# ANATOMY OF FLOWERING PLANTS

## THE TISSUES

- A tissue is a group of cells with a common origin and a common function.
- A plant consists of different kinds of tissues.
- Tissues are classified into two types: **meristematic and permanent tissues**. This is based on ability of the cells to divide.
- The cells of meristematic tissues are capable of division while the cells of permanent tissues do not generally divide further.

1. **Meristematic tissues**

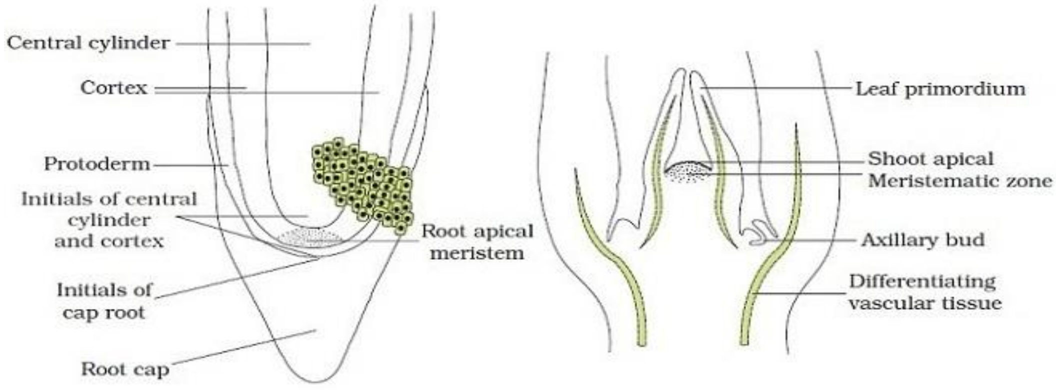
- Growth in plants is largely restricted to specialized regions of active cell division called meristems
- Plants have different kinds of meristems.
- On the basis of their origin, meristems are of two types-primary & secondary.

**Primary meristem**

- Primary meristem are present early in the life of a plant forms the primary plant body
- Primary meristem is of two types: apical &intercalary meristem.

**i) Apical meristem**

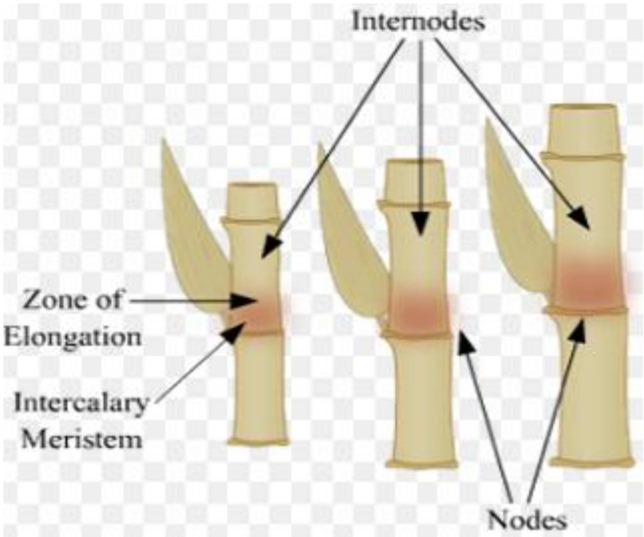
- The meristems present at the shoot and root tips.
- They produce primary tissues.
- There are two types of apical meristem: **shoot apical meristem & root apical meristem**.
- **Root apical meristem**: Present at root tips
- **Shoot apical meristem**: Present at the shoot tip.
- Some cells left behind from shoot apical meristem during the formation of leaves and elongation of stem, constitute the **axillary bud**.
- Such buds are present in leaf axils and can form a branch or a flower.



Apical meristem: (a) Root (b) Shoot

**ii) Intercalary meristem**

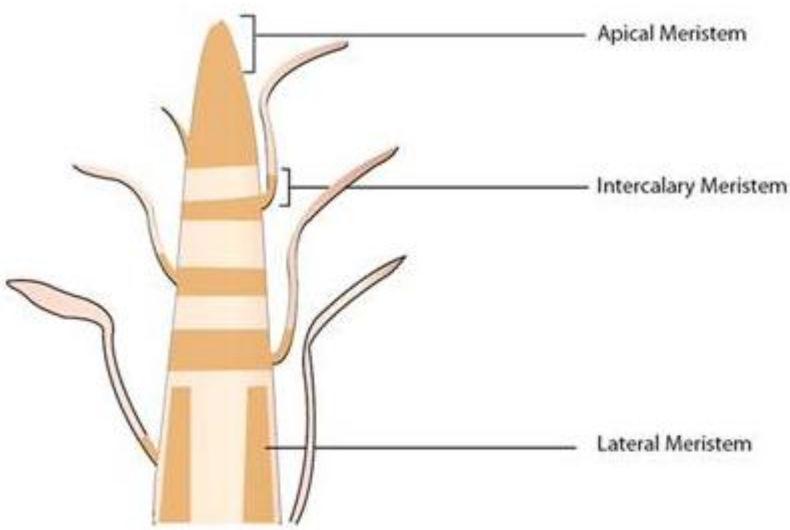
- The meristem present between mature tissues is called intercalary meristem.
- They are seen in grasses. Their function is to regenerate parts destroyed by the grazing herbivores.




**Secondary meristems**

The meristems present in the differentiated regions of roots and shoots plants are called the secondary or lateral meristem. They increase the girth of the stem and usually give rise to woody axis. They are formed later than primary meristem.

- Examples of lateral meristems include fascicular vascular cambium, interfascicular cambium and cork cambium.
- These produce secondary tissues.

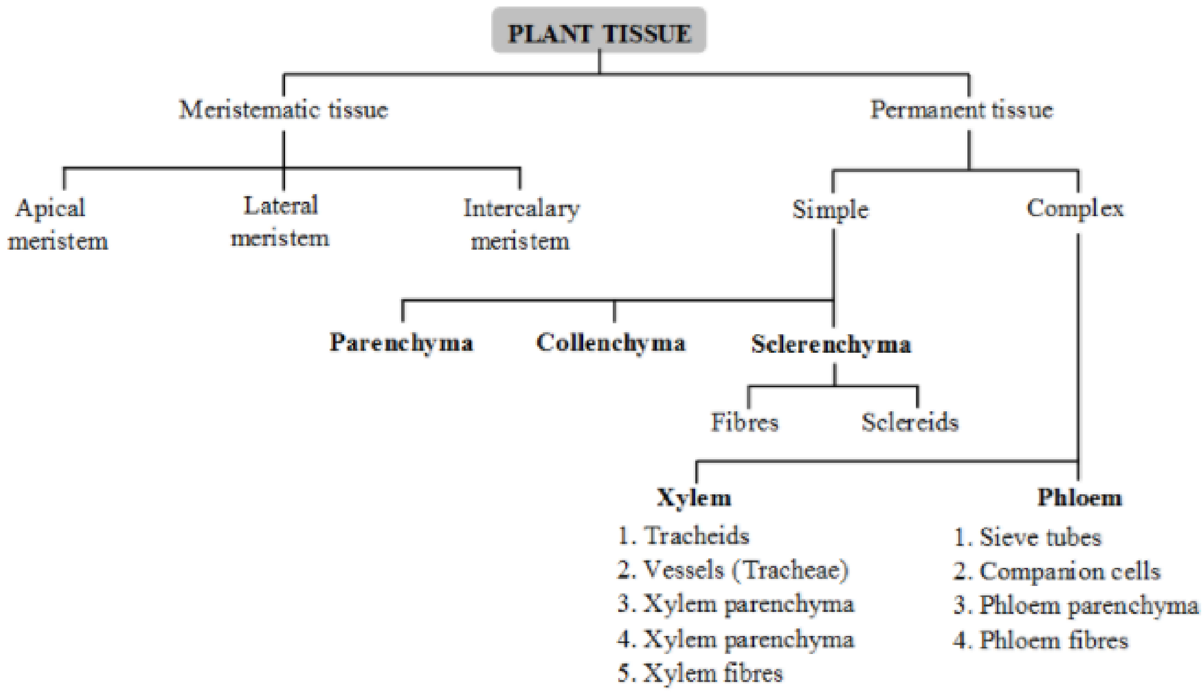



**Permanent tissues**

- The cells that are differentiated from meristems and are specialized in their structure and function constitute permanent tissues. These cells do not generally divide further.
- Permanent tissues that are made up of cells that are similar in structure and function are called simple tissues.
- Permanent tissues made up of different types of cells are called complex tissues.

**Simple tissues**

- A tissue consisting only one type of cells.
- They are parenchyma, collenchyma and sclerenchyma.




**Parenchyma**

- Parenchyma is the most common tissue type.
- The parenchyma consists of cells that are isodiametric.
- They vary in shape depending on function.
- They have thin walls made up of cellulose.
- They usually are closely packed or may have small intercellular spaces.
- Parenchyma cells are modified to perform various functions like photosynthesis, storage, secretion.

**Collenchyma**

- The collenchyma occurs in layer below the epidermis in dicotyledonous plants as hypodermis.
- It is found either as a homogeneous layer or in patches.
- It consists of cells which are much thickened at the corners due to a deposition of cellulose, hemicelluloses and pectin.
- Collenchyma cells vary in shape and often contain chloroplast.
- In collenchyma cells containing chloroplasts food is assimilated.
- Intercellular spaces are absent.
- They provide mechanical support to the growing parts of the plant. They allow the part to bend without breaking. They are present in young parts such as young stem and petiole of a leaf (in dicot herb)

**Types of Collenchyma**

- **Majumdar** divided collenchyma into three types :-
  **1. Lamellar / plate collenchyma: -** The cells of collenchyma arranged in lamellar forms. The cell has thickening on the tangential walls. Due to such type of deposition, cell looks like a lamellar or plates. Ex. *Raphanus*
- **2. Angular collenchyma: -** This collenchyma is formed abundantly. The cells of this tissue is angular. The deposition of pectin at the angles of cell. e.g., *Datura, Cucurbita*
- **3. Lacunar collenchyma: -** Large intracellular spaces are present in between these cells. Deposition of pectin on the wall of intracellular spaces. Intra-cellular spaces of collenchyma thickened. Ex. Sunflower stem.

**III. SCLERENCHYMA**

Name coined by Mettenius –

Main features:-

- Sclerenchyma is the main mechanical tissue.
- These cells are long, narrow, thick walled and dead.
- Cell wall of their cells is thick and lignified.
- Various types of pits are formed due to the deposition of lignin on hard wall.

**Type of Sclerenchyma**

Sclerenchyma cells are of two types - Sclereids & Sclerenchymatous fibers

**I. Sclereids -**

These cells are small extremely thick walled and their ends are pointed. Sclereids are isodiametric or irregular in shape, Sclereids cells have more pits and lumen is almost very small. Their pit cavity (lumen) is branched. Tsirch classified the sclereids on the basis of their shapes:-

**a. Stones cells or Brachysclereids or Grit cells:-**

These cells are spherical or oval in shape. They are found in endocarp of drupe fruits, so that endocarp becomes hard.

**Example -** They are present in endocarp of coconut, mango, almond, walnut etc.

Besides dry fruit brachysclereids also present in fleshy (edible) part of pear. Grittiness in pear fruit is due to this sclereids.

**b. Macro-sclereids or Rod cells or Malpighi cells:-**

They are small and rod like cells. They are present in seed coats.

**Example -** They form part of seed coat in legume plants. Due to their presence seed coat becomes hard. Seed coats of lotus is hardest (stony). Seed coat of French bean is harder among the leguminous plants. They aid seed dormancy in leguminous seeds.

**c. Osteio-Sclereids:-**

These are known as prop-cells. These are pillar like cells. Both end of the cells spread to form a bony structure.

**Example -** These cells are found in leaves of *Hakea* and *Osmanthus*.

**d. Astero Sclereids:-**

These cells are stellate shaped. They are found in floating leaves.

**Example -** The leaves of *Victoria*, lotus etc.

**e. Trichoselereids:-**

These are also known as internal hairs. They are spine-like, bifurcated cells which is present in floating leaves.

**Example -** *Victoria, Nelumbo, Nymphea*.

**II. SCLERENCHYMATOUS FIBER**

On the basis of structure fibers classified into two parts:-

**a. Libriform fibers:-**

They are extremely thickened long fibers. They possess simple pits. Libriform fibers are present in

Phloem, xylem, pericycle and hypodermis. They are present maximum in phloem.

**b. Fiber Tracheids:-**

They are highly thickened as compared to others. Bordered pits are present in these fibers. They are only found in xylem.

On the basis of position fibers divided into three types -

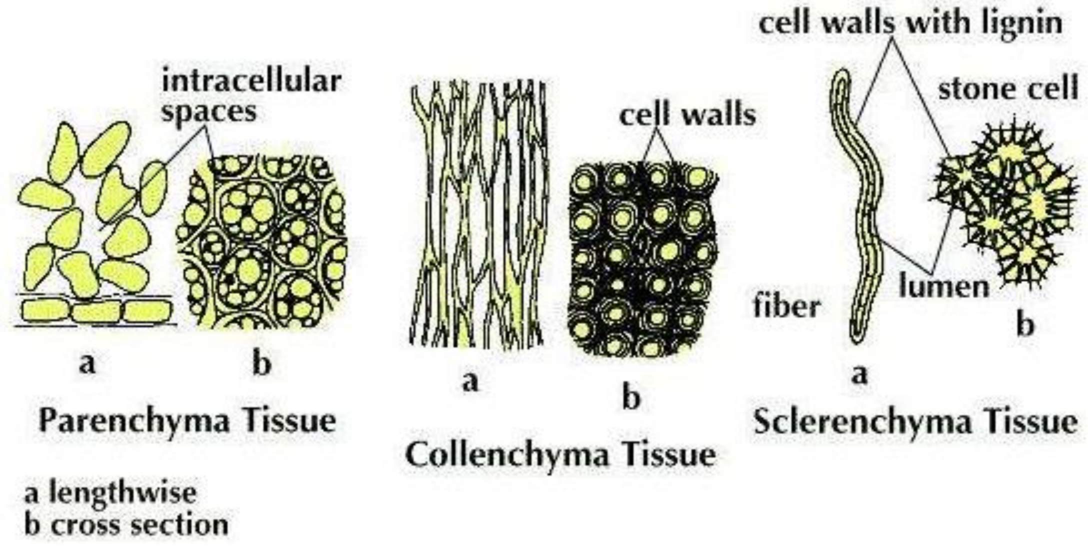
**(i) Surface fibers -** They are also called "Filling fibers". They are present on the surface of plant bodies.

Example - Cotton fibers are formed by the outgrowth of seed coat. They are not any type of tissues.

Cotton fibers composed of cellulose and not lignified. So that cotton fibers are not true fibers. Two types of fibers are found in cotton. Long fibers are called 'lint' and small fibers known as 'fuzz'. Fuzz is filling fiber. Coir of coconut is also type of surface fibers. They are derived from the mesocarp. It is true fiber.

**(ii) Xylary or wood fibers:** They are hard fibers. They are lack of flexibility. They cannot be knitted so that they are not useful. They are found in xylem. Ex. munj fiber

**(iii) Bast fibers: -** They are also known as commercial fibers. They are flexible and can be knitted. These fibers are obtained from the phloem and pericycle of plants. The best fibers of *Corchorus* spp (Jute) and *Crotalaria juncia* (Sun hemp) are obtained from the phylum. The base fibers of hemp (*Cannabis sativa*) and *Linum usitatissimum* (flax) are obtained from pericycle. The bast fibers have great economic value.




**Complex Permanent Tissue**

A complex tissues are a collection of different type of cells. This is a heterogeneous group of cells.

Complex tissue is absent in gametophytes.

Complex tissues is of two types -

a. Xylem b. Phloem

**A. Xylem**

The term 'Xylem' was coined by Nageli. Xylem also provides mechanical support to the plant in addition to conducting water and minerals. On the basis of development xylem divided into primary xylem and secondary xylem. Primary xylem originates from procambium. Parenchyma of primary xylem does not differentiate and medullary rays are also absent. Secondary xylem originates through the secondary growth. The elements of xylem are (i) Tracheids, (ii) Vessels or tracheae xylem fibers.

- **Tracheids** are elongated cells with tapering ends.
- Tracheids having a large lumen as compared to the fibers.
- Tracheids join together at their ends to form a long rows. These rows extend from the roots via stem to the leaves.
- A transverse septum lies between any two tracheids. It bears pits.
- Tracheids are dead and lignified cells. The deposition of lignin on cell wall is responsible for various thickenings. Lignification also forms various types of pits. Pits are the non-thickened areas.
- Bordered pits are mainly present on the wall of tracheids. The maximum bordered pits are found in the tracheids of Gymnospermic plants.
- Maximum deposition of lignin is in pitted thickening.
- Different types of thickening of lignin are found in tracheids.
- Spiral, annular and reticulate thickening of lignin is found in protoxylem.
- Pitted thickening of lignin is found in metaxylem.

**2. Vessels:-**

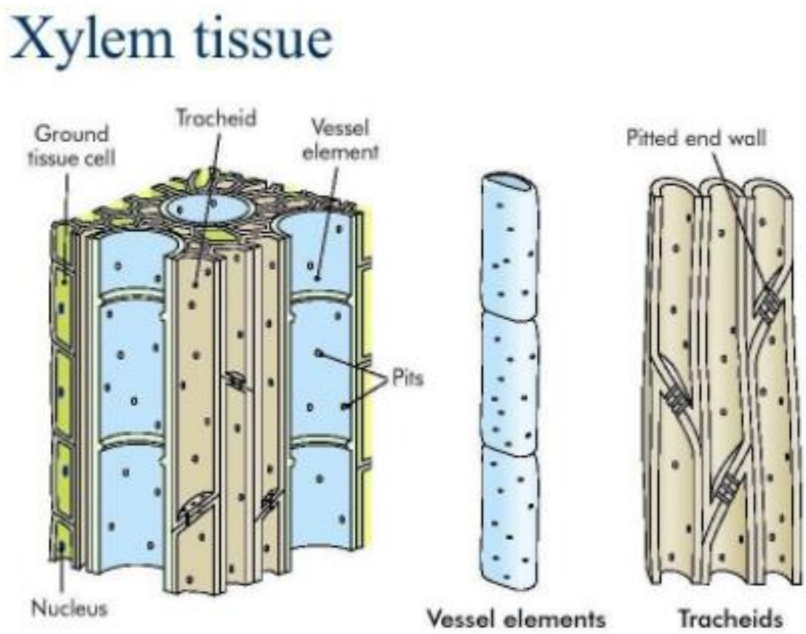
- Advance conductive element of xylem.
- The basic structure of vessels is the same as tracheids.
- They are also dead elements of xylem.
- The lumen of vessels is wider than the tracheids.
- Vessels are only found in xylem of angiosperms but some gymnosperms like *Ephedra, Gnetales* and *Welwitschia* also show the presence of vessels as an exception.
- Similarly vessels are absent in some Angiospermic plants such as *Dracaena, Yucca, Dazinaria, Drymeace, Vintera, Tetracentron* and *Trochodendron* etc.
- Transverse septum is absent between two cells. If present then it is porous. Thus vessels are more capable than tracheids.
- Vessels usually contain simple pits. Thickening of wall is the same as tracheids.
- Due to the absent of transverse septum, vessels work as a pipeline during conduction of water.

**3. Xylem fibers:-**

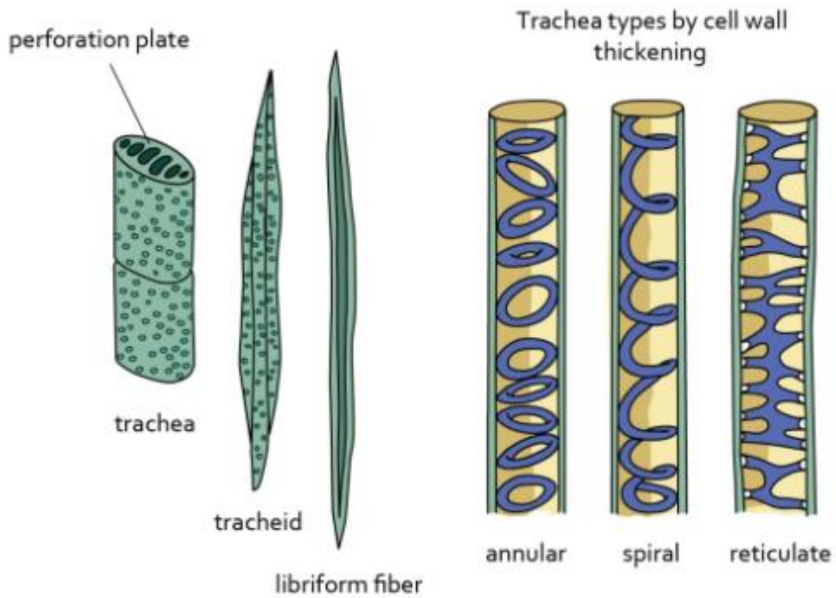
- This is also dead part of xylem.
- Xylem fibers provides strength to the tracheids and vessels. Mainly they provide strength to the vessels.
- They are more abundant in secondary xylem.
- The radial conduction of water is the function of xylem parenchyma.

**Water Conduction Elements of Xylem:-**

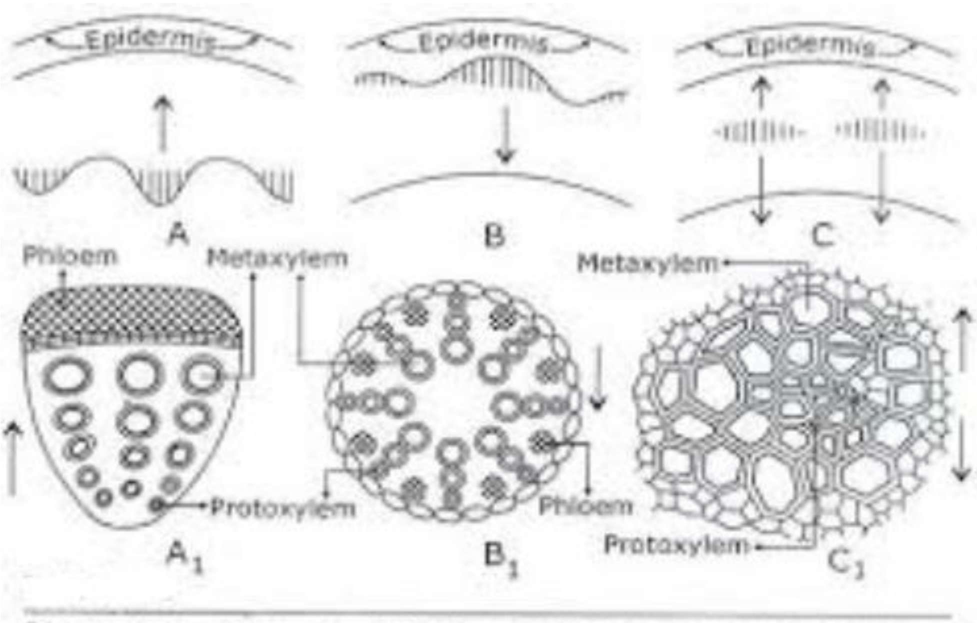
- Tracheid and vessels are collectively known as water conducting elements or "Hadrome". Development of conducting elements by three types :-
  **I. Centrifugal: -** In this type of development, the protoxylem formed near the centre axis and metaxylem is formed away from the centre towards the periphery. This condition is known as **endarch**. Ex. stem of angiosperm &Gymnosperm.
  **II. Centripetal: -** In which protoxylem is formed away from the centre near the pericycle and metaxylem is formed towards the centre. This condition is called **exarch**. Ex. Roots.
  **III. Centrifugal and centripetal: -** In which elements of metaxylem is formed from both side of the elements of protoxylem. So that protoxylem is surrounded by metaxylem. This condition is known as **mesarch** ex. stem of fern.




**Components of Xylem Tissue**




**Types of thickening is Tracheids**



Diagrams showing order of development of primary vascular tissues in transverse views. A. & $A_1$. Centrifugal with endarch xylem. B. & $B_1$. Centripetal with exarch xylem. C. & $C_1$. Both centrifugal and centripetal with mesarch xylem.

**B. PHLOEM**

The term 'Phloem' was coined by Nageli. The main function of phloem is the transport of organic materials from one place to another place. On the basis of development, phloem is classified into two categories primary and secondary phloem. Primary phloem is derived from procambium and secondary phloem is derived from vascular cambium. Phloem remains active for lesser time compared to xylem.

Phloem consist of 4 types of cells as below:-

**1. Sieve cell:-**

- Sieve element was discovered by Harting.
- Sieve element is living and has thin walled cells.
- A matured sieve cell lacks nucleus. Thus these are non-nucleated living cells.
- Central vacuole is present in each sieve cells. Cytoplasm of sieve cells streams in the form of thin layer around the vacuole (cyclosis).
- In Angiosperms sieve cells are arranged end-to-end and form sieve tube.
- Sieve plate (transverse perforated septa) is present between the two sieve cells. It is porous. Materials are transported only through these pores.
- Callose is deposited on the radius of pores during dropping (falling) season of leaves to form a thick layer. This is called Callus pad.
- Sieve plate protected by callus pad. It also prevents bacterial infection and protects against drought.
- Callose dissolves during spring season.
- In Gymnosperm and pteridophytes, sieve cells do not form sieve plates and are arranged irregularly. Sieve elements have sieve plates on their lateral walls.
- Thus conduction of food is in zig-zag manner.
- Sieve cells contain special type of protein-**P-protein** which is related with conduction of food and it repairs damaged sieve cells.

- Sieve cell and companion cell originate together. Both of them originate from a single cell sister cells.
- The companion cells and sieve cells connect their cytoplasm through plasmodesmata.
- Companion cells are only found in Angiosperms (exception -*Austrobaileya*).
- Companion cell is a living cell with a large nucleus. This nucleus also controls the cytoplasm of sieve cells.
- Special type of cells are attached with the sieve cells in conifers. They are called **albuminous cells**.

**3. Phloem fibers: -** A fiber which are present in phloem is called **Libriform** fibers. These fibers provide support to the sieve cells. The main function of that fibers to provide mechanical support. They are used for making ropes, rough clothes and mats etc.

**4. Phloem Parenchyma: -** It is also called **bast parenchyma**. They are living and thin walled cells. They store various food materials. Phloem parenchyma is absent in monocotyledonous plants. The main function of phloem parenchyma is conduction of food in radial direction and storage of food. The vascular part of phloem sieve cells is called **Leptom**.

**Special tissue or secretory tissue**

**I. Lactiferous tissue:-**

They are made up of long, highly branched and thin walled cells. These cells filled with milky juice, it is called Latex. Latex is known as plant milk. Latex obtained from the plants that is called **petrocrops**.

- Latex is the mixture of saccharides, starch granules, alkaloids minerals and waste materials. Starch granules present in latex are dumbbell shaped. Latex provides protection to the plant. It also protects the plants from grazing animals. It prevents the infection of bacteria and fungus. Lactiferous tissue is of two types - Latex cells and latex vessels.

**i. Latex cells -** They are non-articulated latex ducts/tubes. They are long branched and multinucleate cells. Such types of cells are called **coenocytic cells**.

**Example: -** Latex cells are found in *Calotropis, Euphorbia* and *Nerium*.

**ii. Latex vessels: -** They are articulated vessels. Latex vessels are formed due to dissolution of cell walls of meristematic cells. Thus they are syncytic cells. Latex vessels are also multinucleated.

**Example: -** Latex vessels are present in *Heavea*, Banyan tree, *Ficus*, *Papaver* etc. Highly developed latex vessels are found in the fruit wall of *Opium*.

- As the name indicates, this tissue is present in the form of glands. These glands contains secretory or excretory materials. Glandular tissues have two types of glands.
- Glands are found in *Urtica dioica* (Bicchubutti) are unicellular, these cells are present on the surface of the leaves. They are spiny glands in which formic acid is filled. Multicellular glands are of two types.

**1. External Glands: -** They are located on the surface of the plants, or arising as an outgrowth from the epidermis. These glands are of various types:-

**i. Digestive glands: -** Digestive glands are found in insectivorous plants. These insectivorous plant compensate their deficiency of Nitrogen. They are found in *Utricularia, Drosera, and Dionia* etc. plants.

**ii. Oil Glands**: - These glands secrete volatile oil. These glands are present in the leaves of *Eucalyptus* and external fruit wall of *Citrus* (Lemon).

**iii. Nectar Glands: -** These glands are embedded in the tissues. They are found in floral parts mainly in thalamus. These glands secrete nectar to attract the insects.

**2. Internal Glands: -** These glands are embedded in the tissues. Internal glands are of following types.
**i. Mucous secreting glands: -** These glands secretes mucous. They are found in the leaves of betel.

**ii. Oil glands: -** Oil glands are of both types external and internal. These secretes oil. It act as an antiseptic. These glands are found in lemon orange etc. fruits.
**iii.** Tannin, resin, gum secretory glands are also internal glands. Maximum resin glands are present in palm. Gum glands are found in *Acacia* (Babool). Resin ducts are schizogenous.
**iv.** Water gland:-Water glands are open on Hydathode. These glands are related to guttation. Hydathodes are present in Tomato, *Pistia, and Ichornia Nasturtium* etc. It is related with epitheme tissue.

- Tracheids of pteridophytes have long or elongated bordered pits. Such type of pits are called scalar form pits.

**Tissue System**
On the basis of division of labour, tissues are categorised into three different system. Each system usually consists of an association of tissues which performs specific function.
**1. The Epidermal tissue system: -** This system includes epidermis and its related cells, hairs, pores, etc.
**2. Ground tissue system: -** It is the largest tissue system. It includes hypodermis, cortex, endodermis, pericycle and medullary rays (pith rays).
**3. Vascular tissue system: -** This tissue system originates from the cambium. It consists of xylem and phloem.

**Types of vascular Bundles**

- On the basis of arrangement of different parts of vascular bundles are divided into three categories.

**I. Conjoint collateral vascular bundles -**When the xylem and phloem are present on the same radius in vascular bundle. In this vascular bundle order of condition is found. This vascular bundle is found in gymnosperm and angiosperm. Open vascular bundle is found in dicotyledons and gymnosperm. Closed vascular bundle is found in monocots.

**II. Conjoint bicollateral vascular bundle -** These are two patches of phloem one on each side of xylem.
In such a vascular bundles there are two strips of cambium one on each side of xylem. Only found when vascular bundle is open. Such type of vascular bundle is known as bicollateral vascular bundle. Ex. stem of family Cucurbitaceae.

**III. Radial vascular Bundles:-**When the xylem and phloem are present on different radii the vascular bundles are called radial vascular bundle. All the roots of plants contains radial vascular bundle. The development of xylem in these vascular bundle is centripetal. Thus, these vascular bundles are called exarch.

**IV. Concentric vascular bundles: -** In this vascular bundle either xylem surrounds the phloem surrounds the xylem. Concentric vascular bundles are always closed. They are of two types -
**i. Amphicribal or Hadrocentric:-**The xylem is in the centre and is surrounded on all sides by phloem. Such vascular bundle is termed amphicribal. The development of xylem in

these vascular bundles either centripetal or centrifugal manner. These are known as mesarch vascular bundle. Such types of vascular bundles are found in ferns and lower Gymnosperms.

**ii. Amphivasal or Leptocentric: -** In this type of vascular bundle xylem completely surrounds the phloem. It means phloem is present in the centre of the vascular bundles.

- Such type of vascular bundle is termed endarch. Such vascular bundle exceptionally formed in Angiosperms e.g. *Dracaena, Yucca* etc.,
- The stele is the whole central mass of vascular tissue with or without pith surrounded on the outer side by endodermis. **Vantieghem** and **Douliot** gave the hypothesis to explain stele. According to their hypothesis, stele is the central part or core of the plant which includes the vascular system and its relative structures.
- The tissues which lies inside the stele is called intrastelar tissues and the tissues which lie outside the stele is known as extrastelar tissues. Stele is surrounded by endodermis. However endodermis is originally the part of cortex.

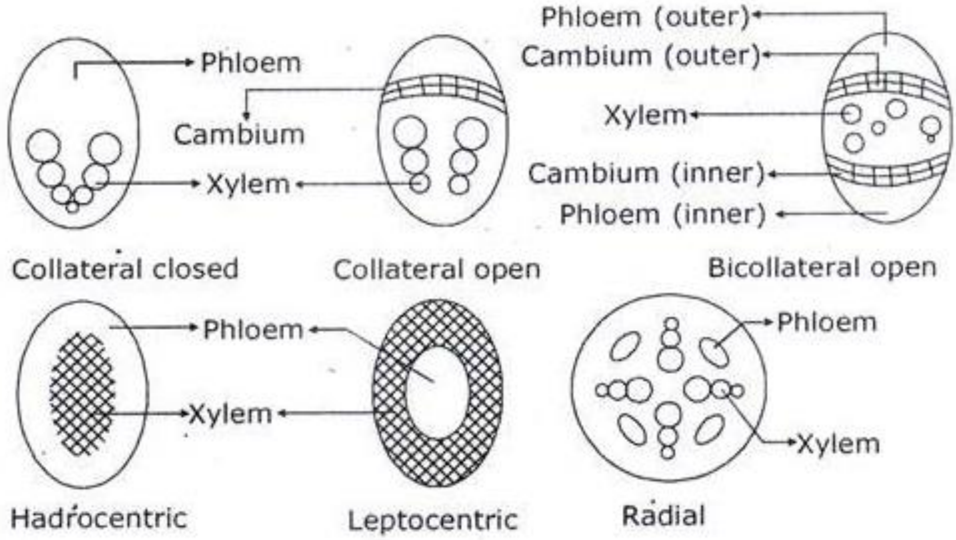



Diagram showing types of vascular bundle in t.s. (diagrammatic).

**1. <u>Protostele or Monostele</u>:-**

Protostele is the most primitive and simplest type of stele. It consists of a solid mass of xylem completely surrounded by phloem. Such type of stele is devoid of pith. Solid stele is of following types:-

**i. Haplostele: -** In this stele, xylem surrounded by a smooth layer (some thickness) of phloem. Central xylem is in cylindrical form.

**ii. Actino stele: -** Actino stele is that in which the central xylem has radiating ribs and assume a star shaped appearance.

Example - *Psilotum* & *Isoetes.*

**iii. Plecto Stele**: - A such type of solid stele in which the xylem divides into a number of separate plates which lie parallel to one another.

Example - Most of the species of *Lycopodium*.

2. **<u>Siphono stele</u>** -

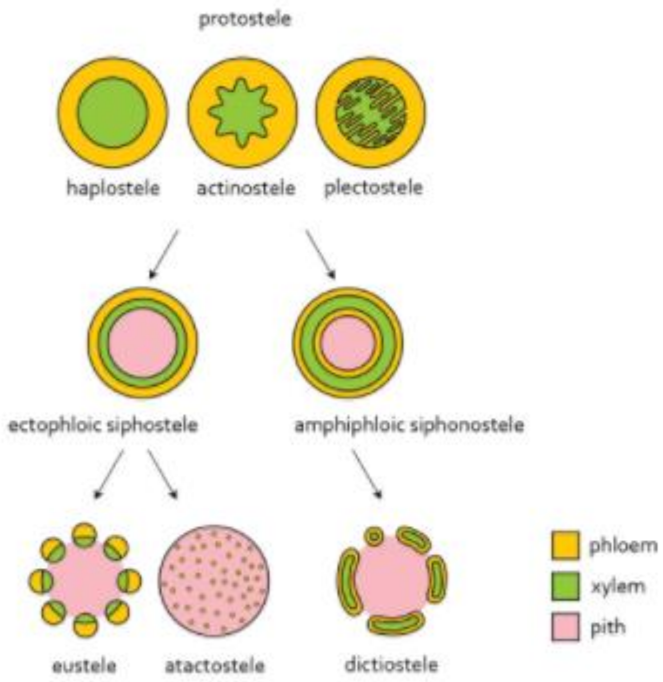
Siphono stele is that stele in which the pith is present in centre of hollow vascular cylinder. Siphono is of following two types -

i. **Ectopholic siphonostele** - In such type of vascular tissue of stele phloem is always present outside of the xylem.
Example - *Equicetum, Osmunda*
ii. **Amphiphloic siphonostele** – In the vascular tissue of such type of stele xylem is surrounded by phloem on the both sides
Example -*Adiantum, Marsilea*
3. **Soleno Stele**:-
Solenostele is that stele in which leaf gaps are produced in the main vascular tissue. Leaf gaps are produced by breaking of main vascular tissues due to the leaf. These broken pieces of stele are called soleno stele.
Soleno stele also may be Ectophloic or Amphiphloic

**4. Dictyo Stele -**
When the production of many leaf gaps in solenostele main vascular cylinder, breaks into many fragments, then such type of solenostele is called Dictyostele. Each divided fragment (piece) is called meristele. Each meristele has its own separate endodermis and pericycle. Dictyostele is well developed type of stele in Pteridophytes.
Example - *Pteridium, Pteris, Dryopteris*

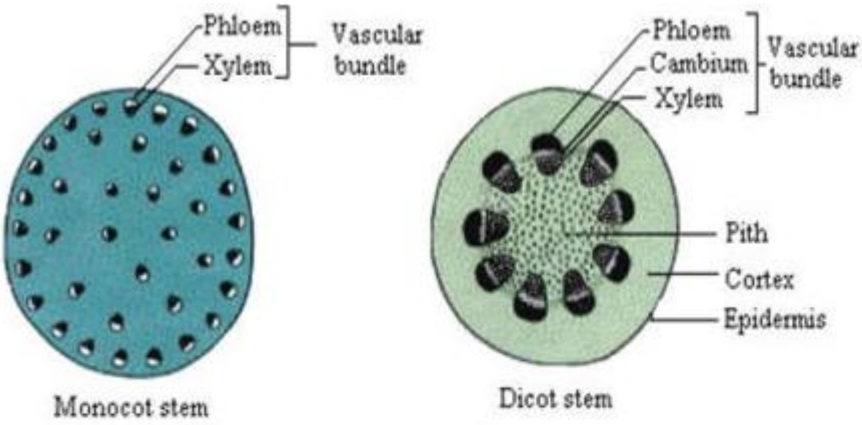
**5. Eustele -**
In this type of stele, vascular bundle present in circle and medullary rays located in between them. Such type of stele is found in gymnosperm and dicotyledonous plants.

**6. Atactostele -**
Many vascular bundles are distributed in the ground tissue. Such type of stele is called atactostele.
This is highly developed type of stele. Endodermis and pericylce is absent in atacto stele. Such type of stele is the main characteristic feature of monocotyledons.



**Dicot stem**
Primary structure of a typical dicot stem shows following features -
1. Epidermis - Epidermis is the outermost layer of the stem. It is made up of single layer of cells and lack of chloroplast. Multicellular hairs and stomata are found on epidermis. Epidermis play a significant role in protection.
2. Hypodermis - It is present just below the epidermis. It is provides additional support to the epidermis.
It is thick multicellular layer. This layer is composed of collenchyma and their cells contain chloroplast. So the hypodermis is green and photosynthetic.
3. Cortex - This part is composed by parenchyma. Storage of food is the main function of the cortex. The innermost layer of the cortex is termed endodermis.
4. Endodermis - This is thick single layer of cells. The cells of endodermis are barrel shaped. These cells accumulate starch in dicot stem. Therefore it is also called as **"starch sheath".**
5. Pericycle - This layer is situated in between the endodermis and vascular bundles (below the epidermis and above the vascular bundle). The pericycle of stem is multi-layered and made up of scerenchyma.
Pericyle is also known as **Hard bast.** In stem of sunflower, pericycle is made of alternate bands of parenchymatous and sclerenchymatous cells. The cells of pericycle in front of the vascular bundle is made up of sclerenchyma and remaining is composed by parenchyma. A pericycle situated in front of vascular bundle is known as **Bundle cap.**
6. Vascular Bundle - The vascular bundle of dicot stem arranged in a ring. Well-developed pith is present below the ring. Each vascular bundle is **conjoint collateral endarch**, and **open**. Each vascular bundle is made of phloem and xylem. Eustele is present in dicot stems.

**Monocot Stem**
The following structure is seen in a typical monocotyledon stem -
1**.** Epidermis **-** Epidermis is the outermost one called thick layer. It is covered with thick cuticle lined with stomata. Multicellular hairs are absent. The number of stomata is also less comparatively.
2**.** Hypodermis **-** Hypodermis of monocotyledon stem is made up of **sclerenchyma.** This are made of 2-3 layer of sclerenchyma.
3**.** Ground tissues **-** The entire mass of parenchyma cells next to hypodermis and extending to the centre is called ground tissue. These is no differentiation into endodermis, cortex, pericycle etc.
4. Vascular Bundle **-** Many vascular bundles are scattered in the ground tissue. Vascular bundles that lie toward the centre are larger and lesser in number. Vascular bundles situated towards the periphery are smaller but greater in number. Each vascular bundle is **conjoint collateral endarch and closed** type. Vascular bundles surrounded by the layer of sclerenchyma is known as **bundle sheath.**
Monocotyledon stem contain only xylem and phloem.
**i.** Xylem**-** Xylem element of monocotyledon are arranged like a 'Y' and it has limited no. of vascular elements. Two small vessels are positioned radially toward axis in the form of protoxylem. Due to presence of water in this cavity, it is also called **water cavity.** This cavity is formed by disintegration of the element present below the protoxylem and neighbouring parenchyma.
5**.** Pith and stele **-** Atactostele is found in monocotyledon .This is highly developed stele.

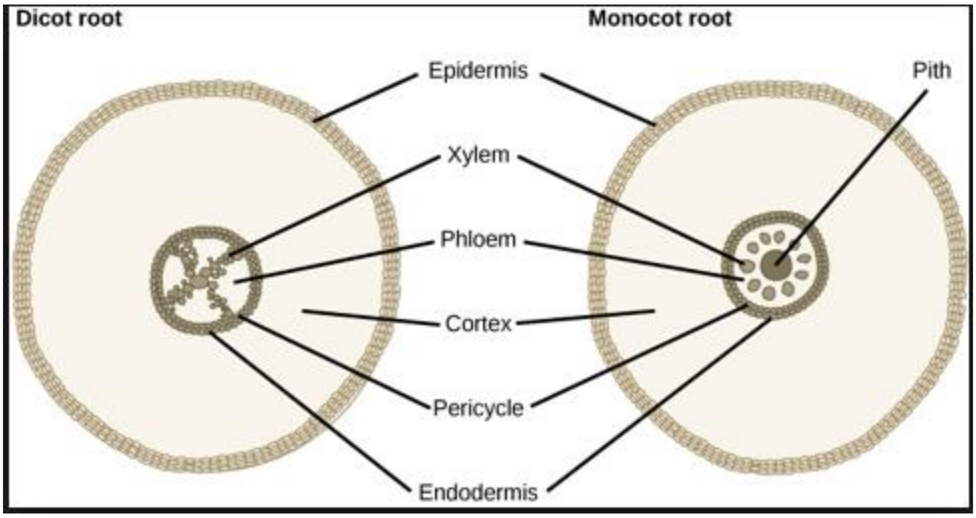



**DICOT ROOT**

1. Epidermis - It is a uniseriate outermost layer. Unicellular root hairs arising from the some cells of epidermis of root is known as **epiblema** or **Rhizodermis** or **Piliferous layer.**
2. Cortex - This part is made up of parenchymatous cells. The cells of outer part of cortex are suberized in old root. It is called **Exodermis.**
3. Endodermis - This layer is situated between the vascular tissues and cortex. Casparian strips present radially in innermost layer of endodermis. These strips are made up of suberin.
4. Pericycle - This is a single called thick layer. It is composed by a type of parenchyma, which is called **prosenchyma.** Pericycle of roots is single layered. Cork cambium is formed from this layer during the secondary growth. Lateral root originates from the pericycle. Thus lateral roots are endogenous in origin. The branches of stem are exogenous in origin, because they originate from the outer part of cortex.
5. Vascular bundles - Vascular bundles are radial and exarch, xylem and phloem are separate and equal in number. The number of vascular bundle in dicot is two to six (diarch to hexarch). But in *Ficus* (Banyan tree) polyarchic condition is found as an exception. Tissues are situated between the xylem and phloem are called **conjugative tissue.** These are consist of parenchyma. Vascular cambium is formed from the conjugative tissue during the secondary growth. Thus all cambium is formed after the secondary growth in roots.
6. Pith - It is found in the centre and is less developed or absent. Flexibility occurs due to this.

**Monocot Root & Leaf of Structure**

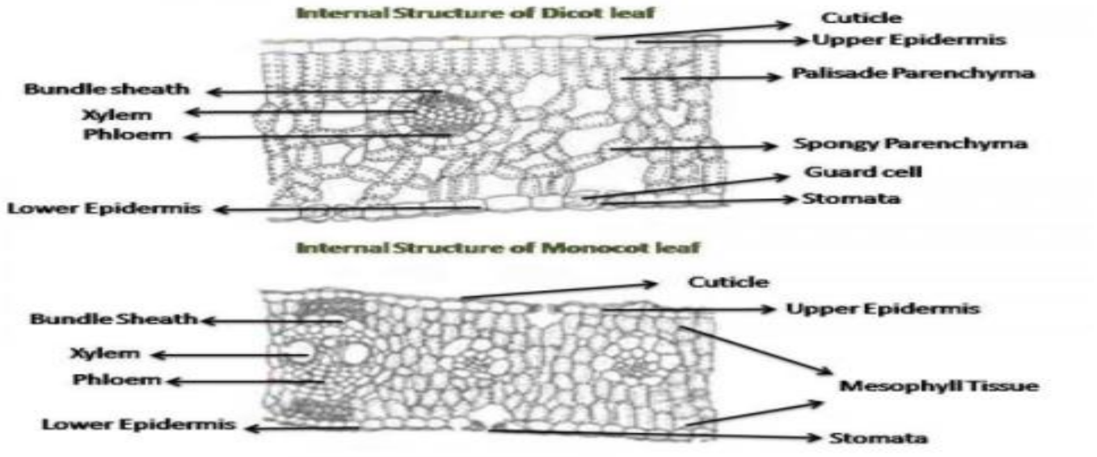
The internal structure of a typical monocot root is the same as dicot root. But number of vascular bundle is more than six in monocot root. But exceptionally the number of vascular bundle in onion is two to six. In monocot root pith is well developed.




**Internal structure of leaf -**

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

1. Dorsiventral leaves are attached at right angles to the stem while isobilateral leaves attached parallel to the stem.
2. The structure of both the surface of dorsiventral leaves is different, while in isobilateral, structure of both surface is similar.
3. Dorsiventral leaves found in dicot but exceptionally, isobilateral leaves also formed in *Eucalyptus*.
4. Isobilateral leaves occurs in monocotyledon, but *Lilium longiflora* is the exception of this.




**Secondary Growth**

"The growth in diameter (girth) of the plant organs, is called secondary growth".

A permanent internal structure of the organs is formed through the apical meristems. This structure is formed in the beginning of some weeks of the first year. This structure is known as **primary structure.**

Primary structure is only found in Pteridophytes and monocotyledon plants.

A normal secondary growth is found in roots and stem of dicotyledons and Gymnosperms. Due to lack of vascular cambium in monocotyledons, secondary growth is absent. But exceptionally secondary growth is found in some monocotyledons. Such as Palm, yucca, Draccaena, Smilax, Agave, Coconut etc.

**Secondary growth in Dicot Stem**

**A. Secondary growth in vascular Region -**
Secondary growth in vascular region begins (starts) earlier than the cortical region. It is complete in the following steps -
**I. Formation of ring of vascular cambium -**
A cambium present in vascular bundle is called **intrafascicular cambium.** This is a type of primary meristem. First of all, cells of medullary rays becomes meristematic and forming interfascicular cambium. Intrafascicular and interfascicular cambium are collectively known as **vascular cambium.**
Vascular cambium is formed in the form of a complete ring which is made by single layer of the cells.
Two types of cells are found in the ring of this vascular cambium.
**Fusiform initials and ray initials.**
Fusiform initials are long with pointed ends, while ray initials are spherical (oval). More fusiform initials are present in vascular cambium.
**II. Activity of vascular cambium-**
A continuous periclinal division or tangential division takes place in fusiform initials. The plane of division in periclinal divisions is parallel to longitudinal axis of a cell. Few cells are formed towards the radius (periphery) through this type of activity and these cells differentiates into **secondary phloem or bast.**
Some of the cells are formed towards the central axis and these cells are differentiate into **secondary xylem or wood.** Normally more secondary xylem is formed as compared to secondary phloem. By the pressure of secondary phloem primary phloem is pushed towards the outside and gets crushed. Thus epidermis and hypodermis cannot be seen during the secondary growth in stem. By the pressure of secondary phloem primary pushed toward the outside gets crushed. Thus epidermis and hypodermis cannot be seen during the secondary growth in stem. By the pressure of secondary xylem, all the primary tissues - such as primary xylem, pith, old secondary xylem etc. degenerated in the centre of stem because **woody.**
**I. Ring porous wood -** Vessels are arranged in the form of a ring in this wood. Such wood conducts water more efficiently.
**II. Diffused porous wood –** Asystematical distribution of vessels is found in this type of wood.
**Formation of Annual Rings**
The activity of cambium does not remains equal but it is changeable in the whole year. In winter or autumn season the activity of the cambium is poor and the secondary xylem or wood formed is not extensive through the vascular cambium. Cells formed during this period, are small thick walled and have narrow lumen. This is called **autumn wood** or **late wood.**
The vascular cambium is highly active in **spring** or summer season and secondary xylem formed during this period is extensive and cells of secondary xylem are larger, thin walled and have wider lumen. This wood is known as **spring wood** or **early wood.** The autumn and spring wood is formed in rings. The ring of any type of wood is called **growth ring.** Thus two growth rings are formed during a year. A ring of autumn wood and a ring of spring wood collectively known as **Annual ring.** Thus an annual ring consist of two growth ring. The number of annual rings formed in a tree come give the idea of the age of the tree.
The study of determination of age of the plant by this techniques is called **Dendrochronology.**
The annual rings are counted form the base of the stem. This is because basal part has maximum annual rings and upper part has less. Therefore, counting form the basal region can give the correct idea. A piece is taken from the stem up to central region with the help **increment borer** instrument. The annual ring is counted from that piece and again inserted (fitted) into the same stem at the same place. Annual ring is formed more distinct in changeable seasons.

A more distinct annual ring is formed in temperate plants. A distinct annual ring is not formed in tropical plants. A clear annual ring is not formed in India except Himalayan regions.
Lesser distinct annual ring is formed in seashore regions because their climate remains the same the whole year. Clearer annual ring is formed in deciduous plants as compared to evergreen plants.
Periclinical division also goes on continuously in ray initials of vascular cambium. Some of the cells are formed on the inner side and some of the cells are formed on the outer side through these divisions. All these cells are made up of parenchyma. Radial lines of cells of parenchyma are formed in the stem. They are called **Vascular rays.** Medullary rays are primary and vascular rays are secondary. Both of them conduct water and food in radial direction.

**B. Secondary growth in Cortical Region**

As a result of the addition of the secondary vascular tissues, increasing the diameter of circle of xylem region and cortical region, comes under stress and strain. Therefore some cortical tissues ultimately get ruptured. To make good this loss, protective tissues of epidermis tries to compensate but they are fail and get ruptured at many places. This loss in fulfilled by the activity of cork cambium. Cork cambium is also known as Phellogen or **Extrastelar cambium.** Cork cambium arises from the hypodermis or from the outer layer of cortex because they become meristematic.
Those cells formed towards the inside differentiate into parenchyma. These are called **secondary cortex or Phelloderm.** Phellogen, cork and phelloderm are collectively known as **periderm.**

**Phellogen + Phellem (cork) + Phelloderm = Periderm**

Cork is produced in high quantity and secondary cortex is made in less quantity from the cork cambium. The highest activity of cork cambium is in winter season. Most of the cells of phellem are dead. But in some places living cells are also found. Suberin is not deposited in these places. These places are known as **Lenticels.** Lenticels appears on the outer surface of the plant either in small points or in the form of areas of protuberance. Lenticels are made up of scattered collection of living cells. These cells are known as **complementary tissue.** Lenticels are normally formed below the stomata. Lenticels serve for exchange of gases between the plant and atmosphere. Transpiration also takes place through the lenticels. It is known as lenticular transpiration. Adventitious roots cutting originate from the living cells of lenticels in vegetative reproduction. Lenticels are mainly formed on stem and are never found on leaves. Even lenticels are present all over the plant body. They are also present on fruits. Cork cambium remains living only for the one year. Each year, a new cambium is formed below the previous cambium. This new cambium is derived from the secondary cortex on phelloderm.

**Bark**

All the tissue situated outside the vascular cambium is called **Bark. Bark** has two parts.
**1. Outer Bark -** Outer bark is dead. All the tissues that lie outside the cork cambium are called **outer bark.**
It is also known as Rhytidome.
**2. Inner Bark -** The region in between the cork cambium and vascular cambium is called inner bark. Most of this part is living. The main region of inner bark is the **secondary phloem** or bast.

Thus bark consists of both type of tissues: living and non-living (dead). A plant will die if we remove the complete bark of the plant because maximum loss of water occurs due to this. If a ring of bark is removed from the base of the plant, within a few days a plant dies. This happens because phloem is separated due to this activity and plant comes in the state of deficiency of food.

**Kind of Bark**

1. Ring Bark - Ring bark is formed around the stem in a complete ring. When the ring of cork cambium is complete then it is known as ring bark.

Example - *Betula vulgaris* - Bhojpatra, A complete distinct ring bark is formed in this plant. Its bark was used as writing material as a paper in the ancient period. Ring bark is also formed in Eucalyptus.

2. Scaly Bark - This bark is formed around the stem in the form of pieces or fragments. When the ring of cork cambium is not continuous, the scaly bark is formed.

**Secondary growth in Dicot Root -**

Secondary growth is essential in roots. This is important to provide strength to the growing aerial parts of the plants and fulfill the requirement of water and minerals. Secondary growth is not found in monocot roots. First of all, conjunctive tissue becomes meristematic during the secondary growth in a dicot-root to form a vascular cambium which is formed in separate curved strips. Then after, the cells of pericycle lying outside the protoxylem also becomes meristematic. This forms additional strips of cambium. In this way a complete ring of vascular cambium is formed. The portion of vascular cambium is formed by pericycle is less. The main portion of vascular cambium is formed by conjunctive tissue.

The shape of ring 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 ring becomes circular by the pressure of secondary xylem (Pushing outwards).

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 toward the outer side by vascular cambium. The portion of vascular cambium which is formed by pericycle is responsible for the formation of **pith rays.** These are made by parenchyma. These pith rays are known as **primary medullary rays.** A few medullary or pith rays are also formed from vascular cambium. These are called **secondary medullary rays.** Thus two types of medullary rays are found in the secondary structure of roots. The presence of two types of medullary rays is basic characteristic features of roots. Only secondary rays are found in stem. Both of the medullary rays conduct water and food in radial direction. Cork cambium is developed from the **pericycle** in roots. Cork is formed towards the outside and secondary cortex is formed towards the inner side by the cork cambium.

**Functions of secondary meristem (Cambium)**

**1. Healing of wounds -**When wound is formed on any stem, then living cells of the wound are responsible to form a cambium. This is called **wound cambium.** It is also called inducible cambium. This newly formed cambium forms a cork towards the outside. The cork covers the wound entirely. Thus the wound is healed. An outgrowth like structure of parenchymatous cells are found on the margins of the wound. This is known as **Callus.**

**2. Abscission -** The leaves of most of the Pteridophytes and branched angiosperms either fall after degeneration or when destroyed on the plants.

The leaves in gymnosperms and woody dicotyledons are separate through the abscission before their death. Middle lamella dissolves in abscission layer. Abscission and primary walls also dissolve partially or completely. The place from where leaf gets separated, is called **leaf scar.** The living cells present in leaf scar are responsible to form cork cambium. As a result cork is formed towards the outside. So ultimately the leaf gets detached from the plant. This is termed abscission.

**Anomalous secondary growth in stem-**

**1. Anomalous/abnormal position of vascular cambium-** Normally vascular cambium is circular, but is folded in stem of some plants. Later on these folds break and separate from each other. Each fold is responsible to form a complete vascular bundle. Many vascular bundles are formed in stem.

**Example -** *Thinowia, Serjania, Bauhinia***.**

**2. Abnormal Activity of vascular Cambium -** Parenchyma is formed form the maximum part of the vascular cambium. Only (rarely) in some places xylem and phloem is formed, while generally xylem and phloem is formed from the maximum part of the vascular cambium, and medullary rays are formed from the few part of vascular cambium.

**Example -** *Aristolochia, Vitis vinifera (Grape).*

**3. Sequential or successive ring of vascular cambium-** In some of the plants, a new ring of vascular cambium is formed in each year. This is formed outside the previous ring.

**Example -** *Cycas, Gnetum, Mirabilis, Boerahvia, Bougainvilia***,** etc.

**4. External Stelar vascular cambium -** Vascular cambium is formed from the pericycle in plants of Amaranthaceae and Chinopodiaceae family. A complete ring of vascular cambium is formed from the
pericycle.

**5. Interxylary Cork -** Parenchyma of secondary xylem becomes meristematic in some of the plants and behave like a cork cambium. It means cork is formed to the interior of wood.

**Example -** *Artemesiatridentata etc.*

**6. Cork cambium from Epidermis -** Cork cambium originates from the epidermis in same of the plants.

**Example –** *Solanum dulcamara, Quercus suber* (oak). Commercial cork is obtained from the oak.

**7. Secondary Growth in Monocotyledons -** In some members of plants such as *Dracaena, Yucca, Lomandra, Kingia, Senseviera, Agave, Aloe arboresence,* Vascular cambium formed from the outer region of the ground tissues. Parenchyma is formed towards the outside by the vascular cambium and vascular bundles are formed toward the inner side.

In some plants, the girth of the stem increases without cambium. Such as Palms, Musa, Tulips etc. The apical meristem of these plants is special type. This is known as **primary thickening meristem.** This apical meristem is responsible for the growth in both length and girth (thickness) of the plant.