ANATOMY OF FLOWERING PLANTS

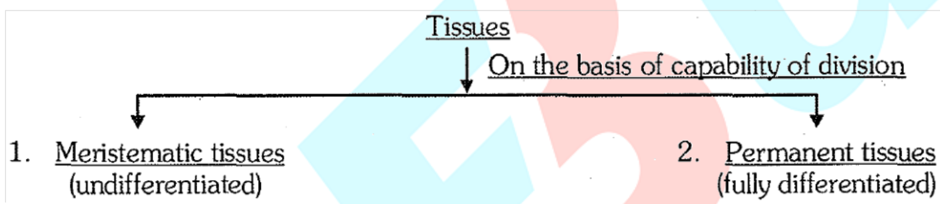
PLANT ANATOMY :

- ♦ The branch of botany which deals with study of internal structures and organization of plants or plant organs (plant parts) is known as plant anatomy I Study of internal structure of plants is called plant anatomy.
- ♦ N.Grew (Nehemiah Grew) is known as father of plant anatomy.
- ♦ K.A. Chaudhary is known as father of Indian plant anatomy.

  Note : Book- "The anatomy of seed plants" was written by Katherine Esau (K. Esau). It was published in 1960. It was referred to as Webster's of plant biology -It is encyclopediac.

TISSUE:

- ♦ A group of cells having a common origin and usually perform a common function is called tissue.
- ♦ The term tissue was coined by Nehemiah Grew .
- ♦ The tissues were divided into two groups by Karl Nageli :-



Meristematic tissues	Permanent tissues
→ Cells have capacity of division	→ Cells have no capacity of division
→ Composed of immature cells	→ Composed of mature cells

- 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
- Meristem term was given by Nageli. It is derived from a Greek word meristos (means Divided/Divisible)

CHARACTERISTICS OF MERISTEMATIC TISSUE

- It is an undifferentiated tissue.
- Cell cycle of meristem is in continuous state of division. Thus, meristematic tissue is composed of immature cells.
- Meristematic cells have only primary cell wall which is thin and flexible (elastic) and made up of cellulose with abundant plasmodesmatal connections.
- Secondary cell wall is absent.
- Cells of meristem are small and generally isodiametric.
- They have dense cytoplasm.
- They have prominent and large nucleus.
- Normally vacuoles are absent in meristematic cells, if present then they are small in size.
- Meristematic cells are metabolically highly active, so reserve food is absent in these cells.
- Plastids are absent in meristems. If they are present, then only in the proplastid stage.
- They do not have intercellular spaces. Cells are closely arranged/ closely fitted (packed) together, so it is a compact tissue.

- Ergastic (non living) substances are absent.

CLASSIFICATION OF MERISTEMATIC TISSUE/MEIDSTEM:

[A] MERISTEM BASED ON ORIGIN AND DEVELOPMENT

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

(i) PROMEIDSTEM/PRIMORDIAL MEIDSTEM/URMEIDSTEM

- This meristem develops in the beginning during embryonic stage. It forms primary meristem. eg. Embryonic meristem

(ii) PRIMARY MEIDSTEM

- 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.

  e.g. Apical meristem, intercalary meristem, intrafascicular cambium (Fascicular vascular cambium).

(iii) 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 .

  e.g. Interfascicular cambium & cork cambium of diCot stem, vascular cambium & cork cambium of dicot root.

Promeristem
↓
Primary meristem
Differentiation ↓
Primary permanent tissue
Dedifferentiation ↓
Secondary meristem
Redifferentiation ↓
Secondary permanent tissue

[B] MERISTEM BASED IN LOCATION (POSITION) IN PLANT BODY

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

(a) APICAL MEIDSTEM : 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.

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

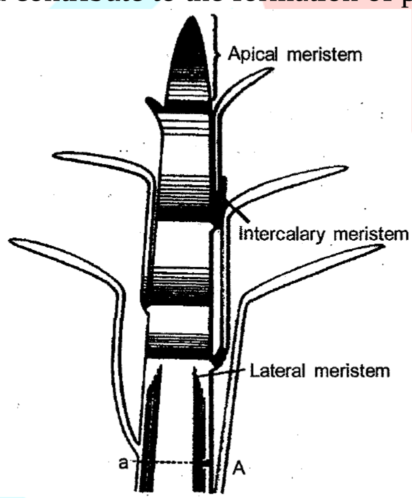
(i) **Protoderm :** It is the outer most layer of eumeristem. By the activity of protoderm epidermal tissue system is formed. E.T.S. includes epidermis, stomata, stem hair(shoot hair/trichomes) etc.

(ii) **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)

(iii) **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) and pith(medulla). 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.
- It is present at the base of internode of monocots stems e.g. grasses, bamboo, sugarcane etc. It is also present at the base of leaves. By the activity of this meristem, length of leaves increases.
- Intercalary meristem occurs between mature tissues.
- By the activity of this meristem length of the plant organs increases.
- 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.
- All secondary meristems are lateral meristems.
- Lateral meristems are both primary and secondary in origin (mostly secondary in origin).

(I) **Primary lateral meristems :** **1. Marginal meristem**
2. Intrafascicular cambium

1. **Marginal meristem :-** It occurs at the margin of young leaf. Its activity increases the width of leaf (not thickness). For total growth of leaf only primary meristems are responsible.

2. **Intrafascicular cambium /fascicular cambium :** This cambium occurs inside the vascular bundles of dicot stems and gymnosperms stems.

(II) Secondary lateral meristems :- Interfascicular cambium and cork cambium (phellogen) of dicot stem and gymnosperm stem. Cork cambium and vascular cambium of dicot roots

Note : Generally lateral meristems are cylindrical.

Note : 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.

COMPOSITION/ORGANISATION OF APICAL MERISTEM IN DIFFERENT PLANTS

♦ Apical meristem is absent in most of the algae and fungi. All the cells of these plants are divisible, so they do not show apical growth. Thus such type of growth in these plants is called diffused growth. Diffused growth also occurs in animals.
♦ In some algae (eg.- brown algae), bryophytes and some pteridophytes one meristematic cell is present at the apex. Generally the shape of apical cell is pyramid like.
♦ In ferns, gymnosperms and angiosperms apical meristem consists of many cells.

[1] HISTOGEN THEORY :

♦ This is most valid theory for root apex organisation.
♦ This theory was proposed by Han stein (1870).
♦ According to Han stein, the apical meristems (root and shoot apices) are distinguished into three histogens (meristematic regions). These are as follows.
  - **(i) Dermatogens :-** This is the outermost histogen & composed of single layer of cells. These cells form uniseriate (single layered) epidermis.
  - **(ii) Periblem :-** This region is situated just below the dermatogen. It forms cortex (hypodermis, general cortex and endodermis).
  - **(iii) Palermo** :- This is the innermost histogen. Stele formation ta,kes place by division of these cells. It means formation of pericycle, vascular bundles, pith rays (medullary rays) and pith(medulla).

♦ This theory is true only for root apex. It is not applicable for shoot apex of higher plants because in most of the gymnosperms and angiosperms, shoot apex is not differentiated into three histogens.
♦ Including above described three histogens, a fourth histogen is also present in monocotyledon root apex. This is known as calyptrogen. Root cap is produced by calyptrogen in monocots. Root cap & epiblema/epidermis are produced by dermatogen in dicotyledons.
Due to presence of root cap, position of root apical meristem is sub terminal/sub apical, so maximum growth in root takes place behind the apex.

- In hydrophytes root cap is absent eg. Pistia. In place of root cap, root pockets are present.
- Generally, root cap is single but in Pandanus (screw pine) multiple root cap is present.
- Root cap is living, it contains large amount of golgi bodies which secrete mucilage, which makes the root slimy.
- In monocot root, epidermis and calyptrogens are derived from dermatogens.

Type of root	Number of histogens	Outer most histogen	Root cap is formed by
Dicot root	3	Dermatogen	Dermatogen
Monocot root	4	Calyptrogen	Calyptrogen

Note :-Root cap is formed by calyptrogens (If dicot or monocot is not given)

QUIESCENT CENTRE :-

♦ Quiescent centre term was coined by "Clowes". Quiescent centre was discovered by Clowes in Maize root.

♦ A group of inactive or less active cells present between the dermatogen and calyptrogen of monocot root is called quiescent centre. The cells of quiescent centre contain less amount of DNA, RNA, light cytoplasm, small nuclei and synthesis of protein is also less.

Function : The quiescent centre in the root meristem serves as a reserve for replenishment of damaged cells of the meristem or Inactive cells of quiescent centre become active when previously active initials of calyptrogen get damaged.

Quiescent centre is crescentic shaped.

[2] TUNICA CORPUS THEORY :-

This theory was proposed by Schmidt (1924). It is most valid theory for shoot apex organisation of angiosperms. It is based on planes of division. According to this theory two zones are found in the shoot apex:-

(I) TUNICA:

♦ This is peripheral layer. In tunica cells, anticlinal division takes place only in one plane. Epidermis is formed by tunica.

♦ Generally, tunica is single layered, but sometimes it is multilayered, then the outer most layer forms the epidermis and remairiing layers of tunica form rest types of tissues with the assodation of corpus.

(II) CORPUS : The mass of cells present below the tunica is called corpus. The cells of this zone divides in all directions (all planes) due t? which volume increases. The cells of corpus are usually larger than the cells of tunica.

Function : Formation of ground tissue system and vascular tissue system. or Formation of cortex and stele.

[3] CYTO-HISTOLOGICAL ZONATION THEORY :-

According to Foster, shoot apical meristem is classified into two regions on the basis of rate of division :- **(I). Summit** **(II). Flanks**

VEGETATIVE SHOOT APEX:-

(I) SUMMIT :

The rate of division is slow in this region. This region is located at the apex.

(II) FLANKS :

The rate of division is very fast in this region. This region lles behind/below the summit and leaf primordial are formed by this region.

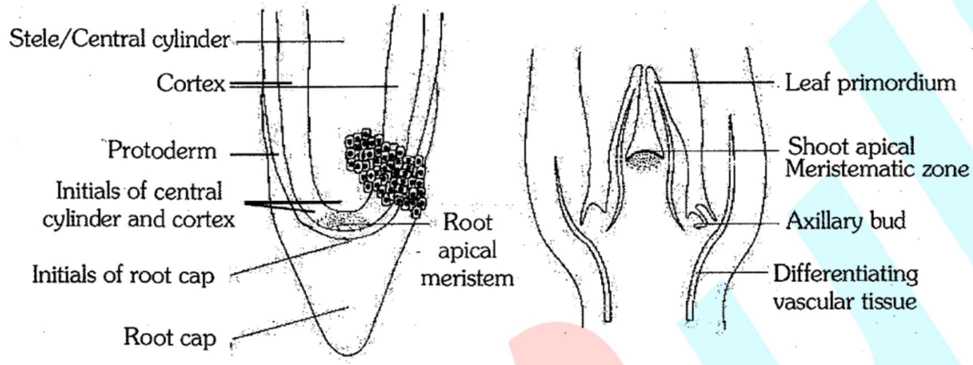
- Time period between initiation of two successive leaf primordial is called ‘Plastochron’.
- Shape of vegetative shoot apex → Dome (mainly) or conical shaped
- Shape of reproductive shoot apex → Broad & flat
- Shoot apex is terminal in position
- Growth of leaf primordium → First apical then marginal.

- Function of leaf primordium → Provide protection to shoot apex.

REPRODUCTIVE SHOOT APEX:

During reproductive phase i.e., at the time of flowering, vegetative shoot apex transforms into reproductive shoot apex. This change of shoot apex is induced by florigen & light.

♦ In reproductive shoot apex, summit zone is more active (rate of cell division fast) and it forms stamens (androecium) & carpels (gynoecium) and flanks zone is less active (rate of cell division slow) and it forms sepals (calyx) and petals (corolla).



Apical meristem : (a) Root (b) Shoot

- 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

PERMANENT TISSUES

Permanent tissues are composed of cells which have lost the power of division temporarily or permanently. They are formed by division and differentiation of meristematic tissues. The cells of permanent tissues do not generally divide further.

- Their cells may be living or dead. Permanent tissues are of three types :-

A. Simple tissue (Homogenous tissue)
B. Complex tissues (Heterogeneous tissue)
C. Special tissue (Secretory tissue)

Mainly of 2 types i.e. simple and complex tissues

[A] Simple permanent tissue

This tissues 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. Collenchymas** **III. Sclerenchyma**

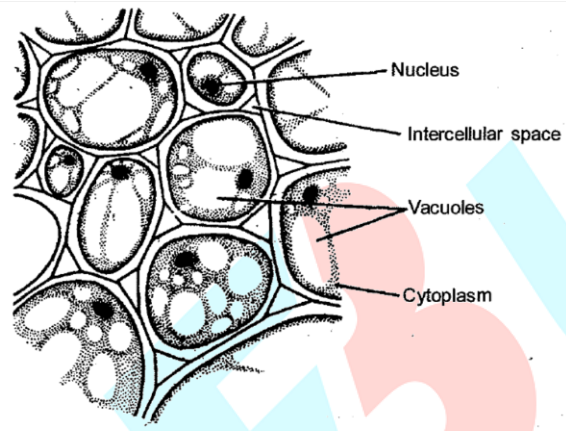
I. PARENCHYMA : It is very primitive type of tissue. It is first evolved tissue. Remaining different types of tissues are derived from this tissue, so it is also called fundamental tissue or precursor of other tissues. Parenchyma forms the major component within organs.

- Parenchyma term was coined by Grew.

CHARACTEWSTIC FEATURES :

♦ It is a living tissue.

- ♦ It is first differ~ntiated tissue.
- ♦ It is a universal tissue.
- ♦ Pulp of a fruit is mainly composed of parenchyma.
- ♦ Body of bryophytes is mainly composed of parenchyma.
- ♦ The cells of parenchyma are thin walled. Cell wall is made up of pectocellulose means pectin + cellulose (mainly cellulose). So parenchyma is a soft tissue.
- ♦ Each cell contains large tentral vacuole. So the main function of a parenchyma cell is storage of food.
- ♦ Parenchymatous cells may either be closely packed or have small intercellular spaces.
- ♦ It is found in cortex, pericycle, medullary rays, pith, leaf mesophyll etc. It forms major component within organs.



T.S. of Parenchyma

SHAPE :

- ♦ The cells of parenchyma are generally isodiametric. They may be spherical (rounded), oval, elongated or polygonal in shape.

MODIFICATIONS OF PARENCHYMA :

1. **Prosenchyma :-** The cells of this parenchyma are thick walled, long with pointed ends. This parenchyma forms the pericyte of roots. Function: To provide strength.
2. **Aerenchyma :-** This parenchyma is made up of rounded cells. These cells surround the large air chambers. Aerenchyma is usually found in cortex region. It provides buoyancy to hydrophytes (aquatic plants).
3. **Stellate parenchyma :**
   Found in leaf bases of banana.
   The cells of this tissue are stellate (star shaped). Main function of this parenchyma is to provide mechanical support/mechanical strength to leaf bases (pseudo stem) of banana.
4. **Chlorenchyma :** Such type of parenchyma contains abundant quantity of chloroplasts. It is found in the mesophyll of leaves. Its function is to perform photosynthesis.
5. **Mucilage Parenchyma :**
   In the mucilage parenchyma large vacuoles and mucilage are present.-
   e.g. Succulent (fleshy) xerophytic plants. e.g. Aloe, Opuntia, Cactus, Euphorbia.
   Function- storage of water. Functions of parenchyma :

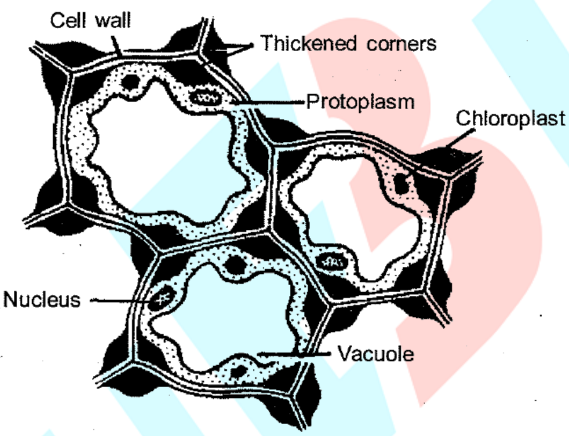
- The parenchyma performs various functions like storage. photosynthesis. secretion etc.
- The main function of this tissue is storage of food.

- Some cells of parenchyma store waste materials. They are called "idioblast cells". ldioblast cells store oils, tannin and crystals.
- Photosynthesis (by chlorenchyma)

II. COLLENCHYMA : Term was coined by Schleiden.

Main characteristics :

- ♦ Collenchyma is a living mechanical tissue.
- ♦ It is made up of more or less elongated cells (In transverse section cells appear ovaL spherical/rounded or polygonal in shape).
- ♦ Localized deposition of pectin (mainly). cellulose & hemicellulose occurs mainly at comers.
- ♦ Usually intercellular spaces are absent.
- ♦ Generally chloroplasts are found in the cells of collenchymas or cells often contain chloroplasts.
- ♦ These cells assimilate food when they contain chloroplasts.



T.S. of Collenchyma (Angular)

Occurrence :-

- ♦ Collenchyma is not a universal tissue. 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 forms the hypodermis of dicotyledon stems. Cells of collenchyma are flexible due to hydrophilic nature of pectocellulose, so flexibility occurs in dicotyledonous/dicot stems.
- ♦ Margins of leaf lamina and petiole of leaves also bear collenchyma. It protects the lamina margins from cracking by the action of wind.
- ♦ Collenchyma is absent in mature/woody plant parts (After secondary growth in dicot stem), roots and monocotyledons.

FUNCTIONS :-

- ♦ Collenchyma performs both functions mechanical as well as biological/vital functions. Provides tensile strength against bending & swaying (mechanical function).
- ♦ They provide mechanical support to the growing parts of the plant such as young stem and petiole of a leaf.

- Due to the presence of chloroplast, photosynthesis process (assimilation of food) takes place in collenchymas (vital function).

III. SCLERENCHYMA :-

Term was coined by Mettenius.

Main features :-

- Sclerenchyma is the main mechanical tissue. It is dead mechanical tissue.
- 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.

Function : It provides mechanical support/mechanical strength to plant organs.

- Various types of pits are formed due to the deposition of lignin on the walls.

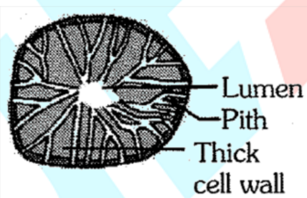
Types of sclerenchyma :-

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

(I) Sclereids

(II) Sclerenchymatous fibres

(I) 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). Sclereids 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 (Stone cells); seed coats of legumes and leaves of tea etc.

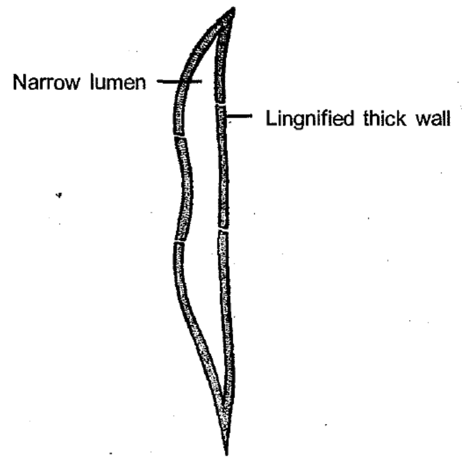


A sclereid

(II) SCLERENCHYMATOUS FIBRES :-

The fibres are thick walled, elongated and pointed cells.

- Fibres are longest cells in plant body. Their both ends are pointed (tapering). Due to thick cell wall, lumen is reduced and generally occurring in groups in various parts of the plant.
- Their cell wall contains pits.



L.S. of Single Selerenchymatous fibre

- On the basis of position, fibres are divided into three types -
  - **A. Surface fibres :-** They are present on the surface of seeds, fruits etc. These fibres are also called filling
  - **(i) Seed surface fibres -**

    Example 1 : Cotton fibres (Gossypium fibres)- Cotton fibres are out growth of seed coat/festa.

    Cotton fibres are composed of cellulose. They are non-lignified~ So cotton fibres are not true fibres. Two types of fibres are found in cotton. Long fibres are called 'lint' and small fibres are known as 'fuzz'. Lint fibres are used in cloth industry. Fuzz are filling fibres.
  - **(ii)** Coir of coconut is also a type of surface fibres. They are derived/ obtained from the fibrous mesocarp of coconut (Cocos nucifera). These are true fibres, because they are lignified.
  - **B. Xylary fibres/lntraxylary fibres/Wood fibres :-** These are hard fibres. These fibres are not·flexible. These fibres are obtained from xylem (mainly from secondary xylem or wood).

    Ex. Munj fibre (Saccharum munja)
  - **C.** Phloem fibres/Extra xylary fibres I Bast fibres :-These are commercial fibres. These fibres are flexible and can be knitted (weaved) easily. They have great economic value.
- These fibres are obtained from the phloem and pericycle of plants.
- The bast fibres of Corchorus capsularis (Jute),Crotalaria juncea (Sunn hemp) and Hibiscus salxfariffa (patua) are obtained from the phloem (secondary phloem) of stem.
- The bast fibres of Hemp (Cannabis sativa) and Aax (Linum usitatissimum) are obtained from the pericycle.
- Phloem fibres of jute. flax and hemp are used commercially.
- Fibres are longest plant cells. Longost fibres occure in phloem of Boehmeria nivea (Ramie plant) length -55 cm.
- IN plant kingdom hardest, thickest and Largest leaves are found in Victoria regia.
- Longest commercial fibres – Jute fibres

[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 heterogeneous.
- Complex tissues are absent in gametophytes.
- During vascularisation in plants differentiation of procambium is followed by the formation of primary phloem and primary xylem simultaneously.
- Complex tissues are also known as vascular tissues or conducting tissues.
  Complex tissues are of two types - (a) Xylem (b) Phloem

(a) Xylem

- The term 'Xylem' was coined by Nageli .
- 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.
- For efficient conduction of water death of protoplasm is must. Dead tissues are more developed in water scares conditions.
- In hydrophytes xylem is poorly developed, while in xerophytes xylem is well developed.
- On the basis of origin, xylem is divided into primary xylem and secondary xylem.

1. **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.
   (1) Protoxylem **(2) Metaxylem**

- Cells of protoxylem are small as compared to metaxylem. The first formed primary xylem elements are called protoxylem and the later formed primary xylem is called metaxylem.

2. **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

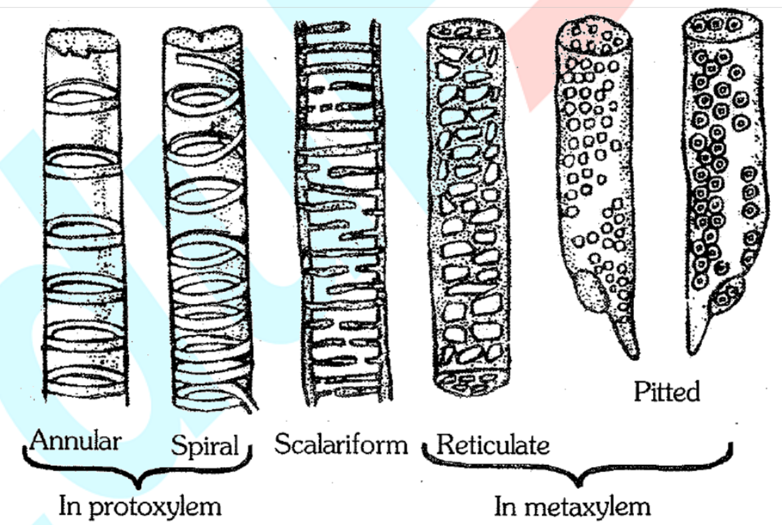
(1) Tracheids, (2) Vessels or tracheae, (3) Xylem fibres (4) Xylem parenchyma

Dead elements: (1) Tracheids, (2) Vessels or tracheae, (3) Xylem fibres
Living element: (4) Xylem parenchyma

1. 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 I 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.
- Types of thicknening in tracheids and vessels are annular, spiral, reticulate, pitted and scalariform.
- The deposition of lignin on cell wall is responsible for the formation of different types of thickenings.i.e., annular (primitive type), spiral, scalariform, reticulate and pitted.
- Annular and spiral type of thickening of lignin is found in protoxylem.
- Reticulate and pitted (mainly) type of thickening of lignin is found in metaxylem.
- Scalariform Gadder like) type of thickening is found in metaxylem tracheids of pteridophytes and in metaxylem tracheids of Cycas (gymnosperm).
- Maximum deposition of lignin is found in pitted type of this;kening and pits are formed in this type of thickening.
- Pits are unlignified areas on lignified walls



Different types of thickening on the walls of tracheids and vessels

2. VESSELS = TRACHEAE

- ♦ Vessel is an advanced conducting element of xylem.
- ♦ Vessel is a long cylindrical. tube like structure with lignified walls and a wide Qarge) central lumen/cavity.
- ♦ Vessel is multicellular, it is made up of many cells called vessel members or vessel elements.
- ♦ Vessel is an example of dead syncyte. Vessel cells are also devoid of protoplasm.

- The end wall is perforated. Thus vessels are more capable for conduction of water than tracheids. Due to presence of perforated end walls, vessels work as a pipe line during conduction of water.
- Vessel members are interconnected through perforations in their common walls. The perforation may be simple (only one pore) or multiple (several pores). Vessels contain usually simple pits on their lateral walls.

1. 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).

2. Vessels are absent in some angiosperm plants such as Dracaena, Yucca, Dagenaria, Drimys. There are some angiosperm families in which vessel less angiosperms are included. e.g.Winteraceae, Tetracentraceae and Trochodendraceae.

3. Tracheids and vessels are called tracheary elements of xylem.

4. In flowering plants, tracheids and vessels are the main water transporting elements.

Syncyte: Structure which is formed by fusion of cells is called syncyte.j

3. XYLEM FIBRES = WOOD FIBRES :

- They may either be septate or aseptate.
- Xylem fibres provide strength to the tracheids and vessels .
- They have highly thickened walls and obliterated central lumens.
- They are abundantly found in secondary xylem (wood).
- They are generally not found in gymnosperm wood (so gymnosperms are also called soft wood spermatophytes).

4. 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.

Hadrome:-

Conducting part of xylem is known as hadrome.

Tracheids and vessels are collectively known as water conducting elements or "Hadrome". Hadrome term was proposed by Haberlandt.

(b) PHLOEM

- The term 'Phloem' was coined by Nageli.
- The main function of the phloem is to conduct/trasport 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 protophloem and metaphloem.

- The protophloem (first formed primary phloem) has narrow sieve tubes whereas metaphloem Gater formed primary phloem) has bigger sieve tubes.
- Phloem remains active for less duration as compared to xylem.

Phloem consists of 4 types of cells I elements:-

- ♦ Sieve tube elements, companion cells, phloem parenchyma & phloem fibres (In angiosperms).
- ♦ Sieve cells, albuminous cells, phloem parenchyma & phloem fibres (In gymnosperms).

1. Sieve cell / Sieve tube element :

Sieve cell ↓ **In Gymnosperms and pteridophytes**

Sieve tube element ↓ **In Angiosperms**

1. Sieve element was discovered by Hartig.
2. In Angiosperm plants, sieve tube elements are joined from 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 (oblique perforated septa). Translocation of food material takes place through these pores.
- Sieve tube is an example of living syncyte.

3. Sieve tube elements are long, tube like structures arranged longitudinally and are associated with companion cells.
4. Sieve cells and sieve tube elements are living and thin walled.
5. A mature sieve tube element possess a peripheral cytoplasm & a large vacuole but lacks a nucleus.
6. Mature sieve tube elements are enucleated living cells (enucleated means without nucleus).
7. The function of sieve tubes are controlled by the nucleus of companion cells.
8. A central large vacuole is present in each sieve cell and sieve tube element and around the central vacuole thin layer of cytoplasm is present.

Note :-

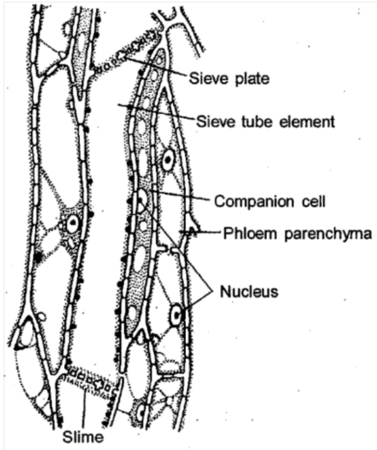
1. Callose deposition takes place on the radius of sieve pores during dropping season/falling season of leaves (autumn), to form a thick layer. This is called callus pad /callose pad. It is formed mainly in deciduous plants.
2. Sieve plate is protected by callose pad. It protects sieve plate from bacterial infection and drought (dry ness).
3. Callose dissolves during spring season. Callose is a polymer of β-1, 3-glucan.
4. Sieve elements contain special type of protein-P-protein (p=phloem). Most likely function of p-protein is sealing mechanism on wounding along with callose and it is also related with conduction of food.
5. In Pteridophyte and gymnosperms, sieve cells are arranged in zig-zag manner. In sieve cells, sieve areas are located laterally. Sieve cells are narrow elongated cells.

2. COMPANION CELLS :

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

- ♦ The sieve tube elements and companion cells are connected by pit fields present in their common longitudinal walls.
- ♦ Companion cell is laterally associated with each sieve tube lement in angiospermic plants.
- ♦ Sieve tube element and companion cell originate together. Both of them originate from a single mother cell. So they are called sister cells
- ♦ Companion cell is a living cell with large elongated nucleus. This nucleus also controls the activity/functions of sieve tube element.

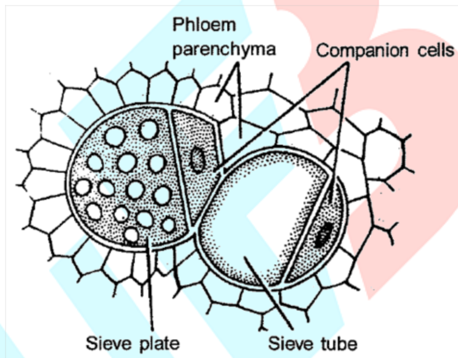
- ♦ Companion cells are found only in angiosperms.



L.S. of Phloem Tissue

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

Note: Special type of cells are attached with the sieve cells in gymnosperm and in pteridophytes in place of companion cells. These cells are called albuminous cells/Strasburger cells.



T.S. of Phloem Tissue

3. **PHLOEM FIBRES I 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.

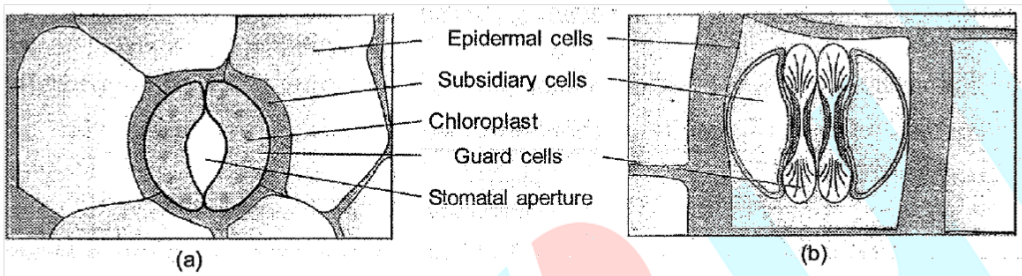
4. **PHLOEM PARENCHYMA:**

- ♦ It's cells are living, elongated, tapering, cylindrical which have dense cytoplam 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.
- ♦ The conducting element of phloem is called Leptome .
- ♦ Leptome term was given by Haberlandt.

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 loeation/position & structure I 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 andcomprises epidermis, stomata and epidermal appendages. e.g. Root hairs. trichomes.



Diagrammatic representation : (A) stomata with bean-shaped guard cells (b) stomata with dumb-bell shaped guard cells (Grass family).

- **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.
- **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. The trichomes help in preventing water loss due to transpiration.

  Note : In shoot system. trichomes are usually multicellular.

  Function : The trichomes help in reduction of water loss.
- **Root hairs** :- The root hairs are formed due to the elongation of the epidermal cells. These have a vacuolated protoplasm. The thin wall is made up of cellulose and pectic materials.

  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 includes hypodermis, general cortex, endodermis, pericycle and medullary rays (pith rays), pith. In leaf G.T.S. consists of mesophyll. GTS is also called fundamental tissue system. G.T.S. is made of simple tissues such as parenchyma. collenchyma & sclerenchyma. The GTS forms the main bulk of the plant.

3. **Vascular/conducting tissue system :-** The V.T.S. consists of complex tissues. xylem and phloem. It is also called specific tissue system.

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

Types of development of primary xylem :-

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

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

III. **Centrifugal and Centripetal** :- Elements of metaxylem are formed on both sides of the elements of protoxylem. In this condition xylem is known as mesarch. ex. Fern rhizome (underground stem).

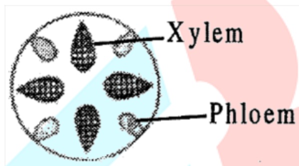
VASCULAR BUNDLES

♦ Xylem and phloem are collectively termed as vascular bundles.
Which may or may not have cambium.

Types of vascular bundles

On the basis of arrangement of elements means location of xylem and phloem, vascular bundles are divided into three categories.

(I) **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.

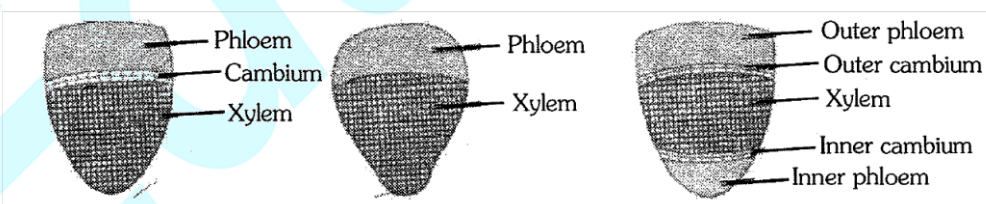
♦ In these vascular bundles xylem is exarch. The order of development of xylem in these vascular bundles is centripetal

Example : Most of the roots. (Dicot, monocot, gymnosperm, fern root)

♦ **Exception :-** In Radish, carrot, turnip and sugar beet (Beet root) roots, conjoint, collateral vascular bundles are present.

II. **Conjoint vascular bundles :**

In these type of vascular bundles xylem and phloem are present on the same radius of vascular bundles and combine into a bundle. These are of two types –



Collateral (Open) Collateral (Closed) Bicollateral

(1) **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) **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.

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

Ex. Monocotyledons stem and leaves of angiosperms.

- ♦ In this type of vascular bundle, xylem is end arch and order of development of xylem is centrifugal.

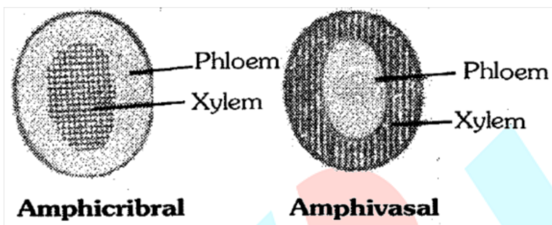
(2) Conjoint, bicollateral and open vascular bundle- In this type of V.B. two patches of phloem, one on each side of xylem are found. There are two strips of cambium (outer and inner), one on each side of xylem are found. Only outer cambium is functional.

- ♦ Order of development of xylem is centrifugal means endarch condition is found
Ex. stem of family cucurbitaceae and some plants of family solanaceae.

III. Concentric vascular bundles :

In these type of vascular bundles either xylem surrounds the phloem or phloem surrounds the xylem. Concentric vascular bundles are always closed. They are of two types

(a) Amphicribral or Hadrocentric :



- ♦ In this type of vascular bundle xylem is completely surrounded by phloem. It means xylem is present in the centre of vascular bundle.
- ♦ Such types of vascular bundles are found in ferns rhizome (Underground stem).
- ♦ The order of development of xylem in ferns rhizome is of both centripetal and centrifugal and xylem is menarche.

(b) Amphivasal or l.eptocentric :

- ♦ In this type of vascular bundle phloem is completely surrounded by xylem. It means phloem is present in the centre of the vascular bundle.
- ♦ In this type of vascular bundle, xylem is end arch. e.g. stem of Dracaena, Yucca etc.

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

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

3. Which of the following is primitive tissue :-
(1) Parenchyma (2) Collenchyma (3) Sclerenchyma (3) Xylem

4. Conjoint, collateral vascular bundles are found in :-
(1) Stems (2) Leaves (3) Roots (4) Both (1) % (2)

GOLDEN KEY POINTS

1. Meristos is a Greek word which means divided.

2. A simple tissue is made of only one type of cells where as the complex tissues are made of more than one type of cells.
3. Generally gymnosperms lack vessels.
4. All tissues except epidermis and vascular bundles constitute the ground tissue.
5. In the monocotyledons, the vascular bundles have no cambium, hence they are referred to as closed.

INTERNAL STRUCTURE OF YOUNG STEMS, ROOTS & LEAVES

INTERNAL STRUCTURE OF DICOT STEM:

Internal structure of a typical dicot (dicotyledonous) stem shows following features :-

1. **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 .

2. **Cortex :** The cells arranged in multiple layers between epidermis and peric.ycle constitute the cortex. In dicotyledon stem cortex is divided into three parts or sub zones.

(a) Hypodermis **(b) General cortex** **(c) Endodermis**

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

(b) **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.Resin canals mucilage canals are present in it. These are schizogenous in origin. The innermost layer of the cortex is called endodermis.

(c) **Endodermis :** It is single layered. The cells of endodermis are rich in starch grains, thus it is also known as "starch sheath".

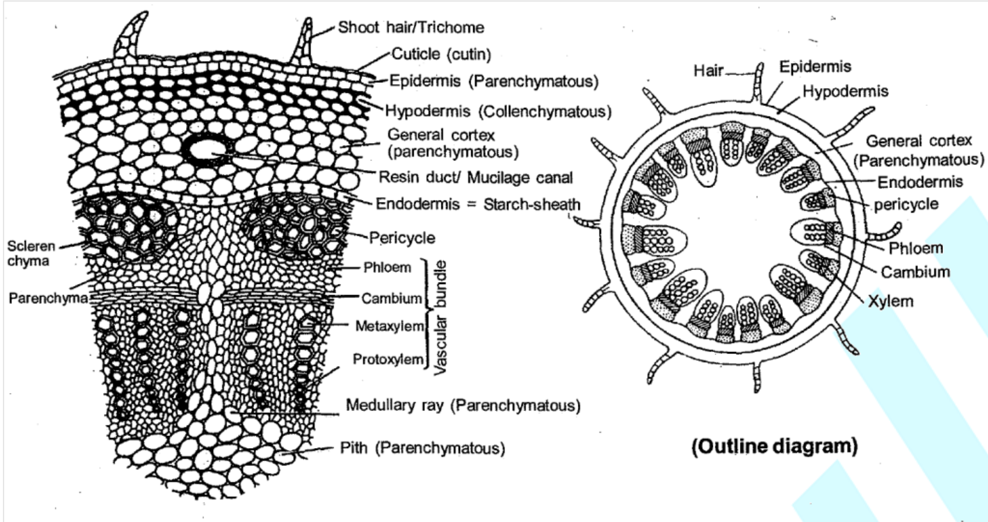
3. **Pericycle :** Pericycle is situated below the endodermis. The pericycle of stem is multilayered. In sunflower stem, pericycle is made of alternate bands of parenchymatous and sclerenchymatous cells. The part of pericycle which is present infront of the vascular bundle is made up of sclerenchyma and remaining part is composed of parenchyma. Part of pericycle which is situated in front of vascular bundle is known as Bundle cap. In sunflower stem, pericycle is heterogenous in nature. Sclerenchymatous part of pericyle is also known as Hard bast.

Note :- Pericycle is present above the phloem in the form of semilunar patches of sclerechynia.

4. **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.

5. **Pith :-** This is well developed region, present in the centre. The cells of this region are made up of parenchyma.

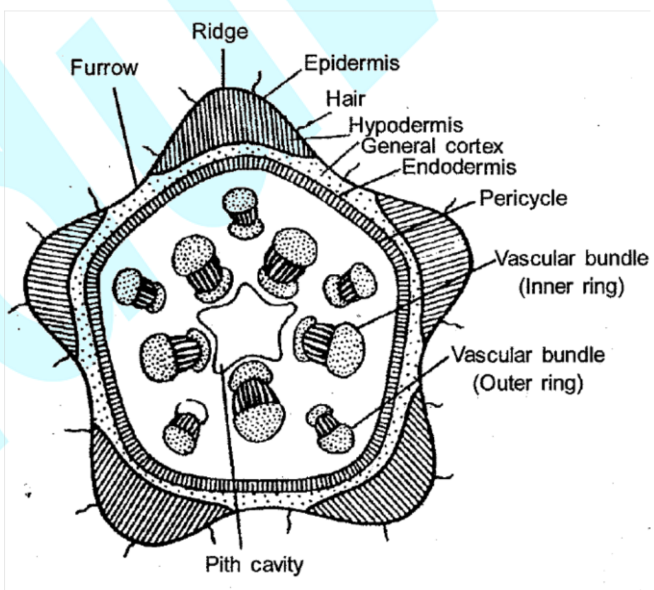
6. **Medullary rays :** Radially arranged parenchymatous cells in between the vascular bundles, called pith rays or medullary rays. The main function of pith rays is radial conduction of food and water.



T.S. OF SUNFLOWER STEM - [A part of cellular diagram]

INTERNAL STRUCTURE OF CUCURBITA STEM :

- It contains five ridges and five furrows. The vascular bundles are arranged in two rings. Each ring has five vascular bundles. In this way the totallo vascular bundles are present.
- The vascular bundles of outer ring are small in size and situated below the ridges while the vascular bundles of inner ring are large in size and located below the furrows.
- Vascular bundles are conjoint, bicollateral and open and xylem is end arch. Outer cambium is functional.
- Hypodermis is mainly present in ridge region.
- General cortex is Chlorenchymatous.
- Pericycle is sclerenchymatous.



Outline diagram of Cucurbita stem

INTERNAL STRUCTURE OF MONOCOTYLEDONOUS STEM

1. **Epidermis** :- Epidermis is the outer most single celled thick layer. It is covered with thick cuticle. Multicellular hairs are absent.
2. **Hypodermis** :- Hypodermis of monocotyledon stem is made up of sclerenchyma. It is 2-3layered thick. In monocot stem rigidity is more in hypodermis whereas in dicot stem elasticity is more. It provides mechanical support to the plant.
3. **Ground tissue** :- It is large. conspicuous parenchymatous. There is no differentiation of ground tissue in monocotyledon stem. It means ground tissue is not differentiated into general cortex, endodermis, pericycle, pith & medullary rays.

   Note : Sometimes in some grasses, wheat etc. the central portion of ground tissue becomes hollow and is called pith cavity (pith cavity is found in stems of Cucurbita, Ricinus amongst divots).
4. **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 then the centrally located ones.

   Vascular bundles which are situated towards the centre are large in size and less in number.

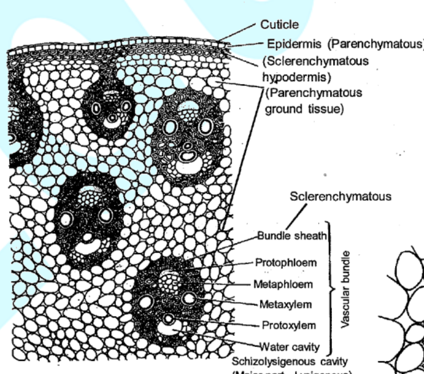
   Vascular bundles which are situated towards the periphery are small in size but more in number.

   Each vascular bundle is conjoint, collateral and closed and xylem is endarch. Each vascular bundle is surrounded by sclerenchymatous bundle sheath, So vascular bundles are called fibro vascular bundles.

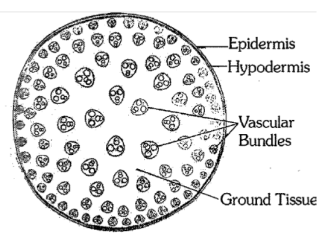
   Water containing cavities are present within the vascular bundles.

   (a) **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. Vessels are arranged in the form of V or Y. Just beneath protoxylem 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).

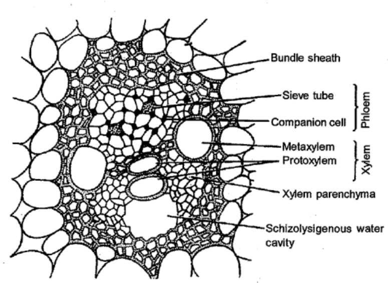
   (b) **Phloem** :- It consists of sieve tube elements and companion cells. Phloem parenchyma is absent.



T.S. of maize *Stem*
(A part of cellular diagram)



(Outline diagram)



A Vascular Bundle

INTERNAL STRUCTURE OF DICOTYLEDONOUS ROOT

Internal structure of a typical dicotyledon root shows following features :-

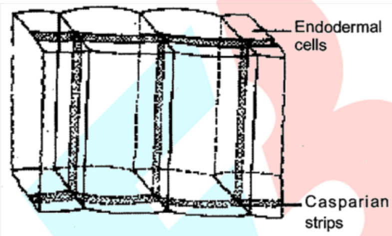
1. **Epiblema/Epidermis :-** It is uniseriate (single layered) outermost layer. Cuticle and stomata are absent. Many of the epidermal cells protrude in the form of unicellular root hairs means unicellular root hairs are formed due to elongation of cells of epiblema. Epiblema is also known as Rhizodermis or Piliferous layer. Root hairs are present in maturation zone of root. Root hairs are short lived.

Note : Cells of epiblema which develop root hairs are called trichoblast cells.

- Hypodermis is absent in the roots.

2. **Cortex** :- It is made up of thin walled parenchymatous cells with intercellular spaces.
Chloroplast is absent, so they are non-photosynthetic but chloroplasts are present in roots of Tinospora, Trapa and Taeniophyllum, so they are photosynthetic (Assimilatory roots).

3. **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.

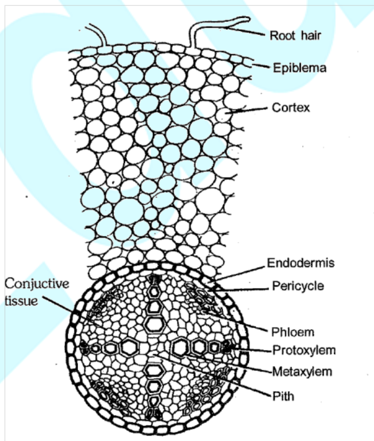


Endodermal cells : Casparian strips on tangential and radial walls

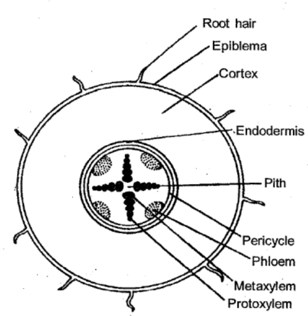
♦ The cells of endodermis which are situated infront of protoxylem cells are devoid of casparian strips. These are called passage cells/path cells.

♦ 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.



* T. S. of typical dicotyledon root (Gram root)
(A part of cellular diagram)



(Outline diagram)

* In a T. S. OF Dicot root, xylem vessels appear hexagonal / polygonal / angular

4. **Pericycle** :- It is a single or few layers of thick walled parenchymatous cells (It is composed of prosenchyma).

- ♦ Lateral roots usually originate from the part of pericycle which is lying opposite to protoxylem. Thus lateral roots are endogenous in origin.

  Note:

  (i) The branches of stems (vegetative branches) are exogenous in origin because they originate from extrastelar region.

  (ii) Adventitious roots are endogenous in origin because they originate from stelar region.

5. Vascular Burtdles :- Vascular bundles are radial and exarch. xylem and phloem are separate and equal in number. 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 conjunctive tissue.
- ♦ In dicot root xylem vessels appear angular (polygonal/hexagonal) in T.S.

6. Pith :- In dicot root pith is small (less developed) or inconspicuous or absent.

INTERNAL STRUCTURE OF MONOCOTYLEDONOUS ROOT

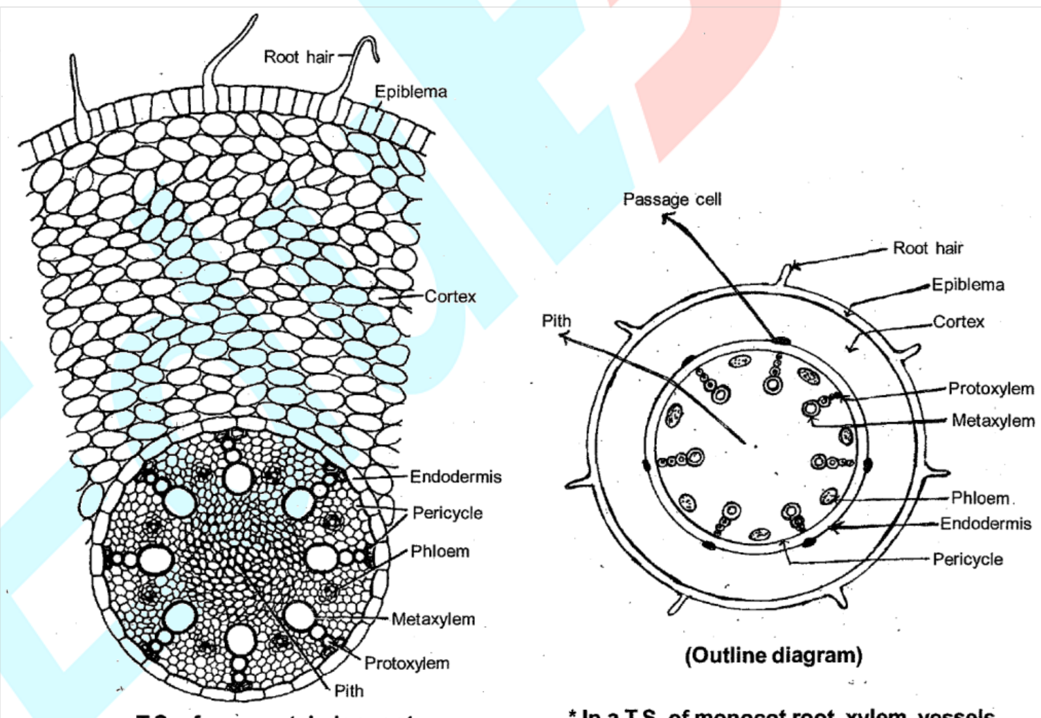
- The internal structure of a typical monocotyledon root is similar to dicotyledon root except some differences which are as follows:-

  (1) Number of xylem bundles are usually more than six (polyarch) in monocotyledon root.

  (2) Pith is large and well developed in monocotyledon root

  (3) Xylem vessels appear circular or oval in T.S.

  (4) Monocotyledonous roots do not undergo any secondary growth.



T.S. of monocotyledon root
(A part of cellular diagram)

(Outline diagram)

* In a T.S. of monocot root, xylem vessels appear circular/rounded or oval shaped.

Note : As the epiblema dies off (in old roots), a few outer layers of the cortex become suberized (mainly) or cutinized and form the exodermis. Exodermis is usually found in monocot roots.

Note : **Velamen** :-This spongy tissue is found in aerial roots or hanging roots of epiphytes (eg. Orchids-Vanda)

- It is an example of multilayered epidermis
- It absorbs atmospheric moisture by imbibition.

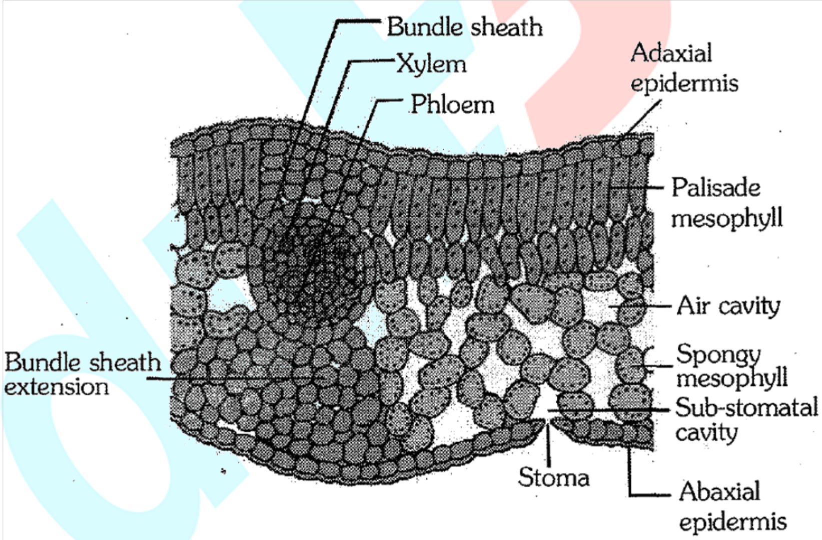
INTERNAL STRUCTURE OF LEAF

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

Dorsiventral of Bi - facial	Iso - bilateral of Equifacial
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 :- Dicots Exceptions - Eucalyptus and Nerium (leaves are isobilateral)	2. Both surfaces of leaf receive equal amount of sun light so no difference occurs between internal structure of upper & lower surfaces. Example :- Monocots Exception - Lilium longiflorum (leaves are dorsiventral)

INTERNAL STRUCTURE OF DORSIVENTRAL LEAF

♦ Cuticle is present on both surfaces but cuticle on upper surface is more thick.
♦ In dorsiventralleaves stomata are more on lower surface and stomata on upper surface are absent or less in number.



V.S./T.S. of Dorsiventral Leaf

♦ 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.
♦ 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.

INTERNAL STRUCTURE OF ISOBILATERNAL LEAF

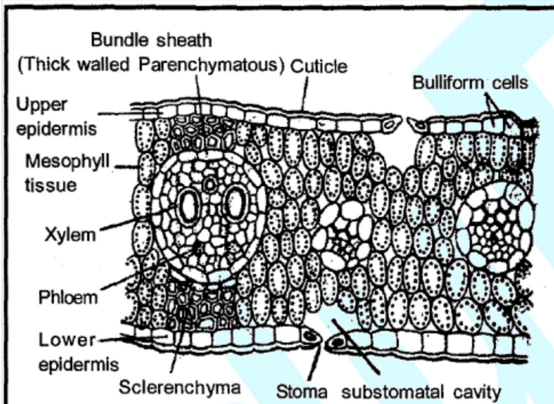
- ♦ The thickness of cuticle is equal on both surfaces.
- ♦ Usually stomata on both surfaces are equal in number.
- ♦ Mesophyll is not differentiated into palisade and spongy tissues in isobilateralleaves. Mesophyll cells have only a few intercellular spaces.

Note: (1) 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.

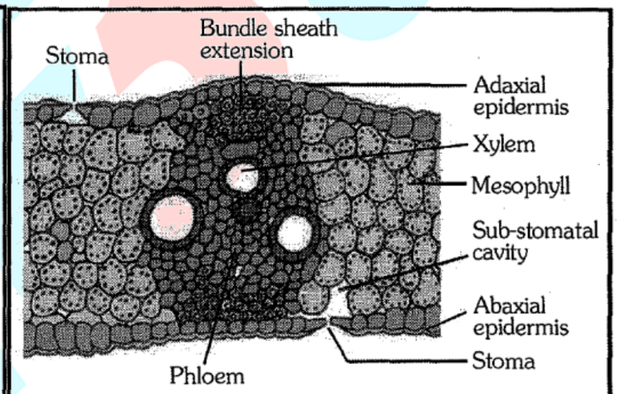
(2) In dorsiventral leaf, two distinct patches of parenchyma (mainly)/collenchyma are present above and below the large vascular bundle' and extend up to the upper and lower epidermal layers. These are called bundle sheath extensions. Chloroplasts are absent in bundle sheath extensions.

VASCULAR BUNDLES OF LEAVES :

- Similar types of vascular bundles are found in both dorsiventral and isobilateralleaves. 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.



V.S./T.S. OF ISOBILATERAL LEAF



V.S./T.S. OF ISOBILATERAL LEAF

- ♦ Druses → Crystal of calcium oxalate, star shaped e.g. Nerium.
- ♦ Cystolith → Crystal of calcium carbonate, like bunch of grapes e.g. Ficus (Banyan, Rubber plant)
- ♦ Raphides → Crystal of calcium oxalate, Needle shaped e.g. Eichhornia

Note:

1. In the leaves of C_4-plants (eg. sugarcane, maize etc.) bundle sheath is chlorenchymatous.
2. In grasses, certain adaxial epidermal cells along the veins modify themselves into large, empty colourless cells. These are called buDiform 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.
3. The stomata aperture guard cells and the surrounding subsidiary cells are together called stomata apparatus.

4. 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.
5. 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.

- Both upper & lower epidermis of Nerium leaves are multilayered This is an adaptation to reduce transpiration.
- Xerophytes with isobilateral leaves contain palisade tissue on both sides and few amount of spongy tissue is present in between palisade tissue.
  Example :- Eucalyptus & Nerium.

Leaf	Stomata position	Examples
Epistomatic leaf	Stomata are present only on upper surface	Floating leaves Example-Lotus (Nelumbium Victoria regia, Nymphaea)
Hypostomatic leaf	Stomata are present on lower surface	Mostly dicot leaves
Amphistomatic leaf	Stomata are present on both surface	Submerged leaves Examples - Vallisneria, Hydrilla

SECONDARY GROWTH

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 stem 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. But exceptionally secondary growth takes place in some monocotyledons. Such as- Palm, Date Palm, Coconut Palm, Yucca, Dracaena, Kingia, Sansiviera, Smilax, Agave etc. These plants show abnormal secondary growth.

SECONDARY GROWTH IN DICOT STEM

[A] SECONDARY GROWTH IN STEIAR REGION BY VASCULAR CAMBIUM :
Secondary growth in stellar 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 medullaty rays adjoining intrafascicular cambium become meristamatic to form interfascicular cambium which is a secondary lateral meristem.
♦ 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 diocot 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.

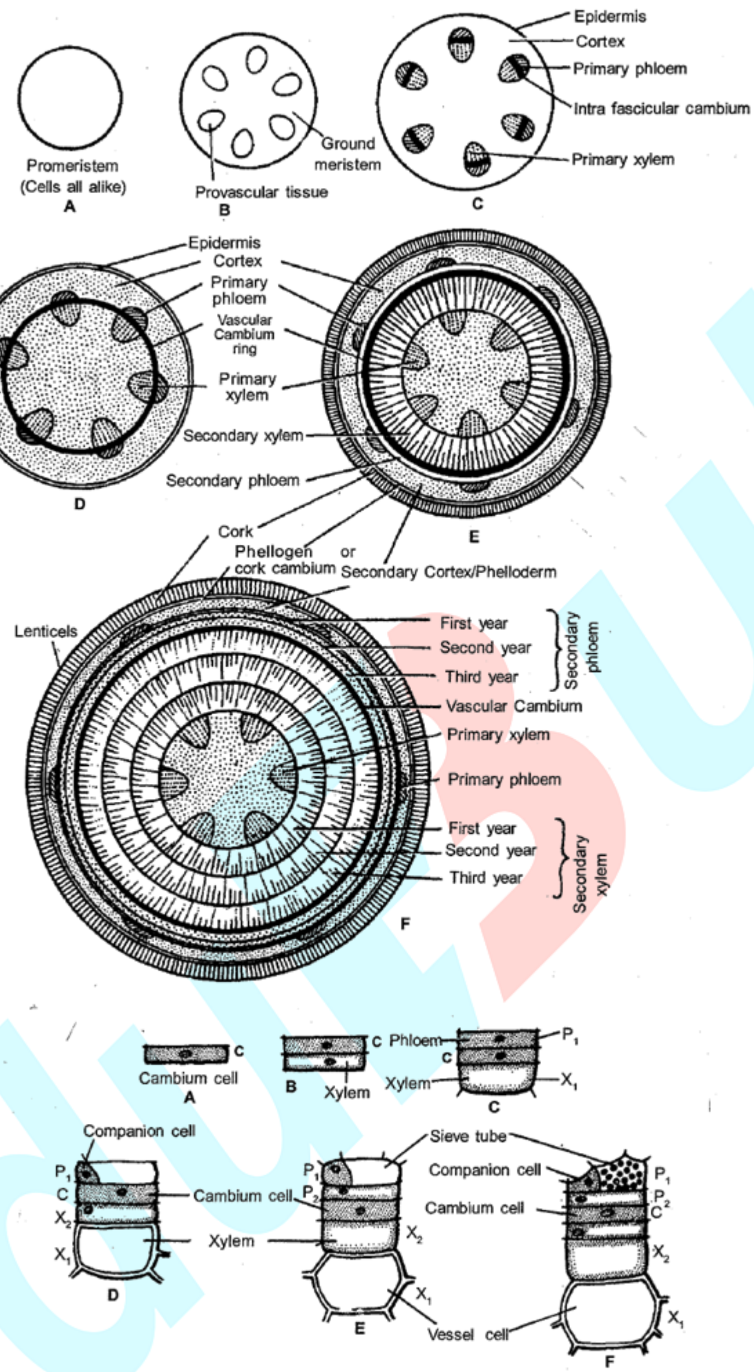
(i) Fusiform initials **(ii) Ray initials.**

- 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 ipitials :

- Continuous periclinal divisions (parallel to longitudinal axis} 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 innerside 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 sec. phloem).



DIFFERENT STAGES OF SECONDARY GROWTH IN DICOTYLEDONAE STEM

- By the pressure of secondary xylem, all the primary tissues- such a~ 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** :- Due to periclinal divisions 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. The order of development of vascular rays are both centripetal and centrifugal.

(III) Formation of Annual Rings

Annual rings are formed due to unequal activity of vascular cambium.

- ♦ The activity of cambium does not remain same, it is changeable in the whole year.
- ♦ 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.
- ♦ 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.

Note:

(1) The autumn and spring wood are formed in the form of concentric rings, called growth rings.

(2) 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.

(3) The annual rings are counted from the base of the stem because basal part has maximum annual rings and upper part has less. Therefore, counting from the basal region can give the correct idea.

(4) A piece of wood is taken from the stem up to central region from the base of stem with the help of increment borer instrument. The annual rings are counted from that piece and again inserted (fitted) into the same stem at the same place.

(5) More distinct/dear annual rings are formed in that regions where climatic variations are sharp.

(6) More distinct annual rings are formed in temperate plants. Because in temperate regions, the climatic conditions are not uniform throughout the year.

(7) Distinct annual rings are not formed in tropical plants. Distinct/clear annual rings are not formed in India except Himalayan regions (Shimla, Nainital etc.).

(8) Least distinct annual rings are formed in seashore regions/coastal regions because the climate remains the same throughout the year.

(9) More clear annual rings are ·formed in deciduous plants as compared to evergreen plants.(In temperate region)

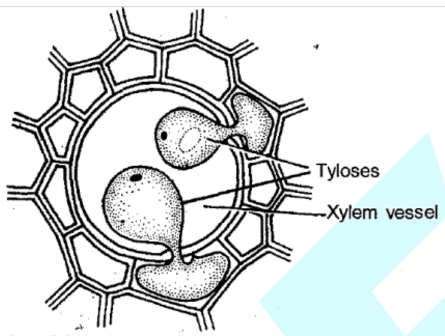
(10) In deserts annual rings are less distinct.

(11) In annual rings bands of secondary xylem and xylem rays (Ray parenchyma) are present.

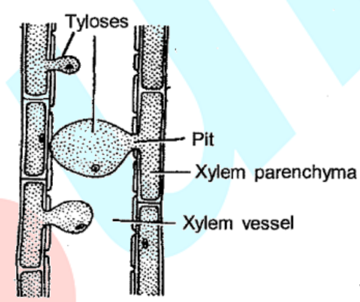
HEART WOOD & SAP WOOD :

- In old trees, the greater part of secondary wlem 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 wlem which is light in colour, is called sap wood or albumum.
- The function of sap wood is conduction of water and minerals.
- Heart wood does not conduct water because :-
  1. Cavities of tracheids and vessels are progressively filled with waste materials.
  2. The bladder/balloon like ingrowth of parenchyma cells enter in the lumen of vessels (mainly) & tracheids through the pits. Such bladder like ingrowths are called tyloses or tracheal plugs. Tyloses block the lumen of tracheary elements (vessels & tracheids).



T.S. of Sec. xylem vessel showing tyloses



L.S. of Sec. xylem vessel showing tyloses

- Heart wood provides stiffness to the stem. The waste materials of heart wood are antiseptic in nature. Heart wood is resistant to the attacks of termites and insects and in rainy season it does not imbibe water. Thus it is the best quality of wood.
- Study of wood is known as Xylotomy. 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 .

CLASSIFICATION OF WOOD :

[A] On the basis of amount of parenchyma wood is classified into two groups :-

1. **Manoxylic wood** :- Such type of wood contains more amount of living parenchyma. It is loose wood. Eg. Cycas.

2. **Pycnoxylic wood** :- Such wood contains less amount of living parenchyma.
Example :- Pinus (Conifers)

[B] **Classification based on vessels :-**
On the basis of presence or absence of vessels, wood is classified into two categories -

1. **Non-porous wood / Homoxylous wood** :- Vessels are absent in this type of wood.
Example :- Mostly gymnosperms

2. **Porous wood / Heteroxylous wood** :-Vessels are present in this type of wood. e.g Mostly dicots (Angiosperms) On the basis of arrangement of vessels porous wood is divided into two groups.

I. **Ring porous wood** :- Vessels are arranged in the rings in this type of wood.
Example = In temperate region plants. Ex. Dalbergia

II. **Diffused porous wood** :- Asystematical distribution of vessels is found in this type of wood.
Example :- In tropical region plants. Ex. Azadirachta (Neem).

- Most durable wood → Tectona grandis (Teak = Sag wan)

[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 corkcambium 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.

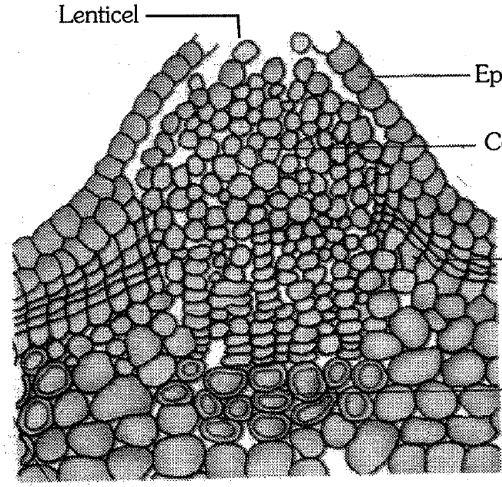
♦ Cork cambium divides periclinally to form some cells towards the outside (towards epidermis) and some cells towards the inside (towards general cortex). Those cells which are formed towards outside become suberized. Due to this, these cells become dead. These dead cells are known as cork or phellem. 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.

♦ Ring of cork cambium remains living and active only for one year.Each year, a new cork cambium is formed below the previous cambium. This new cambium is derived from the secondary cortex or phelloderm.
  - All the tissues which occur outside the innermost cork cambium are collectively termed as rhytidome. Rhytidome includes cork and tissues which become dead due to the pressure of cork.

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 stem passing through a lenticel

- Lenticels are found in most of the woody trees. (Absent in woody climbers)
- 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:

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

BARK

There are two views about the bark.

1. **Old view** :- All the tissues situated outside the cork cambium are called bark. According to old view bark includes mainly dead tissues.
2. **Modem view** :- Bark is a non-technical term that refers to all tissues exterior to the vascular cambium, therefore including secondary phloem. According to modern view bark includes both living and dead tissues.

KINDS OF BARK

1. **Ring Bark = Sheet bark** :- Continuous bark of equal thickening is called ring bark. It is formed around the stem in the form of a complete ring. When cork cambium is continuous then ring bark is formed.
   Example :- Bhojpatra (Betula utilis) -A complete distinct ring bark is formed in this plant. Its bark was used as a writing material /as a paper in ancient period, only cork layer was used. Ring bark is also formed in Eucalyptus.
2. **Scaly Bark** :- Discontinuous bark of unequal thickening is called scaly bark. This bark is formed around the stem in the form of pieces or fragments or patches. When cork cambium is discontinuous then scaly bark is formed. eg. Guava (Psidium guajava). Neem (Azadirachta indica), Mango {Mangifera indica) and Tamarind = lmli (Tamarindus) etc. plants.

- Highly distinct scaly bark is formed in Psidium guajava (Guava)
- Scaly bark is found in most of the woody plants.

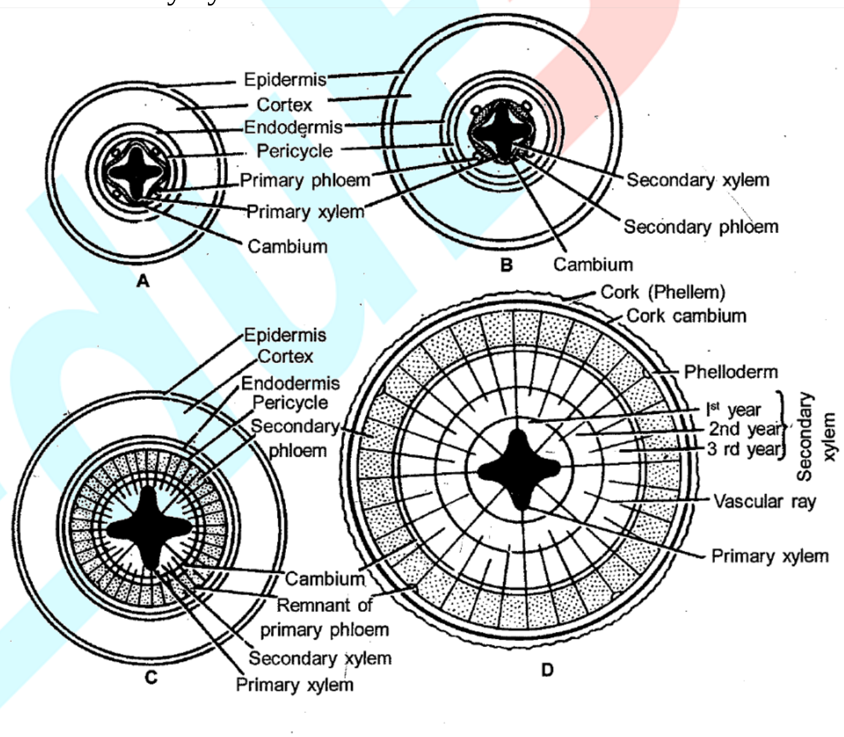
- If bark is removed in the form of a ring (Girdling) from the base of main stem then root dies first due to lack of food.
- Girdling is not possible is monocot stem because vascular bundles are scattered.
- If complete bark is removed then plant dies due to excessive water loss.
- Bark that is formed 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.

SECONDARY GROWTH IN DICOT 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 dicotyledon root and forms separate curved strips of vasular 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 portion of vascular cambium which is formed by pericycle is less. The main portion of vascular cambium is formed by conjunctive tissue.

♦ 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 IN SECONDARY GROWTH OF 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. The portion of vascular cambium which is formed by pericycle is responsible for the formation of pith rays or medullary rays. These are made up of parenchyma. These pith rays are known as primary medullary rays (Multiseriate). A few medullary rays or pith rays are also formed from remaining vascular cambium. These are called secondary medullary rays (uniseriate). Thus two types of medullary rays are found in the secondary structure of roots.

Note : Two types of medullary rays are formed in the dicot roots during secondary growth. The presence of two types of medullary rays is basic characteristic feature of roots. Only secondary medullary rays are formed in dicot stem during the secondary growth. Both of them 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. Lenticels are also found in roots but less in number as compared to stem. 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

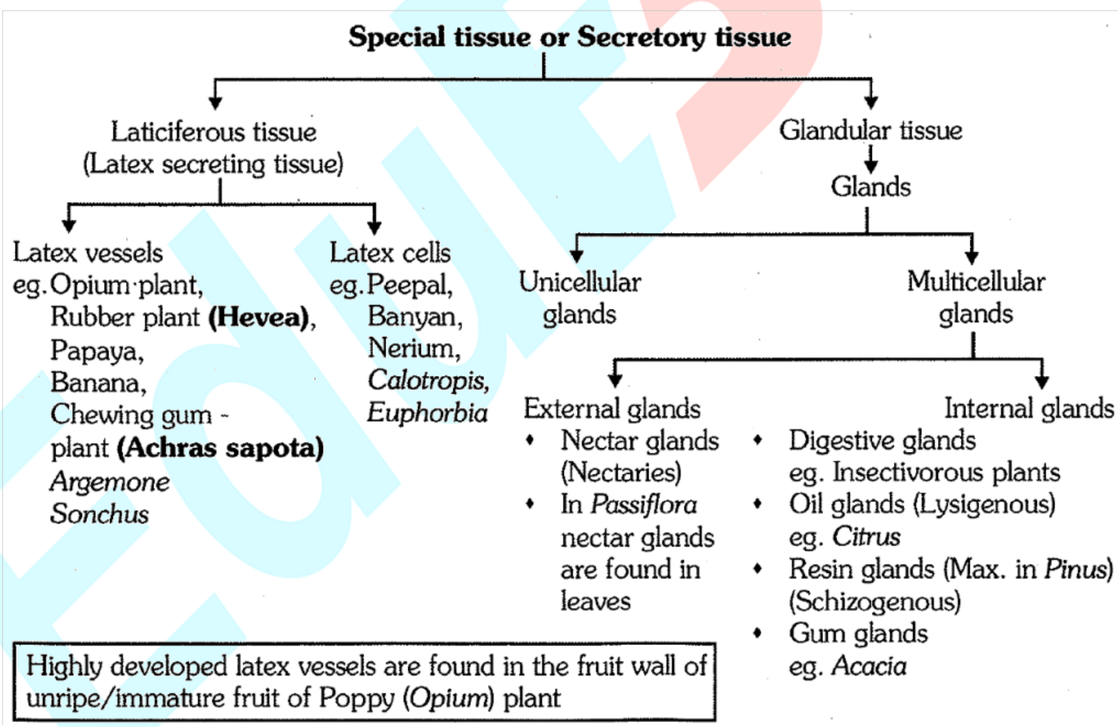
(i) Secondary growth is essential in roots to provide strength to the growing aerial parts of the plants and fulfill the requirement of water and minerals.

(ii) Generally clear annual rings are not seen in roots because roots are not effected by the changes of environment.

(iii) Secondary growth is not found in monocot roots.

(iv) In dicot roots, all cambia and pith rays (medullary rays) are secondary in origin.

SPECIAL TISSUES



STELE

♦ All the tissues which are present inside the endodermis constitute the stele.

♦ The stele is the whole central mass of vascular tissue (vascular cylinder) with or without pith surrounded by endodermis. Stele is surrounded by endodermis but endodermis is originally the part of cortex. It is not a part of stele. Van Tieghem and Douliot put forward the concept of stele/stelar theory.

- According to him stele is the central part or core of the axis of the plant which includes the vascular system and its related structures.
- The tissues which lies inside the stele are called intrastelar tissues and the tissues which lies out side the stele are known as extra stelar tissues.
- Stelar system started from pteridophytes.

TYPES OF STELE (On the basis of evolution)

1. Protostele or Mono stele or solid stele eg.- Rhynia, Homiophyton, Psilotum, Lycopodium.
2. Siphonostele :-
   I. Ectophloic siphonostele
   Example :- Equisetum, Osmunda
   II. Amphiphloic siphonostele
   Example :- Adiantum, Marsilea
3. Dictyostele or Polystele
   Example - Pteridium, Pteris, Dryopteris
4. Eustele :- eg. stem of gymnosperms and dicots.
5. Atactostele :-
   e.g. :- Monocot stems

ANOMALOUS PRIMARY STRUCTURE

[1] Anomalous structure in dicotyledon stem

- **Scattered Vascular Bundles** :- In some of dicotyledon stem, vascular bundles are not arranged in a ring, they are Scattered in the ground tissue.
  Examle : Thallictrum, Nymphaea, Papaver orientale & Peperomia. _,

[2] Anomalous structure in monocot stem :-

- Normally vascular bundles are found in monocotyledon stems in scattered form but in the stem of some monocotyledon plants vascular bundles are arranged in rings. Ex. Members of family Gramineae, such as Triticum (Wheat), Secale, Avena, Oryza (Rice) etc.

Some Extra Points

(1) Cricket bat → from Salix [Willow] wood
(2) Hockey blade → from Morus [Mulberry] wood
(3) Billiards's ball → Phytelophus Uvory Palm)
(4) Violin → Picea (Spruce)
(5) Monarch Condition → in Trapa root
(6) Triarch Condition → in Pisum root
(7) Tetrarch Condition → in Helianthus annuus (Sunflower) and Cicer arietinum (Gram) root
(8) Chewing gum is made by latex of Achras sapota.
(9) Cystolith containing cells are found in the upper epidermis of Ficus leaf, called lithocytes/Uthocysts.
(10) Lignin (xylem) is stained by safranin and phloem is stained by fast green.
(11) Transition of exarch bundles of root to endarch bundles of stem occurs in hypocotyl.

(12) A nectar secreting gland cell contains granular cytoplasm and a large conspicuous nucleus.

(13) In some plants like datepalm increase in thickeness of stem occurs due to primary thickening meristem.

ANOMALOUS SECONDARY GROWTH IN DICOT STEM

1. Formation of cork cambium from Epidermis
Example : Malus pumila, Solanum dulcamara, Quercus suber(oak).

♦ The commercial cork is obtained from the plant Quercus suber,which is commonly found in Portugal and Port of Spain

2. **Formation of cork cambium from pericycle** :- Example- Clematis

3. **Formation of cork cambium from phloem** :- Vilis and Berberis '

4. Phloem is embedded into the secondary xylem in some plants. Such phloem is called included phloem or intraxylary phloem. This is secondary anomalous structure.
Example : Leptadaenia, Salvadora etc. dicot stem.

ANOMALOUS SECONDARY GROWTH

Gymnosperm stem :- In Cycas and Gnetum ula, successive rings of vascular cambium are found.

BEGINNER'S BOX-2

PRIMARY INTERNAL STRUCTURE TO SECONDARY GROWTH

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

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

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

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

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

GOLDEN KEY POINTS

1. In roots the parenchymatous cells which lie between the xylem and the phloem are called conjunctive tissue.

2. The tissues involved in secondary growth are the two lateral meristems i.e. vascular cambium and cork cambium.

3. During secondary growth the primary xylem however remains more or less intact. in or around the centre.
4. Bark is a non-technical term that refers to all tissues exterior to the vascular cambium.
5. In monocot stem, water containing cavities are present within the vascular bundles.

ANSWER KEY

BEGINNER'S BOX-1

1.	(2)	**2.**	(4)	**3.**	(1)	**4.**	(4)

BEGINNER'S BOX-2

1.	(4)	**2.**	(1)	**3.**	(1)	**4.**	(2)	**5.**	(2)