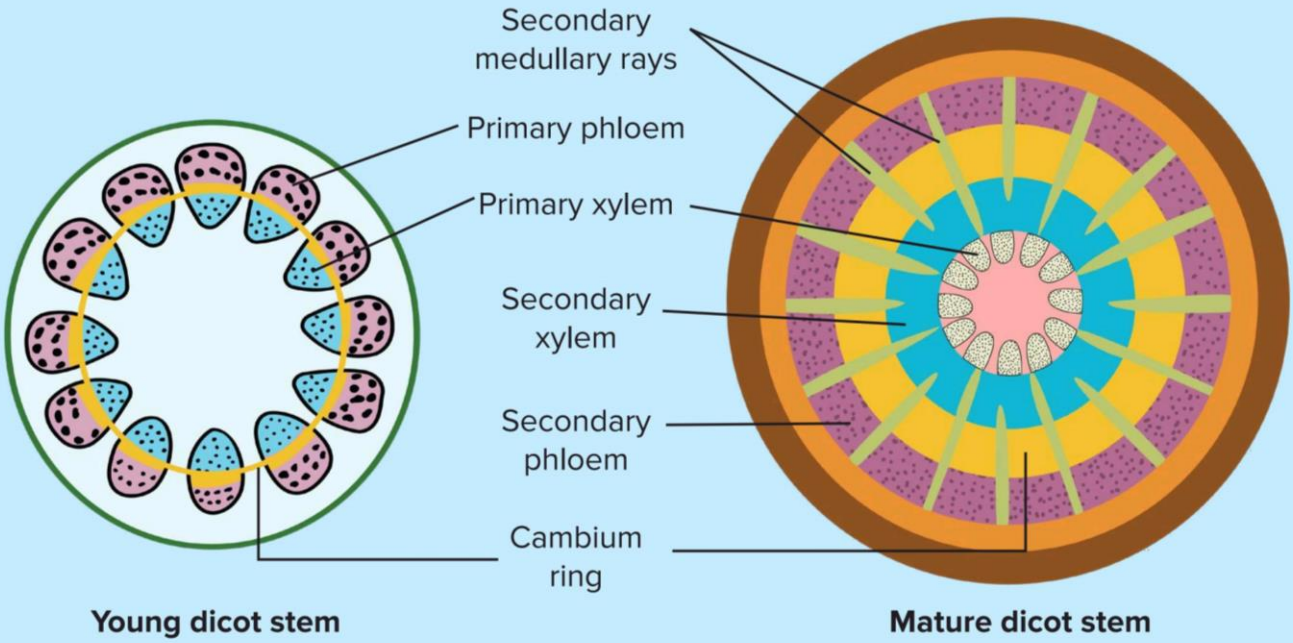
Interfascicular and intrafascicular cambium

Cambial ring activity

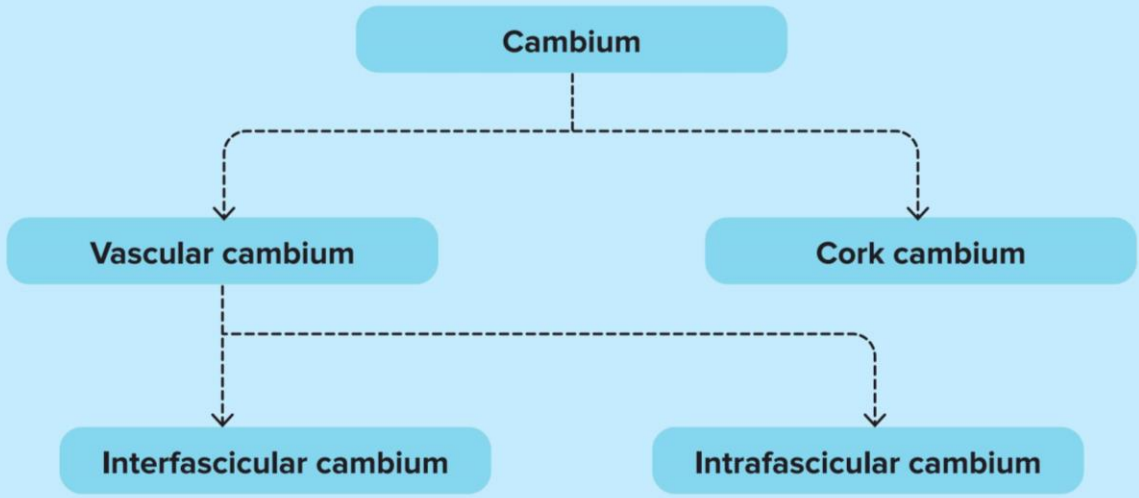


- The cambium ring becomes active and cuts off cells on both the sides.
- On the outer side or towards the periphery, it leads to the formation of secondary phloem, and towards the inner side (or pith) it gives rise to the secondary xylem.
- Thereby, the dicot plant's girth increases.
- As the secondary phloem layers are being created outwards, the older phloem layers are crushed.
- The secondary xylem layers formed inside accumulate inwards. The different primary xylems from different vascular bundles merge together.

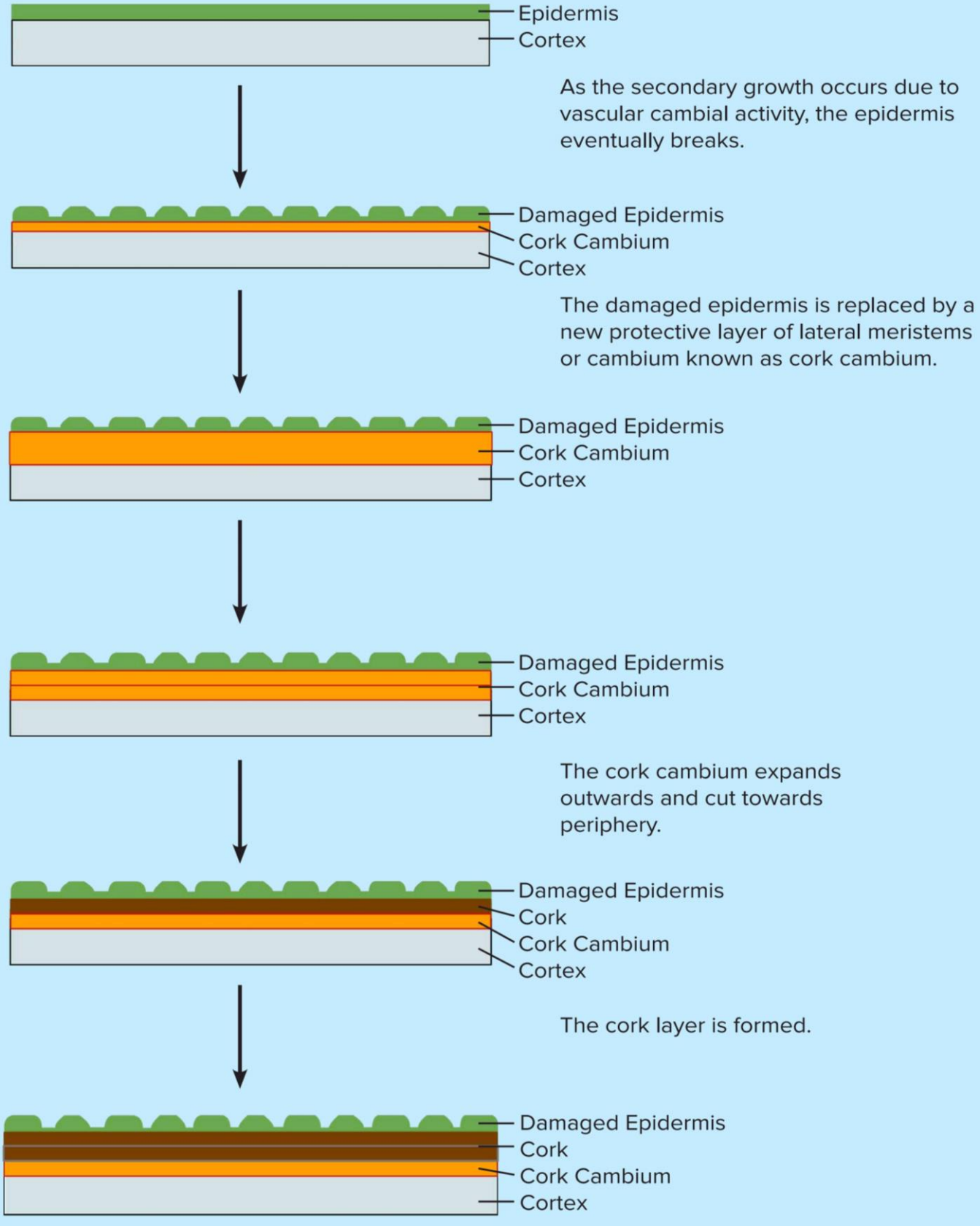
Secondary medullary rays: As the cambium cuts off the xylem and phloem, there are some strips of the cambium cell that cut off parenchyma cells both inward and outward, known as the secondary medullary rays.



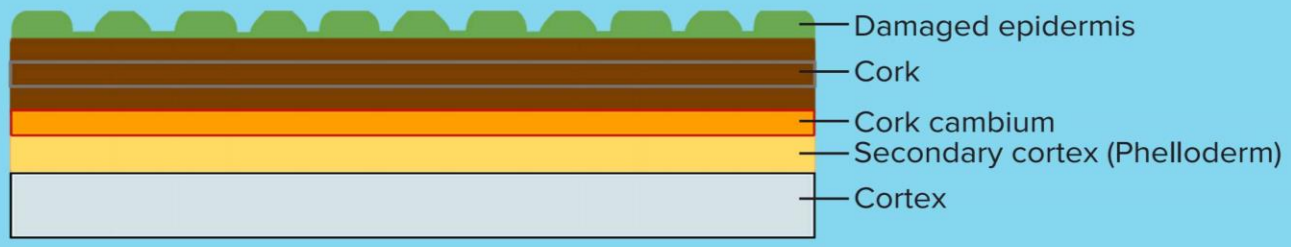
Cork cambium or phellogen



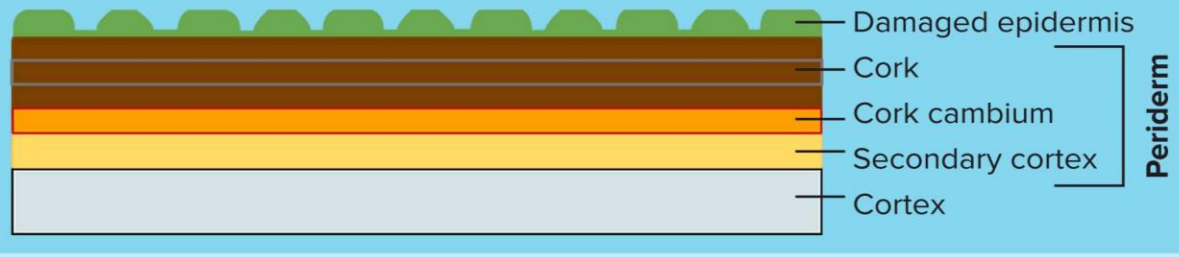
- **Cork cambiums** are the meristematic tissues formed in the **cortex**.
- Cork cambium cells are narrow, thin-walled and rectangular.


Epidermis
Cortex
As the secondary growth occurs due to vascular cambial activity, the epidermis eventually breaks.
Damaged Epidermis
Cork Cambium
Cortex
The damaged epidermis is replaced by a new protective layer of lateral meristems or cambium known as cork cambium.
Damaged Epidermis
Cork Cambium
Cortex
Damaged Epidermis
Cork Cambium
Cortex
The cork cambium expands outwards and cut towards periphery.
Damaged Epidermis
Cork
Cork Cambium
Cortex
The cork layer is formed.
Damaged Epidermis
Cork
Cork Cambium
Cortex
Similarly, layers of cork are formed.

- 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.



- As the cork layers form, the cork cambium cuts off inward and a new layer forms that is known as the **phelloderm**.

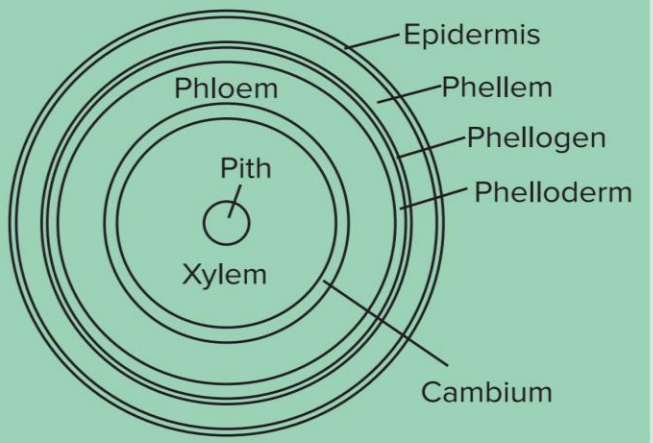


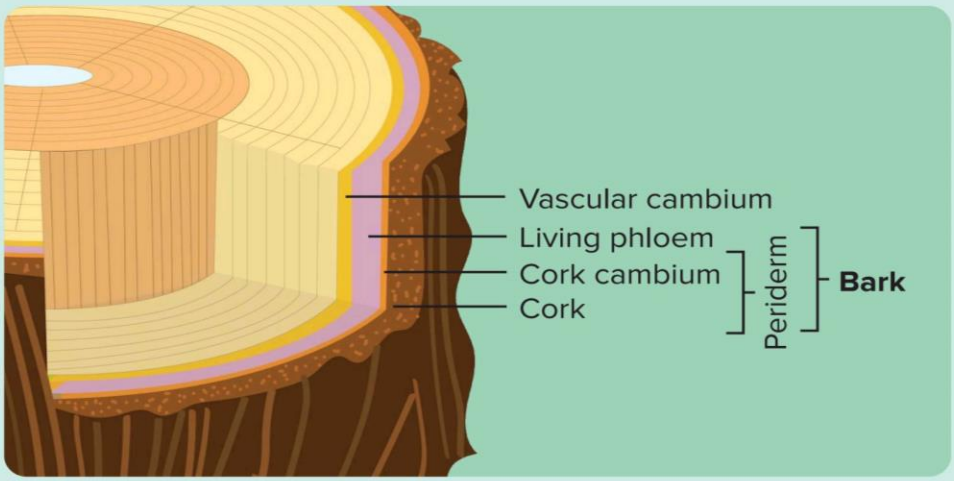
- Together, all the three layers of cork, cork cambium and secondary cortex are known as periderm.

BARK

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

Phelloderm, Phellogen, Phellem (Cork) → Periderm; Secondary phloem, Periderm → Bark





- Barks drop off or have rough texture because of the following:

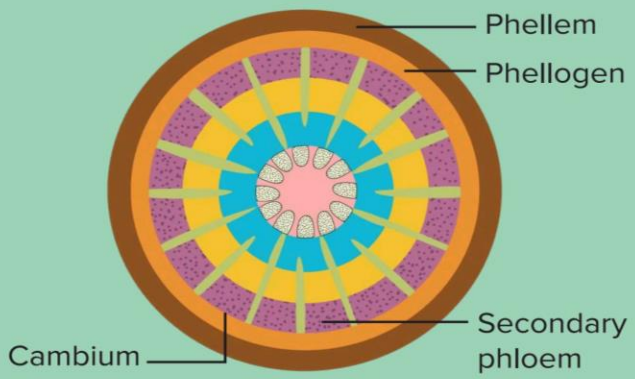
Cork cambium activity

↓

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

↓

Phellem parts die and fall off.



Bark

Early or soft bark

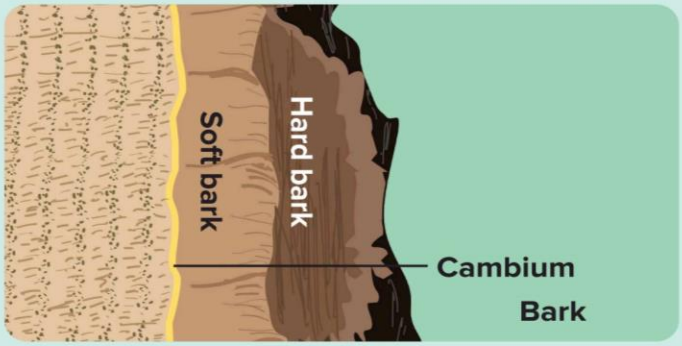
↓

Formed **early** in the season

Late or hard bark

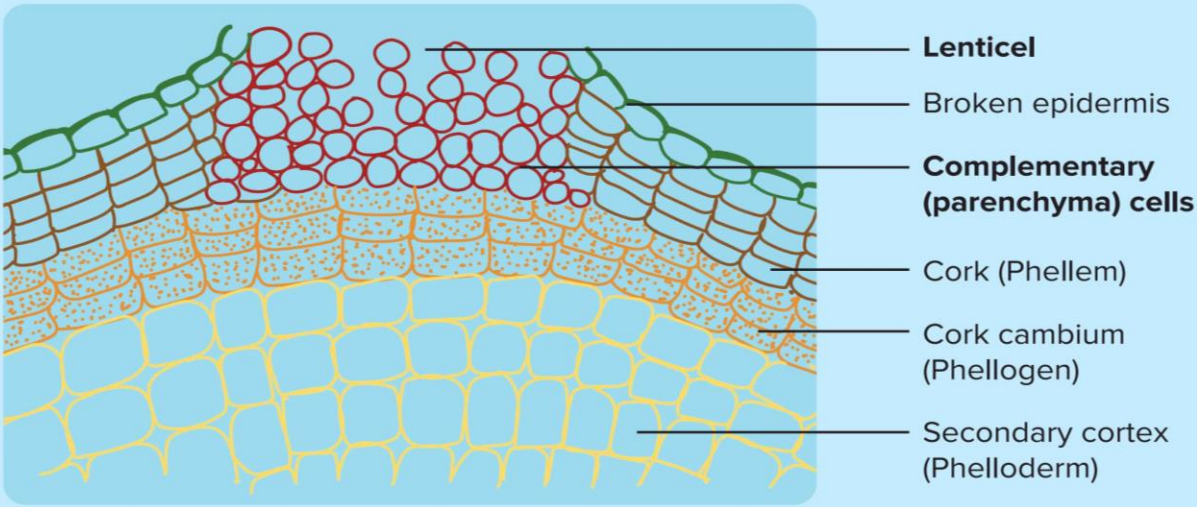
↓

Formed in the **end** of the season



Lenticels

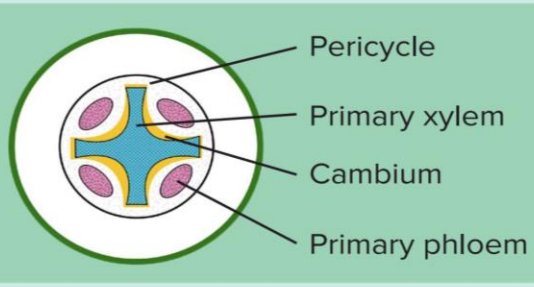
- The **lens-shaped** openings that are known as **lenticels** are created when the epidermis ruptures.
- They help in exchange of gases between the outer atmosphere and the internal tissue.
- They are found as raised circular, oval, or elongated parts on the surface of the bark.
- Phellogen or cork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



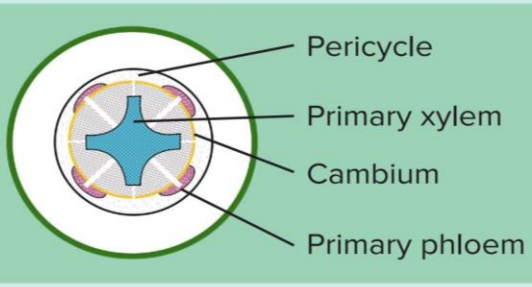
Lenticels

Dicot Root - Secondary Growth

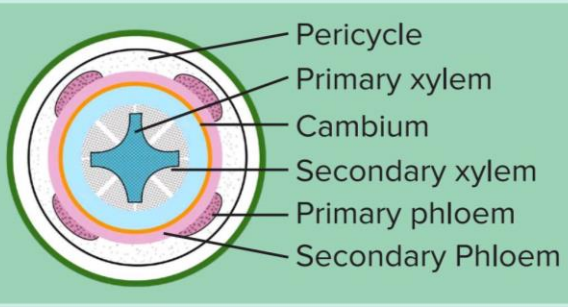
- The vascular cambium is formed during secondary growth.
- It starts off as a complete and **continuous wavy ring** that later becomes **circular**.



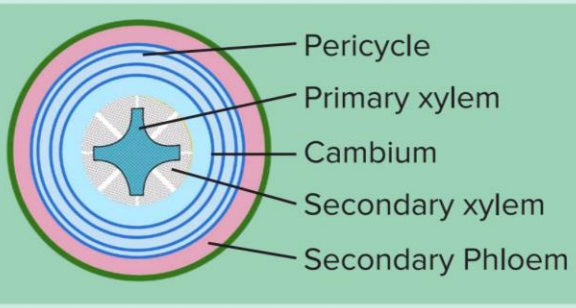
1. As the secondary growth is initiated, parenchymal cells beneath the phloem become meristematic. Then, the vascular cambium originates from the tissue between xylem and phloem.



2. As the cambial cells divide tangentially, cambial strips are formed. The first formed cambial ring extends towards the pericycle and forms cambium ring.



3. The cambial cells divide to form secondary tissues (mainly xylem). The cambial cells divide to produce more xylem elements compared to that of the phloem.



4. The cambium cells extend towards all edges and wavy cambial ring forms complete circular cambial rings. As cells divide continuously more cambial rings are formed.

Annual Ring

Dendrochronology

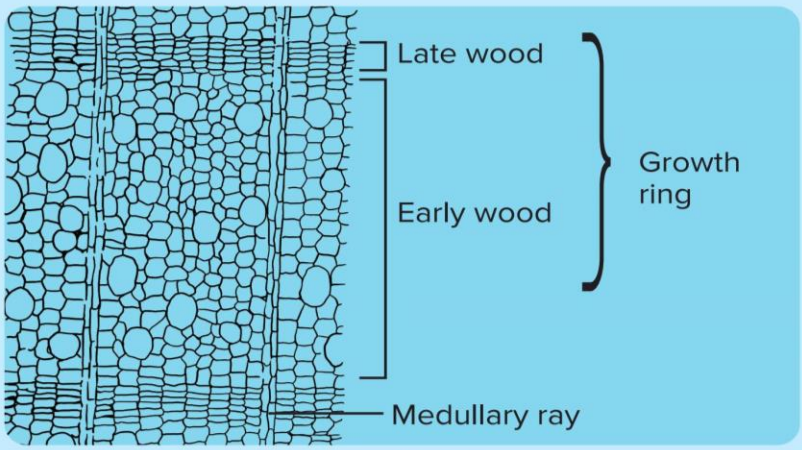
- Cross section of a the tree trunk has a characteristic ring-like pattern.
- Each ring actually signifies one year of the tree's growth.
- Counting all the rings, one can tell the age of the tree.
- This science is known as dendrochronology.

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**.

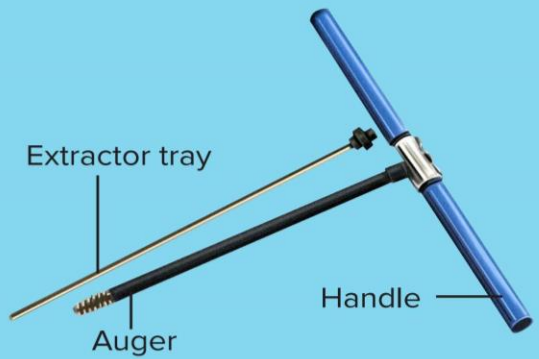
Early wood	Late wood
Also known as spring wood	Also known as autumn wood
Xylary elements grow quickly and are **large in number**	**Fewer** xylary elements
Xylary elements have **wider cavities** and have **thin cell walls**	Xylary elements have **narrow vessels**
Appears to be **lighter** in colour	Appears to be **darker** in colour
Lower density	**Higher** density
	
The cambium is very **active**.	The cambium is **less active**.

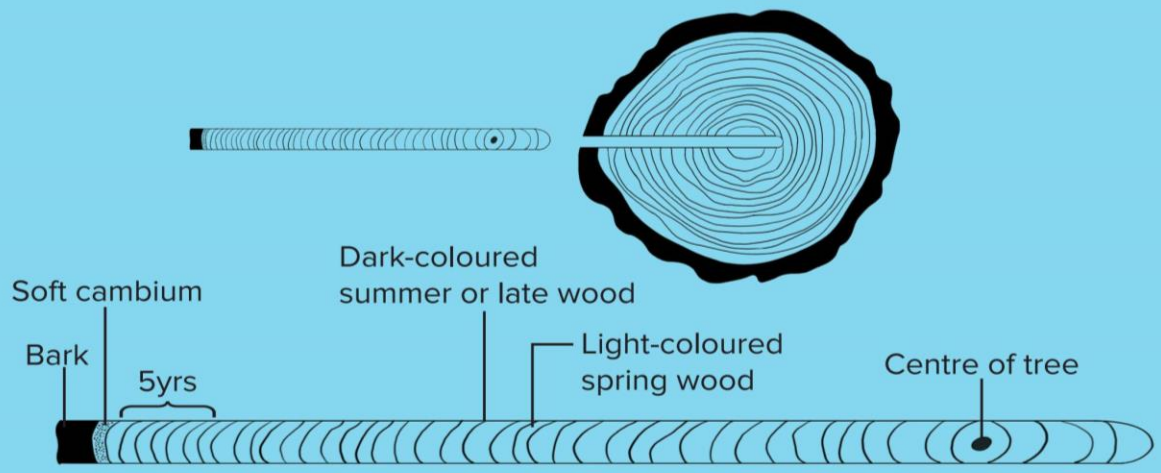


Growth ring

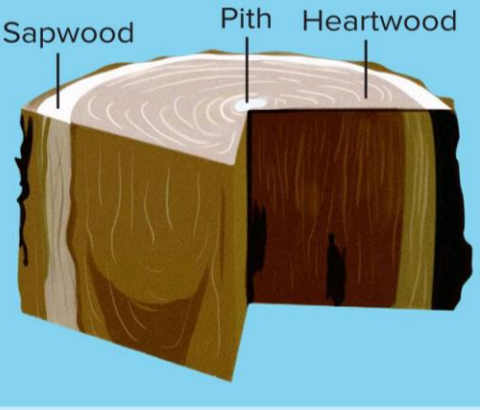
Increment borer

- An increment borer is an instrument that is used to find the age of the tree without cutting it down.
- It has three parts:
  - Extractor tray
  - Auger
  - Handle
- The handle and the auger together form a kind of a drill.





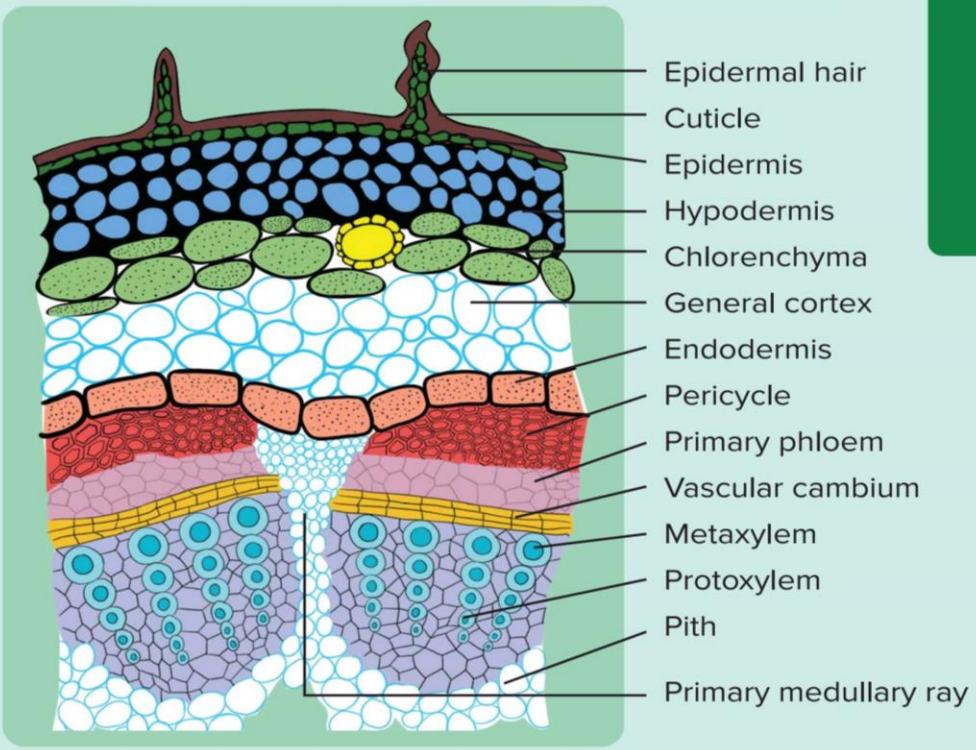
Sapwood	Heartwood
Sapwood is the **light brown** secondary xylem	Heartwood is the **dark brown** secondary xylem
• All wood begins as **sapwood** from the cambium in trees. • In **young** trees, **all wood** that is present is **sapwood**.	• It gives **mechanical** support and is hard and durable. • 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 Sheet

- In the dicots stem's transverse section, the following layers are seen.

Epidermal tissue	Vascular tissue	Ground tissue
Epidermis	Vascular bundles	Hypodermis General cortex Endodermis Pericycle Medullary rays Pith



Part of the dicot stem	Description
Epidermis	Outermost protective layer i) **Trichomes** are epidermal cells that are modified as hair. ii) The **cuticle** is a thin and waxy layer present on plant surfaces. It prevents water loss.
Cortex	It is the inner layer to the epidermis. It is made of three layers. i) **Hypodermis**: Outer cortex made of collenchymatous cells ii) **General cortex**: Middle layer made of collenchyma and parenchyma cells iii) **Endodermis**: Inner layer has the **starch sheath**
Pericycle	Layer followed right after endodermis Made of sclerenchymatous cells
Vascular bundles	Xylem and phloem follow the endarch and the ring arrangement They are in a conjoint-open system.
Medulla rays	Radially placed strips of parenchymatous cells between the vascular bundles
Pith	Centremost part with a large number of parenchymatous cells

Difference between the monocot stem and the dicot stem

Characters	Monocot stem	Dicot stem
Hypodermis	Sclerenchymatous	Collenchymatous
Ground tissue	Not differentiated but is a continuous mass of parenchyma	Differentiated into cortex,endodermis, and pericycle and pith
Starch sheath	Absent	Present
Medullary rays	Absent	Present
Vascular bundles	• Closed • Scattered in the ground tissue • Secondary growth usually does not occur	• Open • Arranged in a ring • Secondary growth occurs

- Secondary growth: **Lateral** meristems (**cambium**) **increase** (**girth**)
    - ➝ Vascular cambium: Patchy cambium between xylem and phloem
        - ○ Interfascicular cambium
        - ○ Intrafascicular cambium
    - ➝ Cork cambium: Cells are narrow, thin-walled, and rectangular.
- Interfascicular + Intrafascicular = **Cambial ring**
- Bark is a non-technical term for layers beyond the vascular cambium.
- **Lenticels** help in the **exchange** of **gases** between the outer atmosphere and the internal tissue.
- The annual ring is the layer of light and dark coloured wood, i.e., early wood and latewood, formed in a year depending on the seasons.
- Increment borer is used to count annual rings to determine age of a plant without cutting the trunk of the tree.
- A tree has the following types of woods.
    - ➝ Sapwood: Living cells that conduct water and minerals
    - ➝ Heartwood: Dead-lignified cells that do not conduct water and minerals