6. ANATOMY OF FLOWERING PLANTS

- **Anatomy** is the study of internal structure of plants and other organisms.

THE TISSUES

➔ **Tissue**:- *It is a group of cells having a common origin and performing a common function.*

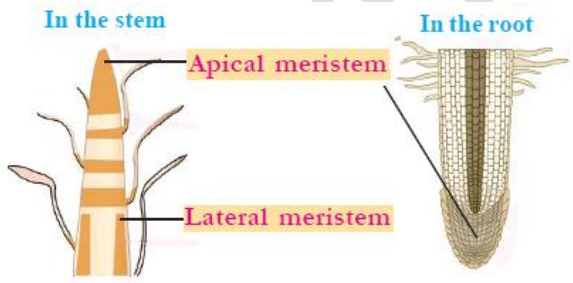
Based on the capability of cell division, plant tissues are 2 groups: **Meristematic** and **Permanent.**

Meristematic Tissues *(Meristos^{G}*=divisible*)*

➔ **These are the tissues where active cell division and growth occurs.**

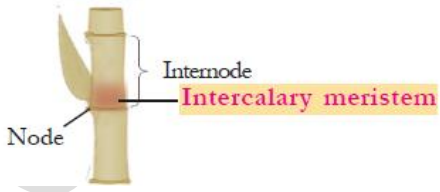
Based on the position, meristems are 3 types:-

(i) **Apical meristems:** They occur at the apices (tips) of roots and shoots.
(ii) **Intercalary meristems:** They occur between mature tissues.
(iii) **Lateral meristems:** The meristems that occur along the **lateral sides** of roots and shoots. They are seen in gymnosperms and dicots**. Ex:** Vascular cambium, cork cambium.



Based on the origin and development, meristems are 2 types:-

(i) **Primary meristems** that appear early in a plant life and contribute to the formation of the primary plant body. *Apical* and *intercalary* meristems are 1^{0} meristems**.**
(ii) **Secondary meristems** are responsible for producing the secondary tissues. *Lateral* meristem is a 2^{0} meristem**.**



Permanent Tissues

➔ **These are the tissues composed of cells produced by meristems, which lose the ability to divide and become structurally and functionally specialized.**

Based on its constituents, they are grouped into **simple** and **complex**.

I. Simple Tissues

➔ **These are the tissues made up of one type of cell.**

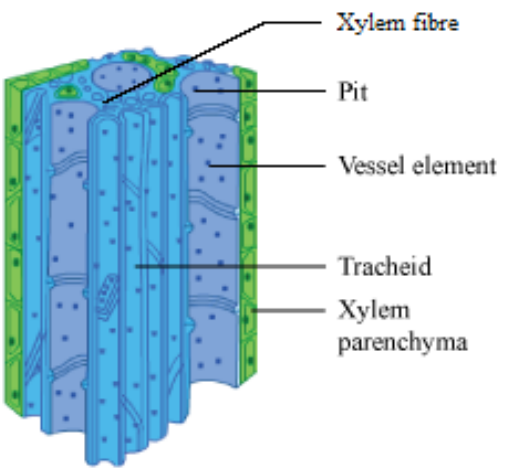
Simple permanent tissues found in plants are ***Parenchyma***, ***Collenchyma*** and ***Sclerenchyma***.

Simple tissue	Features	Function
i. **Parenchyma**	▪ **Occurs in:** Epidermis, cortex, pith and pericycle (almost all parts). ▪ **Shape:** Spherical, polygonal or elongated. ▪ **Cell wall:** Thin and made up of cellulose ▪ Cells are closely packed or have small intercellular spaces.	Photosynthesis, storage (sugar / protein / oil drops), secretion etc.
ii. **Collenchyma**	▪ **Occurs in:** Layers below the epidermis in dicot plants. ▪ **Shape:** Oval, spherical or polygonal ▪ **Cell wall:** Thickened corners due to deposition of cellulose (20%), hemicellulose (35%) and pectin (45%). ▪ Intercellular spaces are absent.	- Provide mechanical support to young stem and petiole of a leaf. - The cells that contain chloroplasts assimilate food.
iii. **Sclerenchyma**	▪ The cells have lost their protoplasts and hence dead. ▪ **Cell wall:** Thickened with lignin having a numerous pits. ▪ Based on the structure, sclerenchyma is 2 types: a. **Fibres:** These are thick-walled, elongated and pointed cells. **Occurs in:** Cortex, pericycle, xylem, phloem etc. b. **Sclereids:** These are spherical, oval or cylindrical cells with very narrow cavities (lumen). **Occurs in:** Fruit walls of nuts; pulp of fruits like guava, pear and sapota; and leaves of tea.	It provides mechanical support to organs.

II. Complex Tissues

➔ **These are made of more than one type of cells working together as a unit.**

2 types: Xylem and phloem.

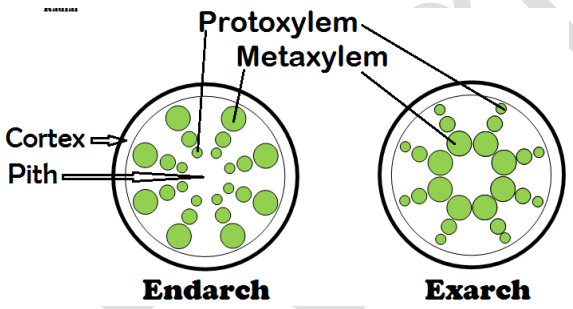


(i) Xylem / Wood

- Xylem is a complex tissue meant for conducting water and minerals from roots to the stem and leaves. It also provides mechanical strength to the plant parts.
- It is composed of 4 kinds of elements: **tracheids, vessels, xylem fibres** and **xylem parenchyma**

Xylem Element	Features	Function
i. **Tracheids**	▪ Elongated dead cells with pointed ends and lignified walls.	- Conduct water and dissolved minerals - Provide mechanical support
ii. **Vessels**	▪ Tube-like structure made up of many dead cells **(vessel members),** each with lignified walls and a large central cavity. Vessel members are interconnected with pores in their cross-walls through which water moves upwards. ▪ The vessels are a characteristic feature of angiosperms.	”
iii. **Xylem fibres**	▪ Schlerenchyma fibres associated with xylem.	- Provide strength
iv. Xylem parenchyma	▪ Parenchyma cells associated with xylem. ▪ The cells are living and thin walled.	- Store food materials (starch or fat) and substances like tannins.

- Depending upon the structure and time of origin, the xylem is of 2 types:
  - **Protoxylem:** The early formed xylem (bearing narrow vessels).
  - **Metaxylem:** The later formed xylem (bearing large vessels).
- Based on the position of protoxylem, xylem can be distinguished into 2 types-
  - **Exarch:** Here the protoxylem is facing towards the cortex (as in roots).
  - **Endarch:** Here the protoxylem is facing towards the centre / pith (as in stems).



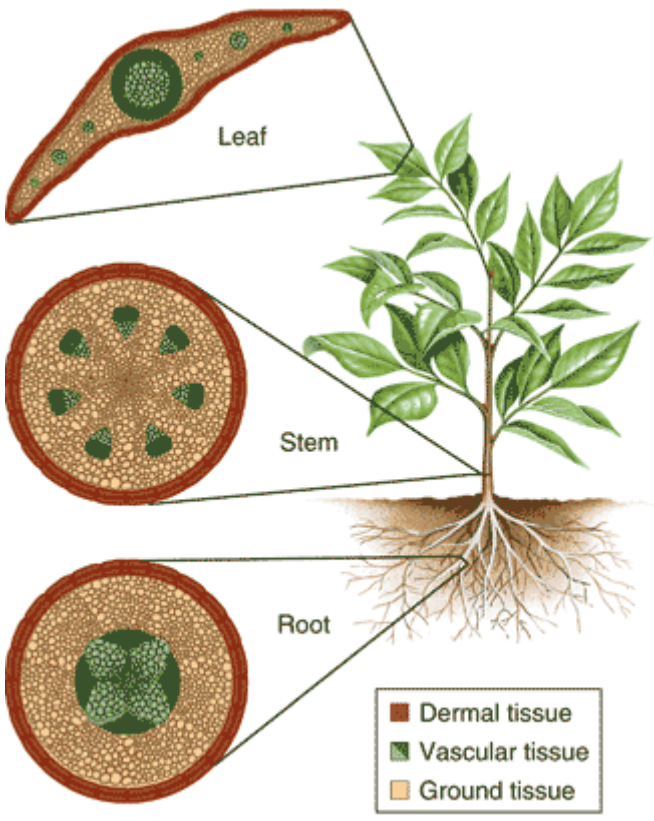
(ii) Phloem / Bast

- Phloem transports food materials from leaves to other parts of the plant.
  In angiosperms, phloem is composed of **sieve tubes, companion cells, phloem parenchyma** and **phloem fibres.**

Phloem Element	Features	Function
i. **Sieve tubes**	▪ Long, narrow tubes, arranged longitudinally. ▪ End walls are perforated to form the **sieve plates.** ▪ Possess peripheral cytoplasm and a large vacuole but lacks a nucleus.	- Conduction of photosynthates to sink.
ii. **Companion cells**	▪ Specialized parenchymatous cells that are connected with sieve tubes by ***pit fields*** present between their common longitudinal walls.	- Helps to regulate the rate of flow along the sieve tubes.
iii. **Phloem parenchyma**	▪ Elongated, tapering cylindrical cells with dense cytoplasm and nucleus. ▪ Absent in monocotyledons.	- Stores **starch** and substances like resins, latex and mucilage.
iv. Phloem fibres	▪ Elongated sclerenchyma cells having needle like tips.	- Give mechanical support - Protect soft tissues.

THE TISSUE SYSTEM

➔ **Tissue system**: A group of tissues performing related function.
On the basis of the structure and location, there are 3 systems- **Epidermal, Ground & Vascular.**



I. Epidermal Tissue System / Covering *(Epi^{G}=upon, derma^{G}=skin)*

- It forms the outer-most covering of the whole plant body.
  It comprises **epidermis, stomata** and **epidermal appendages.**

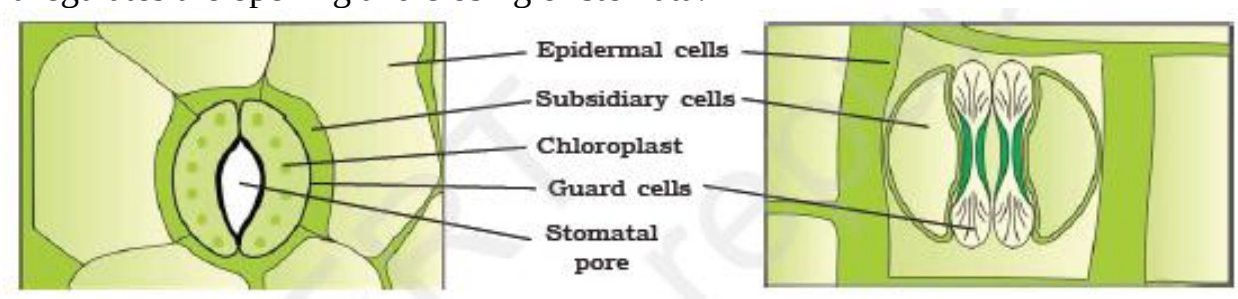
1) **Epidermis**

- It is the outermost *protective layer* of the plant body.
- Epidermis is usually **single layered** compactly arranged **parenchymatous** cells.
- The epidermis is covered with a waxy coating **(cuticle).** It is absent in roots.

  Function: Prevents the loss of water.

2) **Stomata**

- These are **minute pores** present in the epidermis of leaves.
- Each stoma is made of two *bean-shaped* **guard cells** in dicots**.** In monocots, the guard cells are *dumb-bell shaped*.
  It regulates the opening and closing of stomata.



Stomata in dicot In monocot

- The cells seen near the guard cells are known as **subsidiary cells.**

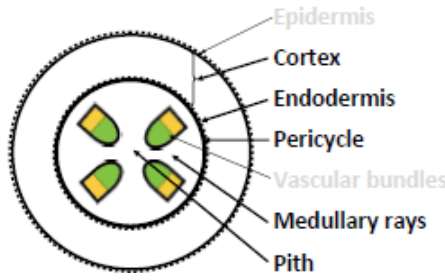
  Stomatal pore + guard cells + subsidiary cells = ***Stomatal apparatus.***

  Function: Gaseous exchange and transpiration

3) **Epidermal appendages**

- The cells of epidermis bear a number of outgrowths. They are of 2 types:-
  - **Root hairs:** They are unicellular elongations of the epidermal cells. **Function**: Help to absorb water and minerals from the soil.
  - **Trichomes:** They are the epidermal hairs on the stem. They are multicellular, branched or unbranched and soft or stiff. They may be secretory. **Function**: Help in preventing water loss due to transpiration.

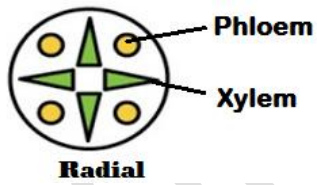
II. Ground Tissue System / Fundamental



- All tissues except epidermis and vascular bundles constitute the **ground tissue**. It consists of **simple tissues**.
- It forms the major bulk of the plant body. It is differentiated into various zones such as cortex, endodermis, pericycle, pith and medullary rays.
  Functions: The storage of food, mechanical support, photosynthesis, respiration etc.

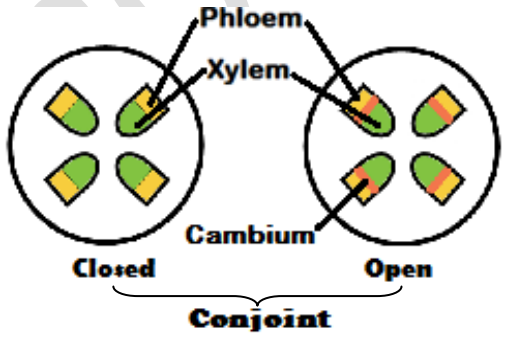
III. Vascular Tissue System / Conducting

- The **conducting tissues** -xylem and phloem- are seen present in the form of strands in roots, stem and leaves. A group of xylem and phloem forms **vascular bundles.**



Based on the arrangement of xylem and phloem, vascular bundles are 2 types:

1) **Radial type:** In this, xylem and phloem within a vascular bundle are arranged in an alternate manner on different radii (as in roots).
2) **Conjoint type:** In this, xylem and phloem are situated at the same radius of vascular bundles. Seen in stems and leaves. The conjoint vascular bundles have the phloem located only on the outer side of xylem.



Based on the presence or absence of **cambium,** vascular bundles are 2 types:

i. **Open type:** In this, cambium is present between phloem and xylem. So vascular bundles can form 2^0 xylem and phloem tissues. i.e., ***open for 2^0 growth*** (as in **dicot** stem).
ii. **Closed type:** In this, cambium is absent. Hence, they do not form 2^0 tissues (as in **monocots**).

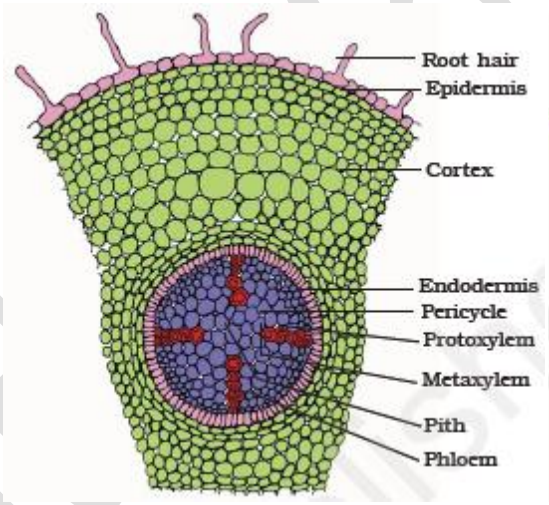
1^0 Structure of Root, Stem & Leaf

In angiosperms, monocots and dicots are anatomically different.

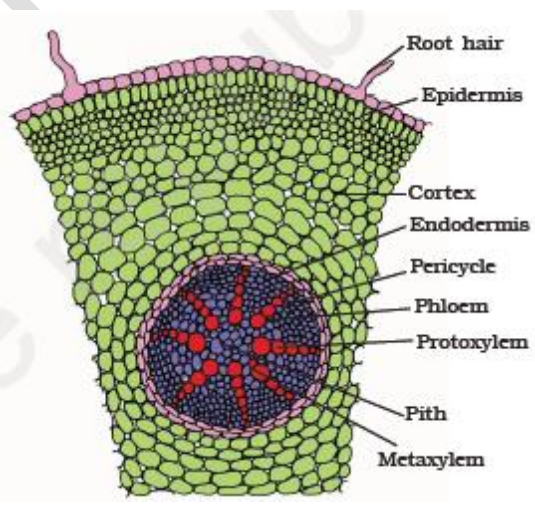
Dicot Root

The transverse section of a dicot root shows 3 regions:-

1) **Epidermis:** The outermost layer**.** *Root hairs* are present.
2) **Cortex:** It consists of several layers of thin-walled parenchyma cells.
- **Endodermis:** The innermost layer of the cortex**.**
  The endodermal cells of roots show a band of thickening called **casparian strips** due to the deposition of water impermeable, waxy material ***suberin***. **Function**: Maintain root pressure.
3) **Stele:** All tissues on the inner side of the endodermis together constitute stele. They include -
   (i) **Pericycle:** A few layers of parenchyomatous cells inner to the endodermis.
   Role: - Lateral roots initiate from pericycle
   - Vascular cambium (during the 2^0 growth) originates from these cells.
   (ii) **Vascular bundles:** There are usually 2-4 xylem and phloem patches radially arranged.
   (iii) **Conjunctive tissue:** The parenchymatous cells which lie between the xylem and the phloem.
   (iv) **Pith:** Innermost region of the stele. It is small or inconspicuous.



T.S of Dicot root



T.S of Monocot root

Monocot Root

The anatomy of the monocot root is much similar to that of dicot root. It has **epidermis, cortex** and **stele.**

- There are more than 6 **(polyarch)** xylem bundles in the monocot root.
- Pith is large and well developed.
- Monocot roots do not undergo any secondary growth.

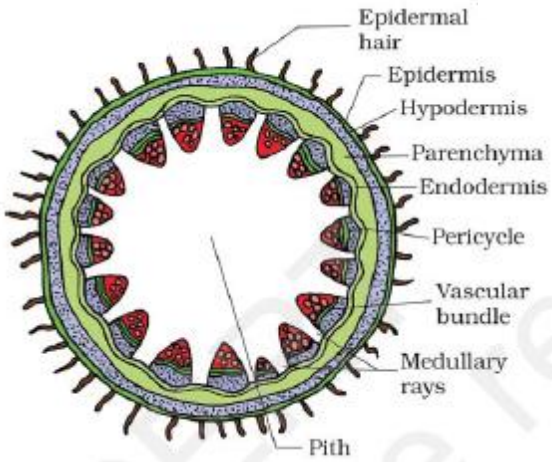
Difference between dicot and monocot root

Dicot root	Monocot root
1. Xylem and phloem elements are limited in number (2-6).	1. Xylem and phloem are numerous (above 6)
2. Xylem vessels are polygonal in shape	2. Xylem vessels are round in shape
3. Pith is small or absent.	3. Pith is large
4. Undergo for secondary growth	4. Do not undergo any secondary growth.

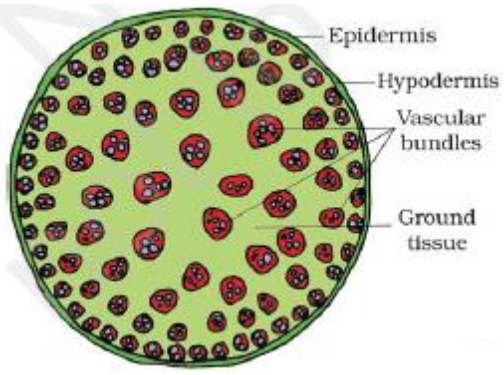
Dicot Stem

The transverse section of a dicot stem shows 3 regions:-

1) **Epidermis:** It is the outermost layer. Covered with a thin layer of cuticle, it may bear trichomes and a few stomata (in young).
2) **Cortex:** It is the multiple layers of heterogenous cells arranged in between epidermis and stele**.**
   It consists of three sub-zones.
   (i) **Hypodermis:** It consists of a few layers of ***collenchymatous*** cells just below the epidermis. It provides mechanical strength.
   (ii) **Cortical layers:** Below hypodermis. They consist of rounded thin walled parenchyma cells.
   (iii) **Endodermis:** Innermost layer of the cortex. The cells are rich in starch. So the layer is also called as the **starch sheath.**
3) **Stele:** It is the central part of the stem inner to endermis. It consists of **pericycle, vascular bundles, medullary rays & pith.**
   (i) **Pericycle:** It is found as semi-lunar patches of ***sclerenchyma*** above the phloem, called **bundle cap**.
   (ii) **Vascular bundles:** They are large in number arranged in a ring. Each VB is **conjoint, open**, and with **endarch** protoxylem.
   (iii) **Medullary rays:** These are few layers of radially placed parenchymatous cells in between vascular bundles.
   (iv) **Pith:** The central portion of the stem where a large number of rounded, parenchyma cells with large intercellular spaces.



T.S of Dicot stem



T.S of Monocot stem

Monocot Stem

- The large, parenchymatous **ground tissue is not differentiated** into cortex, endodermis, pericycle and pith.
- It has a **sclerenchymatous hypodermis.**
- A large number of scattered **vascular bundles,** each surrounded by a ***sclerenchymatous*** **bundle sheath.** Peripheral bundles are smaller than centrally located ones. **Vascular bundles** are **conjoint** and **closed.**
  The phloem parenchyma is absent, and water-containing cavities are present within the vascular bundles.

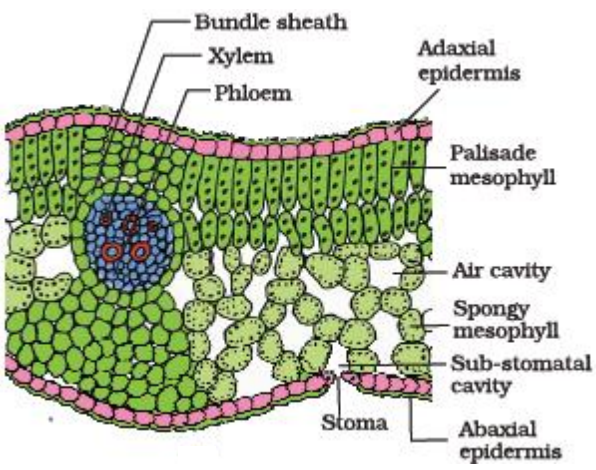
Difference between dicot and monocot stem

Dicot stem	Monocot stem
1. Epidermal hair is present	**1.** Absent
2. Collenchymatous hypodermis.	**2.** Sclerenchymatous hypodermis
3. The ground tissue gets differentiated into cortex and stele.	**3.** Undifferentiated ground tissue.
4. Vascular bundles are limited in number and are arranged in the form of a broken ring.	**4.** Vascular bundles are numerous and scattered.
5. Vascular bundles are open. Hence secondary growth is present.	**5.** Vascular bundles are closed. Hence secondary growth is absent.
6. Vascular bundles have sclerenchymatous **bundle cap.**	**6.** Vascular bundles have sclerenchymatous **bundle sheath.**

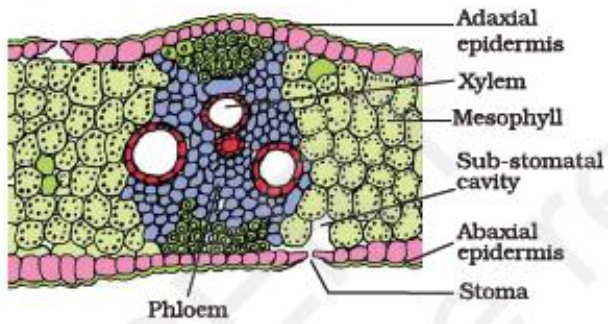
Dicot Leaf (Dorsiventral)

➔ This type of leaves have distinct dorsal and ventral surface
The vertical section of a dicot leaf shows 3 regions: **Epidermis, mesophyll** & **vascular bundles.**

1) **Epidermis:** It covers both the upper surface **(adaxial epidermis)** and lower surface **(abaxial epidermis)** of the leaf. It has cuticle.
   - *Lower surface generally bears more stomata than the upper surface.*
2) **Mesophyll:** The ground tissue between the upper and the lower epidermis. It is made up of parenchyma. They contain chloroplasts for photosynthesis. It has 2 types of cells:
   (i) **Palisade layer:** It is adaxially placed, made up of elongated cells arranged at right angles to the epidermis.
   (ii) **Spongy tissue:** The oval or round and loosely arranged cells, situated below the palisade cells.
3) **Vascular bundles:** They are located in the veins and midrib as reticulate venation.
   - Vascular bundles are surrounded by a layer of thick walled **bundle sheath cells**.



T.S of Dicot leaf



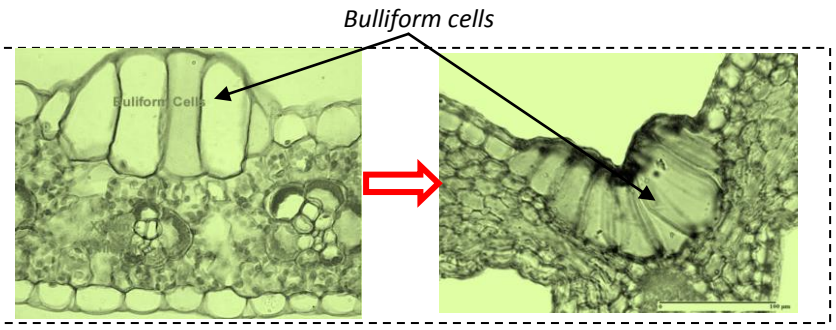
T.S of Monocot leaf

Monocot Leaf (Isobilateral)

➔ This type of leaves have similar dorsal and ventral surface
The anatomy of monocot leaf is similar to that of the dicot leaf in many ways. It shows the following differences:

1) **Epidermis:** Stomata are present on both surfaces of the epidermis.

In grasses, upper epidermis has **bubble** (large, empty and colorless) like **bulliform cells.** It helps to roll and unroll the leaves to regulate water loss.
- When they have absorbed water and are turgid, the leaf surface is exposed (unrolled).
- When they are flaccid due to water stress, they make the leaves curl (roll) inwards to minimize water loss.



2) **Mesophyll:** Consists of spongy parenchyma.
3) **Vascular bundles:** Parallel venation.

Difference between dicot and monocot leaf

Dicot leaf	Monocot leaf
1. Stomata are more on lower surface. The guard cells are *bean-shaped.*	1. Equal number of stomata on both surfaces. The guard cells are *dumb-bell shaped.*
2. Mesophyll is differentiated into palisade and spongy tissues.	2. Undifferentiated mesophyll.
3. Bulliform cells are absent.	3. Bulliform cells are present in the upper epidermis
4. Reticulate venation is present	4. Parellel venation is present

2° GROWTH

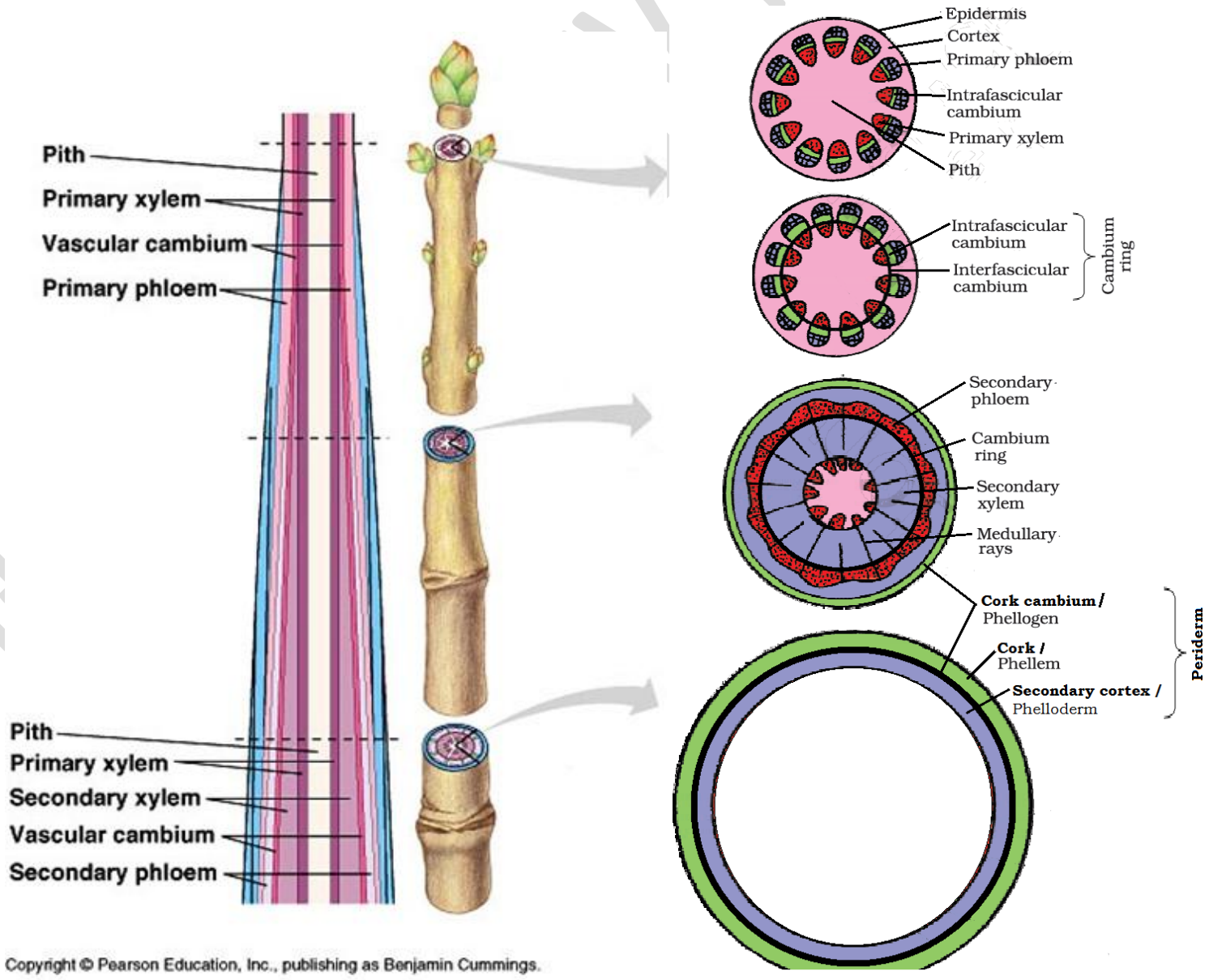
- **Primary growth:** The growth of the roots and stems in length with the help of apical meristem**.**
- **Secondary growth:** The growth taking place in dicot plants soon after 1^0 growth is over till death. It increases thickness / girth due to the formation of additional vascular tissues and periderm (new outer covering). This is due to the activity of **vascular cambium & cork cambium** respectively.

Significance of Secondary Growth

- More vascular tissues for effective conduction
- Additional strength

A. Vascular Cambium / Intrafascicular cambium

- It is the **single meristematic layer** present in vascular bundles (between primary xylem & phloem) of dicot stem.



Secondary growth in dicot stem includes following steps-

Step 1. Formation of Cambial Ring

On the onset of 2^0 growth, a single layer of cells of medullary rays that is fall in line with the intrafascicular cambium become meristematic and form the **interfascicular cambium**. Thus, a continuous ring of **vascular cambium** is formed.

Step 2. Formation of Secondary Vascular Tissues

- The cambial ring becomes active and cut off new cells, both towards the inner and outer sides.
  - The cells that cut off towards pith, mature into **secondary xylem.**
  - The cells cut off towards periphery mature into **secondary phloem**.
- Primary and secondary phloems get gradually crushed due to the continued formation and accumulation of secondary xylem. The primary xylem however remains more or less intact, in or around the centre.

Step 3. Formation of Secondary Medullary rays

- The cambium forms a narrow band of parenchyma passing through the secondary xylem and the secondary phloem in the radial directions. These are the **secondary medullary rays.**

B. Cork Cambium / Phellogen

- It is a multi layer cambium develops in the cortex region.
- It provides new protective cell layers **(periderm)** to replace the broken cortical and epidermal layers as the stem increase in girth due to the activity of vascular cambium and **lenticels** on periderm for gas exchange.

Activity of the Phellogen

- Phellogen cuts off cells on both sides.
  - The outer cells differentiate into **cork (phellem)**
  - The inner cells differentiate into **secondary cortex (phelloderm).** Cells of secondary cortex are parenchymatous.

The cork is impervious to water due to ***suberin*** deposition in the cell wall. **Function**: Check loss of water from stem

Phellogen + phellem + phelloderm = ***Periderm***

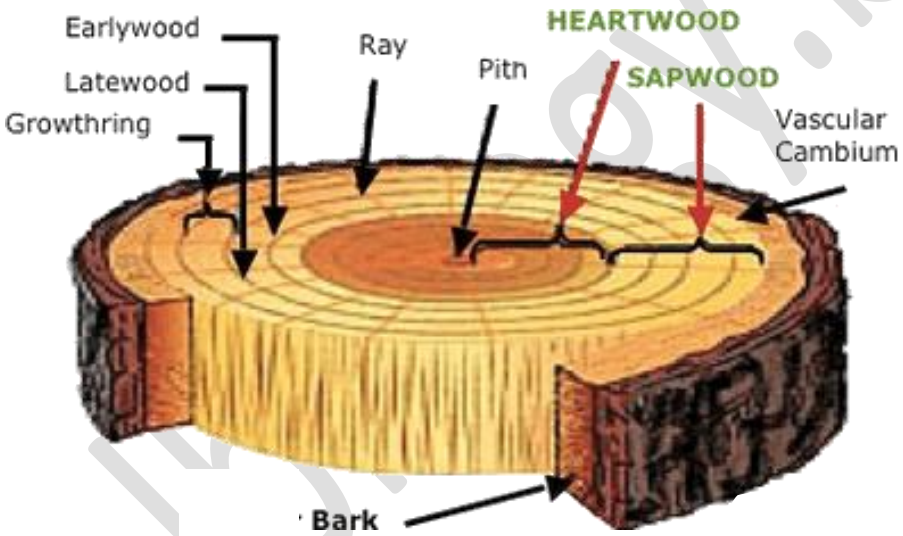
Spring wood and autumn wood

Vascular cambium active throughout life, but season affects.

- In spring season, cambium is very active and produces a large number of xylem elements having vessels with wider cavities. The wood formed during this season is called **spring wood (early wood)**. It is lighter in colour and has a lower density.
- In winter, cambium is less active and forms fewer xylary elements that have narrow vessels. This wood is called **autumn wood (late wood)**. It is darker and has a higher density.
- These two kinds of woods that appear as alternate concentric rings constitute an **annual ring.** This is used to estimate the age of tree.

Difference between spring wood and autumn wood

Spring wood (Early wood)	Autumn wood (Late wood)
1. Formed during spring season.	1. Formed during winter season.
2. Wider vessels	2. Narrow vessels
3. Light in colour.	3. Dark in colour
4. Lower density	4. Higher density



Heartwood and sapwood

- **Heartwood:** It is the central, hard, dead, dark-coloured, non-functional part of the secondary xylem of old trees.
  - The dark colour is due to deposition of **organic compounds** (tannins, resins, oils, gums, aromatic substances, essential oils etc).
  - These substances make it hard, durable and resistant to the attacks of microorganisms and insects.

Function: It gives mechanical support to stem.

- **Sapwood:** It is the peripheral region of secondary xylem. It is living and lighter in colour**.**

Function: Conduct water and minerals from root to leaf.

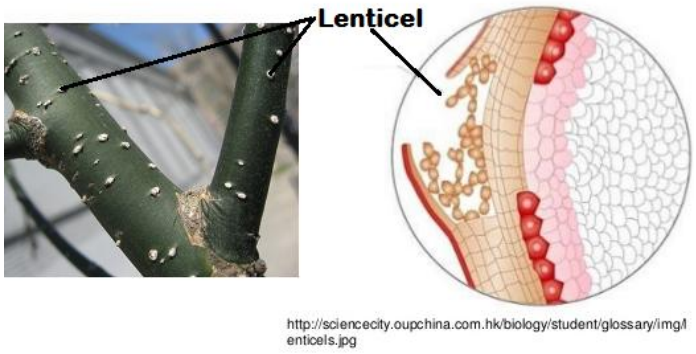
Difference between Heart wood and Sap wood

Heart wood	Sap wood
1. Central part of 2^0 xylem.	1. Outer part of 2^0xylem.
2. Dark colored	2. Light colored
3. Consist of dead cells, a thus non-functional.	3. Consists of live cells and hence functional.
4. Durable	4. Less durable
5. Function: Provide mechanical support.	5. Function: Conduction of water and minerals

Bark:

All the tissues (phloem + pericycle + cortex) exterior to the vascular cambium constitutes the **bark**. It is 2 types:

- o **Early (soft) bark:** It is formed early in the season**.**
- o **Late (hard) bark:** It is formed towards end of season.



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Lenticels:

These are openings in cork**.** These occur in most woody trees.

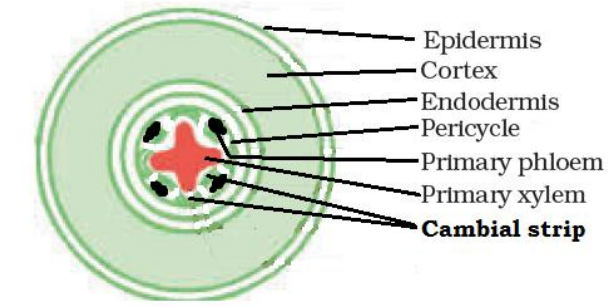
- **Function:** Gas exchange between atmosphere and the tissue of the stem.

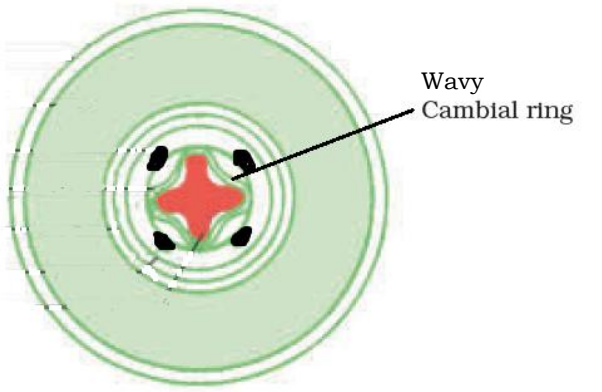
SECONDARY GROWTH IN ROOTS

- In dicot root, vascular cambium is completely secondary in origin.

Step 1. Formation of Cambial Ring

- The conjunctive tissue between primary xylem and phloem become meristematic and give rise to **conjuctival cambium** strips / segments**.**
- The pericycle cells arching over the protoxylem also become meristematic and produce a second set of **pericyclic cambium** strips.
  These cambial strips unite to form a complete and continuous **wavy cambial ring** (*later it becomes circular*- this is because **conjuctival cambium** becomes active first and cut more xylem than **pericyclic cambium**).





Step 2. Activity of the Cambial Ring

- The cambial ring cut off new cells, both towards the inner and outer sides.
  - The cells that cut off towards pith, mature into **secondary xylem.**
  - The cells cut off towards periphery mature into **secondary phloem**.

Difference in the cambial ring in dicot stem and dicot root

Dicot stem	Dicot root
1. The cambial ring formed is partially primary (vascular cambium) and partially secondary (phellogen).	1. Completely secondary in origin.
2. Vascular cambium formed by joining of fascicular and inter-fascicular cambium	2. Cambial strip formed from inner to phloem and outer to protoxylem.
3. Cambial ring is circular	3. Cambial ring is wavy