Unit IV: Plant Anatomy (Structural Organisation)

Chapter 9

Tissue and Tissue System

Learning Objectives

The learner will be able to,

- *Study major types of plant cells and their function.*
- *Differentiate the various types of cells.*
- *Study the relationship between the distribution of tissues in the various parts of plants.*
- *Describes the ground tissue system [cortex and pith] and vascular systems*
- *Interpret cross sections and longitudinal sections of dicot and monocot root, stem and leaf.*
- *Compare the internal organization of dicot root and monocot root.*

Chapter Outline

CL3PMM

Nehemiah Grew
Father of Plant Anatomy

1641–1712

Katherine Esau (1898–1997)

A legendary Role model for women in science. She was a scintillating Botany teacher and pioneering researcher for six decades. Her classic book **Anatomy of Seed Plants** is the best literature in Plant Anatomy. In recognition of her distinguished service to science, she was awarded **National Medal of Science (1989) by USA.**

This chapter introduces the internal structure of higher Plants. The study of internal structure and organisation of plant is called plant Anatomy (*Gk: Ana = as under; temnein = to cut*). Plants have cells as the basic unit. The cells are organised into tissues. The tissues in turn are organised into organs. The different organs in a plant have different internal structures. It is studied by means of dissection and microscopic examination.

Milestones in Anatomy

- 1837 Hartig: Coined the term **Sieve tubes**
- 1839 Schleiden: Coined the term **Collenchyma**
- 1857 Hofmeister: Proposed **Apical cell theory**
- 1858 Nageli. C: Coined the term **Xylem and Phloem, Meristem and** supporter of **Apical cell theory**
- 1865 Mettenius: Coined the term **Sclerenchyma**
- 1868 Hanstein: Proposed **Histogen theory**
- 1885 Tschirch: Coined the term **Sclereids** Named Four types of **Sclereids** (Brachy, Macro, Osteo & Astro) in 1889
- 1914 Haberlandt: Coined the term xylem as **Hadrome** and Phloem as **Leptome and Classification of meristem.**
- 1924 Schmidt A: Proposed **Tunica – Corpus theory**
- 1926 Schűepp: **Mass, rib, & plate meristem**
- 1946 Bloch: Discovered the **Trichosclereids**
- 1952 Popham: Explained the organization of **Shoot apex of Angiosperms**
- 1955 Duchaigne: Discovered the **Annular collenchyma**
- 1961 Clowes: Proposed **Quiescent centre concept**
- 1963 Sanio: Coined the term **Tracheids**

The Tissues

A Tissue is a group of cells that are alike in origin, structure and function. The study of tissue is called Histology. A plant is made up of different types of tissues.

There are two principal groups:

1. Meristematic tissues
2. Permanent tissues

9.1 Meristematic Tissue

9.1.1 Characteristics and classification

The characters of meristematic tissues: (Gr. *Meristos*-**Divisible**)

The term meristem is coined by **C. Nageli** 1858.

- The meristematic cells are isodiametric and they may be, oval, spherical or polygonal in shape.
- They have generally dense cytoplasm with prominent nucleus.
- Generally the vacuoles in them are either small or absent.
- Their cell wall is thin, elastic and essentially made up of cellulose.
- These are most actively dividing cells.
- Meristematic cells are self-perpetuating.

Classification of Meristem

Meristem has been classified into several types on the basis of position, origin, function and division.

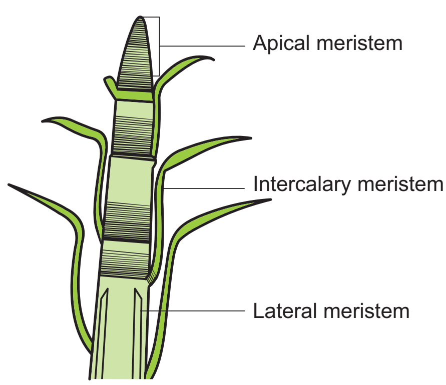


Figure 9.1: Different types of meristems on the basis of position in plant body

Classification of Meristem

Position	Origin	Function	Plane of division
Apical meristem Present in apices of root and shoot. It is responsible for increase in the length of the plant, it is called as primary growth.	**Primary Meristem** It is derived from embryonic stages and differentiated into primary permanent tissues.	**Protoderm** It gives rise to epidermal tissue system and develops into epidermis,stomata and hairs.	**Mass meristem** It divides in all planes. Example: endosperm,young embryo and sporangium
Intercalary meristem Occurs between the mature tissues. It is responsible for elongation of internodes.	**Secondary meristem** It is derived during later stage of development of the plant body. It produces cork cambium and interfascicular cambium.	**Procambium** It gives rise to primary vascular tissues. Example: xylem and phloem .	**Rib meristem or File meristem** It divides anticlinally in one plane. Example: development of cortex and pith
Lateral meristem Occurs along the longitudinal axis of stem and root. It is responsible for secondary tissues and thickening of stem and root. Example: vascular cambium and cork cambium.		**Ground Meristem** It gives rise to all tissues except epidermis and vascular strands.	**Plate meristem** It divides anticlinally in two planes. Example: development of epidermis

Theories of Meristem Organization and Function

Many anatomists illustrated the root and shoot apical meristems on the basis of number and arrangement and accordingly proposed the following theories – An extract of which are discussed below.

Shoot Apical Meristem

Apical Cell Theory

Apical cell theory is proposed by **Hofmeister** (1852) and supported by **Nageli** (1859). A single apical cell is the structural and functional unit.

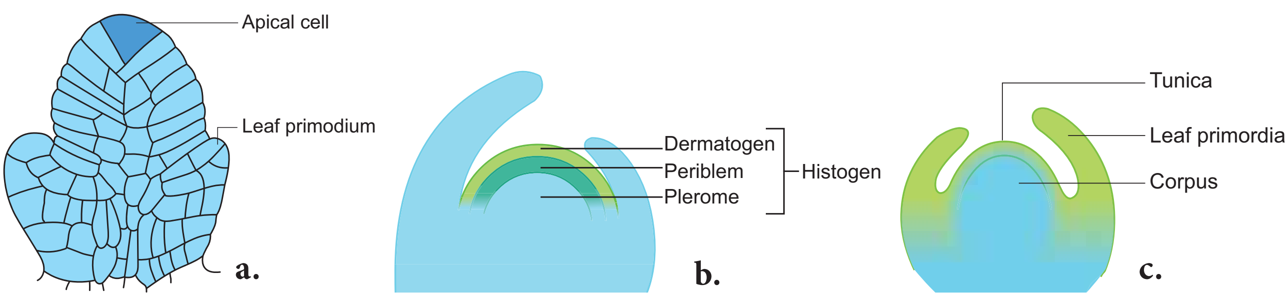


Figure 9.2: Shoot apical meristem a) Apical cell theory, b) Histogen theory, c) Shoot Tunica corpus theory

This apical cell governs the growth and development of whole plant body. It is applicable in Algae, Bryophytes and in some Pteridophytes.

Histogen Theory

Histogen theory is proposed by **Hanstein** (1868) and supported by **Strassburgur.** The shoot apex comprises three distinct zones.

1. **Dermatogen:** It is a outermost layer. It gives rise to epidermis.
2. **Periblem:** It is a middle layer. It gives rise to cortex.
3. **Plerome:** It is innermost layer. It gives rise to stele

Tunica Corpus Theory

Tunica corpus theory is proposed by **A. Schmidt** (1924).

Two zones of tissues are found in apical meristem.

1. **The tunica**: It is the peripheral zone of shoot apex, that forms epidermis.
2. **The corpus**: It is the inner zone of shoot apex,that forms cortex and stele of shoot.

Root Apical Meristem

Root apex is present opposite to the shoot apex. The roots contain root cap at their apices and the apical meristem is present below the root cap. The different theories proposed to explain root apical meristem organization is given below.

Apical Cell Theory

Apical cell theory is proposed by **Nageli.** The single apical cell or apical initial composes the root meristem. The apical initial is tetrahedral in shape and produces root cap from one side. The remaining three sides produce epidermis, cortex and vascular tissues. It is found in vascular cryptogams.

Histogen Theory

Histogen theory is proposed by **Hanstein (1868)** and supported by **Strassburgur**. The histogen theory as appilied to the root apical meristem speaks of four histogen in the meristem. They are respectively

i. **Dermatogen:** It is a outermost layer. It gives rise to root epidermis.

ii. **Periblem:** It is a middle layer. It gives rise to cortex.

iii. **Plerome:** It is innermost layer. It gives rise to stele

iv. **Calyptrogen:** It gives rise to root cap.

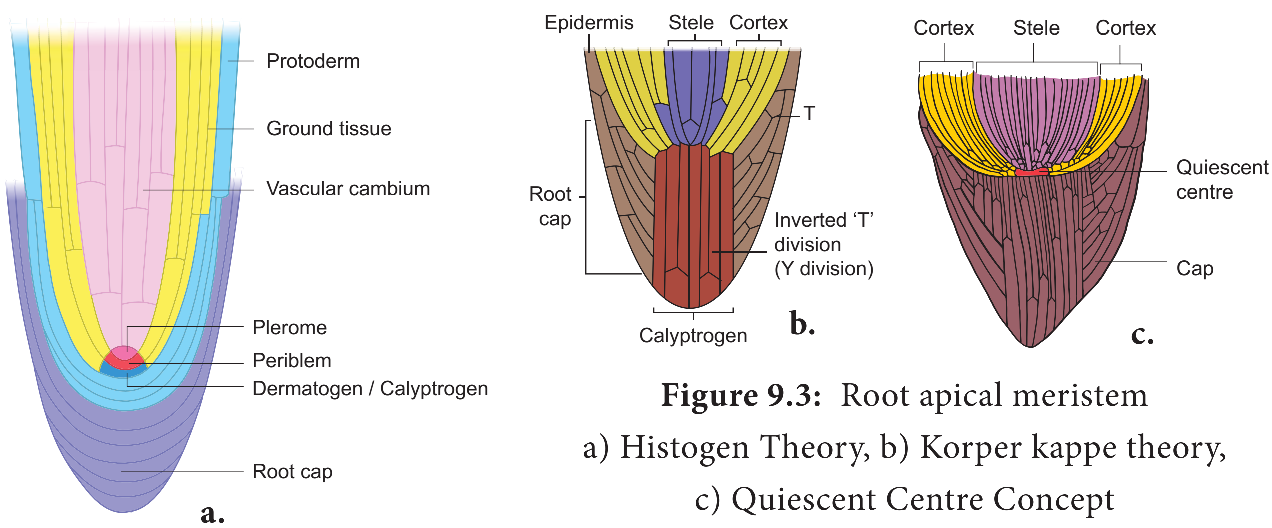


Figure 9.3: Root apical meristem

a) Histogen Theory, b) Korper kappe theory, c) Quiescent Centre Concept

Korper Kappe Theory

Korper kappe theory is proposed by **Schuepp**. There are two zones in root apex – Korper and Kappe

1. **Korper zone** forms the body.
2. **Kappe zone** forms the cap. This theory is equivalent to tunica corpus theory of shoot apex.The two divisions are distinguished by the type of T (also called Y divisions). Korper is characterised by inverted T divisions and kappe by straight T divisions.

Quiescent Centre Concept

Quiescent centre concept was proposed by **Clowes** (1961) to explain root apical meristem activity. These centre is located between root cap and differentiating cells of the roots. The apparently inactive region of cells in root promeristem is called quiescent centre. It is the site of hormone synthesis and also the ultimate source of all meristematic cells of the meristem.

9.2 Permanent Tissues

The Permanent tissues develop from apical meristem. They lose the power of cell division either permanently or temporarily. They are classified into two types:

1. Simple permanent tissues.
2. Complex permanent tissues.

Simple Permanent Tissues

Simple tissues are composed of one type of cells only. The cells are structurally and functionally similar. It is of three types.

1. Parenchyma
2. Collenchyma
3. Sclerenchyma

Parenchyma (Gk: *Para*-beside; *enehein*- to pour)

Parenchyma is generally present in all organs of the plant. It forms the ground tissue in a plant. Parenchyma is a living tissue and made up of thin walled cells. The cell wall is made up of cellulose. Parenchyma cells may be oval, polyhedral, cylindrical, irregular, elongated or armed. Parenchyma tissue normally has prominent intercellular spaces. Parenchyma may store various types of materials like, water, air, ergastic substances. It is usually colourless. The turgid parenchyma cells help in giving rigidity to the plant body. Partial conduction of water is also maintained through parenchymatous cells.

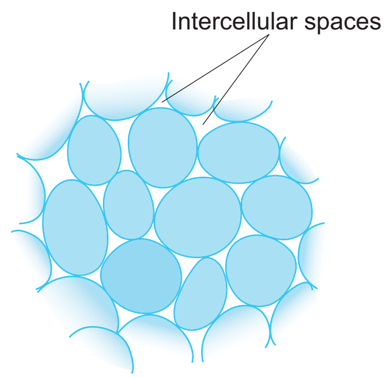


Figure 9.4: Parenchyma

Occsionally Parenchyma cells which store resin, tannins, crystals of calcium carbonate, calcium oxalate are called idioblasts. Parenchyma is of different types and some of them are discussed as follows.

Types of Parenchyma

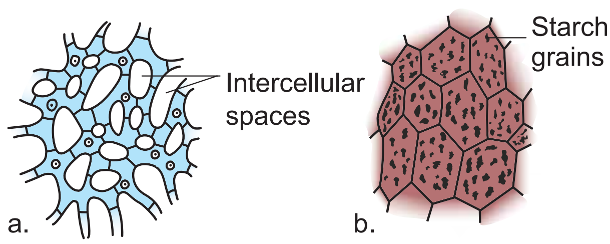


Figure 9.5: Types of Parenchyma

a) Aerenchyma, b) Storage parenchyma

1. Aerenchyma:
Parenchyma which contains air in its intercellular spaces. It helps in aeration and buoyancy. Example: *Nymphae and Hydrilla.*

Parenchyma

2. Storage Parenchyma:
Parenchyma stores food materials. Example: Root and stem tubers.

3. How?.... Stellate Parenchyma
Star shaped parenchyma. Example: Petioles of *Banana and Canna.*

4. Chlorenchyma
Parenchyma cells with chlorophyll. Function is photosynthesis. Example: Mesophyll of leaves.

5. Prosenchyma:
Parenchyma cells became elongated, pointed and slightly thick walled. It provides mechanical support.

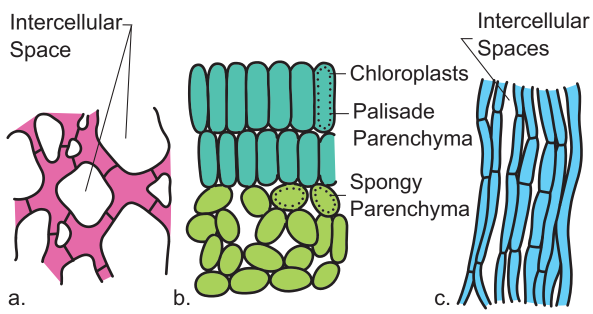


Figure 9.5: a) Stellate parenchyma, b) Chlorenchyma, c) Prosenchyma

Collenchyma (Gk. Colla-glue; enchyma – an infusion)

Collenchyma is a simple, living mechanical tissue. Collenchyma generally occurs in hypodermis of dicot stem. It is absent in the roots and also occurs in petioles and pedicels. The cells are elongated and appear polygonal in cross section. The cell wall is unevenly thickened. It contains more of hemicellulose and pectin besides cellulose. It provides mechanical support and elasticity to the growing parts of the plant. Collenchyma consists of narrow cells. It has only a few small chloroplast or none. Tannin maybe present in collenchyma.Based on pattern of pectinisation of the cell wall, there are three types of collenchyma

Types of Collenchyma

1. Angular collenchyma
It is the most common type of collenchyma with irregular arrangement and thickening at the angles where cells meets. Example:Hypodermis of *Datura* and *Nicotiana*

2. Lacunar collenchyma
The collenchyma cells are irregularly arranged. Cell wall is thickening on the walls bordering intercellular spaces. Example:Hypodermis of *Ipomoea*

3. Lamellar collenchyma
The collenchyma cells are arranged compactly in layers(rows). The Cell wall is thickening is at tangential walls.These thickening appear as successsive tangential layers. Example:Hypodermis of *Helianthus*

Diagramatic structures

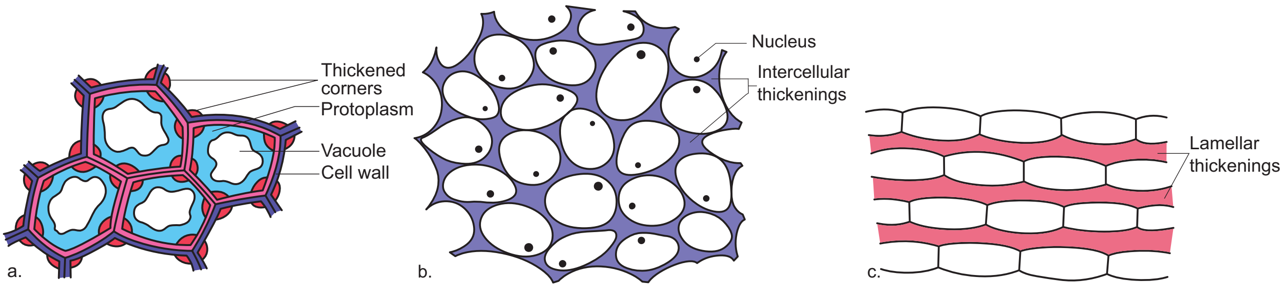


Figure 9.6: Types of Collenchyma a) Angular collenchyma, b) Lacunar collenchyma, c) Lamellar collenchyma

Annular Collenchyma: Duchaigne (1955) reported another type called Annular collenchyma in petiole of Nerium. The lumen is more or less circular in shape.

Sclerenchyma (Gk. Sclerous- hard: enchyma-an infusion)

The sclerenchyma is a dead cell and lacks protoplasm. The cells are long or short, narrow thick walled and lignified secondary walls. The cell walls of these cells are uniformly and strongly thickened. The sclerenchymatous cells are of two types:

1. Sclereids
2. Fibres

Sclereids (Stone Cells)

Sclereids are dead cells, usually these are isodiametric but some are elongated too. The cell wall is very thick due to lignification. Lumen is very much reduced. The pits may simple or branched. Sclereids are mechanical in function. They give hard texture to the seed coats, endosperms etc., Sclereids are classified into the following types.

Types of Sclereids

1. Branchysclereids or Stone cells:
Isodiametric sclereids, with hard cell wall. It is found in bark, pith cortex, hard endosperm and fleshy portion of some fruits. Example: - Pulp of *Pyrus*.

2. Macrosclereids:
Elongated and rod shaped cells, found in the outer seed coat of leguminous plants. Example: *Crotalaria and Pisum sativum*.

3. Osteosclereids (Bone cells):
Rod shaped with dilated ends. They occur in leaves and seed coats. Example: seed coat of *Pisum and Hakea*

4. Astrosclereids:
Star cells with lobes or arms diverging form a central body. They occur in petioles and leaves. Example: *Tea, Nymphae and Trochodendron*.

5. Trichosclereids:
Hair like thin walled sclereids. Numerous small angular crystals are embedded in the wall of these sclereids, present in stems and leaves of hydrophytes. Example: *Nymphaea leaf* and Aerial roots of *Monstera*.

Diagramatic Structures

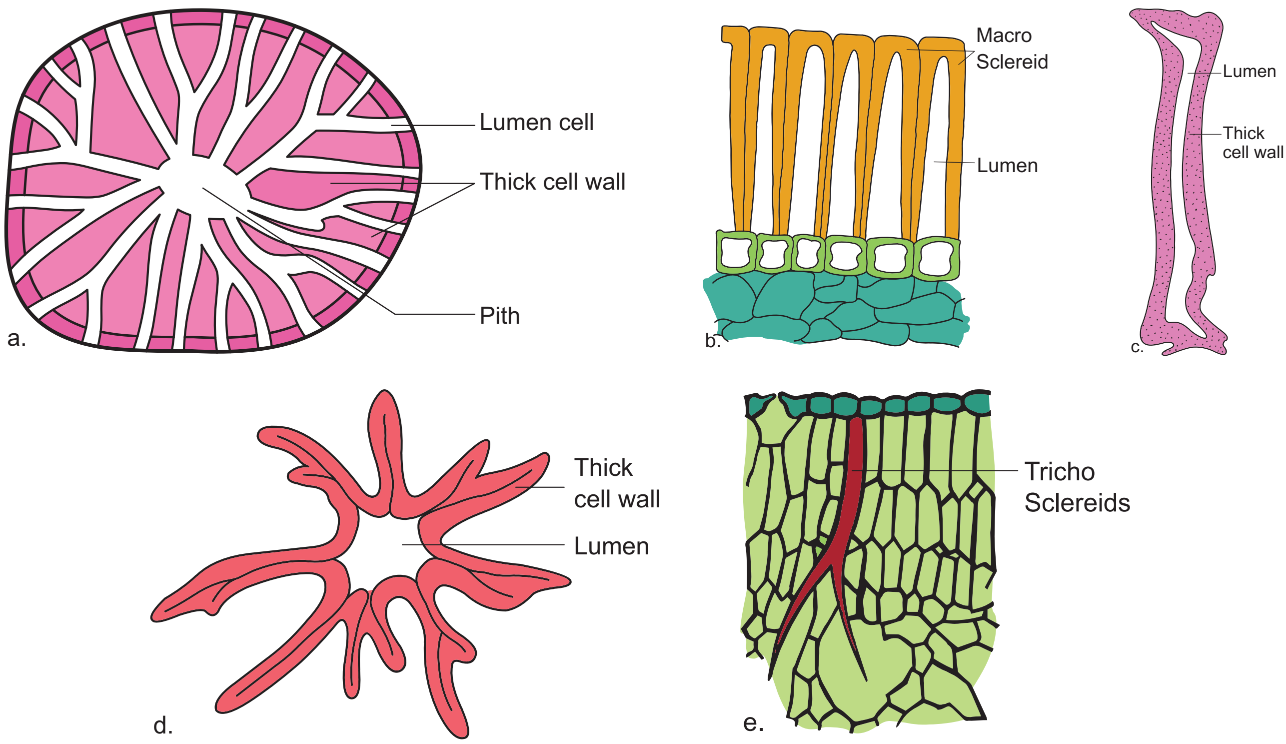


Figure 9.7: Types of Sclereids a) Brachysclereids, b) MacroSclereids, c) Osteosclereids, d) Astrosclereids, e) Trichosclereids

Filiform Sclereids: The sclereids are present in the leaf lamina of Olea europaea. They are very much elongated fibre like and about 1m.m length.

Sclerenchyma Found in Some Fruits

a. b. c.

Figure 9.8: a) Pear fruit, b) Strawberry, c) Guava

Fibres

Fibres are very much elongated sclerenchyma cells with pointed tips. Fibres are dead cells and have lignified walls with narrow lumen. They have simple pits. They provide mechanical strength and protect them from the strong wind. It is also called supporting tissues. Fibres have a great commercial value in cottage and textile industries.

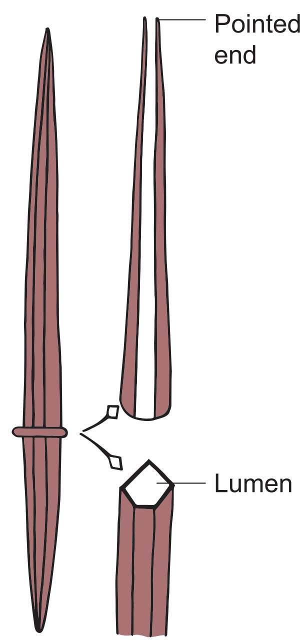


Figure 9.9 T.S of fibre

Fibres are of five types

Wood Fibres or Xylary Fibres

These fibres are associated with the secondary xylem tissue. They are also called xylary fibres. These fibres are derived from the vascular cambium. These are of four types. a. Libriform fibres

b. Fibre tracheids c. Septate fibres d. Gelatinous fibres.

DO YOU KNOW?

Fibres are the longest plant cells. Longest Fibres occur in *Boehmeria* (Ramie fibre) 55 cm long

a. **Libriform fibres:** These fibres have slightly lignified secondary walls with simple pits. These fibres are long and narrow.
b. **Fibre tracheids:** These are shorter than the libriform fibres with moderate secondary thickenings in the cell walls. Pits are simple or bordered.
c. **Septate fibres:** Fibres that have thin septa separating the lumen into distinct chambers. Eg. Teak
d. **Gelatinous fibres:** Fibres in which lignin is less in amount and cellulose is more in this cell walls.

These fibres are characteristic of tension wood which is formed in the underside of leaning stems and branches.

Bastfibres or Extra Xylary Fibres

These fibres are present in the phloem. Natural Bast fibres are strong and cellulosic. Fibres obtaining from the phloem or outer bark of jute, kenaf, flax and hemp plants. The so called pericyclic fibres are actually phloem fibres.

Surface Fibres

These fibres are produced from the surface of the plant organs. Cotton and silk cotton are the examples.They occur in the testa of seeds.

Mesocarp Fibres

Fibres obtained from the mesocarp of drupes like Coconut.

Leaf Fibres

Fibres obtained from the leaf of *Musa, Agave and Sensciveria.*

Fibres in Our Daily Life

Economically fibres may be grouped as follows

1. **Textile Fibres:** Fibres utilized for the manufacture of fabrics, netting and cordage etc.
   a. **Surface Fibres**: Example: Cotton.
   b. **Soft Fibres**: Example: Flax, Jute and Ramie
   c. **Hard fibres:** Example: Sisal, Coconut, Pineapple, Abaca *etc.*
2. **Brush fibre:** Fibres utilized for the manufacture of brushes and brooms.
3. **Rough weaving fibres:** Fibres utilized in making baskets, chairs, mats etc.
4. **Paper making fibres:** Wood fibres utilized for paper making.
5. **Filling fibres:** Fibres used for stuffing cushions, mattresses, pillows, furniture etc. Example: *Bombax* and Silk cotton.

Complex Tissues

A complex tissue is a tissue with several types of cells but all of them function together as a single unit. It is of two types – xylem and phloem.

CLCKPA

Xylem

The xylem is the principal water conducting tissue in a vascular plant. The term xylem was introduced by **Nageli**(1858) and is derived from the Gk. *Xylos* – wood. The xylem which is derived from Procambium is called **primary xylem** and the xylem which is derived from vascular cambium is called **secondary xylem**. Early formed primary xylem elements are called protoxylem, whereas the later formed primary xylem elements are called metaxylem.

Protoxylem lies towards the periphery and metaxylem that lies towards the centre is called **Exarch.** It is common in *roots.*

Protoxylem lies towards the centre and meta xylem towards the periphery this condition is called **Endarch**. It is seen in *stems.*

Protoxylem is located in the centre surrounded by the metaxylem is called **Centrarch**. In this type only one vascular strand is developed. Example: *Selaginella sp.*

Protoxylem is located in the centre surrounded by the metaxylem is called **Mesarch.**In this type several vascular strands are developed. Example: *Ophioglossum sp.*

Student Activity

Cell lab: students prepare the slide and identify the different types tissues.

Xylem Consists of Four Types of Cells

1. Tracheids
2. Vessels or Trachea
3. Xylem Parenchyma
4. Xylem Fibres

Xylem is called **hadrome phloem** is called **leptome.** These terms are coined by **haberlandt (1914)**

Tracheids

Tracheids are dead, lignified and elongated cells with tapering ends. Its lumen is broader than that of fibres. In cross section, the tracheids are polygonal.

There are different types of cell wall thickenings due to the deposition of secondary wall substances. They are annular (ring like), spiral (spring like), scalariform (ladder like) reticulate (net like) and pitted (uniformly thick except at pits). Tracheids are imperforated cells with bordered pits on their side walls. Only through this conduction takes place in Gymnosperms. They are arranged one above the other. Tracheids are chief water conducting elements in Gymnosperms and Pteridophytes. They also offer mechanical support to the plants.

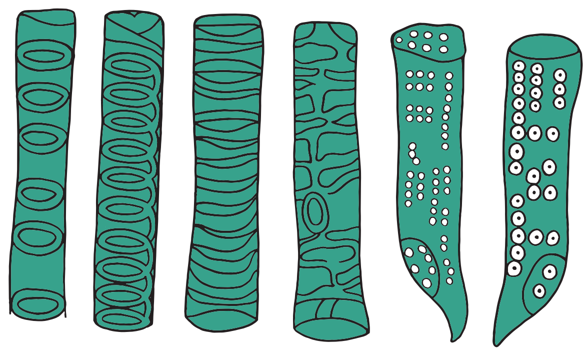


Figure 9.10: Types of secondary wall thickenings in tracheids and vessels

Vessels or Trachea

Vessels are elongated tube like structure. They are dead cells formed from a row of vessel elements placed end to end. They are perforated at the end walls. Their lumen is wider than Tracheids. Due to the dissolution of entire cell wall, a single pore is formed at the perforation plate. It is called **simple perforation plate**, Example: *Mangifera*. If the perforation plate has many pores, it is called **multiple perforation plate**. Example *Liriodendron*.

The secondary wall thickening of vessels are annular, spiral, scalariform, reticulate, or pitted as in tracheids, Vessels are chief water conducting elements in Angiosperms and absent in Pteridophytes and Gymnosperms. In *Gnetum* of Gymnosperm, vessels occur. The main function is conduction of water, minerals and also offers mechanical strength.

Xylem Fibre

The fibres of sclerenchyma associated with the xylem are known as xylem fibres. Xylem fibres are dead cells and have lignified walls with narrow lumen. They cannot conduct water but being stronger provide mechanical strength. They are present in both primary and secondary xylem. Xylem fibres are also called libriform fibres.

The fibres are abundantly found in many plants. They occur in patches, in continuous bands and sometimes singly among other cells. Between fibres and normal tracheids, there are many transitional forms which are neither typical fibres nor typical tracheids. The transitional types are designated as **fibre-tracheids**. The pits of fibre-tracheids are smaller than those of vessels and typical tracheids.

DO YOU KNOW?

Vessels are found in Gymnosperms like *Ephedra*, *Gnetum* and *Welwitschia*

Vesselless angiospermic families *Winteraceae*, *Tetracentraceae* and *Trochodendracae*.

Xylem Parernchyma

The parenchyma cells associated with the xylem are known as xylem parenchyma. These are the only living cells in xylem tissue. The cell wall is thin and made up of cellulose. Parenchyma arranged longitudinally along the long axis is called **axial parenchyma**. Ray parenchyma is arranged in radial rows. Secondary xylem consists of both axial and ray parenchyma, Parenchyma stores food materials and also helps in conduction of water.

Phloem

Phloem is the food conducting complex tissues of vascular plants. The term phloem was coined by **C. Nageli** (1858) The Phloem which is derived from procambium is called primary phloem and the phloem which is derived from vascular cambium is called secondary phloem. Early formed primary phloem elements are called **protophloem** whereas the later formed primary phloem elements are called **metaphloem**. Protophloem is short lived. It gets crushed by the developing metaphloem.

Phloem Consists of Four Types of Cells

1. Sieve elements
2. Companion cells
3. Phloem parenchyma
4. Phloem fibres

Sieve Elements

Sieve elements are the conducting elements of the phloem. They are of two types, namely sieve cells and sieve tubes.

Sieve Cells

These are primitive type of conducting

elements found in Pteridophytes and Gymnosperms. Sieve cells have sieve areas on their lateral walls only. They are not associated with companion cells.

Sieve Tubes

Sieve tubes are long tube like conducting elements in the phloem. These are formed from a series of cells called sieve tube elements. The sieve tube elements are arranged one above the other and form vertical sieve tube. The end wall contains a number of pores and it looks like a sieve. So it is called as sieve plate. The sieve elements show nacreous thickenings on their lateral walls. They may possess simple or compound sieve plates The function of sieve tubes are believed to be controlled by campanion cells.

In mature sieve tube, Nucleus is absent. It contains a lining layer of cytoplasm. A special protein (P. Protein = Phloem Protein) called slime body is seen in it. In mature sieve tubes, the pores in the sieve plate are blocked by a substance called **callose** (callose plug).The conduction of food material takes place through cytoplasmic strands. Sieve tubes occur only in Angiosperms.

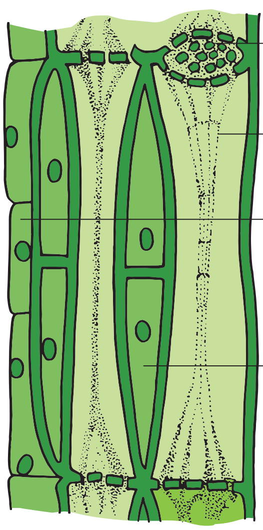


Figure 9.11: Different types of phloem elements

Companion Cells

The thin walled, elongated, specialized parenchyma cells, which are associated with the sieve elements, are called companion cells. These cells are living and they have cytoplasm and a prominent nucleus. They are connected to the sieve tubes through pits found in the lateral walls. Through these pits cytoplasmic connections are maintained between these elements. These cells are helpful in maintaining the pressure gradient in the sieve tubes. Usually the nuclei of the companion cells serve for the nuclei of sieve tubes as they lack them. The companion cells are present only in Angiosperms and absent in Gymnosperms and Pteridophytes. They assist the sieve tubes in the conduction of food materials.

Phloem Parenchyma

The parenchyma cells associated with the phloem are called phloem parenchyma. These are living cells. They store starch and fats. They also contain resins and tannins in some plants. Primary phloem consists of axial parenchyma and secondary phloem consists of both axial and ray parenchyma. They are present in Pteridophytes,Gymnosperms and Dicots.

Phloem Fibres (or) Bast Fibres

The fibres of sclerenchyma associated with phloem are called phloem fibres or bast fibres. They are narrow, vertically elongated cells with very thick walls and a small lumen. Among the four phloem elements, phloem fibres are the only dead tissue. These are the strengthening as well as supporting cells.

Concept Map

Plant tissues

Meristematic tissue:
Capable of active cell division.
Thin walled and living.
Compactly arranged.
Found in root and shoot apex.

Based on position:
1. Apical
2. Intercalary
3. Lateral

Based on origin:
1. Primary
2. Secondary

Based on function:
1. Periderm (Epidermis)
2. Procambium (Primary vascular tissues)
3. Ground meristem (Cortex and Pith)

Based on division:
1. Mass meristem: Divides in all planes
2. Rib meristem: Anticlinal division in one plane
3. Plate meristem: Anticlinal division in two planes.

Permanent tissues:
Lose the power of cell division.
Have definite shape, size and form.

Simple tissues:
One type of cells.

Parenchyma:
Thin walled,isodiametric, found in all the parts.
Types:
1. Aerenchyma.
2. Storage parenchyma.
3. Stellate parenchyma.
4. Chlorenchyma.
5. Prosenchyma.

Collenchyma:
Hypodermal position. Provide mechanical strength.
Types:
1. Angular collenchyma.
2. Lacunar collenchyma.
3. Lamellar collenchyma.

Sclerenchyma: Dead cells and lignified walls.
Types:
1. Sclereids
2. Fibres

Sclereids:
1. Brachysclereids: Stone cells
2. Macro sclereids: Rod shaped
3. Osteosclereids: Bone shaped
4. Astrosclereids: Star shaped
5. Trichosclereids: Hair cells

Fibres:
1. Wood fibres xylary fibres
2. Bastfibres: Extra xylary fibres
3. Surface fibres: *Cottan*
4. Mesocarp fibres: *Ccoconut*
5. Leaf fibres: *Musa, Agave*

Complex tissues:
More than one type of cells.

Xylem: Water conducting tissue.
1. Tracheids: Dead, elongated with tapering end
2. Vessels: Made of row of dead cells
3. Xylem fibres: Lignified and sclerenchymatous.
4. Xylem parenchyma: Living and cellulosic

Phloem: Food conducting tissue
1. Sieve elements: Sieve cells & sieve tubes
2. Companion cells: Only in Angiosperms.
3. Phloem parenchyma: Living & absent in Monocots.
4. Phloem fibres: Thick walled & sclerenchymatous, giving mechanical strength.

DO YOU KNOW?

Syncyte: Cell which is formed by fusion of cell is called Syncyte.

Example: Vessels (Dead syncyte), sieve tube (living syncyte)

Table 9.1: Different types of tissues					
	Distribution	**Main functions**	**Nature**	**Cell shape**	**Wall materials**
Parenchyma	Cortex, Pith medullary rays and Packing tissues in vascular system	Packing tissue, support, gaseous exchange, food storage	Living	Usually Isodiametric	Mainly Cellulose and Pectinase
Collenchyma	Outer region of cortex as in angles of stems, mid-rib of leaves	Mechanical	Living	Elongated, Polygonal	Mainly Cellulose, Pectin and Hemi-cellulose
Sclerenchyma (a) Fibre	Outer region of cortex, pericycle of stems, vascular bundles	Mechanical	Dead	Elongated and Polygonal with tapering ends	Mainly Lignin
(b) Sclereids	Cortex, Pith, Phloem shells and stones of fruits and seed coats	Mechanical Protection	Dead	Roughly Isodiametric with much variation	Mainly lignin
Tracheids and Vessels	Vascular System	Translocation of water and mineral salts	Dead	Elongated and Tubular	Mainly lignin
Phloem Sieve tubes	Vascular System	Translocation of organic solutes	Living	Elongated and Tubular	Cellulose, Pectin and Hemicellulose
Companion Cells	Vascular System	Work in association with sieve tubes	Living	Elongated and narrow	Cellulose, Pectin and Hemicellulose

Difference Between Meristematic Tissue and Permanent Tissue

Meristematic tissue	Permanent tissue
• Cells divide repeatedly	• Do not divide
• Cells are undifferentiated	• Cells are fully differentiated
• Cells are small and Isodiametric	• Cells are variable in shape and size
• Intercellular spaces are absent	• Intercellular spaces are present
• Vacuoles are absent	• Vacuoles are present
• Cell walls are thin	• Cell walls maybe thick or thin
• Inorganic inclusions are absent	• Inorganic inclusions are present

Difference Between Collenchyma and Sclerenchyma

Collenchyma	Sclerenchyma
• Living Cells • Contains Protoplasm • Cell walls are cellulosic • Thickening of cell wall is not uniform • Keeps the plant body soft • Sometimes it has chloroplast	• Dead cells • Cells are empty • Cell walls are lignified • Thickening of cell wall is uniform • Keeps plant body stiff and hard • Do not have chloroplast

Difference between Fibre and Sclereids

Fibre	Sclereids
• Long cells • Narrow, Elongated pointed ends • Occurs in bundles • Commonly unbranched • Derived directly from meristematic tissue	• Short cells • Usually short and broad • Occurs individually or in small groups • Maybe branched • Develops from secondary sclerosis parenchyma cells

Difference between Tracheids and Fibres

Tracheids	Fibres
• Not much elongated • Possess oblique end walls • Cell walls are not as thick as Fibres • Possess various types of thickenings • Responsible for the conduction and also mechanical support	• Very long cells • Possess tapering end walls • Cell wall are thick and lignified • Possess only pitted thickenings • Provide only mechanical support

Difference Between Sieve Cells and Sieve Tubes

Sieve cells	Sieve tubes
• Have no companion cells • The sieve areas do not form sieve plates • The sieve areas are not well differentiated • They are elongated cells and are quite long with tapering end walls • The sieve are smaller and numerous • Found in Pteridophytes and Gymnosperms	• Have companion cells • The sieve areas are confined to sieve plates • The sieve areas are well differentiated • They consist of vertical cells placed one above the other forming long tubes connected at the walls by sieve pores • The sieve pores are longer and fewer • Found in Angiosperms

9.3 The Tissue System

Introduction to Tissue System, Types and Characteristics of tissue System

As you have learnt, the plant cells are organised into tissues, in turn the tissues are organised into organs. Different organs in a plant show differences in their internal structure. This part of chapter deals with the different type of internal structure of various plant organs and its adaptations to diverse environments.

A group of tissues performing a similar function, irrespective of its position in the plant body, is called a ***tissue system***. In 1875, German Scientist ***Julius von Sachs*** recognized three tissue systems in the plants. They are:

Figure 9.12: Julius von Sachs

1. Epidermal tissue system (derived from protoderm)
2. Ground tissue system (derived from ground meristem)
3. Vascular tissue system (derived from procambium)

> DO YOU KNOW?
>
> **Histology**
>
> (Greek. histos – web, logos – science) It is the study of tissues, their composition, and structure as observed with the help of microscope.

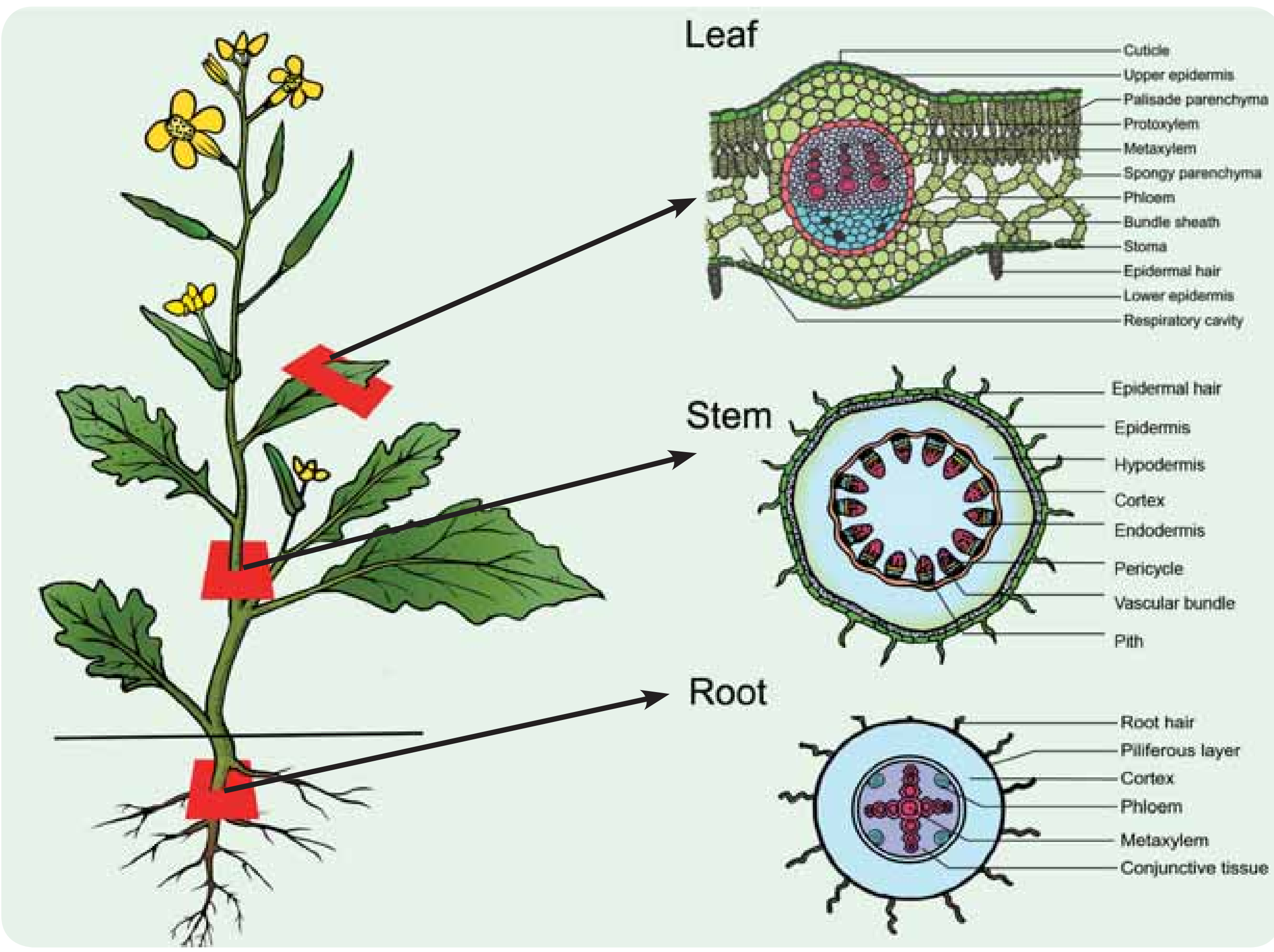


Figure 9.13: Tissue system

Table 9.2: Types and characteristics of tissue systems				
S.No.	**Types/ Characters**	**Epidermal tissue system**	**Ground or fundamental tissue system**	**Vascular or conduction tissue system**
1.	Formation	Forms the outermost covering protoderm	Forms the ground meristem	Forms the procambial bundles
2.	Components	epidermal cells, stomata and epidermal outgrowths	Simple permanent tissues – Parenchyma and Collenchyma	Xylem and Phloem
3.	Functions	Protection of plant body; absorption of water in roots; gas exchange for photosynthesis and respiration; transpiration in shoots	Gives mechanical support to the organs; prepares and stores food in leaf and stem	Conducts water and food; gives mechanical strength

9.4 Epidermal Tissue System

Introduction

Epidermal tissue system is the outer most covering of plants. It is in direct contact with external environment. It consists of epidermis derived from protoderm. Epidermis is derived from two Greek words, namely 'Epi' and 'Derma'. 'Epi' means *upon* and 'Derma' means *skin*. Although epidermis is a continuous outer layer, it is interrupted by stomata in many plants.

Root Epidermis

The outer layer of the root is known as ***piliferous layer* or *epiblema*.** It is made up of single layer of parenchyma cells which are arranged compactly without intercellular spaces. It is devoid of epidermal pores and cuticle. Root hair is always single celled, it absorbs water and mineral salts from the soil. The another important function of *piliferous layer* is *protection*.

Stem Epidermis

It is protective in function and forms the outermost layer of the stem. It is a single layer of parenchymatous rectangular cells. The cells are compactly arranged without intercellular cells. The outer walls of epidermal cells have a layer called *cuticle*. The cuticle checks *transpiration*. The cuticle is made up of *cutin*. In many plants it is also mixed wax to form epicuticular wax. Epidermal pores may be present here and there. Epidermal cells are living. Chloroplasts are usually absent except in guard cells of stomata. In many plants a large number of epidermal hairs occur on the epidermis.

Leaf Epidermis

The leaf is generally *dorsiventral*. It has upper and lower epidermis. The epidermis is usually made up of a single layer of cells that are closely packed. Generally the cuticle on the upper epidermis is thicker than that of lower epidermis. The minute openings found on the epidermis are called ***stomata (singular: stoma).*** Usually, stomata are more in number on the lower epidermis than on the upper epidermis. A stoma is surrounded by a pair of specialised epidermal cells called guard cells. In most dicots and monocots the guard cells are bean-shaped. While in grasses and sedges, the guard cells are dumbbell- shaped. The guard cells contain chloroplasts, whereas the other epidermal cells normally do not have them.

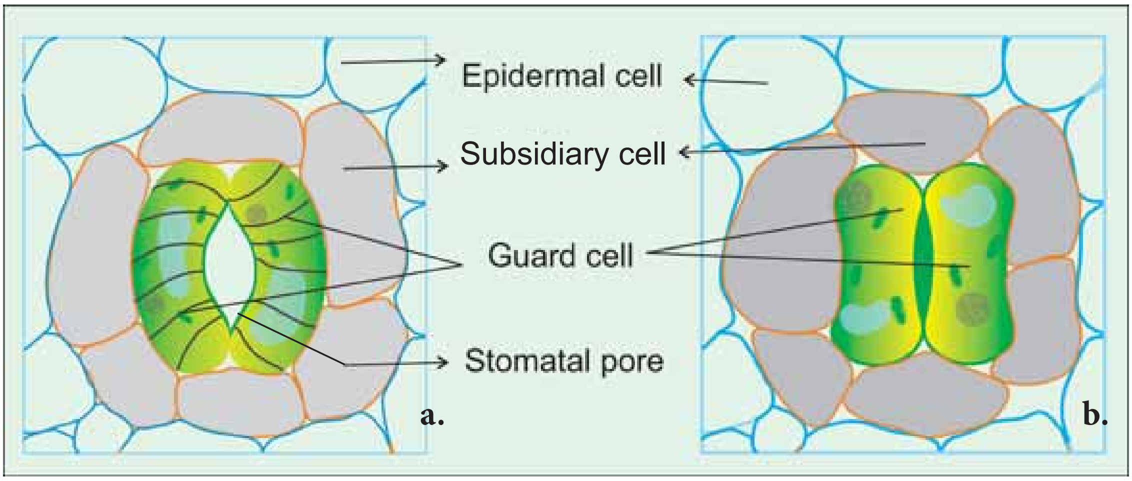


Figure 9.14: (a) Stoma with bean-shaped guard cells. (b) Stoma with dumb-bell shaped guard cells

Some cells of upper epidermis (Example: Grasses) are larger and thin walled. They are called **bulliform cells** or **motor cells**. These cells are helpful for the rolling and unrolling of the leaf according to the weather change. Some of the epidermal cells of the grasses are filled with silica. They are called **silica cells.**

Check Your Grasp!

In which group of plants the guard cells are dumb-bell shaped?

Grasses and sedges

Subsidiary Cells

Stomata are minute pores surrounded by two guard cells. The stomata occur mainly in the epidermis of leaves. In some plants addition to guard cells, specialised epidermal cells are present which are distinct from other epidermal cells. They are called **Subsidiary cells**. Based on the number and arrangement of subsidiary cells around the guard cells, the various types of stomata are recognised. The guard cells and subsidiary cells help in opening and closing of stomata during gaseous exchange and transpiration.

Sunken Stomata

In some Xerophytic plants (Examples: Cycas, Nerium), stomata is sunken beneath the abaxial leaf surface within stomatal crypts. The sunken stomata reduce water loss by transpiration.

Multilayered or Multiseriate Epidermis

Generally, epidermis is single layered, but in certain leaves, multilayered upper epidermis is present, Example: ***Ficus, Nerium, and Peperomea***.

In *Ficus* upper epidermal layer contains cystoliths made up of calcium carbonate crystals.

In *Nerium*, in the multilayered epidermis the outer layer alone is **cutinized.**

Epidermal Outgrowths

There are many types of epidermal outgrowths in stems. The unicellular or multicellular appendages that originate from the epidermal cells are called **trichomes**. Trichomes may be branched or unbranched and are one or more one celled thick. They assume many shapes and sizes. They may also be glandular (Example: *Rose, Ocimum*) or non-glandular.

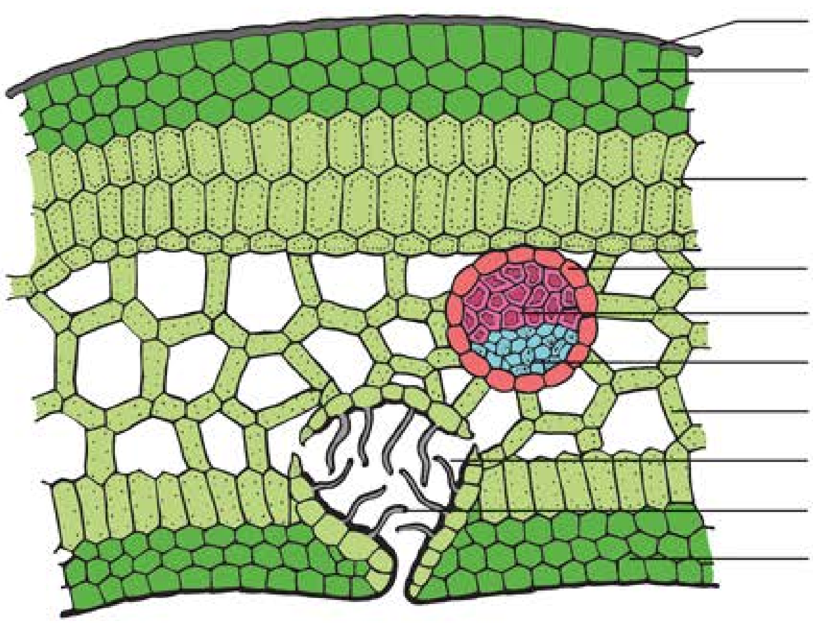


Figure 9.15: T.S. of *Nerium* Leaf

The trichomes on the leaves of insectivorous plants secrete muco-polysaccharides that trap insects.

Piliferous layer of the root has two types of epidermal cells, long cells and short cells. The short cells are called **trichoblasts**. Trichoblasts are elongate into root hairs. Epidermal hairs can also be in the form of stellate hairs (star shaped) present in plants. Example: styrax, many members of Malvaceae and Solanaceae.

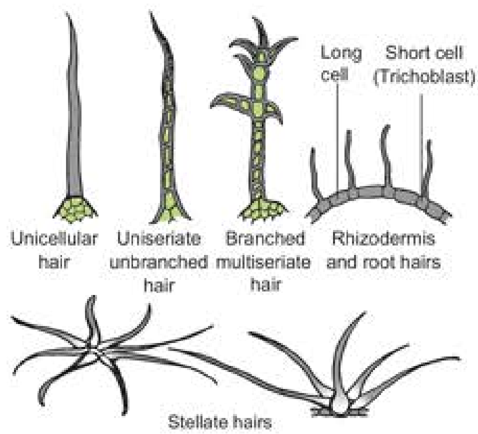


Figure 9.16: Types of Trichomes

Prickles

Prickles, are one type of epidermal emergences with no vascular supply. They are stiff and sharp in appearance. (Example: Rose).

Figure 9.17: Prickles

Functions of Epidermal Tissue System

1. This system in the shoot checks excessive loss of water due to the presence of cuticle.
2. Epidermis protects the underlying tissues.
3. Stomata is involved in transpiration and gaseous exchange.
4. Trichomes are also helpful in the dispersal of seeds and fruits, and provide protection against animals.
5. Prickles also provide protection against animals and they also check excessive transpiration
6. In some rose plants they also help in climbing.
7. Glandular hairs repel herbivorous animals.

9.5 Fundamental Tissue System

The ground or fundamental tissue system constitutes the main body of the plants. It includes all the tissues except epidermis and vascular tissues. In monocot stem, ground tissue system is a continuous mass of parenchymatous tissue in which vascular bundles are found scattered. Hence ground tissue is not differentiated into cortex, endodermis, pericycle and pith. Generally in dicot stem, ground tissue system is differentiated into three main zones – cortex, pericycle and pith. It is classified into extrastelar ground tissue (Examples: cortex and endodermis) and intrastelar ground tissue (Examples: pericycle, medullary ray and pith)

Extrastelar Ground Tissue

The ground tissues present outside the stele is called extrastelar ground tissue. (Cortex)

Intrastelar Ground Tissue

The ground tissues present within the stele are called intrastelar ground tissues. (pericycle, medullary rays and pith).

Different Components of Ground Tissue Systems are as follows

Hypodermis

One or two layers of continuous or discontinuous tissue present below the epidermis, is called hypodermis. It is protective in function.

In dicot stem, hypodermis is generally collenchymatous, whereas in monocot stem, it is generally sclerenchymatous. In many plants collenchyma form the hypodermis.

General Cortex

The Cortex occurs between the epidermis and pericycle. Cortex is a few to many layers in thickness, In most cases, it is made up of parenchymatous tissues. Intercellular spaces may or may not be present.

The cortical cells may contain non living inclusions of starch grains, oil, tannins and crystals.

Sometimes in young stem, chloroplasts develop in peripheral cortical cells, which is called **chlorenchyma.**

In the leaves, the ground tissue consists of chlorenchyma tissues. This region is called mesophyll. In hydrophytes, cortex is **Aerenchymatous** (with air cavities).

Its general function is storage of food as well as providing mechanical support to organs.

Endodermis

The cells of this layer are barrel shaped and arranged compactly without intercellular spaces.

Endodermis is the innermost cortical layer that separates cortex from the stele. This layer may be a true endodermis as in root or it is an endodermis like layer in stems. This layer is morphologically homologous to the endodermis found in the root.

The cells of endodermis like layer had living cells containing starch grains. Hence it is known as starch sheath. In true root endodermis, radial and inner tangential walls of endodermal cells possess thickenings of **lignin, suberin and some other carbohydrates** in the form of strips they are called **casparian strips**.

The endodermal cells, which are opposite to the protoxylem elements, are thin walled without casparian strips. These cells are called **passage cells**. Their function is to transport water and dissolved salts from the cortex to the protoxylem.

Water cannot pass through other endodermal cells due to casparian strips. The main function of casparian strips in the endodermal cells is to prevent the re-entry of water into the cortex once water entered the xylem tissue.

The other suberized cells acts as water-tight layer between vascular and non-vascular regions to check the loss of water.

Pericycle

Pericycle is single or few layered parenchymatous found inner to the endodermis. It is the outermost layer of the stele. Rarely thick walled sclerenchymatous. In angiosperms, pericycle gives rise to lateral roots.

Pith or Medulla

The central part of the ground tissue is known as pith or medulla. Generally this is made up of thin walled parenchyma cells with intercellular spaces. The cells in the pith generally stores starch, fatty substances, tannins, phenols, calcium oxalate crystals, etc.

Albuminous Cells: The cytoplasmic nucleated parenchyma, is associated with the sieve cells of Gymnosperms. Albuminous cells in *Conifers* are analogous to companion cells of Angiosperms. It also called as strasburger cells.

9.6 Vascular Tissue System

This section deals with the vascular tissue system of gymnosperms and angiosperms stems and roots.The vascular tissue system consists of xylem and phloem. The elements of xylem and phloem are always organized in groups. They are called **vascular bundles.**

The stems of both groups have an eustele while roots are protostele. In eustelic organization, the stele contains usually a ring of vascular bundles separated by interfascicular region or medullary ray

The structural and organizational variation in vascular bundles is shown below.

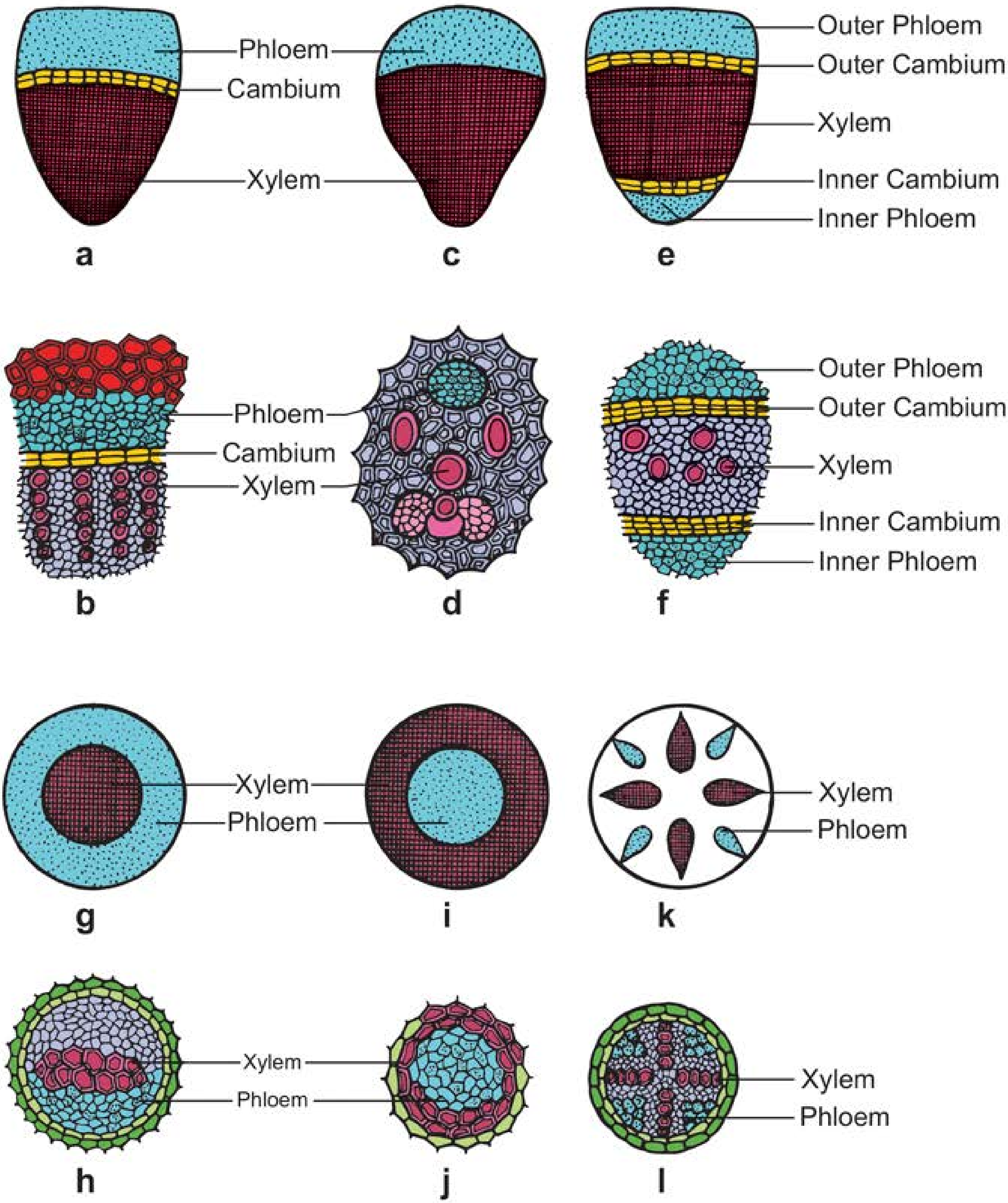


Figure 9.18: Types of vascular bundles

(a) and **(b)** - Conjoint, collateral and open; **(c)** and **(d)** - Conjoint, collateral and closed **(e)** and **(f)** - Conjoint, bicollateral and open; **(g)** and **(h)** - Concentric and amphicribral; **(i)** and **(j)** - Concentric and amphivasal; **(k)** and **(l)** - Radial

Types of vascular Bundles

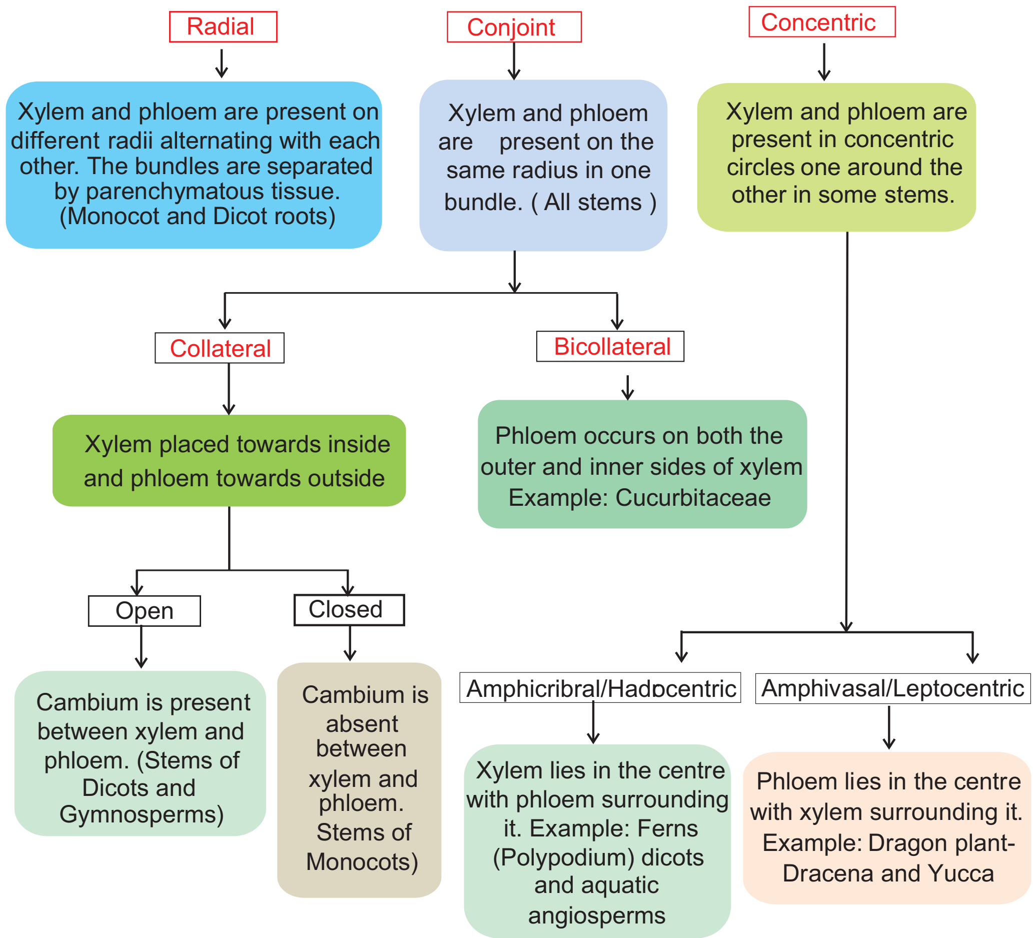


Table 9.3: Comparison of vascular tissues

Proto xylem	Meta xylem
• First formed primary xylem • Found in developing organs • Elements relatively smaller in size	• Later formed primary xylem • Found in developed primary organs • Elements relatively larger in size
Proto phloem	**Meta phloem**
• First formed primary phloem • Found in developing organs • Elements relatively smaller in size	• Later formed primary phloem • Found in developed primary organs • Elements relatively larger in size
Primary xylem	**Secondary xylem**
• The primary xylem is derived from the procambium of the apical meristem	• The secondary xylem is derived from the vascular cambium which is a lateral meristem
Primary phloem	**Secondary phloem**
• The primary phloem is derived from the procambium of the apical meristem	• The secondary phloem is derived from the vascular cambium, which is a lateral meristem

9.7 Comparison of Primary Structure – Dicot and Monocot Root, Stem and Leaf

Anatomy of Dicot and Monocot Roots

In different parts of the plants, the various tissues are distributed in characteristic patterns. This is best understood by studying their internal structure by cutting sections (transverse or longitudinal or both) of the part to be studied.

Primary Structure of Dicot Root – Bean Root

The transverse section of the dicot root (Bean) shows the following plan of arrangement of tissues from the periphery to the centre.

Piliferous Layer or Epiblema

The outermost layer of the root is called **piliferous layer or epiblema.** It is made up of single layer of parenchyma cells which are arranged compactly without intercellular spaces. It is devoid of epidermal pores and cuticle. It possesses root hairs which are single celled. It absorbs water and mineral salts from the soil. The chief function of piliferous layer is **protection.**

Cortex

Cortex consists of only parenchyma cells. These cells are loosely arranged with intercellular spaces to make gaseous exchange easier. These cells may store food reserves. The cells are oval or rounded in shape. Sometimes they are polygonal due to mutual pressure. Though chloroplasts are absent in the cortical cells, starch grain are stored in them. The cells also possess leucoplasts. The innermost layer of the cortex is endodermis. Endodermis is made up of single layer of barrel shaped parenchymatous cells. Stele is completely surrounded by endodermis. The radial and the inner tangential walls of endodermal cells are thickened with **suberin and lignin.** This thickening was first noted by **Robert Casparay** in 1965. So these thickenings are called **casparian strips.** But these casparian strips are absent in the endodermis cells which are located opposite the protoxylem elements. These thin-walled cells without casparian strips are called **passage cells** through which water and mineral salts are conducted from the cortex to the xylem elements. Water cannot pass through other endodermal cells due to the presence of casparian thickenings.

Check Your Grasp!

Give the exact location and function of passage cells?

In roots some cells of the endodermis usually the ones opposite to protoxylem, remain thin walled. These cells are called passage cells. They help in radial diffusion of water.

Stele

All the tissues present inside endodermis comprise the stele. It includes pericycle and vascular system.

Pericycle

Pericycle is generally a single layer of parenchymatous cells found inner to the endodermis. It is the outermost layer of the stele. Lateral roots originate from the pericycle. Thus, the lateral roots are endogenous in origin.

Vascular System

Vascular tissues are in **radial arrangement**. The tissue by which xylem and phloem are separated is called **conjunctive tissue**. In bean, the conjuctive tissue is composed of parenchyma tissue. Xylem is in **exarch condition**. The number of protoxylem points is four and so the xylem is called **tetrach**. Each phloem patch consists of sieve tubes, companion cells and phloem parenchyma. Metaxylem vessels are generally polygonal in shape. But in monocot roots they are circular.

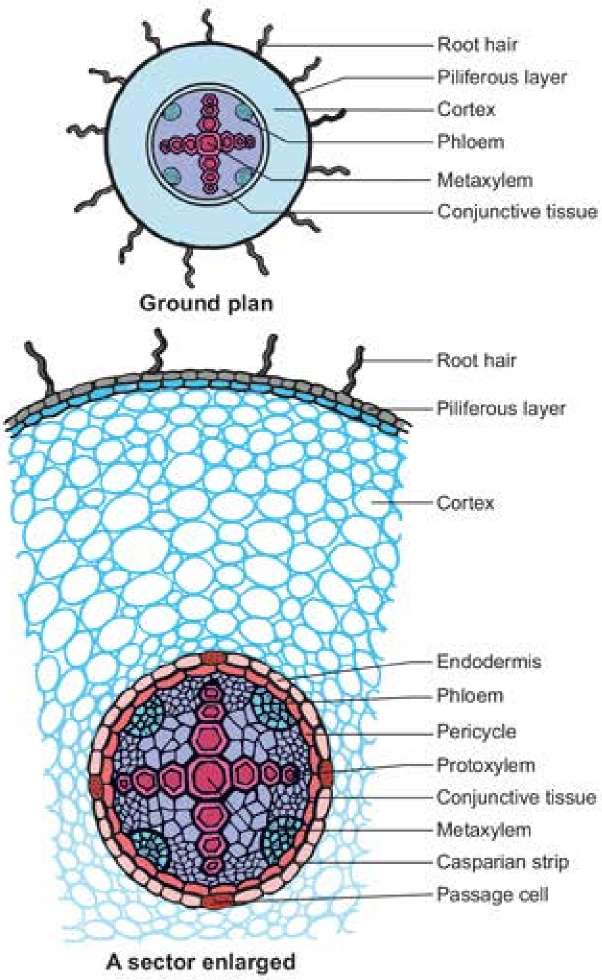


Figure 9.19: T.S. of Dicot root (Bean root)

Primary Structure of Monocot Root-maize Root

The transverse section of the monocot root (maize) shows the following plan of arrangement of tissues from the periphery to the centre.

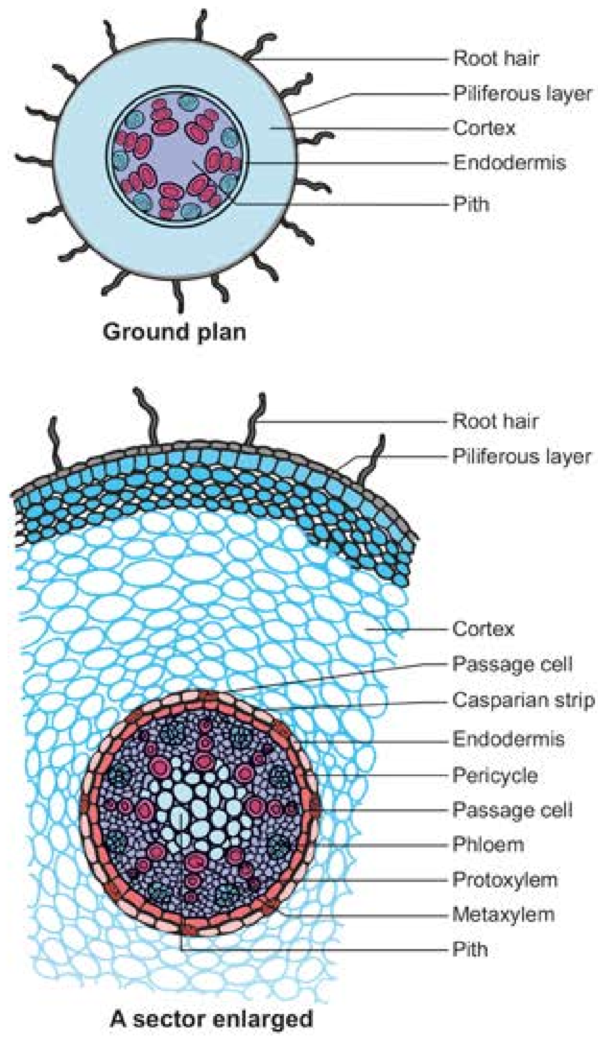


Figure 9.20: T.S of Monocot root (Maize root)

Piliferous Layer or Epiblema

The outermost layer of the root is known as **piliferous layer**. It consists of a single row of thin-walled parenchymatous cells without any intercellular space. Epidermal pores and cuticle are absent in the piliferous layer. Root hairs that are found in the piliferous layers are always unicellular. They absorb water and mineral salts from the soil. Root hairs are generally short lived. The main function of piliferous layer is protection of the inner tissues.

Cortex

The cortex is homogenous. i.e. the cortex is made up of only one type of tissue called parenchyma. It consists of many layers of thin-walled parenchyma cells with lot of intercellular spaces. The function of cortical cells is storage. Cortical cells are generally oval or rounded in shape. Chloroplasts are absent in the cortical cells, but they store starch. The cells are living and possess **leucoplasts.** The inner layer of the cortex is endodermis. It is composed of single layer of barrel shaped parenchymatous cells. This forms a complete ring around the stele. There is a band like structure made of **suberin** and **lignin** present in the radial and inner tangential walls of the endodermal cells. They are called **casparian strips** named after **casparay** who first noted the strips. The endodermal cells, which are opposite the protoxylem elements, are thin walled without casparian strips. These cells are called passage cells. Their function is to transport water and dissolved salts from the cortex to the xylem. Water cannot pass through other endodermal cells due to casparian strips. The main function of casparian strips in the endodermal cells is to prevent the re-entry of water into the cortex once water entered the xylem tissue.

Stele

All the tissues inside the endodermis comprise the stele. This includes pericycle, vascular system and pith.

Pericycle

Pericycle is the outermost layer of the stele and lies inner to the endodermis. It consists of single layer of parenchymatous cells.

Vascular System

Vascular tissues are seen in radial arrangement. The number of protoxylem groups is many. This arrangement of xylem is called polyarch. Xylem is in

Anatomical differences between dicot root and monocot root

S.No.	Characters	Dicot root	Monocot root
1.	Pericyle	Gives rise to lateral roots, phellogen and a part of vascular cambium.	Gives rise to lateral roots only.
2.	Vascular tissue	Usually limited number of xylem and phloem strips.	Usually more number of xylem and phloem strips,
3.	Conjunctive tissue	Parenchymatous; Its cells are differentiated into vascular cambium.	Mostly sclerenchymatous but sometimes parenchymatous. It is never differentiated in to vascular cambium.
4.	Cambium	It appears as a secondary meristem at the time of secondary growth.	It is altogether absent.
5.	xylem	Usually tetrach	Usually polyarch

exarch condition, the tissue which is present between the xylem and the phloem, is called conjunctive tissue. In maize, the conjunctive tissue is made up of sclerenchymatous tissue.

Pith

The central portion is occupied by a large pith. It consists of thin-walled parenchyma cells with intercellular spaces. These cells are filled with abundant starch grains.

Anatomy of Dicot and Monocot Stems

The transverse section of the dicot stem [sunflower] shows the following plan of arrangement of tissues from the periphery to the centre.

Epidermis

It is protective in function and forms the outermost layer of the stem. It is a single layer of parenchymatous rectangular cells. The cells are compactly arranged without intercellular spaces. The outer walls of epidermal cells have a layer called cuticle. The cuticle checks the transpiration. The cuticle is made up of waxy substance known as cutin. Stomata may be present here and there. Epidermal cells are living. Chloroplasts are usually absent. A large number of multicellular hairs occur on the epidermis.

Cortex

Cortex lies below the epidermis. The cortex is differentiated into three zones. Below the epidermis, there are few layers of collenchyma cells. This zone is called **hypodermis.** It gives mechanical strength of the Stem. These cells are living and thickened at the corners.

Inner to the hypodermis, a few layers of collenchyma cells are present. This zone is called hypodermis. It gives mechanical strength to the stem. These cells are living and thickened at the corners. Inner to the hypodermis, a few layers of chlorenchyma cells are present with conspicuous intercellular spaces. This region performs photosynthesis. Some resin ducts also occur here. The third zone is made up of parenchyma cells. These cells store food materials. The innermost layer of the cortex is called **endodermis**. The cells of this layer are barrel shaped and arrange compactly without intercellular spaces. Since starch grains are abundant in these cells, this layer is also known a **starch sheath**. This layer is morphologically homologous to the endodermis found in the root. In most of the dicot stems, endodermis with casparian strips is not developed.

Check Your Grasp!

Why the endodermis in dicot stem is also referred to as the starch sheath?

The cells of the endodermis are rich in starch grains and thus this layer is also referred to as the starch sheath.

Stele

The central part of the stem inner to the endodermis is known as **stele**. It consists of pericyle, vascular bundles and pith. In dicot stem, vascular bundles are arranged in a ring around the pith. This type of stele is called **eustele.**

Pericycle

Pericycle is the layers of cells that occur between the endodermis and vascular bundles. In the stem of **sunflower**

(Helianthus),a few layers of sclerenchyma cell occur in patches outside the phloem in each vascular bundle. This patch of sclerenchyma cell is called **Bundle cap or Hardbast**. The bundle caps and the parenchyma cells between them constitute the pericycle in the stem of sunflower.

Vascular Bundles

The vascular bundles consist of xylem, phloem and cambium. Xylem and phloem in the stem occur together and form the vascular bundles. These vascular bundles are **Wedge shaped**. They are arranged in the form of a ring. Each vascular bundle is **conjoint, collateral, open and endarch**.

Phloem

Primary phloem lies towards the periphery. It consists of **protophloem and metaphloem.** Phloem consists of sieve tubes, companion cells and phloem parenchyma. Phloem fibres are absent in the primary phloem. Phloem conducts organic food materials from the leaves to other parts of the plant body.

Cambium

Cambium consists of **brick shaped** and thin walled meristematic cells. It is one to four layers in thickness. These cells are capable of forming new cells during **secondary growth**.

Xylem

Xylem consists of xylem fibres, xylem parrenchyma vessels and tracheids. Vessels are thick walled and arranged in a few rows.

Xylem conducts water and minerals from the root to the other parts of the plant body.

Pith

The large central portion of the stem is called **pith**. It is composed of parenchyma cells with intercellular spaces. The pith is also known as **medulla**. The pith extends between the vascular bundles. These extensions of the pith between the vascular bundles are called primary pith rays or primary medullary rays. Function of the pith is **storage of food.**

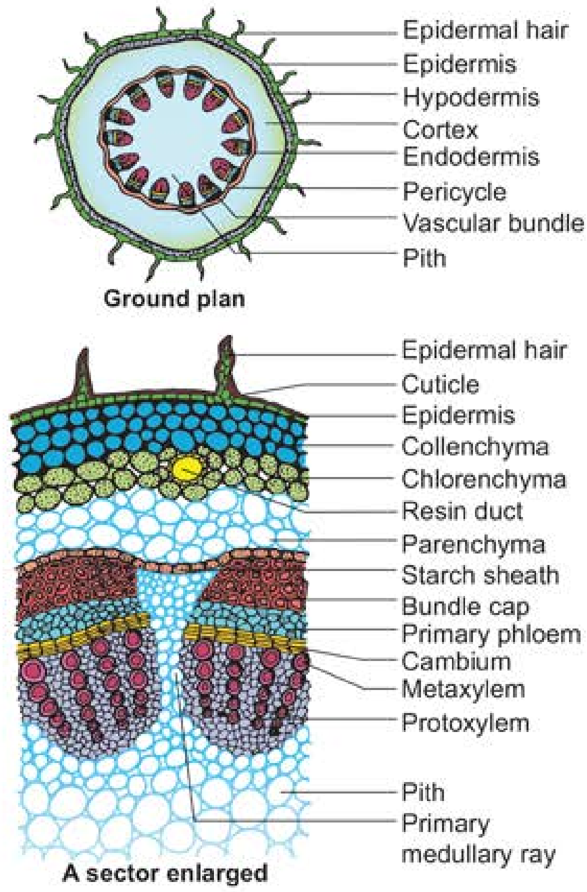


Figure 9.21: T. S of Dicot Stem (Sunflower stem)

Primary Structure of Monocot Stem-maize Stem

The outline of the maize in transverse section is more or less circular. The transverse section of the monocot stem [maize] shows the following plan of arrangement of tissues from the periphery to the centre.

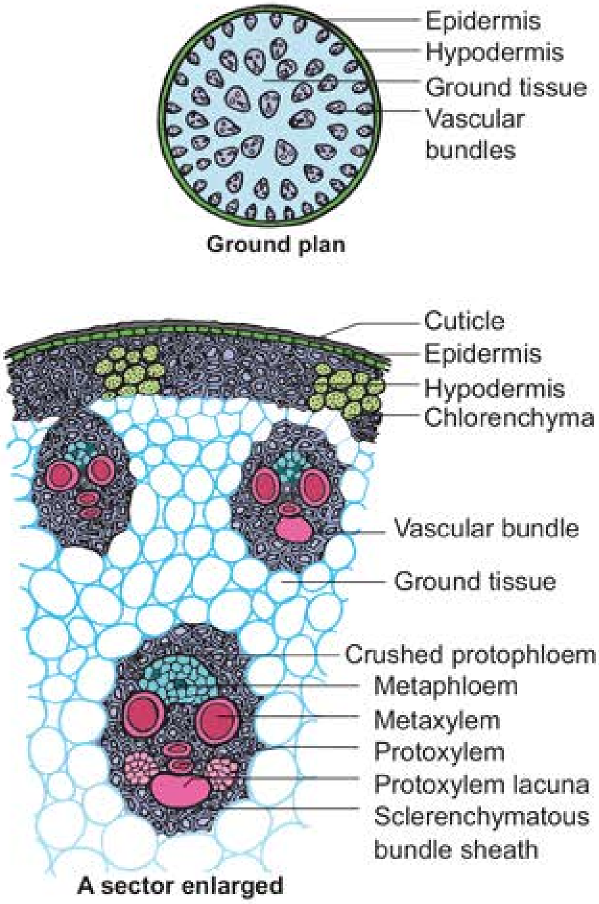


Figure 9.22: T.S. Monocot stem (Maize stem)

Epidermis

It is the outermost layer of the stem. It is made up of single layer of tightly packed parenchymatous cells. Their outer walls are covered with thick cuticle. The continuity of this layer may be broken here and there by the presence of a few stomata. There are no epidermal outgrowths.

Hypodermis

A few layer of sclerenchymatous cells lying below the epidermis constitute the hypodermis. This layer gives mechanical strength to the plant. It is interrupted here and there by chlorenchyma cells.

Ground Tissue

There is no distinction into cortex, endodermis, pericycle and pith. The entire mass of parenchyma cells lying inner to the hypodermis forms the ground tissue.

The cell wall is made up of **cellulose**. The cells contain reserve food material like **starch**. The cells of the ground tissue next to the hypodermis are smaller in size, polygonal in shape and compactly arranged.

Towards the centre, the cells are loosely arranged, rounded in shape and bigger in size. The vascular bundles lie embedded in this tissue. The ground tissue stores food and performs gaseous exchange.

Vascular Bundles

Vascular bundles are **scattered (atactostele)** in the parenchymatous ground tissue. Each vascular bundle is surrounded by a sheath of sclerenchymatous fibres called **bundle sheath**. The vascular bundles are **conjoint, collateral, endarch** and **closed**.Vascular bundles are numerous, small and closely arranged in the peripheral portion. Towards the centre, the bundles are comparatively large in size and loosely arranged. Vascular bundles are **skull or oval shaped.**

Phloem

The phloem in the monocot stem consists of sieve tubes and companion cells. Phloem parenchyma and phloem fibres are absent. It can be distinguished into an outer crushed protophloem and an inner metaphloem.

Xylem

Xylem vessels are arranged in the form of **'Y'** the two metaxylem vessels are located at the upper two arms and one or two protoxylem vessels at the base. In a mature bundle, the lowest protoxylem disintegrates and forms a cavity known as **protoxylem lacuna**.

Table 9.4: Anatomical differences between dicot stem and monocot stem

S.No.	Characters	Dicot Stem	Monocot Stem
1.	Hypodermis	Collenchymatous	Sclerenchymatous
2.	Ground tissue	Differentiated into cortex, endodermis and pericycle and pith	Not differentiated, but it is a continuous mass of parenchyma.
3.	Starch Sheath	Present	Absent
4.	Medullary rays	Present	Absent
5.	Vascular bundles	(a) Collateral and open	(a) Collateral and closed
		(b) Arranged in a ring	(b) Scattered in ground tissue
		(c) Secondary growth occurs	(c) Secondary growth usually does not occur.

Table 9.5: Anatomical differences between root and stem

S.No.	Characters	Root	Stem
1.	Epidermis	Absence of cuticle and epidermal pores.	Presence of cuticle and epidermal pores.
		Presence of unicellular root hairs.	Presence of unicellular and multicellular trichomes
2.	Outer Cortical cells	Chlorenchyma absent	Chlorenchyma present
3.	Endodermis	Well defined	ill-defined or absent.
4.	Vascular bundles	Radial arrangement	Conjoint arrangement
5.	Xylem	Exarch	Endarch

Anatomy of a Dicot and Monocot Leaves

Leaves are very important vegetative organs. They are mainly concerned with **photosynthesis and transpiration**. Like stem and roots, leaves also have the three tissue system – dermal, ground and vascular. The dermal tissue system consists of an upper and lower epidermis. The ground tissue system that lies between the epidermal layers of leaf is known as **mesophyll tissue**. Often it is differentiated into **palisade parenchyma** on the adaxial (upper) side and **spongy parenchyma** on the abaxial (lower) side.

In dorsiventral leaves the mesophyll is differentiated into palisade and spongy parenchyma, the former occurring on the upper side and the later on the lower side Example: Sunflower. In isobilateral leaf palisade is present on both sides of the leaf and inbetween them spongy parenchyma is present. Example: Nerium. In some plants Example: Ficus calcium crystals are present. There are also leaves where spongy tissue alone is present in some epidermal cells Example: Grasses.

The presence of air spaces is a special feature of spongy cells. They facilitate the gaseous exchange between the internal photosynthetic tissue (mesophyll) and the external atmosphere through the stomata.

The vascular tissue system is composed of vascular bundles. They are **collateral** and **closed.** The vascular tissues forms the skeleton of the leaf and are known as **veins.** The veins supply water and minerals to the photosynthetic tissue. Thus the morphological and anatomical features of the leaf help in its physiological functions.

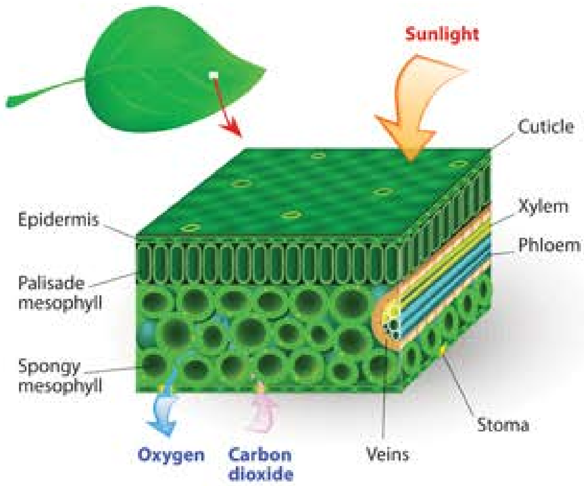


Figure 9.23: Anatomy of Leaf

Anatomy of a Dicot Leaf-sunflower Leaf

Internal structure of dictoyledonous leaves reveal epidermis, Mesophyll and vascular tissues.

Epidermis

This leaf is generally **dorsiventral.** It has upper and lower epidermis. The epidermis is usually made up of a single layer of cells that are closely packed. The cuticle on the upper epidermis is thicker than that of lower epidermis. The minute openings found on the epidermis are called **stomata**. Stomata are more in number on the lower epidermis than on the upper epidermis. A stomata is surrounded by a pair of **bean shaped** cells called guard cells.

Each stoma internally opens into an air chamber. These guard cells contain chloroplasts, whereas other epidermal cells do not contain chloroplasts. The main function of the epidermis is to give protection to the inner tissue called **mesosphyll**. The cuticle helps to check transpiration. Stomata are used for transpiration and gas exchange.

Mesophyll

The entire tissue between the upper and lower epidermis is called the **mesophyll (GK meso = in the middle, phyllome = leaf).** There are two regions in the mesophyll. They are **palisade parenchyma and spongy parenchyma.** Palisade parenchyma cells are seen beneath the upper epidermis. It consists of vertically elongated cylindrical cells in one or more layers. These cells are compactly arranged and are generally without intercellular spaces. Palisade parenchyma cells contain more chloroplasts than the spongy parenchyma cells. The function of palisade parenchyma is **photosynthesis.** Spongy parenchyma lies below the palisade parenchyma. Spongy cells are irregularly shaped. These cells are very loosely arranged with numerous airspaces. As compared to palisade cells, the spongy cells contain lesser number of chloroplasts. Spongy cells facilitate the **exchange of gases** with the help of air spaces. The air space that is found next to the stomata is called **respiratory cavity or substomatal cavity**.

Vascular Tissues

Vascular tissues are present in the veins of leaf. Vascular bundles are **conjoint,**

Collateral and closed. Xylem is present towards the upper epidermis, while the phloem towards the lower epidermis. Vascular bundles are surrounded by a compact layer of parenchymatous cells called **bundle sheath or border parenchyma**.

Xylem consists of metaxylem and protoxylem elements. Protoxylem is present towards the upper epidermis,while the phloem consists of sieve tubes, companion cells and phloem parenchyma. Phloem fibres are absent. Xylem consists of vessels and xylem parenchyma. Tracheids and xylem fibres are absent.

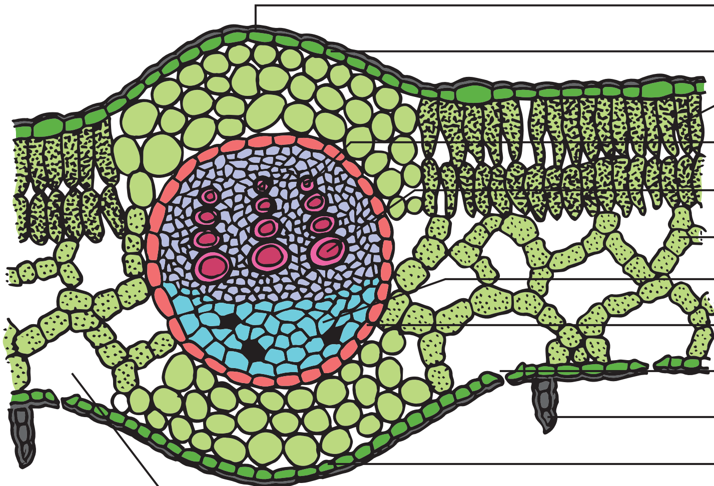


Figure 9.24: T.S. of Dicot Leaf (Sunflower)

Anatomy of a Monocot Leaf – Grass Leaf

A transverse section of a grass leaf reveals the following internal structures.

Epidermis

The leaf has upper and lower epidermis. They are made up of a single layer of thin walled cells. The outer walls are covered by thick cuticle.

The number of stomata is more or less equal on both the epidermis. The stomata is surrounded by **dumb – bell shaped** guard cells. The guard cells-contain chloroplasts, whereas the other epidermal cells do not have them.

Some special cells surround the guard cells. They are distinct from other epidermal cells. These cells are called **subsidiary cells.**

Some cells of upper epidermis are large and thin walled. They are called **bulliform cells** or motor cells. These cells are helpful for the rolling and unrolling of the leaf according to the weather change.

Some of the epidermal cells of the grass are filled with silica. They are called **silica cells**.

Mesophyll

The ground tissue that is present between the upper and lower epidermis of the leaf is called **mesophyll.** Here, the mesophyll is not differentiated into **palisade and spongy parenchyma.** All the mesophyll cells are nearly isodiametric and thin walled. These cells are compactly arranged with limited intercellular spaces. They contain numerous chloroplasts.

Vascular Bundles

Vascular bundles differ in size. Most of the vascular bundles are smaller in size. Large bundles occur at regular intervals.Two patches of sclerenchyma are present above and below the large vascular bundles. These sclerenchyma patches give mechanical support to the leaf. The small vascular bundles do not have such sclerenchymatous patches. Vascular bundles are **conjoint, collateral and closed**. Each vascular bundle is surrounded by a parenchymatous bundle sheath. The cells of the bundle sheath generally contain starch grains. The xylem of the vascular bundle is located towards the upper epidermis and the phloem towards the lower epidermis.In C_4 grasses, the bundle sheath cells are living and involve in C_4 photosynthesis. This sheath is called **Kranz sheath**.

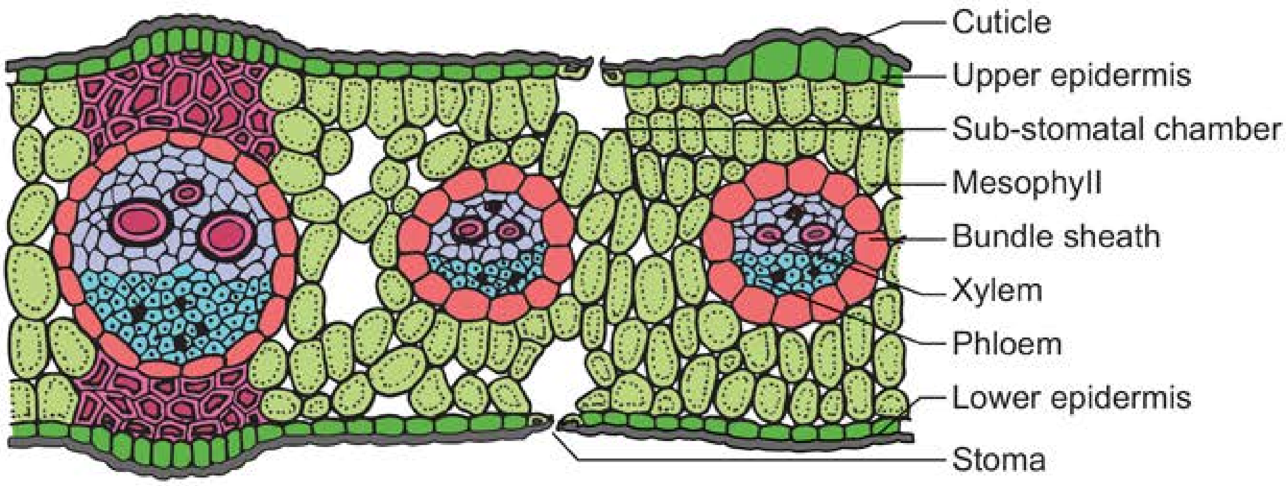


Figure 9.25: T.S. of monocot leaf (Grass)

Water Stomata (or) Hydathodes

A **hydathode** is a type of epidermal pore, commonly found in higher plants.

Structurally, hydathodes are modified stomata, usually located at leaf tips or margins, especially at the teeth.

Hydathodes occur in the leaves of submerged aquatic plants such as **Ranunculus fluitans** as well as in many herbaceous land plants.

Hydathodes are made of a group of living cells with numerous intercellular spaces filled with water, but few or no chloroplasts. These cells open out into one or more sub-epidermal chambers. These, in turn, communicate with the exterior through an open pore. The water stoma structurally resembles an ordinary stoma, but is usually larger and has lost the power of movement.They are connected to the plant vascular system by a tracheid or vessel element.

Hydathodes discharge liquid water with various dissolved substances from the interior of the leaf to its surface. This process is called **guttation**. Example many grasses.

Differences Between Stomata and Hydathodes

Stomata	Hydathodes
Occur in epidermis of leaves, young stems.	Occur at the tip or margin of leaves that are grown in moist shady place.
Stomatal aperture is guarded by two guard cells.	Aperture of hydathodes are surrounded by a ring of cuticularized cells.
The two guard cells are generally surrounded by subsidiary cell.	Subsidiary cells are absent.
Opening and closing of the stomatal aperture is regulated by guard cells.	Hydathode pores remain always open.
These are involved in transpiration and exchange of gases.	These are involved in guttation.

DO YOU KNOW?

Can mangroove trees grow in salt water?

These amazing trees and shrubs cope with salt. Salt water can kill Plants, so mangroves must extract fresh water from the sea water that surrounds them. Many mangrove species survive by filtering out as much as 90 percent of the salt found in seawater as it enters their roots.

Mangrove excrete salt through glands in their leaves.

Halophiles

- Plants that grow in salty environment are called **Halophiles**.
- Plant growth in **saline habitat** developed numerous adaptations to **salt stress**. The secretion of ions by salt glands is the best known mechanism for regulating the salt content of plant shoots.
- Salt glands typically are found in **halophytes**. (Plants that grow in saline environments)

Figure 9.26: Halophytes

Figure 9.27: Removes excess salts through special salt glands on leaves

Summary

A Tissue is a group of cells that are alike in origin, structure and function. There are two principal groups: (1) Meristematic tissues and (2) Permanent tissues. Meristematic tissues comprise of self-perpetuating cells. Meristems are classified into several types on the basis of position, origin, function and activity. Many anatomists illustrated the root and shoot apical meristems on the basis of the type and arrangement and accordingly proposed many theories. The permanent tissues normally develop from apical meristem. They are classified into two types: 1)Simple permanent tissues and 2)Complex permanent tissues. Simple tissues are composed of a single type of cells only. It is of three types: (1) Parenchyma (2) Collenchyma and (3) Sclerenchyma. A complex tissue is a tissue with several types of cells but all of them function together as a single unit. It is of two types – xylem and phloem. Secretory tissues produce different types of chemicals. Some are in the form of enzymes, hormones, rubber, gum etc.

The tissues can be classified on the basis of their function, structure and location into epidermal tissue system, ground tissue system and vascular tissue system. Epidermal tissue system develops as the outermost covering of the entire plant body. It consists of epidermal cells and associated structures. All tissues except epidermis and vascular tissues constitute the ground tissue. The vascular tissue system is formed of vascular bundles.

In the primary structure, the outermost layer of the root is called piliferous layer. Cortex consists of only parenchyma cells. All the tissues present inside endodermis comprise the stele. In dicot (Example: bean) root, xylem is tetrach. Its phloem patch consists of sieve tubes, companion cells and phloem parenchyma. In monocot (Example: maize) root, xylem is polyarch.

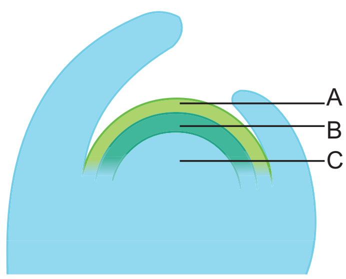
In dicot (Example: sunflower) stem, stele is eustele type and its vascular bundles are wedge shaped, conjoint, collateral, open and endarch. In monocot stem (Example: maize) vascular bundles are scattered and skull shaped, conjoint, collateral, closed and endarch.

In dicot (Example: sunflower) and monocot (Example: grass) leaves vascular bundles are conjoint, collateral and closed.

Hydathodes discharge liquid water with various dissolved substances from the interior of the leaf to its surface. Plants that grow in salty environment are called halophiles. Salt glands typically are found in halophytes.

Evaluation

1. Refer to the given figure and select the correct statement



   i. A, B, and C are histogen of shoot apex
   ii. A Gives rise to medullary rays.
   iii. B Gives rise to cortex
   iv. C Gives rise to epidermis

   a. i and ii only
   b. ii and iii only
   c. i and iii only
   d. iii and iv only

2. Read the following sentences and identify the correctly matched sentences.
   i. In exarch condition, the protoxylem lies outside of metaxylem.
   ii. In endarch condition, the protoxylem lie towords the centre.
   iii. In centarch condition, metaxylem lies in the middle of the protoxylem.
   iv. In mesarch condition, protoxylem lies in the middle of the metaxylem.
   a. i, ii and iii only
   b. ii, iii and iv only
   c. i, ii and iv only
   d. All of these
3. In Gymnosperms, the activity of sieve tubes are controlled by
   a. Nearby sieve tube members.
   b. Phloem parenchyma cells
   c. Nucleus of companion cells.
   d. Nucleus of albuminous cells.
4. When a leaf trace extends from a vascular bundle in a dicot stem, what would be the arrangement of vascular tissues in the veins of the leaf?
   a. Xylem would be on top and the phloem on the bottom
   b. Phloem would be on top and the xylem on the bottom
   c. Xylem would encircle the phloem
   d. Phloem would encircle the xylem
5. Grafting is successful in dicots but not in monocots because the dicots have
   a. Vascular bundles arranged in a ring
   b. Cambium for secondary growth
   c. Vessels with elements arranged end to end
   d. Cork cambium
6. Why the cells of sclerenchyma and tracheids become dead?
7. Explain sclereids with their types.
8. What are sieve tubes ?explain.
9. Distinguish the anatomy of dicot root from monocot root.
10. Distinguish the anatomy of dicot stem from monocot stem.

ICT Corner

Plant and Animal Tissues

Let's explore **Plant tissues.**

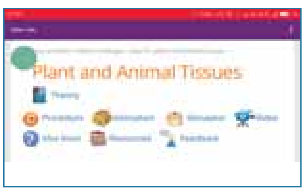
Steps

- Scan the QR code or go to Google play store
- Type online labs and install it.
- Select biology and select plant and animal tissues
- Click free sign up and provide your basic information with valid mail-Id
- Login with your registered mail id and password
- Choose theory tab to know the basic about anatomical structure
- Choose animation to view the sectioning process

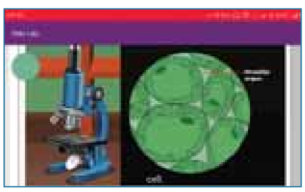
Activity

- Choose simulation tab and view the section of plant parts under microscope

Step 1



Step 2



Step 4

Step 3

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