ANATOMY OF FLOWERING PLANT

Contents

2. ANATOMY OF FLOWERING PLANT

2.1 Introduction

- We can very easily see the structural similarities and variations in the external morphology of the larger living organism, both plants and animals.
- Similarly, in the internal structure, there are several similarities as well as differences.
- "Study of internal structure of plants is called anatomy. " Plants have cells as the basic unit, cells are organized into tissues and in turn the tissues are organized into organs.
- Different organs in a plant show differences in their internal structure. Within Angiosperms, the monocots and dicots are also seen to be anatomically different. Internal structures also show adaptations to diverse environments.

2.2 Definition

"Anatomy is branch of botany, which deals with the study of gross internal structure of plant organs as observed after section cutting."

Or

"Plant anatomy or **phytotomy** is the general term for the study of the internal structure of plants."

2.3 Tissue

"A tissue is a group of cells having a common origin and usually performing a common function. "

- A plant is made up of different kinds of tissues.
- Tissues are classified into two main groups, namely, meristematic and permanent tissues based on whether the cells being formed are capable of dividing or not.

2.3.1 Meristematic Tissue-

- Growth in plants is largely restricted to specialised regions of active cell division called meristems (*Gk. meristos*: divided).
- "A **meristem** is the tissue in all plants consisting of undifferentiated cells (**meristematic cells**) and found in zones of the plant where growth can take place."
- Growth in plants is largely restricted to specialised regions of active cell division called meristems (*Gk. meristos*: divided). Plants have different kinds of meristems.
- The meristems which occur at the tips of roots and shoots and produce primary tissues are called apical meristems.

2.3.2 Characteristics of Meristem

- Cells of meristem are living and are at active divisional stage**.**
- The cells are usually small and isodiametric**.** The cells of cambium are, however, elongated.
- The cells are compactly arranged without any intercellular spaces.
- The cell wall is thin and made up of cellulose.
- Cytoplasm is dense, granular with a central, large and prominent nucleus.
- Vacuoles are either very small or absent. The cells of cambium are, however vacuolated.
- Metabolic activity is high, so is the rate of respiration.
- Cytoplasm has all the cell organelles, but instead of plastids there are proplastids. Ribosomes are abundant.

2.3.3 Classification of Meristem

Meristem have been classified on the basis of origin, position, function and plane of cell division.

BASIS	TYPES
Origin	Promeristem, Primary Meristem and Secondary Meristem
Position	Apical Meristem, Lateral Meristem and Intercalary Meristem
Function	Protoderm, Procambium and Ground or Fundamental Meristem
Plane of Cell Division	Rib Meristem , Plate Meristem and Mass Meristem

2.3.4 Meristem Based on Origin

2.3.4.1 Promeristem

- The first formed meristem originating from zygote and lying in embryonic condition is Promeristem or primordial meristem or embryonic meristem or urmeristem.
- It is situated at the apices of radicle and plumule.
- It is a mother meristem from which other meristem, primary meristem develops.
- This is undifferentiated part of an apical meristem.

2.3.4.2 Primary Meristem

- Apical meristems can be differentiate into three kinds of primary meristem:

2.3.4.2.1 Protoderm

- It lies around the outside of the stem and develops into the epidermis.

2.3.4.2.2 Procambium

- It lies just inside of the protoderm and develops into primary xylem and primary phloem. It also produces the vascular cambium, a secondary meristem.

2.3.4.2.3 Ground meristem

- It develops into the pith.
- It produces the cork cambium, another secondary meristem.
- It originates from Promeristem.
- It is so called because it is responsible for primary growth and builds up the primary body of the plants.
- Cells of Primary meristem divide rapidly and after loosening their divisional capacity they form primary permanent tissue, except intrafascicular cambium, a primary meristem but forms secondary permanent tissue.
- It is situated at the apices of root, stem and also at the nodal region of stem and its branches e.g. apical meristem, intercalary meristem, intrafascicular cambium, etc.

2.3.4.3 Secondary Meristem

- There are two types of secondary meristems, these are also called the ***lateral meristems*** because they surround the established stem of a plant and cause it to grow laterally.
- **Vascular cambium** - produces secondary xylem and secondary phloem, this is a process which may continue throughout the life of the plant.
- This is what gives rise to wood in plants. Such plants are called arborescent. This does not occur in plants which do not go through secondary growth.
- **Cork cambium** - gives rise to the bark of a tree.

2.3.5 Meristem Based on Position

2.3.5.1 Apical Meristem

- The meristems which occur at the tips of roots and shoots and produce primary tissues are called apical meristems.
- Root apical meristem occupies the tip of a root while the shoot apical Meristem occupies the distant most region of the stem axis.
- During the formation of leaves and elongation of stem, some cells 'left behind' from shoot apical meristem, constitute the axillary bud. Such buds are present in the axils of leaves and are capable of forming a branch or a flower.
- The apical meristems is primary meristems because they appear early in life of a plant and contribute to the formation of the primary plant body.

2.3.5.2 Lateral Meristem

- The meristem that occurs in the mature regions of roots and shoots of many plants, particularly those that produce woody axis and appear later than primary meristem is called the **secondary or lateral meristem.**
- Fascicular vascular cambium, interfascicular cambium and cork-cambium are examples of lateral meristems. These are responsible for producing the secondary tissues. They are cylindrical meristems.

2.3.5.3 Intercalary Meristem

- The meristem which occurs between mature tissues is known as intercalary meristem.
- They occur in grasses and regenerate parts removed by the grazing herbivores.

2.3.6 Meristem Based on Function

2.3.6.1 Protoderm

- It lies around the outside of the stem and develops into the epidermis.

2.3.6.2 Procambium

- It lies just inside of the protoderm and develops into primary xylem and primary phloem. It also produces the vascular cambium, a secondary meristem.

2.3.6.3 Ground Meristem

- It develops into the pith. It produces the cork cambium, another secondary meristem.

2.3.7 Meristem Based on Plane of Cell Division

2.3.7.1 Rib or File Meristem

- It is a type of meristem in which cells divide in one plane anticlinally.
- Some layers of cortex and pith are formed by rib meristem.

2.3.7.2 Plate Meristem

- The cells of this meristem divide in two planes anticlinally to form plate like structure.
- It forms uniseriate epidermis and multiseriate leaf blade, e.g. epiblema, epidermis, etc.

2.3.7.3 Mass Meristem

- The cells of this meristem divide in all planes (1xbxh) and forms a mass of cells e.g. , endosperm, seed coat, pericarp, etc.
- All these meristems are primary in nature as they form primary plant body.

2.3.7.4 Apical Meristem

- In vascular plants the meristem which first appears in the embryonic shoot or embryonic root is known as apical meristem.
- All primary tissues of the plant body originate from the shoot and root apical meristem.

2.3.7.5 Shoot Apical Meristem

- It is the terminal meristem of the shoot.
- It continuously gives rise to new cells and tissues from which new organs are formed.
- According to Foster, Gifford and Clowes "shoot apex is a portion of shoot above the youngest primordium".
- It is conical in shape and shows rhythmic change in size.
- It is self-determining and autonomous organizing centre of the plant.
- Plastochron is applicable to shoot apical meristem.

2.3.7.6 Root Apical Meristem

- The root apical meristem is relatively simple than the shoot apex. It is sub- terminal in position as root cap is present at the apex.
- It is not associated with the formation of lateral appendages and differentiation of nodes and internodes.

2.4 Theories of Shoot Apex Organization

- Several theories have been proposed to explain the organization of shoot apex. Some important ones are as follows:

2.4.1 Apical Cell Theory

- This theory was advanced by Hofmeister (1875) and supported by Negeli (1858).
- According to this theory, there is a single apical cell with three cutting faces, which governs the whole process of growth.
- This theory is applicable only to cryptogams but fails to explain the organization of the shoot apex in higher plants.

2.4.2 Histogen Theory

- This theory was proposed by Hanstein (1868).
- According to this theory, three distinct meristematic zones (histogens) can be recognized in the shoot apex of angiosperms.
- They are dermatogens, periblem and plerome.
- The dermatogens are the outermost histogens and gives rise to the cortex including endodermis.
- The innermost histogen is plerome that forms the vascular tissue including pith.
- However, in most of the gymnosperms and angiosperms, this zonation could not be established, hence this theory was later dropped.

2.4.3 Tunica-Corpus Theory

- This theory was given by Schmidt (1924). According to this theory, there are only two distinct zones, tunica and corpus, in the shoot apex of angiosperms.
- The tunica is peripheral zone consisting of one or more layers of regularly arranged smaller cells.

- The corpus represents the central core with large cells.
- If tunica is single cell layered, then entire tunica is involved in the formation of epidermis.
- But if tunica is multilayered, the outer layer of tunica forms epidermis and remaining layer of tunica and entre corpus forms the rest of the plant body. This is the most accepted theory.
- Tunica and corpus can be distinguished on the basis of plane of cell divisions. The cells of tunica divide only anticlinally, while those of the corpus divide in all planes.
- The former is responsible for surface growth while the later for volume growth.

2.5 Theories of Root Apex Organization

- Different theories of root apex organization are as follows:

2.5.1 Apical Cell Theory

- According to this theory, proposed by Negeli (1858), a single tetrahedral apical cell is structural and functional unit of the root apical meristem.
- The three upper sides from the root whereas the lower side forms the root tip. This theory, however, is not applicable.

2.5.2 Histogen Theory

- In 1868 differentiated four embryonic zones or histogens in the root apex. The dermatogens form the epidermis.
- The periblem gives rise to the cortex and plerome forms the central cylinder comprising stele.
- A fourth histogen called calyptrogens is also identified which forms the root cap.

2.5.3 Quiescent centre: In between root cap and the active centre of cell division, there is a cup shaped region of inactive cells, called quiescent centre. It is a reserve meristem where divisions are very few as the DNA synthesis is very rare. Cells of quiescent centre have low DNA, RNA and proteins.
When there is the need, cells divide and repair the damaged parts of roots. Quiescent centre was discovered by Clowes (1956) in the root of *Zea mays*.

2.5.4 Korper-kappe Theory

- This theory was proposed by Scheupp (1917).
- According to this theory, two zones, Korper and Kappe, can be distinguished in the root apex.
- Both these zones are characterized by peculiar type of cell division. Cells of kappe show straight 'T' type division while those of Korper show inverted 'T' type division.

2.6 Permanent Tissue

"The meristematic tissues that take up a specific role lose the ability to divide are called permanent tissues".

- This process of taking up a permanent shape, size and a function is called cellular differentiation. Cells of meristematic tissue differentiate to form different types of permanent tissue.
- There are 2 types of permanent tissues.
- The cells of the permanent tissues do not generally divide further.

2.6.1 Simple Permanent Tissues

- Permanent tissues having all cells similar in structure and function are called simple tissues.
- These tissues are called simple because they are composed of similar types of cells which have common origin and function.
- They are further classified into -

2.6.1.1 Parenchyma

- Parenchyma is Greek word where "parn" means besides and "enchien" means to pour.
- In 1682 Grew said that it is the most basic type of differentiated tissue from which other types have evolved.

- **Characters**
    - Parenchyma is the most specialized primitive tissue.
    - It mainly consists of thin-walled cells which have inter-cellular spaces between them, either Schizogenous or Lysigenous.
    - The cells are living and may be rounded, oval, rectangular, star shaped but usually polygonal.
    - The cell wall is thin and made up of cellulose, hemicellulose and pectin.
    - Though the cell wall of xylem parenchyma is thick, that of epidermal cells is cutinized and that of endodermal cells is suberized.
    - It is widely distributed in various plant organs like root, stem, leaf, flowers and fruits.
    - They mainly occur in the cortex epidermis, and pith, as well as in the mesophyll of leaves.

- **Modification**
    - To perform functions other than normal it gets modified into following types:-
        - **Chlorenchyma**- Having chloroplast, found in mesophyll and carries out photosynthesis.
        - **Aerenchyma-** They are filled with air spaces, found in hydrophytes, meant for buoyancy.
        - **Prosenchyma-** Much longer than their breadth and slightly thick walled to provide strength, found in pericycle or anywhere in plants.
        - **Stellate Parenchyma-** Having star shaped cells, found in leaf base of Banana and *Canna*, meant for expansion of leaf base. Provides lightness and strength.
        - **Idioblast-** Their cells secrete mucilage, gums, resins, alkaloids, terpenes, etc. Citrus, Eucalyptus, etc.

- **Origin**

Parenchyma originates from the cells of meristem by loosening their divisional capacity.

- **Functions**
    - The main function of parenchymatous tissue is assimilation and storage of reserve food materials like starch, fats and proteins.
    - Formation of cambium and cork cambium in dicot root.
    - Formation of accessory cambium in monocot stems which exhibits secondary growth.
    - Formation of wound cambium to heal up wounds.
    - Formation of interfascicular cambium and cork cambium in dicot stems.
    - Vegetative reproduction.
    - When turgid parenchyma provides mechanical support and maintain shape of the plant body.

- Parenchyma associated with xylem and phloem helps in conduction of sap and transportation of food.
- They also store waste products such as gums, resins, and inorganic waste materials.

1.6.1.2 Collenchyma

- Collenchyma is Greek word where "Collen" means gum and "enchyma" means infusion. It is a living tissue of primary body like Parenchyma.
- **Characters**
  - Cells are thin-walled but possess thickening of cellulose and pectin substances at the corners where number of cells join together.
  - Cells are elongated, tubular and are arranged along the long axis of the stem.
  - This tissue gives a tensile strength to the plant and the cells are compactly arranged and do not have inter-cellular spaces.
  - It occurs chiefly in hypodermis of stems and leaves. It is absent in monocots and in roots.
  - It is present in margin of leaves and resist tearing effect.
- **Functions**
  - Collenchymatous tissue acts as a supporting tissue in stems of young plants.
  - It provides mechanical support, elasticity, and tensile strength to the plant body.
  - It helps in manufacturing sugar and storing it as starch.
  - It forms cork cambium in dicot stems during secondary growth.
- **Types of Collenchyma**

  On the basis of mode of wall thickenings Collenchyma can be divided into three types:-
  Lammelar- Thickenings are deposited on the tangential walls. E.g.-*Raphanus, Helianthus* etc.
  Angular- Thickenings are deposited at the corners or angles of the cell walls E.g.- *Datura, Lycopersicum, Solanum ,Ficus* etc.
  Lacunar - Thickenings are deposited around the intercellular spaces E.g.-*Malva, Monestra* etc.

2.6.1.3 Sclerenchyma

- Sclerenchyma is Greek word where "Sclrenes" means hard and "enchyma" means infusion.
- **Characters**
  - These cells have hard and extremely thick secondary walls due to uniform distribution of lignin.
  - Lignin deposition is so thick that the cell walls become strong, rigid and impermeable to water.
  - They appear as hexagonal net in transverse section because these cells are closely packed without inter-cellular spaces between them.
  - The cells are cemented with the help of lamella.
  - The middle lamella is a wall that lies between adjacent cells.
  - Sclerenchymatous cells mainly occur in hypodermis, pericycle, secondary xylem and phloem.
  - This tissue consists of thick-walled, dead cells.
  - They also occur in endocarp of almond and coconut. It is made of pectin, lignin, protein.
  - **Types of Sclerenchyma**
    - The cells of sclerenchyamtous cells can be classified as :-
      1. Fibres- Fibres are long, elongated sclerenchyamtous cells with pointed ends.

2. Sclerides- Sclerenchymatous cells which are short and possess extremely thick, lamellated, lignified walls with long singular piths. They are called sclerides.

❖ **Functions**
   - The main function of Sclerenchymatous tissues is to give support to the plants.
   - It protects internal soft tissues.
   - It saves plant from stresses and strains of environmental forces like strong winds.

2.6.1.4 Difference between Parenchyma & Collenchyma

Parenchyma	Collenchyma
This is found everywhere in the plant body.	This is found in hypodermis of dicot stem and at the leaf base.
It can be both primary and secondary tissue.	It is usually primary tissue.
Cells are isodiametric.	Cells are elongated.
It provides turgidity to softer tissues.	It provides mechanical strength as well as elasticity to soft tissues.
This can dedifferentiate rapidly to form meristematic cells.	Cells dedifferentiate rarely.

2.6.2 Complex Permanent Tissues

"Permanent tissues having many different types of cells are called complex tissues."

- A complex permanent tissue may be classified as a group of more than one type of tissue having a common origin and working together as a unit to perform a function.
- These tissues are concerned with transportation of water, mineral, nutrients and organic substances.
- The important complex tissues in vascular plants are xylem, phloem.

2.6.2.1 Xylem

- Xylem (Gk. Xylos: wood; Nageli 1858 term hadrom for xylem by Haberlandt, 1914) is a complex tissue, composed of several types of living and dead cells.
- Xylem is a chief, conducting tissue of vascular plants.
- It is responsible for conduction of water and inorganic solutes.
- It is composed of four different kinds of elements: -
  Tracheids, vessels, xylem fibres and xylem parenchyma.

2.6.2.2 Phloem-

"Phloem is a chief conducting tissue of vascular plants. It is regarded as a living tissue responsible for translocation of organic solutes."

1. Sieve tube - Sieve tubes are long tubular structures composed of elongated sieve tube elements placed one above other forming a continuous tube.
2. Companion cell - Companion cells are living cells always associated with sieve tubes. Sieve tube elements and companion cells arrive from the same, initial cell and therefore form a single functional unit. Each companion cell shows presence of fine piths with all the living components of the cell.
3. Phloem Parenchyma - These cells are living parenchymatous cells that are present in phloem. These cells help in storage of food.
4. Phloem Fibres - Phloem fibres are formed by dead, sclerenchymatous fibres.
   - The main function of phloem is translocation of organic solutes from the leaves to the storage organ and later from the storage organ to the growing part.
   - Sieve tube allows free diffusion of soluble, organic substances across sieve plates due to the presence of large number of sieve pores.

2.6.2.3 Cambium

"The **vascular cambium** is a lateral meristem in the vascular tissue of plants."

- The vascular cambium is the source of both the secondary xylem (inwards, towards the pith) and the secondary phloem (outwards), and is located between these tissues in the stem and root. A few leaf types also have a vascular cambium.

Difference between Xylem & Phloem

Xylem	Phloem
It consists of tracheids, vessels, and parenchyma and xylem fibres.	It consists of sieve tubes, companion/albuminous cells, phloem parenchyma and phloem fibres.
Xylem has two types of conducting elements, tracheids and vessels.	This has one types of translocating elements called sieve elements.
Three of the four types of Xylem elements are dead. They are tracheids, vessels and fibres.	Only phloem fibres are dead.
Only xylem parenchyma is the living elements.	Phloem has three types of living elements , sieve tubes, companion cells and phloem parenchyma.
Xylem takes part in conduction of sap.	Phloem takes part in translocation of organic solutes.
The conducting elements posses lignified thickenings.	The translocating elements unlignified and without any thickenings.
Besides conduction, xylem provides mechanical strength.	Phloem has little mechanical strength.
Bulk of xylem continues to increase with secondary growth.	The bulk of phloem does not increase because as soon as new phloem becomes functional, the older one gets crushed.

2.7 Special Tissues or Secretory Tissues

The tissue that is concerned with the secretion with the secretion of gums, resins, volatile oils, nectar, latex and other such substances is called secretory tissue.
Secretory tissue may be external or internal in origin.

2.7.1 External Secretory Tissue

The external secretory tissues are epidermal in origin or derived from the sub epidermal cells. Some common external secretory tissues are as follows:

2.7.1.1 Glandular Trichomes

- They are the simplest type of secretory structure. A glandular trichome has a unicellular or multi cellular stalk and a head composed of one or more cells which produce secretions.
- Digestive glands are present on the inner surface of the pitcher wall and they secrete proteolytic enzymes, acid phosphate and esterase . A large number of glands are present along the margins and on the adaxial surface of the leaf of *Drosera*. They act as capturing, digesting and absorbing organs, e.g. *Urtica diocia*.
- Insectivorous plants have specialized glandular hairs on under surface of leaves, e.g. *Urtica diocia for trapping insects. Alluring glands , which are present on the under surface of the lid of the pitcher, secrete nectar.*

2.7.1.2 Hydathodes

- "A **Hydathodes** is a type of secretory tissue in leaves, usually of Angiosperms, that secretes water through pores in the epidermis or margin of leaves, typically at the tip of a marginal tooth or serration."
- They probably evolved from modified stomata. It is involved in guttation, where water is released from the top in order to transport the nutrients in the water from the roots to the leaves.
- Hydathodes are connected to the plant vascular system by a vascular bundle

2.7.1.3 Nectaries

- Floral nectaries are generally located at the base of the perianth, so that pollinators are made to brush the flower's reproductive structures, the anthers and pistil, while accessing the nectar.
- They are commonly associated with flower but they also occur on vegetative parts.
- The cells of nectaries have dense cytoplasm and contain numerous mitochondria and abundant endoplasmic reticulum. They secrete nectar, e.g. *Euphorbia pulcherima*.

2.7.2 Internal Secretory Tissue

There is a wide variety in internal secretory structures. They may consist of a single cell, small group of cells or a whole tissue. Some common internal secretory structures are:-

2.7.2.1 Secretory Cells

They are specialized cells dispersed in the ground parenchyma. These cells contain a variety of contents, such as oils, resins, tannins, gums, mucilages and crystals of various types.
The secretory cells, which are distinct from neighbouring cells, are called Idioblasts.

2.7.2.2 Glands

Several plants like *Citrus* have internal glands. These glands originate by breakdown of middle lamella or by lysis of some cells.

2.7.2.3Resin Ducts- They are long intercellular spaces lined with epithelial cells, which produce resins. They form complex vertical and horizontal systems within the plant body. E.g. *Pinus*.

2.7.2.4Lacticefers- They are specialized parenchyma cells, which secrete a viscous fluid, known as latex. These tissues are present through the ground tissue of plant and contain organic substances of much importance, e.g. Papain enzyme (in Papaya) chicle (chewing gum) rubber, etc.

2.8 Tissue System

"All the plant tissues, which perform common function, irrespective of their position in the body, constitute Tissue System".

- Their structure and function would also be dependent on location. On the basis of their structure and location, there are three types of tissue systems:-
- The Epidermal Tissue System,
- The Ground or Fundamental Tissue System
- The Vascular or Conducting Tissue System.

2.8.1 Epidermal Tissue System

The epidermal tissue system forms the outer-most covering of the whole plant body and comprises epidermal cells, stomata and the epidermal appendages – the trichomes and hairs.

2.8.1.1 Epidermis

- The epidermis is the outermost layer of the primary plant body. It is made up of elongated, compactly arranged cells, which form a continuous layer.
- Epidermis is usually single-layered. Epidermal cells are parenchymatous with a small amount of cytoplasm lining the cell wall and a large vacuole.
- The outside of the epidermis is often covered with a waxy thick layer called the Cuticle which prevents the loss of water. Cuticle is absent in roots.
- Stomata are structures present in the epidermis of leaves. Stomata regulate the process of transpiration and gaseous exchange. Each stoma is composed of two bean-shaped cells known as guard cells.
- In grasses, the guard cells are dumb- bell shaped. The outer walls of guard cells (away from the stomatal pore) are thin and the inner walls (towards the stomatal pore) are highly thickened.
- The guard cells possess chloroplasts and regulate the opening and closing of stomata. Sometimes, a few epidermal cells, in the vicinity of the guard cells become specialised in their shape and size and are known as subsidiary cells.
- The stomatal aperture, guard cells and the surrounding subsidiary cells are together called stomatal apparatus
- The cells of epidermis bear a number of hairs. The root hairs are unicellular elongations of the epidermal cells and help absorb water and minerals from the soil.
- On the stem the epidermal hairs are called trichomes. The trichomes in the shoot system are usually multicellular. They may be branched or unbranched and soft or stiff. They may even be secretory. The trichomes help in preventing water loss due to transpiration.

2.8.1.2 Cortex

"**Cortex** (Latin: "bark", "rind", "shell" or "husk") the outer portion of the stem or root of a plants."

2.8.1.3 Pith

"**Pith** is a substance that is found in vascular plants."

- It consists of soft, spongy parenchyma cells, and is located in the center of the stem in eudicots (both herbaceous and woody) and in the center of the roots in monocots.
- It is encircled by a ring of xylem (woody tissue), and outside that, a ring of phloem (bark tissue).
- In some plants the pith is solid, but for most it is soft. A few plants, such as walnuts, have distinctive chambered pith with numerous short cavities

2.8.2 Ground Tissue System

- All tissues except epidermis and vascular bundles constitute the ground tissue.
- It consists of simple tissues such as parenchyma, collenchyma and sclerenchyma. Parenchymatous cells are usually present in cortex, pericycle, pith and medullary rays, in the primary stems and roots.
- In leaves, the ground tissue consists of thin-walled chloroplast containing cells and is called mesophyll.

2.8.3 Vascular Tissue System

- "The vascular system consists of complex tissues, the phloem and the xylem. The xylem and phloem together constitute vascular bundles."
- In dicotyledonous stems, cambium is present between phloem and xylem. Such vascular bundles because of the presence of cambium possess the ability to form secondary xylem and phloem tissues, and hence are called **open** vascular bundles.
- In the monocotyledons, the vascular bundles have no cambium present in them. Hence, since they do not form secondary tissues they are referred to as **closed**.
- When xylem and phloem within a vascular bundle are arranged in an alternate manner on different radii, the arrangement is called radial such as in roots.
- In conjoint type of vascular bundles, the xylem and phloem are situated at the same radius of vascular bundles. Such vascular bundles are common in stems and leaves. The conjoint vascular bundles usually have the phloem located only on the outer side of xylem.

2.9 Secondary Growth

- The growth of the roots and stems in length with the help of apical meristem is called the primary growth.
- Apart from primary growth most dicotyledonous plants exhibit an increase in girth.
- This increase is called the secondary growth.
- The tissues involved in secondary growth are the two lateral meristems: **vascular cambium and cork cambium.**

2.10 Anatomy and Function of Root

The internal tissue organisation of Dicot Root is as follows:

- The outermost layer is epidermis. Many of the epidermal cells protrude in the form of unicellular root hairs.
- The cortex consists of several layers of thin-walled parenchyma cells with intercellular spaces.
- The innermost layer of the cortex is called endodermis.
- It comprises a single layer of barrel-shaped cells without any intercellular spaces.
- The tangential as well as radial walls of the endodermal cells have a deposition of water- impermeable, waxy material-suberin-in the form of casparian strips.
- Next to endodermis lies a few layers of thick-walled parenchyomatous cells referred to as pericycle.
- Initiation of lateral roots and vascular cambium during the secondary growth takes place in these cells. The pith is small or inconspicuous.
- The parenchymatous cells which lie between the xylem and the phloem are called conjuctive tissue.
- There are usually two to four xylem and phloem patches. Later, a cambium ring develops between the xylem and phloem.
- All tissues on the innerside of the endodermis such as pericycle, vascular bundles and pith constitute the stele. The internal tissue organisation of Monocot Root is as follows:
- The anatomy of the monocot root is similar to the dicot root in many respects. It has epidermis, cortex, endodermis, pericycle, vascular bundles and pith.
- As compared to the dicot root which have fewer xylem bundles, there are usually

more than six (polyarch) xylem bundles in the monocot root.
- Pith is large and well developed. Monocotyledonous roots do not undergo any secondary growth.

2.11 Anatomy and Function of Stem

The internal tissue organisation of Dicot Stem is as follows:
- The transverse section of a typical young dicotyledonous stem shows that the epidermis is the outermost protective layer of the stem.
- Covered with a thin layer of cuticle, it may bear trichomes and a few stomata.
- The cells arranged in multiple layers between epidermis and pericycle constitute the cortex.
- It consists of three sub-zones. The outer hypodermis, consists of a few layers of collenchymatous cells just below the epidermis, which provide mechanical strength to the young stem.
- Cortical layers below hypodermis consist of rounded thin walled parenchymatous cells with conspicuous intercellular spaces. The innermost layer of the cortex is called the endodermis.
- The cells of the endodermis are rich in starch grains and the layer is also referred to as the starch sheath.
- Pericycle is present on the inner side of the endodermis and above the phloem in the form of semi-lunar patches of sclerenchyma. In between the vascular bundles there are a few layers of radially placed parenchymatous cells,which constitute medullary rays.
- A large number of vascular bundles are arranged in a ring ; the 'ring' arrangement of vascular bundles is a characteristic of dicot stem. Each vascular bundle is conjoint, open, and with endarch protoxylem.
- A large number of rounded, parenchymatous cells with large intercellular spaces which occupy the central portion of the stem constitute the pith.

The internal tissue organisation of Monocot Stem is as follows:
- The monocot stem has a sclerenchymatous hypodermis, a large number of scattered vascular bundles, each surrounded by a sclerenchymatous bundle sheath, and a large, conspicuous parenchymatous ground tissue.
- Vascular bundles are conjoint and closed. Peripheral vascular bundles are generally smaller than the centrally located ones.
- The phloem parenchyma is absent, and water-containing cavities are present within the vascular bundles.

2.12 Anatomy and Function of Leaves
- The vertical section of a dorsiventral leaf through the lamina shows three main parts, namely, epidermis, mesophyll and vascular system.
- The epidermis which covers both the upper surface (adaxial epidermis) and lower surface (abaxial epidermis) of the leaf has a conspicuous cuticle.
- The abaxial epidermis generally bears more stomata than the adaxial epidermis. The latter may even lack stomata.
- The tissue between the upper and the lower epidermis is called the mesophyll.
- Mesophyll, which possesses chloroplasts and carry out photosynthesis, is made up of parenchyma.
- It has two types of cells – the palisade parenchyma and the spongy parenchyma.
- The adaxially placed palisade parenchyma is made up of elongated cells, which

are arranged vertically and parallel to each other.

- The oval or round and loosely arranged spongy parenchyma is situated below the palisade cells and extends to the lower epidermis.
- There are numerous large spaces and air cavities between these cells. Vascular system includes vascular bundles, which can be seen in the veins and the midrib. The size of the vascular bundles are dependent on the size of the veins. The veins vary in thickness in the reticulate venation of the dicot leaves. The vascular bundles are surrounded by a layer of thick walled bundle sheath cells.
- The anatomy of isobilateral leaf is similar to that of the dorsiventral leaf in many ways. It shows the following characteristic differences.
- In an isobilateral leaf, the stomata are present on both the surfaces of the epidermis; and the mesophyll is not differentiated into palisade and spongy parenchyma.
- In grasses, certain adaxial epidermal cells along the veins modify themselves into large, empty, colourless cells. These are called bulliform cells.
- When the bulliform cells in the leaves have absorbed water and are turgid, the leaf surface is exposed.
- When they are flaccid due to water stress, they make the leaves curl inwards to minimise water loss.
- The parallel venation in monocot leaves is reflected in the near similar sizes of vascular bundles (except in main veins) as seen in vertical sections of the leaves.

2.13 Points to Remember

- Anatomically, a plant is made of different kinds of tissues. The plant tissues are broadly classified into meristematic (apical, lateral and intercalary) and permanent (simple and complex).
- Assimilation of food and its storage, transportation of water, minerals and photosynthates, and mechanical support are the main functions of tissues.
- There are three types of tissue systems – epidermal, ground and vascular.
- The epidermal tissue systems are made of epidermal cells, stomata and the epidermal appendages.
- The ground tissue system forms the main bulk of the plant. It is divided into three zones – cortex, pericycle and pith.
- The vascular tissue system is formed by the xylem and phloem.
- On the basis of presence of cambium, location of xylem and phloem, the vascular bundles are of different types.
- The vascular bundles form the conducting tissue and translocate water, minerals and food material.
- Monocotyledonous and dicotyledonous plants show marked variation in their internal structures.
- They differ in type, number and location of vascular bundles. The secondary growth occurs in most of the dicotyledonous roots and stems and it increases the girth (diameter) of the organs by the activity of the vascular cambium and the cork cambium.
- The wood is actually a secondary xylem. There are different types of wood on the basis of their composition and time of production.