INTERNAL ORGANISATION OF PLANTS

- In unicellular and colonial forms every cell behaves as an independent unit and performs all functions
- Levels of organisation in plant Anatomy are Tissues - Tissue systems - Organs - Plant body.
- Study of tissues and tissue systems of plant body is called **Histology**
- A group of similar or dissimilar cells that have a common origin and function is called **tissue.**
- Tissues are formed as a response to **division of labour.**

Tissues are of two types namely.

A) Meristematic tissue

B) Permanent tissue.

A) Meristamatic tissue:

A group of undifferentiated cells having the power of cell division is called **Meristematic tissue or Formative tissue.** The term **'meristem'** was coined by **K. Nageli (1858)**

Characters of meristematic tissue

i) Cells are smallin size and isodiametric, cubical or polyhedral in shape.

ii) Cells are young and immature

iii) Cells are arranged compactly without intercellular spaces.

iv) Cell wall is thin and formed of cellulose.

v) Dense cytoplasm and abundant with numerous smaller vacuoles

vi) Proplastids are present.

vii) Ergastic substances absent.

viii) Prominent big Nucleus is present

ix) Cells divide continously and show active metabolism.

Types of Meristems:

Basing on origin,

meristems are classified into two types namely **Primary meristems** & **Secondary meristems.**

Meristems which originate from embryonic tissues and continue to remain active in mature parts of the plant is called **primary meristems.** (mainly seen in apices of root which is continuation of radical) and main stem which is continuation of Plumule)

Meristem derived from permanent cells by dedifferentiation is called **secondary meristem.**

Eg: Interfascicular cambium, and cork cambium etc.

Secondary meristems are lateral in position parallel to the periphery and help in secondary growth.

Basing on position meristems are classified into 3 types,

i) Apical

ii) Intercalary and

iii) Lateral meristems.

Apical meristems are present at the tips of roots, stems, branches etc,

Primary plant body is derived from apical meristems.

They also help in linear growth of primary plant body.

intercalary meristem : Meristem present between permanent tissues is called **intercalary meristem**

Eg : Meristem at the base of inter node and leaf sheaths of grasses,

Intercalary meristem is formed from the apical meristem

Intercalary meristems are short lived and causes internodal elongation in grasses.

They help in linear growth of stem and leaves. Active only for a short period and later becomes permanent tissue

Lateral Meristem present at the lateral sides of the plant body. The cells divide periclinically and increase the thickness of the organs like stem and root.

Vascular cambium is an example of Lateral meristem. It helps in secondary growth and produces secondary Xylem and secondary phloem.

Phalloge and cork cambium is another example. It helps in the formation of periderm.

Permanent tissue

A group of differentiated cells with definite shape and specific function is called permanent tissue. Major bulk of the plant body constitutes permanent tissue

If necessary, some permanent tissues undergo dedifferentiation and became meristematic.

Permanent tissue is of 3 types -

i) Simple-tissue

ii) Complex tissue and

iii) Special tissue.

Simple tissue

Permanent tissue having only one kind of cells is called simple tissue.

Parenchyma, Collenchyma and Sclerenchyma are the simple tissues.

PARENCHYMA

Parenchyma is the most primitive tissue, fundamental tissue, ground tissue

In lower plants perenchyma is present and performs all the major functions

Abundant tissue in the primary plant body is -Parenchyma.

Parenchyma is characterized by thin cell wall made of cellulose and hemi cellulose,

intercellular spaces may or may not be present,

vacuolated active protoplast with variable shapes depending on function.

Primary pit fields are present in the cell wall and cells are interconnected by plasmodesmic connection

Each mature parenchyma cell consists a single nucleus and a large central vacuole.

In higher plants various types of parenchyma are observed they are of following types

Chlorenchyma is found in mesophyll of leaves, pericarp of unripe fruits, cortex of young stem and branches.

*A***erenchyma** Parenchyma abundant in hydrophytes is called **A***erenchyma.* it has large inter cellular spaces. It gives buoyancy and helps in respiration and exchange of gases. Aerenchyma is found in plants such as Musa.Vallisnaria and Hydrilla

Storage parenchyma: Food storage parenchyma is abundant in Storage organs.(fruits, seeds, tubers, leaf base of onions) Idioblastic parenchyma stores tannins, oil, inorganic crystals (Cystoliths, Raphides). etc. in succulent xerophytes like Aloe, Opuntia Euphorbia the cells secrete hydrophilic mucilaginous substances that hold large amount of water

Parenchyma may regain meristematic activity and help in regeneration of tissues, wound healing, grafting, etc. As epidermal cells, parenchyma gives protection. Turgid parenchyma gives mechanical support to herbs, hydrophytes.

COLLENCHYMA

Living mechanical tissue is collenchymas present in stem and leaves with a main function of Protection

Collenchyma is characterised by

i) Unevenly thickened cell wall due to excess deposition of cellulose and pectin.

ii) High % of pectin and water (60%) in the cell wall

iii) Vacuolated protoplast.

iv) Intercellular spaces may be present or absent.

v) Chloroplasts may be present

Collenchyma is absent in roots and monocots.

Collenchyma is abundant in young stems, petioles, pedicels, leaf lamina leaf margin, etc., in dicots.

The characteristic position of collenchyma in the plant organs is - hypodermal position. It is present as a continuous hypodermal ring in (Helianthus) and discontinuous ring in (Cucurbita)

Collenchyma provides mechanical strength, elasticity and flexibility. Hence plant parts bend but not break.

Majumdar identified 3 types of collenchyma.

i) Angular collenchymas
ii) Lacunar collenchymas
iii) Lamellar collenchyma

The most common type of collenchyma is angular collenchyma.

Cells are arranged irregularly. Intercellular spaces are absent and corners are highly thickened with cellulose and pectin.

Angular collenchyma is found in - Datura, Solanum, Helianthus, Cucurbita, etc.

Lacunar collenchyma is found in -Leucas, Lactuca, Compositae members, aerial roots of Monstera.

It has small intercellular spaces and cell wall is thickened around the intercellular space.

Lamellar collenchyma is found in stems of Sambucus and Euphatorium

Cells are in horizantal rows, thickenings are in the form of tangential plates.

Tangential walls are more thickened than radialwalls.

Function of collenchyma

1. Gives flexibility and tensile strength
2. Helps in synthesis of food materials

SCLERENCHYMA

Widely distributed and important mechanical tissue is - sclerenchyma.

Sclerenchyma is characterised by

i) dead and empty cells with reduced lumen.
ii) highly thickened and lignified wall.
iii) It helps in overcoming stress and weight.

Sclerenchyma composed of two types of cells

FIBRES

Elongated sclerenchyma cells with tapering ends are called fibres.

The cell walls are thick, lignified and hard. Cel wall consists circular or slit like pits.

The lumen is long and narrow.

They form strands or occur as isolated cells.

Cells are with out inter cellular spaces

Sclerenchyma fibres are present in cortex, pericycle, pericarps, vascular tissue and around the vascular bundles.

Functions of fibres:

Fibres provide mechanical suppport and rigidity to the plant parts.

In T.S. they are polygonal without intercellular spaces

Fibres extracted from different plant parts useful in textile and Jute industries.

Pure cellulosic bast fibres are flax fibres, (obtained from Linum usitatissimum). They have high commercial value.

SCLEREIDS

Vary widely in shape, size and characteristic features of their walls

Short sclerenchyma cells are called sclereids.

They are found in fleshy fruits, seeds, roots and leaves.

Sclereids have highly thickened, lignified and stratified wall. Lumen is very narrow.

Pits may be simple or bordered.

Based on their shape they are classified in to 6 types

i. Brachy-sclcreids short isodiametric, resemble parenchyma cells in their shape.
   They are found in cortex, phloem,pith of stems and pericarp of fruits Eg; Pear (Pyrus) and Coconut (Cocos)
ii. Macro-sclereids are **columnar** in shape. Rod shaped cells appear as palisade layer and found beneath the epidermis of leguminous seeds. Macrosclereids are also known as Malpighian cells. They occur as a palisade layer below the epidermis of legume seeds.
iii. Osteo-sclereids are bone shaped sclereids. They are found in the leaves of Hakea cotyledons of Mouriria, etc.
iv. Asterosclereids are stellate (or) star-shaped sclereids. They are found in the petioles and lamina of Nymphaea, Asterosclereids show varied degrees of ramifications
v. Trichosclereids are hair like sclereids extending into the inter cellular spaces. They are found in the leaves of Olea, aerial roots of Monstera.
vi. Filiform sclereids - long and slender cells resembling filaments. They are found in leaves of Olea.

II Complex tissue

Heterogenous tissue having more than one kind of cells but acting as one unit performing one main function is called Complex tissue.

Xylem and phloem are the complex tissues.

The terms 'xylem' and 'phloem' were coined by K. Nageli.

Xylem and phloem are conducting tissues or vascular tissues help in conducting water and minera in the plant body.

Xylem and phloem are component parts of vascu|ar bundles.

XYLEM

Xylem is a complex tissue meant for the conduction of water and mineral salts.

Xylem is also called **hydrome.**

Xylem is a dead tissue except its Parenchyma.

Xylem consists of –

A) Tracheary element : xylem element that conduct water and dissolved salts in upeward direction.these can be recognized in to two types
   i. tracheids,
   ii. Vessel members

Primitive type of conducting elements in xylem are tracheids.

Tracheid is an elongated cell with tapering ends, moderately thick lignified wall, and narrow lumen.

Tracheids are found in all groups of vascular plants including angiosperms.

Conducting elements in the xylem of pteridophytes and gymnosperms -Tracheids.

Trachieds have imperforated end walls. Bordered pits are found on the lateral walls. They help in mainly conduction of mineral salts and water

Vessel members: elongated wide cylindrical cells with thick lignified secondary walls are called **vessel member.**

Dead cells without protoplast and show wide lumen.

The end walls are oblique and perforated hence called perforation plates.

The vessel members arranged one above the other and form in to a continuous tube called vessel or trachea.

Vessels are efficient conducting structures in xylem. Phylogenetically they are more advanced structures than tracheids.

Xylem vessels (Tracheae) are found in (characteristic of) -Angiosperms.

Vessels are compound tubular structures formed by joining of a series of cells called vessel members.

Cross walls in vessel are called Perforation plates. They may be simple or multiple perforation plates.

Perforations may occur on the lateral walls also.

Xylem tracheids and vessels show different types of secondary wall thcikenings such as annular, spiral, scalariform, reticulate and pitted.

Xylem fibres:

They are elongated spindle shaped dead cells with sharp and tapering ends.

They give mechanical support to vascular bundles

They are of two types

i. Libriform fibres
ii. Fibre trachieds

Libriform fibers are true fibers having simple pits. Fiber-tracheids show bordered pits.

Xylem parenchyma

They are thin walled parenchymatic living cells filled with vacuolated and nucleolated cytoplasm.

The cell wall is thick but non linified and flexible.cells are rectangular in shape

Primary xylem has axial parenchyma only. xylem consists of axial system and ray system.

Secondary xylem has both axial and ray parenchyma.

Primary xylem is derived from Procambium and secondary xylem from Vascular cambium.

Xylem vessels and tracheids become useless when they are blocked by balloon - like protrusions called Tyloses.

Tyoses are formed from parenchyma into lumen of vessels. Pit membrane bulges & forms tylosis.

Tyloses are formed when sap wood is converted into heat wood.

Tyloses block xylem vessels & check the spreading of pathogenic fungi.

PHLOEM

Living conducting tissue is Phloem. It is also called leptome or bast. Phloem conducts food materials. Phloem is a complex tissue having Sieve cells, Sieve tubes, companion cells, phloem fibres and phloem parenchyma.

Except phloem fibres all are living cells.

A. Sieve elements: living cells with vacuolated protoplast.

Highly specialized chief conducting cells

Presencnce of sieve areas in the cell walls is the characteristic feature. (lateral walls forming cell to cell connections are sieve areas). Based on degree of differentiation they are two types

i. Sieve cells: cell with unspecialized sieve areas. Contains vacuolated protoplast with out a nucleus.each sieve area is formed of numerous minute pores called sieve pores.. Gymnosperms mainly composed of sieve cells which help in conduction of food materials.

ii. Sieve tube members: living cells with morte specialized sieve areas. Phylogeteically these are advanced than sieve cells. Found only in Angiosperms and help ful in conduction.sieve plate with single perforation called simple sieve plate (eg. Cucurbita). If many perforations are present called compound sieve plate (Eg:Vitis)

B. Companion Cells: elongated rectangular parenchyma cells associated with the sieve tube members (ontogenically realted). Each sieve tube meber is associated with one or many companion cells.

C. Phloem fibres: only dead cells of the phloem. They give mechanical strength to vascular bundles. Bast fibres have high commercial value (Corchorus capsularis)

D. Phloem Parenchyma: rectangular thin walled parenchyma cells filled with vacuolated protoplasm with sonspicuous nucleus. Cytoplasm with starch, fats, accumulated tannins and resins.

Special tissue:

Special tissues are loacated in different parts of the plant body and widely distributed in different plant genera. Special tissue is also called secretory tissue or glandular tissue.

Secretory tissues are classified into various types basing on their occurrence, type of secretion, place of storage of secretory material, etc.

A. Digestive glands are found in insectivorous plants. They help in extracellular digestion.Main type of enzymes secreted by digestive glands - proteolytic enzymes.Digestive glands are found at the tip of tentacles in Drosera, inner surface of pitcher in Nepenthes.

B. Nectar secreting gland is called Nectary gland.

i. Floral nectaries are found in floral parts usually at the base of the ovary Eg: Hibiscus, Cucurbits, Citrus.

ii. Extra flora nectarines are found on vegetative parts of the plant. Extra floral nectaries are found on petiole in Passiflora. In euphorbia they are present on involucres of bracts.

C. Osmophors special glands for fragrance. Fragrance of flowers of some plants is due to special glands called Osmophores. Glands secrete aromatic or essential oils and attract insects for cross pollination Eg: Orchids.

D. Secretory cavities:secretions are released and stored in the spaces with in the gland. It is of two types

i. Lysigenous cavities: formed by the lysis of the secretory cells Eg: oil glands of citrus and Eucalyptus

ii. Schizogenous cavities: formed by the enlargement of intercellular spaces between the secretory cells. Eg; Pinus

E. Hydathodes: Water secreting structures are Hydathodes or Water glands. They are found along margin and apex of leaf. Exudation of water through water stomata is called guttation. Hydathode consists of vein ends, epithem tissue, chamber and pore (Permanently opened stomata without opening and closing mechanism).Loosely arranged colourless parenchyma in the hydathode is - epithem tissue. Guttation is common on humid and cool mornings that follow warm nights. Guttation is seen in Colocasia, Tomato, Pothos, Tropaeolum, grasses, etc.

F. Latiferous tissue: Latex secreting tissue is laticiferous tissue. It grows in the intercellular spaces of tissues in various parts of the plant such as pith, cortex, phloem, etc. Latex is an emulsion of dissolved and undissolved substances such as proteins, starch, sugar, alkaloids, enzymes, rubber, etc in a watery matrix. Latex cells are called simple laticifers, They are of two types

i. Laticifarous cells: isolated cells Eg: Nerium, Ficus (Indian rubber from Ficus elastic)

ii. Laticiferous vessels: end walls are dissolved to from continuous canals. Eg: Hevea, Carica.

Para rubber is obtained from the latex of Hevea brasiliensis. (40-50% rubber present in latex) Indian rubfter or Assam rubber is obtained from the latex of Ficus elastica.

INTERNAL STRUCTURE OF DICOT ROOT:

The TS of young primary root of dicotyledonous plant shows 3 zones

Epidermis:

Outermost layer with compactly arranged rectangular living cells with out intercellular spaces.

Cuticle and stomata are absent

Epidermal cells show root hairs formed due to the distension of cell wall. So epidermal cells are called Epiblema or Rhizodermis or piliferous layer.

The cells give rise to root hairs called trichoblasts. Root hairs grow into soil and help in absorb water.

Epidermis gives protection to inyternal parts

Cortex:

Present between the epidermis and stele

It is divisible in to

i. Exodermis:

- outer cortex with 2-3 rows of thick walled, suberised dead cells.
- It prevents the exit of water from the cortex. In root exodermis replaces epidermis and protects from leakage

ii. General Cortex:

- present beneath the exodermis. Several rows of thin walled living parenchyma cells. Cells possess leucoplast and store food materials.
- it helps in lateral conduction of water from the root hair to xylem vesels present in the stele.

iii. Endodermis:

- innermost layer of the cortex and is made up of a single row of barrel shaped cells arranged without intercellular spaces.
- The radian and transvesrse walls of endodermal cells are wrapped by **Casparian strips.**
- These are lingo suberised bands which prevents the movement of water. **Endodermis acts as a barrier between the cortex and the stele**
- Protoxylem cells without Casparian strips are called **Passage cells** which allow water to enter from cortex to stele

iv. Stele:

- Central conducting cylinder is stele
- Smaller in size than cortex
- It has 3 parts namely pericycle, vascular bundles and Medulla
  Pericycle: layer of cells that surrounds the stele.
  Lateral roots arise from pericycle
  Some pericycle cells differentiate into cambium and help in secondary growth of root.
  Vascular Bundles:**Vascular bundles are separate & radial.**
  Xylem is exarch and Monarch to Octarch.

Monarch	**-**	**Trapa natans**
Diarch	**-**	**Nicotiana, tabacum**
Triarch	**-**	**Pisum sativum**
Tetrarch	**-**	**Gossypium, herbaceum**
Pentarch	**-**	**Ricinus, communis**
Octarch	**-**	**Castanea**

Medull or pith:
Medulla is absent or highly reduced (scanty).
Non vascular tissue (ground tissue) between xylem and phloem is the conjunctive tissue (parenchymatic.)

INTERNAL STRUCTURE OF MONOCOT ROOT

Monocot roots show only primary structure.
Anatomy of monocot root is same as that of dicot root except the following differences.

i) Presence of distinct parenchymatic medulla.

ii) **Polyarch condition of xylem.**
iii) **Pericycle gives rise to only lateral roots.**
iv) **Conjuctive tissue gives mechanical support.**
v) **Madulla is large**

INTERNAL STRUCTURE OF DICOT STEM

- **Young dicot stem shows primary structure.**
- **In T.S, dicot stem has 3 regions namely Epidermis, Cortex & Stele.**
- **Stele is b*igger* than the *cortex***
- **Epidermis is the outermost region. It is uniseriate. Cuticle & stomata present. Multicellular hairs called trichomes are be present.**
- **Cortex is divisible into 3 regions -Hypodermis, middle cortex and endodermis.**
- **Hypodermis multilayered; (3-6 layers) collenchymatic; gives mechanical support.**
- **General cortex is large multiseriate, (5-10 layers) parenchymatic. It helps in storage** and **radial conduction.**
- **Outer layers of general cortex are chlorenchymatic and photosynthetic.**
- **Inner layers of general cortex contain leuco plasts.**
- **In-Helianthus stem, resin ducts are seen in middle cortex.**
- **Endodermis is indistinct casparian thickenings are present. Endodermis is** also **called starch sheath.**
- **Stele is eustele. It consists of pericycle, vascular bundles, medulla and medullary rays**
- **Pericycle is multiseriate & sclerenchymatic,**gives **mechanical support.**
- **Sclerenchyma occurs as semi lunar caps outside the vascular bundles, alternating with parenchyma masses of Parenchyma.**
- **Sclerenchymatic strands over vascular bundles as in Tridax, Helianthus, etc are called bundle caps, (hard bast)**
- **Sclerenchyma of the pericycle is caled hard bast.**
- **Vascular bundles are limited in number** and **are arranged in one or two rings**
- **Each vascular bundle is Wedge shaped, conjoint, collateral and open type with endarch xylem.**
- **Distinct well developed parenchymatic medulla, and medullary rays are present**

INTERNAL STRUCTURE OF MONOCOT STEM

- **Monocot stem** shows **only primary structure. Eg: Maize.**
- **It is divisible into 3 regions - Epidermis, Cortex and Stele.**
- **Epidermis is uniseriate with tabular cells. Cuticle & stomata are present. Hairs are usually absent.**
- Cortex **is reduced and is usually represented by sclerenchymatic hypodermis.**
- Ground tissue is parenchymatic & extensive. It stores food materials. It occupies the bulk of the stem.
- Vascular bundles are numerous and scattered irregularly in the ground tissue. Hence the stele is called atactostele. It is highly evolved stele.
- Vascular bundles are oval shaped, conjoint, collateral and closed type with endarch xylem.

- Xylem vessels are limited in number and are arranged in the form of 'Y'.
- Protoxylem lacuna may be formed. It is a lysigenous cavity. It acts as water reservoir.
- Parenchyma is absent in the phloem.
- Bundle is surrounded by sclerenchymatic bundle sheath. (Fibro vascular bundle)
- Differentiation of middle cortex, endodermis, pericycle, medulla, medullary rays is usually absent.

INTERNAL STRUCTURE OF DICOT LEAF

- Dicot mesophytic leaf has **dorsiventral plan.**
- It has epidermis, mesophyll, vascular bundles, bundle sheath, hypodermal mechanical tissue strands.
- Epidermis is uniseriate on both surfaces of leaf. Cells are parenchymatic, colourless except **guard cells.**
- Cuticle & stomata are present. Stomatal frequency is more on the lower (adaxial) surface.
- Mesophyll is differentiated into upper (abaxial) **palisade tissue** & lower (abaxial) **spongy tissue.**
- Mesophyll is **chlorenchymatic** and **photosynthetic**
- Palisade cells are cylindrical, arranged compactly in 1 or 3 layers **perpendicularly** to upper epidermis. Cells have more chloroplasts and dark green.
- Palisade is primarily concerned with photosynthesis.
- Spongy tissue has loosely arranged irregular chlorenchyma with large intercellular spaces.
- Spongy parenchyma has fewer chloroplasts, light green. Aeration & photosynthesis are the functions.
- Veins are represented by vascular bundles. They are located between palisade and spongy tissues.
- Vascular bundles are conjoint, **collateral** and **closed.** Xylem facing upper epidermis and phloem lower epidermis. (Xylem is **adaxial** & phloem is **abaxial).**
- Protoxylem is towards upper side.
- Bigger bundles have xylem vessels but smaller bundles have tracheids with annular & spiral thickenings.
- Colourless parenchymatic bundle sheath is present. Bundle sheath cells are also called **border parenchyma.**
- Bundle sheath extensions are parenchymatic. They help in conduction of food materials from mesophyll to vascular bundles.

INTERNAL STRUCTURE OF MONOCOT LEAF

- Monocot leaf is an **isobilateral leaf.**
- **Bulliform cells or motor cells** are present in the upper epidermis of grass leaf.
- Bulliform cells help in **rolling and unrolling** of leaf.
- Stomatal frequency is same in both epidermal layers.
- Mesophyll is **undifferentiated.** It is made up of either columnar cells or spongy cells.
- Sclerenclymatic hypodermal patches are present which give mechanical strength.
- Vascular bundle is surrounded by parenchymatic bundle sheath. In some cases it may be sclerenchymatic.
- In grasses, bundle sheath is **homologous** to endodermis as its cells possess Casparian strips.

IMPORTANT POINTS

- Stems have **bigger stele, conjoint & collateral** vascular bundles and **endarch** xylem.
- Roots have **bigger cortex, radial** vascular bundles and **exarch** xylem.

- Dicot stem has **limited number of open, collateral** vascular bundles **in a ring** and distinct medulla and medullary rays.
- Monocot stem has numerous scattered, closed collateral bundles and indistinct medulla.
- Monocot root has distinct medulla and exarch & polyarch **\ylem**.
- Medulla is distinct in dicot stem and monocot root.
- Isobilateral dicot leaf is Eucalyptus, pseudoisobilateral dicot leaf is Nerium.
- Palisade tissue is found on both sides of the leaf in - Eucalyptus, Nerium.

SECONDARY GROWTH IN DICOT STEM

Secondary growth is common in **gymnosperms** and **dicots** but absent in monocots.

Secondary growth occurs in two phases –

a) **intrastelar** secondary growth and

b) **extrastelar** secondary growth.

Secondary growth is accomplished by the activity of **vascular cambium** and **cork cambium.**

Intra-stelar secondary growth is due to the activity of **vascular cambium** and it results in the formation of **secondary xylem** and **phloem.**

Formation of **vascular cambium ring** is the first step during secondary growth.

Vascular cambium is **partly primary** and **partly secondary meristem.**

Fascicular cambium strips are **primary meristems.**

Interfascicular cambium strips are **secondary meristems.**

Interfascicular cambium strips are derived from **medullary rays.**

Cells of Vascular cambium divide mainly **periclinally**

Inner derivatives of vascular cambium transform into **secondary xylem** and outer derivaties into **secondary phloem.** Vascular cambium has two types of initials **fusiform initials and ray initials.**

Derivatives of **fusiform initials** transform into secondary vascular tissues and those of **ray initials** transform into **vascular rays.**

Vascular rays show radial elongation The rays may be uni, bi or multisertate and help in radial conduction.

Secondary growth starts in Spring season.Secondary xylem is called **wood.**

Wood constitutes the major part of the secondary plant body.

In temperate plants cambial activity is **seasonal.** Cambium is **more active** in the **Spring** and **less active** in **Autumn.**

Wood formed in spring season is called **Spring wood** or **Early wood.**

Wood formed in Autumn season is called **Autumn wood** or **Late wood.**

Spring wood and Autumn wood of the same year constitute one **growth ring** or **annual ring.**

Annual rings are distinct in temperate plants due to **much seasonal variation.**

Annual rings are indistinct or absent in tropical trees due to absence of marked seasonal variations. Indistinct annual rings are called **growth marks.**

The age of the temperate trees can be estimated by counting the **number of growth rings.**

The science dealing with the estimation of the age of the plant is called **Dendrochronology.**

The age fo Sequoiadendron growing in America is estimated to be about 3,500 years.

Pseudo annual rings are formed either due to hormonal changes or **heavy leaf fall or diseases**

Age of a tree can not be estimated accurately due to the formation of pseudo annual rings.

Thickness of the annual rings depends upon **climatic conditions.**

Annual rings are thicker in **active monsoons** but they are thinner in **dull monsoons.**

Chopping the trees, avoiding water lodging affect the annual rings of existing plants.

Variations in annual rings indicate **phenological changes** that have occured in the past years.

The outermost (peripheral) recently formed, light coloured wood is called **sap wood** or **alburnum.**

The central, dark coloured wood is called **heart wood** or **duramen.**

Duramen is highly durable and **alburum** is less durable.

Sap wood is useful for conduction and **heart wood** is useless for conduction.

Inner most layers of Sap wood transforms into heart wood.

During the conversion of sap wood into heart wood, xylem vessels are blocked by **tyloses.** Various organic compounds such as resins, tannins, gums, oils, aromatic substances, etc. are dumped in to duramen. Hence duramen becomes useless for conduction. Duramen becomes **dark coloured, heavier and durable.**

The amount of heart wood is ever increasing and the amount of sap wood remains almost constant since as new sap wood is forming, old sap wood is transformed into heart wood.

Intrastelar secondary growth affects the primary plant body

i) Primary xylem and primary phloem are well separated.
ii) Primary xylem is pushed towards centre and medulla is crushed
iii) Primary phloem is pushed outwards and is crushed.
iv) Cortex and epidermis receive constant pressure from inside and hence rupture.

Periderm is formed in the cortex to give **protection.**

Periderm formation in cortex is considered as **cortical** or **extrastelar secondary growth.**

Secondary growth occuring in the cortex is called **cortical secondary growth or extrastelar secondary growth.**

Extrastelar secondary growth is due to **cork cambium** and results in the formation of **periderm.** Cork cambium is a **totally secondary meristem.** It is derived from **hypodermis** or **middle cortex.**

The outer derivatives of cork cambium transform into **cork** and inner derivatives become **secondary cortex.**

Cork, cork cambium and secondary cortex are together called **periderm.** It is meant for protection

Cork is **phellem,** cork cambium is **phellogen** and secondary cortex is **phelloderm.**

Cork is a dead tissue with **suberized walls.**

Non suberized thin walled cork cells are called **phelloids.**

Lenticels are formed in the cork to **facilitate the exchange of gases** and also allow transpiration.

Cork is a **compressible, resilisnt,** light tissue with **thermal insulation quaities.**

The loosely arranged parenchyma cells in the lenticel are called **complementary** tissue.

Commercial cork is obtained from **Quercus suber** (Oak plant).

Secondary cortex is chlorenchymatic and photosynthetic.

Bark includes all the tissues outside the **vascular cambium**

Bark includes secondary phloem and periderm.

During secondary growth, plant part grows in thickness only but donot elongate. Hence the nail introduced into trunk **remains at the same height** forever.

The sequence of various tissues from outside to centre of secondary stem is

Bark, cork, cork cambium, secondary cortex, primary cortex, pericycle, primary phloem, secondary phloem, vascular cambium, sap wood, heart wood, primary xylem, pith.

Epidermis protects the primary plant body and cork protects the secondary plant body.