PLANT ANATOMY (PLANT TISSUES)

- Branch of Botany that deals with study of internal structures and organization of plants is called **plant anatomy.**
- **Tissue** is group of cells similar in origin, structure and function.
- The term tissue was coined by **N. Grew**, he is known as **"Father of plant anatomy"**.
- **Carl Nageli** divided tissues into two types

  A. Meristematic tissue **B. Permanent tissue**

A. Meristematic Tissues:

- Meristem is a part of the embryonic tissue.
- The meristematic tissue produces leaves, branches, flowers etc.
- Such a localized group composed of young cells and possessing the ability of continuous divisions is known as meristematic tissue and the region as meristem (undifferentiated tissue).

Characteristics of Meristematic Cells:

(i) Meristematic cells are isodiametric, small & thin walled.
(ii) They are compactly arranged without intercellular spaces.
(iii) They have dense cytoplasm with a prominent nucleus.
(iv) The vacuoles are either small or absent.
(v) Endoplasmic reticulum is not fully developed.
(vi) They possess plastids in protoplastid stage.
(vii) Metabolically, these are the most active cells.
(viii) Cell cycle of meristem is in continuous state of division. It means they have the capacity to divide continuously. So meristematic tissue is composed of immature cells.

Classification of Meristems:

Meristems are classified on the basis of plane of **division, origin & development, position and function**.

(i) Meristems based on origin & development:

On the basis of time when meristem develops they are of following three types –

1. **Promeristem or Primordial meristem:** It is the first formed meristematic region and is regarded as embryonic stage for other developing meristems. It gives rise to primary meristem.
2. **Primary meristem:** It is situated at the tips of root, stem and appendages. In fact, it is a derivative of promeristem which continues to divide and later the derivatives differentiate into permanent tissues.
3. **Secondary meristem:** The permanent tissue (Mainly parenchyma) may become meristematic through dedifferentiation at a later stage. **For example**, **cork cambium, Interfascicular cambium** (The detailed study of these examples will be in secondary growth, the last topic of this chapter)**.**

- Tissues
  - Meristematic tissue
    - On the basis of origin
      - Promeristem
      - Primary meristem
      - Secondary meristem
    - On the basis of position
      - Apical meristem
      - Intercalary meristem
      - Lateral meristem
  - Permanent tissue
    - Simple tissue
      - Parenchyma
        - Chlorenchyma
        - Aerenchyma
        - Prosenchyma
        - Stellate parenchyma
        - Mucilage Parenchyma
      - Collenchyma
        - Angular collenchyma
        - Lamellar collenchyma
        - Lacunar collenchyma
      - Sclerenchyma
        - Fibres
        - Sclereids
    - Complex tissue
      - Xylem
        - Trachieds
        - Vessels
        - Wood parenchyma
        - Wood fibres
      - Pholem
        - Sieve elements
        - Companion cells
        - Phloem parenchyma
        - Phloem fibres
    - Special tissue
      - Laticiferous tissue
        - Latex vessels
        - Latex cells
      - Glandular tissue
        - External glands
          - Glandular hairs
          - Stinging hairs
          - Nectaries
        - Internal glands
          - Oil glands
          - Mucilage secreting glands

(ii) Meristems based on position:

Meristems can occur in different positions in the plant body. These are as follows:

1. **Apical meristems:** These are situated at the tips of the root and the stem. Plants elongate and increase in height as a result of divisions in this meristem. Promeristem and primary meristem are included in this type of meristem.
2. **Lateral meristem:** The **vascular cambium and cork cambium** are the two examples of lateral meristem, being placed along the side of the central longitudinal axis of the plant. Vascular cambium **increases the girth of the plant** by producing secondary vascular tissues.

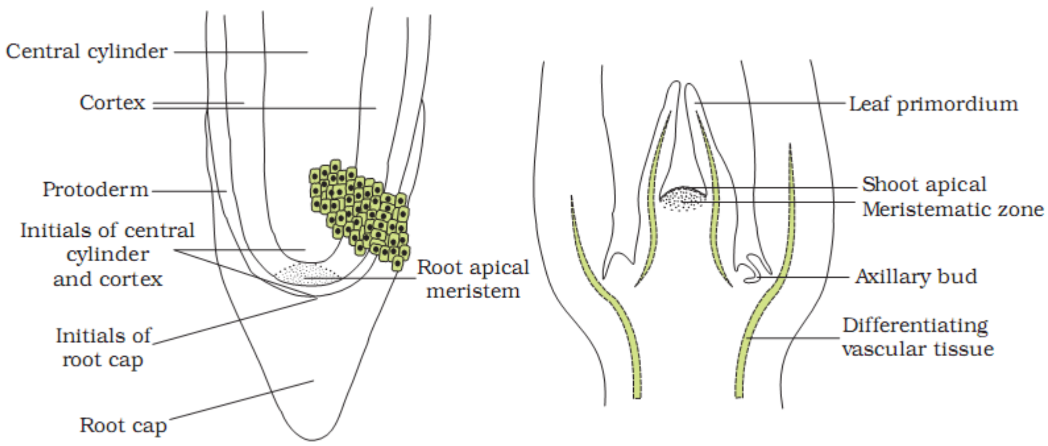


Fig. Apical meristem: (i) Root (ii) Shoot

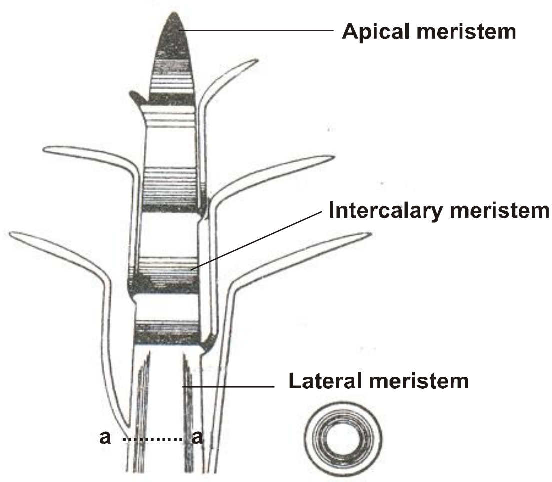


Fig: Different types of meristems on the basis of position in plant body

The cork cambium or phellogen develops later by dedifferentiation of the permanent tissues. Lateral meristems are both primary and secondary in origin (mostly secondary in origin). Secondary lateral meristem involves two types - cork cambium and interfascicular cambium.

All lateral meristem are not secondary.

Exception : Intra fascicular cambium and marginal meristem of leaf are primary in origin.

3. **Intercalary meristem:** Intercalary meristem is located away from the apical meristem, between the two differentiated regions.

- ❖ In fact grass stem elongates due to the activity of intercalary meristem.
- ❖ Both apical & intercalary meristems are primary meristems as they appear early in life of plant and contribute to the formation of the primary plant body.

Apical Meristem:

- The apical meristem occurs at the apices of the main and lateral shoot and roots. This is the first formed meristem that can be seen in the embryonic shoot and embryonic root. All primary tissues of the plant are derived from shoot and root apical meristems.
- Apical cell is seen in higher algae (eg. Sargassum, Fucus), Bryophytes and some Pteridophytes. Apical cell is pyramid in shape and divide into two lateral planes.
- Apical meristem in Ferns, Gymnosperms and Angiosperms consists of many cells.
- Many theories have been put forward to explain the organization of the Apical Meristem. Some of the major theories are given below :-

1. Histogen theory:

- ❖ This theory was proposed by **Hanstein (1870).**
- ❖ He stated that angiosperm is made of following three distinct meristematic regions or layers called **histogens**.

(a) Dermatogen: It is the **outer most uniseriate layer**, the cells divide only anticlinally and **develop in to the epidermis**.

(b) Periblem: It lies inner to the dermatogen and is composed of isodiametric cells. These cells divide actively and develop in **primary cortex.**

(c) Plerome: It is the innermost histogen layer, its cells divide in all planes. Plerome develops in to the **vascular cylinder e.g. primary xylem and phloem, medullary rays and medulla or pith.**

❖ The histogen theory is not accepted because :-

(i) There is no sharp and clear distinction between dermatogen and periblem.

(ii) The tissues destined to be produced by a particular histogen were sometimes formed by another histogen also.

For example: the dermatogen which is supposed to produce epidermis also forms a part of the cortex destined to be formed by periblem. It is applicable for root apex only.

Special points

- **Quiescent centre :** In some roots, **e.g. Zea mays (maize)** there is a central region of cells which normally does not divide. This **central inactive region was called quiescent centre** by **F.A.L. Clowes.**
- He showed that the cells of this region have **lesser amount of RNA and DNA**. These cells also have a lower rate of protein synthesis. Mitochondria and endoplasmic reticulum are less developed. Nucleus and nucleoli are smaller. The cells of the quiescent centre are usually inactive. However, if already existing cells are injured or become inactive due to any other reason, the cells of quiescent centre become active.
- Except above described three histogens, a fourth type of histogen is present in monocotyledons. It is called **Calyptrogen**. **Root cap is formed by Calyptrogen in monocots. Root cap is produced by dermatogen in dicotyledons**. Due to presence of root cap, position of root apex is subterminal. So maximum growth in root takes place behind the apex.

2. Tunica corpus theory:

❖ This theory was proposed by **Schmidt**.

❖ This theory is **applicable only to shoot apex**.

❖ According to this theory, shoot apex consists of two zones or regions-the tunica and the corpus.

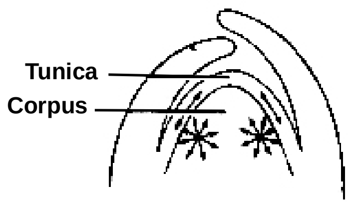


Fig. Growth of shoot apex according to tunica-corpus theory

(a) Tunica:

❖ These cells divide mostly by **anticlinal divisions**.

❖ It results epidermis formation.

❖ If tunica is more than one layered the outermost layer forms the epidermis and the remaining layers take part in the formation of leaf primordial and tissue of cortex by changing the plane of their division.

(b) Corpus:

❖ The cells of the corpus divided in almost all the planes and give rise to a part of the cortex, the vascular tissue and pith.

❖ **It is still the most convenient and acceptable theory of shoot apices.**

B. Permanent tissues:

❖ Permanent tissue is a group of cells, which have lost the capacity of division.

- Cell cycle of permanent tissue is **arrested at G_0 stage.**
- Permanent tissues are the derivatives of meristematic cells, which by gradual differentiation lose the power of division and mature into specific types of cells.
- Permanent tissues developing from primary meristematic tissue (e.g.– promeristem) are called **primary permanent tissues (e.g.– parenchyma, collenchyma etc).**
- Similarly, permanent tissues developing from secondary meristematic tissue (e.g., cork cambium) are known as **secondary permanent tissues (e.g.– cork, secondary xylem and secondary phloem).** Its cells may be living or dead.

- Permanent tissues can be divided into three groups:

I. Simple tissues **II. Complex tissues** **III. Special tissues**

I. Simple tissues:

- Tissues composed of only one type of cells are called simple tissues.
- These occur in homogeneous groups. Simple tissues include Parenchyma, Collenchyma, and Sclerenchyma.

(a) Parenchyma (Term coined by Grew):

(i) Parenchyma is a simple permanent **living tissue** which is made up of **thin-walled** similar isodiametric cells.

(ii) It is the most abundant and common tissue of plants.

(iii) Its cells may be oval, rounded or polygonal in outline.

(iv) The cell wall is made of cellulose. Usually **secondary wall is absent** in it.

(v) Small intercellular spaces are generally present in between the parenchyma cells for exchange of gases. The former are schizogenous in origin.

(vi) Internally each cell encloses a large central vacuole and a peripheral cytoplasm containing nucleus.

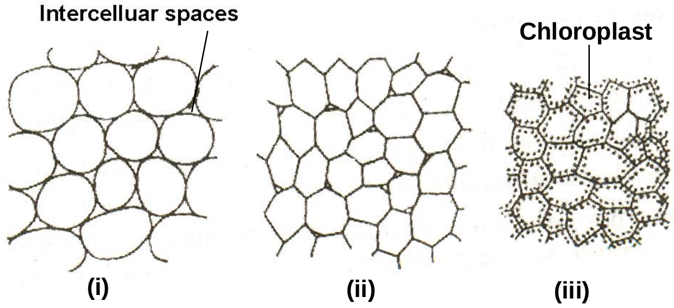


Fig. Types of parenchyma (i) Rounded, (ii) Angular, (iii) Chlorenchyma

Modifications of parenchyma:

1. Prosenchyma:

- Its cells are long with pointed ends.
- **It forms the pericycle of roots**. It helps in mechanical support, protection & conduction.

2. Stellate parenchyma:

- ❖ Its cells are stellate and branched with less developed air spaces.
- ❖ Main function of this parenchyma is to provide mechanical support.
- ❖ **It is found in the leaf bases of banana**.

3. Aerenchyma:

- ❖ Its cells are rounded surrounded by the large air chambers.
- ❖ **Air chambers are lysigenous in origin**.
- ❖ Oxygen is stored in these chambers which is evolved from photosynthesis which help in respiration.
- ❖ It is found in cortex region.
- ❖ **It provides buoyancy to hydrophyte plants.**

4. Chlorenchyma: chloroplasts are found in it. Two types of chlorenchyma are present in dorsiventral leaves.

(a) Palisade tissues:

- ❖ Their cells are rectangular, tightly fitted together & inter cellular spaces are absent.
- ❖ They are present towards **adaxial / ventral / upper** side of leaf.
- ❖ Number of chloroplasts are more in palisade tissue as compare to spongy parenchyma.
- ❖ So upper surface of a leaf appears greener as compared to lower surface.

(b) Spongy parenchyma:

- ❖ Large intercellular spaces are present between these cells.
- ❖ So they facilitates transpiration and gaseous exchange.
- ❖ They are present towards **abaxial / dorsal / lower** side of leaf.

5. Mucilage Parenchyma: It has large vacuoles and mucilage e.g. Succulent xerophytic plants such as **Aloe**. **Function-storage of water.**

6. Idioblast cells: Some cells of parenchyma **store waste materials**. They are called **"idioblast cells"**. The latter store oils, tannin and crystal of calcium oxalate.

Functions of parenchyma:

(i) Storage of food & water.
(ii) To perform gaseous exchange & provides buoyancy to hydrophytes.
(iii) Fibre-like elongated parenchyma is called prosenchyma. It provides rigidity and strength.
(iv) To maintain shape of plant body.
(v) They perform all the vital activites of plant.

(b) Collenchyma:

- ❖ This term coined by **Schleiden.**
- ❖ Collenchyma is a simple permanent tissue of refractile living cells which possess **pectocellulose thickenings** in specific areas of their walls.
- ❖ **Lignin and intercellular spaces are absent**.
- ❖ The cells are either isodiametric or somewhat elongated.

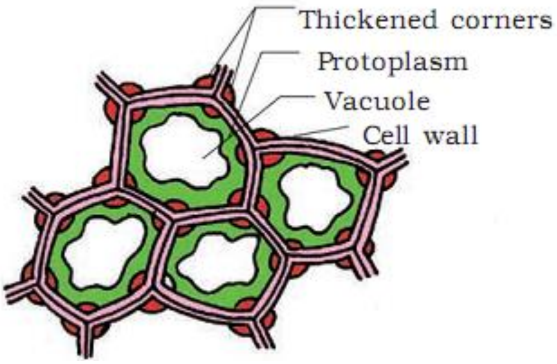


Fig. Collenchyma

- They are circular, oval or angular in transverse section.
- Internally each cell possesses a large central vacuole**,** a peripheral cytoplasm and usually chloroplast either as a homogenous layer or in patches.
- Cells of Collenchyma are flexible due to hydrophilic nature of pectocellulose so flexibility occurs in dicotyledon stems.
- Its wall possesses longitudinal thickenings in specific areas.

Modification of Collenchyma

- Collenchyma is not a universal tissue. It is found in the stems of herbaceous dicotyledons either as a homogenous layer or in patches. **Collenchyma is absent in parts of woody plant parts, roots and Monocotyledons.**

According to **Majumadar,** collenchyma is of three types on the basis of the thickening:

(i) **Lamellate Collenchyma:** The thickenings occur on the tangential walls (plate thickenings), **e.g. Stem of Sunflower.**

(ii) **Angular Collenchyma:** The thickenings are present at the angles (angular thickenings), **e.g. Stem of Tomato.**

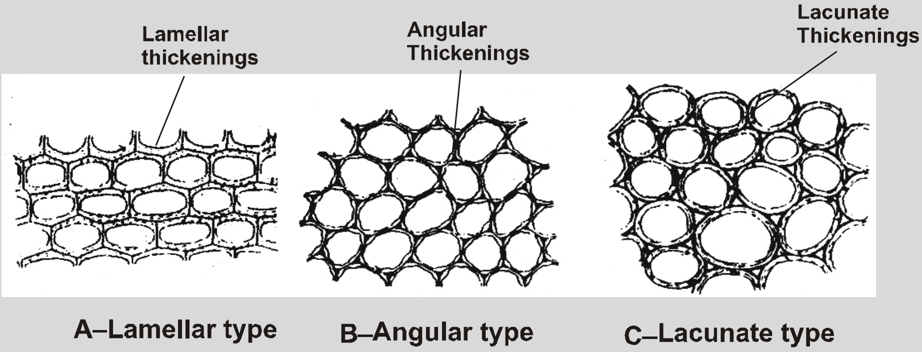


Fig. Types of collenchyma

(iii) **Lacunar / tubular collenchyma:** Cells bear large intercellular spaces. Deposition of pectocellulose takes place on the marginal wall of intercellular spaces. **e.g. Hypodermis of Cucurbits stem and aerial roots of Monstera.**

Functions:

(i) It **provides mechanical strength** to young dicot stems, petioles and leaves (first mechanical tissue)

(ii) Collenchyma also **provides elasticity** to the organs and allows their bending. **e.g. Cucurbits stem**

(c) Sclerenchyma:

- Sclerenchyma is a simple mechanical tissue of **highly thick-walled dead cells** with little or no protoplasm.
- The cell cavities are narrow.
- The thickening of the wall may be made up of cellulose or lignin or both having few or numerous pits.

On the basis of variation in form, structure, Origin and development, sclerenchyma may be of two types:

(A) Sclerenchyma fibres **(B) Sclereids**

(A) Sclerenchyma Fibres:

(i) The sclerenchyma fibres are highly elongated (1-90cm), narrow and spindle shaped thick-walled dead cells with pointed ends.

(ii) Cells wall is thick and lignified.

(iii) The fibres generally occur in longitudinal bundles where the pointed ends of adjacent fibres get interlocked to form a strengthening tissue.

(iv) The adjacent fibres possess simple oblique pits (unthickened areas with common pit). **e.g. Monocot stem**.

(v) Commercial fibres obtained from plants are usually sclerenchyma fibres. **e.g. Jute, Flax, Hemp**.

(B) Sclereids:

(i) They may be spherical, oval and cylindrical.

(ii) They are lignified, extremely thick walled. So the lumen of the cells is almost obliterated. They are found in hard parts of the plant. **e.g. Endocarp of coconut and Almond, Tea leaves.**

(iii) The grittiness of the fruits like guava and pears is due to the occurrence of stone cells in their pulp.

- **Types of sclereids:**

  On the basis of structure **Sclereids** involve following types

1. **Brachysclereids (Stone cells) :** They are thick walled isodiametric cells **e.g. bark, pith, phloem, cortex, hard endocarp and fleshy portion of some fruits like guava, pear and sapota**

2. **Macrosclereids (Rod cells) :** These are elongated **rod like e.g. seed coat of leguminous plants.**

3. **Osteosclereids (Prop cells) :** These are **bone like** with dilated ends or barrel shaped **e.g. leaves and seed coat of many monocots.**

4. **Asterosclereids (Star cells) :** These are **stellate** in form or star shaped. **e.g. stem and leaves of xerophytes**.

5. **Trichosclereids (Internal hair) :** Long, **hair like** branched sclereids. Branching project inter cellular spaces. **e.g. hydrophytes, Olea.**

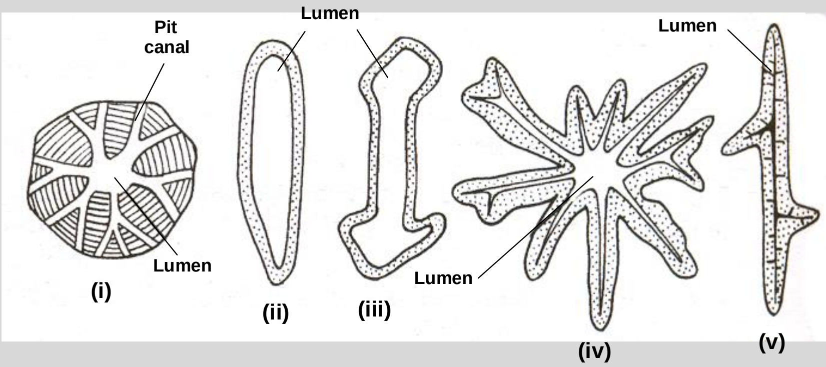


Fig. Types of sclereids: (i) Brachysclereid (stone cells); (ii) Macrosclereid; (iii) Osteosclereid ; (iv) Astrosclereid ; (v) Filiform sclereid (Trichosclereids)

Functions:

(i) Sclerenchyma is the **chief mechanical tissue** of the mature plant organs.

(ii) It allows the plant organs to tolerate bending, shearing, compression and pull caused by environmental factors like wind.

(iii) Surface fibres help in dispersal of seeds & fruits.

II. Complex tissues:

- The complex tissues are composed of more than one type of cells and they work as a unit they are heterogenous.
- They are absent in gametophytes.
- Complex tissues are of two types.

(i) Phloem **(ii) Xylem**

(i) Phloem

- The term **'Phloem'** coined by **Nageli.**
- Phloem is classified into **two** categories **on the basis of origin**

(a) Primary

(b) Secondary phloem.

- Primary phloem originates from **procambium** while secondary phloem by **vascular cambium.**
- On the basis of **development** primary phloem divided into **protophloem** and **metaphloem.**
- The **protophloem** has narrow sieve tubes whereas **metaphloem** has large sieve tubes.
- The main function of the phloem is the conduction of **food materials,** usually from the leaf to other plant parts (source to sink).
- Phloem remains active for less duration as compared to xylem. Phloem is composed of 4 **types** of cells.

1. Sieve tube:

- They are **living and thin walled.**
- A mature sieve tube element lacks nucleus. Thus these are **enucleated** living cells. In this condition there function is controlled by adjacent companion cells.
- **In Angiosperm plants,** these elements are arranged with their ends and form **sieve tube.**
- **Sieve plate (oblique transverse perforated septa)** is present between the two sieve tube elements at their end wall. It is porous. Materials are transported through these pores.
- **Large central vacuole** is present in each mature sieve tube element. Cytoplasm of sieve tube element shows **cyclosis** in the form of thin layer around the vacuole.

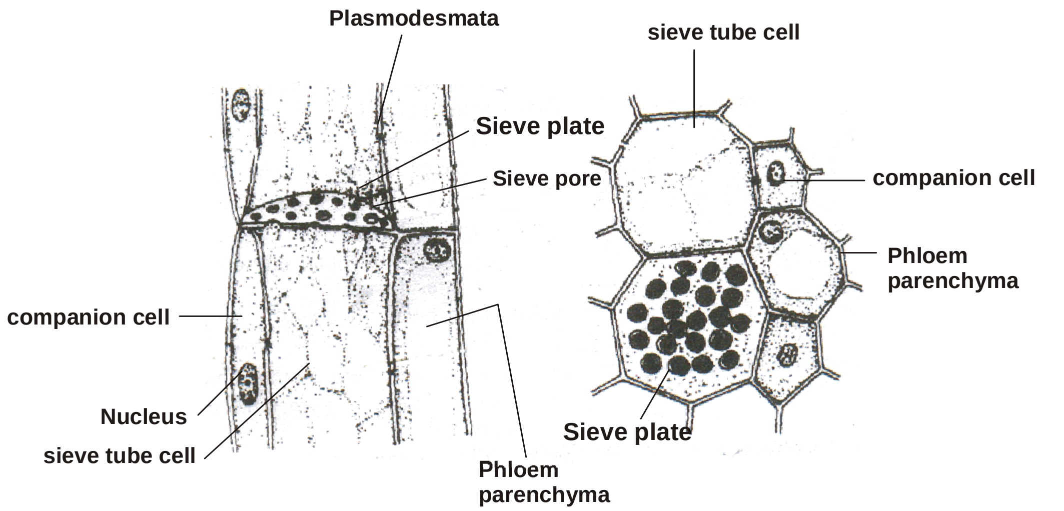


Fig. (i) L.S. of phloem **Fig. (ii) T.S. of phloem**

Special points

- **Callose** deposited on the radius of pores in dropping season of leaves **during autumn** to form a thick layer. It is called **Callose pad.** It hinders the conduction of food but on the onset of the spring season this callose pad is dissolved (by callase enzyme) and conduction again restarted.
- In Angiosperms food conduction is erect and efficient. Sieve elements bear special type of **protein-P-protein** (p-phloem). Function of p-protein is sealing mechanism on wounding and it is also related with conduction of food. Food conduction is **bidirectional** in sieve tube.

2. Companion cells:

- These are **thin walled living cells.**
- Sieve tube element and companion cell originates together. Both of them originates from a single mother cell. So called as sister cells.
- The sieve tube elements and companion cells are connected **by pit fields** present in their longitudinal walls which is common wall for both and with the death of one, other cell also dies.
- A companion cell is laterally associated with a sieve tube element in Angiospermic plants (In carrot more than one) by cytoplasmic connections that are called **plasmodesmata.**
- Companion cell is a living cell with large nucleus. This nucleus also controls the activity in cytoplasm of sieve tube element.
- **The companion cells play an important role in the maintenance of a pressure gradient in the sieve tubes. Occurrence of companion cells is a characteristic feature of Angiosperms.**

3. Phloem Parenchyma:

- It's cells are living and thin walled. It stores various materials. **e.g. Resin, Latex, Mucilage etc.**
- **Phloem parenchyma is absent in most of stems of monocots.**
- The main function of phloem parenchyma is transport of food in radial direction and storage.

4. Phloem fibres (Bast fibres):

- These are dead sclerenchymatous fibres having pointed, needle like apices that are called **Libriform fibres**. **These fibres absent in primary phloem**.
- These fibres **provide mechanical support** to the conducting elements (sieve cells and sieve tube). These are used for making ropes and rough cloth. **e.g. Fibre of jute, flax and hemp.**

Special Points

1. Special type of cells are connected with the sieve cells in **gymnosperm and pteridophytes** in place of companion cell. These cells are called as **albuminous cells.**
2. Albuminous cells of conifers are analogous to companion cells of angiosperms. They are modified phloem parenchyma cells.
3. Sieve cells of phloem of pteridophytes and gymnosperms are comparable to the tracheids.
4. The conducting element of phloem is called **Leptom by Haberlandt.**
5. **Hadrom** term was proposed by **Haberlandt** for conducting part of xylem.

(ii) Xylem:

- Xylem is **water conducting tissue**.
- This is mainly responsible for conduction of water and minerals from the roots to the top of plants and provides mechanical strength to the plant body.
- The term '**Xylem**' coined by **Nageli**.
- For conduction of water, death of protoplasm is must.
- On the basis of origin, xylem is divided into primary xylem and secondary xylem.

1. Primary xylem originates from procambium. On the basis of development primary xylem divided into two parts.
   (a) Protoxylem **(b) Metaxylem**

- Cells of protoxylem has narrow lumen as compare to metaxylem.

2. Secondary xylem originates from vascular cambium.

- Xylem is composed of 4 types of cells.
  (1) Tracheids **(2) Vessels** **(3) Xylem fibres** **(4) Xylem parenchyma**

(1) Tracheids:

- Tracheids are unicellular, dead, long and tubular with tapering ends.
- These are primitive conducting elements of xylem containing narrow lumen.
- Tracheids having a large lumen as compared to the fibres.
- Due to presence of transverse septum lumen is discontinuous in tracheids.
- Tracheids are dead and lignified cells.
- The deposition of lignin on cell wall is responsible to form a different type of thickenings.
- Tracheids join together from their ends to form a long rows. These rows extending from the roots via stem to the leaves.

- Usually bordered pits are present at end wall of tracheids.
- **The maximum bordered pits are found in the tracheids of gymnosperm plants.**

(2) Vessels:

- Vessel are multicellular.
- The basic structure of vessels is same as tracheids.
- **The lumen of vessels is wider than tracheids and end wall is perforated (Transverse septum is absent between two vessel elements, if present then porous) Thus vessels are more capable for conduction of water than tracheids.**
- **Vessels contains usually simple pits** at their lateral wall. Thickening of wall is the same as tracheids.

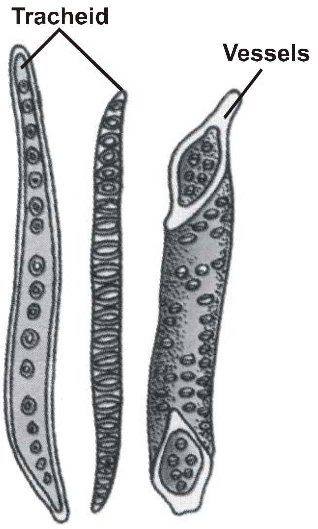


Fig : Xylem

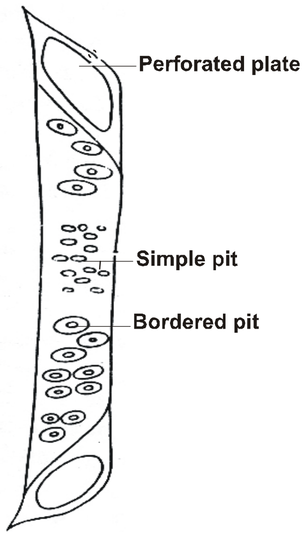


Fig. Vessel of xylem

3. Xylem fibres:

- They are sclerenchymatous fibres found in xylem.
- They are long, narrow and tapering at both ends.
- Their walls are lignified. They **provide mechanical support**.
- They are present more abundant in secondary xylem.
- These are either septate or aseptate.

4. Xylem Parenchyma:

- These are thin walled living cells.
- It's cell wall is made up of cellulose.
- It stores starch, fats and tannin etc.
- The **radial conduction of water** is the function of xylem ray parenchyma.

Special points

1. Usually vessels are found only in xylem of angiosperm but exceptionally these are also observed in some **Gymnosperms. e.g. Ephedra, Gnetum and Welwitschia.**
2. There are some angiosperm families in which vessel less angiosperms are included. **e.g. Winteraceae, Tetracentraceae and Trochodendraceae.**
3. Vessels are absent in some Angiospermic plants **e.g. Dracaena, Yucca, Dazinaria, Drimys.**

Tissue System:

- It is a group of tissues derived from a portion of meristem that performs a similar function in the plant body irrespective of its position. These tissues form tissue system. They may have no structural or morphological similarity and may also differ in their origin.
- On the basis of **location and structure**, **Sachs** (1875) distinguished three tissue system in plants–

(i) Epidermal tissue system

(ii) Ground or Fundamental tissue system

(iii) Vascular or Fascicular tissue system.

(I) Epidermal tissue system:

- It forms the outermost protective covering of various plant organs which remains in direct contact with the environment.
- It originates from the outer most layer of apical meristem.
- It performs various functions including protection, absorption, excretion, gaseous exchange, restriction of transpiration, secretion etc.

It involves following parts.

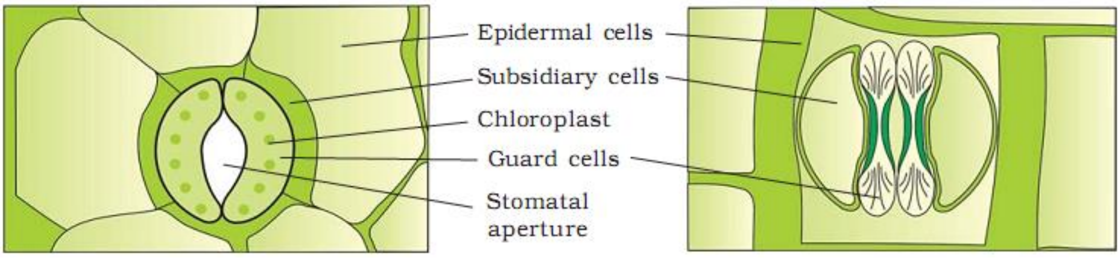
(1) Epidermis (2) Stomata (3) Cuticle & wax (4) Epidermal Appendages.

(1) Epidermis :

- It is uniseriate in most of the plant organs but in some plants it may be **multilayered. e.g. Ficus, Nerium, Pepromia.**
- Its cells are parenchymatous living and compactly arranged. The outer tangential walls are usually thicker as compared to inner wall.
- Each cell has a large central vacuole & a peripheral thin cytoplasm. They may contain chloroplasts, anthocyanin pigments, tannins, oils and crystals etc.
- Some upper epidermal cells in some monocot leaves become larger, thin walled, have vacuoles & are called **bulliform cells**. They play an important role in folding of leaves during deficiency of water **e.g. Grasses.**
- In **aerial roots** of **epiphytes**, the multiple epidermal cells are modified to **velamen** which absorb **moisture from atmosphere.**

(2) Stomata :

- Stomata are minute pores in the epidermis. Each pore is surounded by two **kidney shaped** cells, called as **guard cells**.
- Guard cells are **dumb-bell shaped** in the members of **Gramineae** family (Monocots).
- Guard cells contain chloroplasts. Inner wall of guard cell is thickened. Usually there is a large air cavity below each stomata. It is called substomatal cavity.



(a) (b)

Figure: Diagrammatic representation: (a) stomata with bean-shaped guard cells (b) stomata with dumb-bell shaped guard cell

- **Stomata** are **absent in roots, underground parts and submerged hydrophytes.**
- In **xerophytes stomata** are **sunken** in grooves due to which transpiration is greatly reduced, stomata are embedded in **Pinus, Capparis etc**.
- The function of stomata is exchange of gases and control of tranpiration.

(3) Cuticle and Wax:

- Cutin is a fatty substance deposited over the outer surface of epidermal cells in the form of a separate layer which is called **cuticle**.
- The cutinised walls are less permeable to water. The impermeability depends upon the thickness of cutin.
- Cuticle is

  - thick in xerophytes,
  - thin in mesophytes and
  - absent in submerged parts of hydrophytes.
  - It is also absent in underground parts.

(4) Epidermal Appendages :

(i) Trichomes:

- They are multicellular stem hairs.
- They may be branched or unbranched.
- Their main function is to provide protection against sudden changes of temperature and high rate of transpiration.

(ii) Root Hairs:

- They are unicellular thread like delicate structures that take part in absorption of water and mineral salts from soil.

(II) Ground Tissue System:

- It is formed by ground meristem or partly plerome and partly periblem.
- It constitute main body of the plants. It consists of parenchyma, collenchyma, sclerenchyma, glandular and laticiferous tissues. (except epidermis and vascular bundles)
- This system is composed of different types of tissues and perform many functions. Therefore it is a heterogenous zone.
- This tissue system mainly **originates** from **ground meristem**.
- It is divided into two parts.

(a) Extrastelar ground tissue **(b) Intrastelar ground tissue**

(a) Extrastelar ground tissue:

- It involves only cortical region. Cortex is the region which lies between epidermis and pericycle.
- It involves the following tissues :

1. Hypodermis:

- The layer below epidermis is called hypodermis which is absent in roots.
- It provides mechanical strength and rigidity.
- Dicot stem has **collenchymatous** hypodermis while monocots stem has **sclerenchymatous** hypodermis.

2. General cortex:

- Its cells are thin walled, parenchymatous & may be rounded, polygonal or cylindrical.
- The cells have prominent intercellular spaces. Starch grain, oil, tannin, and crystals of various types are found in cortical cells.
- In hydrophytes the general cortex is **aerenchymatous.**
- **This region stores food materials & provides mechanical support.**

3. Endodermis:

- The inner most layer of cortex is called **endodermis**. Its cells are compactly arranged.
- Endodermis is not found in woody stem of dicots and gymnosperms.
- In young stem of angiosperms, endodermis is also called as **starch sheath** due to abundant starch granules present in them.
- There are several functions of endodermis
  (i) It act as a water tight jacket between vascular & non vascular region.
  (ii) It stores starch.
  (iii) It may serve as protective layer and maintain root pressure.

(b) Intrastelar ground tissue: It includes pericycle, medullary rays and pith.

(1) Pericycle:

- It lies between endodermis and vascular tissues. It is a single layered or multilayered.
- The pericycle is generally parenchymatous but in some cases it is made up of many layers of sclerenchymatous cells (Cucurbits stem) or in the form of alternating bands of sclerenchymatous & parenchymatous cells (sunflower stem).
- In roots, the pericycle is single layered & made of thin-walled parenchymatous cells which later develop in to lateral roots (endogenous origin of roots).
- In dicot root the **vascular cambium** originates from **pericycle**. The latter also give rise to a part of vascular cambium.

(2) Medullary rays:

- They lie between the vascular bundles out side the pith.
- These are made of parenchymatous cells and external from pith towards periphery.
- They serve the function of lateral conduction of solutes.

(3) Pith:

- The central portion of roots & dicot stem are occupied by pith. It is also called as **medulla**.
- It is generally composed of large parenchymatous cells with intercellular space (sometime sclerenchymatous)

The main function of pith is **storage of water and food reserves**.

(III) Vascular or Fascicular system:

- The central cylinder of the shoot or root surrounded by cortex, is called stele.

- These tissue originate from procambium of apical meristem.
- The varying number of vascular bundle formed inside the stele constitute vascular tissue system. Each vascular bundles is made up of xylem and phloem with or without cambium.
- The main function of vascular bundles is conduction of water and minerals, translocation of organic solutes and to give mechanical support to the plant body.
- On the basis of relative position of xylem & phloem following types of vascular bundles are recognized.

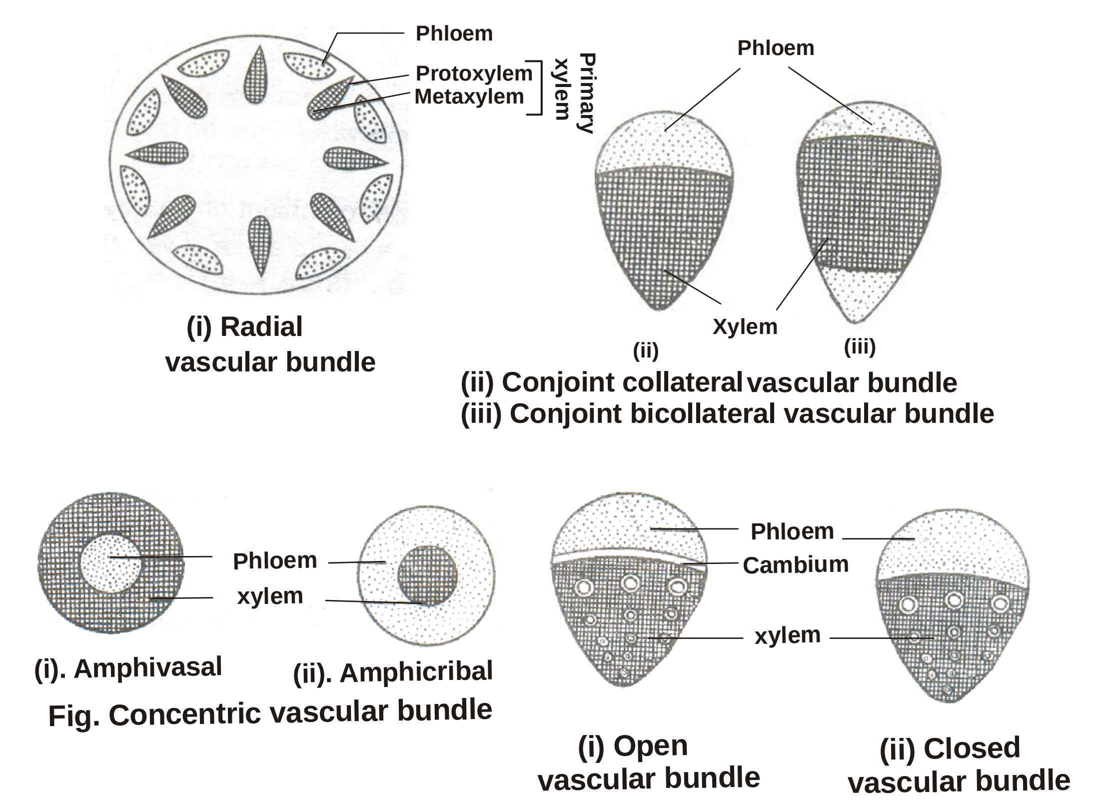
Vascular Bundle
- Radial (Roots)
- Conjoint (Stem)
  - Collateral (Sunflower)
  - Bicollateral (Cucurbit)
- Concentric
  - Amphivasal (Dracaena,Yucca)
  - Amphicribal (Ferns)

(1) Radial : When xylem & phloem are located on different radii, in an alternate manner the bundles are called **radial**. **e.g. roots.**

(2) Conjoint : A vascular bundle having both xylem & phloem together, is called **conjoint**. Normally. The xylem & phloem occur in the same radius. These are found in stem. They are of two types.

(a) Collateral: In this type, phloem lies towards outside & xylem towards innerside. **e.g. sunflower**.

(b) Bicollateral : In such vascular bundles, two patches of phloem one on each side of xylem are present. **e.g. Cucurbits**.



(i) Radial vascular bundle

(ii) Conjoint collateral vascular bundle
(iii) Conjoint bicollateral vascular bundle

(i). Amphivasal **(ii). Amphicribal**

Fig. Concentric vascular bundle

(i) Open vascular bundle **(ii) Closed vascular bundle**

(3) Concentric: In this type, any one of the two, xylem or phloem is present in the centre and the other surrounds it. They are also of two types.

(a) **Amphivasal (Leptocentric):** Here, the xylem completely surrounds the phloem. **e.g. Dracaena, Yucca.**

(b) **Amphicribal (Hadrocentric):** In this, xylem is in centre surrounded on all sides by phloem. **e.g. Ferns.**

On the basis of presence or absence of cambium, the bundles are classified into two categories.

(a) **Open :** When cambium lies between xylem & phloem elements, the bundle is said to be open. **e.g. dicot stem**. This cambium is called as **intrafascicular cambium**.

(b) **Closed :** When there is no cambium inside, the bundle is described as closed **e.g. monocot stem.**

On the basis of relative position of proto and metaxylem elements, the following two xylem conditions are differentiated.

(a) **Exarch :** When the Protoxylem lies at periphery and metaxylem in the centre, the condition is said to be **exarch**.Here the direction of development is **centripetal**. **e.g. Root.**

(b) **Endarch :** When the protoxylem lies towards the centre and metaxylem at the periphery, the condition is called **endarch**. Here the direction of development is **centrifugal**. **e.g. Stem.**

ANATOMY OF PLANT PARTS:

(I) Internal structure of dicotyledon root:

Internal structure of a dicotyledon root shows following features

1. Epiblema (Rhizodermis or Piliferous layer):

- ❖ It is outermost layer having tubular living components.
- ❖ Cuticle and stomata are absent.
- ❖ Unicellular root hairs are formed by the elongation of some cells of it in maturation zone of root.
- ❖ These hairs perform absorption of water from the soil.

2. Cortex:

- ❖ It is composed of thin walled parenchymatous cells. Its cell are circular or polygonal with intercellular spaces.

3. Endodermis:

- ❖ It is innermost single layer of cortex, without inter cellular spaces that lies between pericycle and cortex radial and tangential wall of endodermis bear **Casparian strips** (discovered by Caspari).
- ❖ These strips contain suberin. Casparian strips are absent in those cells of endodermis that lie at the front of protoxylem.
- ❖ These are called **passage cells** or transfusion cells that help in the passage of water from cortex to pericycle.

4. Pericycle:

- ❖ It is single layered.
- ❖ It consists of parenchyma (prosenchyma).
- ❖ Lateral roots originate endogenously from pericycle.

5. Vascular Bundles:

- ❖ Vascular bundles are **radial and exarch**.

- The number of xylem bundles are **two to six (diarch to hexarch)** [**exception**– Ficus (Banyan tree) root is polyarch].
- Parenchyma that lies between xylem and phloem is called **Conjunctive tissue**.
- The latter takes part in the formation of vascular cambium during secondary growth.

6. Pith :

- In dicot root pith is less developed or absent.

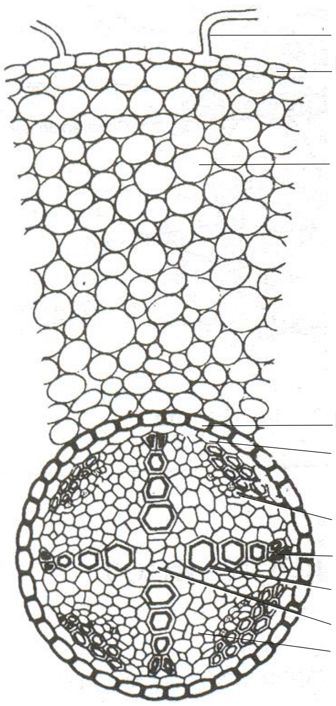


Fig. T.S. Of Dicot root

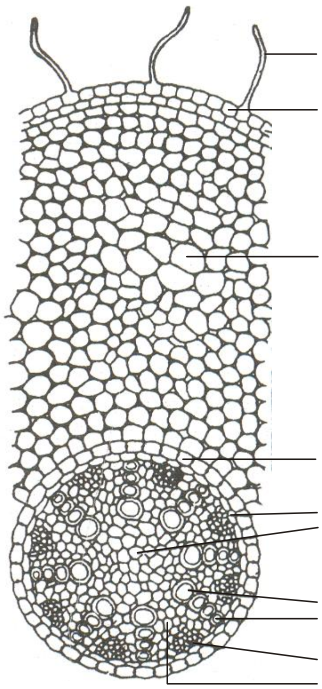


Fig. T.S. of Monocot root.

Internal structure of monocotyledon root: It is similar to dicotyledon root except following points.

(1) Xylem is **polyarch** (more than six) but exceptionally xylem bundles are **two to six in onion.**

(2) Pith is well developed in monocot root.

(3) Conjunctive parenchyma does not produce cambium.

Differences between dicot root and monocot root		
S. No.	**Dicot Root**	**Monocot Root**
1	Xylem is diarch to hexarch	Xylem is polyarch
2	Pith is less developed or absent	Pith is well developed
3	Cambium is formed and proceeds secondary growth	Cambium absent **(AIPMT-2015)** and secondary growth is absent

Internal structure of dicot stem:

Internal structure of a dicot stem involves following features–

1. **Epidermis:**

- ❖ Epidermis is the outermost layer of the stem.
- ❖ It is single layered.
- ❖ Outer side of epidermis is surrounded by a layer called **cuticle** that is composed of cutin.
- ❖ Multicellular hairs and stomata are found on epidermis.

2. **Cortex** In dicotyledon stem cortex divided into three parts:

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

(i) Hypodermis :

- ❖ It lies just below the epidermis.
- ❖ It consists of collenchyma and Its cells possess extra cellulosic thickening in various regions.

(a) On the tangential walls **(lamellate collenchyma, e.g. Sunflower).**
(b) At the angles **(angular collenchyma, e.g. Castor).**
(c) Near the small intercellular spaces. **(lacunate collenchyma, e.g. Cucurbita).** Collenchyma cells are green and enclose small intercellular spaces.

Its functions are - It provides mechanical strength as well as flexibility, storage of food, manufacture of food with the help of chloroplasts.

(ii) General Cortex :

- ❖ It consists of parenchyma. Resin canal/mucilage canal are present in it.
- ❖ These are schizogenous in origin.
- ❖ The main function of the cortex is storage of food.

(iii) Endodermis:

- ❖ It is single layered.
- ❖ Its cells are barrel shaped.
- ❖ Endodermal cells contain conspicuous starch grains as food reserve.
- ❖ Therefore, It is called **starch sheath.**

3. **Pericycle :**

- ❖ It lies between the endodermis and vascular bundles.
- ❖ The pericycle of stem is multi layered and made up of **sclerenchyma**.
- ❖ Sclerenchymatous pericycle is also known as **Hard bast**.
- ❖ The pericycle is **heterogenous**.& composed of alternate bandsp of parenchymatous and sclerenchymatous cells. **e.g. sunflower stem**.
- ❖ Part of pericycle which is situated in front of vascular bundle is known as **Bundle cap**.
- ❖ In plants like Cucurbits, Aristolochia, it is present as a continuous cylinder of sclerencymatous cells.

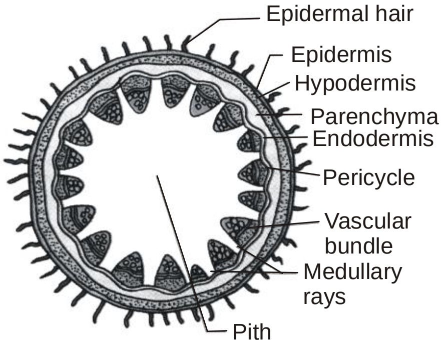


Fig : T.S. of stem dicot

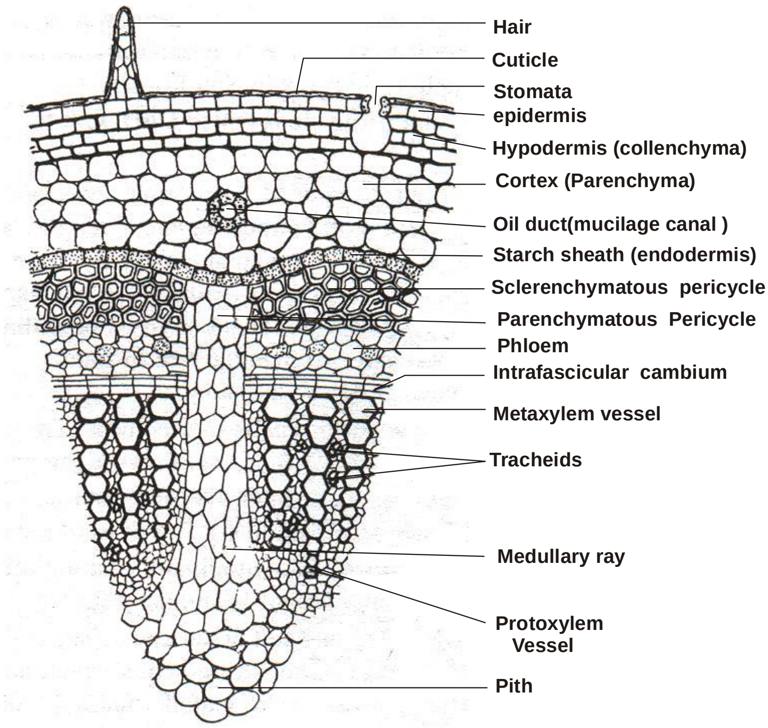


Fig. T.S. of Dicot stem (cellular)

4. **Vascular Bundle:**

- Vascular bundles are **conjoint, collateral, open and endarch**.
- The vascular bundles are arranged in a ring & wedge shaped.
- Each vascular bundle is made of phloem, cambium and xylem.
- **Eustele** (vascular bundles arranged in ring) is present in dicotyledon stems.
- In **Cucurbits vascular bundles** are **bicollateral.**

5. **Medullary rays:**

- Rows of parenchymatous cells arranged radially from pith towards periphery which appear like spokes of a wheel are called medullary rays.
- They provide pathway for radial conduction of food and water.

6. Pith :

- It is found from ring of vascular bundles to the centre.
- The cells of this region are composed of parenchyma.
- Function Storage of water and food.

Internal structure of monocotyledon stem:

1. Epidermis:

- It is outer most single celled thick layer covered by thick cuticle.
- Multicellular hairs are absent & stomata are also less.

2. Hypodermis:

- It consists of sclerenchyma.
- It is 2–3 layered.
- It provides mechanical support to plant.

3. Ground tissue:

- The entire mass of parenchyma cells next to hypodermis and extending to the centre is called ground tissue.
- Ground tissue **is not differentiated into endodermis, cortex, pericycle etc.**

4. Vascular Bundle:

- Vascular bundles are scattered in the ground tissue and generally oval shape.
- Vascular bundles are smaller towards the periphery and larger towards the centre.
- Vascular bundles are **conjoint, collateral, closed with endarch xylem**.
- Each vascular bundle is surrounded by a layer of sclerenchymatous fibres that is known as **bundle sheath**.
- **Atactostele** (vascular bundles not arranged in ring) is found in monocot.
- Normally secondary growth does not occur in monocotyledonous stem but in Yucca & Draceana Anomalous secondary growth is found.

(a) Xylem: In xylem, Vessels (metaxylem & protoxylem) are arranged in **V** or **Y** shape.

- There is a water- containing **schizolysigenous cavity** at the end of protoxylem vessels and parenchyma.
- It is called **Lysigenous cavity**.
- This cavity is formed by disintegration of the element present below the protoxylem and neighbouring parenchyma.
- In *Asparagus* water cavity & bundle sheath are absent.

(b) Phloem:

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

5. Pith:

- Pith is undifferentiated in monocotyledon stems.
- Sometimes in some grasses, wheat etc. the central portion of ground tissue becomes hollow and is called pith cavity.

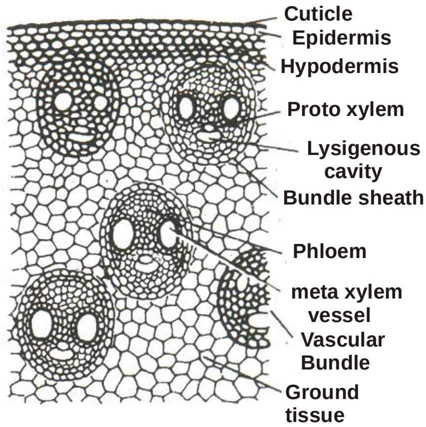


Fig. T.S. of monocot stem

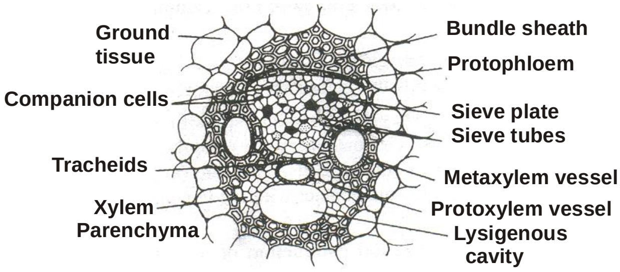


Fig Vascular bundle. of Monocot stem

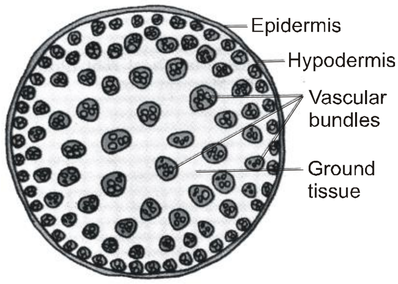


Fig : T.S. of stem Monocot

Differences between anatomy of monocot stem and dicot stem		
S.No.	Monocot stem	Dicot stem
1	Hairs are generally absent.	Multicellular hairs are present.
2	Epidermis consists of larger cells.	Epidermis is composed of comparatively smaller cells.
3	Hypodermis is sclerenchymatous.	Hypodermis is collenchymatous.
4	Cortex is generally absent, but from hypodermis to centre of stem ground tissue is present.	Cortex consists of many layered parenchymatous cells.
5	Endodermis is absent.	Endodermis is present but usually poorly developed.
6	Pericycle is absent.	Pericycle is made of one or many layers.
7	Medullary rays are absent.	Medullary rays are present between Vascular Bundles.
8	Pith is absent.	Pith is present.
9	Vascular Bundles :	
i	Scattered V.B.	V.B. are arranged in a ring.
ii	V.B. are conjoint, collateral and closed.	V.B. are conjoint, collateral and open
iii	V.B. in centre are larger in size and towards periphery are smaller.	V.B. are of same size.
iv	Bundle sheath is present around vascular bundle in monocot stem.	Bundle sheath is absent.
v	Oval vascular bundles.	Wedge shaped vascular bundles.
vi	Phloem parenchyma is absent.	Phloem parenchyma is present.
vii	Xylem vessels are ‘Y’ or ‘V’ shaped.	Xylem vessels are radial.

Anatomy of leaf:

On the basis of anatomy, leaves are of two types-Dorsiventral leaves and isobilateral leaves.

- The leaves are mostly horizontally oriented so that there is clear distinction between the upper & lower surface these are called **dorsiventral** leaves. **e.g. Dicot.**
- The leaves of monocots are generally vertically oriented, therefore, both surfaces of leaves get almost equal amount of light. Such leaves are called **isobillateral leaves. e.g. Monocots**
- The surface of leaf which is nearer to the axis of stem is called **Adaxial** / **Ventra**l / **Upper surface**. The other end of surface is called **abaxial** / **Dorsal** / **lower surface**.

Internal structure of a dorsiventral leaf (Dicot leaf):

Mango leaf shows following features in vertical transverse section

1. Epidermis:

- Each leaf bears upper and lower epidermis.
- Each of them consists of single layer of compactly arranged parenchymatous cells.
- **Exception–multi layered upper epidermis** is found in *Ficus elastica*, Piper.
- Cuticle is present on both surfaces but cuticle of upper epidermis is more thick.
- Dorsiventral leaves are mostly **hypostomatic** in which stomata present on lower surface.
- In **amphistomatic dorsiventral leaves** stomata are more on lower epidermis as compared to upper epidermis. **e.g. Potato**

2. Mesophyll:

- Mesophyll is divided into two regions - **Palisade** tissue and **spongy** parenchyma.
- Palisade tissue is found towards **upper surface.**
- These cells have **more chloroplasts** and spongy parenchyma is found towards lower surface intercellular spaces are well developed between cells of spongy parenchyma.

3. Vascular bundles:

- Vascular bundles are **conjoint, collateral and closed type**.
- Xylem is **endarch**.

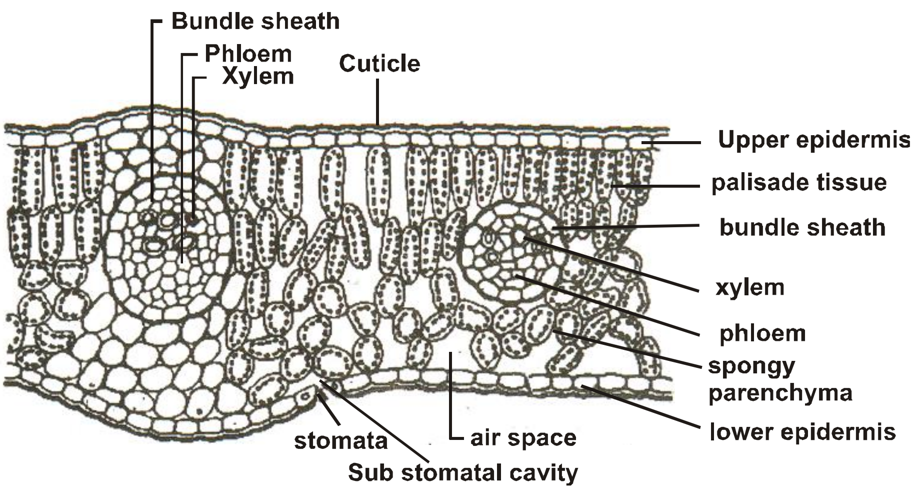


Fig. T.S. of dorsiventral leaf

- **Xylem** is towards **adaxial or upper surface** and **phloem** towards **abaxial surface.**

- ❖ Each vascular bundle is surrounded by a sheath of parenchymatous cells called **bundle sheath**. Vascular bundle of midrib is the largest and parenchyma is spread from bundle sheath on both sides upto epidermis.

Internal structure of a isobilateral leaf (Monocot leaf):

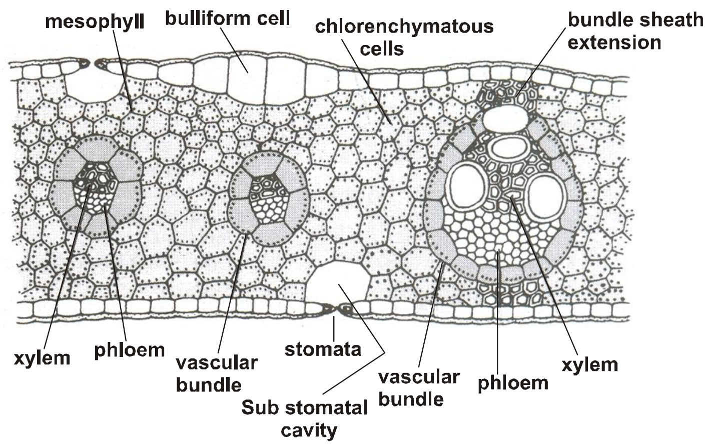


Fig. T.S. of isobilateral leaf

1. Epidermis:

- ❖ Each leaf bears upper & lower epidermis.
- ❖ Each of them composed of single layer of compactly arranged cells.
- ❖ The thickness of cuticle on the both epidermis is equal.
- ❖ Distribution of stomata on both epidermis are almost **equal** thus Isobilateral leaves are **Amphistomatic.**

2. Mesophyll:

- ❖ Mesophyll is not differentiated into palisade tissue and spongy parenchyma.
- ❖ It is completely composed of spongy parenchyma.
- ❖ In isobilateral leaf, two distinct patches of **sclerenchyma** are present above and below each of the large vascular bundles and extend up to the upper and lower epidermal layers respectively.

3. Vascular bundles:

- ❖ Vascular bundles in both dorsiventral and isobilateral leaves are of similar types.
- ❖ Vascular bundles are **conjoint, collateral** and **closed.**
- ❖ Xylem is situated towards the **adaxial** surface and phloem towards the **abaxial** surface in the vascular bundle. Vascular bundles may be surrounded by a **bundle sheath.**

Note:- Leaves are devoid of **endodermis** and **pericycle.**

Resonate the Concept

(1) The period between initiations of two successive leaf primordia is called **"Plastochron".**

(2) Apical meristem has two regions at embryonic stage

(a) Primordial Meristem or Promeristem–It develops in embryonic stage.

(b) Eumeristem–It is developed by the division of Promeristem.

(3) **Intercalary meristem:** occurs in the leaves and internodes of many monocotyledons, the flowering scape and pedicels of some species, gynophore of Arachis (ground nut), below the node in Mentha, at the base of leaf in pines, etc.

Korper-kappe theory

- It was proposed by **Schuepp** (1917). He stated that the cells of central and peripheral part of the root apex exhibit differences in planes of cell divisions.
- In peripheral region each cell first divides transversely and there after the lower daughter cell divides longitudinally thus forming the shapes of 'T'. These divisions are called the Kappe divisions. In the central region, T is inverted (⊥) as the second division takes place in the upper daughter cell. Such divisions are called the Korper divisions. As a result of these 'T' or '⊥' divisions, the cells in root apex remain arranged in rows.
- The number of rows increases downwardly by Kappe divisions and upwardly by Korper divisions.
- **Annular** and **Spiral** type of thickening of lignin are found in **protoxylem**. **Reticulate** and **Pitted** (mainly) **type of thickening** of **lignin** are found in **metaxylem**.

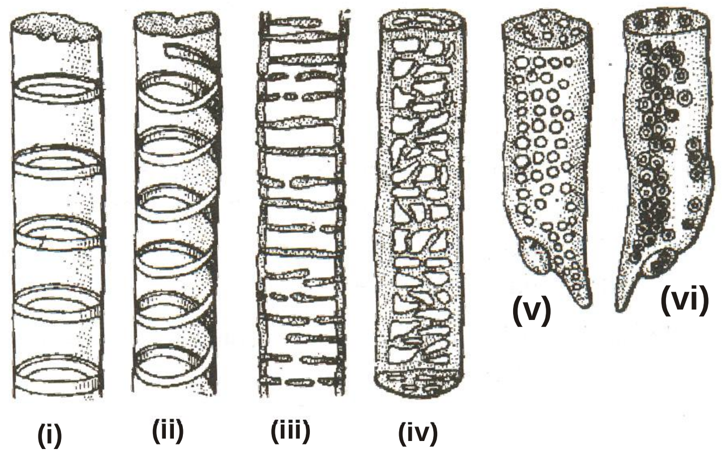


Fig. Various Lignified thickening of xylem
(i) Annular, (ii) Spiral, (iii) Scalariform,
(iv) Reticulate, (v) Simple pit, (vi) Bordered pit

- Maximum deposition of lignin is found in pitted type of thickening. Tracheids of **pteridophytes** have long or **elongated bordered pits**. Such type of pits are called **scalariform pits**.
- Leaves can be classified in different types on the basis of position of stomata:
  (a) Epistomatal - Stomata present on upper surface **e.g. Lotus.**
  (b) Hypostomatal - Stomata present on lower surface **e.g. Apple.**
  (c) Amphistomatal - Stomata present on both surface **e.g. Maize.**
  (d) Astomatal - Stomata absent **e.g. Vallisneria.**
- The number of stomata can vary from 15- 1000 per m.m. Generally it is upto 50-300 per m.m. The total leaf area approx 1-2% is covered by stomata.

*__Note:__ Stomata with both kidney and dumbell shaped guard cells are found on the leaf of **Cyprus**.

Special points on anatomy of roots

(1) In old root, cell of outer layer of cortex are suberized. It is known as **rhizodermis**.

(2) **Trichoblast** cells of epiblema form root hairs.

(3) Cell of cortex are usually non photosynthetic due to absence of chloroplast but in **Trapa** and **Tinospora,** its cells are photosynthetic due to presence of chloroplasts.

1. The guard cells of stomata are **dumb-bell shaped. e.g. Grasses (family Poaceae).**
2. **Bulliform cells:** Large & thin walled parenchymatous cells in upper epidermis of many grasses are called **bulliform cells or motor cells.** These cells help in rolling & unrolling of leaves to regulate loss of water (To reduce the Transpiration). **e.g. Grasses, Ammophila, Poa** and **Agropyron** etc. are Psammophytic grasses.
3. **Bundle sheath** in **C_4 plants** is **chlorenchymatous** and remaining plants have **parenchymatous or sclerenchymatous (mainly parenchymatous)** bundle sheath.

Special Tissues:

❖ These tissues perform special function in the plants such as secretion of resin, gum, oil and latex. These tissues are of two types.

1. Laticiferous tissue **2. Glandular tissue**

1. Laticiferous tissue:

❖ This tissue is mainly composed of **thin walled elongated, branched and multinucleate tube like structures** that contains colourless milky or yellow coloured juice called **latex**.

❖ Latex is the mixture of saccharides, starch granules, alkalloids, minerals and waste materials. **e.g. Calotropis, Euphorbia, Nerium, Ficus religiosa, Hevea, Papaver, papaya, Argemone and Sonchus.**

1. **Opium** is obtained from the **latex of Papaver somniferum**. It contains an **alkalloid** named as **morphine**.
2. **An enzyme papain** is obtained from the **latex of papaya (Carica papaya)**.
3. **Indian rubber** is obtained from **Ficus elastica** and **para rubber** is obtained from **Hevea brasiliensis**.
4. Mostly latex is white in colour but in some plants latex is coloured. **e.g. Papaver-Dark brown Argemone, Sonchus–Yellow colou**r. In some plants **latex** is **colourless e.g. Banana.**

Function:

(1) Latex provides protection to the plant.

(2) It prevents the plants from infection of bacteria and fungus.

2. Glandular tissue:

❖ This tissue is made up of glands. These glands contain secretory or excretory materials. They have two types of glands.

(1) **Glandular hairs:** They secrete gum like sticky substances **e.g. Tobacco and Plumbago, digestive juicy substance in Drosera.**
(2) **Nectar Glands:** Secrete nectar for attracting the insects.
(3) **Digestive glands: Found in insectivorous plants. e.g. Utricularia, Drosera, Dionaea**
(4) **Oil glands:** These secretes Volatile oil. **e.g. fruits & leaves of lemon & orange.**

Special points on Glandular tissue:

1. Oil glands which secrete volatile oils called **osmophores**. Osmophores develop fragrance in flowers.
2. Tannin, resin, gum secreting glands are also internal glands.
3. **Maximum resin glands** are found in **Pinus.**
4. **Resin canals** are **schizogenous in origin. Gum glands** are found in **Acacia.**
5. **Water glands–Hydathode**. These glands are related with **guttation**. **e.g. Garden nasturtium, Tomato, Pistia & Eichhornia etc.**