

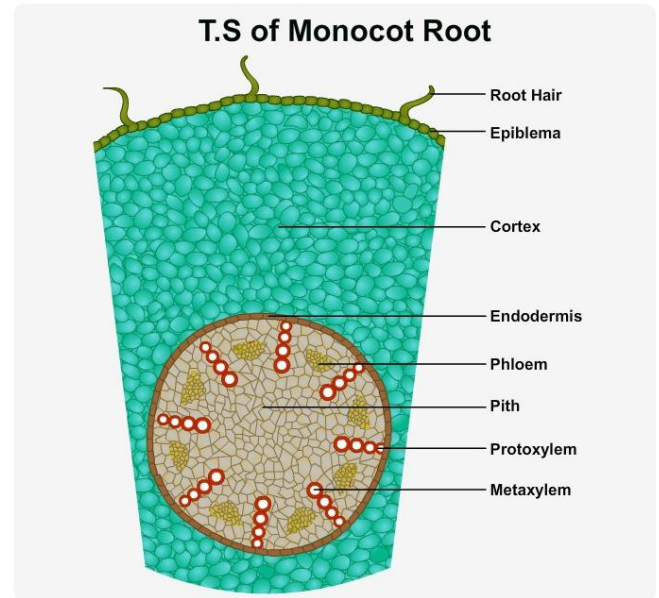
## Primary Structure of Monocot Root Anatomy

Monocot roots shows following distinct regions:

1. **Epiblema**
2. **Cortex**
3. **Endodermis**
4. **Pericycle**
5. **Vascular bundles**
6. **Pith**

### Features of Different Regions of Monocot Root

1. **Epiblema** is the **outermost single layer** made from compactly arranged parenchymatous cells **without intercellular space**. Usually Epiblema has **no stomata** but bears unicellular epidermal root hairs and **less amount of cutin**. The root hairs and thin walled **epidermal cells take part in the absorption of water and minerals from the soil**. The epiphytes have several layered hygroscopic epidermis, called **Velamen tissues**. It is made from spongy dead cells which help in absorption of water from atmosphere. It also checks excessive loss of water from cortex. Usually the wall of velamen has spiral or reticulate secondary thickening of cellulose, pectin and lignin.
2. **Cortex** is a multi-layered well developed and made from **oval parenchymatous cells** with intercellular spaces. **The intercellular spaces usually help in gaseous exchanges, storage of starch, etc.** In monocots and several old roots, few layers of cortex just below epiblema give rise to a single or multilayered cuticularised sclerenchymatous region called **exodermis**. **Cortex helps in mechanical support to the roots** (like hypodermis to stem).
3. **Endodermis** is innermost layer of cortex made from barrel shaped parenchyma. It forms a definite ring around the stele. These cells are characterized by the presence of casparian stripes. It is **deposition of suberin and lignin**, and their radial and tangential walls. Usually passage cells are absent in monocot roots. Due to presence of **Casparian stripes, endodermis forms water tight jacket around the vascular tissues**, hence it is also called biological barrier. It regulates the inward and outward flow of water and minerals and prevents diffusion of air into xylem elements.
4. **Pericycle** is **uniseriate and made from thin walled parenchymatous cells**. It is outermost layer of stellar system. Usually it is made from parenchymatous cells but it **may become sclerenchymatous in older roots**. Several lateral roots arise from this layer. Hence, lateral roots are endogenous in origin.
5. **Vascular bundle** is radial, arranged in a ring (except mangrove, which also contains lenticels), **polyarch** (presence of many alternating xylem and phloem bundles). **Xylem and phloem are found at different radii alternating with each other** (radial). The number of xylem and phloem vary from, 8 to 46 (100 in *pandanus*). **The xylem is exarch**, i.e. the protoxylem lies towards periphery and metaxylem toward center. The protoxylem has smaller vessels with spiral or annular thickening, whereas the walls of **metaxylem contains pitted thickening**. **Phloem consists of sieve tubes, companion cells and phloem parenchyma**. Usually phloem sclerenchyma or fibers are absent. The phloem is also exarch (protophloem towards the periphery and metaphloem towards the center). Secondary growth is absent in monocot roots due to lack of vascular and cork cambium. **Conjunctive tissue** is parenchymatous tissues which separates xylem and phloem bundles. It may become sclerenchymatous in older roots.



6. **Pith** is large, well developed portion of monocot root. It occupies the central portion and made from thin walled parenchymatous tissue with intercellular spaces. It contains abundant amount of starch grains.

Monocot root of maize have bands of vascular bundles. Bundles are not separate and vessels are not found in linear rows, but arranged in V-shaped structure.

### Internal or Anatomical Structure of Monocot Stem

The anatomy or internal structure of a monocot stem can be studied by a Transverse Section (T.S.) taken through the internode of a monocot plant such as grass, bamboo, maize, *Asparagus* etc. The main difference of monocot stem from dicot stem is that, here in monocots the ground tissue is not differentiated into Cortex and Endodermis. The anatomical features of a typical monocot stem are summarized as key points below:

The T.S. of a monocot stem is usually circular in outline. Typically a monocot stem consists of FOUR tissue systems.

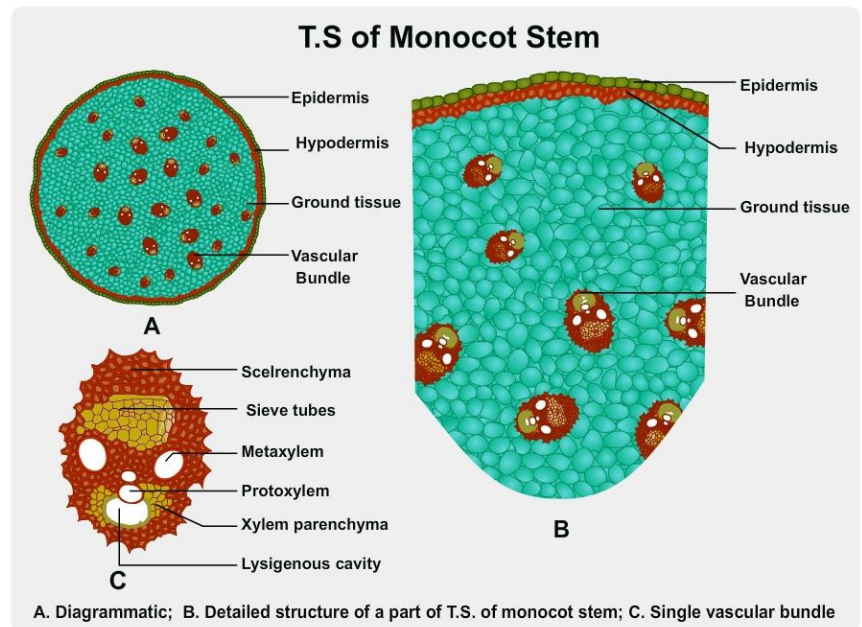
- (1). Dermal tissue system
- (2). Hypodermal tissue system
- (3). Ground tissue system
- (4). Vascular tissue system

#### Dermal tissue system

- Dermal tissue system constitutes the epidermis. Epidermis forms the outermost layer. Usually the epidermis is single layered and made up of parenchymatous cells. Epidermal cells are compactly packed without any inter-cellular spaces
- A thick layer of cuticle is present over the outer wall of epidermis
- A special feature of monocot epidermis is that, cell wall is highly silicified (they show silica deposition)
- Epidermal hairs or trichomes are usually absent in monocots
- Stomata are present (few in number) on the epidermis
- Silica deposition provides mechanical support
- Cuticle prevents transpiration
- Stomata present on epidermis allows gaseous exchange

#### Hypodermal tissue system

- Hypodermal tissue system consists of hypodermis, it occupies immediately below the epidermis
- Cells are polygonal and compactly packed without any inter-cellular spaces
- Hypodermis is multilayered and sclerenchymatous
- Alternate patches of chlorenchyma may be present in some plants (Grass)
- Below the chlorenchyma, the hypodermis is continuous
- Peripheral vascular bundles are sometimes embedded in the hypodermis
- Functions of hypodermis:
  - Provide mechanical support and protection
  - Chlorenchyma can do photosynthesis



### **Ground tissue system**

- Ground tissue composed of cortex only (Ground tissue NOT differentiated) Cortex is parenchymatous; cells are larger and circular Cortical cells are loosely packed with plenty of inter-cellular spaces In aquatic monocots, aerenchyma is present in the ground tissue
- In some plants, central portion of ground tissue is hollow and filled with air.

### **Vascular tissue system**

- composed of vascular bundles. Vascular bundles are numerous and they scatteredly arranged in the ground tissue
- Vascular bundles are widely separated from each other. They show size differences
- Vascular bundles in the outer region are smaller, whereas those in the inner region are larger
- Vascular bundles in most cases are surrounded by a sclerenchymatous bundle sheath
- Bundle cap is absent in monocots
- Vascular bundles are conjoint, collateral and closed
- Cambium is absent (closed VB) and hence no secondary thickening in monocots

### **Vascular bundles composed of Xylem and Phloem**

#### **Xylem**

- Xylem is endarch (Protoxylem arranged towards interior and Metaxylem towards exterior)
- Metaxylem composed of only two large vessels with pitted thickening
- Meta-xylem tracheids present between meta-xylem vessels
- Protoxylem composed of few vessels with annular or spiral thickening
- Protoxylem elements fused to form a lysigenous cavity called
- protoxylem lacuna or protoxylem cavity
- Function of xylem: conduction of water, provide mechanical support

#### **Phloem**

- Phloem lies outer to xylem
- Phloem composed of sieve tubes and companion cells
- Phloem parenchyma is absent in monocot vascular bundles & Function: Conduction of food

## **Anatomical Structure of Monocot Leaf**

Monocot leaves are said to be isobilateral leaves as both the surface of the leaves are with same coloration. The leaves are usually ribbon like with parallel venation. It is because mesophyll is hardly differentiated into palisade and spongy parenchyma cells. The following are the various tissues and their functional activities of monocot leaf:-

### **Upper epidermis:-**

1. It is the uppermost layer or adaxial layer of a monocot leaf. It is a single layered tissue made of cubical or barrel shaped cells and are arranged closely with no inter cellular spaces in between them.
2. Chloroplasts cannot be seen in these cells. Upper epidermis on its outer surface is covered by a thin cuticle.
3. In a monocot leaf equal number of stomata is present on both the surfaces of epidermis. Such condition is usually described as amphi stomatic condition. A few cells present in the upper epidermis are enlarged to form motor cells called bulliform cells.

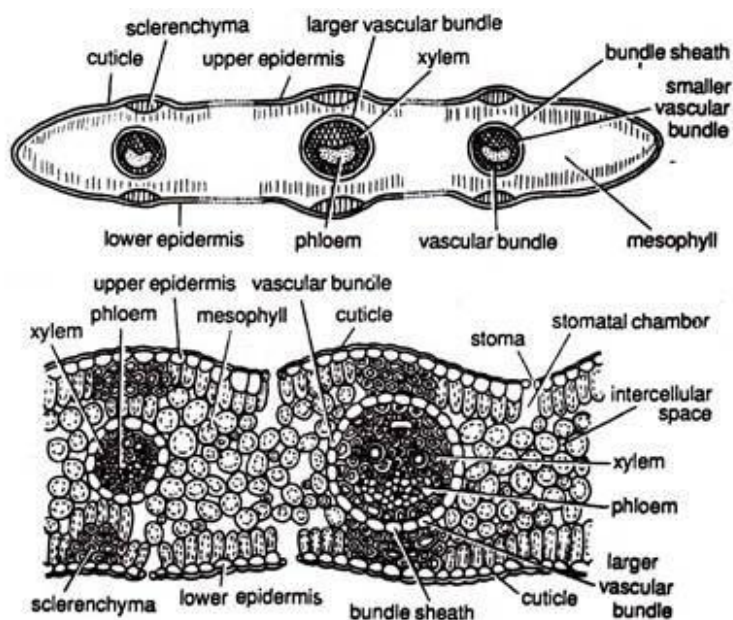
4. These cells are larger when compared to other epidermal cells. These cells will be helpful for the monocot leaves to roll over themselves to reduce the surface area exposed to sunlight become less during hot midday time to reduce rate of transpiration.
5. It is an adaptation for monocot leaves to check the loss of water from their surface during hot summer time.
6. In both upper and lower epidermal layers of monocot leaf equal number of stomata are present unlike more stomata in the upper epidermal layer and less in lower epidermal layer as in the case of Dicot leaf.
7. In the case of monocot leaf, the two guard cells which form the stoma are dum-bell shaped. But the two guard cells which form stoma in dicot leaves are kidney or bean shaped.

### Mesophyll

1. Mesophyll is a ground green tissue present in between upper epidermis and lower epidermis. In monocot leaf mesophyll tissue is not differentiated into palisade parenchyma and spongy parenchyma as in the case of a dicot leaf.
2. The tissue of monocot leaf consists of only one kind of cells which are small oval or spherical or irregular shaped spongy parenchyma cells with chloroplasts and chlorophyll.
3. This tissue is present in 6-7 layers with large intercellular spaces in between them. In between the epidermal layers of the monocot leaf as the undifferentiated spongy parenchyma with less number of chloroplasts and chlorophyll is present both the surfaces of the leaf appears to be of same coloration. T
4. his mesophyll tissue is concerned with photosynthesis process in the leaves of these plants.

### Vascular bundles

1. Vascular bundles represent the veins of the leaves. Vascular bundles are present within the mesophyll tissue. Each vascular bundle consists of xylem and phloem complex tissues surrounded by bundle sheath. Bundle sheath layer of the vascular bundle is made of large barrel shaped endodermal cells.
2. The cells of this layer usually store starch granules. Hence it is also known as starch sheath. Xylem tissue of a vascular bundle is present towards the upper epidermis of the leaf. Xylem complex is a complex permanent tissue consists of xylem tracheids, xylem vessels, xylem parenchyma and xylem fibers.
3. Xylem in a vascular bundle is concerned with conduction of water and dissolved minerals.
4. Phloem tissue in the vascular bundle is present towards the lower epidermal surface of the leaf.
5. Phloem is a complex permanent tissue made of sieve tubes and sieve pores, companion cells, phloem parenchyma and phloem fibers. Phloem tissue in a leaf is concerned with conduction of dissolved food materials (usually glucose).



6. Vascular bundles in monocot leaf is described as conjoint, collateral and closed with endarch xylem. As xylem and phloem are present on the same radius, the vascular bundle is described as conjoint and collateral.
7. The vascular bundle is described as closed as there is no cambium present between xylem and phloem. Xylem vessels are of two types- protoxylem and metaxylem vessels. Protoxylem vessels are newly formed young vessels while metaxylem vessels old and well matured vessels.
8. Xylem bundles are described here as endarch because the protoxylem vessels faces towards the upper epidermis. Vascular bundles help in transport of water, dissolved minerals and dissolved food materials in the leaf. Vascular bundles also provide strength to the leaf.

### Lower epidermis

1. Below the undifferentiated mesophyll tissue a single layer of epidermis is present. This layer is present on the abaxial (lower) surface of the leaf. The cells are cubical or barrel in shape and are arranged very closely without any inter cellular spaces.
2. The same number of stomata are present as like in the upper epidermis. Through the stomata of upper and lower epidermis exchange of gases occur through diffusion method. Just above the stomata of the epidermal layers of both the surfaces of the leaf, air cavities or sub-stomatal chambers are present. These air cavities act as a store house of carbon dioxide or water vapor till they diffuse.

## Anatomical Structure of Dicot Root

Anatomically, the primary structure in a dicot root is differentiated into the following tissue zones:

- (1). Root cap
- (2). Epidermis
- (3). Cortex
- (4). Endodermis
- (5). Pericycle
- (6). Vascular Tissue
- (7). Conjunctive Tissue
- (8). Pith

### Root Cap

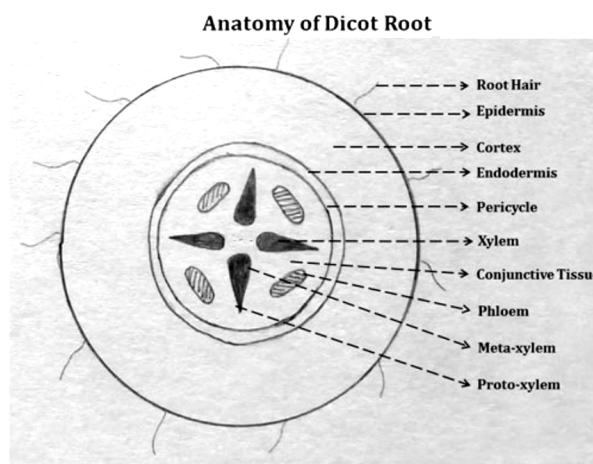
1. Root cap is a mass of tissue present in the exact tip of the root. Root cap is also called as calyptra.
2. Root cap composed of only closed packed parenchymatous cells.
3. Root cap contains specialized gravity perception cells called statocytes.

### Functions of root cap:

1. Protection of root meristem.
2. Acts as the site of perception of gravity.
3. Have the capacity to control the activity of meristematic cells in the root apex by producing growth hormones.

### Epidermis

1. It is also called as piliferous layer, epiblema or rizodermis. It is the outermost layer of cells derived from dermatogen of the root apex.



2. Composed of a single layer of compactly packed parenchymatous cells. Cells are barrel shaped, cuticle and stomata are absent. Some epidermal cells give off unicellular root hairs.
3. Epidermal cells which give rise the root hairs are called Trichoblasts. Root hairs are epidermal extensions. Root hairs absorb nutrients and water from the soil.
4. Root hairs increase the surface area for absorption. Root hairs are ephemeral (= short lived) structures. Root hairs are absent in the exact tip portion of the root.
5. In herbaceous plants, the epidermis is long lived and acts as the chief protective tissue. In a majority of dicots, the epidermis is immediately replaced by the bark during secondary growth.

#### **Functions of epidermis:**

1. Acts as the outermost boundary layer
2. Provide protection
3. Root hairs absorb water and nutrients from the soil

#### **Cortex**

1. Cortex is simple, composed of parenchymatous cells. Cells are thin walled and loosely packed with plenty of intercellular spaces.
2. Cortex is undifferentiated. Chlorenchyma is usually absent in the cortex of roots. In some plants (hydrophytes) cortex contain a large amount of aerenchyma.
3. Cortical cells show distinct pattern of arrangement as distinct rows. Cortical cells store large amount of starch grains.
4. Plenty of secretory structures and idioblasts are present in the cortex.

#### **Functions of Cortex:**

1. Aerenchyma in the cortex facilitates air exchange. Thin walled cells allow the transport of water from cortex to xylem.
2. Cortex maintains the root pressure. Cortical cells store food materials as starch grains.
3. Aerial roots can perform photosynthesis.
4. Sclerenchymatous cells in the cortex provide mechanical support.
5. Air cavities in the cortex of aquatic plants provide buoyancy.
6. Vascular cambium during secondary growth is derived from the cortex.

#### **Endodermis**

1. Endodermis is the innermost layer of cortex. Endodermis is very distinct and prominent in dicot root.
2. Composed of a single layer of barrel shaped cells. Shows special thickening in the radial and inner tangential wall.
3. This special type of thickening is Casparian Thickening of Casparian Band.
4. Endodermal cells opposite to proto-xylem elements remain thin-walled and these cells lack the Casparian thickening. Endodermal cells devoid of Casparian thickening are called Passage Cells.
5. Endodermal cells store plenty of starch grains, hence called Starch Sheath.

#### **Functions of Endodermis:**

1. Regulation of movement of water from cortex to xylem.
2. Endodermal cells can store starch grains.

#### **Pericycle**

1. A layer of cells present next to the endodermis. It is the outermost layer (boundary) of the vascular cylinder.
2. Usually composed of thin walled parenchymatous cells.
3. Pericycle is usually uniseriate (single layered).
4. In some plants (*Ficus benghalensis* and *Morus*) the pericycle is multiseriate.
5. Pericycle is absent in most of the aquatic plants and in some parasites.

### Functions of pericycle:

1. Lateral roots originate from the pericycle.
2. In some plants pericycle also give rise to the phellogen (cork cambium).

### Vascular Tissue

1. In roots, vascular bundles show radial arrangement.
2. Radial arrangement: xylem and phloem bundles are arranged alternatively in different radii.
3. Vascular bundles are limited in number, 2 (diarch) to 6 (hexarch). Usually, it is tetrarch (four xylem and phloem strands).
4. Xylem is exarch (proto-xylem is oriented towards the exterior and meta-xylem towards the interior). Meta-xylem elements are polygonal (angled) in outline.
5. Phloem usually composed of sieve tubes, companion cells and phloem parenchyma. Phloem fibres are generally absent in the primary vascular tissue of dicot root. Proto-phloem occupies toward the periphery whereas the meta-phloem towards the centre.

### Functions of vascular tissue:

1. Conduction of water and minerals (xylem)
2. Conduction of food materials (phloem)
3. Provide mechanical support

### Conjunctive tissue

1. Parenchymatous tissue present between xylem and phloem are called conjunctive tissue.
2. Also called as conjunctive tissue, connective tissue or complementary tissue.
3. Inter-fascicular cambium originates from the conjunctive tissue during secondary growth.

### Pith

1. Pith is usually absent in dicot root
2. If the pith is present, very small and centrally located with loosely packed parenchymatous cells.

## ***Anatomy of the Primary Structure of Dicot Stem***

The anatomy of dicot stem is studied by a T.S. taken through the internode of the stem. The components of cortex and stele are together known as Ground Tissue. Anatomically the dicot stem has the following regions:

1. **Epidermis**
2. **Cortex**
  - a). *Hypodermis*
  - b). *Outer cortex*
  - c). *Inner cortex*
  - d). *Endodermis*
3. **Stele**
  - a). *Pericycle*
  - b). *Vascular bundles*
  - c). *Medullary rays*
  - d). *Pith*

## Epidermis

Epidermis is the outermost layer, composed of parenchymatous cells.

1. Usually, epidermis composed of single layer of cells.
2. Cells are closely packed without any intercellular spaces.
3. The outer tangential wall of epidermal cells is thicker than other walls.
4. This wall area is deposited with fatty substances called cutin. The cutin over the cell wall occurs as separate layer called cuticle.
5. The epidermis of young stem also contains few stomata.
6. Multicellular hairs (called trichome) are usually present in the epidermis.
7. In herbaceous plants, where secondary growth is absent, the epidermis remains throughout the life cycle.
8. However, in woody plants, the epidermis is replaced after the secondary growth due to back formation.

### Functions of epidermis:

1. *Protection*
2. *Cuticle prevent water loss*
3. *Stomata in stem facilitate gaseous exchange.*
4. *Trichomes and hairs provide protection from fungal spores and insect pests.*

## Cortex

Cortex is the tissue occupied just inner to the epidermis. In some plants, the cortex is simple and undifferentiated. In majority of plants, the cortex is differentiated into many zones. Usually the cortex in dicot stem composed of FOUR zones.

- a. *Hypodermis*
- b. *Outer cortex*
- c. *Inner cortex*
- d. *Endodermis*

### (2). Cortex: (a). Hypodermis

1. Hypodermis is the layer of tissue just below the epidermis. Cells of hypodermis are collenchymatous and with thick primary wall.
2. Cells are compactly packed without any intercellular space. In very young stem, the collenchyma is poorly developed.
3. In stem with ridges and furrows, the collenchyma mainly occurs below the ridges. Usually, chloroplasts absent in the hypodermis. Rarely collenchymatous cells of hypodermis do contain chloroplasts.
4. In xerophytic plants, the hypodermis is sclerenchymatous.

### Functions of hypodermis:

1. Provide mechanical support.
2. In plants with secondary thickening, hypodermal cells give rise to cork cambium which produces the bark.

### (2). Cortex: (b). Outer cortex

1. Outer cortex consists of the tissue occupied just inner to the hypodermis.
2. Cells of this region are chlorenchymatous (parenchyma with chloroplasts). The green colour of young stem is due to his region.
3. The cells are loosely packed with plenty of intercellular spaces.  
In xerophytes, the outer cortical cells forms palisade like tissue for photosynthesis, since these plants usually lack leaves.

### **Function of outer cortex:**

*photosynthesis*

### **(2). Cortex: (c). Inner cortex**

This is the tissue inner to outer cortex. Composed of loosely packed parenchymatous cells. Function inner cortex: storage of carbohydrates.

### ***Special features of cortex in some plants:***

1. In hydrophytes, the cortex is with plenty of air cavities (aerenchymatous).
2. The Aerenchyma helps in gaseous exchange and provides buoyancy of to plants.
3. Sclerenchymatous patches occur in the cortex of *Eucalyptus*, *Eugenia*, *Ficus*.
4. Secretory cavities occur in the cortex of *Eucalyptus*.
5. Resin canals occur in the cortex of *Anacardium*. Laticifer cells occur in the cortex of latex producing plants.

### **Functions of cortex**

1. Hypodermal layer provides mechanical support.
2. During secondary growth, the hypodermal cells give rise to the cork cambium (phellogen) for the bark formation.
3. Chlorenchymatous cells in the outer cortex can do photosynthesis.
4. Parenchymatous cells of inner cortex can store carbohydrates.
5. Cortical cells also store ergastic substances.
6. Resin canals, latex canals etc. occurs in the cortex.

### **(2). Cortex (d). Endodermis**

1. Endodermis is the innermost layer of cortex. The endodermis is very distinct in lower plants such as Pteridophytes. NOT distinct in the stem of Gymnosperms and Angiosperms.
2. Cells of the endodermis accumulate plenty of starch as grains. Thus, the endodermis is also called starch sheath or starch band or starch layer.
3. If distinct, the endodermis is uniseriate (single layer) with barrel shaped cells. Cells paranchymatous and they compactly arranged.
4. Endodermal cells have characteristic thickness in radial and inner tangential walls.
5. This thickening is called casparian thickening (casparian band, casparian layer).
6. The casparian band is composed of suberin and lignin, both of them are impervious to water.
7. Due to the presence of casparian thickening, they block the passage of water and solutes through the protoplasts of endodermal cells.

### **Functions of endodermis**

1. The exact function of endodermis is not known.
2. They do not allow the passage of water from cortex to stele, thus may have specific role in the conduction of water.
3. They can store food material as starch grains.

### **(3). Stele**

Stele is the central vascular cylinder of the stem. The stele of stem composed of four components.

- a) Pericycle
- b) Vascular bundle
- c) Medullary rays
- d) Pith

### **(3). Stele: (a). Pericycle**

1. Pericycle is the outermost layer of the stele.
2. It is located next (just inner) to the endodermis.

3. The nature of pericycle in stem shows wide variation. Pericycle is absent in some plants. If present, it usually multilayered composed of 3 or more layers of cells.

The pericycle in the stem of different plants may be:

1. *Completely parenchymatous*
2. *Completely sclerenchymatous*
3. *Mixture of parenchyma and sclerenchyma (alternating bands)*
4. Sclerenchymatous pericycle forms the bundle sheath of the vascular bundle in most of the dicot plants.

### **(3). Stele: (b). Vascular bundle**

1. Vascular bundles (VB) are also called as fascicles.
2. They are located inner to the pericycle. VB are developed from the pro-cambium.
3. The number of vascular bundles is limited in dicot stem. Usually, 6 to 8 vascular bundles are present and they are arranged as broken ring in the ground tissue.
4. Vascular bundles of a typical dicot stem are:
  - i. Conjoint: (= xylem and phloem together as bundle)
  - ii. Open: (= vascular bundles with cambium)
  - iii. Collateral or Bicollateral
1. Collateral: the usual type of vascular bundle composed of once patch of xylem and one patch of phloem and a strip of cambium between them.
2. Biocollateral: a special type of vascular bundle composed of a median patch of xylem laying in-between two phloem patches.
3. Bicollateral VB is characteristic of Cucurbitaceae family (Example: *Cephalandra*, *Cucurbita*). The vascular bundles composed of (I) Xylem placed inner to cambium; and (II) Phloem placed outer to cambium

#### **(I). Xylem:**

1. Xylem is the water and minerals conducting tissue of vascular bundles.
2. It is a complex tissue, composed of tracheids, vessels, fibres and parenchyma.
3. Xylem in the VB is differentiated into:
  - o Protoxylem*
  - o Metaxylem*
4. *Protoxylem:*
  1. Protoxylem is the first formed part of xylem in the VB.
  2. It is arranged towards the centre of the stem.
  3. Protoxylem composed of very less amount of tracheary elements and large amount of parenchyma. Tracheary elements are with very narrow lumen.
  4. They show annular or spiral thickening in their secondary wall (primitive type).

#### *Metaxylem:*

1. Metaxylem is the xylem part formed after the protoxylem.
2. It is arranged towards the exterior of the stem.
3. They composed of more tracheary elements than protoxylem.
4. The cells of the tracheary elements are with large lumen than that of protoxylem.
5. They show reticulate or pitted thickening (advanced type).

#### **Functions of xylem:**

- i. *Conduction of water*
- ii. *Conduction of minerals*
- iii. *Provide mechanical support*
- iv. *Xylem parenchyma store food materials*

## **(II). Phloem:**

1. Phloem is the food conducting tissue of vascular bundles.
2. Similar to xylem, phloem is also a complex tissue composed of sieve tubes, companion cells, phloem parenchyma and phloem fibres.
3. The primary phloem is differentiated into:  
*Protophloem*: first formed phloem, arranged towards periphery.  
*Metaphloem*: differentiated after protophloem, located near to cambium

## **(III). Cambium**

1. Cambium is a layer of meristematic tissue present between xylem and phloem.
2. Cambium present in the VB is called as fascicular cambium or vascular cambium.
3. It is the remnant of original pro-cambium.
4. The cambial cells are parenchymatous and thin primary cell wall.
5. Cells with dense cytoplasm and prominent nucleus.
6. Secondary growth in dicots occurs due to the activity of cambium.
7. Vascular bundle with cambium is called 'open vascular bundle'.

## **(3). Stele: (c). Medullary Ray**

1. It is also called pith ray.
2. Medullary ray is a layer of tissue occurs between vascular bundles.
3. It is composed of loosely packed parenchymatous cells with plenty of intercellular spaces.
4. The cells of the medullary ray are radially elongated.
5. During secondary growth, cells of the medullary rays give rise to interfascicular cambium.
6. The fascicular and inter-fascicular cambium fuse together to form a complete ring of cambium and this produce secondary xylem and secondary phloem.

### **Functions of medullary ray**

Allow radial transport of water.

Provide inter-fascicular cambium during secondary growth.

## **(3). Stele: (d). Pith**

1. It is also called as medulla.
2. Pith is the exact central portion of the stem.
3. It is located towards the inner side of vascular bundles.
4. Usually, the pith composed of parenchymatous cells.
5. Parenchyma may be loosely arranged with many intercellular spaces.
6. Sometimes the parenchymatous cells undergo secondary wall thickening.
7. Cells of outer region of the pith are smaller whereas, those in the inner region larger.  
In some plants, the pith is replaced by a large air filled cavity called Pith Cavity

### **Function of pith:**

1. storage of food materials
2. Identification
3. reasons of Dicot

## ***Anatomy of the of Dicot Leaf***

Based on the manner of orientation to the main axis of plant and direction of sunlight, leaves in angiosperms can be divided into two types.

### Dorsiventral leaves

Dorsiventral leaves orient themselves at an angle to the main axis and perpendicular to the direction of sunlight. Most dicots have dorsi-ventral leaves that are net-veined, including most trees, bushes, garden plants and wildflowers.

### Isobilateral leaves

Isobilateral leaves orient themselves parallel to the main axis and parallel to the direction of sunlight. Most monocots possess parallel-veined isobilateral leaves, including grasses and grasslike plants, lilies, irises, amaryllises etc.

Most leaves have certain common features like a covering of an epidermal layer on each surface. The ground tissue that occurs between the two epidermal layers is called mesophyll. Vascular bundles, commonly known as veins, are embedded in the mesophyll. The structure and characteristics of each of these layers differ greatly for dorsiventral and isobilateral leaves.

### Anatomy of dorsiventral leaf of mango (*mangifera indica*)

The internal structure of the dorsiventral leaf shows these regions with following features:

Epidermis  
Mesophylls  
Vascular bundles  
anatomy of dorsiventral leaf mango

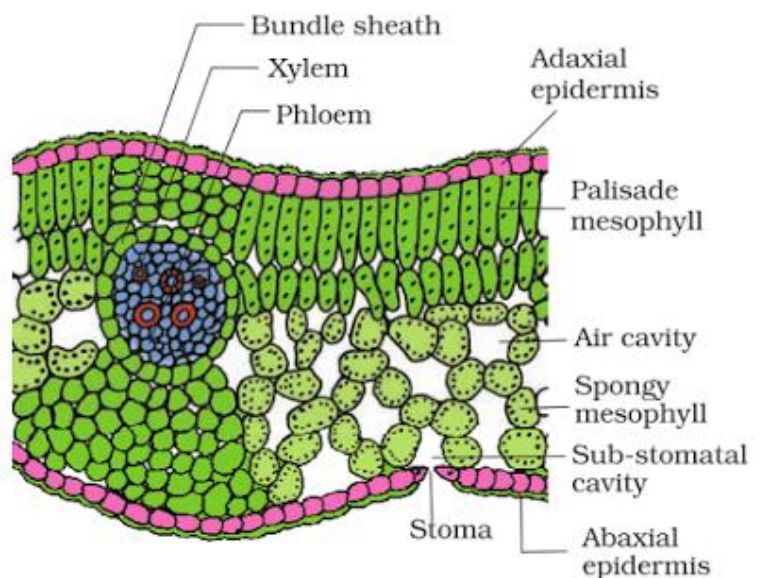
Fig - T.S. of dorsiventral leaf (mango leaf) showing its internal tissues organization

#### Epidermis

1. It is outermost covering of the leaf that forms the boundary between the atmosphere and underlying mesophyll.
2. It is present on both ventral or adaxial (upper epidermis) and dorsal or abaxial (lower epidermis) surface.
3. Both the upper and lower epidermis are covered by a cuticular layer. It consists of uniseriate, compactly arranged thin walled parenchymatous tissue without chloroplast (but present in upper epidermis).
4. Usually upper epidermis is thickly cuticularised. Lower epidermis contains numerous stomata without chloroplast; while upper epidermis contains high amount of chloroplast and no stomata, thus the leaf is hypostomatic (some exceptions exist).

#### Mesophyll

1. It is the ground tissue between the upper and lower epidermis. In dorsiventral leaf, it is differentiated into palisade parenchyma and spongy parenchyma.
2. Palisade parenchyma lies towards the upper epidermis and consists of one, two or three layers of elongated cells, densely packed with profuse intercellular spaces and chloroplasts.
3. Due to large intercellular spaces and chloroplast it helps in gaseous exchange and photosynthesis.



4. Spongy parenchyma lies towards the lower epidermis and made from loosely arranged, irregular, thin walled cells parenchymatous tissues with large intercellular spaces, air cavities and few chloroplasts, Hence, it helps in gaseous exchange in transpiration and photosynthesis.

### Vascular bundles

1. Numerous vascular bundles are scattered in spongy parenchyma. Each bundle is conjoint, collateral and closed.
2. Vascular bundle is surrounded by large parenchymatous bundle sheath or border parenchyma. Collenchyma may also be associated with bundle sheath cells. Xylem lies toward the upper epidermis and phloem toward lower epidermis.
3. Single mid-vein vascular bundle is larger and several smaller veinlet vascular bundles are smaller. Smaller vascular bundles are freely scattered in mesophyll cells of leaf.

### Xylem

1. It consists of vessels, tracheids, wood fibres and wood parenchyma (lies toward the upper epidermis).
2. The xylem tracheids and vessels help in conduction of water and minerals and mechanical supports while parenchyma helps in lateral transport.
3. At maturity, the protoxylem lies towards upper epidermis and metaxylem toward lower epidermis.

### Phloem

1. It consists of sieve tubes, companion cells and some cells of phloem parenchyma (lies towards lower epidermis).
2. The phloem companion cells and sieve tubes help in conduction of food materials and phloem parenchyma helps in lateral conduction and storage of food materials.

### Diagnostic Features of Dorsiventral Leaf

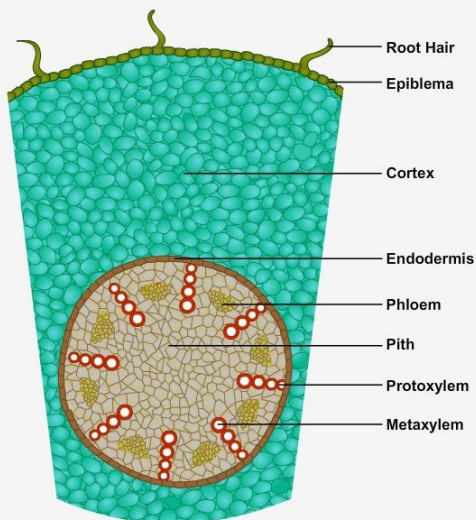
- Hypostomatic - stomata are present only on lower epidermis
- Differentiated Mesophyll - into upper palisade parenchyma and lower spongy parenchyma
- Hypodermal Collenchyma - between bundle sheath of midrib vein and the upper and lower epidermal layers
- Conjoint, collateral Vascular bundles - with endarch xylem
- Vessels and tracheids - in metaxylem and protoxylem

| Characters                  | Dicot leaf                                           | Monocot leaf                                            |
|-----------------------------|------------------------------------------------------|---------------------------------------------------------|
| 1. Nature of orientation    | Typically dorsi-ventral                              | Typically iso-bilateral                                 |
| 2. Stomata                  | Hypostomatic                                         | Amphistomatic                                           |
| 3. Motor cells              | Absent                                               | Present in the upper epidermis                          |
| 4. Mesophyll                | Differentiated into palisade and spongy parenchyma   | Undifferentiated                                        |
| 5. Veins                    | Irregularly scattered                                | Parallelly arranged                                     |
| 6. Xylem vessels            | Many protoxylem and metaxylem vessels in each bundle | Two protoxylem and two metaxylem vessels in each bundle |
| 7. Bundle sheath extensions | Made up of collenchyma                               | Made up of sclerenchyma                                 |

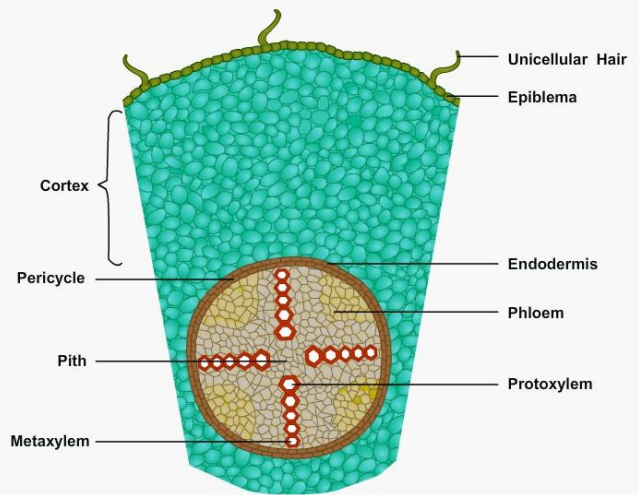
## Comparison of the Anatomy of Dicot and Monocot Roots

| Features                  | Dicot Root                                                  | Monocot Root                                                |
|---------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| Epiblema                  | Single layer of compactly arranged cells.                   | Single layer of compactly arranged cells.                   |
|                           | Bears thin walled root hairs.                               | Bears thin walled root hairs.                               |
| Ground tissue             | Differentiated into cortex, endodermis, pericycle and pith. | Differentiated into cortex, endodermis, pericycle and pith. |
| Vascular bundles          | 2-6 alternate bundles of xylem and phloem.                  | 8 or more alternate bundles of xylem and phloem.            |
| Nature of Vascular bundle | Xylem bundles are exarch.                                   | Xylem bundles are exarch.                                   |
|                           | Xylem vessels are polygonal.                                | Xylem vessels are oval.                                     |

**T.S of Monocot Root**

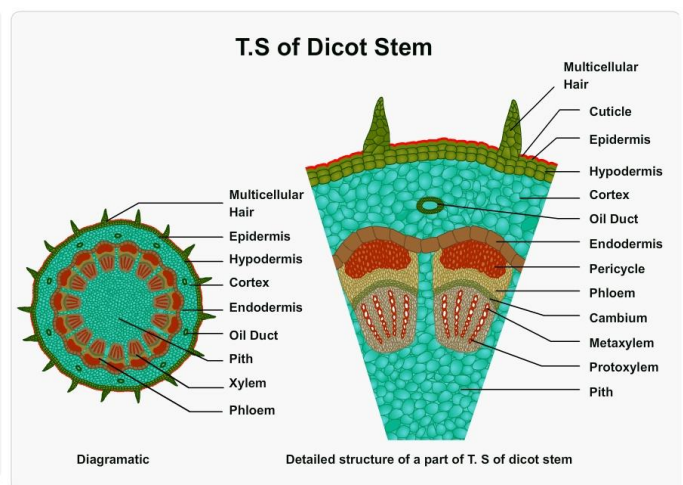
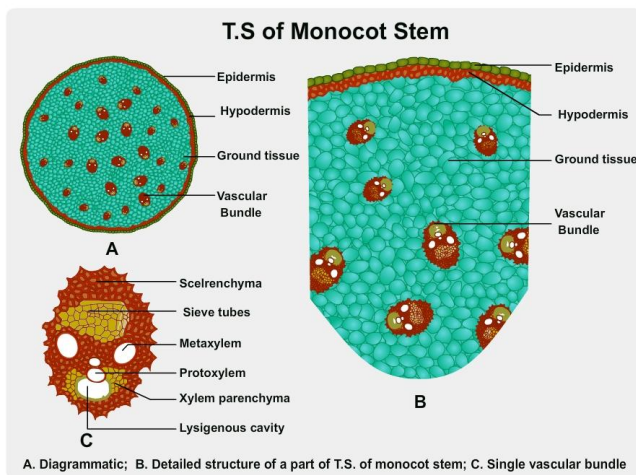


**T.S. of Dicot Root**

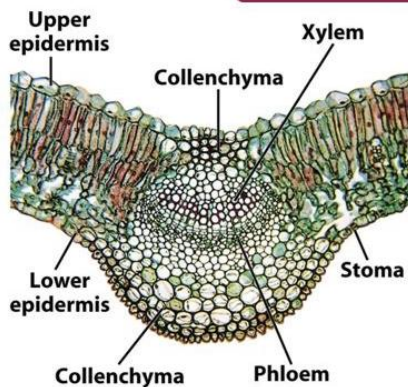


## Comparison of the Anatomy of Dicot and Monocot Stems

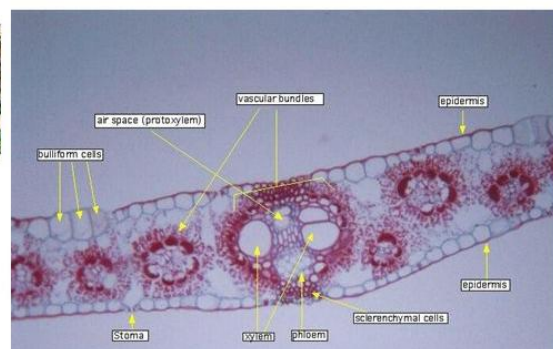
| Features                  | Dicot Stem                                                                  | Monocot Stem                                     |
|---------------------------|-----------------------------------------------------------------------------|--------------------------------------------------|
| Epidermis                 | Made up parenchyma cells.                                                   | Made up of parenchyma cells.                     |
|                           | Bears multicellular hair.                                                   | Usually absent.                                  |
|                           | Cuticle present.                                                            | Cuticle present.                                 |
| Hypodermis                | Made up of few layers of collenchyma cells.                                 | Made up of few layers of sclerenchymatous cells. |
| Ground tissue             | Differentiated into cortex, endodermis, pericycle, medullary rays and pith. | Undifferentiated.                                |
| Vascular bundles          | Wedge shaped.                                                               | Oval in shape.                                   |
|                           | Arranged in a ring.                                                         | Numerous and scattered.                          |
| Nature of Vascular bundle | Conjoint, collateral, open, endarch.                                        | Conjoint, collateral, closed, endarch.           |
|                           | Lysigenous cavity is absent.                                                | Lysigenous cavity is absent.                     |



### Monocot vs. Dicot leaf



Dicot Leaf



Monocot Leaf