Revision Notes

Class 11 Biology

Chapter 6 – Anatomy of flowering Plants

The Tissues

- A tissue is a collection of cells that share a common origin and function.
- A plant is made up of a variety of tissues.
- Meristematic and permanent tissues are the two types of tissues. This is founded on affecting the cells' ability to divide.
- Meristematic tissue cells can divide, whereas permanent tissue cells do not split any farther.

1. Meristematic tissues

- Plant growth is primarily limited to meristems, which are specialised regions of rapid cell division.
- Meristems come in a variety of shapes and sizes.
- Meristems are classified into two types based on their origin: primary and secondary.

I. Primary meristem

- Primary meristems create the primary plant body and are present early in the life of a plant.
- There are two types of primary meristems: apical and intercalary meristems.

a) Apical meristem

- The apical meristem is a type of meristem that is found at the tips of shoot and root.
- They are responsible for the production of primary tissues.
- Shoot apical meristem and root apical meristem are the two forms of apical meristem.
- Root apical meristem: This meristem is found at the root tips.
- Shoot apical meristem: Located at the tip of the shoot.
- During leaf formation and stem elongation, some cells remaining in the shoot apical meristem at the top of the branch formed axillary buds.
- These branches are located in the leaf axils and can form branches or flowers.

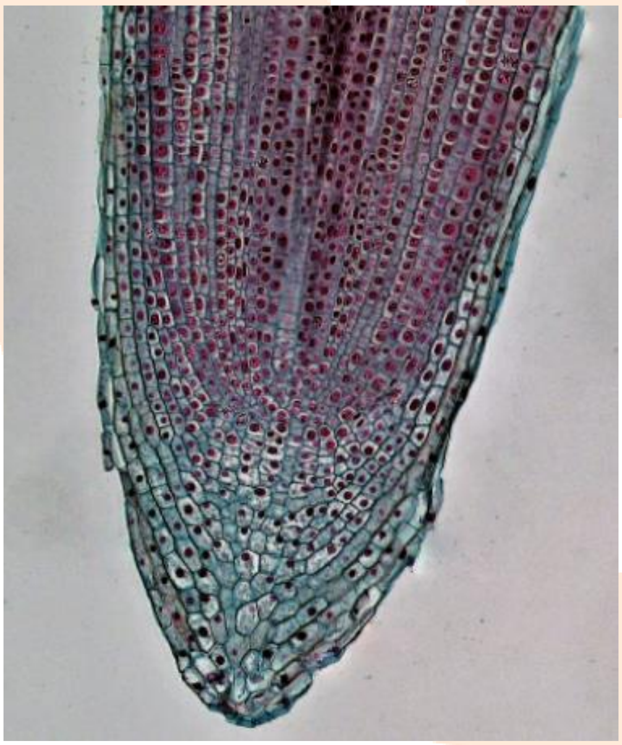

Fig.1. Apical meristem of root

Fig.1. Apical meristem of root and shoot

b) Intercalary meristem

- Intercalary meristem refers to the meristem that exists between mature tissues.
- They can be found in the grasslands. Their job is to regenerate sections that have been killed by grazing herbivores.

II. Secondary meristem

- The secondary or lateral meristems are those found in the differentiated sections of roots and shoots of plants. They broaden the stem's girth and, in most cases, give rise to a woody axis. They appear after the primary meristem has formed.
- Lateral meristems include the fascicular vascular cambium, cork cambium, and interfascicular cambium.
- Secondary meristem produces secondary tissues.

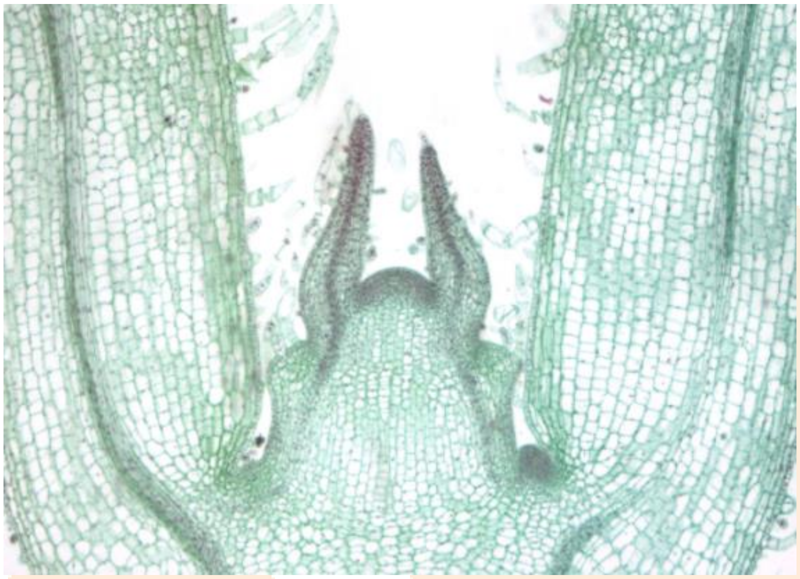

Fig.3. Lateral meristems

2. Permanent tissues

- Permanent tissues are cells that have differentiated from meristems and are specialised in structure and function, but do not divide further.
- Simple tissues are permanent tissues made up of cells that are similar in form and function.
- A permanent tissue composed of different types of cells is called a complex tissue.

I. Simple permanent tissue

- Simple tissues are parenchyma, collenchyma, and sclerenchyma, which are all made up of only one type of cell.

a) Parenchyma

- The major type of simple tissue is parenchyma tissue.
- The parenchyma is made up of isodiametric cells.

- They come in a variety of shapes, depending on their function.
- They have cellulose-based thin walls.
- They have limited intercellular spaces and are usually closely packed.
- Parenchyma cells are adapted to perform diverse roles such as photosynthesis, storage, and secretion.

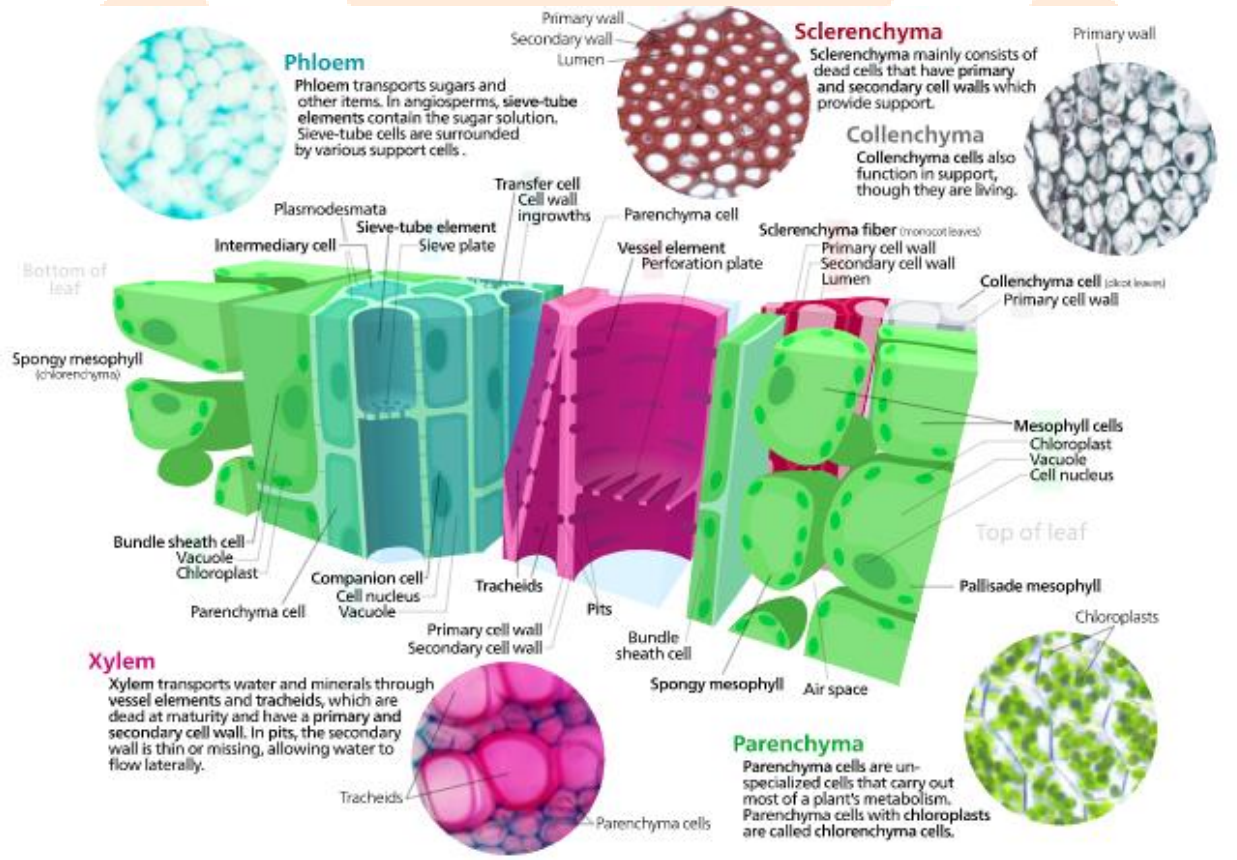

Fig.4. Classification of different types of plant tissues

b) Collenchyma

- In dicotyledonous plants, the collenchyma is found in the hypodermis layer beneath the epidermis.

- It consists of cells that are substantially thickened at the corners due to a deposition of cellulose, hemicelluloses, and pectin.
- Collenchyma cells come in a variety of shapes and sizes, and they frequently contain chloroplast.
- Food is assimilated in collenchyma cells with chloroplasts, and there are no intercellular gaps.
- They provide mechanical support for the plant's growing portions. They give the part the ability to bend without breaking. They can be found in juvenile sections of a plant, such as the stem and petiole of a leaf (in dicot herb).
- Majumdar classified collenchyma into three categories:

1. Lamellar / plate collenchyma: Collenchyma cells grouped in lamellar patterns. The tangential walls of the cell have thickened. Because of this sort of deposition, the cell resembles a lamellar or plate structure. For example, *Raphanus*.

2. Angular collenchyma: This collenchyma forms in large quantities. This tissue's cells are angular. Pectin deposition at the cell's corners. For example, *Datura*, *Cucurbita*, etc.

3. Lacunar collenchyma: These cells have large intercellular gaps between them. Pectin deposition on the intracellular space walls. Collenchyma's intercellular spaces thickened. For example, Sunflower stems.

c) Sclerenchyma

- Mettenius came up with the name ‘Sclerenchyma’.
- Sclerenchyma is the most important mechanical tissue .
- These cells are long, thin, and have thick walls. They are also lifeless.
- Their cells have a thick and lignified cell wall.
- The deposition of lignin on the hard wall causes a variety of pits to appear.

Types of Sclerenchyma tissues: There are two types of sclerenchyma tissues - Sclereids and Sclerenchymatous fibres.

1. Sclereids

These cells have a tiny, thick walled interior and pointed ends. Sclereids have an isodiametric or uneven shape, and their cells have more pits and a very narrow lumen. The lumen (pit cavity) of their pit is branching. The sclereids were categorised by Torch based on their shapes: -

a) **Stones cells or Brachysclereids or Grit cells:** The form of these cells is spherical or oval. They are present in the endocarp of drupe fruits, which causes the endocarp to harden. They can be found in the endocarp of coconuts, mangoes, almonds, walnuts, and other fruits and nuts. Brachysclereids can also be found in the fleshy (edible) section of the pear. Sclereids are responsible for the gritty texture of pear fruit.

b) **Macro-sclereids or Rod cells or Malpighi cells:** They are little, rod-shaped cells. They can be found in seed coats. They are found in the seed coat of legume plants. Seed coat becomes hardened as a result of their presence. Lotus seed coatings are the toughest (stony). Among the leguminous plants, the seed coat of the French bean is the hardest. They help leguminous seeds stay dormant.

c) **Osteio-Sclereids:** Osteio-Sclereids, which are also known as prop-cells are the cells that resemble pillars. The ends of these cells extend out to form a bony structure. These cells can be found in the leaves of *Hakea* and *Osmanthus*.

d) **Astero Sclereids:** These star-shaped cells are found in floating leaves. For example, in the leaves of *Victoria*, Lotus, etc.

e) **Trichoselereids:** Trichoselereids are commonly known as internal hairs. They are bifurcated, spine-like cells found in floating leaves. *Victoria*, *Nelumbo*, and *Nymphea* are the examples.

2. Sclerenchymatous fibres

Sclerenchymatous fibers are divided into two categories based on their structure which are Libriform fibers and Fiber tracheids.

a) **Libriform fibers:** These are very thick long fibers. They have simple pores. These fibers are found in the phloem, xylem, pericycle, and hypodermis layer. They are most often found in the phloem.

b) **Fiber tracheids:** Compared with other fibers, they are very thick. These fibers contain edge holes that can only be found in the xylem.

Sclerenchymatous fibers are divided into three types based on their position which are Surface fibers, Xylary or wood fibers, and Bast fibers.

a) **Surface fibers:** Also known as "filling fibres." They can be found on the external surface of plant bodies. Cotton fibres are cellulose-based and are not lignified. Cotton fibres are therefore not genuine fibres. Cotton contains two types of fibres - long strands are referred to as 'lint,' whereas little fibres are referred to as 'fuzz.' Fuzz is the filling fiber. Coconut coir is another type of surface fibre. They are made up of mesocarpo. It is made up of real fibre.

b) **Xylary or wood fibers:** Xylary fibres, often known as wood fibres, are tough fibres. They are a result of a lack of flexibility. They cannot be crocheted in such a way therefore they won't be useful. They live in the xylem. For example, Munj fibre.

c) **Bast fibers:** Commercial fibres is another name for them. They can be knitted and are flexible. Plant phloem and pericyclic fibres are used to make these fibres. The phylum produces the best fibres from *Corchorus spp.* (Jute) and *Crotalaria juncea* (Sun hemp). Pericycle is where hemp (*Cannabis sativa*) and flax (*Linum usitatissimum*) get their foundation fibres. The bast fibres have a high monetary value.

II. Complex permanent tissue

- A complex tissue is made up of a variety of different cell types. This is a diverse collection of cells.
- In gametophytes, there is no complex tissue.

- There exists two kinds of complex tissues - Xylem and Phloem.

a) Xylem

Nageli was the one who invented the word "Xylem." In addition to conveying water and nutrients, xylem gives mechanical support to the plant. Xylem is separated into primary and secondary xylem based on development. Procambium is the source of primary xylem.The primary xylem parenchyma does not differentiate, and there are no medullary rays. Secondary xylem develops as a result of secondary growth. Tracheids, Vessels, and Xylem fibres are the constituents of xylem.

i. Tracheids

- Tracheids are elongated cells with tapering ends, and their lumen is larger than that of fibres.
- Tracheids produce lengthy rows when they unite at the ends. These rows run from the roots to the leaves via the stem.
- Any two tracheids are separated by a transverse septum. It has pits in it.
- Tracheids are lignified and dead cells. Various thickenings are caused by the deposition of lignin on the cell wall. Bordered pits are mostly found on the walls of tracheids. The tracheids of Gymnosperm plants have the most bordered pits.
- Lignin deposition is greatest in pitted thickening.
- In tracheids, many forms of lignin thickening can be detected.
- Protoxylem has spiral, annular, and reticulate lignin thickening.
- In the metaxylem, there is a pitted thickening of lignin.

ii. Vessels

- Advanced conductive element of xylem.
- Vessels have the same basic structure as tracheids.

- They're also xylem's dead elements.
- The vessels have a larger lumen than the lumen of tracheids.
- Vessels are only found in the xylem of angiosperms, but some gymnosperms, such as *Ephedra*, *Gnetales*, and *Welwitschia*, have vessels as well.
- Some angiosperms also lack vessels, such as *Dracaena*, *Yucca*, *Dazinaria*, *Dry Menace*, *Vintera*, *Tetracentron*, *Trochodendron*, etc.
- In the absence of a transverse septum, vessels act as a pipeline for water transmission.
- There is no horizontal separation called the transverse septum between the two cells. If so, then it is porous. Therefore, xylem vessels are more effective than tracheids.
- These vessels usually contain simple pits. The thickening of the wall is the same as that of the tracheids.
- In the absence of transverse partitions, the xylem vessel acts as a pipe when conducting water.

iii. Xylem fibers

- This is also a section of the xylem that is dead.
- The tracheids and vessels are strengthened by xylem fibres.
- They are more plentiful in secondary xylem and primarily offer strength to the vessels.
- The xylem parenchyma is responsible for water radial conduction.

Water conduction elements of Xylem

- Water conducting elements or "Hadrome" refers to the tracheid and vessels as a whole.
- Three types of water conducting elements are developed in xylem:

1. Centrifugal: Protoxylem forms along the centre axis, but metaxylem forms away from the centre, towards the periphery, in this sort of development. Endarch is the term used for this condition. For example, Angiosperm and gymnosperm stem

2. Centripetal: .Protoxylem is formed distant from the centre near the pericycle, while metaxylem is formed towards the centre in a centripetal pattern. Exarch is the term used for this ailment. For example, Roots.

3. Centrifugal and centripetal: In this condition, metaxylem elements are generated from both sides of protoxylem components. As a result, metaxylem surrounds the protoxylem. Mesarch is the medical term used for this condition. For example, Fern stem.

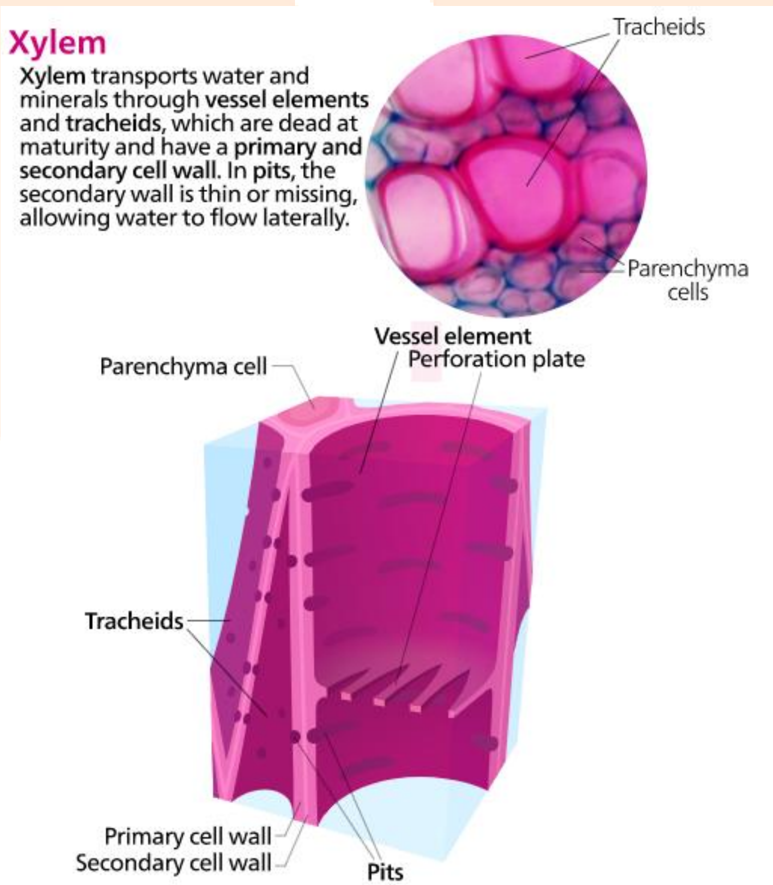

Fig.7. Components of Xylem tissue

b) Phloem

Nageli was the one who invented the term "phloem." Phloem's primary job is to transmit organic materials from one location to another. Phloem is divided into two types based on its development: primary and secondary phloem. Primary phloem comes from the procambium, while secondary phloem comes from the vascular cambium. In comparison to xylem, phloem is active for a shorter period of time. Phloem is made up of four different types of cells which are Sieve cells, Companion cells, Phloem fibers, and Phloem parenchyma.

i. Sieve cells

- Harting was the first to discover the sieve element.
- The sieve element is alive and consists of thin-walled cells.
- A developed sieve cell is devoid of a nucleus. As a result, these are live cells without nuclei.
- Each sieve cell contains a central vacuole. The cytoplasm of sieve cells flows around the vacuole in a thin layer (cyclosis).
- Sieve cells in Angiosperms are arranged end-to-end to form a sieve tube.
- Between the two sieve cells is a sieve plate (transverse perforated septa). It is permeable. Only these pores allow materials to pass through.
- Callose forms a thick layer on the radius of pores during the dropping (falling) season of leaves. This is referred to as a Callus pad.
- During the spring season, callose disappears.
- Sieve cells in Gymnosperms and Pteridophytes do not form sieve plates and are placed in an uneven pattern. The lateral walls of sieve elements have sieve plates.
- Sieve cells contain a unique type of protein called P-protein, which is involved in food conduction and heals damaged sieve cells.

ii. Companion cells

- Companion cells are just seen in Angiosperms (exception -Austrobaileya).
- A live cell with a big nucleus is known as a companion cell. The functions of sieve cells are likewise controlled by this nucleus.
- Both the sieve cell and the companion cell are created at the same time. They are both made up of sister cells from a single cell.
- Plasmodesmata connect the cytoplasm of companion cells with sieve cells.
- Conifers have a special sort of cell that is linked to the sieve cells. Albuminous cells are what they are called.

iii. Phloem fibers

- Libriform fibres are a type of fibre found in the phloem.
- The sieve cells are supported by these fibres.
- The primary role of these fibers is to give mechanical support.
- They are used to make ropes, rough garments, and mats, among other things.

iv. Phloem Parenchyma

- Bast parenchyma is another name for phloem parenchyma.
- They are live cells with thin walls.
- They can store food materials.
- Monocotyledonous plants lack phloem parenchyma.
- The major functions of the phloem parenchyma are food conduction in a radial direction and food storage.
- Leptom refers to the vascular portion.

Special tissue or secretory tissue

1. Lactiferous tissue

They are composed of long, branching cells with thin walls. Latex refers to the milky juice that fills these cells. Plant milk is known as latex. Petrocrops are the types of plants that produce latex.

Saccharides, starch granules, alkaloids minerals, and waste components make up latex.

Dumbbell-shaped starch granules are seen in latex. Plants benefit from latex because it protects them. It also keeps grazing animals away from the plants. It protects against bacterial and fungal infection. Latex cells and latex vessels are two forms of lactiferous tissue.

a) **Latex cells -** These are latex ducts/tubes that are not articulated. They are multinucleate, long-branched cells. Coenocytic cells are the name for these sorts of cells. Examples are *Calotropis, Euphorbia*, and *Nerium*.

b) **Latex vessels -** On the other hand, latex vessels are articulated vessels. Cell walls of meristematic cells dissolve and form latex vessels. For example, *Heavea*, Banyan trees, *Ficus*, *Papaver*, etc. The fruit wall of *Opium* contains highly developed latex channels.

2. Glandular tissue

Glandular tissues are present in the form of glands, as the name suggests. Secretory or excretory contents are stored in these glands. There are two types of glands in glandular tissues resulting in the formation of latex tubes.

As a result, they are known as the unicellular glands found in Urtica dioica (Bicchubutti) are situated on the surface of the leaves. They are spiny glands that contain formic acid. There are two types of multicellular glands - External glands and Internal glands.

a) **External Glands -** They develop on the surface of the plants or emerge from the epidermis as an outgrowth. These glands come in a variety of shapes and sizes syncytial cells.

i. **Digestive glands:** Insectivorous plants have digestive glands. These insectivorous plants compensate for their nitrogen shortage. They are found in plants including *Utricularia*, *Drosera*, and *Dionia*, etc.

ii. **Oil Glands:** These glands produce a volatile oil that is secreted. These glands can be found in *Eucalyptus* leaves and the exterior fruit wall of *Citrus* (Lemon).

iii. **Nectar Glands:** Nectar glands are tissue-embedded glands. They can be found in the parts of flowers mostly in the thalamus. To attract insects, these glands release nectar.

b) **Internal Glands -** Internal glands are located within the tissues. Internal glands are a type of gland found inside the body. The types of internal glands are as follows:

i. **Mucous secreting glands:** Mucus is secreted by these glands. They can be found in the leaves of a variety of plants like Betel.

ii. **Oil glands:** Sebaceous or oil glands are both external and internal. They drain oil that has an antiseptic effect. These glands are found in fruits such as lemons and oranges.

iii. **Gum and resin glands:** The secretory glands of tannin, resin, and gums are also internal glands. Most of the resin glands are located in the palm plant. The gum glands are located in the *Acacia* (babool). Resin ducts are schizogenous.

iv. **Water glands:** The water glands are present on hydathode. These glands are meant for guttation. Hydrathode are found in plants like Tomatoes, Pistils, Nasturtiums, etc., and are present on epithelial tissues.

The tracheids of ferns have long or slender pits. These types of pits are called scalar pits.

Tissue System

Tissue system is divided into three categories based on division of labour. Each system usually consists of a combination of tissue organizations that perform specific functions.

1. **Epidermal tissue system:** This system includes the epidermis and the cells, hair, pores, etc related to that epidermis.

2. **Ground tissue system:** This is the largest tissue system that includes hypodermis, cortex, endodermis, pericycle and medullary rays (pith rays).

3. **Vascular tissue system:** This tissue system is derived from the cambium and is composed of xylem and phloem.

Types of Vascular Bundles

Vascular bundles are divided into four categories based on the arrangement of their different parts.

1. **Conjoint collateral vascular bundles -** These are the vascular bundles in which the xylem and phloem are present on the same radius. The vascular bundle contains the sequence of states. This vascular bundle appears in gymnosperms and angiosperms. Open vascular bundles are found in dicots and gymnosperms. The vascular bundle that is closed is found in monocots.

2. **Conjoint bicollateral vascular bundles -** There are two phloem regions present, one on each side of the xylem. These vascular bundles consist of two cambium belts, one on each side of the xylem. It was only discovered when the vascular bundle was opened. This type of vascular bundle is called the bicollateral vascular bundle. For example, the stem of plants present in the Cucurbitaceae family.

3. **Radial vascular bundles -** When the xylem and phloem have different radii, the vascular bundles are called radial vascular bundles. All plant roots contain radial vascular bundles. The pattern of development of xylem in these vascular bundles is centripetal. Therefore, these vascular bundles are called exarch.

4. **Concentric vascular bundles -** In this vascular bundle, either xylem is surrounding the phloem or the phloem is surrounding the xylem. These concentric vascular bundles are always closed and are of two types which are:

a) **Amphicribral or Androcentric:** Xylem is in the center, surrounded by phloem. That type of vascular bundle is called amphicribral. The development of xylem in these vascular bundles is centripetal or centrifugal. They are called mesangial vascular bundles. This type of vascular bundle is found in ferns and lower Gymnosperms.

b) **Ampivasal or lepto centric:** For this type of vascular bundle, xylem completely surrounds the phloem, that is, the phloem is located in the center of the vascular bundle.

- This type of vascular bundle is called endarch. These kinds of vascular bundles are formed only in angiosperms, such as *Dracaena* and *Yucca*.

- The column is the entire central mass of vascular tissue, with or without medulla, and surrounded by endoderm on the outside. Vantighem and Douliot hypothesized that steles can be explained. According to their hypothesis, the stele is the central part or core of the plant, including the vascular system and related structures.

- Tissues that are present inside the stele are called the interstellar tissues, and the tissues present outside the stele are called the extrastellar organization. The stele is surrounded by an endoderm. However, the endoderm is initially part of the cortex.

Types of Steles

1. **Protostele or monostele:** It is the most simplest and primitive type of stele that consists of solid xylem completely surrounded by phloem. This type of stele does not contain the pith. The hard stele has the following types:

a) **Haplostele:** In this stele, a layer of smooth (a little thick) phloem surrounds the xylem. The central xylem is cylindrical.

b) **Actinoatele:** Actinostele is a star-shaped structure with divergent ribs in the central xylem. Examples are *Psilotum* and *Isoetes*.

c) **Plectostele:** This is a huge stele in which the xylem is divided into several separated plates that are parallel to each other. For example, most of the *Lycopodium* species.

2. **Siphonostele:** The siphonostele is a stele with the pith in the center of a hollow vessel cylinder. There are two types of siphonostele:

a) **Ectophloic siphonostele:** The phloem stele is always outside the xylem in ectophloic siphonostele. Examples are *Equisetum, Osmunda.*

b) **Amphiphloic siphonostele:** The xylem is surrounded by phloem on both sides in this type of vascular bundle. For example, *Adiantum, Marsilea.*

3. **Solenostele:** Solenostele is a stele that forms leaf gaps in the vascular tissue. Leaf gaps are formed due to the rupture of the main vascular tissue of the leaf and these fragments of the stele are called solenostele. Solenostele can be either ectophloic or amphiphloic.

4. **Dictyostele:** When the many leaf depressions formed in the main vascular column of the solenostele are broken down into many fragments, that kind of stele is called the dictyostele. Each segment (piece) is called meristele. Each meristele has its own endoderm and peripheral chakra. It is the type of stele that is most developed in ferns. Examples are Pteridium, Pteris, Dryopteris.

5. **Eustele:** In this type of stele, the vascular bundles are displayed in a circle with medullary rays in between those circles. This type of stele is found in Gymnosperms and Dicots.

6. **Atactostele:** There are several vascular bundles which are distributed in the ground tissue of this stele. This type of stele is called an atactostele. Atactostele is the most developed stele. This kind of stele does not have endodermis and pericycle. This type of stele is the main feature of monocots.

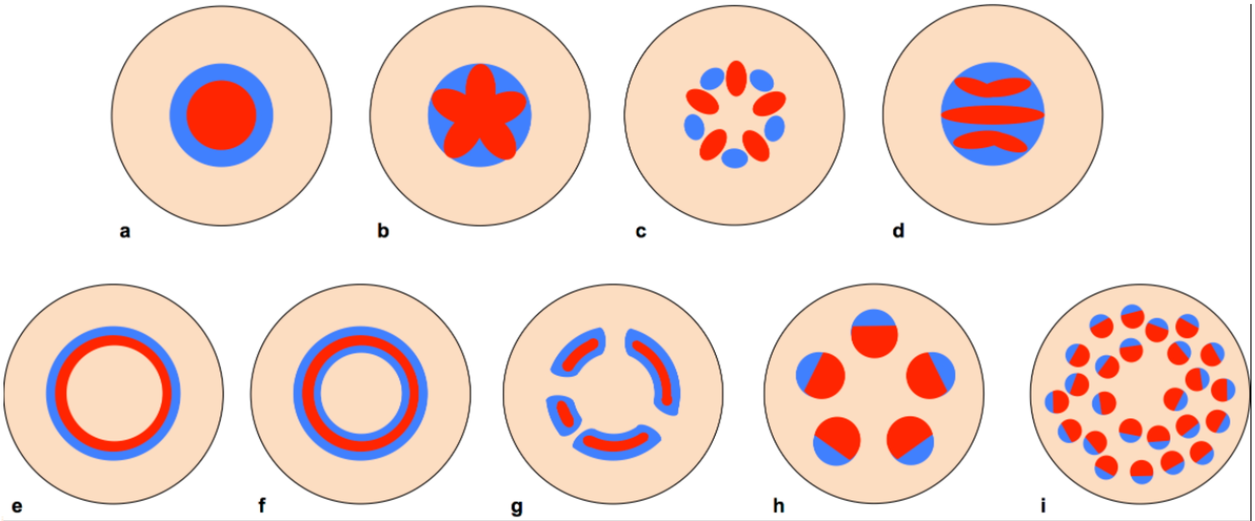

Fig.9. Types of steles

Anatomy of a Dicot stem

The primary structure of the stem of a typical dicot tree has the following characteristics:

1. **Epidermis:** It is the stem's outermost layer. It is composed of a single layer of cells without chloroplasts. The epidermis contains multicellular stem hair and stomata. The epidermis provides protection.

2. **Hypodermis:** This layer exists under the epidermis. It is meant to provide additional support for the epidermis. It is a thick layer with different kinds of cells. This layer consists of collenchyma which have chloroplasts. Therefore, it is green and photosynthetic.

3. **Cortex:** This part has parenchyma. Food storage is the main function of the cortex. The innermost membrane of the cortex is termed as the endodermis.

4. **Endodermis:** This is a single thick layer of cells. The endoderm cells are barrel-shaped. These cells store starch in the stem of dicotyledonous trees, that is why it is also called "starch sheath".

5. **Pericycle:** This layer is located between the endoderm and the vascular bundle (below the epidermis and above the vascular bundle). The stem's pericycle is

multi-layered and consists of sclerenchyma tissue. Another name of the pericycle is "Hard bast". In the sunflower stem, the peripheral ring is composed of alternating bands of parenchyma cells and sclerenchyma cells. The pericyclic cells in front of the vascular bundle are composed of sclerenchyma tissue and the rest of the parenchyma. The pericycle present in front of the vascular bundle is called the bundle cap.

6. **Vascular Bundles:** The vascular bundles of the trunk of a dicotyledonous tree, form a ring pattern. There is a well-developed pitch present under the ring. Each vascular bundle is an open conjoint collateral endarch. Each vascular bundle is composed of phloem and xylem. Eustele occurs in dicotyledonous plants.

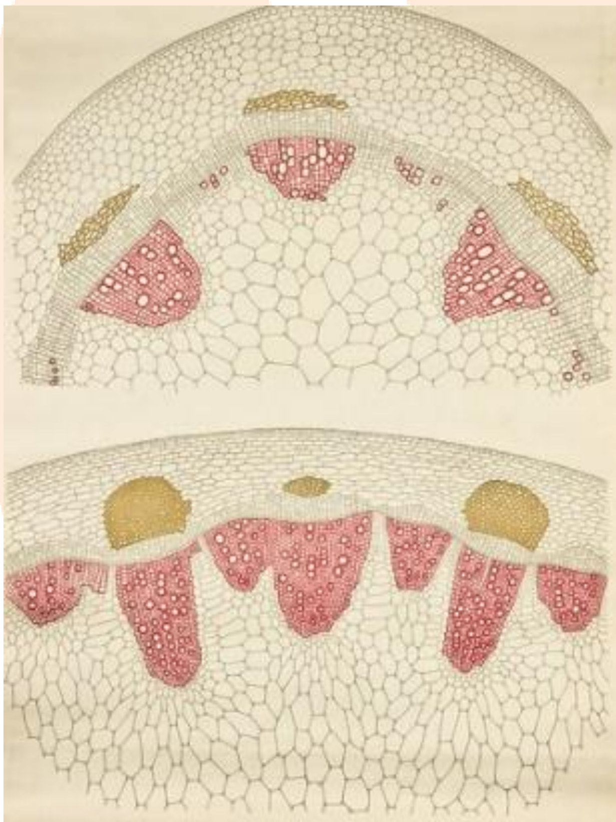

Fig.10. Anatomy of dicot stem

Anatomy of a Monocot stem

The following structures can be seen on a typical monocot strain :

1. **Epidermis:** The epidermis is the outermost layer, called the thick layer. It is covered with a thick skin bearing stomata but lacking multicellular hair. The number of stomata is also relatively small.

2. **Hypodermis:** The hypodermis of a monocot stem is composed of 2-3 layers of sclerenchyma tissue.

3. **Ground tissue:** The whole parenchymal cells near the hypodermis layer reach to the center and are called ground tissue. There is no difference between its endoderm, cortex, perimeter, etc.

4. **Vascular bundles:** Vascular bundles are present in scattered form in ground tissue.The vascular bundles converging toward the center are larger and less numerous. The peripheral vascular bundles are smaller but more numerous and each of the vascular bundles is closed conjoint collateral endarch type. Bundle sheath is a layer of sclerenchyma tissue that surrounds the vascular tissue. Monocot stems contain only xylem and phloem. The xylem elements of monocots are made into the shape of the letter "Y", and the number is limited. Two small xylem vessels in the form of protoxylem are located radially toward the axis. Because there is water in this cavity, it is also called a water cavity. The cavity is formed by the decomposition of elements located under the protoxylem and adjacent parenchyma.

5. **Pith and Stele:** Atactostele, which is a highly developed stele, occurs in monocots.

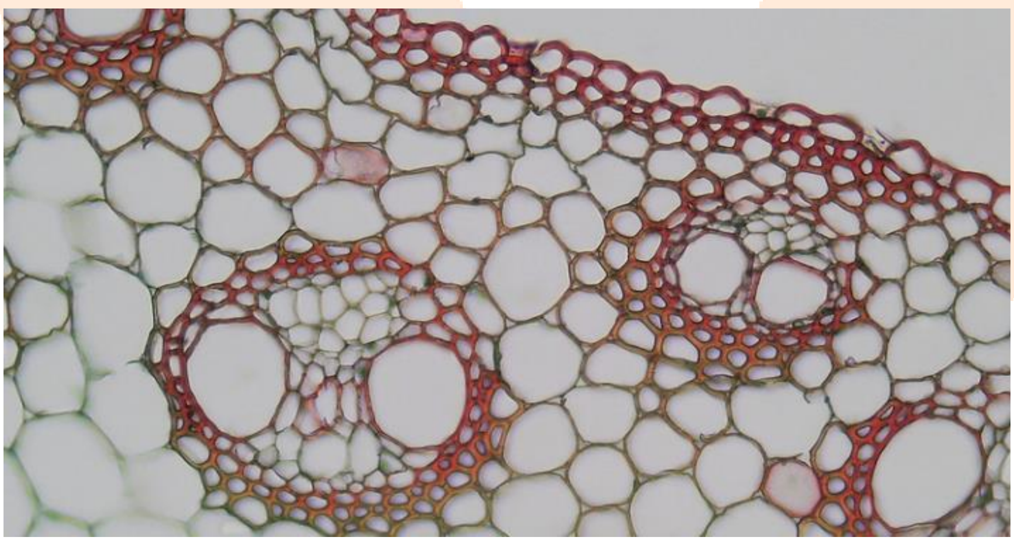

Fig.11. Anatomy of monocot stem

Anatomy of Dicot root

1. **Epidermis:** This is the outermost layer of a single row. This layer having unicellular root hair produced by certain cells of the root epidermis is called Epiblema or Rhizodermis or Piliferous layer.

2. **Cortex:** This part is composed of parenchymal cells. The cells outside the cortex in the old roots are suberized. It is called the exodermis.

3. **Endodermis:** This layer is located between the vascular tissue and the cortex. Casparian strips are located radially in the innermost layer of the endoderm. Suberin makes these strips.

4. **Pericycle:** This is a thick single layer. It is composed of a kind of parenchyma called prosenchyma. It is single layered. Cork cambium is formed by this layer during secondary growth. Lateral roots grow from the pericycle, therefore, lateral roots are endogenous. But the stems are exogenous because their branches come from the outside of the cortex.

5. **Vascular Bundles:** Vascular bundles are radial and exarch, with xylem and phloem partly separated and equal in number. The number of vascular bundles of dicots ranges from two to six (from diarch to hexarch). Polyarchic vascular bundles are found in *Ficus* (Banyan tree) as an exception. Conjugative tissues are the tissues that are situated between the xylem and phloem and they are composed of parenchyma. The vascular cambium is formed by the conjugative tissue during the secondary growth process. As a result, all cambium layers are formed on the roots after secondary growth.

6. **Pith:** It is located in the center, underdeveloped or non-existent. Therefore, it is flexible.

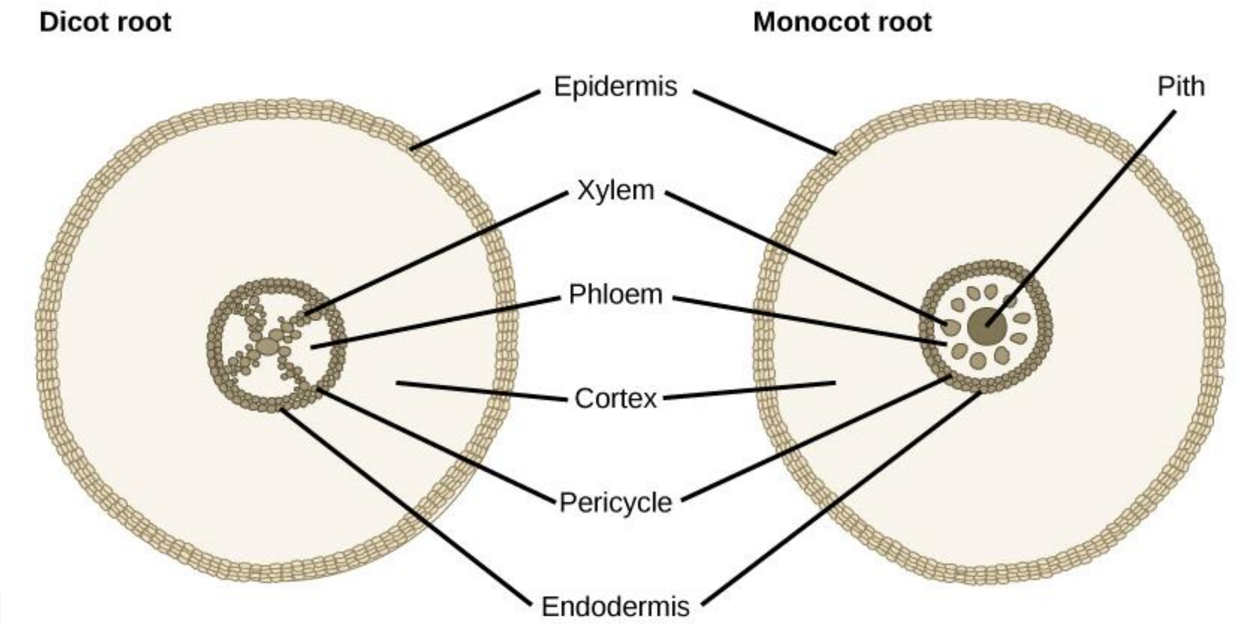

Fig.12. Dicot root and Monocot Root

Root and leaf anatomy of monocots

The internal structure of typical monocot roots corresponds to that of dicots, but the number of vascular bundles in the roots of monocots is greater than six.

But in special cases like onion, the vascular bundle number ranges from two to six. In the root of monocots, the pith is well-developed.

Types and internal structure of leaf

The leaves are generally divided into two categories: Dorsal Ventral leaves and isobilateral leaves.

The difference between the two is as follows:

- The dorsal and ventral leaves are attached at right angles to the stem whereas the isobilateral leaves are attached parallel to the stem.
- The dorsoventral leaves have different structures on both sides whereas in isobilateral leaves these structures are similar on both sides.

- The dorsoventral leaves appear in dicots, but as an exception, *Eucalyptus* has isobilateral leaves.
- Monocotyledonous plants have isobilateral leaves, but there is an exception i.e. *Lilium longiflorum*.

Secondary Growth

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

The permanent internal organ structure is formed by the apical meristem. This structure is formed at the beginning of the first few weeks of the year. This structure is called the primary structure.

The primary structure is only found in ferns and monocots.

Normal secondary growth is found on the roots and stems of dicots and gymnosperms. Due to the lack of vascular cambium in monocots, there is no secondary growth. But some of the monocots can have secondary growth like Palm, yucca, Dracaena, Smilax, Agave, Coconut etc.

Secondary growth in dicot stem

A. **Secondary growth in vascular region:** The secondary growth in the vascular area starts earlier than the cortical area. This is done according to the steps given below:

I. **Forming the vascular ring cambium:** The cambium that exists in the vascular bundle is called intrafascicular cambium. It is a primary meristem. First, the cells of the medullary ray become meristems and form the interfascicular cambium. Intrafascicular and interfascicular cambium are collectively referred to as vascular cambium. The vascular cambium consists of a layer of cells forming a complete ring. Two cell types were found in the ring of this vascular cambium which are fusiform initials and ray initials. The fusiform initials of the spindle are long with pointed ends, and the initials of the rays are spherical. There are more fusiform initials present in the vascular cambium.

II. **Activity of vascular cambium:** Fusiform initials appear in continuous circumferential or tangential divisions. The division plane of periclinal division is parallel to the longitudinal axis of the cell. This type of activity only produces a few cells in the radius (periphery), and these cells form the secondary phloem or bast. Some cells form toward the central axis, and these cells differentiate into secondary xylem or wood. Usually the secondary xylem is formed more than the secondary phloem. Under the pressure of the secondary phloem, the primary phloem pushed outward is destroyed. During the secondary growth period, the epidermis and hypodermis in the stem are not visible. Under the pressure of the secondary xylem, all primary tissues such as the primary xylem, pith, and old secondary xylem in the center of the tree stem are degraded due to its woody nature.

a) Ring porous wood: In this tree, the vessels are arranged in a ring which conducts water more efficiently.

b) Diffuse porous wood: This wood is characterized by the asymmetric distribution of the vessels.

III. **Formation of annual rings:** The activity of the cambium will not remain the same, but will change during the course of the year. In winter or autumn, the activity of the cambium is insufficient, and the resulting secondary xylem or wood will not spread over the entire vascular cambium. It causes formation of small, thick-walled and narrow lumen cells. This is called autumn wood or late wood.

- The vascular cambium is very active in spring or summer. During this period, the secondary xylem formed is extensive. The cells of the secondary xylem are large, with thin walls and have broad lumen. This kind of wood is called spring wood or early wood. Rings made of any type of wood are called annual rings. In this way, two annual rings are formed in one year. Autumn wood growth rings and springwood growth rings are collectively referred to as annual rings. Therefore, the annual ring consists of two growth rings. The number of annual rings formed on the tree provides information about the age of the tree.

- The study of the use of this method to determine the age of plants is called dendrochronology. Growth rings are counted from the base of the stem, because the base has the largest number of annual rings, so the upper part has fewer rings. Basal area can give the right idea. Incremental drilling tools are used to pull the piece from the stem upto center area. The annual rings are counted from this segment and re-inserted (adjusted) on the same site in the same position. These rings are formed more clearly in the different seasons.

- In plants of the temperate zone, the pattern of annual rings is more distinct. But the tropical plants do not form a separate or distinct annual ring. A clear annual ring does not form in plants of India, except for the zone of Himalayas. In coastal areas, the formation of the annual ring is less distinctive due to the climate that remains unchanged all year round. Deciduous plants form clearer tree rings than evergreens.

- The periclinal division of cells also continues in the ray initial part of vascular cambium. As a result, some of the cells were formed on the inner surface, and some on the outer. These cells consisted of parenchyma. In the stem, parenchymal cell lines are formed, which are called vascular rays. Medullary rays are primary but the vascular rays are secondary. Both vascular and medullary rays are meant to conduct water and food in the radial direction.

B. Secondary growth in cortical region: As a result of the addition of secondary vascular tissue, the circular diameter of the xylem region increases and the cortical region is subjected to pressure and stretching, so that part of the cortical tissue eventually ruptures. To make up for this loss, the protective tissues of the epidermis are trying to replenish, but they are damaged and destroyed in many places. This loss is replenished by the action of the cambium plug. Phellogen or Extrastelar Cambium are the other names used for cork cambium. Cork cambium grows from the hypodermis or outer layer of the cortex, becoming the meristem.

- The cells that form internally differentiate into a parenchyma known as the secondary cortex or phelloderm, while phellogen, cork, and phelloderm are collectively known as peridermis.

- Phellogen + Phellem (cork) + Phelloderm = Periderm

- Cork is formed in large quantities and the secondary cortex in lesser quantities from the cork cambium. Cork is most active in the winter. Most of the phellem cells died. But in some places, there are also living cells because suberin does not deposit in these places. These places are called lenticels. Lenticels appear on the outer plant surface in small spots or in the places of swelling of the cells. They are made up of groups of living cells that are scattered. These cells are called complementary tissue. Lentils usually form under the stomata and are used for gas exchange between plants and the atmosphere. as well as transpiration (lenticular transpiration).

- Cuttings of adventitious roots occur from living cells of lenticels during vegetative propagation. Lenticles form mainly on the stem and never occur on the leaves, even lentils are present throughout the body of the plant. They are also found in fruits. Cork cambium survives for only one year. Each year, under the previous layer of cambium, a new type of cambium is formed. This new type of cambium is derived from the phelloderm's secondary cortex.

Bark

- Outside of the vascular cambium, bark refers to all tissue. It is divided into two sections.

1. **Outer bark:** The tissues of the outer bark are dead. All of the tissue present outside the cork cambium is called an outer bark. This is also known as rhytidome.

2. **Inner bark:** The area between the vascular cambium and the cork cambium is called the inner bark. Much of this zone is living. The primary area of the inner bark is the secondary phloem or bast.

Thus, the bark consists of both types of tissue: living and nonliving (dead). It is very necessary for the survival of a tree or plant because they will die if we remove all the bark from them as this leads to the maximum loss of water from the tree. This is because the phloem is degraded by this activity and the plant goes into a food shortage situation.

Types of bark:

1. **Ring bark:** The ring bark forms a complete ring around the stem. After the formation of a complete cambium ring, it is called ring bark. In plants like *Betula vulgaris*, a completely distinct ring bark is formed. In ancient times, it was used as a writing material such as paper. The ring bark also forms in *Eucalyptus* trees.

2. **Scaly bark:** This bark forms around the plant's stem as fragments or pieces. A scaly bark formed when there is no continuous ring of cork cambium.

Secondary growth in dicot root

Secondary growth is necessary for the roots, which is important to ensure the strength of the aerial parts of the plant and to meet the water and mineral requirements. There is no secondary growth that occurs in the roots of monocot plants. First, at the secondary stage, the conjunctive tissue becomes the meristem in the roots of dicotyledonous plants with the formation of a vascular cambium filament, which forms distinct curved stripes. Then after the pericycle cells, outside the protoxylem cell also becomes the meristem. This forms additional bands of cambium. Thus, the ring is made of cambium with a complete circumference. Pericycle forms a very little part of vascular cambium but the conjunctive tissue forms its major parts.

The vascular cambium's ring shape is wavy intially, however due to pressure from the secondary xylem, it becomes round. The vascular cambium part produced by the conjunctive tissue first becomes meristem and then forms secondary xylem towards the center. Finally, the ring forms into a circle due to the pressure of the secondary xylem (outward pushing). The action of the root's vascular cambium root is similar to that of the stem's vascular cambium.

Secondary xylems are formed internally, and secondary phloem - externally by the vascular cambium. The vascular part of the cambium, formed by the pericycle, is responsible for pith formation. They are composed of parenchyma. The rays of pitch are called primary medullary rays. Some pith or medullary rays are also produced from the vascular cambium, known as secondary medullary rays. There are two types of medullary rays in the secondary structure of the roots. The presence of two types of medullary rays is an essential feature of the roots. The stem has only secondary rays. Medullary rays of both kinds conduct water and food in a radial direction. The cork cambium develops from the root pericycle. The cork layer is formed outward, and the secondary cortex is formed from the inside by the cork cambium.

Functions of secondary meristem (Cambium)

1. **Wound healing:** When a wound forms on a stem, the living cells of the wound are responsible for the formation of a cambium layer known as wound cambium, also known as cambium induction. This newly formed cambium produces an

outward cork that completely covers the wound. As a result, the wound heals quickly. Along the edge of the wound, there is a structure that looks like an outgrowth of parenchymal cells called Callus.

2. **Abscission:** The leaves of branched angiospermous species and most of the Pteridophytes fall off after degenerative or vegetative destruction. Gymnosperms and woody dicot leaves fall off before death through abscission. The middle plate dissolves in the abscission layer but the abscission and primary walls can dissolve either partially or completely. Leaf scar is the place from where the leaf gets separated. The living cells present at the place of leaf scar are responsible for the formation of a cork cambium causing the cork to form outward. Eventually, the leaf separates from the plant, which is called abscission.

Anomalous secondary growth in stem

1. **Anomalous/abnormal position of vascular cambium:** Usually, vascular cambium has a round shape but is folded in the stems of some plants. Then these folds break and disintegrate from each other. Each fold is responsible for the formation of a complete vascular bundle. Many vascular bundles are formed on the stem. For example *Thinowia, Serjania, and Bauhinia*.

2. **Abnormal Activity of vascular Cambium:** The parenchyma forms in the maximum part of the vascular cambium. Only xylem and phloem are formed in some places, while in general xylem and phloem are formed from most of the vascular cambium, and the medullary rays are formed from several parts of the vascular cambium. Example: *Aristolochia*, *Vitis vinifera* (grape).

3. **Sequential or successive ring of vascular cambium:** In some plants, each year a new ring of vascular cambium is formed outside the previous ring. Examples of *Cycas, Gnetum, Mirabilis, Boerahvia, Bougainvillea*, etc.

4. **External Stelar vascular cambium:** In plants of the families Amaranthaceae and Chenopodiaceae, the vascular cambium is formed from the pericycle. Pericycle forms a complete ring of vascular cambium.

5. **Interxylary Cork:** The secondary xylem parenchyma becomes the meristem in some tree species and acts as a cork cambium, that is, a cork cambium forms on the internal side of the wood. An example is *Artemisia Tridentata*.

6. **Cork cambium from Epidermis:** The cork cambium is obtained from the epidermis of the plant. Examples are *Solanum dulcamara*, *Quercus suber* (oak). Commercial cork is made from oak.

Secondary Growth in Monocotyledons

The vascular cambium is formed from the outer regions of the ground tissue in some plants like *Dracaena, Yucca, Lomandra, Kingia, Sansevieria, Agave, Aloe arborescens*, etc. On the outer side of the vascular cambium, parenchyma is formed but the vascular bundles are formed inside of the vascular cambium. In some plants, the stem circumference is increased without cambium like Palms, Musa, Tulip, etc. The apical meristem of these plants is of a special type and is called the primary thickening meristem. It is responsible for the growth in both length and girth (thickness) of the plant.