1th SEM B.Sc. BOTANY

UNIVERSITY OF CALICUT

Angiosperm Anatomy, Reproductive Botany & Palynology

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Prepared by

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BOT1B01T. Angiosperm Anatomy, Reproductive Botany & Palynology

Syllabus

ANGIOSPERM ANATOMY

Module - I

1. Cell Wall - Structure and development; Growth of Cell wall; cell wall materials

2. Non-living inclusions

a. Reserve food materials: carbohydrates, proteins, fats & oils. Carbohydrates: sugars & starch; Starch grains- structure, types with examples; Proteins- Aleurone grains with examples; Fats & oils examples.

b. Secretory materials

c. Waste materials - Nitrogenous – alkaloids, Non-nitrogenous- gums, resins, tannins, organic acids, essential oils; Mineral crystals - Calcium oxalate, Druses, Raphides, Calcium carbonate –cystoliths with examples

Module-II

1. Tissues: Definition –Types

a. Meristematic tissues - classification.

i. Theories on apical organization - Apical cell theory, Histogen theory, Tunica Corpus theory

ii. Organization of shoot apex and differentiation of tissues (protodern, procambium and ground meristem).

iii. Organization of root apex in dicots- common types with three sets of initials- in monocots: Maize type with four sets of initials

b. Mature tissues: definition classification- simple complex and secretory

i. Simple tissues: structure occurrence and function.

ii. Complex tissues: Xylem & Phloem -structure, origin, phylogeny and function

iii. Secretory tissues: glands, glandular hairs, nectaries, hydathodes, schizogenous and lysigenous ducts, resin ducts, laticifers –articulated and non-articulated

Module – III

1. Vascular bundles - Origin and types - conjoint, collateral, bi-collateral, open closed, radial, concentric - amphicribral and amphivasal.

2. Primary structure of root, stem & leaf (brief account only)

Module- IV

1. Normal secondary growth in Dicot stem and Dicot root. Formation of vascular cambial ring - structure and activity of cambium – storied and non-storied, fusiform and ray initials; Formation of secondary wood, secondary phloem, vascular rays, growth ring, heart wood, sapwood.

2. Extra stelar Secondary thickening in stem and root - Periderm formation. Structure - phellogen, phellem, phelloderm, bark, lenticels - structure & function

3. Anomalous secondary growth - general account with special reference to the anomaly in Dicot stem – *Boerhaavia*, *Bignonia* and Monocot stem- *Dracaena*

Module-II

1. **Tissues :- Definition –Types**

   Tissue is an organized group of cells which have a common origin, similar structure, and the same function

   Based on location and function,

   1. Meristematic tissues
   2. Permanent tissues
   3. Secretory tissues
   4. Lactiferous tissues

Part A: Meristematic tissues - classification.

- Are group of living, immature and undifferentiated cells, which
- remain in a state of continuous division
- Cells are thin walled, isodiametric, compactly arranged, with or
- without intercellular spaces
- Formed of cellulose

- Abundant protoplasm
- Cells do not store reserve food materials

❖ **Classification of Meristems**

A. Based on Position

1. Apical meristem
2. Intercalary meristem
3. Lateral meristem

B. Classification based on origin

1. Promeristem or Primordial meristem

- Consists of meristamatic cells representing the earliest stage of a growing organ
- Location: extreme tip of stem and root
- Function: forms primary meristem and later the primary structure of the plant body

2. Primary meristem

- Consists of meristamatic cells formed from promeristem
- Location: Seen just below promeristem
- Function: forms the primary structure of the plant body
- EG: promeristem at the shoot apex give rise to protoderm, procambium, ground meristem or fundamental meristem
- Protoderm- epidermal tissue system
- Procambium- primary vascular tissues
- Ground meristem- into cortex and pith

3. Secondary meristem

- Consists of meristamatic cells formed from primary
- permanent tissues.
- Some of the primary permanent tissues regains the
- merisitamatic activity and becomes secondary meristem
- Location: Laterally placed in stem and root
- Function: responsible for secondary growth of the plant
- Example: Inter fascicular cambium and cork cambium of stem,

- cambium of root.

C. Based on plane of division

1.Mass Meristem

- In mass Meristem, cells divide in all planes forming mass of tissues.
- Eg: Development of embryo, endosperm and sporangia etc

2.Plate Meristem

- In Plate Meristem, cells divide in two planes forming a plate like structure.
- Eg: Single layered epidermis

3.Rib Meristem

- In Rib Meristem, cells divide in only one plane and forms rows or columns of cells.
- Eg: Responsible for the increase in length of organs

i. Theories on apical organisation - Apical cell theory, Histogen theory, Tunica corpus theory

1. **APICAL CELL THEORY**
   - Nageli-1958
   - Single tetrahedral apical cell in the root apex brings about growth
   - Apical cell theory is confined to vascular cryptogams only as the root apical meristem of flowering plants does not have a single apical cell.
2. **Korper – kappe theory**
   - By schuepp (1917)
   - The cells at the root apex divides in two planes
   - First transverse, then one of the daughter cell divides longitudinally
   - This sequence division is called T division
   - Zone with inverted T type division – Korper (cap)
   - Straight T type division – Kappe (body)
   - Fails to explain the differences in behavior in different species
3. **Histogen Theory**

- Proposed by Hanstein (1870)
- Apical root meristem consists of different meristematic zones or layers called Histogens
  1. Dermatogen
  2. Periblem
  3. Plerome
  4. Calyptrogen

ii. Organization of shoot apex and differentiation of tissues- (protodern, procambium and ground meristem should be mentioned).

- Organisation of shoot apex
- Shoot apex is the apical meristem present at the tips of stems

1. Apical cell theory

2. Histogen theory

3. Tunica corpus theory

- proposed by Schmidt in 1924
- Outer Tunica and inner Corpus
- Tunica cells divides anticlinally, so surface area increases
- Corpus cells divides anticlinally and periclinally

iii. Kopper-Kappe theory- organization of root apex in dicots- common types with three sets of initials- in monocots – Maize type with four sets of initials

1. Ranunculus type

2. Casuarina type

3. Common type

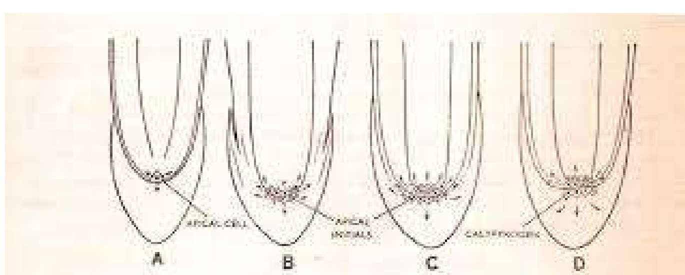


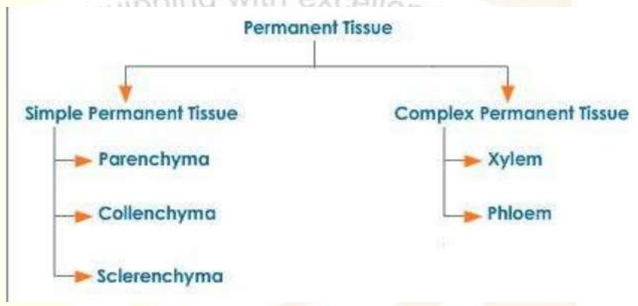
Fig. Root apices (diagrammatic)—A. Type found in pteridophytes with solitary apical cell. B. As found in gymnosperms. C. As found in dicotyledons. D. As found in monocotyledons.

MODULE II

PART B: Mature tissues- definition classification- simple complex and secretory

i. Simple tissues – parenchyma, collenchyma, sclerenchyma, - fibres and sclereids- structure occurrence and function.

- Simple tissues are tissues wherein the growth process has been ceased. originate from both the primary and the secondary meristematic tissue and possess a definite shape and organization, however, they lack the potential to divide



1. **Paremchyma**
   - they are living cells and walled, soft in nature due to the presence of thin-walled cells
   - The cells of parenchyma are isodiametric or polyhedral in shape. They may be polygonal, oval, round or elongated
   - These cells are closely packed or may have small intercellular space
   - They are made up of thin cell wall made up of cellulose, calcium pectate

   ➢ **Types of Parenchyma**

   1. Prosenchyma: These are fibre-like elongated cells, which are thick-walled and provide rigidity and strength to the plant

   2. Aerenchyma: They contain very large intercellular spaces. These are present in aquatic plants.

   3. Chlorenchyma: Cells which have chloroplast and perform photosynthesis

4. Storage Parenchyma: These store various substances like water, starch, proteins etc. They act as a food and water reservoir.

2. Collenchyma

- Is the living supporting or mechanical tissue.
- Formed of living elongated thick walled cells
- Formed of cellulose and pectin-cell wall
- Elastic and extensible and are adapted for rapid growth

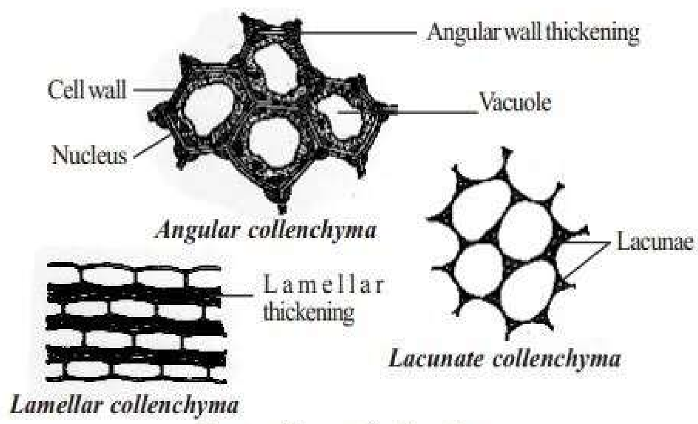
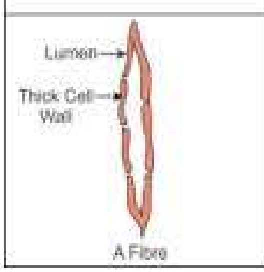
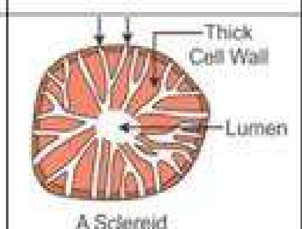
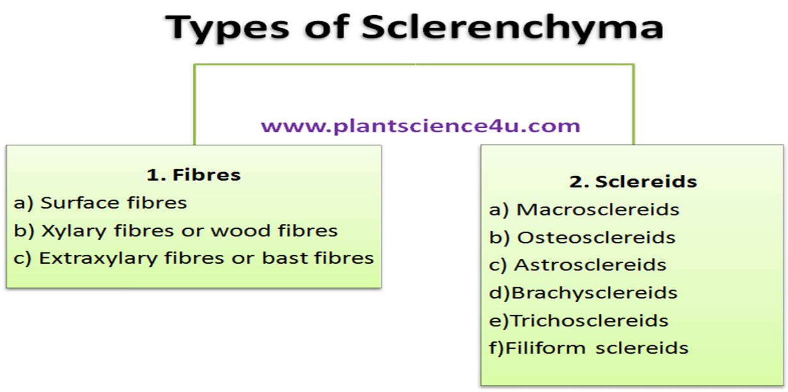


Fig. Types of collenchyma

3. Sclerenchyma

- Non living, supporting or mechanical tissue
- Cells are hard, thick walled, elastic, dead
- Compactly arranged without intercellular spaces
- Cell wall with cellulose and lignin deposits

Fibres	Sclereids
The cells of the fibres are elongate and tapering at end.	The cells of sclereids are short and of same diameter with blunt end.
Generally they are unbranched.	May be branched or maybe unbranched.
	



ii. Complex tissues - Definition - Xylem & Phloem structure, origin and function

1. **Xylem**
    - The xylem is the principal water-conducting tissue of vascular plants. It consists of tracheary elements, tracheids and wood vessels and of additional xylem fibres. All of them are elongated cells with secondary cell walls that lack protoplasts at maturity
    - Tracheids are the chief water-conducting elements plants. Tracheids are elongated cells, closed at both ends. Tracheids look often square in cross-section, the lignified secondary wall is relatively thin. The walls are opened by numerous pits
    - The pits are often surrounded by a halo and are then called bordered pits.
    - Botanists think of wood vessels (tracheae) as the water-filled tubes of the xylem. Wood vessels are the chief water-conducting elements of plants.
    - In contrast to the tracheids the final walls of the single vessels are perforated and are therefore generally thought to be more efficient water conductors than tracheids.
2. **Phloem**
    - Movement of water through xylem is a passive process – the cells that make up xylem are dead Transport of sugars and amino acids is an active process needing energy, phloem is living tissue.
    - Movement of substances such as sugars and ions through phloem is called translocation

- The main components of phloem are sieve elements and companion cells.
- Sieve tubes Phloem is made from columns of parenchyma cells
- Each parenchyma cell is adapted to form a sieve element
- Columns of sieve elements join together to form sieve tubes
- The cross walls between successive cells (sieve elements) become perforated forming sieve plates . The cell walls are thin . Although the cell contents are living , the nucleus disintegrates and disappears . The lumen is filled with a slimy sap
- As the sieve elements mature the lose several plant cell organelles – the nucleus, ribosomes and Golgi body degenerate. This allows materials to pass through them more easily
- Sieve elements do have a cell wall, cell membrane, er and mitochondria.
- The amount of cytoplasm is very small and lines the inside of the cellulose wall.
- Companion cells -Each sieve element has at least one companion cell next to it.
- Companion cells have the normal plant cell structure with extra ribosomes and mitochondria
- Companion cells are metabolically very active
- Companion cells are linked to the sieve elements by numerous plasmodesmata .
- As might be expected, it is companion cells that enables the sieve element to stay alive.

iii. Secretory tissues - glands, glandular hairs, nectaries, hydathodes, schizogenous and lysigenous ducts, resin ducts, Laticifers –articulated and non-articulated

- The secretory structures vary greatly in structure and position.
- They may be either simple glandular trichomes or multicellular glands with vascular tissues.
- They may be external when originate from epidermis or deep seated or internal such as laticifers and resin ducts.

1. **Glandular Trichomes:**

- These trichomes consist of a stalk with a head above.
- The stalk may be unicellular or multicellular and in the latter case the cells may be arranged in several rows.
- The head is the secretory part and may be composed of single cell (ex. Pelargonium) or many cells (e.g. Callitriche).
- The head is covered with a cuticle. The secretion is accumulated beneath the cuticle.

2. **Nectary**

- Nectary can be defined as a gland or part of a flower that secretes nectar to the exterior of plants.
- They are divided into floral and extrafloral nectaries.
- The former is situated within the flower and is directly involved in pollination; the latter occurs on the vegetative organs and is not directly associated with pollination.
- The nectaries are present on the epidermis.

3. ***Glands and Ducts:***

- They comprise a group of cells or sometimes a single cell that is readily distinguishable from the neighbouring cells and secretes a specific substance.
- These cells are thin walled with dense protoplasm and sometimes occur as layer surrounding a cavity, known as secretory cavity.

4. **Schizogenous glands**

- These are formed by the dissolution of middle lamella, thus separating apart the cells to form cavity.
- Example: oil glands of Eucalyptus, the secretory ducts of Rhus glabra, resin duct of Pinus etc.
- This cavity remains surrounded by a ring of intact parenchyma cells, termed epithelium, which forms a well-defined boundary of the gland.

5. **Lysigenous glands**

- These glands originate by lysis of a few cells thus forming the cavity
- (ex. glands present in the leaves and fruits of Citrus sp., that are also formed schizogenously).

6. ***Laticifers***

- Laticifers can be defined as a specialized cell or a row of such cells that secrete the milky fluid termed latex.

- The word laticifer is used as a general term to denote the various latex-secreting structures — latex cell, latex vessel, latex duct, latex tube and laticiferous duct.
- The laticiferous duct is a cavity into which latex is secreted.

7. **Non-articulate laticifer**

- The former is derived from the enlargement of a single cell.
- This cell has the potentiality of unlimited and rapid growth, and elongates to form long latex tubes.
- The tubes may remain unbranched termed non-articulate unbranched laticifer (e.g. Vinca, Cannabis, Urtica etc.).

8. **The articulate laticifers**

- also termed laticiferous vessel, consist of longitudinal files of cells.
- The transverse end walls of the individual cell either remain intact or break down partly or wholly to form a continuous tube —the latex vessel.
- So the articulated laticifers are always compound in origin.
- They occur in primary or secondary phloem and may be present in cortical parenchyma.

MODULE 3

Chapter 1:

- **Vascular bundles – types: conjoint - collateral, bicollateral, concentric and radial**
- **Vascular bundles**

➢ Vascular bundles are components of Vascular Tissue System
➢ Also called as 'fascicle'
➢ Part of TRANSPORT system in plants
➢ One of the PRIMARY tissue system in plants
➢ It is a COMPLEX tissue system in plants
➢ 1. Xylem: water conducting tissue
➢ 2. Phloem: food conducting tissue
➢ Components of xylem: Tracheids, Vessels, Xylem fibres & Xylem parenchyma
➢ Components of phloem: Sieve cells, Sieve tube elements, companion cells, Phloem parenchyma, Phloem fibres

- **Types of vascular bundles**

1. **Conjoint**

- Conjoint vascular bundles - Xylem and phloem are arranged together
- Xylem and phloem in same radius
- Conjoint VB are found in STEM and LEAVES
- Three types:

1. **COLLATERAL**
    - A type of conjoint VB
    - Phloem located ONLY OUTSIDE of the xylem
    - Xylem towards interior, phloem towards exterior
    - Collateral VB may be Open or Closed
    - **Cambium may be present or absent in between xylem and phloem, and so there are the following two types of collateral bundle:**
    - **(a) Closed collateral bundle:**
    - In this type cambium is absent in between xylem and phloem. Therefore stems having this type of bundle do not have normal secondary growth. Ex. Monocotyledonous stem.
    - **(b) Open collateral bundle:**
    - An open collateral vascular bundle has cambium called fascicular cambium between xylem and phloem. The bundles can increase in diameter by normal secondary growth with the help of fascicular cambium. Ex. Dicotyledonous stem.
2. **BI-COLLATERAL**
    - A type of conjoint VB
    - Phloem present in two groups
    - One outside the xylem, other inside the xylem (xylem in the middle, phloem both sides)
    - Characteristic of some Angiosperms
    - Bi-collateral vascular Bundle -Example: members of Cucurbitaceae (Cephalandra, C ucurbita)
    - Bi-collateral vascular bundles are always OPEN
3. **CONCENTRIC**
    - A type of conjoint vascular bundle
    - One VB element completely surrounds the other
    - Either phloem surrounds xylem or xylem surrounds the phloem
    - Two types: a) Amphicribal: b) Amphivasal

A). Amphicribal: A type of concentric vascular bundle

- Xylem lies at the centre, surrounded by a ring of phloem
- Example: Meristeles of ferns, small vascular traces of flowers, fruits and ovules

B). Amphivasal:

- A type of concentric vascular bundle
- Phloem lies at the centre, surrounded by a ring of xylem
- Example: Dracaena stem, Rumex, Begonia

2. Radial vascular bundles

- Radial Vascular bundle -Based on the arrangement of VB components
- Xylem and phloem are arranged separately
- Arranged alternatively in different radii
- Radial vascular bundles are found in ROOTS
- There is no primary cambium in this bundle and the secondary thickening occurs by the secondary cambium that originates at the time of secondary growth in dicotyledonous root only.

Chapter 2

- **Primary structure of dicot and monocot root, dicot and monocot stem and leaf in dicot and monocot.**

I. Structure of monocot root

1. Rhizodermis of epiblema

- The outermost layer is the Rhizodermis.
- It is made up tubular living cells. Some of the epidermal cells are protruded out in the form of root hairs.
- These root hairs are useful in the absorption of water.
- The epiblema gives protection to the roots.

2. Cortex:

- The cortex is broad and consists of parenchyma cells with large intercellular spaces.
- The cells are living and possess leucoplasts.
- Their function is storage.
- The last layer of the cortex is endodermis.
- The endodermal cells contain bands like structure made of suberin in their radial and transverse walls.
- These band-like structures are known as Casparian strips.
- Those endodermal cells in front of protoxylem are thin walled and known as passage cells. These passage cells conduct water from the cortex to xylem.

3. Stele:

- Stele in dicot root is differentiated into pericycle and vascular system.

4. Pericycle:

    - Pericycle is a single layer of thin-walled parenchyma cells forming the outermost layer of the stele. Lateral roots arise endogenously from pericycle.

5. Vascular system:

The primary xylem and phloem are arranged in alternate radii.

Xylem and phloem are separated by the conjunctive tissue.

Such a vascular bundle is said to be radial vascular bundles. Xylem occurs in the form of a solid core with a ridge like projections extending towards the pericycle.

The number of protoxylem is four.

Hence the xylem is called tetrarch.

As the first-formed xylem is pointing towards the periphery the xylem of roots is exarch.

Phloem consists of sieve tubes, companion cells and phloem parenchyma.

Pith is usually absent.

2. Structure of Dicot root

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

1. Rhizodermis or epiblema:
    - The outermost layer is made up of single layer of parenchymatous cells without intercellular spaces. Stomata and cuticle are absent.
    - Root hairs are always single celled.
2. Cortex:
    - Cortex consists of oval or rounded loosely arranged parenchymatous cells.
    - These cells may store food reserves.
3. Endodermis
    - It is made up of single layer of barrel shaped parenchymatous cells.
    - The radial and the inner tangential walls of endodermal cells are thickened with suberin. These thickenings are known as casparian strips.
    - But these casparian strips are absent in the endodermal cells which are located opposite to the protoxylem elements.
4. Stele: All the tissues present inside endodermis comprise the stele.
    A. Pericycle
    - Pericycle is generally a single layer of parenchymatous cells found inner to the endodermis. Lateral roots originate from the pericycle.

    B. Vascular system

- Vascular tissues are in radial arrangement.
- The tissue by which xylem and phloem are separated is called conjunctive tissue.
- Xylem shows exarch and tetrarch condition
- Metaxylem vessels are generally polygonal in shape

5. Pith: Usually absent

3. Monocot stem

- In monocotyledons secondary growth does not take place. Hence, the plant body consists of only primary tissues.
- A transverse section of a monocotyledonous stem shows four regions. They are epidermis, hypodermis, ground tissue and vascular bundles.
- Monocot stem is differentiated into epidermis, hypodermis and ground tissue.
- Epidermal hairs are absent.
- Cortex is poorly developed and represented by hypodermis.
- Hypodermis is sclerenchymatous.
- General cortex is absent.
- Endodermis is absent.
- Stele is large and of advanced type.
- Stele consists of ground tissues and vascular bundles.
- Pericycle is absent.
- Vascular bundles are numerous and scattered in the ground tissue.
- Sclerenchymatous bundle sheath is present around each vascular bundle.
- The vascular bundle is oval, conjoint, collateral, closed and endarch.
- Xylem consists of few vessels (3 or 4) and arranged in the form of letter Y.
- It disintegrates and forms protoxylem lacuna.
- Phloem is small. Phloem parenchyma is absent.
- Peripheral vascular bundles are small and those situated towards centre are large.
- Medulla and medullary rays are absent.

4. Dicot stem

- In transverse section, dicot stem is differentiated into epidermis, cortex and stele.
- Epidermal hairs are present.

- Cortex is well developed and differentiated into hypodermis, general cortex and endodermis
- Hypodermis is collenchymatous
- General cortex is parenchymatous.
- Endodermis is present. It contains starch grains.
- Stele is bigger than cortex and well developed.
- Stele is differentiated into pericycle,vascular medulla and medullary rays.
- Pericycle is either completely or partly selerenchymatous.
- Vascular bundles are limited in number and arranged in the form of a ring.
- Bundle sheath is absent.
- The vascular bundle is wedge shaped, conjoint, collateral, open and endarch.
- Xylem consists of many vessels and is not arranged in the form of letter Y.
- Protoxylem does not disintegrate.
- Phloem is comparatively large and consists of phloem parenchyma also.
- All the vascular bundles are uniform in size.
- Medulla and medullary rays are distinct.

5. Monocot leaf

1. **Upper Epidermis**

- The upper epidermis is a single layer made up of cubical shaped cells with no intercellular spaces in between them.
- The outer surface of the upper epidermis cell is covered by a thin cuticle.
- A few cells present in the upper epidermis are enlarged to form motor cells referred to as bulliform cells.
- These cells help the leaf to roll over themselves in order to reduce the surface area exposed to sunlight during hot seasons.

2. **Mesophyll**

- Mesophyllis a green tissue between upper epidermis and lower epidermis.
- In monocot leaf, the mesophyll tissue is not differentiated into palisade parenchyma and spongy parenchyma with chloroplast and chlorophyll.
- The mesophyll is usually involved in photosynthesis process in the leaves of these plants.

3. **Vascular Bundles**

- Vascular bundles represent the veins of the leaves.

- Each vascular bundle consists of phloem and xylem tissues surrounded by a bundle sheath.
- Bundle sheath layer of the vascular bundle is made up of large barrel shaped endodermal cells.
- Xylem is usually responsible for conduction of water and dissolved minerals whereas phloem is responsible for conduction of dissolved food materials.

6. Dicot leaf

1. **Epidermis**

- The epidermis is usually made up of a single layer of cells that are closely packed.
- A dicot leaf consist of a lower and upper epidermis with small openings referred to as stomata.
- The upper epidermis is thicker than the lower epidermis.

2. **Mesophyll**

- The mesophyll usually has two regions the spongy and palisade parenchyma.
- The palisade parenchyma cells contain more chloroplasts than the spongy parenchyma cells and thus its function is photosynthesis.
- On the other hand, spongy cells are irregularly shaped and loosely arranged so as to facilitate the exchange of gases within the air spaces.

3. Vascular bundles

- **The vascular bundles** of a dictot leaf are surrounded by a compact layer of paranchymotous cells known as border parenchyma.
- The xylem consists of metaxylem vessels and protoxylem vessels.
- Phloem consists of sieve tubes, companion cells and phloem parenchyma.

MODULE 4

Chapter 1.

1. Normal secondary growth in Dicot stem and Dicot root
   a. Dicot stem
      - **Intrastelar secondary growth-** By th formation of vascular cambium
        1. Formation of vascular cambium- interfascicular and intrafascicular cambium

2. Formation of secondary vascular tissues-secondary xylem and secondary phloem
3. Formation of vascular rays

- **Extrastelar secondary growth-** by the formation of cork cambium

1. Formation of periderm
   i. Formation of phellogen (cork cambium)
   ii. Formation of phellem (cork)
   iii. Formation of phelloderm (secondary cortex)
2. Formation of lenticels

b. Secondary vascular tissues are present

- Formation of cambial ring
- Cambial ring is wavy at the beginning later become circular
- The cambium is completely secondary in origin
- The cambium produces secondary phloem to the outside and secondary xylem to the inside.
- Cork cambium is present and produces cork to the outside and secondary cortex to the inside forming periderm.
- Primary Vascular bundles are radial and xylem is exarch
- Number of xylem and phloem groups limited (2-6 or 8)
- Common material: *Carica Papaya*

2. Formation of vascular cambial ring
   - **Intrafascicular and interfascicular** cambium forms like a ring and called cambial ring
   - Interfascicular cambium develops from the conjuctive tisues found in between xylem and phloem
   - In dicot root, the vacular cambium develops from the procambial cells and produces a wavy cambial ring
3. structure and activity of cambium – storied and non-storied
   - based on the arrangement of fusiform initials, there are two types of cambium
   - **storied cambium-** in which the fusifrom initials are arranged as uniform shape and size
   - in **non-storied cambium-** the fusiform initials are irregularly arranged and overlap with each other

4. fusiform and ray initials
    - The two types of cells in which the vascular cambium are made with
    - **Fusiform initials** are elongated large cells, and it divides to form secondary xylm and phloem during secondary growth
    - **Ray initials** are small sized isodiametric shaped cells, which divides to form medullary rays or vascular rays during secondary growth
5. Formation of secondary wood
    - **Wood** is the secondary xylem formed by the activity of vascular cambium
    - Different types of woods
    - Porous wood and non porous wood
    - Sap wood and heart wood
    - Ring porous wood and diffuse porous wood
    - Spring wood and autumn wood
6. growth ring
    - successive layers of secondary xylem added to a growing tree
    - in the form of concentric rings
    - age determination of a tree by counting their growth rings is called dendrochronology
7. heart wood
    - inner, central part
    - formed of old xylem
    - hard, dead, durable and dark colored
    - filled with gums, resins, tannins, etc
    -
8. sapwood
    - outer or peripheral part
    - formed of new xylem
    - soft, living, non durable and light colored
    - tyloses absent

Chapter 2.

1. Extra stelar Secondary thickening in stem and root -Periderm formation. Structure - phellogen, phellem, phelloderm

- Takes place outside to the stellar region
- Formation of periderm and lenticels outside to the cortex
- Periderm consists of three layer
- Outer phellem or cork
- Middle phellogen or cork cambium
- Inner phelloderm or secondary cortex
- The formation of more and more secondary tissues exerts a pressure on cortex and epidermis
- The epidermis gets ruptured and is replaced by another protective tissue developed in the
- cortex from the cork cambium is the periderm.
- Periderm consists of meristem called phellogen or cork cambium. Cork cambium produces cork or phellum to the outside and phelloderm or secondary cortex to the outside.
- Periderm has specialized openings called lenticels on its surface for gaseous exchange
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2. bark
    - it is the thick extra stellar covering
    - formed of perderm and secondary phloem
    - consists of living and dead tissues
    - commercially important
3. lenticels - structure & function
    - small, isolated and raised openings on the surface of old stems
    - formed at the sites of stomata
    - by the breakdown of epidermis

Chapter 3.

1. Anomalous secondary growth - general account with special reference to the anomaly in Dicot stem – *Boerhaavia*, *Bignonia* and Monocot stem- *Dracaena*
    - Unusual position of cambium
    - Abnormal functioning of the cambium
    - Formation of more than one ring of cambia

- Formation of extra stellar cambial ring
- Formation of interxylary phoem
- Formation of interxylary cork
- Vascular bundles arranged in three rings in *Boerhaavia diffusa*
- Central, middle and outer
- Central two large rings
- Middle consists of 6-14 loosely arranged bundles
- Outer consists of 15-20 small bundles
- Cap like structure of dead cells over the phloem
- Formation of new cambial ring
    - In monocotyledons
        - Secondary growth is rare because of the absence of cambium
        - Activity of specialized primary secondary thickening meristem
        - Outer epidermis, sclerencymatous hypodermis, and large number of closed collateral vascular bundles in parenchymatous ground tissue
        - Cambium behaves abnormally