## ANATOMY OF DICOTYLEDONOUS AND MONOCOTYLEDONOUS PLANTS

To gain a comprehensive understanding of the tissue organization in the roots and stems of dicots and monocots, examining the transverse sections of mature zones of these plant organs proves beneficial.

### Anatomy of Root

### Dicotyledonous Root

In a transverse section of a mature dicot root, the following structural arrangement is observed:

- Epiblema: Positioned as the outermost layer, the epiblema typically consists of a single layer of cells. Notably, certain epiblema cells extend outward in tubular elongations, forming unicellular structures known as root hairs. Root hairs play a crucial role in facilitating the absorption of water and minerals from the soil.

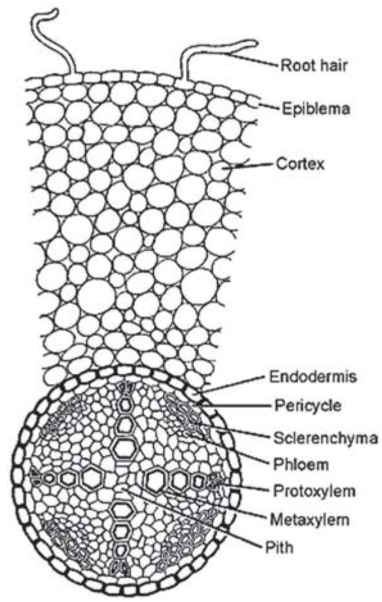


**Fig. :** Detailed structure of a portion of T.S. of gram (dicot) root

- Cortex: Extending below the epidermis to the endodermis, the cortex comprises multiple layers of parenchymatous cells. These cells, characterized by thin walls and a loose packing arrangement, allow unimpeded water movement. This design ensures minimal resistance to the flow of water through the cortex.
- Endodermis: Serving as the innermost layer of the cortex, the endodermis acts as a boundary between the cortex and the stele. The endodermis consists of a single layer of barrel-shaped cells with casparian strips—special thickenings of waxy material suberin in radial and tangential walls. Casparian strips prevent the penetration of water molecules in areas where they are present.
- Pericycle: Situated adjacent to the endodermis, the pericycle is composed of thick-walled parenchymatous cells, with the potential for single- or multilayered configurations. Pericycle cells play a crucial role in the secondary growth of dicot roots. Although cambium is initially absent in dicot root vascular bundles, it develops later as a cambial ring during secondary growth. Meristematic cells of the pericycle contribute to the formation of part of the vascular cambium and lateral roots during this secondary growth phase.
- Vascular Bundles: Radial vascular bundles exhibit a distinctive arrangement of xylem and phloem along different radii. An exarch condition is evident, with metaxylem positioned toward the center and protoxylem toward the periphery. The number of xylem and phloem patches can vary from two to six,

typically ranging from two to four. The nomenclature classifies the dicot root based on its xylem bundles, such as tetrarch (four bundles), triarch (three bundles), or diarch (two bundles).

- **Conjunctive Tissue:** Parenchymatous cell patches are interspersed between the xylem and phloem, constituting the conjunctive tissue.
- **Pith:** Positioned at the root's center, the pith comprises parenchymatous cells with intercellular spaces. In dicotyledonous roots, the pith is relatively small and inconspicuous.

### Monocotyledonous Root:

The anatomical features of a monocot root exhibit similarities to those of a dicot root, with some distinctive differences. The transverse section of a monocot root reveals specific tissue arrangements, as elucidated below:

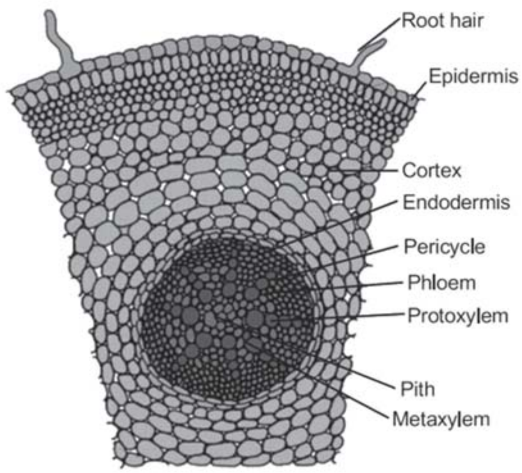


**Fig. :** T.S. : Monocot root

- **Epidermis:** Constituting the outermost layer, the epidermis features a multitude of unicellular root hairs. Notably, the cuticle is absent, and stomata are not present in the epidermis.
- **Cortex:** Unlike dicot roots, the monocot root lacks a hypodermis. The cortex primarily consists of loosely arranged parenchymatous cells. The endodermis is highly conspicuous, comprised of barrel-shaped cells exhibiting casparian strips.
- **Pericycle:** The pericycle is notably distinct and plays a crucial role in the formation of lateral roots. In monocots, the absence of cambium in the pericycle precludes secondary growth, distinguishing it from dicot roots.
- **Vascular Bundles:** Vascular bundles exhibit a radial arrangement, distributed along different radii of the root. In contrast to dicotyledonous roots, monocot roots lack vascular cambium, rendering their vascular bundles closed. The absence of cambium signifies the absence of secondary growth in monocotyledonous roots. Monocot roots typically display more than six xylem bundles (polyarch), differing from dicot roots in this aspect. Phloem components include sieve tubes, companion cells, and phloem fibers, with phloem parenchyma being notably absent in monocots.
- **Conjunctive Tissue:** Parenchymatous cells form the conjunctive tissue, positioned between the patches of xylem and phloem.
- **Pith:** The pith in monocotyledonous roots is substantial and well-developed. Its size and prominence distinguish it from dicot roots, indicating a pivotal role in the structural integrity and support of monocot roots.

| Comparison of Dicot and Monocot Root anatomy | | |
|---|---|---|
| **Character** | **Dicot Root** | **Monocot Root** |
| Pericycle | Gives rise to secondary (lateral) roots, vascular cambium and cork cambium. | Gives rise to lateral roots only. |
| Vascular | Diarch to hexarch i.e., vascular bundles are 2 to 6 in number. | Polyarch, i.e., usually more than 6 vascular bundles are present. |
| Cambium | Develops at the time of secondary growth. | Cambium is absent. No secondary growth. |
| Pith | Small and inconspicuous. | Large and well developed. |

### Anatomy of Stem

## Dicotyledonous Stem:

The cross-sectional view of a typical young dicotyledonous stem unveils distinct zones in its primary structure, offering insights into its anatomy.

- **Epidermis:** Positioned as the outermost layer, the epidermis serves a protective role. Composed of a single layer of cells, the outer walls of epidermal cells are cuticularized with a thin cuticle. Epidermal appendages such as trichomes and a few stomata may be present, particularly in young stems.
- **Cortex:** Situated beneath the epidermis, the cortex is multilayered and encompasses various subzones:
  **Hypodermis:** Constituting the outermost region of the cortex just below the epidermis. Comprised of 3 to 5 layers of collenchymatous cells in dicot stems. Intercellular spaces are absent, and cell walls are thickened at the corners, providing mechanical strength to young stems.
  **General Cortex or Cortical Layers:** Positioned below the hypodermis and above the endodermis. Comprised of parenchymatous cells with thin walls and rounded shapes, featuring intercellular spaces.
  **Endodermis:** The innermost layer of the cortex where cells store starch grains. Referred to as the starch sheath.
- **Pericycle:** Present on the inner side (below) of the endodermis and above the phloem. Forms patches between the endodermis and phloem, exhibiting a semilunar shape and comprising sclerenchymatous cells.
- **Vascular Bundles:** Numerous vascular bundles populate the dicot stem, each consisting of xylem, phloem, and a cambium layer in between. Xylem is positioned toward the inner side of each vascular bundle and follows an endarch arrangement, with protoxylem toward the pith and metaxylem toward the periphery. The cambium, featuring meristematic cells, facilitates secondary growth by adding phloem toward the periphery and xylem toward the center.
  **Characteristics:** Vascular bundles in dicot stems are conjoint, open, and exhibit endarch protoxylem. A characteristic 'ring' arrangement of vascular bundles encircles the central pith.
- **Pith or Medulla:** Occupying the central region of the stem, the pith is composed of numerous parenchymatous cells. These cells are rounded and feature large intercellular spaces.
  **Medullary Rays or Pith Rays:** Parenchymatous cells present between vascular bundles constitute the medullary rays or pith rays. Radially arranged, these cells between bundles form rays that facilitate the radial conduction of food.

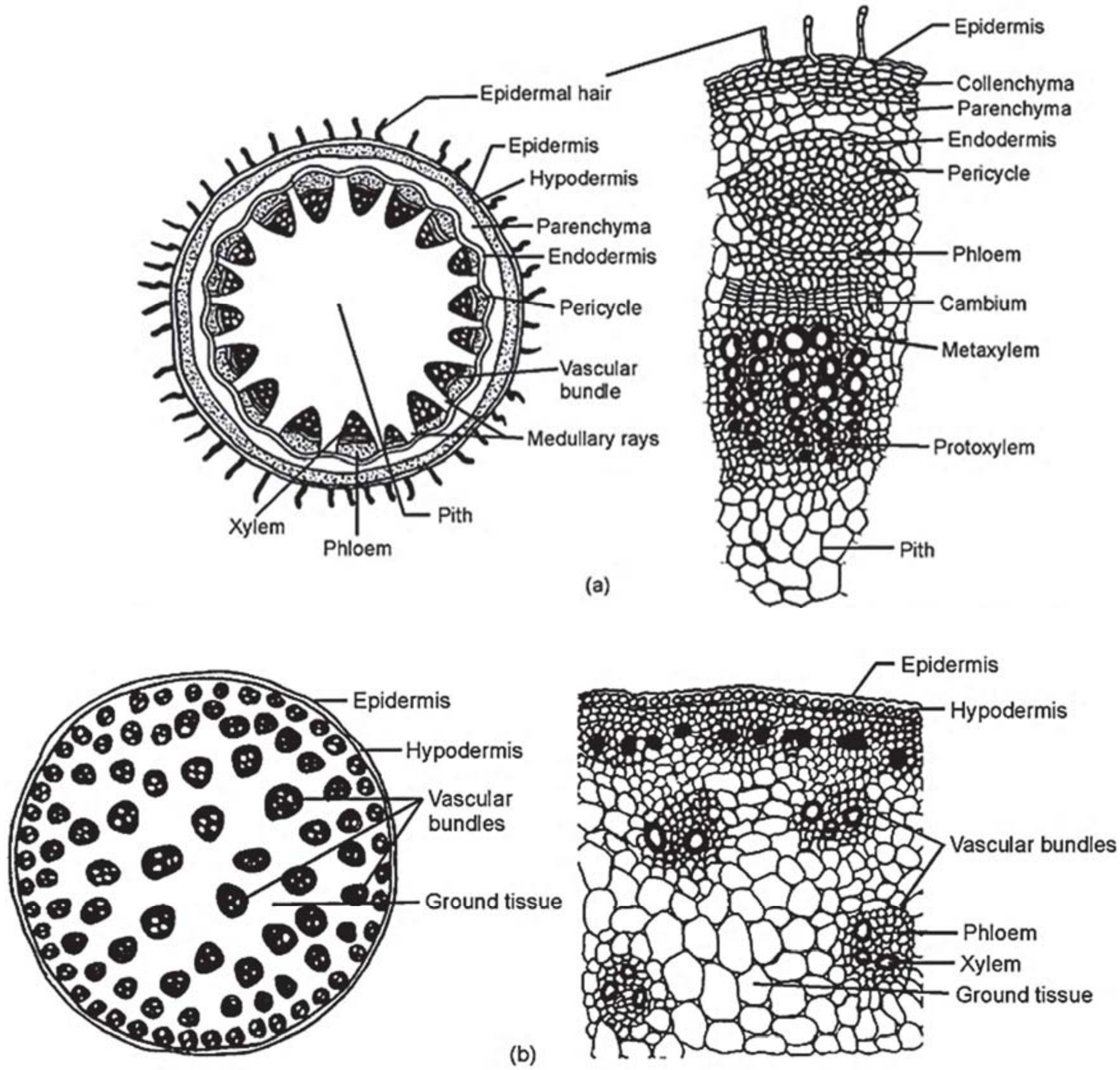


**Fig. : T.S. of Stem : (a) Dicot, (b) Monocot**

## Monocotyledonous Stem:

Examining the cross-sectional view of a monocotyledonous stem reveals distinct layers from the outer to inner side, showcasing unique characteristics:

- Epidermis: As the outermost layer, the epidermis consists of a single layer of cells. The outer walls of epidermal cells are coated with a cuticle, and stomata may be present.
- Hypodermis: Positioned beneath the epidermis, the hypodermis is composed of sclerenchymatous cells in monocot stems (collenchymatous in dicots). The presence of sclerenchyma imparts mechanical support to the stems.
- Ground Tissue: The predominant area in a monocot stem is occupied by the ground tissue. Unlike dicot stems, the ground tissue in monocot stems lacks well-defined cortical layers, endodermis, pericycle, pith, and pith rays. All cells inner to the hypodermis constitute the ground tissue, primarily comprised of parenchymatous cells.
- Vascular Bundles: Numerous vascular bundles are distributed throughout the stem, not arranged in a ring-like manner as observed in dicot stems. Vascular bundles are scattered within the ground tissue, smaller and densely packed towards the periphery, while larger bundles are loosely arranged toward the center of the stem.

**Bundle Characteristics:** Bundles typically have an almost oval outline and include xylem and phloem elements, lacking cambium. Each vascular bundle is enveloped by a sheath composed of sclerenchymatous tissue, known as the bundle sheath.
**Vascular Bundle Nature:** Vascular bundles in monocot stems are conjoint and closed, preventing secondary growth.
**Xylem Arrangement:** Endarch xylem is evident, with protoxylem situated towards the center and metaxylem towards the periphery. The presence of schizolysigenous water-containing cavities within the vascular bundle is a characteristic feature of monocot stems.
**Phloem Composition:** Phloem is composed of sieve tubes, companion cells, and phloem fibers, while phloem parenchyma is absent.

| Comparison of internal structure of Angiospermic Stem and Root | | |
|---|---|---|
| Character | Root | Stem |
| Epidermis | Without cuticle | Usually with cuticle |
| Hypodermis | Absent | Present – collenchymatous or scierenchymatous |
| Endodermis | Distinct | Poorly developed |
| Vascular bundles | Radial | Conjoint |
| Xylem | Exarch | Endarch |

| Comparison of Dicot and Monocot Stem anatomy | | |
|---|---|---|
| Character | Dicot stem | Monocot stem |
| Ground tissue | Differentiated into cortex and pith. | Not differentiated into cortex and pith |
| Hypodermis | Collenchymatous | Sclerenchymatous |
| Endodermis | Single layered | Absent |
| Pericycle | Made up of parenchymatous and/or Sclerenchymatous cells. | Absent |
| Vascular bundles | Almost all are of uniform size<br>Arranged in a ring<br>Conjoint and open<br>Bundle sheath absent<br>Phloem parenchyma present | Larger towards centre and smaller towards periphery.<br>Scattered<br>Conjoint and closed<br>Bundle sheath present<br>Phloem parenchyma absent |
| Pith (medulla) | Made up of parenchymatous cells, situated in the centre. | Absent |
| Medullary rays | Found in between the vascular bundles. | Absent |
| Stele | Eustele (Conjoint, collateral, open) | |

Anatomy of Leaf

- The leaf, typically a flat structure, functions as the primary photosynthetic organ in plants. Positioned between its upper and lower epidermis, the leaf's photosynthetic tissue is well-supported by the vascular system and contains chloroplasts. Notably, in a leaf, the xylem always faces the upper epidermis, while the phloem is oriented towards the lower epidermis.
- The internal structure of a leaf is explored through its vertical section, leading to the classification of leaves into two types based on anatomy:

- **Dorsiventral Leaves:** Dorsiventral leaves are prevalent in dicotyledonous plants. These leaves typically maintain a horizontal orientation, with sunlight predominantly reaching their upper surface. The upper surface of a leaf is termed the ventral surface or adaxial surface, while the lower surface is referred to as the dorsal or abaxial surface. Dorsiventral leaves exhibit distinct differences in color and anatomical features between the dorsal and ventral surfaces, making them easily distinguishable. The upper surface appears darker green compared to the lower surface.
- **Isobilateral Leaves:** Isobilateral leaves are characteristic of monocotyledonous plants. These leaves generally adopt a vertical position. Unlike dorsiventral leaves, isobilateral leaves showcase uniformity in color and anatomical features on both surfaces. Both the upper and lower surfaces of isobilateral leaves are equally green and resemble each other closely.

## Dorsiventral Leaf

The vertical cross-section of a dorsiventral leaf, cutting through the lamina, reveals three distinct parts:

- **Epidermis:** The epidermis envelops both the upper and lower surfaces of the leaf, with specific designations for each:

  **Adaxial or Upper Epidermis:** Positioned on the outermost layer of the leaf, it consists of a single layer of parenchymatous cells. The outer walls of these cells are cuticularized, lacking chloroplasts. Stomata are comparatively fewer on the upper epidermis, and in some cases, they may be entirely absent.

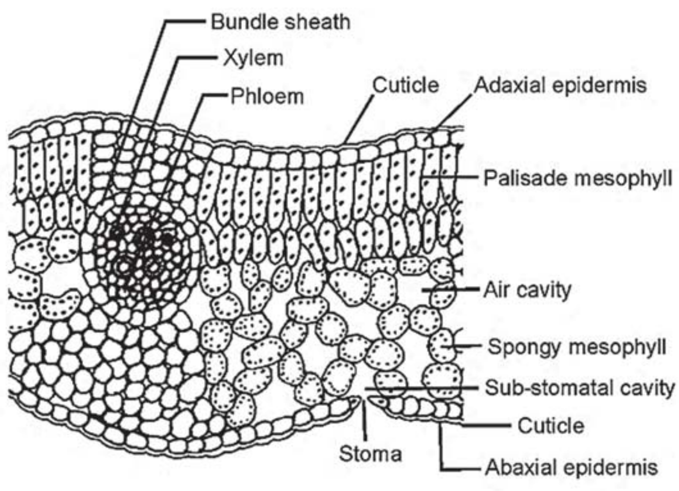


**Fig. :** T.S. of a dicot leaf

  **Abaxial or Lower Epidermis:** Structurally similar to the upper epidermis, it is single-layered, composed of parenchymatous cells, and covered with cuticle. However, the lower epidermis typically bears more stomata than the upper epidermis. Below the stomata, a cavity known as the sub-stomatal cavity facilitates gas exchange. While epidermal cells lack chloroplasts, chloroplasts are present in the guard cells surrounding the stomata.

- **Mesophyll:** The mesophyll, situated between the upper and lower epidermis, constitutes the ground tissue of the leaf and is crucial for photosynthesis. It is divided into two regions:

  **Palisade Parenchyma:** Adaxially placed beneath the upper epidermis, the palisade parenchyma comprises elongated cells arranged vertically at a 90° angle to the upper epidermis. These cells are densely packed, lack intercellular spaces, and contain numerous chloroplasts, actively participating in photosynthesis.

  **Spongy Parenchyma:** Abaxially positioned beneath the palisade parenchyma and reaching the lower epidermis, the spongy parenchyma consists of irregularly arranged oval or rounded cells. Intercellular spaces between these cells are prominent, and the tissue earns its name due to this loose arrangement. Similar to palisade parenchyma, spongy parenchyma cells also contain chloroplasts and contribute to photosynthesis.

- **Vascular System:** The vascular system encompasses scattered vascular bundles within the spongy parenchyma, predominantly located in the veins and midrib of the leaf. Dicotyledonous leaves exhibit reticulate venation, forming a network of veins. The size of vascular bundles correlates with the thickness of veins, with larger bundles in thicker veins and smaller bundles in thinner veins. These vascular bundles lack cambium, rendering them conjoint and closed. Surrounding each vascular bundle, a layer of thick-walled bundle sheath cells is present, providing additional support.

## Isobilateral Leaf:

The anatomical structure of an isobilateral leaf closely resembles that of a dorsiventral leaf in many aspects, exhibiting distinctive features as outlined below:

- **Epidermis:** The isobilateral leaf comprises upper (adaxial) and lower (abaxial) layers of epidermis, both consisting of a single layer of cells and featuring stomata. Notably, stomata are evenly distributed on both surfaces, rendering the leaf isobilateral. Both epidermal layers are characterized by circularization.
  **Bulli form Cells:** In certain grasses, specific cells in the upper epidermis, known as adaxial epidermal cells, undergo enlargement, becoming large, empty, and colorless, referred to as Bulli form cells. These cells, occurring in groups, play a pivotal role in leaf rolling during periods of drought or water scarcity. Their function involves regulating leaf exposure to minimize water loss. When well-hydrated, bulliform cells absorb water, becoming turgid and causing the leaf surface to straighten, allowing water loss. Conversely, under water stress, these cells lose water, becoming flaccid and inducing leaf curling to reduce water loss. Bulliform cells thus contribute to water conservation during challenging conditions.
  **Sub-Stomatal Cavity:** Positioned beneath the stoma of the abaxial epidermis, a sub-stomatal cavity facilitates gas exchange.
- **Mesophyll:** The mesophyll, situated between the upper and lower epidermis, lacks differentiation into palisade and spongy parenchyma. Mesophyll cells, nearly spherical in shape, are irregularly arranged. Despite this lack of differentiation, these cells contain chloroplasts and actively engage in photosynthesis.
- **Vascular Bundles:** The leaf features numerous large and small vascular bundles, each surrounded by a layer of thin-walled cells forming a bundle sheath. Vascular bundles in monocot leaves are conjoint and closed, with xylem positioned towards the upper epidermis and phloem towards the lower epidermis. Larger bundles display a clear distinction between xylem and phloem. Unlike dicot leaves, where vascular bundle size correlates with vein size, monocot leaves exhibit similar-sized vascular bundles due to parallel venation. Parallel venation involves veins running parallel to each other, maintaining nearly equal sizes throughout the leaf.

| Comparison of Anatomy Dicot and Monocot Leaf | | | |
|---|---|---|---|
| | Character | Dicot Leaf | Monocot Leaf |
| 1 | Type of leaf | Dorsiventral | Isobilateral |
| 2 | Stomata | Usually more in number on lower epidermis. | Equal in number on lower and upper epidermis. |
| 3 | Mesophyll | Differentiated into two types of tissues – palisade and spongy parenchyma. | Not differentiated into palisade and Spongy parenchyma. |
| 4 | Bulliform cells | Absent | Present, particularly in grasses. |
| 5 | Vascular bundles | Differ in size due to presence of reticulate venation. | Nearly similar in size due to presence of parallel venation. |