02 Anatomy of Flowering Plants

01. INTRODUCTION

- **Introduction**
- **The Tissues**
- **The Tissue System**
- **Anatomy of Dicotyledonous and Monocotyledonous Plants**
- **Secondary Growth**

- Plant and animals both show the structural similarities and variations in their external morphology as well as in their internal structure (Anatomy).
- Different organs in plants show variations in their internal structures.
- The monocots and dicots are also seen to be anatomically different.
- Internal structural also show adaptations to diverse environments.
- Study of internal structure of plants is called plant anatomy.

02. THE TISSUE

- **A group of cells having a common origin and usually perform a common function is called tissue.** A plant is made up of different kinds of tissues. The tissues are classified into two main groups, namely, meristematic and permanent tissue based on whether the cell being formed are capable of dividing or not.

TISSUES

↓ On the basis of capability of division

(1) Meristematic tissues (undifferentiated)	**(2)** Permanent tissues (fully differentiated)
→ Cells have capacity of division	→ Cells have no capacity of division
→ Composed of immature cells	→ Composed of mature cells

(1) MERISTEMATIC TISSUES :

- **Meristem : Growth in plants is largely restricted to specialised regions of active cell division called meristems** (A meristem is a localised region in which actual cell division occurs).
- It is derived from a Greek word **meristos** (means **Divided/Divisible**)

Classification of Meristematic Tissue/meristem :

(i) Meristem based on origin and development

On the basis of origin and development meristems can be divided into following three types:

(a) Promeristem

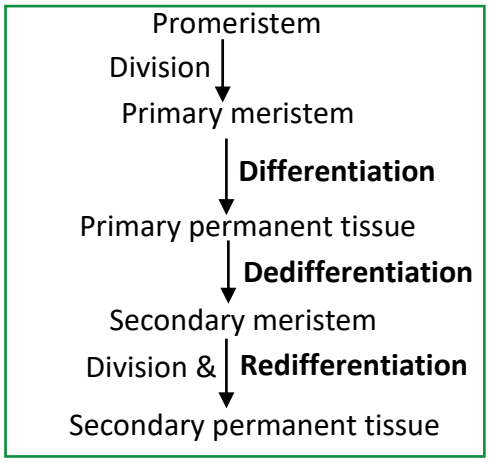
- This meristem develops at embryonic stage. It forms primary meristem.
  e.g. Embryonic meristem

(b) Primary meristem

- Meristematic cells developed from promeristem are known as primary meristem.
- **It appears early in the life of a plant & contribute to the formation of the primary plant body.**
- Cells are always in division phase and form primary permanent tissue by the process of **differentiation**.

(c) Secondary Meristem

- Secondary meristem develops from primary permanent tissue by the process of **dedifferentiation**.
- **Secondary meristem appears later than primary meristem.**
- By the activity of secondary meristems, **secondary growth** takes place.



Following divisions of cells in both primary and as well as secondary meristems, the newly formed cells become structurally and functionally specialised and lose the ability to divide. Such cells are termed permanent or mature cells and constitute the permanent tissues.

(ii) Meristem based on Location (Position) in Plant body :-

On the basis of position, meristems are divided into three types :-

(a) Apical Meristem :

It is an example of primary meristem.

- The meristems which occur at the tips of roots and shoots and produce primary tissues are called apical meristems.
- They are responsible for increase in the length of plant organs. It means they are responsible for primary growth. Examples of apical meristem :-
  Root apex/root apical meristem, shoot apex/shoot apical meristem.

HABERLANDT DIVIDED **EUMERISTEM** (It is a primary meristem i.e. apical meristem) into three regions **on the basis of function.**

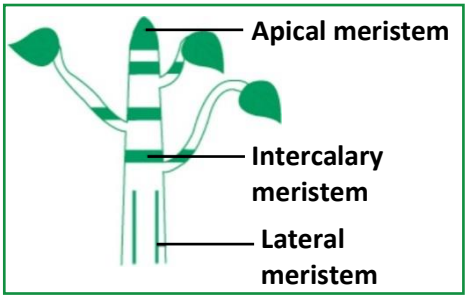
- **Protoderm :** It is the outer most layer of eumeristem. By the activity of protoderm **epidermal tissue system** is formed. E.T.S. includes epidermis, stomata, stem hair (shoot hair/trichomes), root hair etc.
- **Procambium :** It is made up of elongated cells and it gives rise to the **vascular tissue system**.
  V.T.S. includes Xylem, phloem (vascular bundles)
- **Ground Meristem :** The cells of this region are thin walled and isodiametric. **Ground tissue system** is formed by the activity of these cells. G.T.S. includes hypodermis, general cortex, endodermis, pericycle, pith-rays (medullary rays), pith (medulla) and mesophyll.

Note : **During the formation of the primary plant body, specific regions of the apical meristem produce dermal tissues, ground tissues and vascular tissues.**

(b) Intercalary Meristem :

- It is an example of primary meristem.
- Intercalary meristem occurs between mature tissues.
- They occur in grasses and regenerate parts removed by the grazing herbivores.

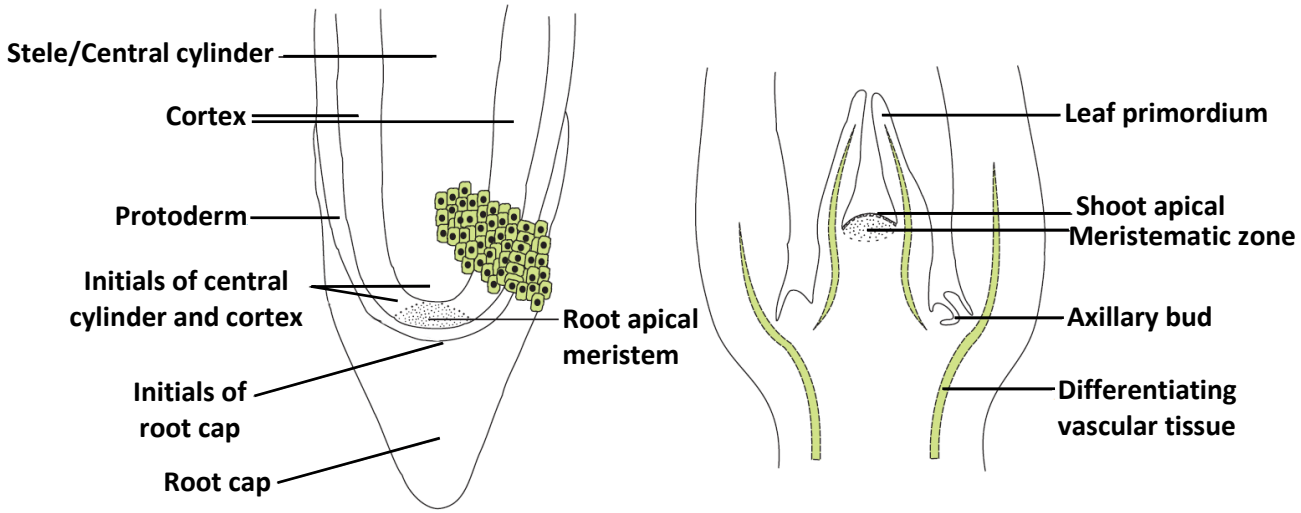
- Both apical meristems & intercalary meristems are primary meristems because they appear early in the life of a plant and contribute to the formation of primary plant body.



(c) Lateral Meristem :

- Lateral meristem occurs on **lateral side** of plant organs.
- Activity of lateral meristem increases the **circumference/girth/thickness of plant organ.**

- Generally **lateral meristems are cylindrical**.
- The meristem that occurs in the mature regions of roots and shoots of many plants, particularly those that produce woody axis and appears later than primary meristem is called the secondary meristem.
- Lateral meristems are responsible for producing the secondary tissues.



(a) Root apical meristem **(b) Shoot apical meristem**

NCERT XI Page No. 85, Figure No. 6.1

- During the formation of leaves and elongation of stem, some cells "Left behind" from shoot apical meristem, constitute the axillary bud. Such buds are present in the axils of leaves and are capable of forming a branch or a flower.
- Root apical meristem occupies the tip of a root while shoot apical meristem occupies the distant most region of the stem axis

Due to presence of root cap, position of **root apical meristem is sub terminal/sub apical** maximum growth in root takes place **behind the apex.**

- In hydrophytes root cap is absent e.g. ***Pistia***.
- Root cap is living, it contains large number of golgibodies which secrete mucilage, makes the root slimy.

03. PERMANENT TISSUES

- The cells of permanent tissues do not generally divide further.
- Their cells may be living or dead. Permanent tissues are of following types :-

(A) Simple permanent tissues

(B) Complex permanent tissues

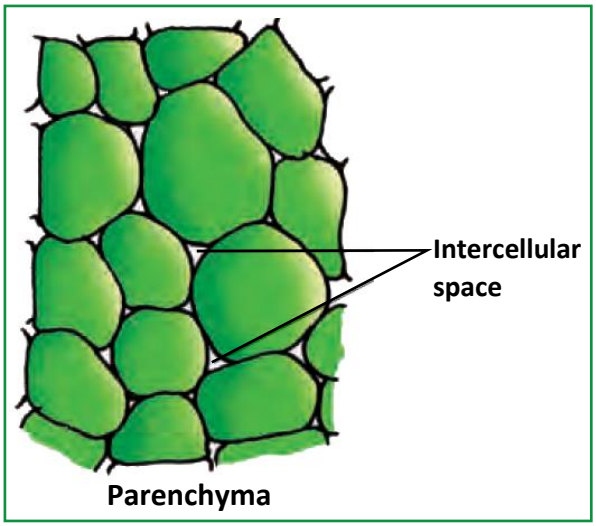
(A) SIMPLE PERMANENT TISSUE :

This tissue is made up of structurally similar type of cells or only one type of cells that perform a common function. Simple tissues are of three types :-

(i) Parenchyma (ii) Collenchyma (iii) Sclerenchyma

(i) Parenchyma :

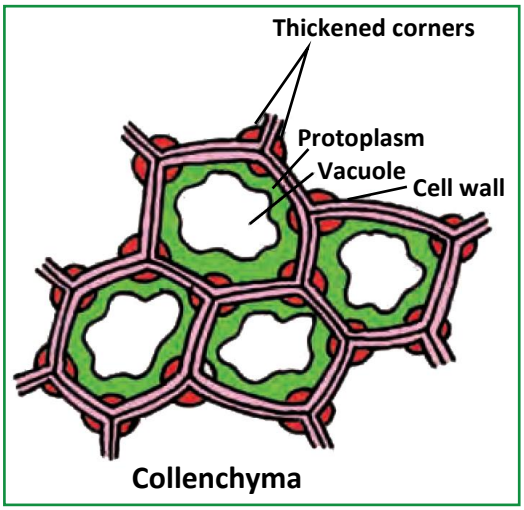
- Parenchyma term was coined by **Grew**.
- It is a primitive tissue and forms the major component within organs.
- The cells of parenchyma are **thin walled.** Cell wall is made up of pectocellulose means pectin and cellulose **(mainly cellulose).**
- Parenchymatous cells may either be closely packed or have small intercellular spaces.
- The cells of parenchyma are generally isodiametric. They may be spherical (rounded), oval, elongated or polygonal in shape.



- It is found in cortex, pericycle, medullary rays, pith, leaf mesophyll etc. It forms major component within organs.
- The parenchyma performs various functions like storage, photosynthesis (chlorenchyma), secretion, buoyancy (Aerenchyma).

(ii) Collenchyma :

- Collenchyma is a **living mechanical tissue.** It devoid of lignin.
- It transverse section cells appear oval, spherical/rounded or polygonal in shape.
- Deposition of pectin (mainly), cellulose & hemicellulose occurs mainly at corners.
- Usually intercellular spaces are absent.
- Cells often contain chloroplasts.
- These cells assimilate food when they contain chloroplasts.
- It is found in the **stems of herbaceous dicotyledons (young dicot stem) below the epidermis either as a homogenous layer** (in sunflower stem) or in **patches** (in *Cucurbita* stem).



Collenchyma

- They provide mechanical support to the growing parts of the plant such as young stem and petiole of a leaf.

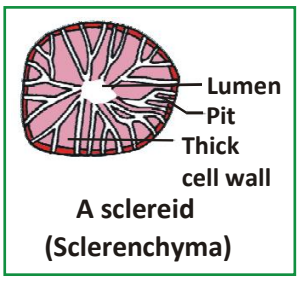
(iii) Sclerenchyma :

- Cells of sclerenchyma are generally long, narrow, thick walled, lignified without protoplasts and dead (Cells become dead at maturity).
- Sclerenchyma is found in the **hypodermis of monocot stem**.
- It provides mechanical support/mechanical strength to plant organs.

TYPES OF SCLERENCHYMA :-

On the basis of variation in form, structure, origin & development sclerenchyma cells are of two types.

- Sclereids
- Sclerenchymatous fibres



A sclereid
(Sclerenchyma)

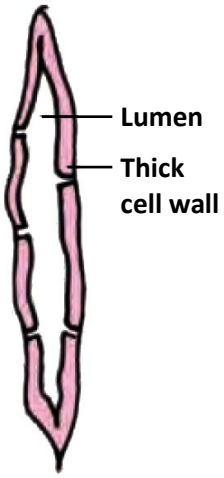
SCLEREIDS :-

- These cells are small, dead extremely thick walled (highly thickened) and generally their ends are not pointed.
- Sclereids are of various shaped (Spherical, oval or cylindrical).

- Sclereid cells have pits and lumen (cavity) is almost very small/very narrow.
- Sclereids are commonly found in fruit walls of nuts, pulp of guava, pear & sapota; seed coats of legumes and leaves of tea etc.

SCLERENCHYMATOUS FIBRES :-

- The fibres are thick walled, elongated and pointed cells.
- Their both ends are pointed (tapering).
- Generally occurring in groups in various parts of the plant.



A fibre Sclerenchyma

(B) COMPLEX PERMANENT TISSUE :

- The complex tissues are made of more than one type of cells or different types of cells and these work together as a unit.
- Complex tissues are absent in gametophytes.
- Complex tissues are also known as vascular tissues or conducting tissues.

Complex tissues are of two types - (i) Xylem (ii) Phloem

(i) Xylem :

- The function of xylem is to conduct water & mineral salts upwards from the roots to stem & leaves and to give mechanical strength to the plant parts.
- On the basis of **origin**, xylem is divided into primary xylem and secondary xylem.

Primary xylem originates from procambium during vascularisation. Xylem which is formed early in the life of a plant is known as primary xylem. On the basis of development primary xylem is divided into two parts.

- **Protoxylem**
- **Metaxylem**
- Cells of protoxylem are smaller in diameter as compared to metaxylem. The first formed primary xylem elements are called protoxylem and the later formed primary xylem is called metaxylem.

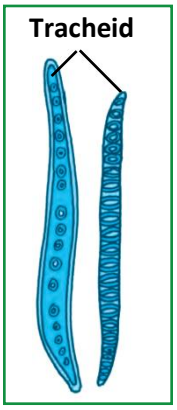
Secondary xylem originates from vascular cambium during secondary growth. Xylem which is formed during secondary growth is known as secondary xylem. Secondary xylem is not differentiated into protoxylem and metaxylem.

- Xylem is composed of four different kinds of elements. The elements of xylem are –

(a) Tracheids, (b) Vessels or tracheae, (c) Xylem fibers — **Dead elements**

(d) Xylem parenchyma — **Living element**

(a) Tracheids :



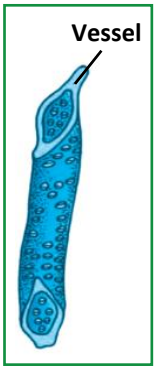
- Tracheids are **primitive conducting elements of xylem**.
- A single tracheid is elongated or tube like cell with thick and lignified walls and possess a **narrow lumen**. The ends of tracheids are tapering or chisel like.
- The tracheids found one above the other and are separated by cross wall / end wall which bears bordered pits.
- Usually **bordered pits** are present at the end walls of tracheids.

The maximum bordered pits are found in the tracheids of Gymnosperm plants.

- Tracheids are dead (without protoplasm) and lignified cells.
- Tracheids are found in pteridophytes, gymnosperms and angiosperms.
- End walls of tracheids are **imperforated** (not porous) but **pitted** (Pits are present).
- Tracheids are **unicellular**.
- The inner layers of cell walls have thickenings which vary in form.
- **Pits** are nonlignified areas on lignified walls.

(b) Vessels = Tracheae

- Vessel is an **advanced conducting element of xylem.**
- Vessel is a long cylindrical, tube like structure with lignified walls and **a wide (large) central lumen/cavity**.



- Vessel is multicellular, it is made up of many cells called vessel members or vessel elements.
- Vessel cells are also devoid of protoplasm.
- The **end wall is perforated.** Thus vessels are more capable for conduction of water and minerals than tracheids.
- Vessel members are interconnected through perforations in their common walls.

- **Presence of vessels is a characteristic feature of angiosperms Vessels are usually absent in gymnosperms** but exceptionally vessels are present in **some gymnosperms like *Ephedra, Gnetum*** and ***Welwitschia*** (order Gnetales).
- Vessels are **absent in some** angiosperm **plants** such as ***Dracaena, Yucca.*** There are some angiosperm families in which vessel less angiosperms are included.
  e.g. **Trochodendraceae**.
- Tracheids and vessels are called tracheary elements of xylem.
- In flowering plants, tracheids and vessels are the main water transporting elements.

(c) Xylem fibres / Wood fibres :

- They may either be septate or aseptate.
- Xylem fibres provide strength to the tracheid's and vessels.
- They have highly thickened walls and obliterated central lumens.

(d) Xylem Parenchyma :

- Cells living and thin walled and their cell walls are made up of cellulose.
- **Function : Storage of food materials in the form of starch or fat and storage of other substances like tannins.**

Note : Function of ray parenchymatous cells (xylem rays) - radial conduction of water.

(ii) Phloem :

- The main function of the phloem is **to conduct/transport food material,** usually from the leaves to other parts of the plant.

On the basis of **origin**, phloem is classified into two categories primary and secondary phloem.

- **Primary phloem** originates from procambium during vascularisation and **secondary phloem** originates from vascular cambium during secondary growth.

On the basis of development primary phloem is categorised into :-

1. Protophloem **2. Metaphloem**.

- The **protophloem** (first formed primary phloem) has narrow sieve tubes whereas **metaphloem** (later formed primary phloem) has bigger sieve tubes.

- Phloem consists of f**our types** of cells / elements:-
- Sieve tube elements, companion cells, phloem parenchyma & phloem fibres (In angiosperms).
- Sieve cells, albuminous cells, phloem parenchyma & phloem fibres (In gymnosperms).

(a) Sieve tube element / Sieve cell :

↓ ↓

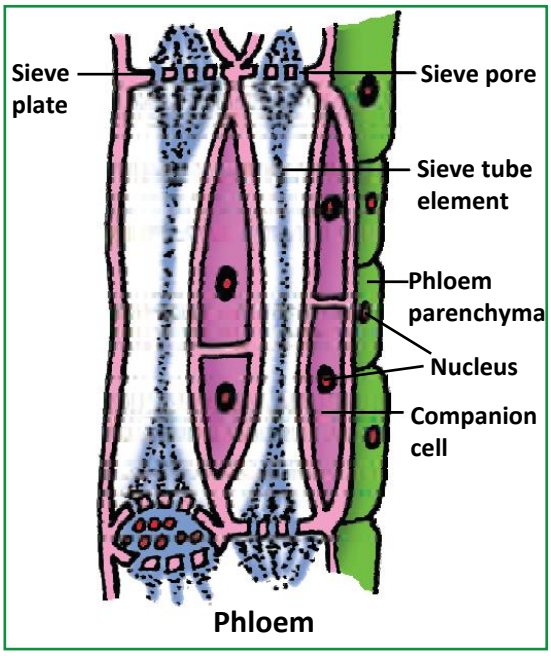
In Angiosperms **In Gymnosperms and pteridophytes**

- Sieve cells and sieve tube elements are **living** and thin walled.
- **In Angiosperm plants,** sieve tube elements are joined with their ends to form **sieve tube.** Their end walls are perforated (means having sieve pores) in a sieve like manner to form the sieve plates. Translocation of food material takes place through these pores.
- Sieve tube elements are long, tube like structures arranged longitudinally and are associated with companion cells.
- A mature sieve tube element possess a peripheral cytoplasm & a large vacuole but lacks a nucleus. (i.e. enucleated).
- The function of sieve tubes are controlled by the nucleus of companion cells.

(b) Companion cells :

These are thin walled, living, **specialised parenchymatous cells,** which are closely associated with sieve tube elements.

- Companion cell is laterally associated with each sieve tube element in angiospermic plants.
- Companion cell is a **living cell** with **large elongated nucleus**. This nucleus also controls the activity/functions of sieve tube element.
- Companion cells are found only in **angiosperms.**



- The companion cells help in maintaining the pressure gradient in the sieve tubes.

(c) Phloem fibres / Bast fibres : These are made up of **sclerenchymatous** cells.

- These are much elongated, unbranched and have pointed needle like apices. The cell wall of phloem fibres is quite thick.
- These fibres are generally not found in primary phloem but are found in the secondary phloem.
- These fibres **provide mechanical support** to sieve elements.
- At maturity fibres lose their protoplasm and become **dead**.
- Phloem fibres of jute, flax and hemp are used commercially.

(d) Phloem Parenchyma :

- It's cells are living, elongated, tapering, cylindrical which have dense cytoplasm and nucleus.
- The wall is composed of cellulose and has pit fields through which plasmodesmatal connection exist between the cells.
- It stores food material and other substances like resins, latex, mucilage etc.
- The main function of phloem parenchyma is storage of food material and function of phloem rays (ray parenchyma) is conduction of food in radial direction.
- Phloem parenchyma is absent in most of the monocotyledons.

04. TISSUE SYSTEM

- In higher plants several tissues work together in the form of a unit to perform a particular function. These tissues have the same origin. Such tissues form a system which is called tissue system. On the basis of **location / position** & **structure / morphology** tissues were categorised by **Von Sachs** (German scientist) into three types of tissue system. Each system usually consist of an association of tissues which perform specific function :-

(1) EPIDERMAL/DERMAL TISSUE SYSTEM :

- This system forms the outer-most covering of the whole plant body and comprises epidermis, stomata, root hairs, trichomes.

(A) Epidermis :

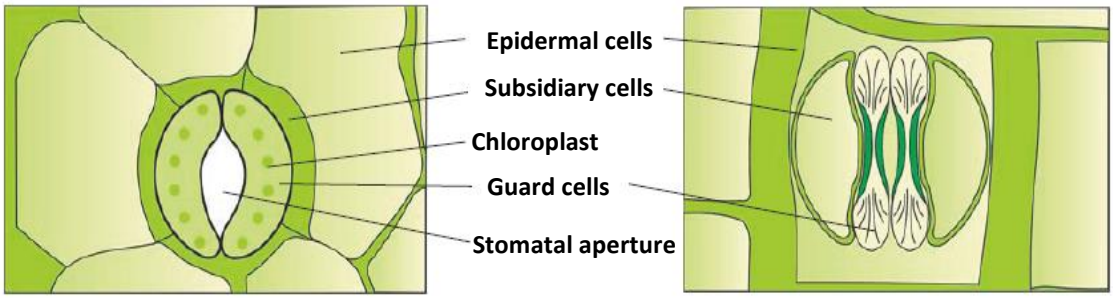
- It is outermost layer of the primary plant body and made up of elongated, compactly arranged cells.

- It is usually single layered and made up of parenchymatous cells.
- Cuticle (Waxy thick layer) is present on the epidermis which prevents the loss of water.
- **Cuticle is absent in roots.**
- Epidermal cells are with a small amount of cytoplasm lining the cell wall and a large vacuole.

(B) Stomata :

- These structures are present in the epidermis of leaves.
- Stomata regulate the process of transpiration and gaseous exchange. Each stoma is composed of two bean shaped cells known as guard cells which enclose stomatal pore.
- In grasses, the guard cells are dumb-bell shaped.
- The outer walls of guard cells (away from the stomatal pore) are thin and the inner walls (towards the stomatal pore) are highly thickened. The guard cells possess chloroplasts and regulate the opening and closing of stomata. Sometimes, a few epidermal cells, in the vicinity of the guard cells become specialised in their shape and size and are known as subsidiary cells.

The stomatal aperture, guard cells and the surrounding subsidiary cells are together called stomatal apparatus.



Diagrammatic representation : (a) Stomata with bean-shaped guard cells (b) Stomata with dumb-bell shaped guard cells.

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(C) Trichomes :

- The cells of the epidermis of dicot stem produce hairs called trichomes.
- The trichomes in the shoot system are usually multicellular.
- They may be branched or unbranched and soft or stiff. They may even be secretory called glandular hairs.
- In shoot system, **trichomes** are **usually multicellular.**

  Function : The trichomes help in preventing water loss due to transpiration.

(D) Root hairs :

- The root hairs are formed due to the elongation of the epidermal cells. These are ephemeral (short lived) structure.
- **Root hairs** are always **unicellular.**

  Function : Root hairs play an important role in absorbing water from the soil.

(2) GROUND TISSUE SYSTEM :

- It is the **largest tissue system**. All tissues except epidermis and vascular bundles constitute the ground tissue.
- It is divided into three zones – cortex, pericycle and pith.
- It includes hypodermis, general cortex, endodermis, pericycle and medullary rays (pith rays), pith. In leaf G.T.S. consists of mesophyll. G.T.S. is also called **fundamental tissue system.**
- G.T.S. is made of simple tissues such as parenchyma, collenchyma & sclerenchyma. The G.T.S. forms the main bulk of the plant.

Primary structure of plant organ or primary plant body is mainly composed of parenchyma.

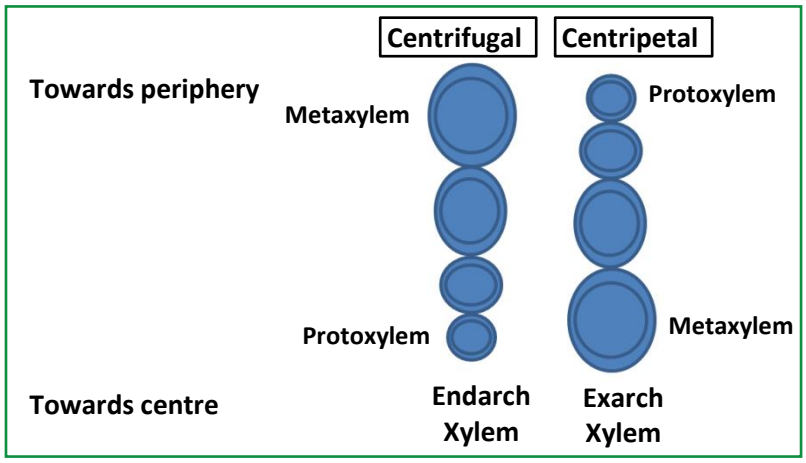
(3) VASCULAR/CONDUCTING TISSUE SYSTEM :

The V.T.S. consists of complex tissues, xylem and phloem.

Types of development of primary xylem :-

- **Centrifugal** :- In this type of development, the protoxylem is formed towards the centre (pith) and metaxylem is formed towards the periphery. In this condition xylem is known as **endarch.** ex. **Stem of angiosperms & gymnosperms**

- **Centripetal** :- In this type of development the protoxylem is formed towards the periphery and metaxylem is formed towards the centre (pith). In this condition xylem is called **exarch.** ex. **Roots.**



05. VASCULAR BUNDLES

- Xylem and phloem are collectively termed as vascular bundles.
  Which may or may not have cambium.
  On the basis of arrangement of elements means location of xylem and phloem, vascular bundles are divided into following categories.
  (1) Radial
  (2) Conjoint

(1) RADIAL VASCULAR BUNDLES :

- When the xylem and phloem are present separately on different radii in alternate manner, then vascular bundles are called radial vascular bundles.
- **Example :** Most of the **roots**. (Dicot, monocot, gymnosperm, fern root)

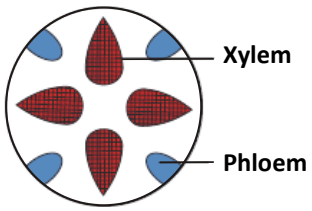


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Figure No. 6.2(a)

(2) CONJOINT VASCULAR BUNDLES :

In these type of vascular bundles xylem and phloem are present on the same radius of vascular bundles. These are of two types -

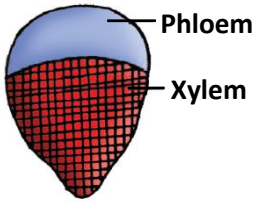
(A) Conjoint Collateral : In this type of vascular bundle xylem and phloem are present on the same radius and phloem is present towards the periphery.

These are two types -

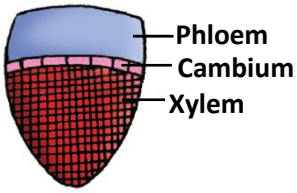
(i) Closed - When cambium is absent between the xylem and phloem of conjoint collateral vascular bundle then it is called closed vascular bundle.

Ex. **Monocotyledons stem and leaves of angiosperms.**

(ii) Open - If the cambium is present between the xylem and phloem, then it is said to be open vascular bundle. Ex. **stem of dicots/dicotyledons** and **gymnosperms**.



(b) Conjoint collateral closed



(c) Conjoint collateral open

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Figure No. 6.2

STELE

- All the tissues which are present inside the endodermis constitute the stele such as pericycle, vascular bundle and pith.

★ Golden Key Points ★

- **Meristos** is a Greek word which means **divided.**
- A simple tissue is made of only one type of cells whereas the complex tissues are made of more than one type of cells.
- Generally gymnosperms lack vessels.
- All tissues except epidermis and vascular bundles constitute the ground tissue.
- When xylem and phloem within a vascular bundle are arranged in an alternate manner along the different radii, the arrangement is called radial such as in roots.
- In conjoint type of vascular bundles, the xylem and phloem are jointly situated along the same radius of vascular bundles.
- In dicotyledonous stems, cambium is present between phloem and xylem. Such vascular bundles because of the presence of cambium possess the ability to form secondary xylem and phloem tissues, and hence are called open vascular bundles.
- In the monocotyledons, the vascular bundles have no cambium, hence they are referred to as closed.

BEGINNER'S BOX-1 MERISTEM TO VASCULAR BUNDLES

1. The process of formation of secondary meristem from primary permanent tissue is called :-

(1) Differentiation (2) Dedifferentiation

(3) Redifferentiation (4) Secretion

BAP296

2. Which of the following are examples of primary lateral meristems :-

(1) Cork cambium and vascular cambium

(2) Interfascicular cambium and cork cambium

(3) Interfascicular cambium and vascular cambium

(4) Intrafascicular cambium and marginal meristem

BAP297

3. Which of the following is primitive tissue :-

(1) Parenchyma (2) Collenchyma (3) Sclerenchyma (4) Xylem

BAP298

4. Conjoint, collateral vascular bundles are found in :-

(1) Stems (2) Leaves (3) Roots (4) Both (1) & (2)

BAP299

5. Phloem parenchyma is absent in :-

(1) Most of the Monocotyledonous stem

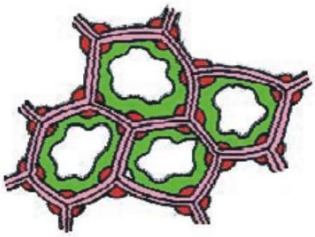
(2) Most of the Dicotyledonous stem

(3) All Monocotyledonous stem

(4) All Dicotyledonous stem

BAP300

6. Identify the tissue stage shown below as well as the related right place of its occurrence in a plant.



Tissue		Site of occurrence
(1) Sclerenchyma	-	Seed coat of legumes
(2) Collenchyma	-	Pulp of guava
(3) Collenchyma	-	Petiole of leaf
(4) Parenchyma	-	Fruit wall of nuts

BAP301

7. **Assertion :** Both apical and intercalary meristems are primary meristems.
Reason : Both appear early in the life of a plant and contribute to the formation of the primary plant body.
(1) Both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.
(2) Both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.
(3) Assertion is True but the Reason is False.
(4) Both Assertion & Reason are False.

BAP302

8. **Assertion :-** Intercalary meristem occurs between mature tissues.
Reason :- Intercalary meristem occur in grasses and regenerate parts removed by the grazing herbivores.
(1) Both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.
(2) Both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.
(3) Assertion is True but the Reason is False.
(4) Both Assertion & Reason are False.

BAP303

9. **Assertion :-** Collenchymatous cells assimilate food when they contain chloroplast.
Reason :- They provide mechanical support to growing part of the plant.
(1) Both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.
(2) Both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.
(3) Assertion is True but the Reason is False.
(4) Both Assertion & Reason are False

BAP304

10. **Assertion** :- Parenchyma is a permanent tissue.
Reason :- Parenchyma forms the major component within organ.
(1) Both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.
(2) Both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.
(3) Assertion is True but the Reason is False.
(4) Both Assertion & Reason are False

BAP305

06. ANATOMY OF DICOTYLEDONOUS AND MONOCOTYLEDONOUS PLANTS

(1) DICOTYLEDONOUS ROOT :

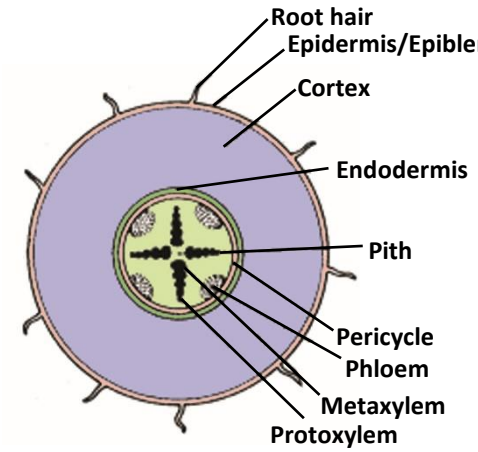
Internal structure of a typical dicotyledonous root shows following anatomical features :-

(A) Epiblema/Epidermis :-

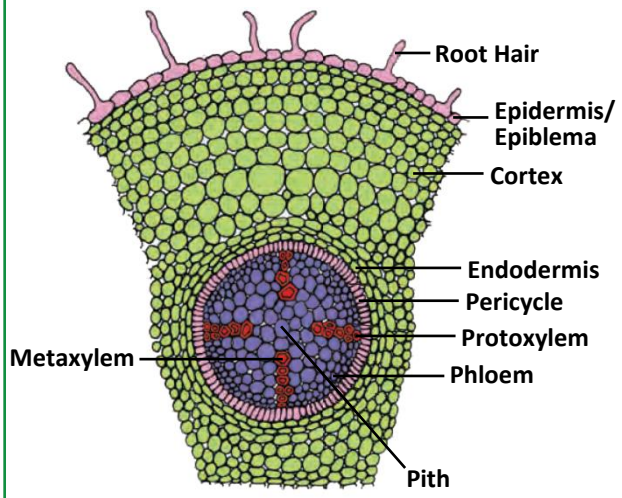
- It is **uniseriate** (single layered) outermost layer. **Cuticle and stomata are absent.**
- Many of the epidermal cells protrude in the form of unicellular root hairs means unicellular root hairs are formed due to elongation of cells of epiblema.
- Hypodermis is absent in the roots.

(B) Cortex :-

- It is made up of thin walled **parenchymatous** cells with intercellular spaces. Chloroplast is absent, so they are non-photosynthetic.



(Outline diagram)



(A part of cellular diagram)

T.S. of Primary Dicotyledonous root

NCERT XI Page No. 74, Figure No. 6.3(a)

(C) Endodermis :-

- The innermost layer of the cortex is called endodermis.
- It comprises a single layer of barrel - shaped cells without any intercellular spaces.
- This layer of **barrel shaped cells** is situated between the pericycle and cortex. Casparian strips/bands are present on radial and tangential walls of endodermis. These strips are made up of **ligno-suberin means lignin & suberin (mainly suberin)**.
- Suberin is water impermeable waxy material.
- Casparian strips were discovered by **Caspari**.
- The cells of endodermis which are situated in front of protoxylem cells are devoid of Casparian strips. These are called **passage cells/path cells.**
- Passage cells provide path to absorbed water from cortex to pericycle.
- Intercellular spaces are absent between the cells of endodermis of root.
- **Endodermis** acts as a **water tight jacket** (Dam) which **prevents leakage of water from stele**.

(D) Pericycle :-

- It is a single or **few layers of thick walled parenchymatous cells**.
- Initiation of **lateral roots** occurs from the cells of pericycle. Lateral roots are **endogenous** in origin because they originate from the stelar region.

(E) Vascular Bundles :

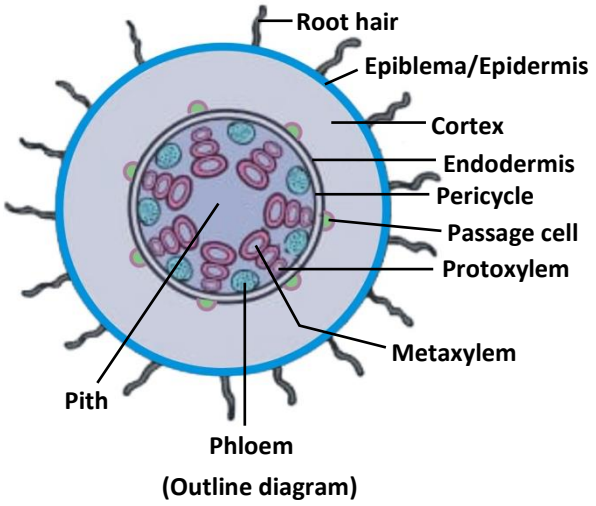
- Vascular bundles are **radial** and xylem is **exarch.**
- The number of xylem patches and phloem patches are usually two to four but they may be two to six (diarch to hexarch).
- Tetrarch condition is found in gram & sunflower.
- Parenchyma which is found between the xylem and phloem is called **conjuctive tissue**.
- In T.S. of dicot root xylem vessels appear hexagonal or polygonal in shape.

(F) Pith :

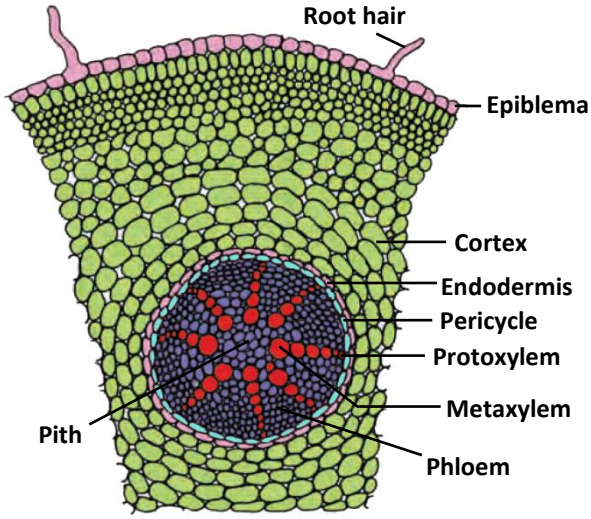
- In dicot root pith is **small (less developed)** or **inconspicuous** or absent.

(2) MONOCOTYLEDONOUS ROOT :

- The internal structure of a typical monocotyledonous root is similar to dicotyledonous root except some differences which are as follows :-
- Number of xylem bundles are usually more than six (polyarch) in monocotyledonous root.
- **Pith is large and well developed** in monocotyledonous root
- **Xylem vessels** appear **circular or oval shape**.



(Outline diagram)



(A part of cellular diagram)

NCERT XI Page No. 74, Figure No. 6.3(b)

T.S. of Monocotyledonous root

(3) DICOTYLEDONOUS STEM :

Internal structure of a typical **dicotyledonous stem** shows following anatomical features :-

(A) Epidermis : Epidermis is the outermost protective layer of the stem. It is made up of elongated compactly arranged cells. It is **single layered** and lack of chloroplasts.

- Stomata, **multicellular hairs (trichomes)** are present on epidermis. Thin **cuticle** is present on epidermis.
- Epidermis plays a significant role in protection.
- Trichomes help in preventing water loss due to transpiration.

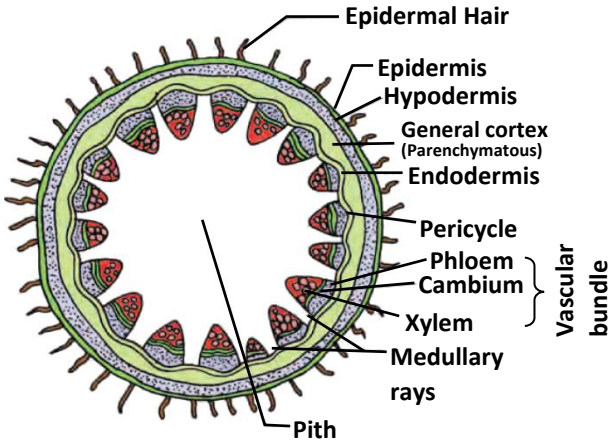
(B) Cortex : The cells arranged in multiple layers between epidermis and pericycle constitute the cortex. In dicotyledon stem cortex is divided into three parts or sub zones.

(i) Hypodermis (ii) General cortex (iii) Endodermis

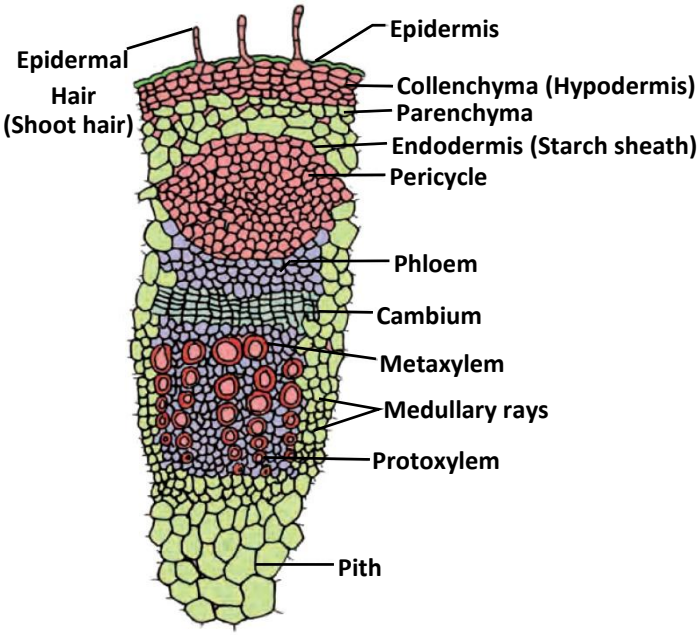
(i) Hypodermis : It is present just below the epidermis. It is multilayered thick. It is **composed of collenchyma** and cells often contain **chloroplasts**.

(ii) General Cortex : This part is composed of rounded thin walled cells of **parenchyma** with conspicuous intercellular spaces. Storage of food is the main function of the cortex. The innermost layer of the cortex is called **endodermis**.

(iii) Endodermis : It is single layered. The cells of the endodermis are rich in starch grains and the layer is also referred to as the starch sheath.



(Outline diagram)



(A part of cellular diagram)

T.S. of Dicotyledonous stem

NCERT XI Page No. 75, Figure No. 6.4 (a)

(C) Pericycle :

- Pericycle is situated below the endodermis. The pericycle of stem is **multilayered.**
- In **sunflower** stem, **pericycle** is made of alternate bands of **parenchymatous** & **sclerenchymatous** cells.
- The pericycle is present above the phloem in the form of semilunar patches of sclerenchymatous called bundle cap or hard bast.

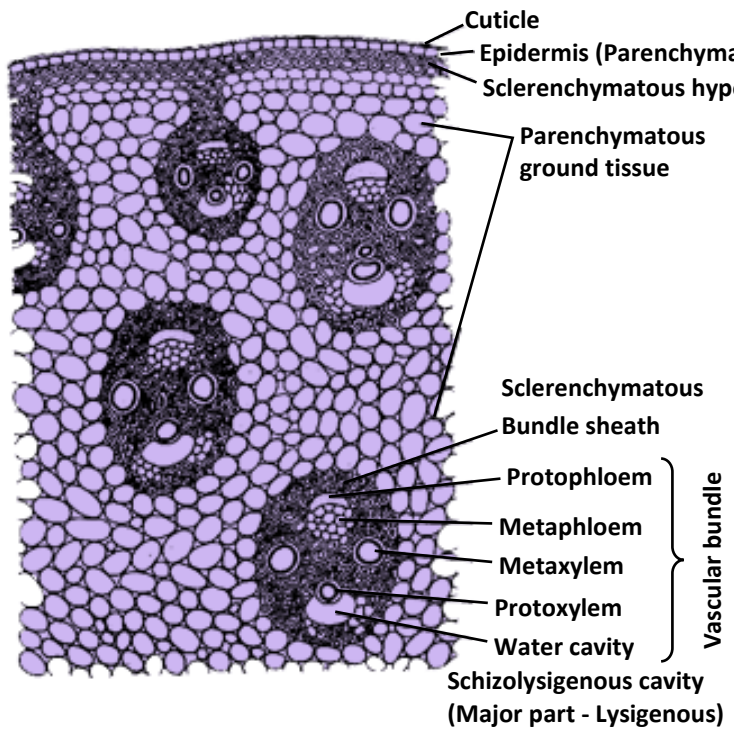
(D) Vascular Bundles : The **wedge shaped** vascular bundles are **arranged in a ring**. The ring arrangement of vascular bundles is a characteristic of dicot stem. Each vascular bundle is **conjoint, collateral** and **open** and **xylem is endarch**.

(E) Medullary Rays : A few layers of radially arranged parenchymatous cells in between the vascular bundles, called **pith rays or medullary rays.** The main function of pith rays is radial conduction of food and water.

(F) Pith : A large number of rounded, parenchymatous cells with large intercellular spaces which occupy the central portion of the stem constitute the pith.

(4) MONOCOTYLEDONOUS STEM :

Internal structure of a typical **Monocotyledonous stem** shows following anatomical features :-



T.S. of Maize Stem - [A part of cellular diagram]

NCERT XI Page No. 75, Figure No. 6.4 (b)

(A) Epidermis :

Epidermis is the outer most single celled thick layer. It is covered with thick cuticle. **Multicellular hairs are absent.**

(B) Hypodermis :-

Hypodermis of monocotyledonous stem is **made up of sclerenchyma**. It is 2-3 layered thick. In monocot stem rigidity is more in hypodermis whereas in dicot stem elasticity is more. It provides **mechanical** support to the plant.

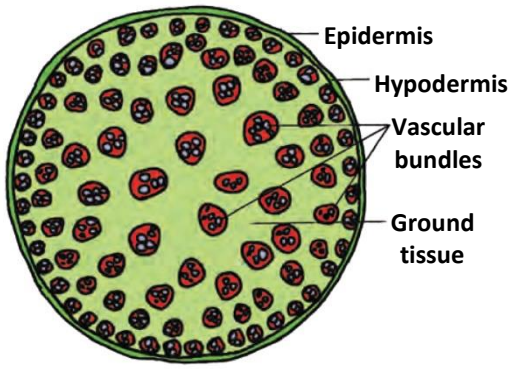
(C) Ground tissue :-

It is large, conspicuous parenchymatous. There is no differentiation of ground tissue in monocotyledonous stem. It means ground tissue is **not differentiated into general cortex, endodermis, pericycle, pith & medullary rays.**

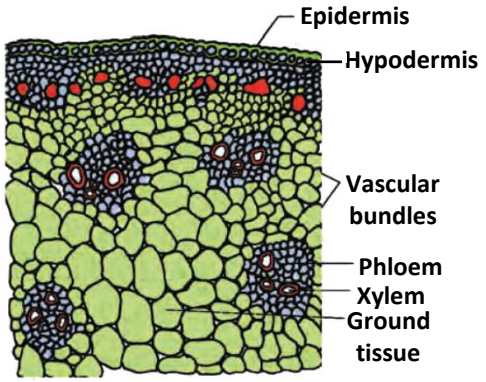
(D) Vascular Bundle :-

- Many vascular bundles are found **scattered** in the ground tissue and V.B. are generally **oval** (egg shaped). Peripheral vascular bundles are generally smaller than the centrally located ones.
- Vascular bundles which are situated towards the **centre** are **large** in size and **less** in number.

  Vascular bundles which are situated towards the **periphery** are **small** in size but **more** in number.
- Each vascular bundle is **conjoint, collateral and closed** and **xylem is endarch**. Each vascular bundle is surrounded by **sclerenchymatous bundle sheath**.
- Water containing cavities are present within the vascular bundles.



(Outline Diagram)



(A part of Cellular Diagram)

T.S. of Monocotyledonous Stem

NCERT XI Page No.75, Figure No. 6.4(b)

(i) **Xylem :-** In xylem number of **vessels** is less. In **metaxylem** there occurs **two large vessels** while in **protoxylem** there occurs **one** or **two small vessels**. There occurs a **water cavity** which is **schizolysigenous** in origin, in which major part of water cavity is **lysigenous** in origin (formed due to lysis of protoxylem elements) and few part of water cavity is schizogenous (formed by separation of cells).

(ii) **Phloem :-** It consists of sieve tube elements and companion cells. **Phloem parenchyma is absent**.

LEAVES

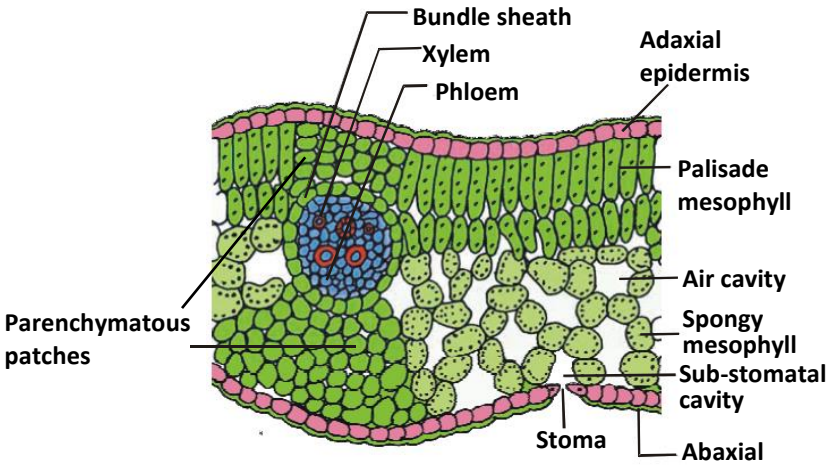
Generally leaves are divided into two categories - Dorsiventral leaves and isobilateral leaves. The differences in between them are as follows :

Dorsiventral	Isobilateral leaf
1. Present at **right angle to stem**	**1.** Arranged **parallel to stem**.
2. Upper surface of leaf receives more sun light as compared to the lower surface, so there occur **difference** between internal structure of upper and lower surfaces Example :- Usually in **Dicots**	**2.** Both surfaces of leaf receive equal amount of sun light so **no difference** occurs between internal structure of upper & lower surfaces. Example :- Usually in **Monocots**

(5) DORSIVENTRAL (DICOTYLEDONOUS) LEAF :

Internal structure of a typical **Dorsiventral Leaf** shows following anatomical features :-

- Cuticle is present on both surfaces but **cuticle on upper surface is more thick.**
- In dorsiventral leaves **stomata are more on lower surface** and stomata on upper surface may even absent or less in number.
- The tissue between the upper & the lower epidermis is called the mesophyll.
- **In dicot leaf, mesophyll is differentiated** into **palisade** parenchyma (palisade mesophyll or palisade tissue) and **spongy** parenchyma (spongy mesophyll or spongy tissue).
- **Palisade tissue** is situated towards the upper (adaxial or ventral) surface. It is made up of elongated cells which are arranged vertically and parallel to each other and have more chloroplasts and a large vacuole.



T.S. of Dorsiventral (Dicotyledonous) Leaf

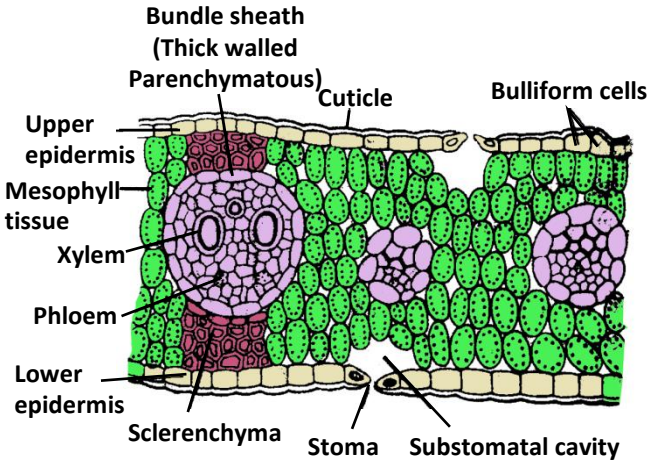
NCERT Page No. 76, Figure No. 6.5(a)

- **Spongy tissue** is situated towards lower (abaxial or dorsal) surface. The cells are oval or rounded and between the cells large air spaces / air cavities are present.
- In **dorsiventral leaf**, two distinct patches of **parenchyma (mainly)/**collenchyma are present above and below the large vascular bundle and extend up to the upper and lower epidermal layers.

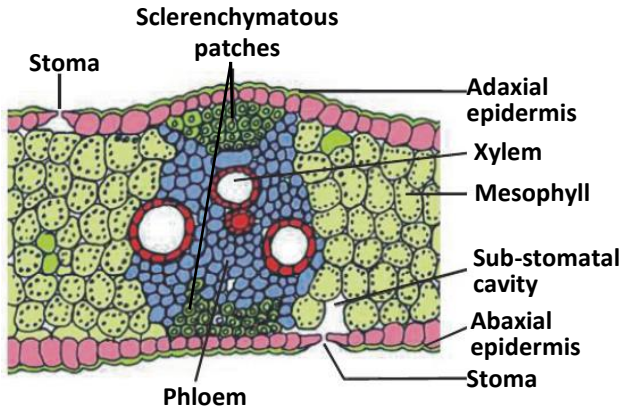
(6) ISOBILATERAL (MONOCOTYLEDONOUS) LEAF :

Internal structure of a typical Isobilateral Leaf shows following anatomical features :-

- The **thickness of cuticle is equal** on both surfaces.
- Usually **stomata on both surfaces** are **equal** in number.
- **Mesophyll is not differentiated** into palisade and spongy tissues in isobilateral leaves. Mesophyll cells have only a few intercellular spaces.
- In **isobilateral leaf**, two distinct patches of **sclerenchyma** are present above and below the large vascular bundle and extend up to the upper and lower epidermal layers. These are called bundle sheath extensions.



T.S. of Isobilateral (Monocotyledonous) leaf



T.S. of Isobilateral (Monocotyledonous) leaf
NCERT XI Page No. 76, Figure No. 6.5(b)

- Similar types of vascular bundles are found in both dorsiventral and isobilateral leaves. Vascular bundles of leaves are **conjoint, collateral** and **closed**.
- **Protoxylem** is situated **towards the adaxial** (upper) surface and **protophloem towards the abaxial** (lower) surface in the vascular bundle. Leaves are **devoid** of **endodermis** and **pericycle**.
- Vascular bundles are surrounded by a **bundle sheath**. It is made up of thick walled **parenchyma.**
- In the leaves of **C_4-plants** (e.g. sugarcane, maize etc.) **bundle sheath is chlorenchymatous.**
- **In grasses**, certain adaxial epidermal cells along the veins modify themselves into large, empty, colourless cells. These are called **bulliform cells or motor cells .** When the bulliform cells in the leaves have absorbed water and are turgid, the leaf surface exposed. When they are flaccid due to water stress, they make the leaves curl inwards to minimise water loss.
- The stomatal aperture, guard cells and the surrounding subsidiary cells are together called stomatal apparatus.
- The size of vascular bundles are dependent on the size of the veins. The veins vary in thickness in the reticulate venation of the dicot leaves.
- The parallel venation in monocot leaves is reflected in the near similar sizes of vascular bundles (except in main veins) as seen in vertical sections of the leaves.

Types of leaves	Position of stomata	Examples
Epistomatic leaf	Stomata are present only on upper surface	Floating leaves Examples - Lotus ***(Nelumbium)*** ***Victoria regia, Nymphaea***
Hypostomatic leaf	Stomata are present on lower surface	Mostly in dicot leaves
Amphistomatic leaf	Stomata are present on both surfaces	Mostly in monocot leaves
Astomatic leaf	Stomata are absent or non-functional	Submerged leaves Examples - ***Vallisneria,*** ***Hydrilla***

07. SECONDARY GROWTH

- By the activity of lateral meristems (vascular cambium and cork cambium), **increase in the circumference/girth/ thickness** of the plant organs is called secondary growth.
- Normally secondary growth takes place in **roots and stems of dicotyledons** & **gymnosperms**.
- The tissues involved in secondary growth are two lateral meristems : vascular cambium and cork cambium.
- Secondary growth is not found in the leaves and monocots.
- Due to lack of cambium in monocotyledons, secondary growth is absent.

(1) SECONDARY GROWTH IN DICOTYLEDONOUS STEM :

(A) Secondary growth in stelar region by vascular cambium :

Secondary growth in stelar region begins earlier than the extrastelar region.

(i) Formation of ring of vascular cambium :- A cambium which is present inside the vascular bundle (means between primary xylem and primary phloem) is called **intrafascicular- cambium**. This is a type of primary lateral meristem.

- First of all, cells of medullary rays adjoining intrafascicular cambium become meristematic to form **interfascicular cambium** which is a secondary lateral meristem form by the process of dedifferentiation.

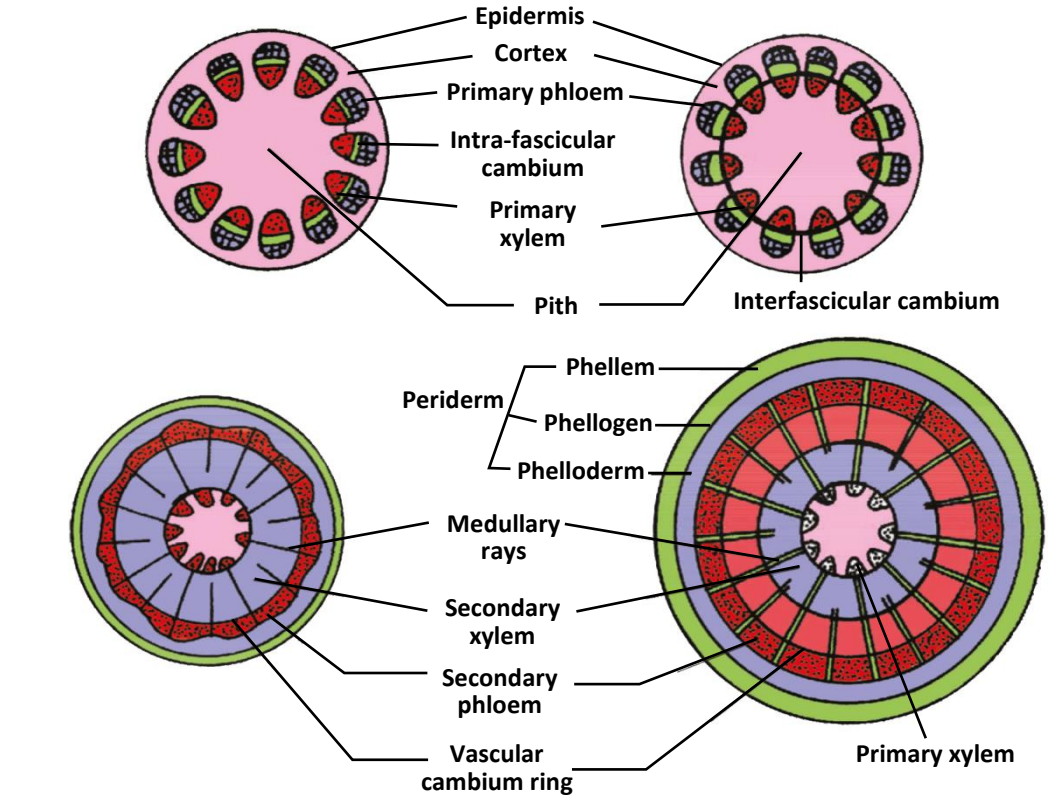
- Intrafascicular and interfascicular cambium are collectively known as **vascular cambium** or intra stelar cambium. Vascular cambium is formed in the form of a complete ring which is made up of single layer of cells.
- In dicot stem, the **vascular cambium is partly primary and partly secondary** in origin.
- Two types of cells are found in the ring of this vascular cambium.
  - **Fusiform initials**
  - **Ray initials**
- Fusiform initials are long with pointed ends, whereas ray initials are spherical/rounded or oval in shape.
- Fusiform initials are more in number in vascular cambium.

(ii) Activity of vascular cambium :

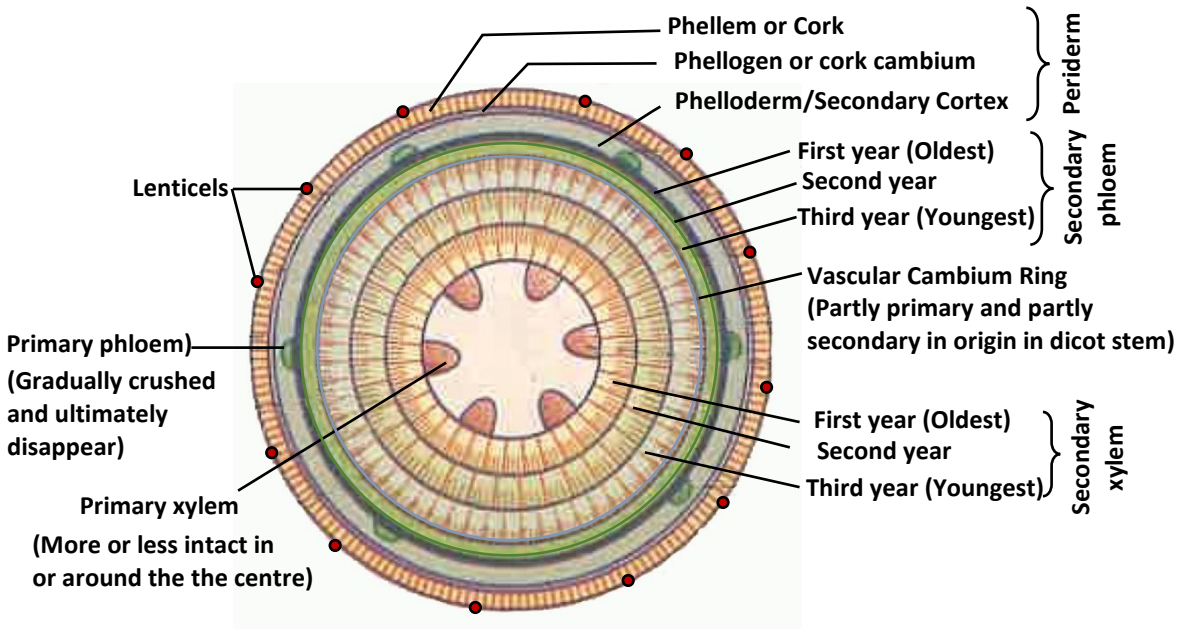
(a) Activity of fusiform initials :

- Continuous periclinal divisions (parallel to longitudinal axis) and anticlinal division takes place in fusiform initials, then few cells are formed towards the periphery and these cells are differentiated into **secondary phloem or bast** and the cells which are formed towards the centre (towards pith) are differentiated into **secondary xylem or wood**.
- The cambium is generally more active on the inner side than on the outer.
- Normally **more secondary xylem** is formed as compared to the secondary phloem **due to unequal distribution of hormones**.

  (**Secondary xylem** is formed **8-10 times more** as compared to the secondary phloem).



Secondary growth in a dicot stem (diagrammatic) – stages in transverse views



T.S. of Woody dicot stem showing secondary growth in stelar and extra stelar regions

*** Primary phloem and earlier secondary phloem get gradually crushed due to the continued formation and accumulation of secondary xylem.

- By the pressure of secondary xylem, all the primary tissues- such as **primary xylem, pith** are pushed towards the centre.

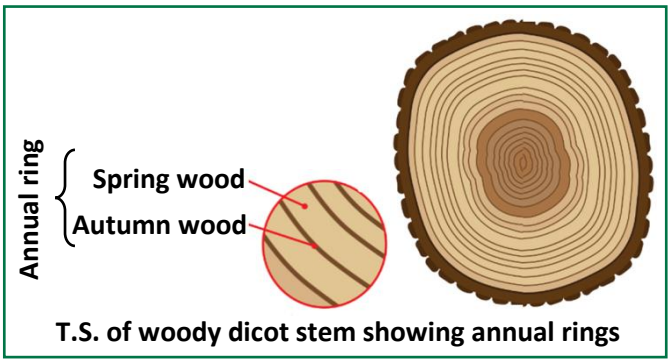
- The **primary xylem** however remains **more or less intact** in or around the centre. The primary phloem and earlier secondary phloem (old secondary phloem) get gradually crushed due to the continued formation and accumulation of secondary xylem.

(b) Activity of Ray initials :-

- Periclinal divisions take place in ray initials.
- Ray initials cuts off (form) parenchymatous cells. These are called **vascular rays** (Xylem rays & phloem rays) or **secondary medullary rays** which passes through the secondary xylem and secondary phloem in the radial direction. They **conduct water** and **food** in **radial direction**.

(iii) Formation of Annual Rings :-

- Activity of vascular cambium is under the control of many physiological and environmental factors.
- In temperate regions, the climatic conditions are not uniform through the year.
- In the spring season, vascular cambium is very active and produces a large number of secondary xylem elements having vessels with wider cavities / lumens. The wood formed during this season is called **spring wood** or **early wood.**



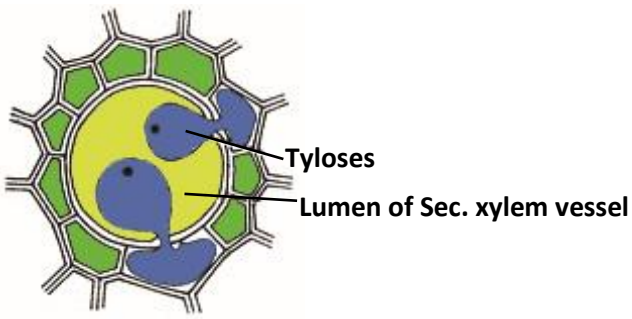
T.S. of woody dicot stem showing annual rings

- In winter and autumn season, the vascular cambium is less active and forms fewer secondary xylem elements that have vessels with narrow lumen and this wood is called winter wood or **autumn wood** or **late wood.**
- The spring wood is lighter in colour and has a lower density whereas the autumn (or winter) wood is darker and has a higher density.
- The **autumn** and **spring wood** are formed in the form of concentric rings, called **growth rings**. The two kinds of woods that appear as alternate concentric rings, constitute an annual ring.
- A **ring of autumn wood** and a **ring of spring wood** are collectively known as **Annual ring**. The number of annual rings, formed in a tree give the idea of the age of the tree.

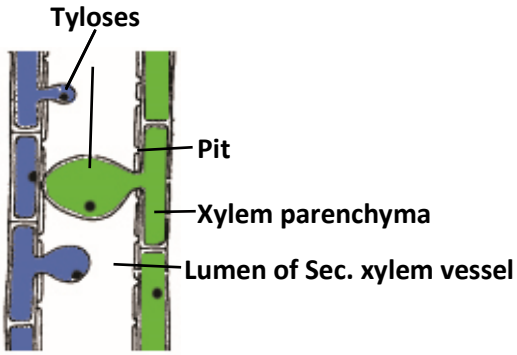
- The study of determination of age of a tree/plant by counting annual rings is called **Dendrochronology**.
- The annual rings are counted from the **base of the stem.**
- **More distinct annual rings** are formed in **temperate plants**. Because in temperate regions, the climatic conditions are not uniform throughout the year.

(iv) HEART WOOD & SAP WOOD :

- In old trees, the greater part of secondary xylem is dark brown.
- The organic compounds like tannins, resins, gums, oils and aromatic substances etc. are filled in lumen of tracheids and vessels of secondary xylem. Due to this, **central region** of secondary xylem becomes **dark brown**. It is called **heart wood or duramen**. These substances make it hard, durable and resistant to the attack of micro-organisms and insects. Heart wood comprises dead elements with highly lignified walls. Heart wood provides mechanical strength to stem.
- The **peripheral region** of secondary xylem which is **light** in colour, is called **sap wood or alburnum**.
- The function of sap wood is conduction of water and minerals.
- **Heart wood does not conduct water** and mineral **because :-**
- Cavities of tracheids and vessels are progressively filled with waste materials.
- The balloon shaped structures called tyloses are extensions of xylem parenchyma cells into vessels or tracheids.



T.S. of Sec. xylem vessel showing tyloses



L.S. of Sec. xylem vessel showing tyloses

- Study the structure of wood is known as **Xylology**. The wood is actually a **secondary xylem**.
- Position of youngest secondary phloem is just outside the vascular cambium.
- Position of oldest secondary phloem is just inside the primary phloem.
- Position of youngest layer of secondary xylem is just inside the vascular cambium.
- Position of oldest layer of secondary xylem is just outside the primary xylem.
- As the time passes amount of heart wood increases more as compared to sap wood.

(v) Classification of wood :

Classification based on vessels :-

On the basis of presence or absence of vessels, wood is classified into two categories

- **Non-porous wood :- Vessels are absent** in this type of wood.

  Example :- **In most of the gymnosperms**
- **Porous wood** :- **Vessels are present** in this type of wood.

  Example :- **In most of the dicots**.

Most durable wood $\longrightarrow$ ***Tectona grandis*** **(Teak = Sagwan)**

(B) Secondary Growth in Extra Stelar Region by Cork Cambium :

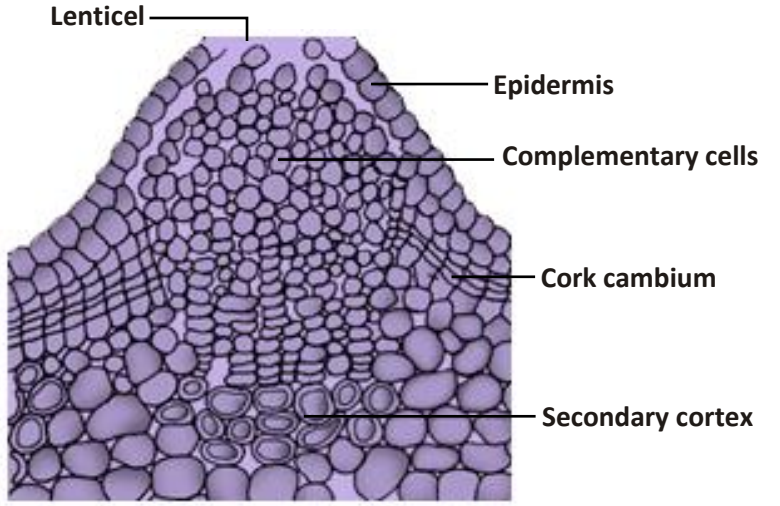
- Secondary growth takes place in extra stelar region **due to the activity of cork cambium**. Cork cambium is also known as **phellogen** or **extrastelar cambium**. The cells of the cork cambium are narrow, thin walled and nearly rectangular. Cork cambium develops usually in cortical region by hypodermis.
- As the stem continues to increase in girth due to activity of vascular cambium the outer cortical & epidermal layers get broken & need to be replaced to provide new protective cell layers Hence sooner or later another meristematic tissue called cork cambium or phellogen develops.
- Cork cambium is derived from the **hypodermis (outer part of cortex)** by dedifferentiation. **Cork cambium is single** or **a couple of layers thick (mainly)**. It forms secondary tissues in extra stelar region.
- Cork cambium divides usually by periclinal division to form some cells towards the outside (towards epidermis) and some cells towards the inside (towards general cortex).

Those cells which are formed towards outside, become suberized. Due to this, these cells become dead. These dead cells are known as **cork or phellem**. Those cells which are formed towards the inside, are differentiated into parenchyma and may contain chloroplasts. These are called **secondary cortex or phelloderm**.

- Phellem, phellogen and phelloderm are collectively known as periderm.
- The **cork is impervious to water** due to **suberin deposition** in the cell wall.
- **Commercial cork** is obtained from ***Quercus suber*** (**oak**). Common bottle cork is made from this cork.
- Cork is formed in high quantity and secondary cortex is in less quantity because activity of cork cambium is more towards outside.
- Due to activity of the cork cambium, pressure builds up on the remaining layers peripheral to phellogen and ultimately these layers die and slough off.

(i) Lenticels :

- At certain regions, the phellogen (cork cambium) cuts off/forms closely arranged parenchymatous cells on the outer side instead of cork cells. These thin walled, rounded, colourless, parenchymatous cells are called complementary cells. These cells are **not suberized.** As the complementary cells increase in number, pressure is exerted on the epidermis due to which it ruptures, forming a lens-shaped openings called **lenticels.**
- Complementary cells are formed by the activity of **phellogen** (cork cambium).



Transverse section of woody dicot stem passing through a lenticel

- Lenticels occur in most woody trees.
- Lenticels are mainly **found on woody stems** and they are **never found** on **leaves**. They are also present on some **fruits**.
- Lenticels are not found in herbaceous dicots and monocot plants.

Functions :

- **Exchange of gases :** Lenticels permit the exchange of gases between the outer atmosphere and the internal tissue of the stem (main function).
- **Help in transpiration** i.e., Lenticular transpiration.

(ii) Bark :

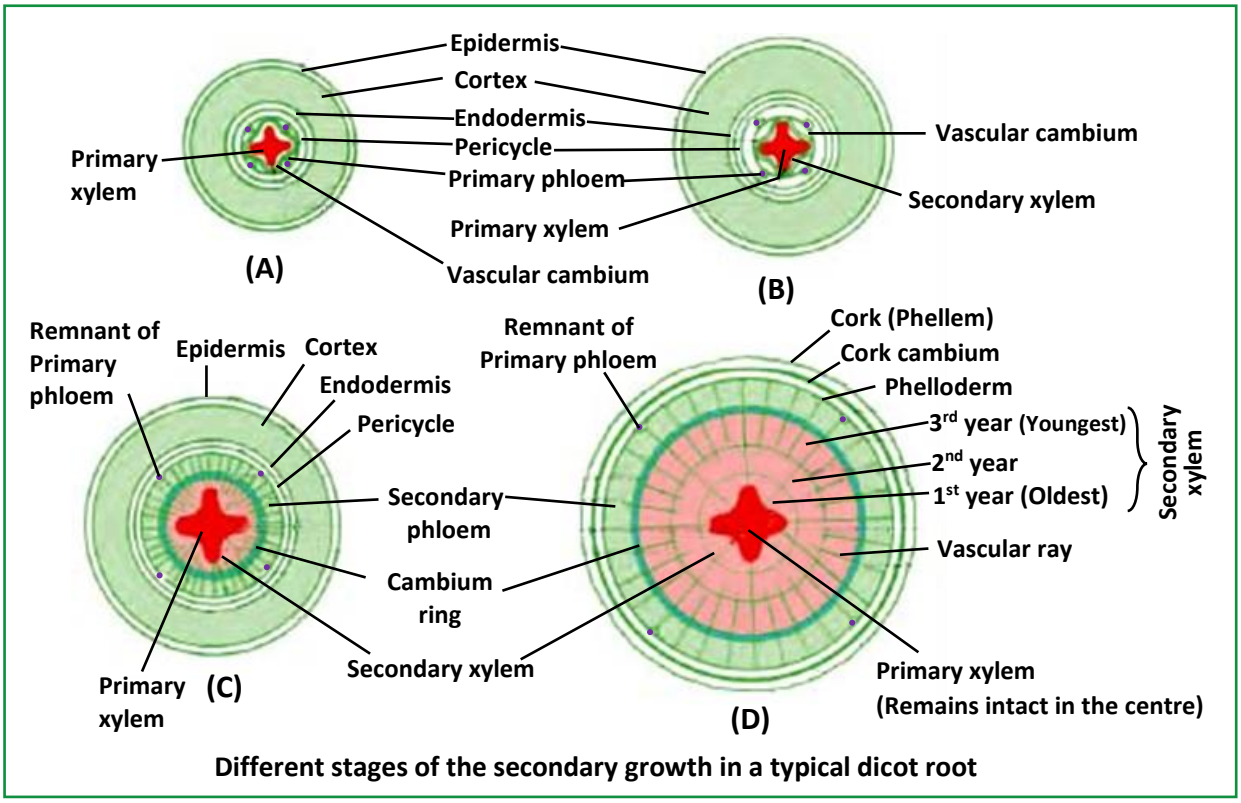
Bark is a non-technical term that refers to **all tissues exterior to the vascular cambium**, therefore including secondary phloem.

- If bark is removed in the form of a ring (Girdling) from the base of main stem then root dies first due to lack of food.
- Girdling is not possible in monocot stem because vascular bundles are scattered.
  If complete bark is removed then plant dies due to excessive water loss.
- Bark that is formed early in the season is called early or soft bark. Towards the end of the season late or hard bark is formed.
- Secondary phloem and periderm are included in bark.

(2) SECONDARY GROWTH IN DICOTYLEDONOUS ROOT :

- In the dicot root, the vascular cambium is completely secondary in origin.
- First of all, the tissue located just below the phloem bundles means **conjunctive tissue** becomes meristematic during the secondary growth in a dicotyledonous root and forms separate curved strips of vascular cambium below the phloem bundles. Then after, the **cells of pericycle lying above the protoxylem** also become meristematic to form additional strips of cambium. In this way a complete wavy ring of vascular cambium is formed.
- The shape of **vascular cambium** is **wavy in the beginning,** but later on it becomes circular due to the pressure of secondary xylem.

- The portion of vascular cambium formed by conjunctive tissue becomes meristematic first and forms the secondary xylem towards the centre. Ultimately the cambium becomes circular by the pressure of secondary xylem.



Different stages of the secondary growth in a typical dicot root

- The activity of vascular cambium of root is the same as the activity of vascular cambium of stem. **Secondary xylem** is formed towards the inner side and **secondary phloem** is formed towards the outer side by vascular cambium.
- In dicot root both primary and secondary medullary rays are formed during secondary growth hence, they are secondary in origin.
- **Cork cambium** is originated **from the pericycle** by the process of **dedifferentiation** in roots. **Cork** is formed towards the outside and **secondary cortex** is formed towards the inner side by the cork cambium.
- Lenticels are also found in roots but less in number as compared to stem.
- Primary cortex completely degenerates in roots after the secondary growth of one or two years. This falls down due to the pressure of cork, whereas in stem, it degenerates after the long duration.

- Secondary growth is essential in roots to provide strength to the growing aerial parts of the plants and fulfil the requirement of water and minerals.
- Generally clear annual rings are not seen in roots because roots are not effected by the changes of environment.
- Secondary growth is not found in monocot roots.
- **In dicot roots, all cambia and pith rays (medullary rays) are secondary in origin.**
- Xylem/lignin is stained by safranin and phloem is stained by fast green.
- Transition of exarch bundles of root to endarch bundles of stem occurs in hypocotyl.
- In some plants like date palm increase in length as well as girth of stem due to primary thickening meristem.

★ Golden Key Points ★

- In roots, the parenchymatous cells which lie between the xylem and the phloem are called conjunctive tissue.
- The tissues involved in secondary growth are the two lateral meristems i.e. vascular cambium and cork cambium.
- During secondary growth the primary xylem however remains more or less intact, in or around the centre.
- Bark is a non-technical term that refers to all tissues exterior to the vascular cambium.
- In monocot stem, water containing cavities are present within the vascular bundles.
- The growth of the roots and stems in length with the help of apical meristem is called the primary growth. Apart from primary growth most dicotyledonous plants exhibit an increase in girth. This increase is called the secondary growth. The tissues involved in secondary growth are the two lateral meristems: vascular cambium and cork cambium.
- The meristematic layer that is responsible for cutting off vascular tissues – xylem and phloem – is called vascular cambium. In the young stem it is present in patches as a single layer between the xylem and phloem. Later it forms a complete ring.
- In dicot stems, the cells of cambium present between primary xylem and primary phloem is the intrafascicular cambium. The cells of medullary rays, adjoining these intrafascicular cambium become meristematic and form the interfascicular cambium. Thus, a continuous ring of cambium is formed.
- In the dicot root, the vascular cambium is completely secondary in origin. It originates from the tissue located just below the phloem bundles, a portion of pericycle tissue, above the protoxylem forming a complete and continuous wavy ring, which later becomes circular.

BEGINNER'S BOX-2

PRIMARY INTERNAL STRUCTURE TO SECONDARY GROWTH

1. Monocot roots are usually :-
(1) Diarch (2) Triarch (3) Tetrarch (4) Polyarch
BAP306

2. In which of the following sclerenchymatous pericycle is found in the form of semi-lunar patches:
(1) Sunflower stem (2) Sunflower root (3) *Zea mays* stem (4) Cucurbita stem
BAP307

3. Position of protoxylem in the vascular bundle of dorsiventral leaf is :-
(1) Adaxial (2) Abaxial
(3) Both (1) & (2) (4) Towards dorsal surface
BAP308

4. The innermost layer of bark is :-
(1) Primary phloem (2) Secondary phloem
(3) Periderm (4) Phelloderm
BAP309

5. Lenticels are found in :-
(1) All plants (2) Woody trees (3) Monocots (4) All vascular plants
BAP310

6. Pick out the incorrect statement from the following :
(1) Study of internal structure of plants is called anatomy.
(2) Different organs in plant show differences in their internal structure.
(3) The monocots and dicots are anatomically same in nature.
(4) Internal structure also show adaptations to diverse environments.
BAP311

7. **Assertion (A) :** Endodermis of dicot root act as water tight jacket.
Reason (R) : Strips of suberin are present on radial and tangential walls of endodermis of dicot root.
(1) Both (A) and (R) are correct but (R) is not the correct explanation of (A).
(2) (A) is correct but (R) is not correct.
(3) (A) is not correct but (R) is correct.
(4) Both (A) and (R) are correct and (R) is the correct explanation of (A).
BAP312

8. **Statement-I:** In grasses, certain adaxial epidermal cells along with the veins modify themselves into large empty, colourless cell. These are called bulliform cells.
Statement-II: All tissues on the outer side of endodermis such as pericycle, vascular bundles and pith constitute the stele.
(1) Both Statement-I and Statement-II are correct.
(2) Both Statement-I and Statement-II are incorrect.
(3) Statement-I is correct but Statement-II is incorrect.
(4) Statement-I is incorrect but Statement-II is correct. **BAP313**

9. **Assertion** :- Monocot roots are polyarch.

Reason :- In monocot root more than six xylem bundles are present.

(1) Both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.

(2) Both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.

(3) Assertion is True but the Reason is False.

(4) Both Assertion & Reason are False.

BAP314

10. Which one of the following option gives the correct categorisation of stem, root and leaves :-

	A **Dicot stem**	**B** **Monocot stem**	**C** **Dicot root**	**D** **Dicot leaves**
(1)	Starch sheath	Vascular bundle conjoint and open	2 to 4 xylem	Spongy parenchyma
(2)	Vascular bundle are conjoint and open	Vascular bundle and conjoint and open	5 to 6 xylem	Spongy parenchyma
(3)	Spongy parenchyma	5 to 6 xylem	Vascular bundle are conjoint and open	Closed vascular bundle
(4)	Starch sheath	Vascular bundle are conjoint and closed	2 to 4 xylem	Palisade and spongy parenchyma

BAP315

BEGINNER'S BOX — ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	4	1	4	1	3	1	2	2	2

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	4	1	1	2	2	3	4	3	1	4

Tissue

Meristematic tissue
Having Cell division capacity

- **Apical meristem**
  - Present at root and shoot apex
  - Primary meristem
- **Intercalary meristem**
  - Present in between mature tissues
  - Primary meristem
- **Lateral meristem**
  - Parallel to longitudinal axis of plants
  - Primary and **secondary** (Mainly)

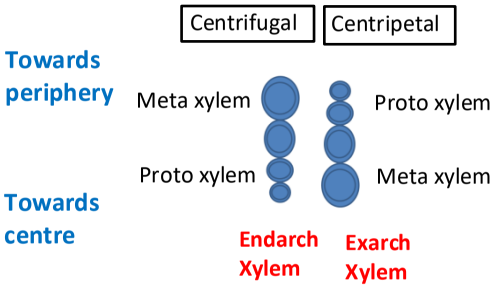
Permanent tissue
No cell division capacity

- **Simple permanent**
  - Made up of only one type of cells (Homogenous tissue)
  - **Parenchyma**
    - Thin walled
    - Form major bulk of plant organ
    - Storage, Secretion, photosynthesis
  - **Collenchyma**
    - Localized thickening
    - Present in Young dicot stem
    - Living mechanical tissue
  - **Sclerenchyma**
    - Highly thickened wall
    - Lignified wall
    - Dead mechanical tissue
- **Complex permanent**
  - Made up of more than one type of cells (Heterogenous tissue)
  - **Xylem**
    (Sap conduction & Mechanical support)
    Tracheids } Dead
    Vessels } Thick walled
    X. Fibres Lignified
    X. Parenchyma- Living
    - Tracheids and vessels are sap conducting elements
  - **Phloem**
    (Food conduction)
    Sieve tube } Living
    Companion cells } Living
    P. Parenchyma
    P. Fibres - Dead
    - Sieve tube and companion cells are found in angiosperms
    - Sieve cells & Albuminous cells are found in gymnosperms & pteridophytes.

Tissue system

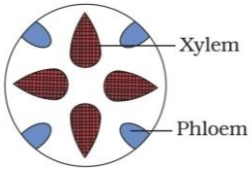
- **Epidermal tissue system**
  - Protection
  - Epidermis, root and stem hair
  - Parenchymatous
- **Ground tissue system**
  - Major part of plant organ
  - Consists of Simple permanent tissues (Mainly parenchymatous)
- **Vascular tissue system**
  - Conducting tissue
  - Xylem and phloem
  - Water, mineral and food conduction

Types of development of primary xylem :-



Types of vascular bundles

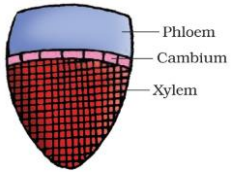
Radial



e.g. Roots

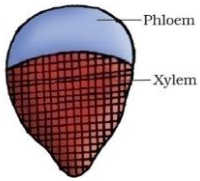
Conjoint collateral

Open



e.g. Dicot stem

Closed



e.g. Monocot stems, Dicot and monocot leaves

Dicotyledonous stem	Monocotyledonous stem
Presence of Trichomes	Absence of Trichomes
Collenchymatous hypodermis	Sclerenchymatous hypodermis
Pith is large & well developed	pith is Undifferentiated
Vascular bundles are open and arranged in a ring	Vascular bundles are closed and scattered

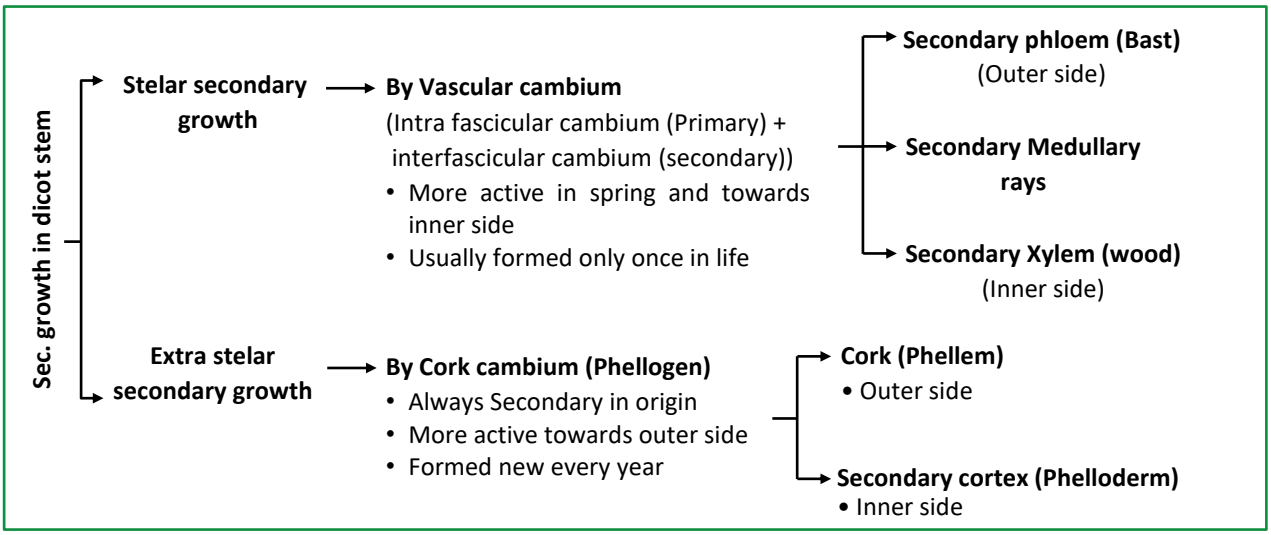
- Ground tissue is undifferentiated in Monocotyledonous stem.

Dicotyledonous root	Monocotyledonous root
Usually 2 to 4 xylem bundles	Usually More than 6 xylem bundles
Hexagonal vessels	Oval shaped vessels
Pith is small or inconspicuous	Pith is large and conspicuous

- In a dorsiventral leaf, mesophyll is differentiated into spongy and palisade mesophyll.
- In a isobilateral leaf, mesophyll is not differentiated into spongy and palisade mesophyll.
- In both types of leaves, xylem is towards adaxial surface while phloem is towards abaxial surface
- Heart wood : Physiologically inactive, Dark brown, Central part of secondary xylem
- Sap wood : Physiologically active, lighter in colour, peripheral part of secondary xylem

Spring wood	Autumn wood
Large number of secondary xylem elements	Fewer secondary xylem elements
Vessels with wide lumens	Vessels with narrow lumens
Lighter in colour	Darker in colour
Lower density	Higher density

- Phellem, Phellogen & Phelloderm are collectively termed as **Periderm**.
- Secondary phloem and periderm are included in bark.
- In dicotyledonous stem, vascular cambium is partly primary and partly secondary in origin.
- In dicot root vascular cambium is completely secondary in origin
- In dicot stem cork cambium usually develops in cortical region (usually from hypodermis) while in dicot root it is usually originated from pericycle.
- Estimate Age of a tree can be determined by counting the annual rings.



NCERT SUMMARY

Anatomically, a plant is made of different kinds of **tissues**. The plant tissues are broadly classified into **meristematic** (apical, lateral and intercalary) and **permanent** (simple and complex). **Assimilation of food and its storage, transportation of water, minerals and photosynthates, and mechanical support** are the main functions of tissues. There are three types of tissue systems – **epidermal, ground and vascular**. The epidermal tissue systems are made of epidermal cells, stomata and the epidermal appendages. The ground tissue system forms **the main bulk of the plant**. It is divided into three zones – **cortex, pericycle and pith**. The vascular tissue system is formed by the **xylem and phloem**. On the basis of presence of cambium, location of xylem and phloem, the vascular bundles are of different types. The vascular bundles form the conducting tissue and translocate water, minerals and food material.

Monocotyledonous and dicotyledonous plants show marked variation in their internal structures. They differ in type, number and location of vascular bundles. **The secondary growth occurs in most of the dicotyledonous roots and stems.**