1 Anatomy of Flowering Plants

Introduction:

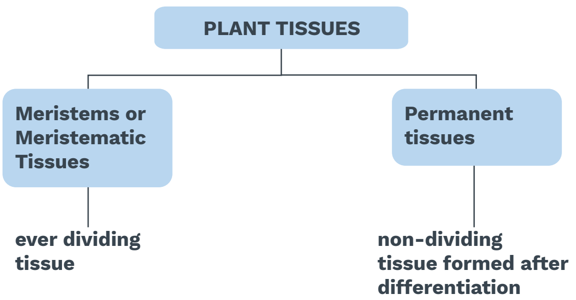
Higher Plants have complex body organization that is made up of many cells that form tissues, tissues give rise to organs and organs to organ systems. This whole process takes place by cell division and cell differentiation. In the beginning, all the newly formed cells arise from meristematic cells that are almost alike. During maturation, they undergo various structural changes by a process called differentiation.

Differentiation leads to the formation of different kinds of cells and tissues from the parent cell where each cell performs a specific function. So, differentiation leads to physiological differentiation or division of labour i.e., performing special functions.

- The branch of Biology that deals with the study of internal structures of organisms is called Anatomy.
- Nehemiah Grew, is known as the "Father of Plant anatomy" and also coined the term 'Tissue'.

Plant Tissues

- A group of similar or dissimilar cells having a common origin and in cooperation with one another, perform a similar function is called tissue.
- Depending upon the capacity to divide, plant tissues have been classified into two fundamental types:



Definition

Anatomy: The branch of Biology that deals with the study of internal organization of plants.

Gray Matter Alert!!!

N. Grew (1682): Father of Plant Anatomy; coined the terms 'Tissue' and 'Parenchyma'.
Nageli (1858): Gave the terms Meristems, Xylem and Phloem.

Definition

Tissue: A group of similar or dissimilar cells having a common origin and in cooperation with one another, perform a similar function is called tissue.

Meristematic Tissues (Meristems)

- A meristematic tissue is composed of similar cells that are capable of dividing and forming new cells throughout life of a plant.
- A plant starts its life as a unicellular structure i.e., fertilized egg cell that develops into embryo, which develops into a young plant.

Meristems (Gk. *Meristos*-divisible) or meristematic tissues can be defined as the tissues made up of a group of live, thin-walled and similar cells that divide continuously forming new cells.

Characteristics of Meristematic Tissue:

- The cells can divide throughout their life.
- These cells are thin-walled and are compactly arranged i.e., without intercellular spaces.
- These cells have only primary cell wall which is made up of cellulose.
- These cells may be isodiametric, rounded, oval or polygonal in shape.
- Cytoplasm is dense means vacuoles are either absent or are exceedingly small.
- The cells do not store reserve food as they are in highly active stage.
- Ergastic substances are usually absent in meristematic cells.

Classification of Meristems

Based on their origin, position, and functions:

1. MERISTEMS ON THE BASIS OF ORIGIN ARE OF TWO TYPES:

Promeristem (Primordial Meristem or Embryonic Meristem)

- These are groups of meristematic cells in germinating embryos or young seedlings.
- Promeristems give rise to primary meristems viz. apical and intercalary meristems.

Gray Matter Alert!!!

Differentiation: When the cells undergo anatomical and morphological changes and lose the capacity of division.

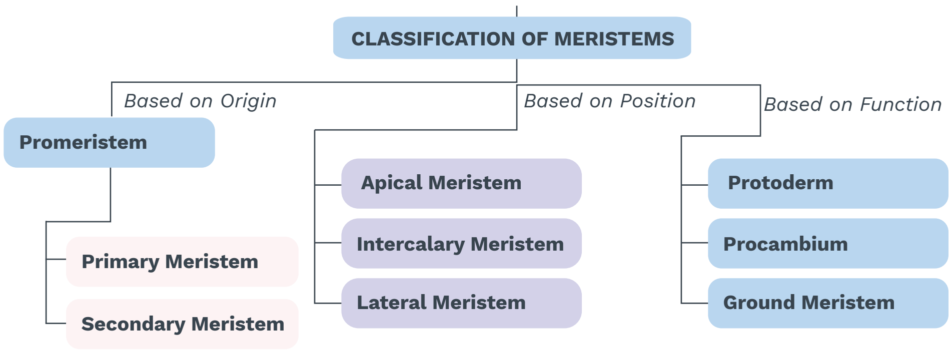
Previous Year's Questions

Promeristem gives rise to which type of meristem?

(1) Lateral
(2) Primary
(3) Apical
(4) Secondary

Rack your Brain

Why meristematic cells are unable to store food?



- They are represented by apical meristems (root apical meristem and shoot apical meristem) and intercalary meristems and intravascular cambium (in the open vascular bundles).
- The primary meristems give rise to different primary permanent tissues (except interfascicular cambium).
- The activity of primary meristem (i.e., apical meristem and intercalary meristem) is responsible for length-wise growth called primary growth.
- The activity of fascicular cambium results in an increase in girth (secondary growth).

Secondary Meristem

- Derived from permanent tissues (like parenchyma) by the process of differentiation.
- Examples:
  - Interfascicular cambium (in dicot stem)
  - Vascular cambium (in dicot roots)
  - Cork cambium or phellogen
  - Wound cambium
  - Accessory cambium.

These all are lateral in position and give rise to secondary permanent tissues that result in the growth in thickness (secondary growth).

- **Interfascicular cambium** develops from primary medullary cells (parenchymatous cells) found in primary dicot stems. It forms fascicular cambium ring by joining with

Definition

Primary Meristem: It appears early in the life of a plant and retains the capacity of division throughout the life, derived from the Promeristem.

Previous Year's Question

Secondary xylem and phloem in dicot stem are produced by
(1) Phellogen
(2) Vascular cambium
(3) Apical meristem
(4) Axillary meristem

Definition

Secondary Meristem: Derived from permanent tissues (like parenchyma) by the process of differentiation. It appears later in the life of a plant.

interfascicular cambium. The fascicular cambium ring gives rise to secondary vascular tissues (secondary xylem, secondary phloem).

- **Vascular cambium** in dicot roots, arises from conjunctive parenchyma and it acts like fascicular cambium ring of dicot stems.
- **Cork cambium** originates from the outer layers of the cortex, epidermis or sometimes pericycle and gives rise to periderm.
- **Wound cambium** arises from the cells surrounding any injury or wound, helpful in mending the injured tissue.
- **Accessary cambium** develops from the ground tissue of monocot stems that show abnormal secondary growth, e.g., *Yucca etc.*

2. MERISTEMS ON THE BASIS OF POSITION

Meristems are classified into three types on the basis of position :

Apical Meristems:

- These arise from Promeristem and form growing points at stem apex and roots apex.
- Being terminal in position, these meristems are called apical meristem.
- Present at root tips but root apical meristems are sub-terminal in position (located below the root caps)
- Apical meristems are responsible for length-wise growth of plants.

Intercalary Meristems

- These are the cells of the apical meristems, separated during the formation of permanent tissues.
- Present at the base of leaves (e.g., *Pinus*), above the nodes (e.g., Grasses) or just below the nodes (e.g., Mint).
- Intercalary meristems assist in lengthening of plant parts.
- Helpful in keeping the stems of cereals, erect.
- These meristems are short lived and are used up

Definition

Cork Cambium: Meristematic tissue (secondary meristem) formed by the process of de-differentiation from the parenchymatous cells (simple permanent tissue) of cortex.

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The initiation of growth takes place by the meristematic activity of a single apical cell (as in higher algal forms, bryophytes and pteridophytes) or by a group of apical cells or apical initials (in spermatophytes).

in the formation of plant parts.

- Exception: The intercalary meristems present at the base of *Pinus* leaf remain active throughout the life of the leaf.

Lateral Meristems

- located along the lateral sides of stems, branches and roots.
- These meristems increase the girth or diameter of the plant organs.
- Lateral meristems are cylindrical, running throughout the plant body.
- Both primary and secondary in origin.
  - Intrafascicular cambium or vascular cambium is primary meristem formed by differentiation process. Also called as Primary lateral Meristem.
  - **Marginal Meristem:** At the leaf margins and helps in expansion of leaf lamina.
  - Interfascicular cambium in stems, vascular cambium in roots, accessory cambium, cork cambium and wound cambium are Secondary Meristems.
  - Secondary meristems are formed by dedifferentiation process.

3. Meristem types (Based on Function):

Haberlandt (1914) classified primary meristem into three types:

Protoderm

- It is the outermost layer of promeristem or apical meristem.
- It leads to epidermal tissue system.
- Epidermal tissue system includes epidermis, root hair, stem hair etc.

Procambium

- It occurs in the form of isolated longitudinal strands of elongated cells, near the central region.

Definition

Lateral Meristems: These are located along the lateral sides of stems, branches and roots. These meristems increase the girth or diameter of the plant organs.

Previous Year's Question

Totipotency is present in ______.

(1) Meristem
(2) Cambium
(3) Phloem
(4) Cork

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Gottlieb Huberlandt, is considered as the "father of tissue culture".

- It develops into primary vascular tissues i.e., primary xylem and primary phloem.

Ground or Fundamental Meristem

- It lies inner to the protoderm and surrounds the procambium.
- It leads to the ground tissue system viz. endodermis, hypodermis, cortex, pericycle, medullary rays and pith.

ROOT CAP

- The root cap cells are made up of parenchyma and have shorter life span.
- Root cap cells possess starch grains that are believed to be responsible for the geotropic response of the root.
- The root cap acts as protective shield between the soil and the apical meristems.
- It appears as thimble and protects the root meristem. It protects the root meristems.
- The cells of the root cap secrete a mucilaginous substance that acts as a lubricant and helps the tender root tip to penetrate deep into the soil.

Quiescent Centre

- In many cases, a tiny region with extremely low mitotic activity is present in the center of the root apex.
- This region is called quiescent center (Clowes, 1961).
- In the cells of quiescent center, there is quite little synthesis of proteins, RNAs and DNAs.
- Quiescent center may act as a reserve meristem.
- Due to the presence of quiescent center, root apical meristem is cup shaped or hemi-spherical in shape.

Root Apex (Root Apical Meristem)

- Root apex is found at the tip of main root and at the tip of branches in tap root system.

Rack your Brain

Which of the following is in low concentration in the cells of quiescent center?
DNA, proteins, or RNA.

Previous Year's Question

Stem of grass and related plants elongate by the activity of __________.

(1) lateral meristem
(2) Apical meristem
(3) Both apical and intercalary meristem
(4) Intercalary meristem

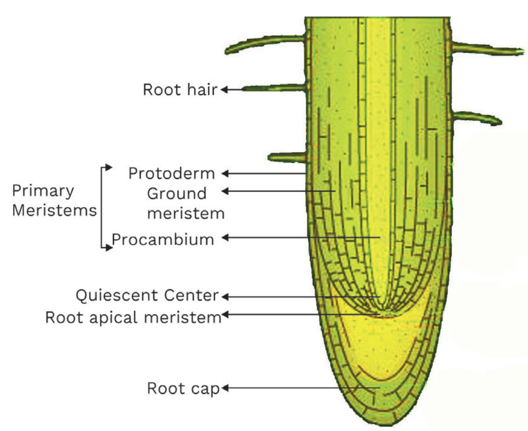


Figure: Structure of Root Apex

- Root apical meristem is subterminal in position.
- Secondary root branches develop much behind the apex, from the deeper layers of the root (pericycle and endodermis), hence are endogenous in origin.

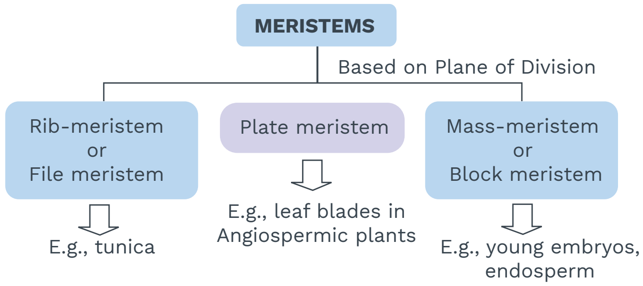
Meristematic regions in the root apical meristem:

- **Protoderm:** It gives rise to epidermal tissue system like epiblema, root cap and root hairs.
- In monocots, the root cap is derived from a special meristematic region at the end of the root called calyptrogens (*calyptras*-cap, *gen*-producing).
- **Procambium:** Gives rise to primary vascular tissues: primary xylem and primary phloem.
- **Ground Meristem:** It helps in the formation of ground tissue system viz. hypodermis, endodermis, pericycle, pith etc.

Classification of Meristems

(Based on Plane of Division)

- **Rib-meristem or File meristem:**
Meristem in which anticlinal division occurs only in one plane.



The cells of this meristem divide perpendicular to the longitudinal axis of the plant organ. As a result, parallel layers of cells (just like ribs) are produced.
Rib meristem produces petiole of leaves (organs of cylindrical form) etc., cells of cortex and pith.

Rack your Brain

Histogen found at the tip of root apical meristem is __________. (plerome/periblem/calyptrogen/ Dermatogen).

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Calyptrogen, a special meristematic region at the end of the roots in monocot plants that forms root cap.

Previous Year's Question

Intercalary meristem causes ___.
(1) Secondary growth
(2) Primary growth
(3) Apical growth
(4) Secondary thickening

Tunica is also a type of rib-meristem.

- **Plate meristem:**
  Meristem which divides anticlinally into two planes, forms flat structure. This leads to an increase in cell number per layer.
  This division causes the meristem to grow as a sheet but not in thickness producing flat organs like leaf.
- **Mass-meristem or Block meristem:** Meristem which divides in all possible planes resulting in an increase in the volume of plant body (organ). The derivative cells are isodiametric or spherical or may not have definite shape.
  For Example: young embryos, endosperm, reproductive organs etc.

Classification of Meristems (On the Basis of Rate of Division)

Cyto-Histological Zonation Theory: Proposed by Foster

1. **Summit:** This region is located at the apex.
   Rate of division: slow
2. **Flank:** This region is located behind the summit region.
   Rate of division: fast
   Plays a crucial role in formation of leaf primordia.

Role of Summit and Flank in the formation of Vegetative Shoot Apex (Shoot Apical Meristem)

- Present at the tip of stem and branches, as a terminal bud.
- Conical or dome-shaped, always covered by young leaves, arising from its sides. These leaves protect the apex.
- Cell division is rapid in flank region, giving rise to leaf primordial.
- Each leaf primordium has axillary meristem or axillary bud in its axil. Axillary buds remain dormant for some time till the plant attains a particular size.

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Ground meristem exhibits two growth forms: plate and rib meristem.

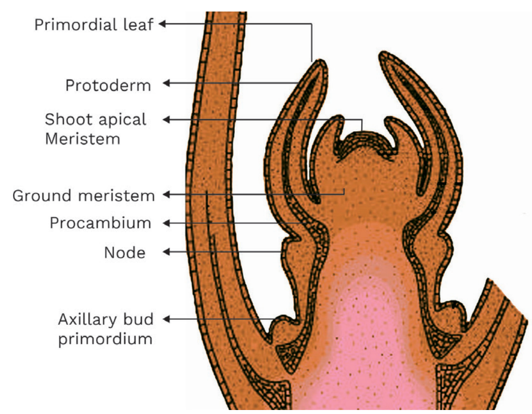

Figure: Longitudinal section of vegetative shoot apex showing distribution of meristems based on the functions.

- The apical meristems add new tissues and elongate the shoot.

Role of Summit and Flank in the formation of Reproductive Shoot Apex (Floral Bud)

- During reproductive phase, the vegetative shoot apex changes into reproductive shoot apex or a single floral bud.
- The cells of summit region (topmost region), that were inactive during the vegetative phase, start dividing actively and give rise to primordium of stamens and carpals.
- In flank region, leaf primordia are replaced by primordial of sepals and petals. Thus, the entire apical meristems undergo morphological changes.

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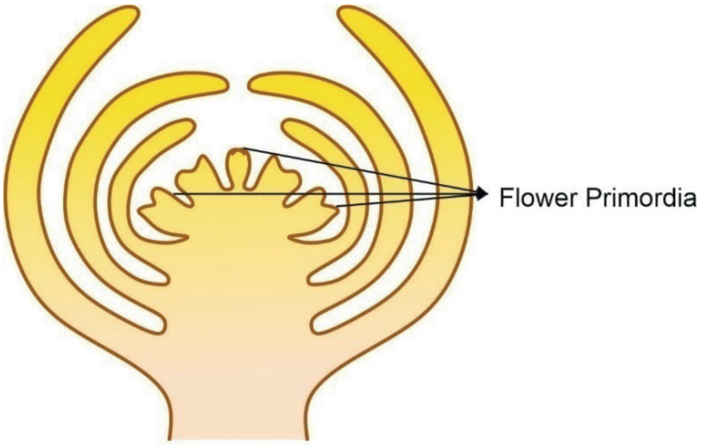
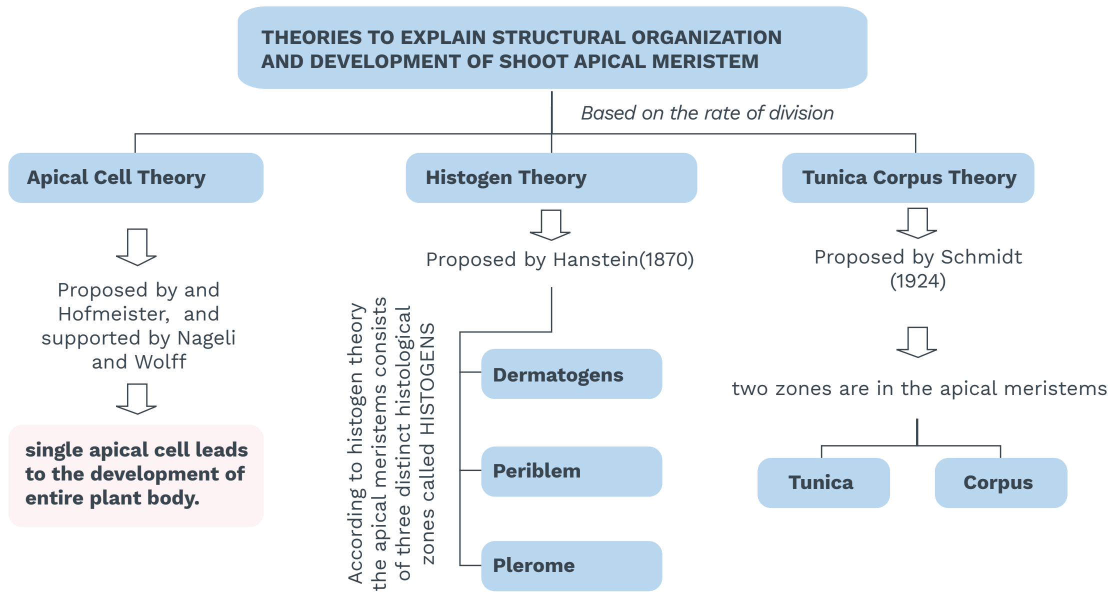
The period between the appearance of two successive leaf primordia is called plastochron.

Gray Matter Alert!!!

Differentiation: When the cells undergo anatomical and morphological changes and lose the capacity of division.



L.S. Through reproductive shoot apex.



Apical Cell Theory: Proposed by Hofmeister and supported by Karl Nageli and Wolff**.**

- According to Nageli (1858), the activity of single apical cell leads to the development of entire plant body.
- This theory is applicable to higher algal forms (e.g., *Fucus, Dictyota* & *Sargassum*) and most of the Cryptogams, but not to the phanerogams (e.g., Angiosperms and Gymnosperms).
- **Histogen Theory**: Proposed by Hanstein (1870)
According to histogen theory, the apical meristems consist of three distinct histological zones called histogens.
  (a) **Dermatogen:** The outermost mantle like layer of cells, usually single cell in thickness. It gives rise to epidermis or epiblema in roots, cortex and endodermis.
  (b) **Periblem:** It lies under the dermatogen. Forms cortex which includes hypodermis, general cortex and endodermis.
  (c) **Plerome:** The central zone (innermost region) of cells is called plerome. It forms vascular cylinder (pericycle, vascular tissues and medullary rays) including pith.

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Histogen theory is true only for root apex.
It is not applicable for shoot apex of higher plants; as in most of the Angiosperms and Gymnosperms, the shoot apex is not differentiated into three histogens.

Gray Matter Alert!!!

Calyptrogen: Fourth type of histogen, found in root apex of grasses (monocots). Calyptrogen forms root cap in roots of monocot plants.
Root cap is developed from Dermatogen in dicot roots.

Haberlandt (1914) proposed the following terms:
(i) Protoderm for dermatogen
(ii) Ground meristem for periblem
(iii) Procambium for plerome
Examples w.r.t exception in number of dermatogens-
In *Ranunculus*, only one histogen is found and in *Casuarina* two histogens are found.

- **Tunica Corpus Theory:** Proposed by Schmidt (1924).
- According to this theory, only two zones are in the apical meristems: TUNICA and CORPUS.

(1) TUNICA:

- The cells of tunica are small.
- They divide anticlinally in one plane (at right angles to the longitudinal axis) only and thus, help in surface enlargement.

Unicellular Tunica: Cells are arranged in one layer. The cells derived from tunica, give rise to epidermis of both stems as well as leaves.
Multilayered Tunica: More than one layer in thickness.

- The outer layer differentiates into epidermis.
- The inner layers contribute to the leaf primordium and cortex.

(2) CORPUS

- The cells of corpus are larger than the cells of Tunica.
- They divide in different planes due to which the volume increases.

The cells derived from corpus give rise to PROCAMBIUM and GROUND MERISTEMS.

(a) PROCAMBIUM

- Composed of somewhat narrow, elongated cells containing dense cytoplasm.
- The cells are arranged parallel to the longitudinal axis of the stem.

Previous Year's Question

Root cap is formed by ___________.
(1) Dermatogen
(2) Calyptrogen
(3) Wound cambium
(4) Vascular cambium

Rack your Brain

How are the cells of meristem different from the rest of the cells of a plant?

- Procambium gives rise to primary phloem, primary xylem and intra-fascicular cambium between xylem and phloem (Gymnosperms and dicots).

(b) GROUND MERISTEM

- Composed of thin walled parenchymatous cells.
- Differentiates into pith in the center, pericycle, endodermis, cortex and hypodermis respectively towards the outer side.

MANTLE CORE THEORY

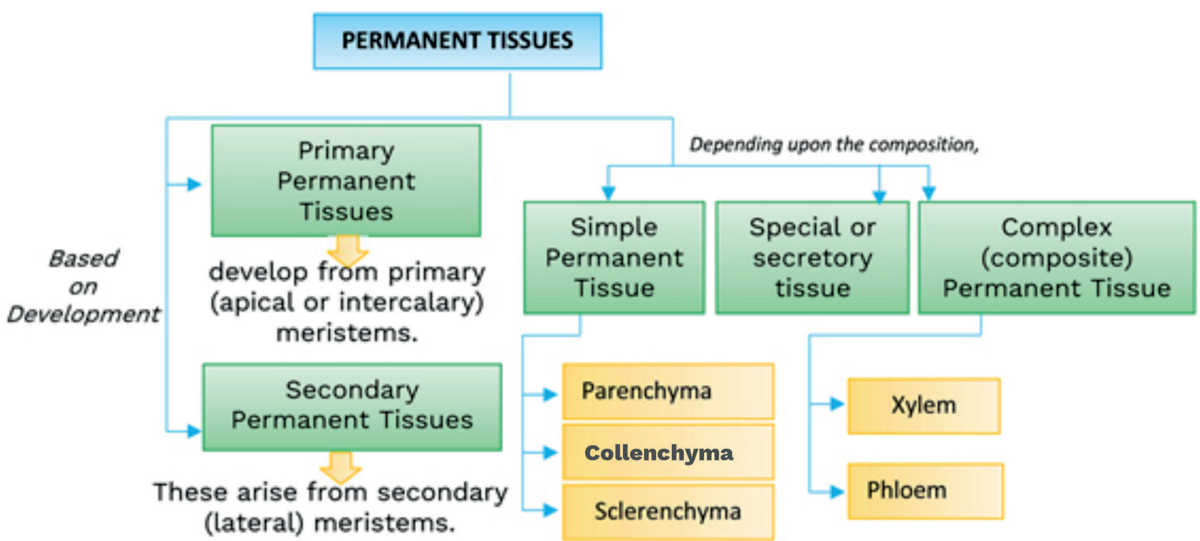
Put forward by Popham and Chan for Shoot Apex

- Here, 'MANTLE' is compared to Tunica.
- Corpus is compared with CORE.
- Core is divided into three regions:
    - Sub Apical Meristem: Present below the Mantle and regenerates damaged Mantle.
    - Central Zone Meristem: Inner-most region which develops pith.
    - Peripheral Meristem: Middle region that forms cortex, pericycle and vascular tissues.

PERMANENT TISSUES (Mature Tissues)

- A permanent tissue may be made up of similar or dissimilar cells.
- Have lost the capacity of division.
- Have attained a permanent shape and size by the process of differentiation.
- Cells may be living or dead.
- The cells are thin or thick-walled.
- The cytoplasm is vacuolated and dilute.
- Intercellular spaces may or may not be present.

Kinds of Permanent Tissue:



I. SIMPLE PERMANENT TISSUES:

A simple permanent tissue is homogeneous in nature viz. made up of similar types of permanent cells.

These carry out the same or similar set of functions.

Types of Simple Permanent Tissues:

- Parenchyma
- Collenchyma
- Sclerenchyma

(a) Parenchyma

- It is made up of thin-walled, isodiametric (equal diameter) living cells. The cells may be oval, rounded or polygonal in shape.
- Cell wall is cellulosic, thin and elastic.
- Small intercellular spaces are generally present between the cells for exchange of gases. Plasmodesmata are commonly present.
- Each mature parenchyma cell has peripheral cytoplasm due to the presence of a large vacuole and nucleus shift towards the periphery.
- Parenchyma occurs in non-woody or soft areas of the plant organs.
- It is also called fundamental tissue as it forms the ground tissue in which the other plant tissues are embedded.

Functions of Parenchyma

- Storage of food
- Provides turgidity.

Modified Parenchyma

- Chlorenchyma
- Prosenchyma
- Aerenchyma
- Xylem parenchyma and phloem parenchyma
- Storage parenchyma

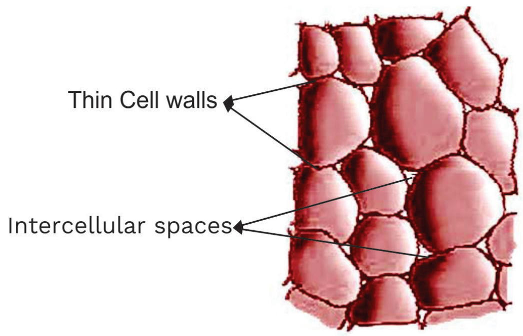
Previous Year's Question

Pistia floats on the surface of water due to the presence of __________ tissue in its petiole.

(1) Parenchyma
(2) Prosenchyma
(3) Aerenchyma
(4) Chlorenchyma

Definition

Permanent Tissue: A group of similar or dissimilar cells which has lost the capacity of division.



Functions of Modified Parenchyma:

(i) **Chlorenchyma**

Parenchyma cell may contain chloroplasts and takes part in photosynthesis. Such parenchyma cell is called chlorenchyma.

- The chlorenchyma of leaves is termed as mesophyll.
- Chlorenchyma of leaves of dicot plants is of two types:

(a) **Palisade Parenchyma:** Compactly arranged columnar cells.
Intercellular spaces absent
Abundant Chloroplasts

(b) **Spongy Parenchyma:** Loosely arranged spherical cells.
large intercellular spaces are present.
Number of chloroplasts is less than the palisade parenchyma.

(ii) **Prosenchyma**

- Parenchyma modified into fiber like extended, slightly thick-walled cells.
- It provides turgidity and strength.

(iii) **Aerenchyma**

- This parenchyma consists of loosely arranged cells with large air cavities.
- Aerenchyma stores air and provide buoyancy to the aquatic plants.
- Found in aquatic and some land plants (e.g., petiole of *Canna*, banana).
- (iv) **Xylem Parenchyma and Phloem Parenchyma**
- Associated with either xylem or phloem.
- They help in storage of food and lateral conduction of water and food.

(v) **Storage Parenchyma**

- It is specialized parenchyma that stores tannins, oils and calcium oxalate crystals.
- Cells of this parenchyma are called idioblasts.
- Idioblasts are enlarged isolated parenchyma cells that are different from the surrounding cells.

Definition

Chlorenchyma:
Parenchyma cells that contain chloroplasts and take part in photosynthesis.

Previous Year's Question

Palisade parenchyma is an example of ________.

(1) Parenchyma
(2) Chlorenchyma
(3) Aerenchyma
(4) Prosenchyma

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Schleiden (1839) coined the term 'Collenchyma'.

(b) Collenchyma

- It is made up of living cells which possess unevenly thickened cell walls.
- The thickening is made up of cellulose, pectin and hemicellulose.
- The cells are either isodiametric or somewhat elongated.
- They appear circular, oval or angular in transverse section. Each cell has a large central vacuole and peripheral cytoplasm.
- Collenchyma occurs below the epidermis in the petiole, leaves and stems of herbaceous dicots. It is prominent below the ridges.

Functions of Collenchyma:

It gives mechanical strength and elasticity to the organs.

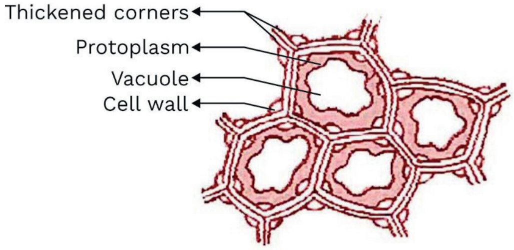
- Sometimes, collenchyma cells possess chloroplasts and are photosynthetic in function e.g., leaf petiole, epicarp of raw fruits.

(c) Sclerenchyma (Gk. *Scleros*-**hard**, *enchyma*-**tissue)**

- It is a simple permanent tissue of dead and highly thick-walled cells.
- The thickening of walls may be made up of cellulose or lignin or both.
- Several unlignified or unthickened area called pits are often present on the walls.
- At maturity, these cells lose protoplasmic contents and become dead.
- Often the thickening in the cells is more so, central cavity (lumen) is obliterated.

Rack your Brain

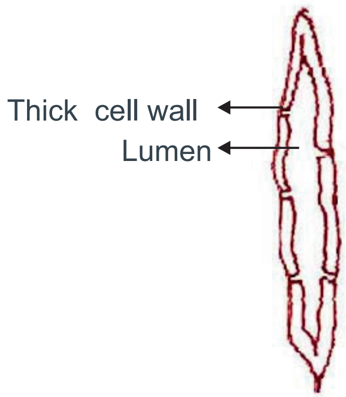
Which type of permanent tissue is found in Sapota?



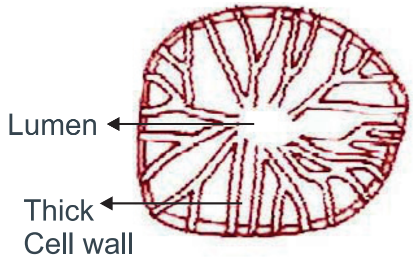
Collenchyma Tissue

Gray Matter Alert!!!

Mettenius (1805): Discovered and gave the term 'Sclerenchyma'.



Fibre



A sclereid

Function of Sclerenchyma

Sclerenchyma is the chief mechanical tissue in plants and can tolerate all types of physical stress.

Types of Cells in Sclerenchyma

It has two types of cells: sclerenchyma fibres and sclereids.

(i) **Sclerenchyma Fibres:**
- Elongated, narrow, spindle shaped, thick-walled cells.
- Pointed or tapering ends.
- Occur in longitudinal bundles (They may also occur singly among other cells).
- Generally, 1-2 mm in length. In special cases such as in hemp, they may attain a length of 90 cm.
- These are probably the longest cell in plants.

(ii) **Sclereids or Sclerotic cells**
- They are short, highly thick-walled, spherical or irregularly shaped sclerenchymatous cells.
- Their wall has branched or un-branched simple pits.
- Sclereids may occur singly or in groups.
- They are commonly present in hard coverings of seeds and nuts, endocarp of stony fruits and pulp of many fruits such as Guava, Pear and Sapota etc.
- The grittiness of the pulp in these fruits is due to the presence of sclerotic cells. Sclereids also occur in cortex, phloem, and pith of certain plants.
- They provide stiffness to the parts in which they occur.

Previous Year's Question

Sclereids belong to __________.

(1) Collenchyma
(2) Xylem
(3) Sclerenchyma
(4) Sclerenchyma fibres

Gray Matter Alert!!!

Fibres are present in the form of patches in the pericycle of dicot stems, cortex and bundle sheath of monocot stems and in xylem and phloem of stems.

Long fibres are of great commercial importance as they are the source of natural fibres like jute, hemp, coir etc.

Rack your Brain

Which type of permanent tissue is found in pods of legumes?

TYPES OF SCLEREIDS DEPENDING ON SHAPE AND SIZE

Brachysclereids or Stone cells	Unbranched, isodiametric with branched (ramiform) pits, e.g., grit of Apple, Pear, and guava.
Macrosclereids	Elongated and columnar or rod like, e.g., epidermal covering of legume seeds.
Osteosclereids	Bone-like columnar with dilated ends. e.g., sub-epidermal cells of some legume seeds.
Astrosclereids	Irregularly branched or star like e.g., leaves and petioles of some aquatic plants.
Filiform sclereids	Fibre-like and scantily branched e.g., *Olea*.

II. COMPLEX PERMANENT TISSUES

- A complex permanent tissue is composed of more than one type of cells which have lost the capacity of division.
- It works as a unit that aids in transportation of water, minerals and food.
- It provides mechanical support.

Definition

Complex permanent tissue is composed of more than one type of cells which have lost the capacity of division.

Types of Complex Permanent Tissue

Xylem

- It is also called wood and forms the bulk of the roots and stems of vascular plants.
- It is a conducting tissue and forms a continuous channel through the roots, stems, leaves, flowers and fruits.
- Conduction in xylem is unidirectional (from roots to the shoot)
- Xylem consists of different types of cells which may be both living (i.e., xylem parenchyma) and non-living (i.e., tracheids, vessels and xylem fibres)

Previous Year's Question

Living part of xylem is ___________.

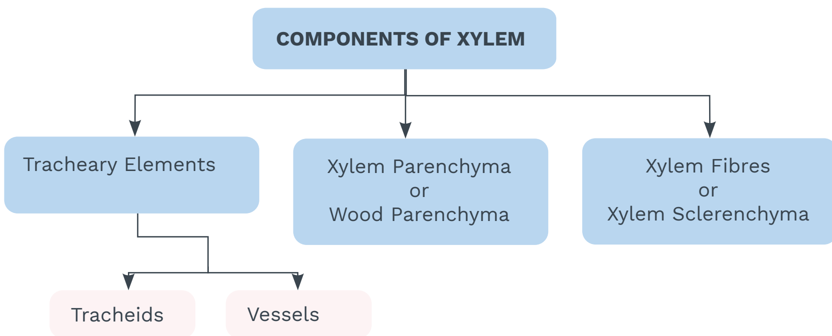
(1) Xylem tracheids

(2) Xylem vessels

(3) Parenchyma

(4) None of these

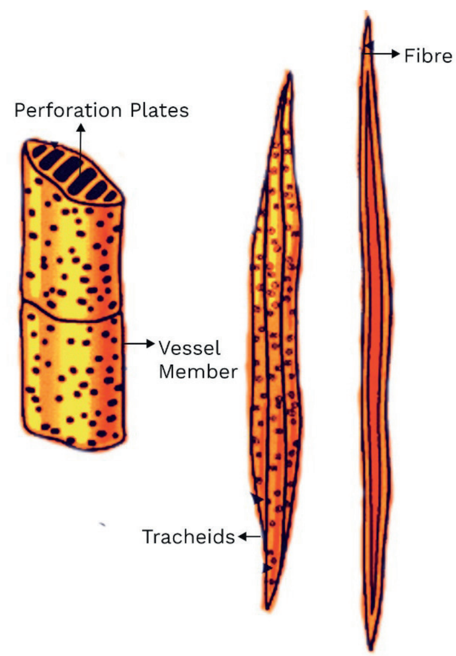
Components of Xylem



(i) **Tracheary Elements** (Xylem): Conducting elements of xylem are recognized as two types: Tracheids and Vessels.

(a) **Tracheids** (Dead Element)

- The tracheids are elongated, spindle shaped dead cells with narrow blunt ends.
- They possess hard lignified walls and wide lumen.
- The walls of tracheids have various types of thickening for mechanical strength. Unthickened areas on their walls allow rapid movement of sap from one cell to another.
- In angiosperms, only few tracheids are present.
- Gymnosperms have only tracheids.
- Tracheids conduct water and minerals in the plants.
- These also provide mechanical strength.



Xylem components

Types of Tracheids (Depending Upon Thickenings)**:**

(a) **Annular** – The thickening material (lignin) is deposited in the form of rings.

(b) **Spiral-**The thickening is laid down in the form of spiral or helix.

(c) **Reticulate –**The thickening is present in the form of a network.

Gray Matter Alert!!!

Harting (1839): Discovered sieve tube.

Sanio (1863): Discovered and gave the term Tracheid.

(d) **Scalariform-**The thickening is laid down in the form of transverse bands to give a ladder like appearance.

(e) **Pitted –**The thickening is uniform except small, unthickened areas called pits.

Pits in Xylem

- The pits are formed in pairs laying one against the other, and appear circular, oval or angular in surface view.
- The area of the primary wall and middle lamella present in between a pair of pits is called pit membrane or closing membrane.
- The pits have several sub-microscopic pores for the translocation of substances.

TYPES OF PITS

- Simple Pits ⇩ Uniform width of the cavity or pit chamber
- Bordered Pits ⇩ The pit cavity is broader towards the base with a narrow opening. The pit membrane of bordered pit develops a swelling in the middle called TORUS. It helps in the regulation of the movement of substances.

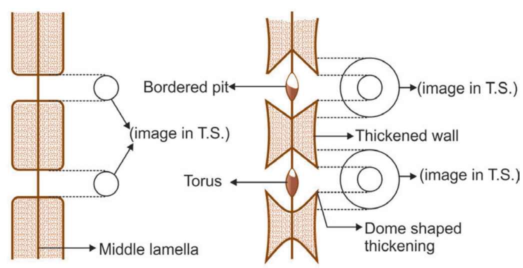
(b) **Vessels or Tracheae (Dead element)**

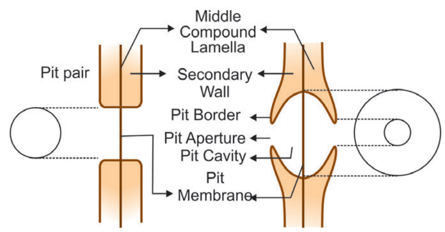
- These are much elongated, tubular channels with wide lumen.
- The vessel elements are joined end to end and have perforated end walls.
- The perforated end walls are called perforation plates.
- The wall of vessels is lignified.
- Vessels help in quick movement of water and minerals.
- Vessels also provide mechanical strength.

Previous Year's Question

Vessels and fibres occur in __________.

(1) Xylem of angiosperms
(2) Xylem of gymnosperms
(3) Xylem of pteridophytes
(4) All the above





Gray Matter Alert!!!

Xylem vessels are absent in Gymnosperms.

- The vessels are rounded in monocots and polygonal in dicots, in cross-section.
- Vessels are present in angiosperms only.

Types of Perforation Plates in Vessels

- **Simple Perforation Plate**: When the vessel has a single large opening at its ends.
- **Multiple Perforation Plate:** In few angiosperms, the end wall of vessel bears several perforations e.g., *Magnolia*.

Types of Thickening in Vessels

- Annular
- Spiral
- Reticulate
- Scalariform
- Pitted (Most common type of thickening in vessels)

1. **Xylem or Wood parenchyma (Live Component)**

- Parenchymatous cells associated with xylem.
- They may be thin-walled or thick-walled with simple pits.
- Assists in the lateral conduction of water or sap.
- Xylem parenchyma stores food.

2. **Xylem or Wood fibres (Dead Component)**

- These are sclerenchymatous fibres.
- Elongated, thick-walled and have narrow lumen.
- Provide mechanical support.

Types of Primary Xylem

Based upon origin, and internal structure:

1. **Protoxylem** (Gk, *protos*-first, *xylem*-wood): First formed xylem.
   It is made up of small tracheids and vessels, thickening is usually annular or spiral.
   Thickenings start much before the complete formation of xylem vessel.
2. **Metaxylem** (Gk, *meta*-after, *xylem*-wood): The later formed xylem.

Previous Year's Question

Which pair has lignin ________.
(1) Tracheids & collenchyma
(2) Sclerenchyma & sieve tube
(3) Sclerenchyma & tracheids
(4) Parenchyma & endodermis

Rack your Brain

What is a common feature between vessel and sieve tube elements?

It consists of larger tracheids and vessels, thickening may be reticulate, scalariform and pitted.
The thickening of cell walls occurs after complete elongation of the xylem cell.

Types of Xylem: (Based upon the position of protoxylem in relation to metaxylem)

1. **Exarch**- Protoxylem lies towards the outer side of metaxylem e.g., as in roots.
2. **Endarch-**Protoxylem occurs towards the inner side of metaxylem e.g., as in stems.
3. **Mesarch-**Protoxylem is present in the middle of metaxylem e.g., ferns.

Previous Year's Question

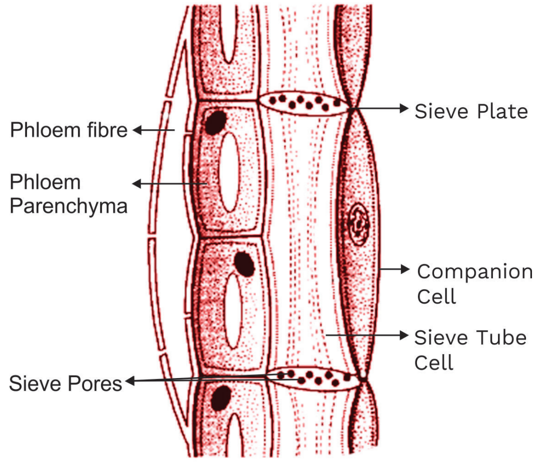
Protoxylem is towards pith and metaxylem towards periphery, the xylem is ________.
(1) Exarch
(2) Endarch
(3) Mesarch
(4) Centrach

Phloem

- Also known as bast or laptone.
- Phloem is a 'live' complex permanent tissue.
- It helps in the translocation of food materials within the plant.
- Translocation of food is bidirectional, from source to the sink and *vice-versa*

COMPONENTS OF PHLOEM

- Sieve Tubes
- Companion Cells
- Phloem Parenchyma
- Phloem Fibres



Phloem Elements

1. **Sieve Elements:** They are the main food conducting elements and are recognized into two types-Sieve tubes and Sieve cells.

Sieve tubes (live component)

- They are elongated tubular channels.
- Each sieve-tube is made up of several cells called sieve-tube members, joined end to end.
- Their end walls are generally bulged out and may be oblique or transverse.
- The end walls have many large pores or sieve pits and are known as sieve plates.

- At maturity, the sieve pores become impregnated with callose.
- The protoplasts of the adjacent members relate to each other through the pores of sieve plates.
- Each sieve tube is always associated with companion cells.
- A mature sieve element (sieve cells or sieve tube) has a peripheral cytoplasm without nucleus. Though nucleus is present in young developing sieve cells.
- The central part of the sieve element is occupied by a network of canals containing fibrils of a special protein called p-proteins (p-phloem).
- During wounding along with callose, p-proteins help in sealing.
- Sieve elements take part in the transport of organic food.

Previous Year's Question

Companion cells are usually seen associated with __________.
(1) Fibres
(2) Tracheids
(3) Vessels
(4) Sieve tubes

Sieve Cells

- Found in non-flowering plants viz. Pteridophytes and Gymnosperms.
- These are elongated cells having several perforated areas called **Sieve Areas,** throughout the lateral walls and end walls.
- Unlike Sieve tubes, Sieve cells are not present in linear rows.
- The companion cells are not present with the sieve cells.

Gray Matter Alert!!!

Sieve Cells are found in Gymnosperms and Pteridophytes. In these plants, Sieve tubes are absent.

2. Companion Cells (Live component)

- Elongated thin-walled parenchymatous cells that lie on the sides of the sieve tubes.
- Through plasmodesmata (present on their common longitudinal walls), these are closely associated with the sieve tubes. These have dense cytoplasm and prominent nuclei.
- The nuclei of companion cells control the metabolic activities of sieve tubes through plasmodesmata.
- The companion cells also play an important role in the maintenance of pressure gradient in the sieve tubes.

- Companion cells are present in angiosperms only. They are replaced by modified parenchyma cells (called albuminous cells) in non-flowering plants.

3. Phloem Parenchyma

- These are ordinary parenchyma cells, which are intermingled with sieve element.
- These store food and assist in the conduction of food, in lateral direction.
- Phloem parenchyma is absent in most of the monocots and some herbaceous dicots.

4. Phloem Fibres (Bast Fibres)

- Sclerenchymatous fibres.
- Provide mechanical strength.
- These occur in groups as sheets or cylinders.
- The textile fibres of flax, hemp and jute are phloem fibres.
- They are obtained after retting the plants in water and are used for making ropes, twines, threads, and course textiles.

Protophloem: This is the outer portion of the phloem, consisting of narrow tube elements.

Metaphloem: This is the inner portion of the phloem, made up of broader sieve tube elements.

TISSUE SYSTEM

1. Epidermis

- Epidermis is usually single layered.
- It is Multilayered in the leaves of some tropical plants (e.g., *Ficus, Nerium* etc.) and in the velamen of the roots of epiphytic plants.
- Cuticle is present on the outer side of the epidermis of aerial parts of the plants made up of cutin.

Function of Epidermis (along with cuticle):

- Protects the inner cells against loss of water.
- Protects against mechanical injury.
- Protects from the attack of pathogens.
- Protects from leaching effect of rain.

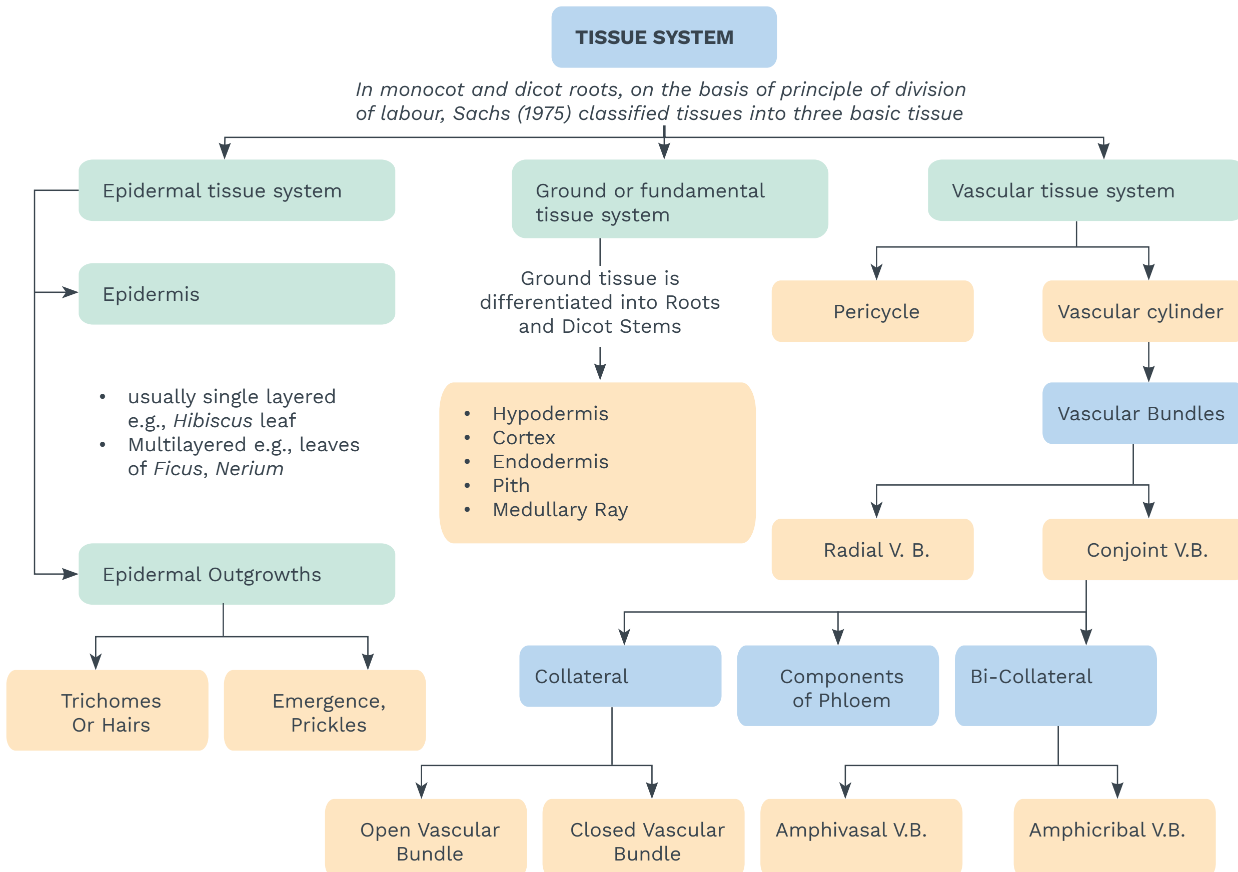
Rack your Brain

From which of the following , the phloem parenchyma is absent? Dicot root, dicot stem, dicot leaf, monocot leaf.

Previous Year's Question

Fibres associated with phloem are

(1) Hard fibres
(2) Wood fibres
(3) surface fibres
(4) Bast fibres



2. Epidermal Outgrowths

They are of two types.

(a) Trichomes or **Hairs:**

The epidermal hairs of aerial part of plants can be-

- Unicellular or Multicellular
- Branched or un-branched

Functions of Trichomes

- Protect the plant organs against water loss.
- Protect against sudden fluctuation in atmospheric temperature.

(b) Emergences or Prickles

- Multicellular
- Sharp and stiff epidermal outgrowths, which contain some inner tissues.

Previous Year's Question

Trichome takes part in __________.

(1) Transpiration and exchange of gases

(2) Protection and reduction of transpiration

(3) Exudation of water drops

(4) Desiccation

- They protect the plant against grazing and excessive loss of water.
- Prickles of some plants help in support e.g., Rose.

3. GROUND OR FUNDAMENTAL TISSUE SYSTEM

- Derived from ground meristems and forms a major part of the plant body.
- Includes all the tissues excluding epidermal and vascular tissues.

The Ground Tissue System in Roots and Dicot Stems

- Hypodermis
- Cortex
- Endodermis
- Pith
- Medullary Ray

The Ground Tissue System of Monocot Stems

- Hypodermis
- Ground Parenchyma

The Ground Tissue System of Dicot Leaves (Mesophyll)

It is differentiated into two types of photosynthetic tissues in dicot leaves

- Palisade Parenchyma
- Spongy Parenchyma
- In monocot leaves mesophyll is made up of same type of cells.

4. VASCULAR TISSUE SYSTEM.

- Pericycle is a constituent of Vascular tissue system and is the outermost layer of Vascular tissue cylinder.
- The endodermal cells of roots possess strips or bands of thickening made up of suberin called casparian strips (Caspary, 1865).
- Among the thick-walled endodermal cells, few small, thin-walled cells opposite to protoxylem are found. These are called passage cells, helpful in the passage of water from cortex to xylem.

Gray Matter Alert!!!

In some plants, the hairs are glandular and secrete essential oil that provide characteristic odour to the plants e.g., *Citrus*. The epidermis of some plants bear stinging hair e.g., *Urtica* (Stinging Nettle).

Previous Year's Question

Casparian strips occur in
(1) Cortex
(2) Pericycle
(3) Epidermis
(4) Endodermis

- This vascular tissue system is derived from procambium.
- In higher plants (Gymnosperms and Angiosperms), the vascular tissue consists of distinct, small patches called vascular bundles prior to the secondary growth.
- Each bundle is made up of xylem and phloem with cambium (in stems of Gymnosperms and Angiosperms) or without cambium (in monocot stems) or only one kind of tissue-xylem or phloem (in roots).

TYPES OF VASCULAR BUNDLES

(a) **Radial Vascular Bundle** (In monocot and Dicot Roots)

Radial vascular bundles are the most primitive type of vascular bundle.

The xylem and phloem form separate bundles and lie on different radii.

(b) **Conjoint Vascular Bundle**

The vascular bundles which contain both xylem and phloem are called conjoint vascular bundles. In this type, xylem and phloem are arranged on the same radius.

Types of Conjoint Bundles: Collateral, Bi-Collateral and Concentric.

(i) **Collateral**

A conjoint bundle with xylem towards the inner side facing the pith and phloem towards the outer side facing the cortex, is called **collateral bundle.**

- **Open Vascular Bundle:** When in a collateral bundle, a strip of cambium is present between xylem and phloem, the bundle is called open bundle, e.g., stems of Gymnosperms and most dicots.
- **Closed Vascular Bundle**: When a collateral bundle is without a strip of cambium, it is said to be closed bundle, e.g., monocot stems.

Definition

Vascular bundle: Xylem and phloem constitute a vascular bundle in plants.

Previous Year's Question

Secondary growth does not occur in monocots as their vascular bundles are -

(1) Radial
(2) Scattered
(3) Enclosed by sclerenchyma
(4) Closed

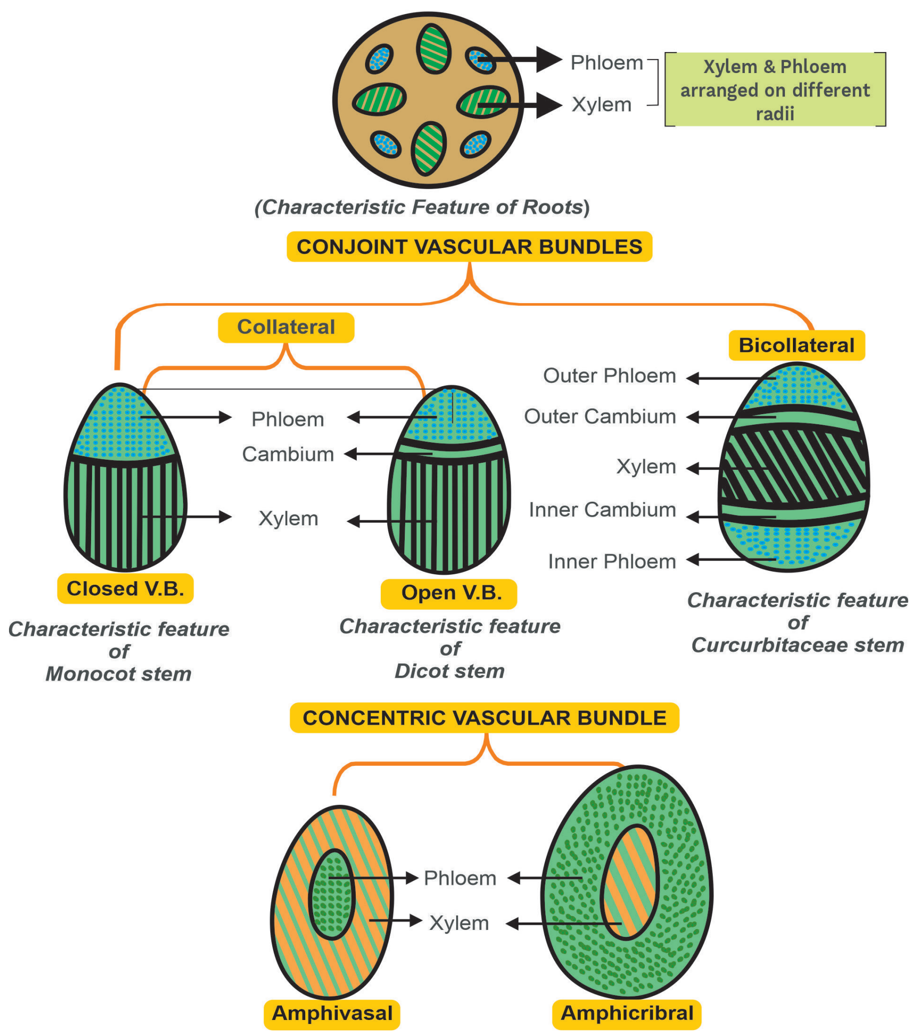
(ii) **Bi-Collateral**

- When a conjoint bundle has phloem both on the outer and inner side of xylem, usually a strip of cambium is present on both outer and inner sides of xylem.
- Bicollateral bundles are characteristic of family Cucurbitaceae.
- They also occur in families Solanaceae, Convolvulaceae etc.

Previous Year's Question

Bicollateral bundles occur in stem of __________.

(1) *Dracaena*
(2) Pumpkin
(3) *Canna*/gram
(4) Sunflower



(iii) **Concentric**

- When one kind of vascular tissue (xylem or phloem) forms a solid core, while the other surrounds it completely on all sides, the vascular bundle is called concentric.
- A strip of vascular cambium is always ABSENT in concentric bundles.

Types of Concentric Bundles

Amphicribal (Hardocentric)

- Xylem forms a central core, while phloem surrounds it on all sides.
- It occurs in some aquatic Angiosperms and staminal bundles of anthers.

Amphivasal (Leptocentric)

- Phloem forms a central core, while xylem surrounds it on all sides.
- It occurs in some aquatic angiosperms and staminal bundles of anthers.

ANATOMY OF ROOT

- **Young Dicot Root** (Primary Dicot Root)
  A young dicot root, which possesses only primary tissue is called primary dicot root. The primary internal structure of a dicot root can be studied from transverse section of a young root of gram.

1. **Epiblema or Piliferous layer**
   - It is the outermost layer of the root.
   - It is made of completely arranged thin walled flattened and slightly elongated living cells.
   - It is typically uniseriate and lacks the cuticle and stomata.
   - Some cells of the epiblema give rise to thin-walled tubular outgrowths called root hair.
   - Due to the presence of the root hair, epiblema is also known as piliferous layer (L. *pilus*-hair, *ferse*-to carry).
   - The root hair markedly increases the absorbing surface of root.

Previous Year's Question

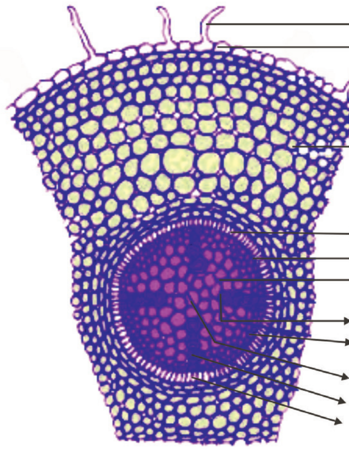
Amphivasal or leptocentric vascular bundles are found in __________.

(1) *Cycas* and *Dryopteris*
(2) *Dracaena* and *Yucca*
(3) *Helianthus* and Cucurbita
(4) Maize and wheat

Rack your Brain

Sunflower plant is a dicot plant still it does not show secondary growth. State the possible reason.

- The root hair lies in between the soil particles and thus always remain in contact with the soil water.
- Root hairs possess a gummy pectin layer on the outside for cementing with soil particles and retaining water on their surface.
- The root hairs commonly live only for few days and die off in older parts of the root.
- The older epiblema cells become suberised and cutinized.



T.S. Dicot Root

2. Cortex

- It is next to the epidermis consists of several layers of thin walled Parenchymatous cells with conspicuous intercellular spaces.
- The cells of cortex store food.
- Cortex also conducts water from the epiblema to the inner tissues.

3. Endodermis

- It is the innermost layer of the cortex.
- It is made up of a single layer of barrel-shaped cells which do not enclose intercellular spaces. The endodermal cells are living and are rich in starch grains.
- They possess characteristic bands of thickening along their radial and tangential walls.
- These are called casparian bands or casparian strips (after Caspary 1885.)
- The casparian strips are made up of suberin and lignin (Esau, 1965).
- Casparian strips prevent plasmolysis of endodermal cells and do not allow wall to wall movement of substance between cortex and pericycle.
- The cells of endodermis, laying opposite the

Definition

Casparian Strips: The endodermal cells of roots have deposition of suberin and lignin on their radial and tangential walls, forming a characteristic pattern of thickening called casparian strips (after Caspary 1885) protoxylem are thin-walled to permit free passage of water and minerals from cortex into the xylem. These are called passage cells.

4. **Stele**

- The world stele is derived from Greek language which means 'Pillar'.
- All tissues inside the endodermis comprise the stele.
- In consists of pericycle, vascular bundles, pith and medullary rays (if present).
- In seed plants i.e., Angiosperms and Gymnosperms, the stele is called eustele.
- In eustele, the vascular bundles are arranged in one or more rings.
- In monocot stems vascular bundles are scattered. Such a stele is a variant of eustele.

(i) **Pericycle**

- It lies inner to the endodermis and consists of thin-walled parenchyma cells.
- It is generally uniseriate but may be multiseriate.
- Pericycle forms the outer boundary of primary vascular cylinder.
- Pericycle is absent in the root of parasites and some aquatic plants.
- The pericycle is a very important layer in the roots as all the lateral roots, cork cambium and a part of vascular cambium arise from the pericycle.

(ii) **Vascular strand**

- It consists of separate bundles of xylem and phloem arranged alternately inner to the pericycle.
- Thus, the xylem and phloem bundles are equal in number and lie on different radii. Such vascular bundles are called radial bundles.
- The number of xylem or phloem bundles

Definition

Stele : The cells that lie in the centre of dicot stems, dicot roots and monocot roots constitute stele, it is bound by pericycle.

Previous Year's Question

Endodermis is part of ________.
(1) Epidermal system
(2) Interstellar tissue
(3) Extrastellar tissue
(4) Vascular tissue

may vary from two to six and very rarely up to eight.

- Based upon the number of xylem bundle, the root may be diarch (with two xylem bundles, e.g., tomato), triarch (with three xylem bundles e.g., pea), tetrarch (with two xylem bundles, e.g., sunflower), pentarch (with five xylem bundles) and polyarch (with more than five xylem bundles.).
- Each xylem bundle consists of the first formed xylem-the protoxylem towards the periphery, and the later formed xylem-the metaxylem towards the centre of the root. Such a xylem is called exarch and is a characteristic of root.
- The metaxylem elements of different bundles, meet in the centre to form a solid star-shaped structure. In such case, pith is absent (e.g., sunflower).
- However, in some cases, the metaxylem elements of different xylem may lie separate from one another so that a small pith is present in the centre of the root (e.g., gram, bean).
- Xylem elements appear polygonal in transverse section. Xylem conducts water and mineral salts to the shoot and provides mechanical strength.
- Phloem consists of sieve tubes, companion cells and phloem parenchyma.
- In some roots, each phloem bundle is provided with a few sclerenchyma cells towards the outer side.
- Phloem conducts organic food from shoot to the root along with its branches as well as to the upper parts too, so translocation of food is bidirectional.

(iii) **Pith**

- It is often absent.

Definition

Protoxylem is the first part of the primary xylem that has xylem vessels of narrow lumen

Definition

Metaxylem differentiates after protoxylem that has xylem vessels of broad lumen.

TYPES OF STELE IN PTERIDOPHYTES

- **Protostele**
  - Haplostele
  - Actinostele
  - Plectostele
  - Mixed protostele
- **Siphonostele or medullated stele**
  - Ectophloic
  - Amphiphloic
  - Equistelic siphonostele
  - Solenostele
  - Dictyostele
  - Polycyclic stele

Previous Year's Question

Endodermis of dicot stem is also called ________.

(1) Bundle sheath
(2) Starch sheath
(3) Mesophyll
(4) Water channel

- If present, the pith is quite small and made of parenchyma cells.
- Intercellular spaces are absent, and the cells store food as well as waste materials.

MONOCOT ROOT

A transverse section of monocot root consists of following tissues from outside to the centre.

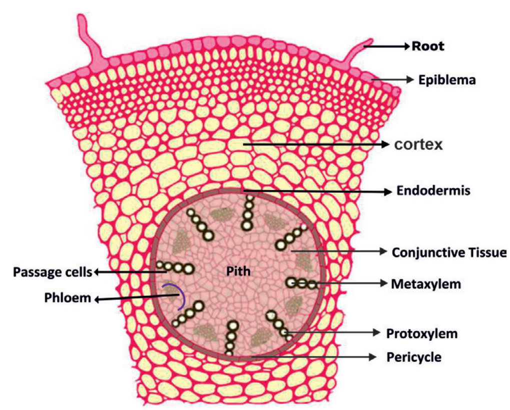


Fig. T.S. of Monocot Root

1. **Epiblema or Piliferous layer**

- It is the outermost layer of thin-walled living cells.
- It is typically unicellular in thickness and lacks the cuticle.
- Some of its cells give rise to root hair.
- Root hairs have pectic layer on their outer surface to bind the soil particles and are also useful in water retention.
- They take part in absorption of water and mineral salts.
- In older part of the root, the root hair dies off and the epiblema becomes impervious.

2. **Cortex**

- It lies inner to epiblema and consists of several layers of parenchymatous cells having intercellular spaces.
- It is a much wider region.
- In older roots, the outer few layers of cortex become thick walled and suberised.
- They constitute the exodermis.
- The cortical cells store food, conduct water and minerals from the root hair to the inner tissues.
- The exodermis takes over the function of protection in older roots, when epiblema decays.

(a) **Endodermis**

- It is the innermost layer of cortex.
- It is made up of compactly arranged barrel-shaped cells.
- The young endodermal cells possess an internal strip of suberin, and lignin called as casparian strip. It soon becomes indistinguishable due to the additional thickening of the endodermal cells.
- The endodermal cells opposite the protoxylem groups, remain thin walled and are called passage or transfusion cells.
- They allow the conduction of the sap from the cortex to the inner tissues.

(b) **Stele** The tissues inside the endodermis constitute stele. These include pericycle, circular strands and pith.

(i) Pericycle

- It is the outer boundary of vascular strand and lies below the endodermis. Pericycle may be uniseriate (single layered, e.g. Maize) or multiseriate (multilayered, e.g., *Smilax*), and is composed of thin-walled parenchymatous cells.

Definition

Passage cells: Unsuberized cells in the endodermis of stem that lie opposite to xylem strands.

Rack your Brain

What is the term used for the waxy coating on the epidermis of young stem?

- In many older roots, some of the pericycle cells become thick-walled.
- In monocot roots, the pericycle produces only lateral roots.

(ii) Vascular strand

- It consists of alternately arranged radial bundles of xylem and phloem.
- The number of these vascular bundles is quite large i.e., always eight or more.
- Thus, the root is polyarch. The vascular bundles are arranged around a large central pith.
- The xylem bundles are exarch i.e., protoxylem lies towards the outside and metaxylem face inwards.
- Xylem is made up of rounded or oval vessels.
- It provides mechanical strength and helps in the conduction of water and minerals.
- The phloem bundles alternate with the xylem bundles.
- The phloem and xylem bundles are separated from each other by means of parenchymatous or sclerenchymatous conjuctive tissue.
- If cells of conjunctive tissue are parenchymatous, then it stores food.
- If cells of conjuctive tissues are sclerenchymatous, then they provide mechanical strength.
- Phloem consists of sieve tubes and companion cells. It helps in the conduction of organic food.

Gray Matter Alert!!!

There is no distinction between the internal structure of a young and old monocot root, since secondary growth is absent in the monocot roots.

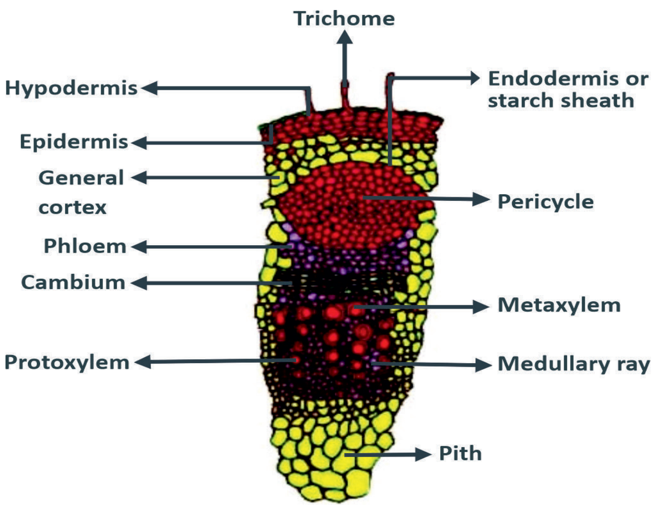
Pith

- It occupies the central part of the root.
- It consists of thin or thick-walled parenchymatous cells with intercellular spaces.
- Pith cells store food in the form of starch.

Anatomy of Young Dicot Stem (Primary Dicot Stem)

The primary structure of a dicot stem can be studied by observing a transverse section of young stem of sunflower (*Helianthus annuus*), it appears circular in outline.

The plan of arrangement of various tissues from periphery to the centre is as follows:



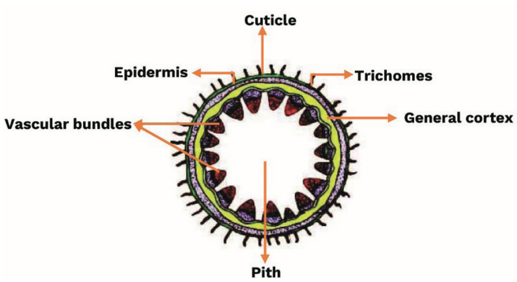
T.S. of Dicot Stem (Cellular diagram)

1. **Epidermis**

- It is the outermost layer of the stem.
- It is made up of tangentially flattened, closely fitted parenchymatous cells, which appear rectangular in a transverse section.
- The cells are transparent and devoid of chloroplasts.
- The outer walls of the epidermal cells are thickened and cutinized.
- The cutin usually forms a distinct non-cellular

Rack your Brain

How is xylem cavity formed in monocot plant?



T.S. of Dicot Stem
(Diagrammatic Sketch)

Previous Year's Question

Which of the following is not a part of epidermal tissue system ________.

(1) Trichome
(2) Companion cells
(3) Guard cells
(4) Subsidiary cells

layer on the outside, called cuticle.

- At places, the epidermis contains minute pores called stomata. Stoma or stomata is guarded by two kidney shaped guard cells.
- The epidermis also possesses several un-branched multicellular hairs or trichomes on its surface.

FUNCTIONS OF EPIDERMIS IN AERIAL PARTS

- protection of internal tissues
- prevention of entry of harmful organisms
- reduction in surface transpiration because of the presence of cuticle.
- exchange of gases through stomata.
- protection against sudden change in temperature with the help of surface hair.

Functions of Epidermis

Rack your Brain

According to Haberlandt, which is the conductivity part of phloem?

2. Hypodermis

- Collenchymatous, present below the epidermis.
- The cells possess extracellular thickening and contain chloroplast.
- Hypodermis provides mechanical strength and flexibility to the stem.
- It also prepares food if chloroplasts are present.

Definition

Hypodermis: It is Collenchymatous and is present below the epidermis.

3. Cortex

- It consists of few to several layers of parenchymatous cells and lies inner to the hypodermis.
- The cells may be rounded or angular and generally enclose intercellular spaces.
- In green stems, outer few layers of cortical cells may possess chloroplasts and thus participate in

food synthesis.

- Cortex also contains several oil ducts. Each oil duct consists of a channel, lined by an epithelium of small glandular cells, which secrete oil.
- The cortex is mainly concerned with the storage of food.

Endodermis

- It is the innermost layer of the cortex. It is a wavy layer of one cell thickness. The cells are barrel-shaped, parenchymatous and without any intercellular space.
- Casparian strips are absent.
- The endodermal cells contain abundant starch grains as food reserve.
- Therefore, the endodermis is called starch sheath.

4. Pericycle

- It is a few layered thick outer boundary of the vascular system and lies beneath the endodermis.
- The pericycle is made up a few layers of sclerenchymatous fibres alternating with parenchymatous cells. Sclerenchyma lies on the outside of the vascular bundles in the form of semi-circular patches called bundle caps.
- Each bundle cap is associated with primary medullary rays.
- The sclerenchymatous pericycle provides mechanical strength to the young stem.
- The parenchymatous pericycle stores food.

5. Vascular strand

- It consists of many vascular bundles, arranged in the form of a ring around the central pith and inner to the pericycle.
- The vascular bundle differentiates from procambium and are definite in number.
- They are obtusely wedge shaped.
- Each Vascular Bundle is Collateral, Conjoint and Open.

Previous Year's Question

A living mechanical tissue having cellulosic wall thickening is __________.

(1) Sclerenchyma
(2) Collenchyma
(3) Parenchyma
(4) Aerenchyma

Rack your Brain

What are the components of stele in a dicot root?

(i) **Phloem**

- It lies on the outer side of the vascular bundle towards the pericycle.
- Phloem consists of sieve tubes, companion cells, phloem parenchyma and phloem fibres.
- Phloem parenchyma helps in lateral conduction of organic food.
- Companion cells control the functioning of sieve tubes.
- Phloem fibres provide mechanical support.

(ii) **Xylem**

- It lies on the inner side of the vascular bundles, towards the pith.
- Xylem consists of tracheids, vessels, xylem parenchyma and xylem fibres.
- Out of these, xylem parenchyma cells are living.
- The xylem elements are arranged in radial rows and are polygonal in outline.
- The first formed xylem-the protoxylem is made up of narrow elements, lies towards the pith.
- The later formed xylem-the metaxylem consists of broader elements, lie towards the periphery.
- Xylem serves for the conduction of water and dissolved minerals from the roots to the aerial parts of the plant.
- It also provides mechanical strength to the stem.
- Xylem parenchyma also serves as the storage of food.

(iii) **Cambium (Intra-fascicular or fascicular cambium)**

- It is a narrow strip of meristematic cells that lies between the phloem and xylem of the vascular bundles.
- Cambium helps in secondary growth or increase in girth of the stem, by producing secondary phloem towards outside and

Definition

Xylem: It is a complex permanent tissue that transports water and minerals in a plant unidirectionally.

Previous Year's Question

Which one is not formed from procambium?

(1) Xylem
(2) Phloem
(3) Intrafascicular cambium
(4) Interfascicular cambium

Definition

Phloem: It is a complex permanent tissue that translocates food in a plant bidirectionally.

secondary xylem towards the inner side.

6. Medullary Rays or Pith Rays

- The regions between the vascular bundles that are occupied by parenchymatous cells are called medullary rays.
- The medullary rays help in radial conduction of food, water, minerals and gases from pith to the cortex and vice versa.

7. Pith or Medulla

- Present in the center of the stem, parenchymatous in nature with less intercellular spaces.
- The cells of pith store food.

Monocot Stem

The monocot stems show only primary structure. They do not have secondary growth.
A typical monocot stem such as maize (*Zea mays*) shows following tissues in transverse section.

1. Epidermis

- It is one-celled in thickness and is the outermost layer of stem.
- A distinct layer of cuticle is present on the outside, hairs are usually absent.
- Made up of small, compactly arranged, rectangular parenchymatous cells.
- The outer walls of epidermal cells possess deposition of silica and cutin.
- At places, the epidermis may possess stomata.
- Each stoma is guarded by two dumb-bell shaped guard cells.

2. Hypodermis

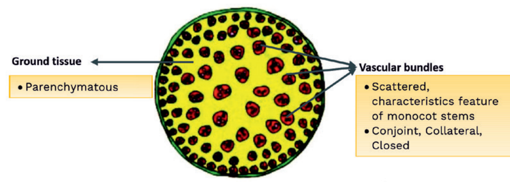
- It is made up of 2-3 layers of sclerenchyma fibres.
- It lies below the epidermis.

3. Ground Tissue

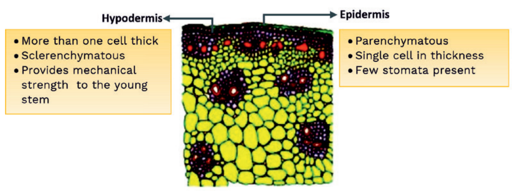
- It consists of a mass of thin walled parenchymatous

Definition

Stomata: Minute pores present on the leaf surfaces that help in transpiration and gaseous exchange.
These are also found on young and green stems.



T.S. of Monocot Stem (Diagrammatic sketch)



T.S. of Monocot Stem (Cellular diagram) cells and extends from hypodermis to the center of the stem.

- It does not show distinction into cortex, endodermis, pericycle and pith.
- The cells are small and angular towards the hypodermis but become large and oval in the inner region.
- Intercellular spaces are more.
- The ground tissue stores food.
- Some of the outer cells may also synthesize food due to the presence of chloroplast in them.

(a) Vascular strand

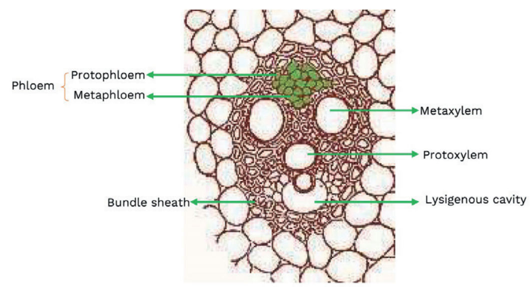
- Large number of vascular bundles lie scattered throughout the ground tissue.
- The vascular bundles are small but more in number towards the periphery.
- They are however, large, and more spaced towards the center.
- The vascular bundles are conjoint, collateral and closed.
- Each vascular bundle is surrounded by a sheath of sclerenchymatous cells called bundle sheath.
- Phloem consists of sieve tubes, companion cells and a few fibres.
- Phloem parenchyma is absent.
- Phloem is distinguished into outer proto-phloem and inner meta-phloem.
- The sieve tubes and companion cells helps in conduction of food.

(i) **Xylem**

- Consists of vessels, tracheids, xylem parenchyma and a few xylem fibres.
- In each vascular bundle, xylem occurs in the form of letter Y and is endarch (i.e., protoxylem lies towards the center of the stem).
- Metaxylem generally consist of two large oval or rounded vessels lying at the upper two angles of the xylem,

Rack your Brain

What are the positions of protoxylem and metaxylem in a dicot root?



Vascular bundle of monocot

Gray Matter Alert!!!

Phloem parenchyma is absent in the vascular bundles of monocot stem.

with polygonal tracheids in between them.
- Protoxylem consists of few small oval vessels.
- It lies at the lower angle of the xylem.
- Xylem parenchyma and few fibres are found just outside them.
- In a mature vascular bundle, some of the protoxylem vessels and the xylem parenchyma cells dissolve to form a water-containing cavity called lysigenous cavity or protoxylem cavity.
- The tracheids and vessels help in conduction of the sap and provide mechanical support.

Previous Year's Question

In floating leaved plant, stomata occur on __________.
(1) Lower surface
(2) Upper surface
(3) Both surfaces
(4) Absent

ANATOMY OF LEAF

A Typical Dorsiventral Leaf (Dicotyledonous Leaf)

A vertical section of typical dorsiventral leaf reveals the following structure:

1. **Epidermis.** The upper (adaxial) and the lower (abaxial) surface of the leaf are bound by upper and lower epidermis respectively.
   (i) **Upper Epidermis (Adaxial Surface)**
   - Single layered, made up of parenchymatous tightly packed, rectangular, barrel-shaped living cells.
   - Cells are achlorophyllous.
   - A distinct layer of cuticle lies on the outside of the epidermis.

   The cuticle prevents excessive transpiration and protects the epidermal cells from mechanical injury. Hair may be found in some cases.

   (ii) **Lower Epidermis (Abaxial Surface)**
   - Single layered, made up of parenchymatous, tightly packed, rectangular, barrel-shaped living cells.
   - Cells are achlorophyllous.
   - A distinct layer of cuticle lies to the outside of the epidermis.

Gray Matter Alert!!!

Dorsiventral or Dual face-leaves: These leaves are oriented horizontally with distinct upper and lower surface, receive unequal amount of sunlight on the two sides, so have distinct colors on their surfaces. Most of the dicotyledonous leaves are dorsiventral.

- The cuticle prevents excessive transpiration and protects the epidermis cells from mechanical injury. Hairs may be found in some cases.
- Dorsiventral leaves usually possess stomata only in lower epidermis. Such leaves are also called hypostomatic leaves.
- The lower epidermis contains many pores called stomata (singular - stoma).

Structure of stomata

- Each stoma has a narrow pore, surrounded by two special kidney-shaped or bean-shaped epidermal cells called guard cells.
- The guard cells possess chloroplasts and their inner concave walls are greatly thickened than the outer walls.

Rack your Brain

Why the stomata are found on lower surface of dicot leaves in general?

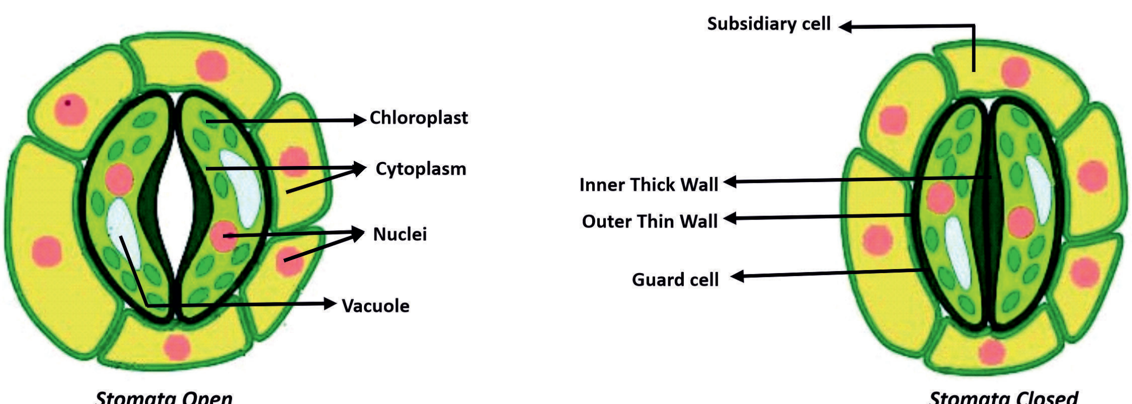


Fig. Stomata in Dicot Plant

- In many leaves, the guard cells are surrounded with two or more specialized epidermal cells called accessory or subsidiary cells.
- Transpiration and gaseous exchange

occurs through the stomata.

2. Mesophyll (Gk. *Meson*-middle, *phyllon*-leaf).

- Ground tissue of the leaf that lies between the two epidermal layers along with veins is mesophyll tissue.
- Parenchymatous and chlorophyllous
- Differentiated into two regions:
  - Upper palisade parenchyma (towards adaxial surface)
  - Lower spongy parenchyma (towards abaxial surface)

(i) **Palisade Parenchyma**

- It occurs beneath the upper epidermis, consists of 1-3 layers of columnar, closely packed parenchymatous cells.
- The cells of this layer have least intercellular spaces.
- Contains abundance of chloroplasts.
- The upper surface of the leaf is dark green.
- Palisade parenchyma is the main photosynthetic tissue of the plant.

(ii) **Spongy Parenchyma**

- It lies between the palisade parenchyma and lower epidermis.
- It consists of parenchymatous cells oval, rounded or somewhat irregular in shape, with large intercellular spaces.
- The large intercellular spaces allow the air to circulate freely throughout the interior cells of the leaf.
- The cells of spongy parenchyma contain few chloroplasts than the cells of palisade parenchyma.

3. Vascular system

- It consists of several vascular bundles of different sizes depending upon the venation in leaves(reticulate or parallel)
- The vascular bundles of the main vein are thicker than those of lateral veins.

Gray Matter Alert!!!

Similar Faced or **Unifacial leaves:** These are cylindrical leaves with no distinction into upper and lower sides e.g., Onion.

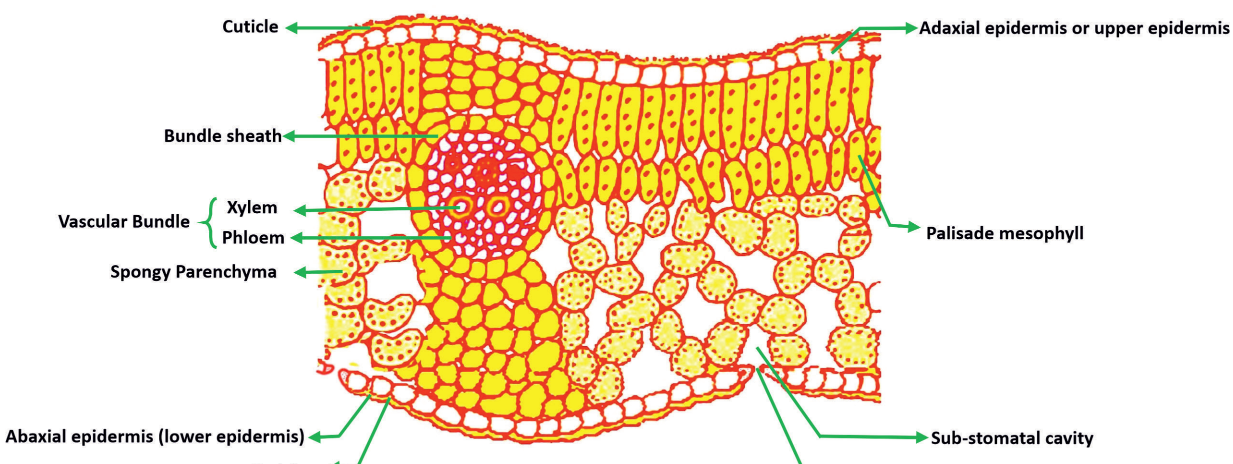
Rack your Brain

What are the positions of protoxylem and metaxylem in a dorsiventral leaf?

- The vascular bundles are generally located at the boundary between palisade and the spongy parenchyma.
- Each vascular bundle is surrounded by a sheath of compactly arranged parenchymatous cells called bundle sheath cells.
- Each vascular bundle is conjoint, collateral and closed.
- Xylem lies towards the upper (Adaxial) side of the leaf.
- Phloem occurs towards the lower (Abaxial) surface.
- The xylem consists of vessels, tracheids, xylem parenchyma and a few xylem fibres.
- Phloem consists of sieve tubes, companion cells and phloem parenchyma.
- Phloem fibres are generally absent.
- Phloem serves for the transport of food from the leaf to different parts of the plant.

Rack your Brain

Name a plant which has unifacial leaves.



T.S. of Dicot Leaf (Dorsiventral leaf)

- A few layers of sclerenchymatous fibres may occur on the outside of vascular tissues of a bundle.
- The sclerenchyma fibres are more abundant on the upper side just above the xylem. These provide mechanical strength to the leaf.

Isobilateral Leaf (Monocotyledonous Leaf)

A vertical section of monocotyledonous leaf (e.g., maize) reveals the following structure:

1. Epidermis

- Both epidermis are single layered, composed of compactly arranged more or less oval cells.
- The outer walls of the epidermal cells are cutinized.
- Some of the cells of upper epidermis are large, thin-walled and highly vacuolated called bulliform or motor cells.
- The bulliform cells play a crucial role in rolling and unrolling of the mature leaves w.r.t. environmental changes and prevent excessive transpiration.
- Stomata are present on both the upper and lower epidermis.
- Such a leaf is amphistomatic leaf.
- Each stoma is surrounded by a pair of dumbbell-shaped guard cells.
- The guard cells are further associated with a pair of epidermal cells called subsidiary or accessory cells that lie parallel to the guard cells.

2. Mesophyll

- Consists of thin-walled, isodiametric cells, intercellular spaces are present.
- Mesophyll is not differentiated into palisade and spongy parenchyma.
- Cells are chlorenchymatous and constitute the photosynthetic tissue of the leaf.

3. Vascular system

- It consists of vascular bundles of almost equal size.
- They are arranged at an equal distance, within the mesophyll.
- Vascular bundles are collateral and closed.
- In each vascular bundle, xylem lies towards the upper surface and phloem is towards the lower surface of the leaf.

Gray Matter Alert!!!

Isobilateral or Equal faced- leaves: These leaves are oriented in such a way that both the surface of the leaves are equally exposed to the sunlight. Such leaves possess uniform colouration on both upper and lower surfaces. Most of the monocot leaves are isobilateral.

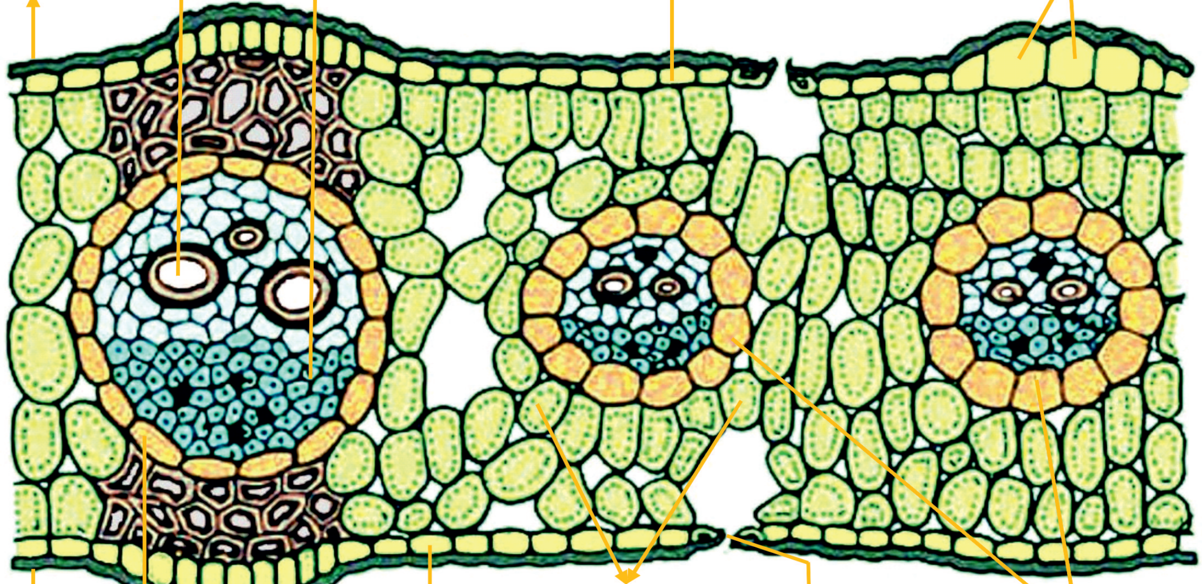
Definition

Motor cells: These are enlarged epidermal cells in monocot leaves and are also called bulliform cells .

Previous Year's Question

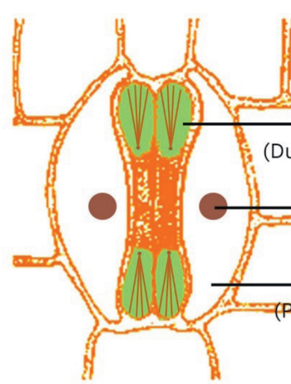
In monocots, the guard cells are __________.

(1) Dumb-bell shaped
(2) Reniform
(3) Spherical
(4) Isodiametric



T.S. of Monocot Leaf (Isobilateral leaf)

- Each vascular bundle is surrounded by parenchymatous cells called bundle sheath cells.
- Cells of bundle sheath contain chloroplasts and often starch grains.
- The larger vascular bundle shows sclerenchymatous bundle sheath extensions. They provide mechanical strength to the leaf.
- The arrangement of enlarged bundle sheath cells with centrifugally positioned chloroplasts is called Kranz anatomy. (Kranz means wreath, the bundle sheath cells and few associated cells resemble a wreath).



Monocot Stomata
(Gramineous Type)

Lenticels

- These are minute pores in the bark of woody plants for the exchange of gases.

- The lenticels appear on the bark of trees as raised scars that contain oval or rounded depressions.
- The lenticels are generally formed beneath the stomata of the primary epidermis.
- In the region of lenticels, the cork cambium instead of producing cork gives rise to loose parenchymatous cells called complementary cells.
- These complementary cells are thin-walled, rounded cells which enclose intercellular spaces for easy gaseous exchange.
- The margin of the lenticels is surrounded by the cork cells.
- In the plants of temperate region, the lenticels get closed during winter by the formation of compactly arranged closing cells over the complementary cells which duly get ruptured on the onset of new season.

Types of Stomata

1. **Anomocytic (irregular celled) or Ranunculaceous**: Stomata remain surrounded by limited number of subsidiary cells which resemble the rest of epidermal cells, e.g., *Hibiscus*.
2. **Amniocytic (unequal celled) or Cruciferous**: Stomata surrounded by three subsidiary cells, where two subsidiary cells are bigger and the third one is much smaller in size. e.g., yellow mustard, *Solanum.*
3. **Paracytic (parallel celled) or Rubiaceous**: Stomata surrounded by two subsidiary cells which are parallel to the guard cells, e.g., West Indian jasmine.
4. **Diacytic (cross celled) or Caryophyllaceous**: Stomata surrounded by two subsidiary cells, placed at right angle to the guard cells e.g., *Dianthus*.
5. **Antimycotic:** Stomata surrounded by four or more subsidiary cells, placed radially to the guard cells e.g., Banana.

Definition

Lenticels: These are minute pores in the bark of woody plants for the exchange of gases.

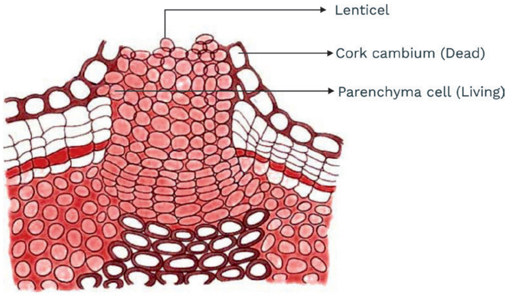
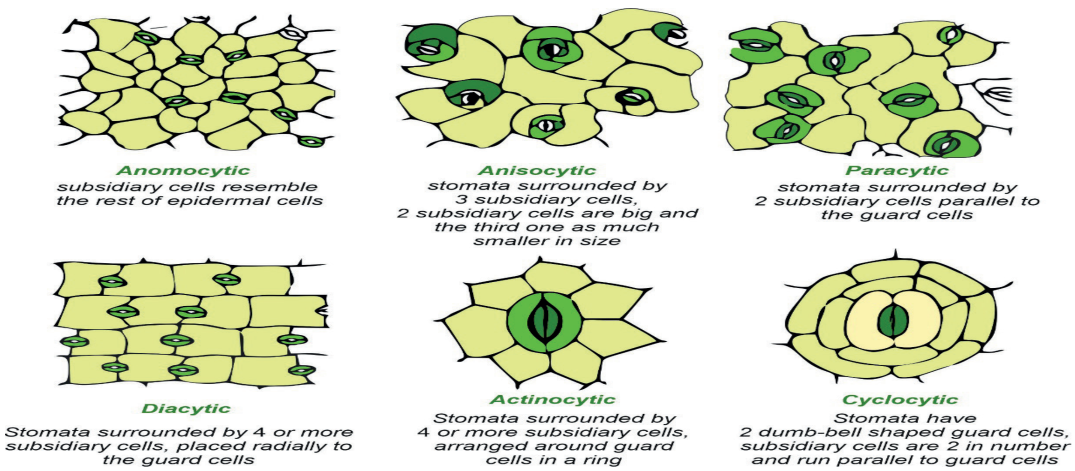


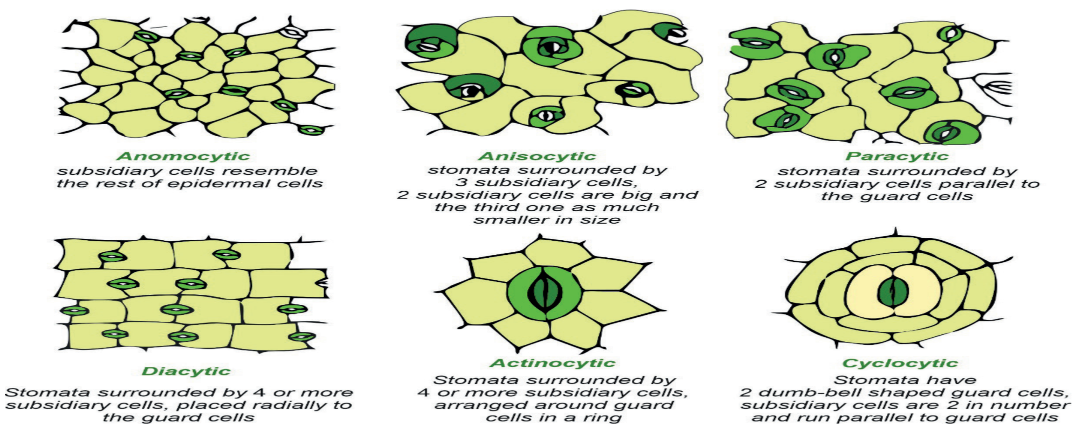
Fig. Lenticel

Previous Year's Question

Lenticels are __________.

(1) Scars on old stem
(2) Special stomata
(3) Aerating pores in bark
(4) Special stomata in hydrophytic plants





6. **Cyclocytic:** Stomata surrounded by four or more subsidiary cells, arranged around guard cells in a ring, e.g., *Pandanus*.
7. **Gramineous Type:** Stomata have two dumb-bell shaped guard cells, subsidiary cells are two in number and run parallel to guard cells, e.g., grass.

Hydathodes:

- It is a type of pore present at the margins of leaves.
- Hydathodes are made up of a group of parenchymatous cells with lots of intercellular spaces. These cells are collectively called an epithem.

Definition

Guttation: The process of removal of excess water in liquid state. It occurs through special structures called hydathodes in herbaceous plants found growing in shady areas

- Veins end into the epithem and open to exterior as pores found in submerged aquatic plants, herbaceous plants like, Water Lettuce, taro, water hyacinth, nasturtium.
- Cells of epithem either lack chloroplast or have few of them.
- Guttation: In some plants, excess water oozes out as water droplets through the hydathodes, this process is called guttation

Vascular Cambium

Vascular cambium is composed of two kinds of cells in flowering plants:

- Ray initials and Fusiform initials.
- Both of these cells look-alike in cross-section.
- In tangential section, Ray initials are short, small cells. Fusiform initials are long and narrow but less in length than in gymnosperms.
- In some dicots, these can be 0.5 mm in length.
- In Gymnosperms, fusiform initials can be several millimeters in length.

Cell division in fusiform initials is at the tangential walls and the cells are partitioned/divided in anticlinal plane, giving rise to two equally long, narrow cells.

- Tracheary elements (xylem vessels and tracheids) or sieve elements (Sieve tubes) differentiate from derivatives of the fusiform initials in secondary xylem and secondary phloem. Hence, these are adapted for long distance vertical transport of solutes.
- Fusiform initials also form wood fibres and xylem parenchyma cells in xylem.
- Ray initials differentiate as ray parenchyma and in ray tracheids in some conifers like ***Pinus*** and ***Larix***.
- Ray parenchyma cells of xylem parenchyma transport water from xylem radially, into the cambium and tissues of phloem as well as transport of photosynthate (secondary metabolites) from the phloem into the cambium

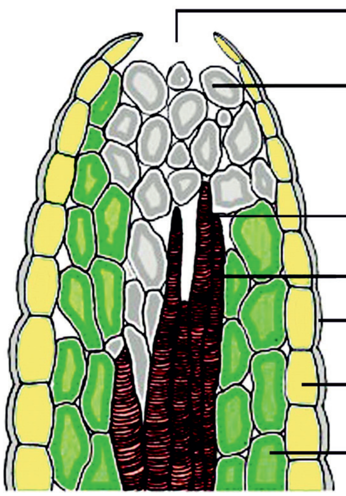


Fig. Hydathode

Gray Matter Alert!!!

Monocot plants like Palm and Joshua tree exhibit secondary growth. These plants possess thickened meristem.

and other living cells of xylem.

- This increases the girth of stem and forms additional vascular bundles in the later added secondary ground tissue.
- As soon as cambial cells stop dividing (except few cells) rest start differentiating.
- Stages in the development of secondary xylem are:
  - Cambial cell division
  - Cell expansion or cell elongation
  - Cell wall thickening
  - Cell modification (cell wall sculpturing)
  - Lignification
  - Cell death (cell autolysis)

SECONDARY GROWTH (Secondary Thickening)

- The increase in thickness or girth of the stem, root or branches, by the activity of vascular cambium and cork cambium is called secondary growth.
- The thickness of the stem is required to support the trees with increase in height and weight of the stem and its branches.
- This support is achieved by the addition of new tissues by the activity of lateral meristems- the fascicular or vascular cambium and cork cambium or phellogen.
- The tissues produced by the lateral meristems are called secondary tissues.
- Vascular cambium produces secondary vascular tissues.
- Cork cambium forms periderm.
- In woody plants, secondary tissues constitute the bulk of the plant.
- The secondary tissues take part in providing protection, support and conduction of water and minerals.
- Secondary growth is characteristic of dicotyledons and gymnosperms.
- Some exceptional monocotyledons (e.g., *Yucca* etc.) increase the thickness of their stem which occurs by a special form of secondary growth.

Definition

Secondary Growth: The increase in girth or thickness of root, stem and branches in perennial woody plants by the activity of vascular cambium and cork cambium.

Previous Year's Question

Secondary growth is absent in ________.

(1) Hydrophytes
(2) Mesophytes
(3) Halophytes
(4) Xerophytes

Secondary Growth in Dicot Stem

The secondary growth in a typical dicotyledonous stem involves the following steps:

1. Formation of Secondary Vascular Tissues

- In a young dicot stem, the vascular bundles are separate and are arranged in the form of a ring. A strip of cambium lying between the phloem and the xylem of each vascular bundle is called intrafascicular or fascicular cambium (primary meristem).
- At the time of secondary growth, the parenchymatous cells of the medullary rays lying in line with the fascicular cambium, become meristematic and form strips of secondary meristem called interfascicular cambium.
- The strips of intrafascicular and interfascicular cambium join with each other to form a complete ring of vascular cambium.
- The vascular cambium consists of two types of cells-fusiform initials and ray initials.
- The fusiform initials divide to produce secondary vascular tissue mother cells, which differentiate into secondary phloem towards the outside and secondary xylem towards the inner side.
- The secondary phloem and the secondary xylem are arranged in vertical rows.
- The ray initials give rise to ray cells (i.e., Phloem and xylem rays) which remain arranged in horizontal manner.
- During the secondary growth, each cambial cell (fusiform initial) divides by its tangential wall, both on the outer and inner sides.
- One of the two daughter cells thus produced remains cambial in nature(meristematic) and continues to divide.
- The other differentiate into secondary vascular tissue (either secondary phloem or secondary xylem).
- The daughter cells formed on the outer side of the cambium ring, mature into secondary phloem

Gray Matter Alert!!!

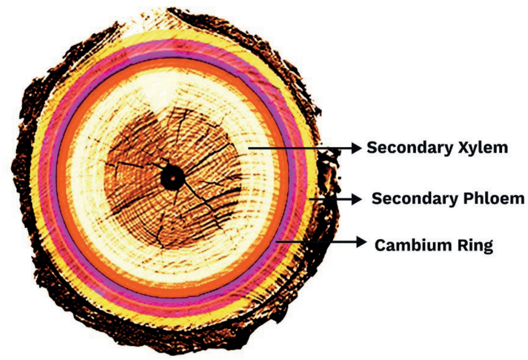
Many herbaceous dicot plants do not show secondary growth because cambium cannot form a complete ring and so the cambial activity is restricted only to the vascular bundles.

Definition

Heartwood: It is the central, dead and non-functional part of secondary xylem. Its vessel elements are plugged by tyloses and their lumen are clogged by other depositions.

and the one produced towards the inner side, mature into secondary xylem.

- The cambium adds more cells on the inner side (in comparison to outer side) due to this, cambium moves gradually to the outside.
- As the stem increases in thickness, some of the cambial cells divide by radial walls to increase the circumference of the cambium ring. This phenomenon is called dilation.
- Cambium exhibits two types of division- the additive (i.e., Periclinal divisions, forming the secondary vascular tissues) and the multiplicative (i.e., The anticlinal divisions bringing about an increase in the diameter of the cambium).
- Secondary xylem formed is more than the secondary phloem.
- The cells of secondary xylem are lignified and do not get crushed due to the pressure of the other tissue. But the cells of the secondary phloem being delicate, get partially destroyed.
- The primary phloem is completely crushed and appears only in the form of small strips outside the secondary phloem.
- The primary xylem is pushed into the pith.
- The pith becomes progressively narrow and may ultimately get destroyed with the increase in girth.
- The secondary phloem or bast forms a narrow circle outside the vascular cambium.
- It does not grow in thickness because the primary and the older secondary phloem present on the outer side get crushed with the development of new functional phloem.
- Secondary phloem is made up of sieve tubes, companion cells, phloem parenchyma and phloem fibres.
- Phloem parenchyma is of two types-axial phloem parenchyma formed by longitudinally arranged parenchyma cells and phloem ray parenchyma made up of radially arranged parenchyma cells



T.S. of Dicot Stem after Secondary Growth

Definition

Sapwood: Functional part of secondary wood and its vessel elements are neither plugged by tyloses nor their lumen are clogged by liquid wastes and depositions.

that constitute the part of the vascular ray present in the phloem.

- Phloem fibres occur either in patches or bands and are also called bast fibres or hard bast.
- The bast fibres are of great economic importance. Many of the natural fibres such as jute. Hemp, flax etc. are the bast fibres.
- The secondary xylem forms a continuous cylinder around the pith and constitutes major part of the trunk and woody branches, commonly called wood.
- The secondary xylem consists of vessels, tracheids, wood fibres and wood parenchyma.
- The wood parenchyma is of two types-axial parenchyma cells, arranged longitudinally and radial ray parenchyma cell, arranged in radial or horizontal fashion.
- The latter is the part of vascular rays present in the secondary xylem. The tracheary elements (Vessel and tracheids) possess scalariform and pitted thickenings.
- The vascular rays or secondary medullary rays are radially elongated parenchymatous cells, formed in the secondary vascular tissues.
- These are few cells in height and may be one cell or more than one cell in thickness.
- The part of the vascular ray present in the secondary xylem is known as xylem or wood ray, while the part present in the secondary phloem is called phloem ray.
- The vascular rays conduct water and organic food in radial direction.
- Vascular rays also help in storage of food and easy exchange of gases with the outer atmosphere.

2. FORMATION OF PERIDERM

(phelloderm + phellogen + phellem = periderm)

- The formation of secondary vascular tissues by the active vascular cambium, creates great pressure on the peripheral tissues (i.e., on the cortex and epidermis) of the stem.

Gray Matter Alert!!!

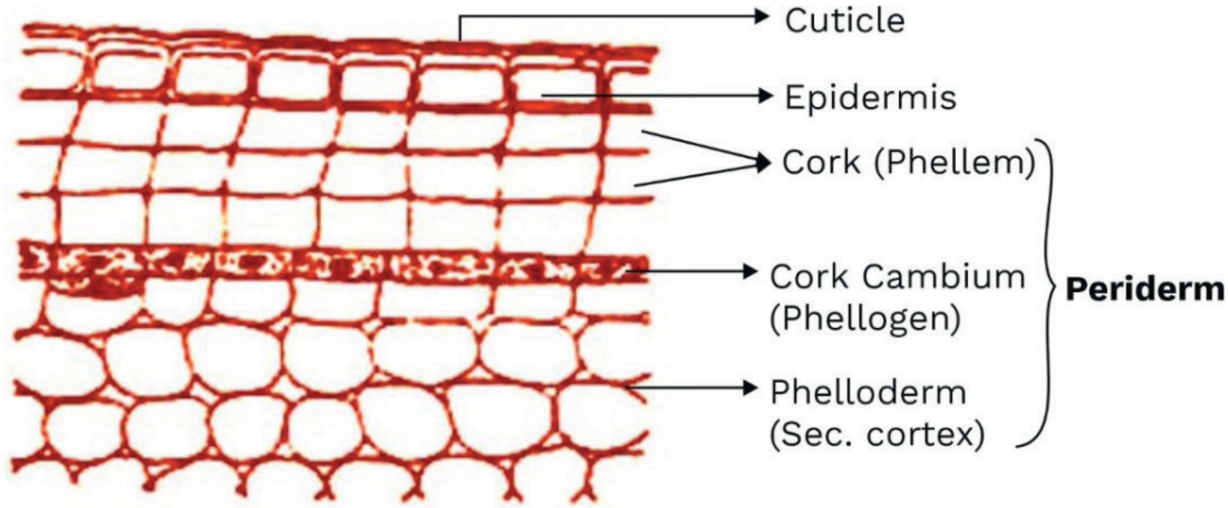
Cork is a peripheral waterproof tissue found in mature woody stems. It is produced by a lateral meristems-the cork cambium (phellogen). It is made up of dead cells with thick walls, impregnated with a waxy material, called suberin.
Commercial cork is obtained from cork of oak tree (*Quercus suber*) as sheets.

Previous Year's Question

Function of cork cambium is to produce__________.

(1) Secondary xylem and secondary phloem
(2) Cork and secondary cortex
(3) Secondary cortex and phloem
(4) Cork

- The epidermis along with some peripheral cortex get ruptured and no longer provide protection to the inner tissues



Periderm

- To protect the inner tissues, a layer of secondary meristems originates from the outer layer of cortex called cork cambium or phellogen.
- In some plants, it may arise from epidermis (e.g., Teak, *Nerium*), hypodermis (e.g., Pear) or deeper layers of the cortex. The cells of cork cambium divide on both outside as well as the inside (bipolar) to form secondary tissues.
- The secondary tissue produced on the inner side is parenchymatous or collenchymatous and is called secondary cortex or phelloderm.
- The cork cambium produces cork or phellem on the outer side.
- It consists of rectangular, thick-walled, dead cells arranged compactly.
- They have lignified and suberised walls.
- The cork cells of some plants are filled with air e.g., cork of oak tree (*Quercus suber*).
- The cork cells contain tannins, hence, appear brown or dark brown in colour.
- Being suberised, the cork cells are impervious to

Definition

Periderm: This is composed of phelloderm, phellogen and phellem.

water and are therefore, a source of bottle cork.

- The secondary tissue in the cortex consists of secondary cortex (Phelloderm), cork cambium (phellogen) and cork (Phellem).

Bark:

- It is the dead tissue, lying outside the cork cambium.
- It includes ruptured epidermis, hypodermis, and cork.
- The outer layers of bark are shed off due to the formation of new secondary tissue inside.
- The peeling of bark may occur in the form of sheets or irregular strips.
- The former is called sheet or ring bark and the latter is known as scaly bark.
- Bark acts as heat-absorbing screen and protects the inner tissue against microorganisms and insects.
- Bark of many plants is of commercial importance, e.g., Quinine, a drug for malaria is obtained from the bark of *Cinchona*.

Significance of Secondary Growth for a Plant:

- Secondary growth adds new conducting tissues by replacing old, less functional elements.
- Secondary growth adds to the girth of the plant and provides mechanical support to the increasing height of the branches and stem.
- Secondary growth produces a bark around the tree trunk that protects the inner tissue.

WOOD

- Wood is a complex secondary tissue that constitutes the bulk of the stem in gymnosperms and perennial dicotyledonous plants. It is the major product of plant biochemical processes.
- Botanically, the term wood is applied to the secondary xylem formed by vascular cambium during secondary growth.

Definition

Spring Wood: Formed during favourable environmental conditions i.e. spring season. It has xylem vessels with wider lumen and makes major part of an annual ring.

Rack your Brain

Catechu applied on the betel leaf anatomically is ____________.

Types of Wood

The characteristic features of a wood depends upon its components required for its identification. Some of the characteristic features are given below:

1. **Spring Wood**

The formation of secondary xylem heavily depends upon environmental conditions.

- During favourable season i.e., spring, cambium produces more wood as the cambium divides rapidly because of ideal atmospheric temperature.
- The wood is light in colour with wide xylary elements. It is formed in the early months of the year, so is also called early wood.

2. **Autumn Wood**

Autumn is considered unfavorable season for cambium, so is less active and produces less amount of secondary xylem (wood).

- This wood is dark in colour in comparison to early wood, smaller xylary elements are produced that have thick walls.
- It is formed in the later months of the year, so is called late wood.

Definition

Autumn Wood: Formed during unfavourable environmental conditions i.e. autumn season .It has xylem vessels with narrow lumen and it forms smaller part of in an annual ring.

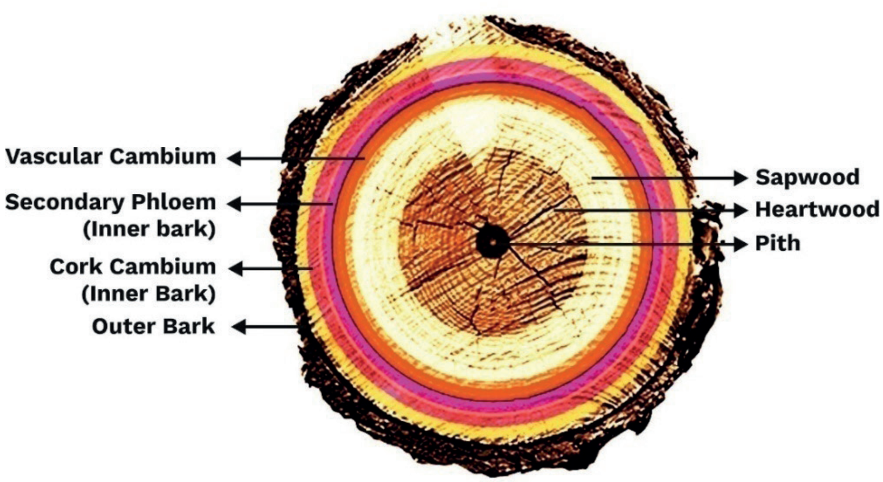


Fig. Sapwood and heartwood

- The spring wood and autumn wood makes one annual ring (growth ring).
- The number of annual rings are helpful in calculating the age of trees.
- Along with the age of the plant, the annual rings also give some clue about the climatic conditions of the habitat and environmental conditions of the plant.

3. **Porous Wood**

The wood of dicotyledonous tree contains abundant vessels.
The vessels appear like pores in cross section hence, such a wood is called **porous wood.**

Types of Porous Wood

- **Ring Porous Wood:**
  - In temperate regions, distinct cold and warm seasons with considerable temperature difference are observed. The annual rings have abundant vessels with wide lumen in early wood (Spring wood).
  - While narrow vessels are found in late wood (autumn wood). Thus, large and small vessels are present in distinct parts as rings in an annual ring of the wood.
  - Such woods are called ring porous wood, e.g., *Quercus* etc.

Diffuse Porous Wood

- Annual rings are not well marked in the trees of tropical areas, due to lack in seasonal variations. Their wood contains vessels of the same size in early wood (Spring wood) as well as in late wood (autumn wood). Such wood is called **diffuse porous wood** e.g., *Betula* etc.

SAPWOOD AND HEARTWOOD

- The wood of many trees show demarcations that appear in two parts- peripheral and central part.

Definition

Ring Porous Wood: Wood of dicot plants that possess well marked rings of light coloured spring wood and dark coloured autumn wood.

Gray Matter Alert!!!

The vessels and tracheids of the heart wood get plugged by balloon like ingrowths of the adjacent parenchyma cells into their cavities through pits.
These ingrowths are called **tylosis**, later the parenchyma cells also become lignified and dead.

- The peripheral part is light in colour and functional.
- Being functional, it conducts water and minerals (sap) in the plants; so is called sapwood or laburnum. This wood consists of newly formed xylem vessels.
- The central part is dark in colour due to the accumulation of tannins, resins etc. (liquid wastes of the plants). As a result, this wood turns non-functional, so is called heartwood or duramen.
- Its main function, after being dead is to provide mechanical support to the plant.

4. **Soft Wood**

- The texture of a wood depends upon the content of fibres and vascular rays in the wood.
- The wood produced by gymnosperms is commercially called soft wood.
- The term is miss leading, though this wood is not soft.
- The soft woods lack fibres.
- Coniferous woods are quite hard.
- The soft wood is made up of more tracheids (above 90%) and less ray cells (below 10 %).
- It lacks vessels, so is also called non-porous wood.

Hard Wood

- The wood of dicotyledonous trees is called hard wood, since it contains abundant vessels and fibres.
- Due to the presence of vessels, the hard wood is also called porous wood. Hard wood is made up of vessels (sometimes tracheids), fibres and parenchyma.
- The hard wood possesses lots of fibres.

Gray Matter Alert!!!

Annual rings are counted by increment borer (a device).
Dendrochronology: It is a branch of science which deals with the determination of the age of a tree by counting annual rings.

Previous Year's Question

Heartwood is __________.

(1) Outer part of secondary xylem
(2) Inner part of secondary xylem
(3) Outer part of secondary phloem
(4) Inner part of secondary phloem

Gray Matter Alert!!!

The cells of heartwood also get filled with various types of plant products such as oils, resins, gums, and tannins. These impart characteristic darker colour to the heartwood and make the wood stronger and durable than the sapwood.

Secondary Growth in Dicot Root

Most dicots show secondary growth in their roots (exception are few short-lived herbs and submerged aquatics).

Two types of secondary tissues-the secondary vascular tissue and the periderm are produced during the secondary growth. These are formed by the lateral meristems: the vascular cambium and cork cambium, respectively.

Formation of Secondary Vascular Tissues:

- The primary dicot roots lack cambium.
- In dicot roots, the vascular cambium appears later as a secondary meristem.
- It develops partially from conjuctive parenchyma cells and partially from pericycle.
- The conjunctive parenchyma cells lying on the inner side of the primary phloem bundles, become meristematic to form cambium strips.
- The cambium strips give rise to small quantity of secondary xylem on the inner side and secondary phloem on the outer side.
- In the process, the cambial strips and phloem are pushed slightly to the outside.
- In the meantime, the cells of the pericycle, just outside the protoxylem also become meristematic.
- These join with the earlier formed cambial strips on either side of the xylem. This gives rise to a continuous, wavy band of vascular cambium.
- The vascular cambium forms secondary xylem on the inner side and secondary phloem on the outer side.
- The cells of cambium derived from pericycle (i.e., the cambial cells present outside the protoxylem group) function as ray initials.
- Ray initials of cambium cut off parenchyma cells both on the outer and inner sides. These multiseriate radial bands of parenchyma are

Rack your Brain

Wood of Gymnosperms consists of tracheids which are highly lignified, still it is termed as soft wood. Why?

Definition

Hard Wood: Wood of Angiosperms that contains abundant xylem fibres or wood fibres. It is also called porous wood due the presence of xylem vessels

Rack your Brain

Why does primary phloem gets crushed quickly than primary xylem on the onset of secondary growth?

called primary vascular rays or medullary rays.

- The formation of ray cells is slower than the formation of secondary xylem on the inner side and secondary phloem on the outer side.
- Consequently, the depressed part of the vascular

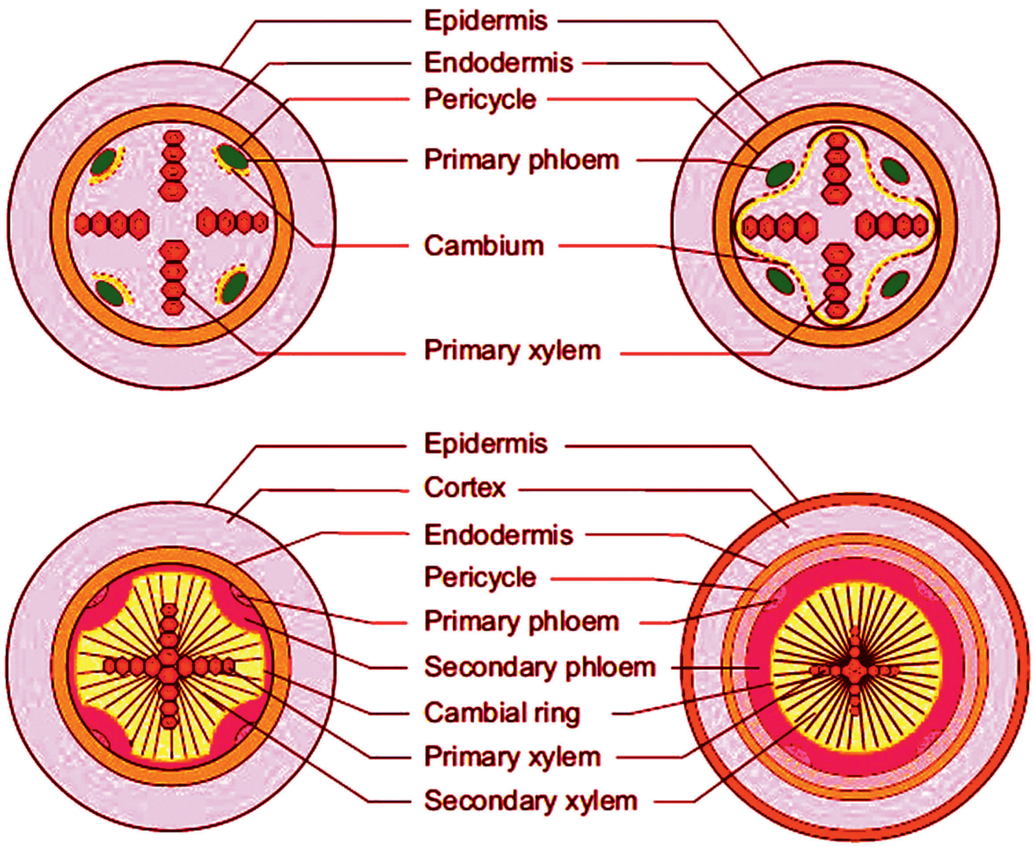


Fig. Different stages of the secondary growth in a typical dicot root

cambium moves outwards, and the wavy cambium becomes circular.

- Now, the whole cambium ring becomes active and produces secondary xylem on the inner side and secondary phloem to the outside.
- These form a continuous cylinder with primary xylem on the inner side and primary phloem on the outer side of the cylinder.
- At this stage, the radial arrangement of primary xylem and phloem bundles get destroyed.
- During the formation of secondary vascular tissues, the cambium is always more active

Gray Matter Alert!!!

Annual Rings in Gymnosperms: Tendency to develop secondary wood is found in Gymnosperms. Annual rings are prominent in Conifers (*Pinus*) but not in Cycadales (*Cycas*).

towards the inner side. Consequently, the secondary xylem increases in greater amount than the secondary phloem.

- With the addition of more secondary xylem, the primary phloem is pushed out and gets crushed.
- The secondary phloem is also partially destroyed, as the new phloem becomes functional.
- The primary xylem bundles remain intact and can be recognized by their exarch nature and central position.
- Some cells of the vascular cambium also produce medullary rays in the general mass of secondary xylem and secondary phloem.
- The part of medullary ray in the region of xylem is called xylem ray and the part present in the region of phloem is called phloem ray.
- The secondary xylem is made up of large vessels, xylem parenchyma and few fibres.
- As compared to primary xylem, the vessels of secondary xylem are broader and thinner.
- In the secondary xylem or wood of the roots, annual ring is not sharp as the underground climate do not show variation during different seasons.
- The secondary phloem consists of sieve tubes, companion cells and phloem parenchyma. Phloem fibres are rarely found.

Formation of Secondary Ground Tissue or Periderm.

- After the initiation of secondary growth in vascular region, the pericycle layer directly or after a few divisions becomes meristematic to give rise to a secondary meristems called cork cambium or phellogen.
- The cells of cork cambium divide to produce new cells both on the outer and inner sides. The tissue produced towards the inner side is called secondary cortex or phelloderm. The cells formed towards the outside become dead and their walls

Previous Year's Question

Gymnosperms are soft-wooded as they lack ___________.

(1) Cambium
(2) Phloem fibres
(3) Thick-walled tracheids
(4) Xylem fibres

Rack your Brain

In case of roots cork cambium is derived from which part?

get suberised to form cork or phellem.

- At places, cork bears lenticels (for exchange of gases).
- The cork is impervious to water. It protects the internal tissues from micro-organisms and mechanical injury.
- The phellem (Cork), phellogen (Cork cambium) and phelloderm (Secondary cortex) collectively constitute secondary ground tissue or periderm.
- All the primary tissues present outside the cork die and form a dead bark.

Anomalous Secondary Growth in Thickness

The term 'Anomalous' means deviating from the normal path or type.

Deviation from the pattern of the normal secondary growth is regarded as abnormal or anomalous secondary growth.

Different ecological situations, adaptations and evolutionary pressures create conditions of deviant behaviour of secondary growth in thickness.

Haberlandt classified anomalous secondary growth into-

(i) Adaptive Anomaly-This is observed in beetroot, some climbers- lianas, in these plants anomalous secondary growth is an adaptive feature for survival

(ii) Non-adaptive Anomaly- Such type of secondary growth is more a case of variation of the design, not an environmental adaptation.

- Anomalous Secondary Growth in *Bignonia*
    - In this plant the initial functioning of cambium is normal producing more secondary xylem towards the pith and less secondary phloem towards the periphery.
    - Later on, cambium cuts off different proportion of secondary xylem and secondary phloem at different points.
    - As a result, xylem and phloem acquire peculiar structure with ridged and furrowed fashion.

IMPORTANCE OF STUDYING ANATOMY

- The study of plant anatomy enriches botanists to understand plant structure and is helpful in solving various taxonomic problems and deciding the phylogeny of plants.
- Plant anatomy helps us to differentiate the inferior woods from the standard ones.

Previous Year's Question

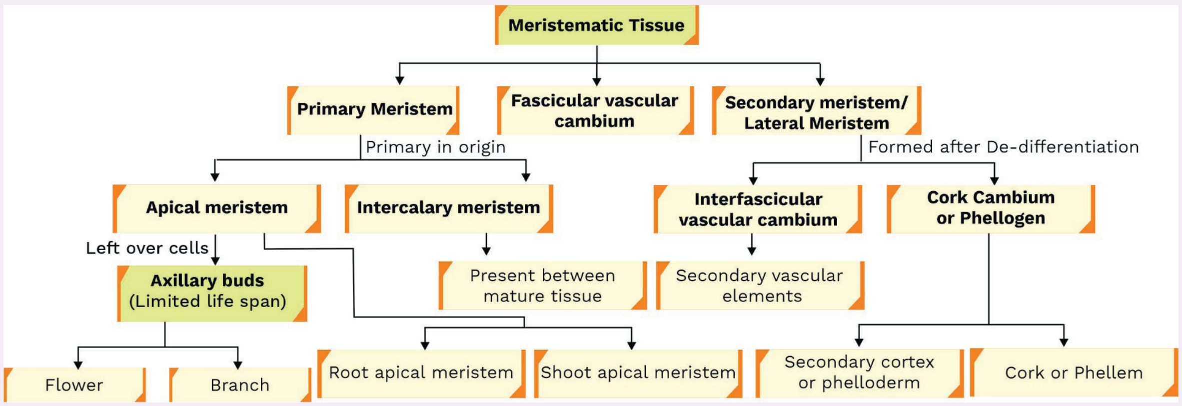
Wound healing in plants takes place by activity of __________.

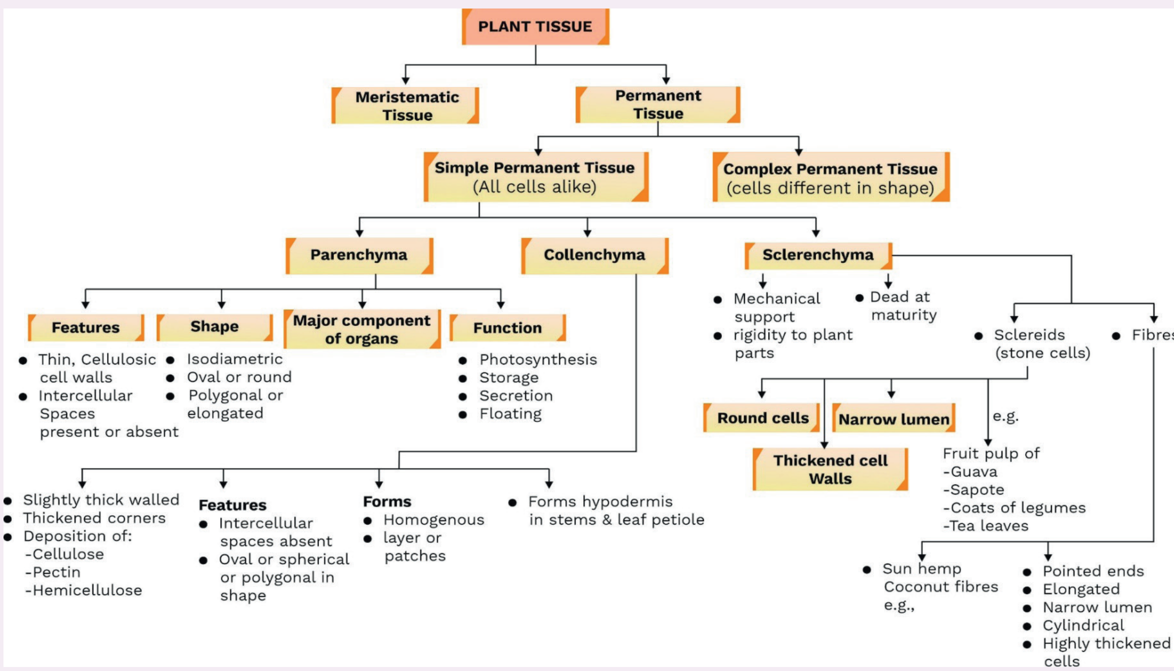
(1) Intercalary meristem
(2) Secondary meristem
(3) Apical meristem
(4) Lateral meristem

Gray Matter Alert!!!

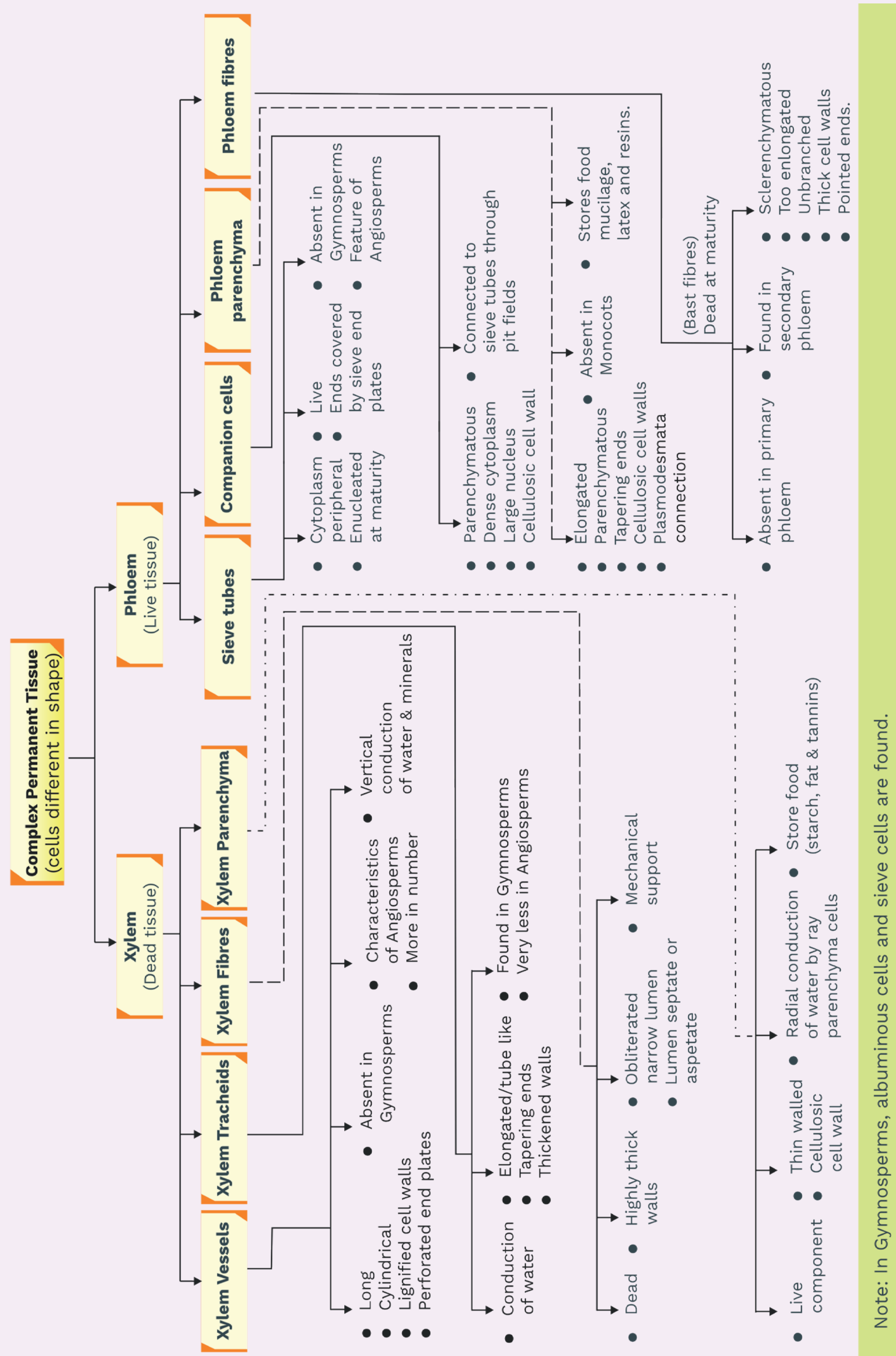
Reaction Wood: The cambium sometimes lay down as Reaction Wood, a compensatory mechanism to cope up with the mechanical stress, resulting due to horizontal growth, this process is under hormonal control.

Chapter Summary





Chapter Summary



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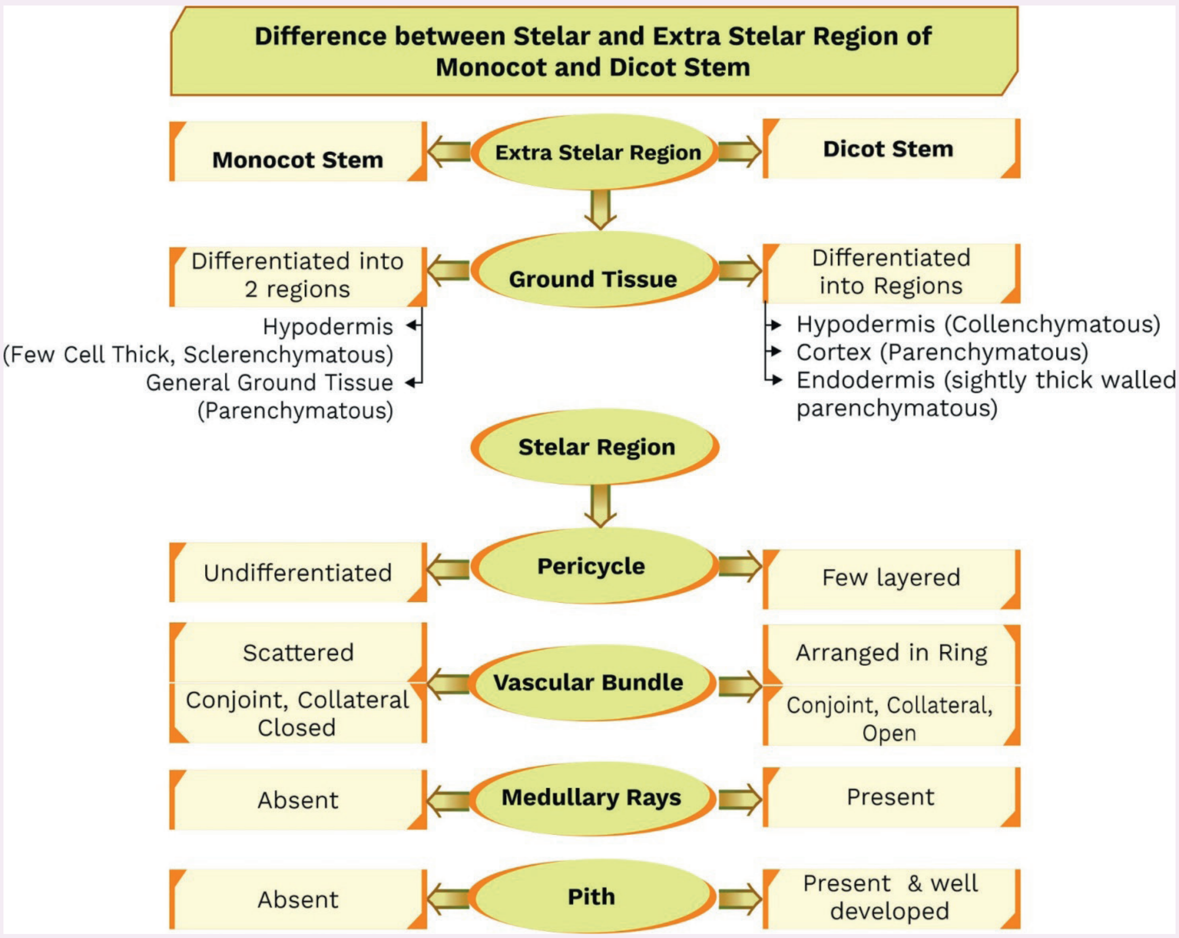

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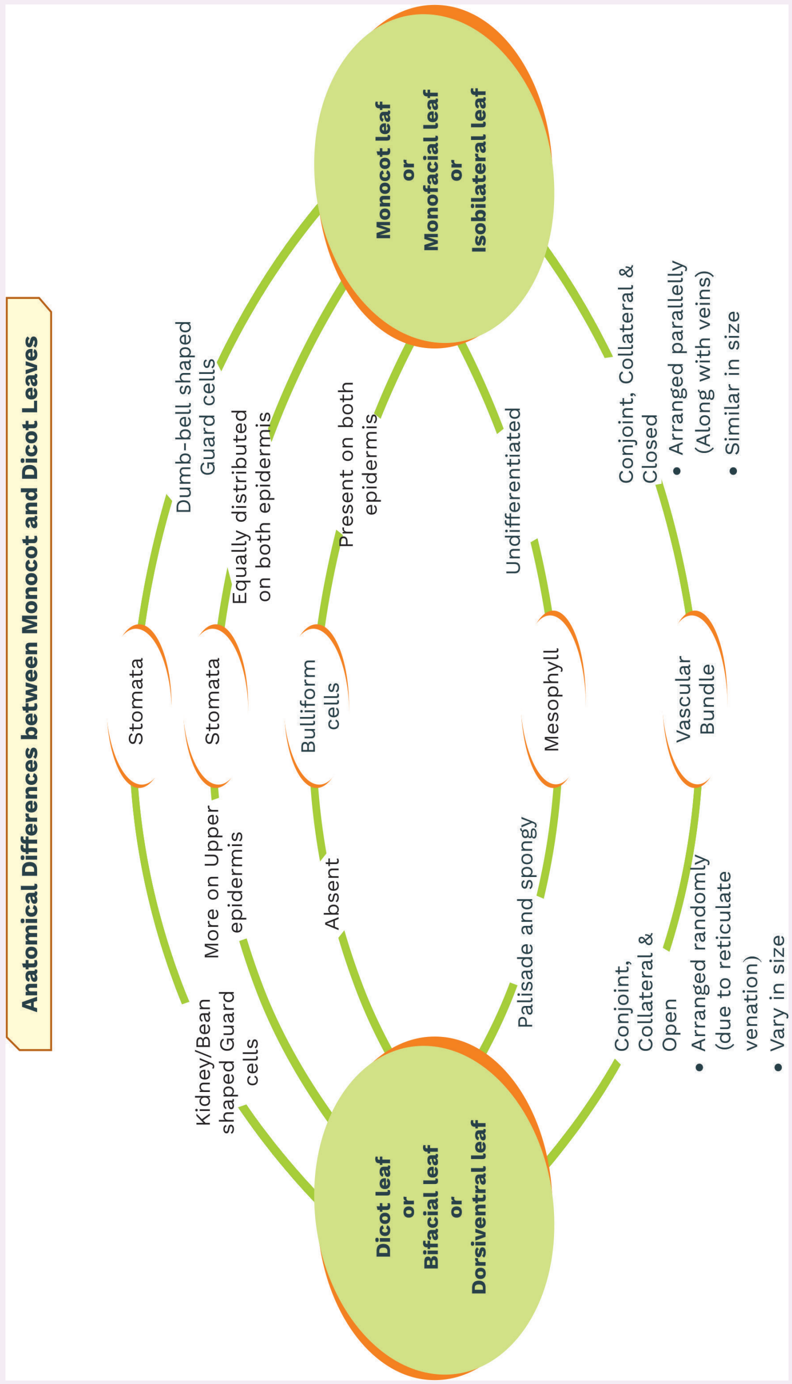

SOLVED EXERCISE

Q1 **Characteristic feature of parenchyma is-**
(1) Uniform thickening (2) Thickening at the corners (3) Lignified walls (4) Inter cellular spaces

A1 **(4)**
Parenchyma is a live tissue, and its cells may be compactly arranged or loosely arranged.

Q2 **Collenchyma is found in -**
(1) Herbaceous plants (2) Bark of the tree (3) Woody climbers (4) Xerophytes

A2 **(1)**
Herbaceous plants do need mechanical support and collenchyma is a live permanent tissue that has thick walls.

Q3 **A simple living tissue having no deposition of lignin is -**
(1) Parenchyma (2) Collenchyma (3) Sclerenchyma (4) Chlorenchyma

A3 **(2)**
Collenchyma has thickening of pectin and hemicellulose.

Q4 **Mechanical tissue consisting of living cells is -**
(1) Sclerenchyma (2) Collenchyma (3) Chlorenchyma (4) Parenchyma

A4 **(2)**
Mechanical support is provided by thick-walled tissue that may be live, or dead. Collenchyma is live and possess slightly thick cell walls.

Q5 **According to histogen theory, during apical organization three histogens are formed. The part differentiated by plerome is-**
(1) Cortex (2) Xylem & Phloem (3) Ground Tissue System (4) Stele

A5 **(4)**
The three histogens are: dermatogen, periblem and plerome.
Plerome gives rise to stelar region.

Q6 **Secondary growth is:**
(1) Length wise increase of plant
(2) Decrease in thickness of stem
(3) Increase in the thickness of roots
(4) Increase in the thickness of woody stems and dicot roots

A6 **(3)**
Secondary growth takes place by the activity of vascular cambium and cork cambium found in dicot stem and dicot roots.

Q7 **Quiescent Centre Theory for demonstrating apical organisation in root was proposed by**
(1) Schuepp (2) Hanstein (3) Clowes (4) Nageli

A7 **(3)**
Clowes theory demonstrates that due to the presence of root cap, the root apical meristem is sub-terminal and a small inactive zone called quiescent centre lies in root apical meristem.

Q8 **Long pointed thick schlerenchyma cells are-**
(1) Fibres (2) Tracheae (3) Wood parenchyma (4) Sclereids

A8 **(1)**
Sclerenchyma fibres are long, pointed at ends with lignified walls.

Q9 **The apical cell theory states that there is a single apical cell with three cutting faces in the shoot apex.**
This theory was given by–
(1) C. Nageli (2) Hanstein (3) Schmidt (4) Clowes

A9 **(1)**
According to C. Nageli the shoot apex of Angiosperms and Gymnosperms possess one active cell that gives rise to different organs.

Q10 **Cork Cambium is**
(1) Primary meristem (2) Complex tissue (3) Permanent tissue
(4) Secondary meristem

A10 **(4)**
Cork cambium is secondary meristem as it is derived from permanent cells and appears later in the life of the plant.