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Programme: M.Sc., Botany

Course Title: Anatomy, embryology and morphogenesis
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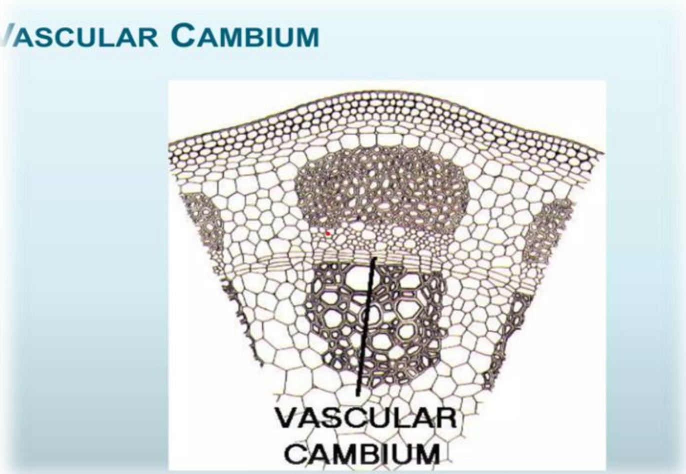
UNIT -II



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Sapwood and Heartwood

Definitions of Sapwood and Heartwood

Sapwood:

"When a tree is young, certain cells within the wood are alive and capable of conducting sap or storing nutrients, and the wood is referred to as **sapwood**. The sapwood also termed as Alebernum."

Heartwood:

"Heartwood also called duramen. Dead central wood of trees. As new sapwood is formed under the bark, the inner sap wood changes to heartwood. In the wood under going this change the living cells die."

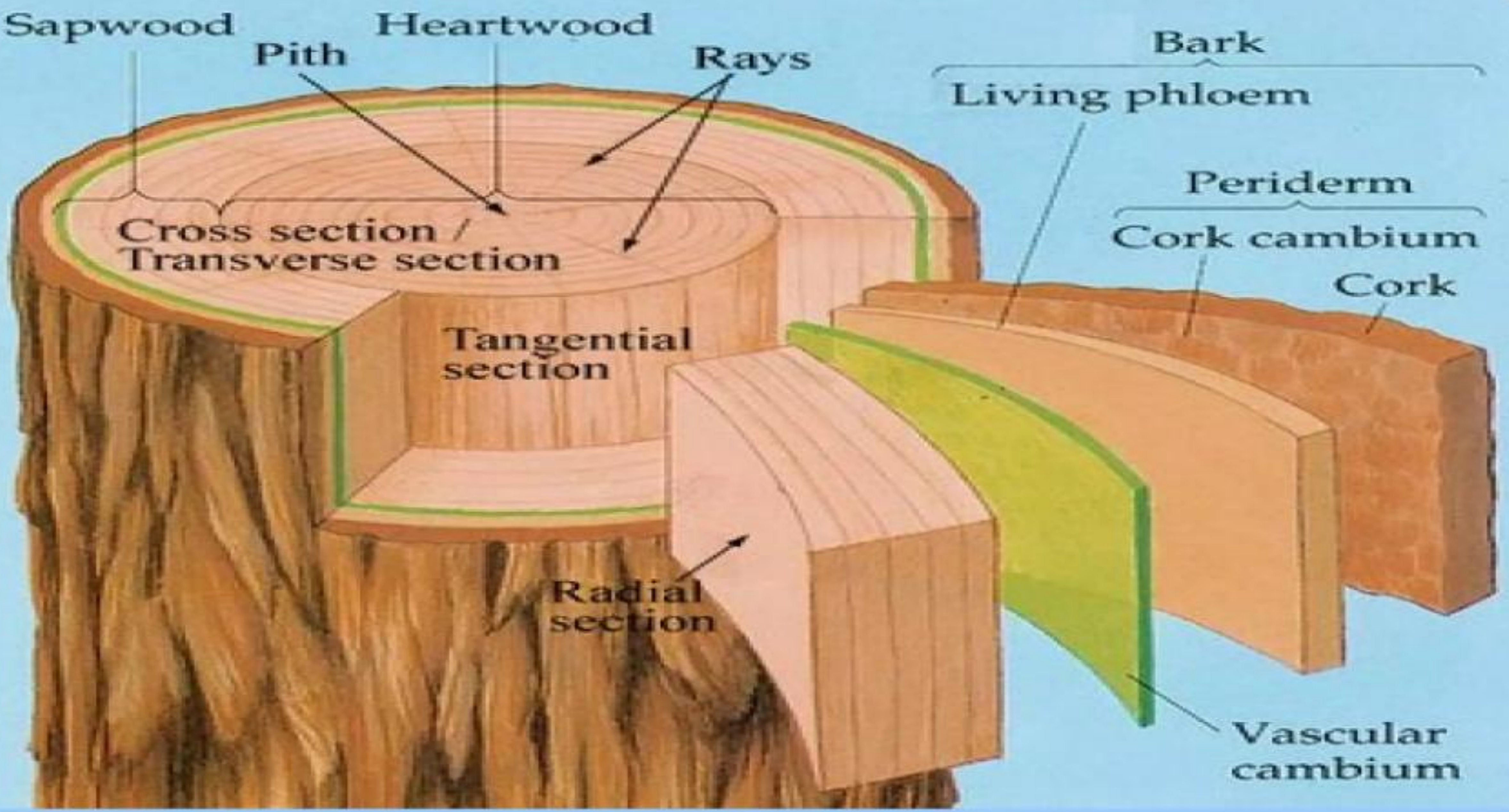
Maple tree and Black locust tree cross section

The sapwood in the centre of the tree dies, forming heartwood, and as the cells die they release chemicals that change the colour of the wood, as well as making the wood stronger and more resistant to attack by insects.

Structure and Development of Sapwood and Heartwood

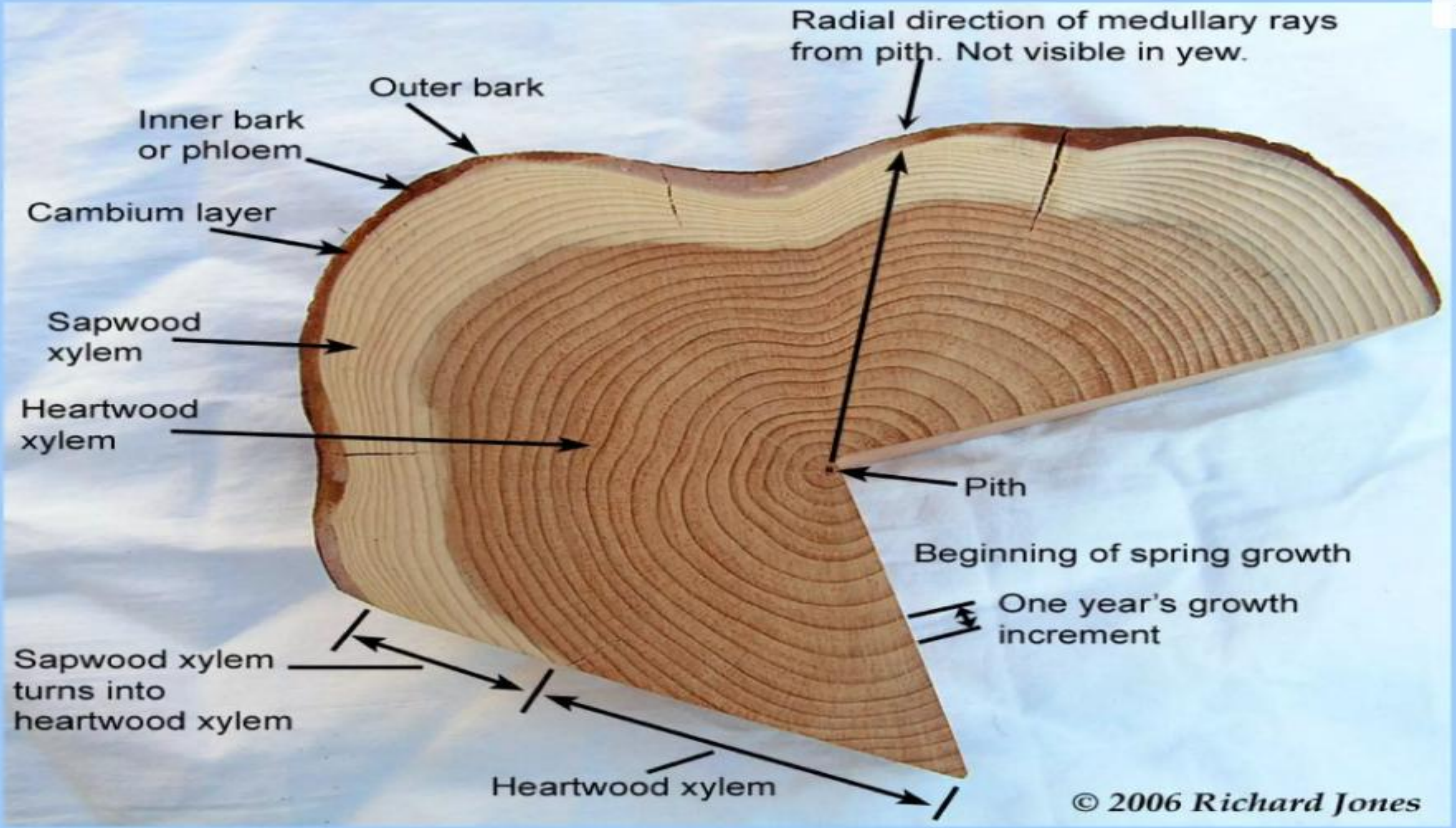
- Sapwood is new wood and is like a pipeline which moves water through the tree up to the leaves.
- The sapwood is lighted colored and formed of living cells associated with vessels and fibers.
- Sapwood commonly ranges from 4 to 6 cm (1-1/2 to 2 in.) in radial thickness.
- Many second-growth trees of merchantable size consist mostly of sapwood.

- Heartwood consists of inactive cells that do not function in either water conduction or food storage.
- The compounds (including resins, phenols, and terpenes, sometimes referred to as extractives) not only help make heartwood more resistant to attack by insects and decay organisms but also tend to give this inner portion of the stem a distinctive darker color.
- The proportion of heartwood to sapwood in the main stem does vary with species. Black locust, for example, usually has a very narrow band – often less than an inch – of functioning sapwood, whereas maple stems often can have many inches of sapwood and relatively narrow cores of heartwood.



Structure of Sapwood and Heartwood

- Sapwood is formed due to the cambial activity of the secondary xylem.
- Heartwood is formed due to accumulation of different compounds, such as oils gums, and resins, etc.
- The oils, resins and colouring materials infiltrate the walls, and gums and resins may fill the lumina of the cells in heart wood.
- During the transformation a number of changes occur – all living cells lose protoplasts; water contents of cell walls are reduced; food materials are withdrawn from the living cells; tyloses are frequently formed which block the vessels, the parenchyma walls become lignified; oils, gums, tannins, resins and other substances develop in the cells.

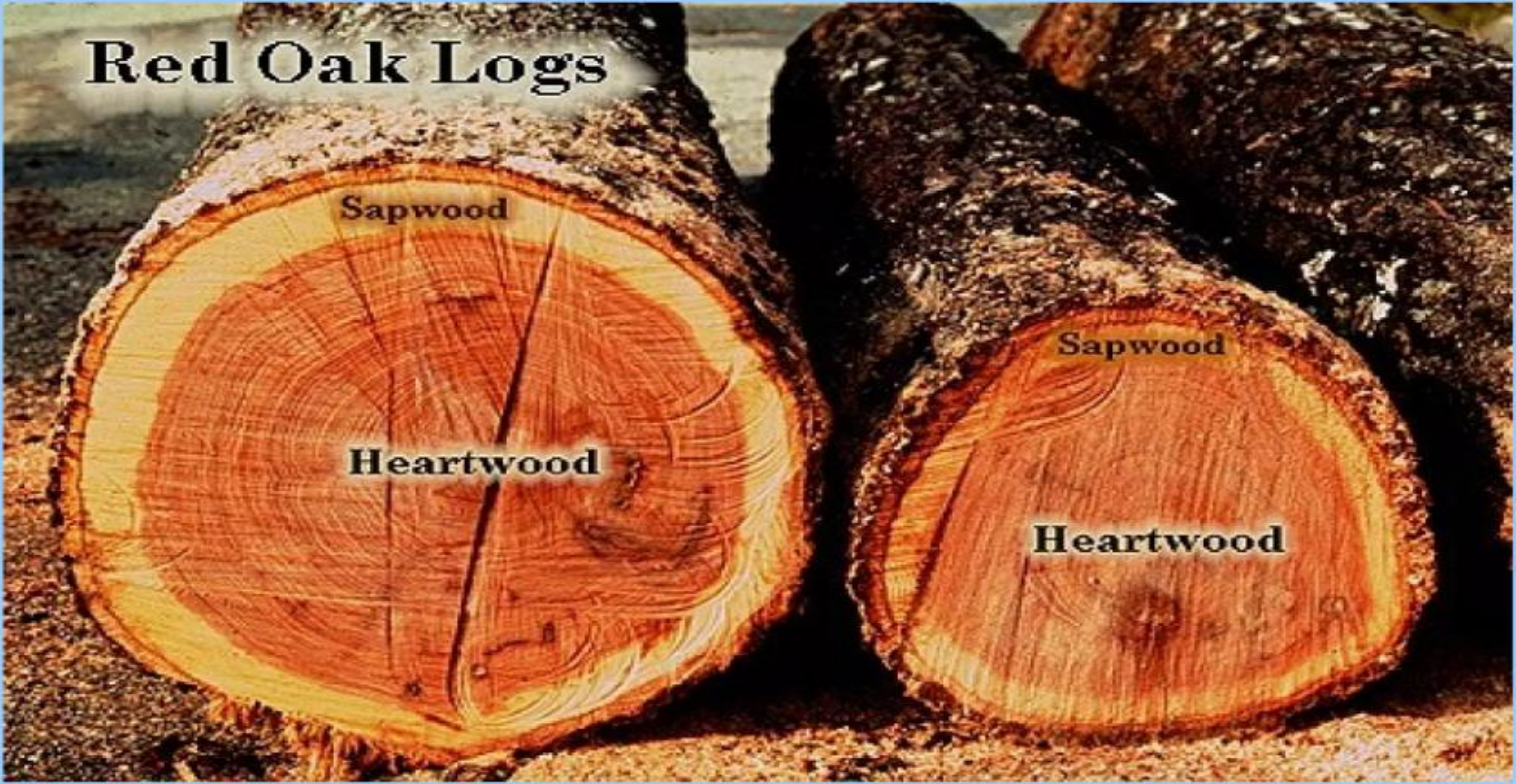

Radial direction of medullary rays from pith. Not visible in yew.
Outer bark
Inner bark or phloem
Cambium layer
Sapwood xylem
Heartwood xylem
Pith
Beginning of spring growth
One year's growth increment
Sapwood xylem turns into heartwood xylem
Heartwood xylem
© 2006 Richard Jones

Functions of Sapwood and Heartwood

- Sapwood performs the physiological activities, such as conduction of water and nutrients, storage of food, etc.
- The function of heartwood is no longer of conduction, it gives only mechanical support to the stem.
- The heartwood part of a tree is also far more susceptible to fungus than the centre of the trunk.
- Heartwood contains far less moisture than sapwood and will have far less shrinkage when it's dried.
- The sapwood in the centre of the tree dies, forming heartwood, and as the cells die they release chemicals that change the colour of the wood, as well as making the wood stronger and more resistant to attack by insects.

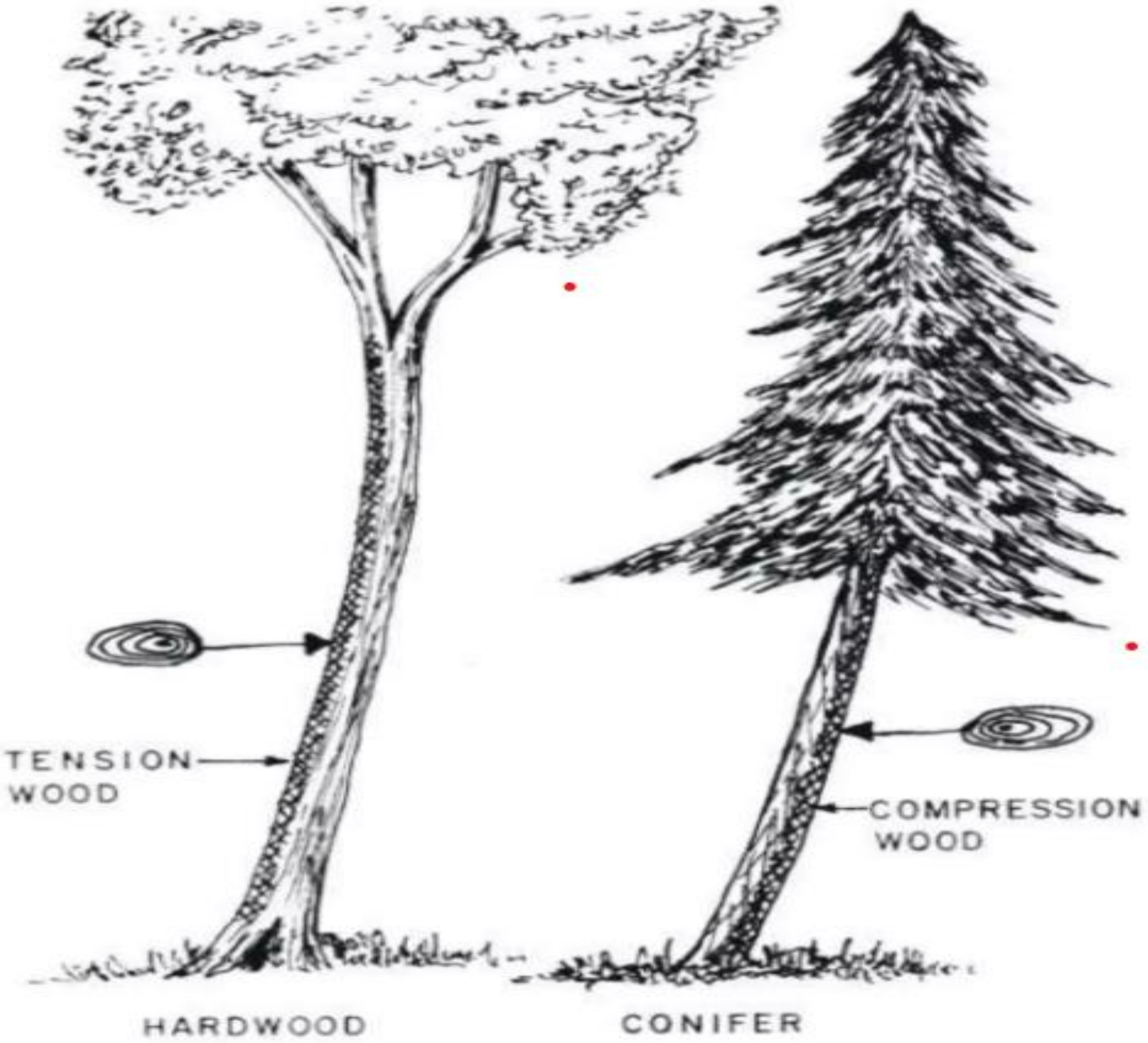
Economic Importance of Heartwood and Sapwood

- Heartwood, as timber, is more durable than sapwood, because the reduction of food materials available for pathogens by the absence of protoplasm and starch.
- The haematoxylin is obtained from the heartwood of **Haematoxylin campechianum**. Because of the absence of resin, gums and colouring substances.
- Sap wood is preferred for pulpwood, and for wood to be impregnated with preservatives.



Red Oak Logs

Reaction Wood



Reaction wood is formed as a response by the tree to a triggering event such as tipping from the vertical.

It is also known to regulate the orientation or angle of branches relative to the main stem

(Haygreen & Bowyer)

Reaction wood

Reaction wood in a woody plant is wood that forms in place of normal wood as a response to gravity, where the cambial cells are oriented other than vertically. It is typically found on branches and leaning stems. It is an example of mechanical acclimation in trees.

There are two different types of reaction wood, which represent two different approaches to the same problem by woody plants:

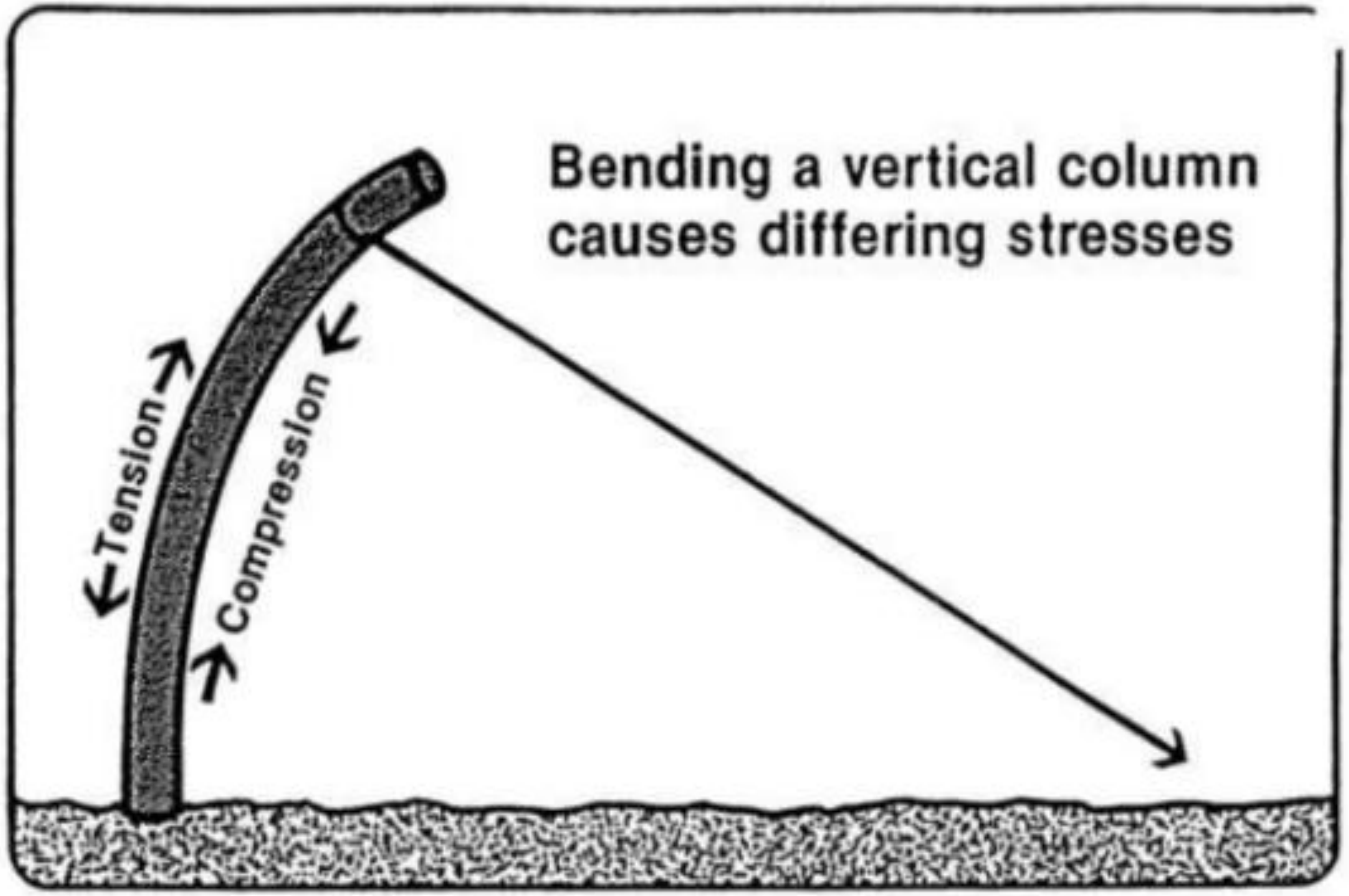
In most angiosperms reaction wood is called **tension wood**. Tension wood forms on the side of the part of the plant that is under tension, pulling it towards the affecting force (upwards, in the case of a branch). It has a higher proportion of cellulose than normal wood. Tension wood may have as high as 60% cellulose.

In gymnosperms and amborella it is called **compression wood**. Compression wood forms on the side of the plant that is under compression, thereby lengthening/straightening the bend. Compression wood has a higher proportion of lignin than normal wood. Compression wood has only about 30% cellulose compared to 42% in normal softwood. Its lignin content can be as high as 40%

- The controlling factor behind reaction wood appears to be the hormone auxin, although the exact mechanism is not clear. In a leaning stem, the normal flow of auxin down the tree is displaced by gravity and it accumulates on the lower side.
- The formation of reaction wood may act in conjunction with other corrective or adaptive mechanisms in woody plants, such as thigomorphism (adaptive response to flexure) and gravitropism (the correction of, rather than the support of, lean) and the auxin-controlled balance of growth rates and growth direction between stems and branches. The term 'adaptive growth' therefore includes, but is not synonymous with, the formation of reaction wood.

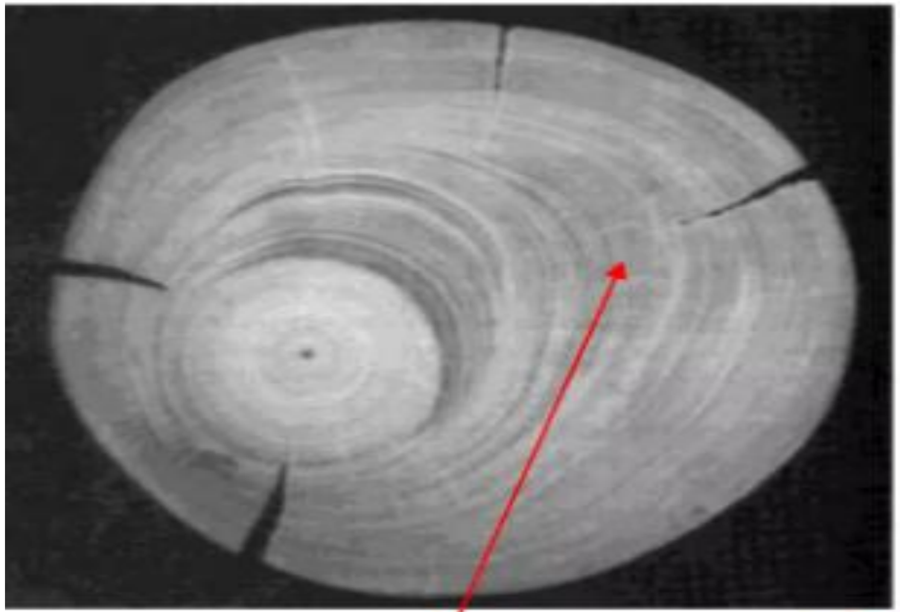
The terminology used to describe reaction wood formed in softwoods and hardwoods comes from the stresses normally present in those locations.

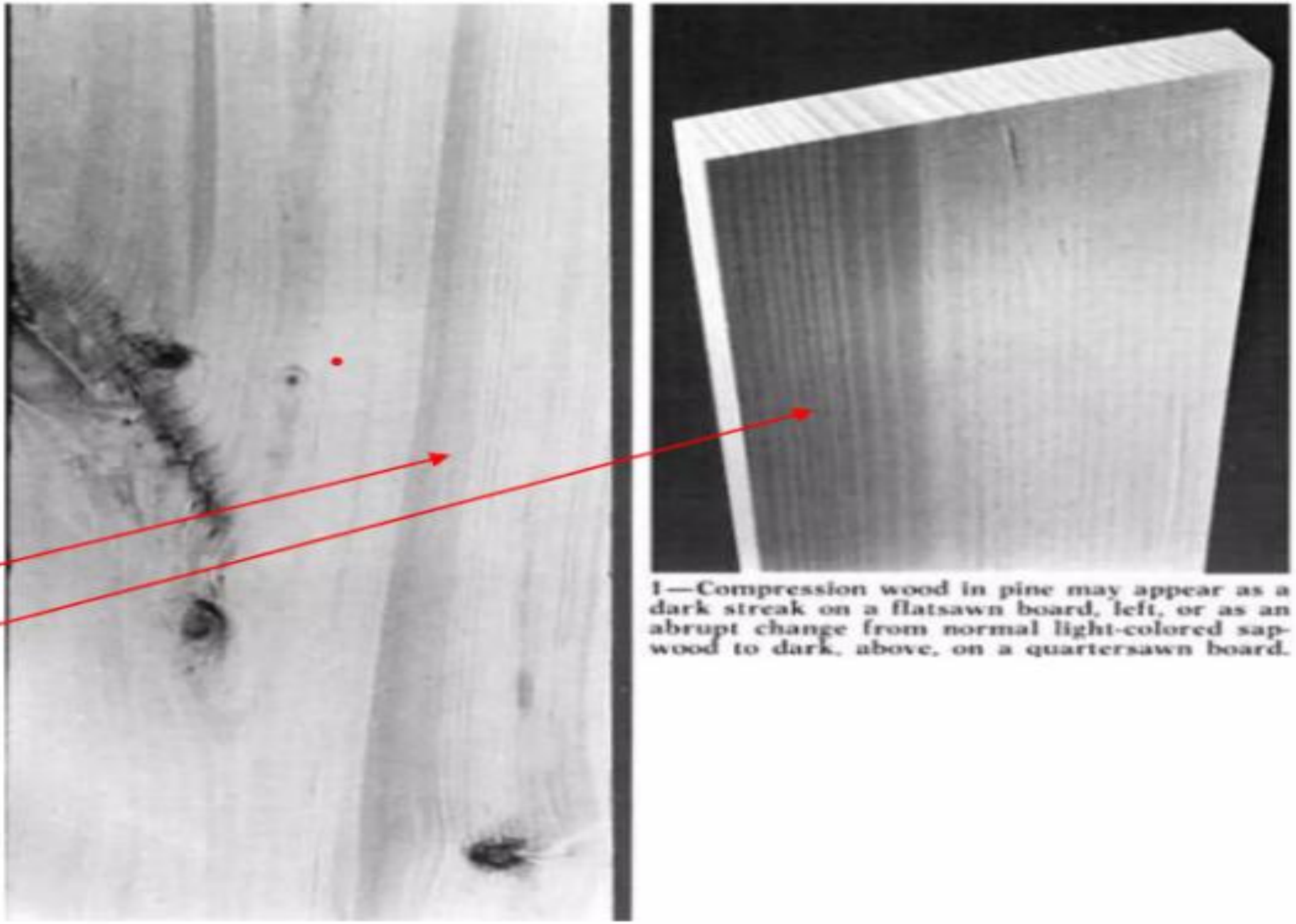
However, those stresses themselves are NOT responsible for the formation of reaction wood.



(Haygreen & Bowyer)

Compression wood – macroscopic appearance

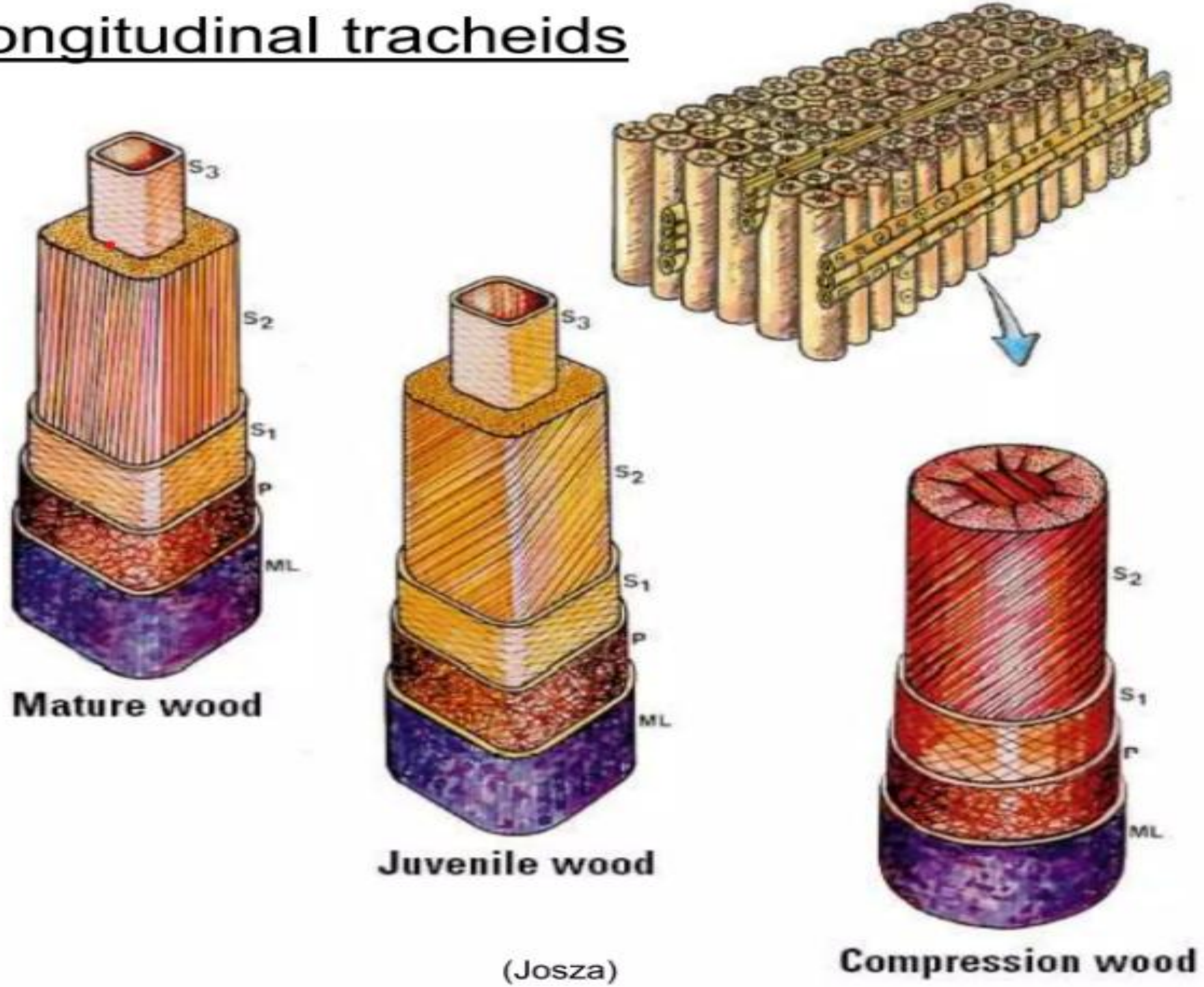




1—Compression wood in pine may appear as a dark streak on a flatsawn board, left, or as an abrupt change from normal light-colored sapwood to dark, above, on a quartersawn board.

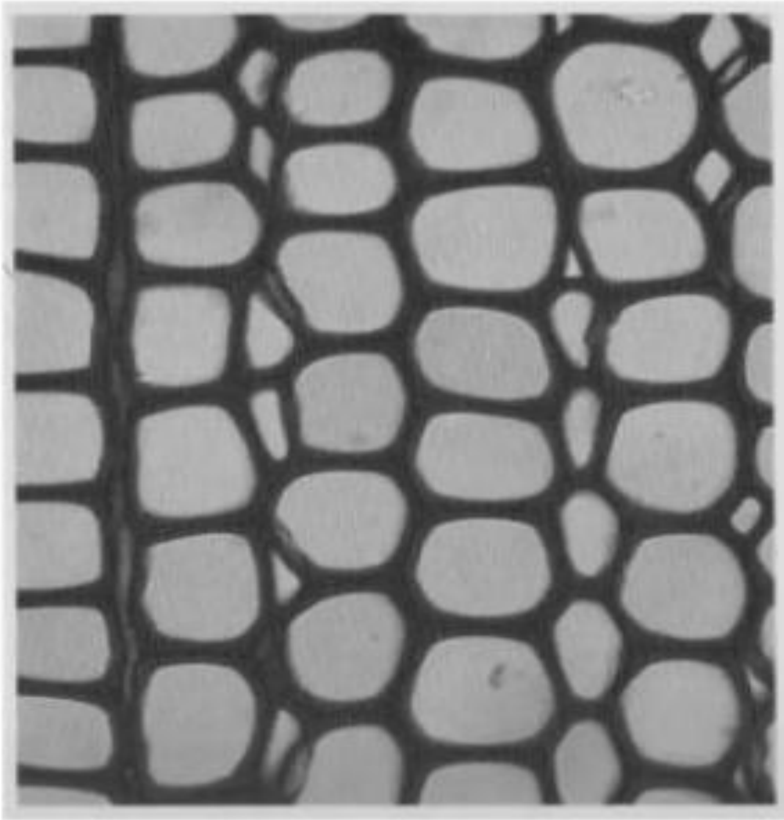
Compression wood

Ultrastructure of longitudinal tracheids

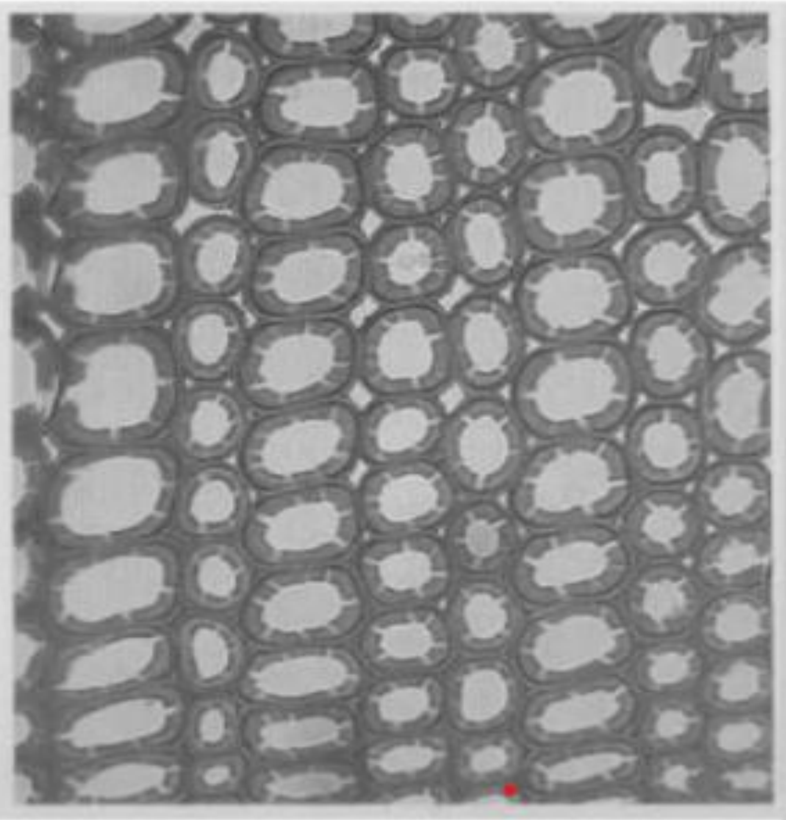


(Josza)

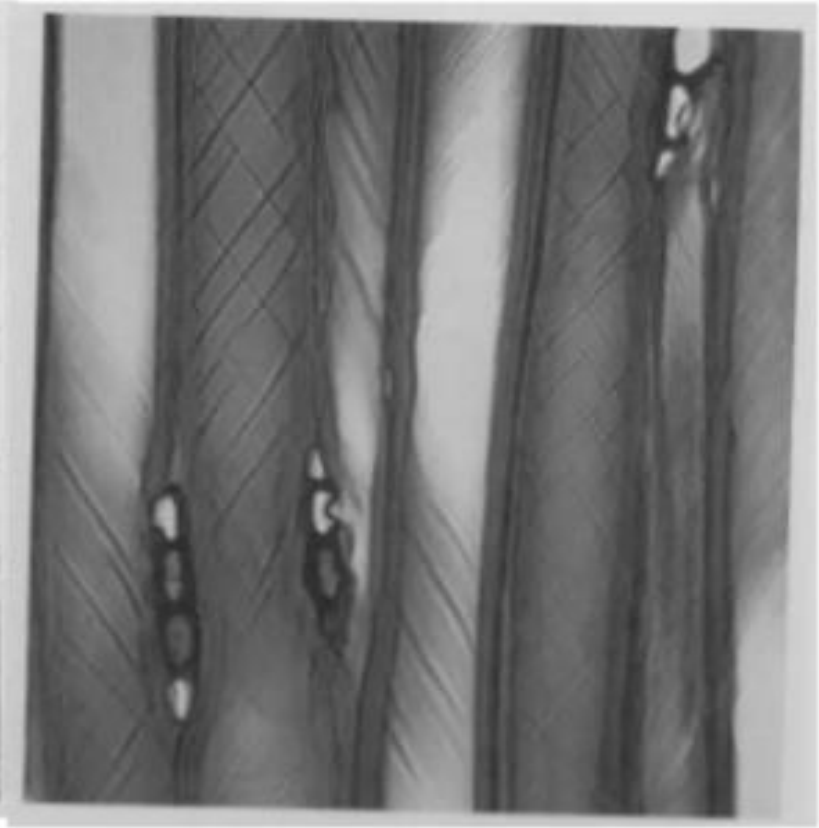
Compression wood – microscopic appearance



Normal wood



Compression wood



Compression wood

*

Compression wood – characteristics and properties

Anatomy

- Wider growth rings
- More latewood
- Shorter longitudinal tracheids
- Rounded cells with intercellular spaces
- Helical striations (following S2Θ)

Ultrastructure

- Larger S2Θ
- S3 absent
- New S1L layer

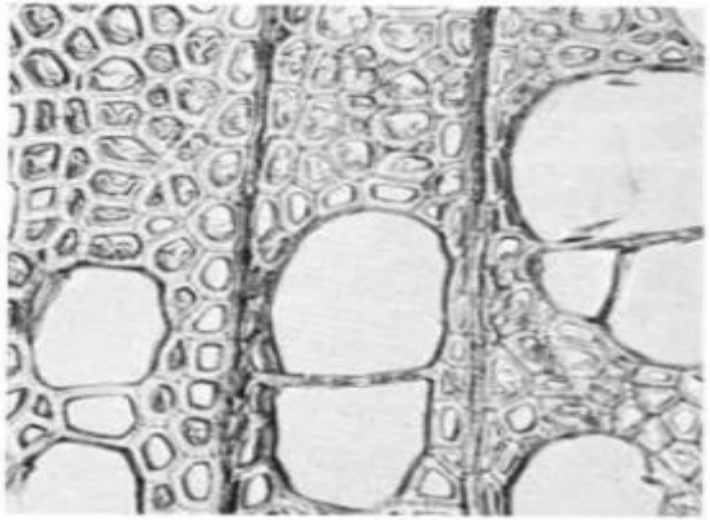
Chemistry

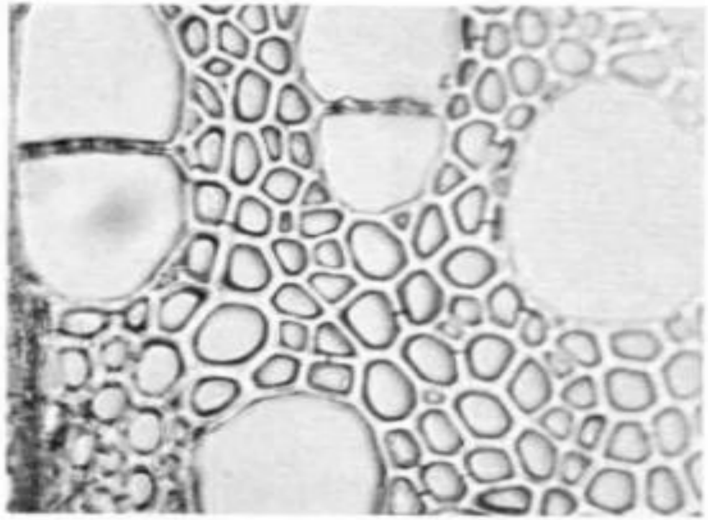
- More lignin
- Less cellulose
- Hemicelluloses differ

Properties

- Higher wood density
- Compression strength ↑
- All other strengths ↓
- Brittle failure
- Greater longitudinal shrinkage
- Lower pulp yields

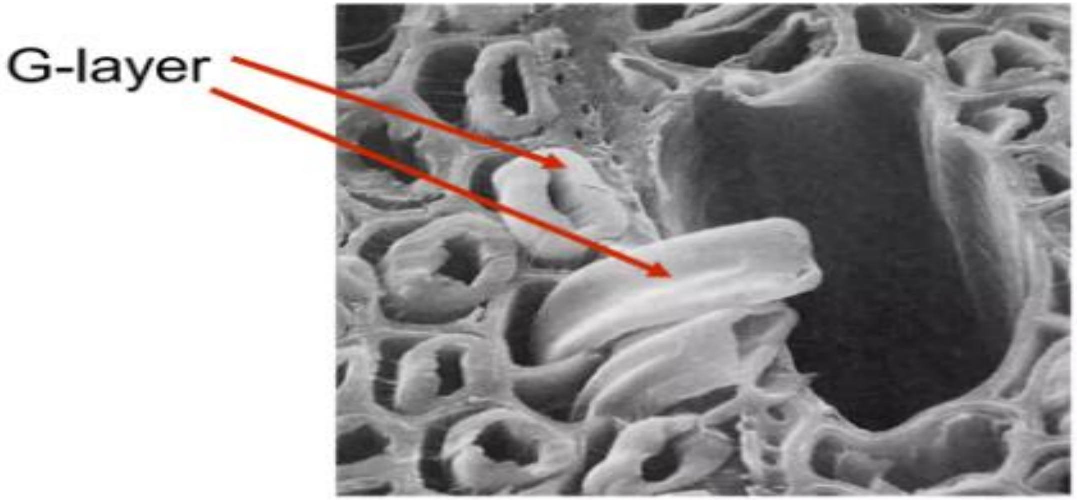
Tension wood – microscopic appearance



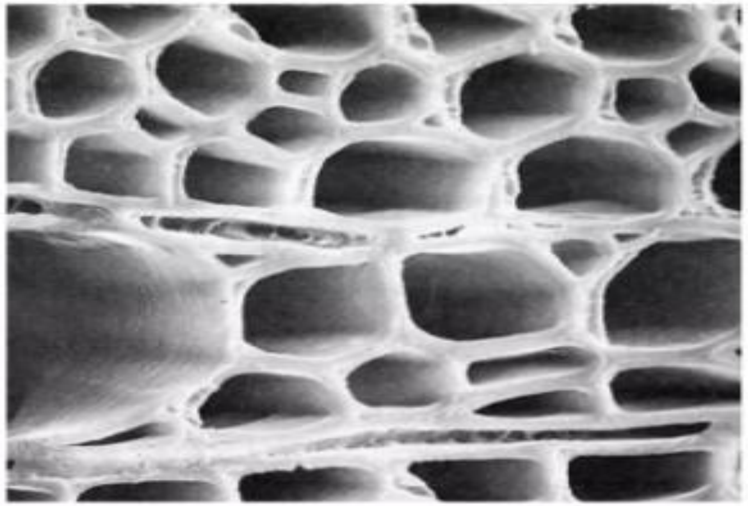


GELATINOUS FIBERS
Normal aspen fibers are shown at near left. By comparison, gelatinous fibers in tension wood have abnormally thick walls whose inner gelatinous layer often separates when sectioned, as shown at far left. (250x)

(Hoadley)



Aspen tension wood



Aspen normal wood

Tension wood – characteristics and properties

Anatomy

- Fibers affected not vessel elements
- Gelatinous fibers (G-layer)

Ultrastructure

- SG - after S3
  - replaces S3
  - replaces S2 + S3
  - replaces some of S1 + S2 + S3
- Microfibrils less closely packed
- Low θ in G-layer
- Higher S1θ

Chemistry

- More cellulose
- Less lignin
- Hemicelluloses differ

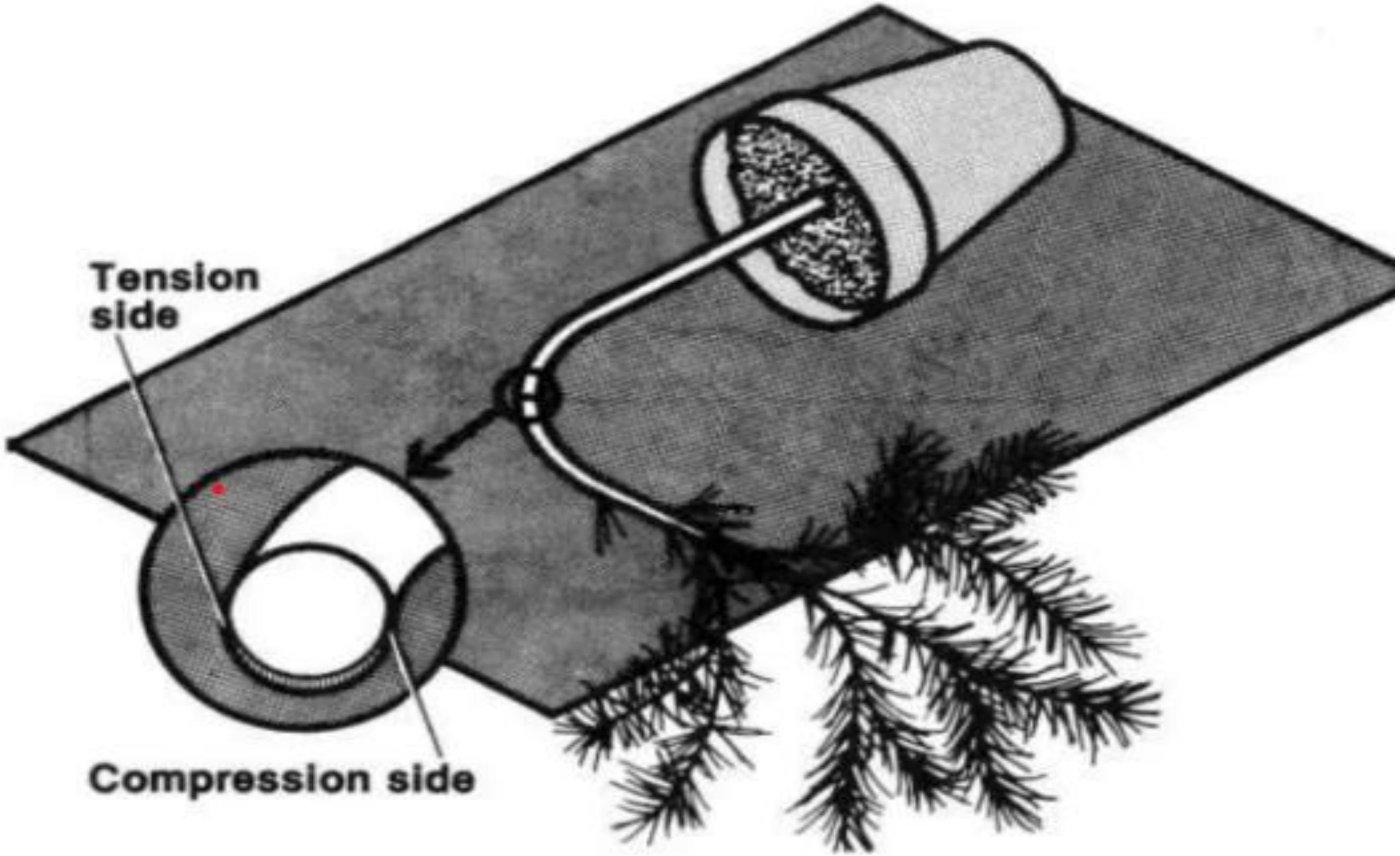
Properties

- Higher wood density
- Compression strength ↓
- Seasoning defects
- Higher pulp yields
- Poor workability ("fuzzy" grain)

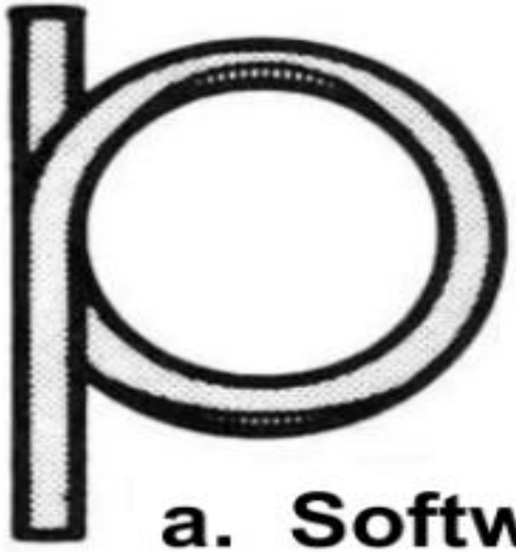
Location of reaction wood formation

Compression wood formation in horizontally oriented stem.

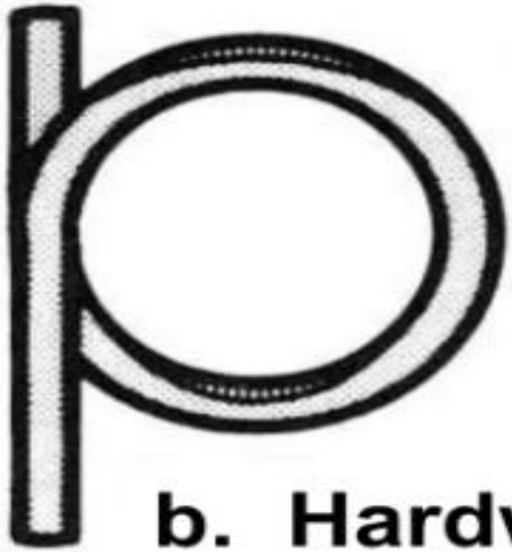
Compression wood is found on underside of stem – not on side of stem under compression.



Location of reaction wood formation



a. **Softwood**



b. **Hardwood**

Reaction wood formation in growing looped stem.

Compression wood is found consistently on underside of stem and tension wood is found consistently on upper side of stem (regardless of the nature of the stresses experienced in those locations).

- The stelar bundles ,which are the continuation of the bundles in the leaf bases, are called leaf traces.

- In the angiosperms and especially in dicots, the primary vascular cylinder is interrupted at each node by the exit of one or more bundles that enter the leaves “ A vascular bundle located in the stem but directly related to a leaf , to represent the lower part of the vascular supply of this leaf , is termed leaf trace.”

- The leaf trace is a vascular bundle that connects the vascular system of the leaf with that of the stem

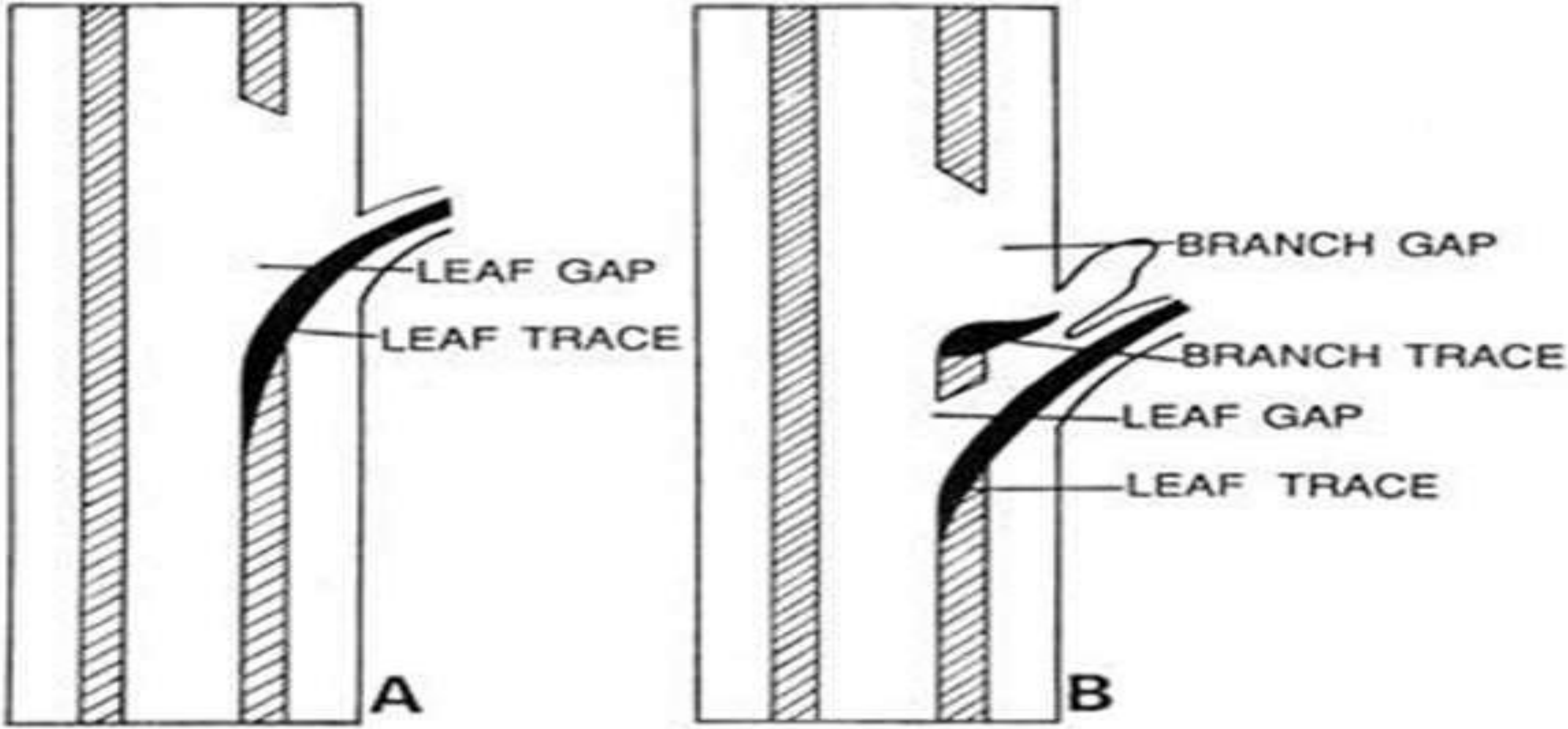


Fig. 38.1. Leaf and branch traces and gaps. A, L.S. of node through leaf trace and gap; B, L.S. of node through branch trace

The transverse sections of such stems show a circle of vascular bundles with the parenchymatous leaf gaps.

There are three common types of nodes in dicots:

1. **Unilacunar**
2. **Trilacunar**
3. **Multilacunar**

UNILACUNAR NODE

The node with a single gap and a single trace to a leaf is known as unilacunar. Eg: ocimum, eucalyptus

TRILACUNAR NODE

the node with three gaps and three traces to a leaf (one median and two lateral) is known as trilacunar. Eg. Brassica, Annona etc

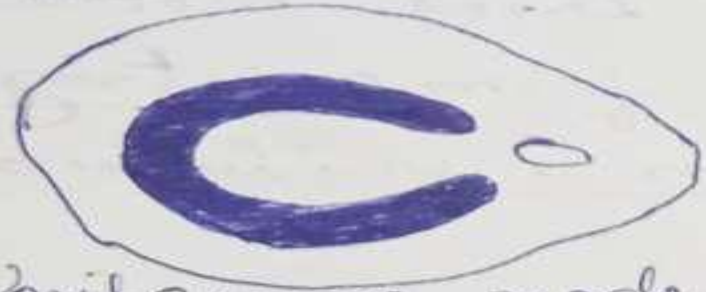
MULTILACUNAR NODE

the node with several to many gaps and traces to a leaf is known as multilacunar. Eg:Rumex,Aralium

Types of Node

Unilacunar node

(a)



Unilacunar node with one leaf trace

(b)

Unilacuthar node with 2 leaf trace

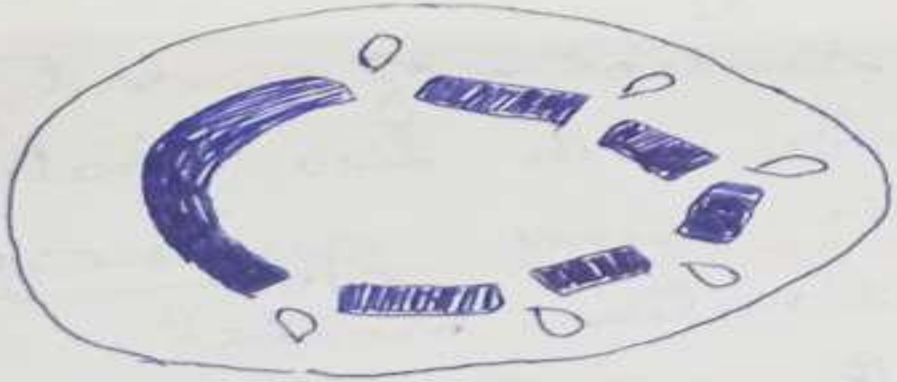
(c)

Unilacunar node with 3 leaf trace

II

Trilacunar node with three leaf trace

III



Multilacunar node with many leaf trace.

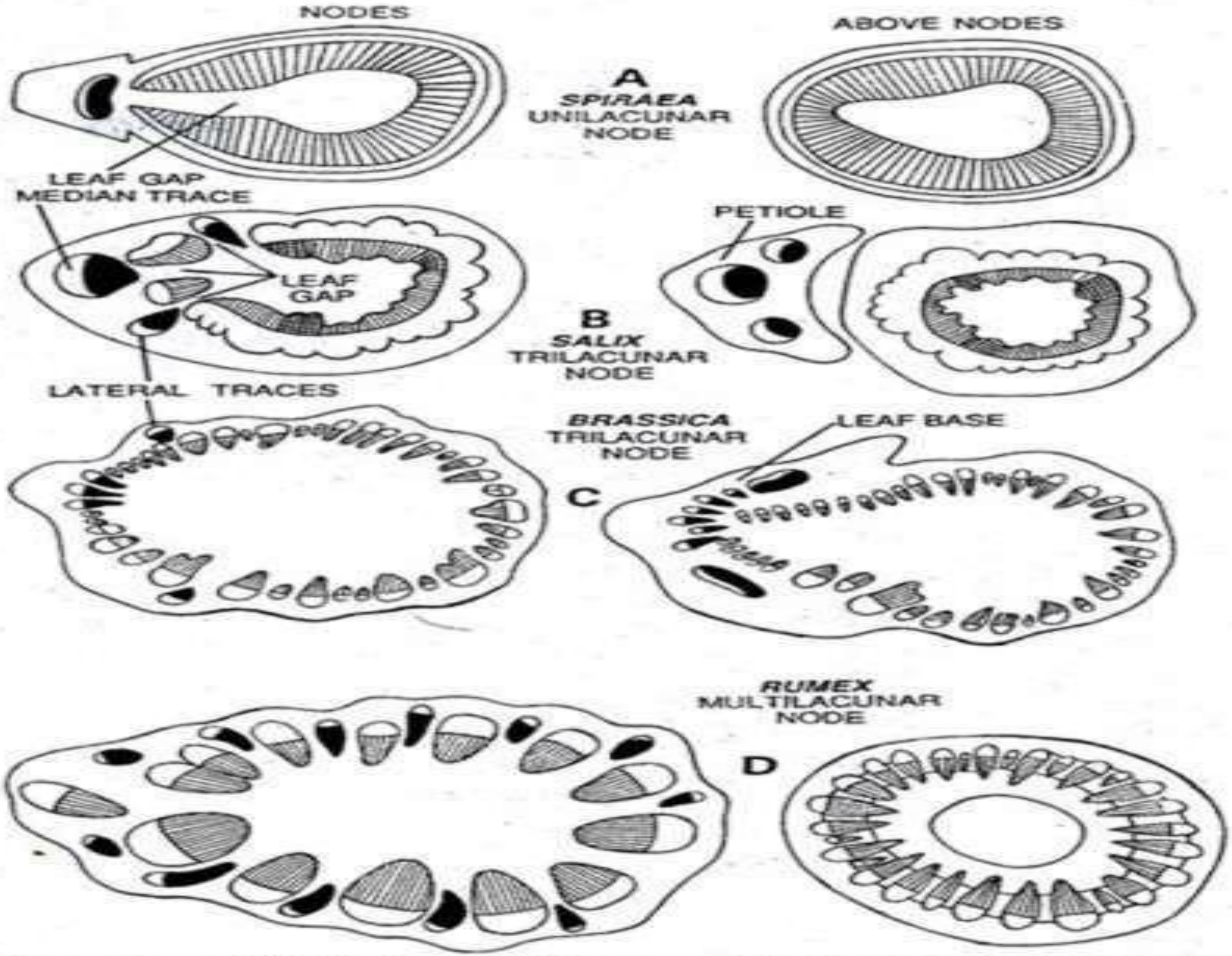


Fig. 38.3. Nodal anatomy of dicotyledons. A. *Spiraea*— each leaf has one leaf trace and one leaf gap (unilacunar node); B. *Salix*— each leaf has three leaf traces and three leaf gaps (trilacunar node); C. *Brassica*— three leaf traces and three leaf gaps per leaf (trilacunar node); D. *Rumex*— many leaf traces and many leaf gaps per leaf (multilacunar node).

Abscission

- Abscission refers to the normal separation of a senescent plant organ
- It occurs to shed or separate the unnecessary plant parts or organs
- For instance, shedding of old leaves at the base of the petiole which usually occurs during autumn
- It is a controlled process that, in most cases, is initiated during the development of the organ by the formation of an **abscission zone**

- In a mature leaf, prior to abscission, a distinct zone of few layers of cells is formed transversally across the petiole base. This zone is called **Abscission zone**
- Abscission zone has two layers :-

(i) **abscission** (or **separation**) **layer**, and

(ii) **protective layer**

Abscission Layer –

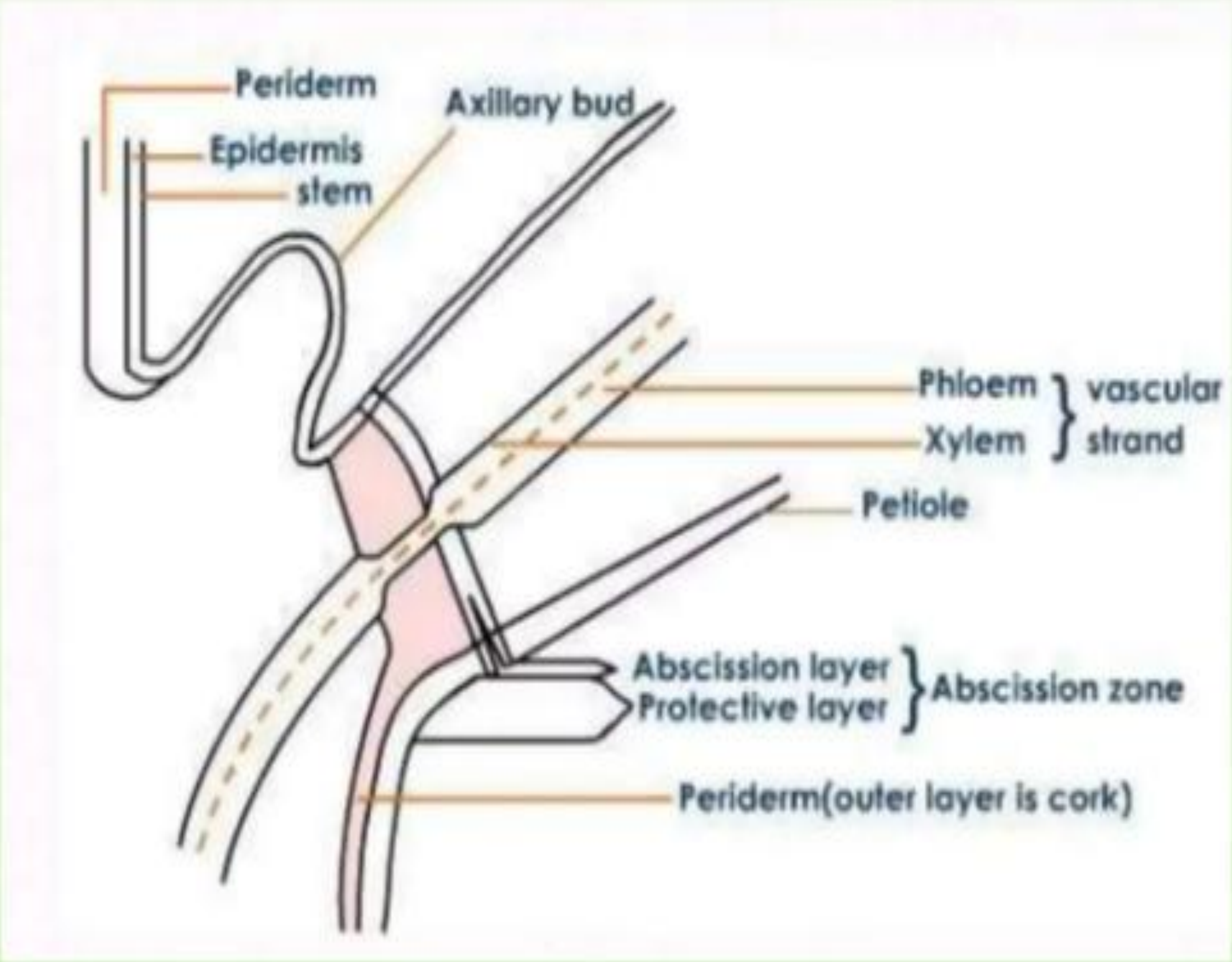
- The cells of abscission layer are thin walled parenchymatous and without the deposition of suberin and lignin
- The vascular bundles in the abscission layer are also reduced in size
- The cells of the abscission layer separate from each other due to the dissolution of middle lamella and primary wall of cellulose by the activity of **pectinase** and **cellulase** enzymes

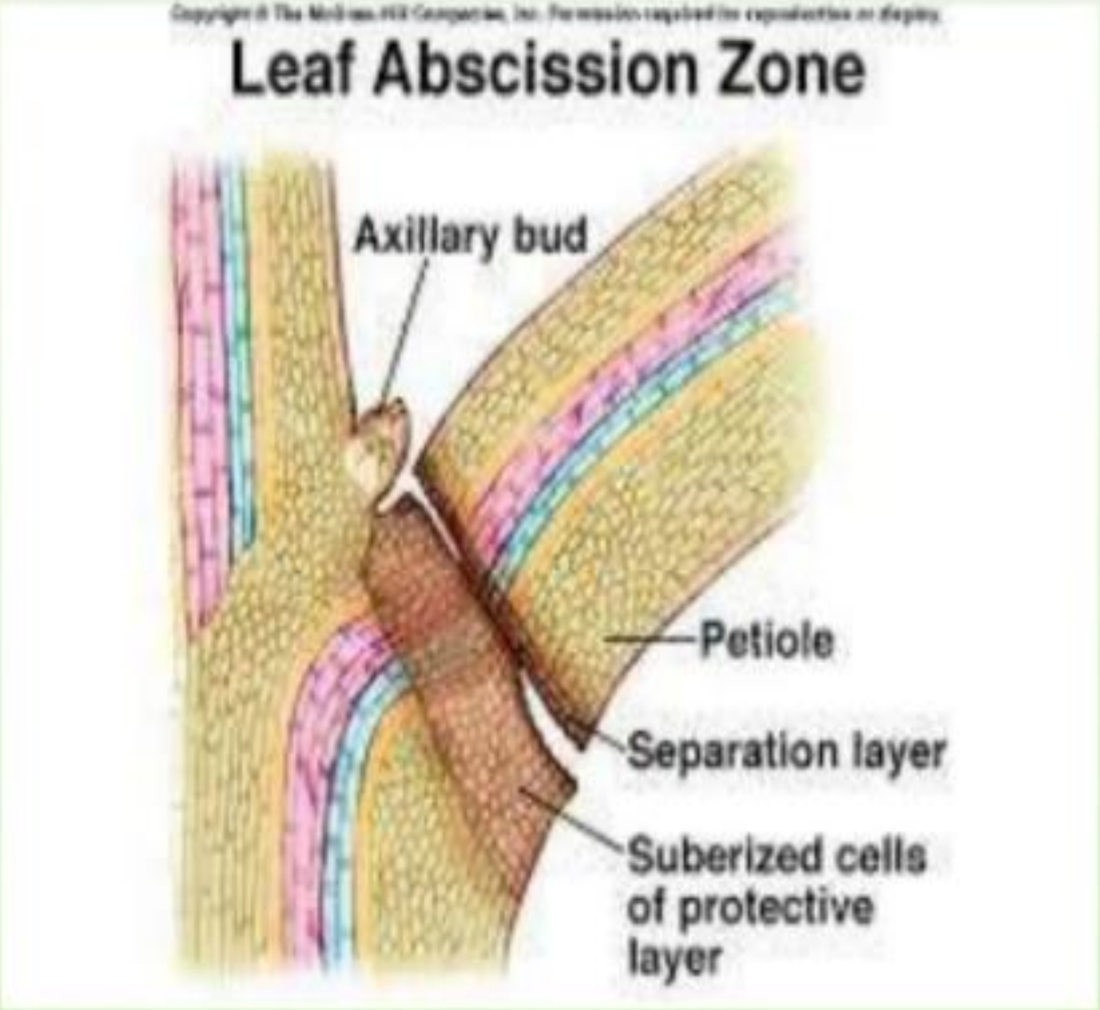
Protective Layer –

- A corky layer containing suberin and lignin forms beneath the abscission layer to protect the exposed surface after leaf fall from dessication and infection.

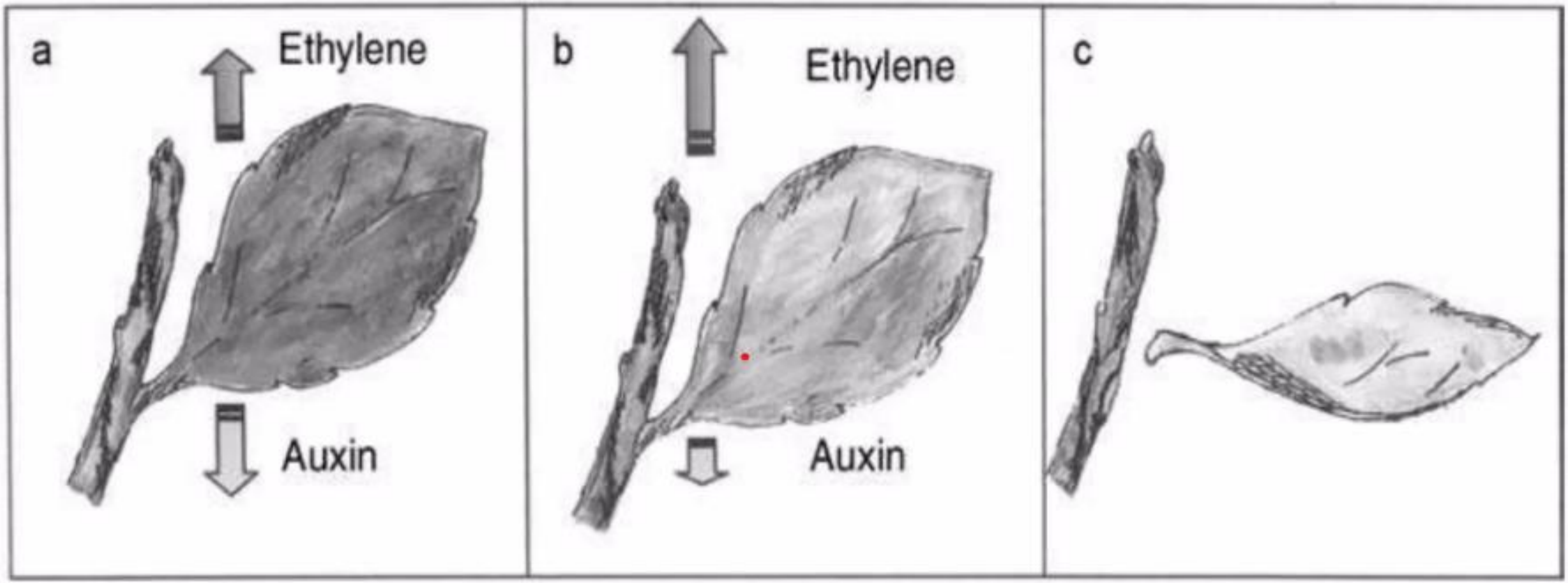
The process of abscission is initiated and proceeds as follows:

- The parenchyma cells start dividing rapidly
- They secrete a layer of suberin in the walls nearest the stem
- The middle lamella, cell walls and the cells of the abscission zone dissolve (enzymatic degradation)
- Detachment of leaf – at this stage, the petiole remains attached to the stem by vascular elements only. But due to its own weight and the wind force, the leaf is detached from the stem


Periderm
Axillary bud
Epidermis
stem
Phloem
Xylem
vascular strand
Petiole
Abscission layer
Protective layer
Abscission zone
Periderm(outer layer is cork)

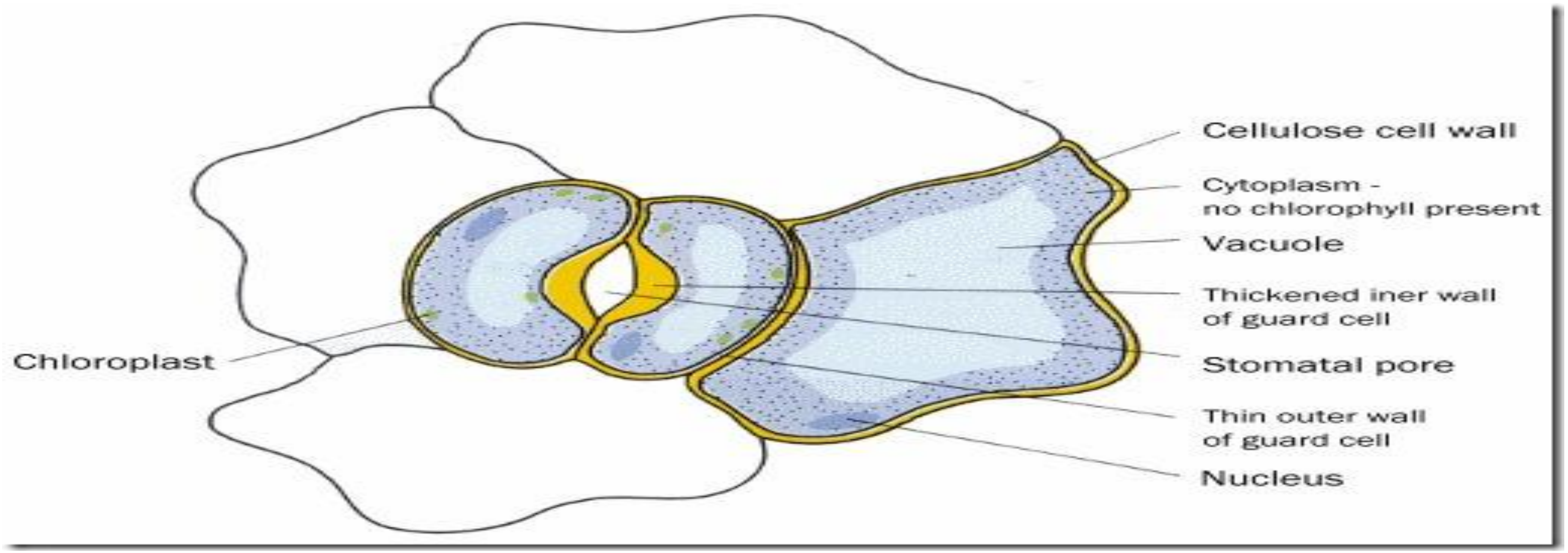

Leaf Abscission Zone
Axillary bud
Petiole
Separation layer
Suberized cells of protective layer

Progressive leaf senescence. a leaf at fully expanded stage characterized by high auxin levels in equilibrium with ethylene production. b Initiation of leaf senescence, auxin content decreases and ethylene production increases. Leaf cells in the abscission zone become sensitive to ethylene action. c Leaf abscission.

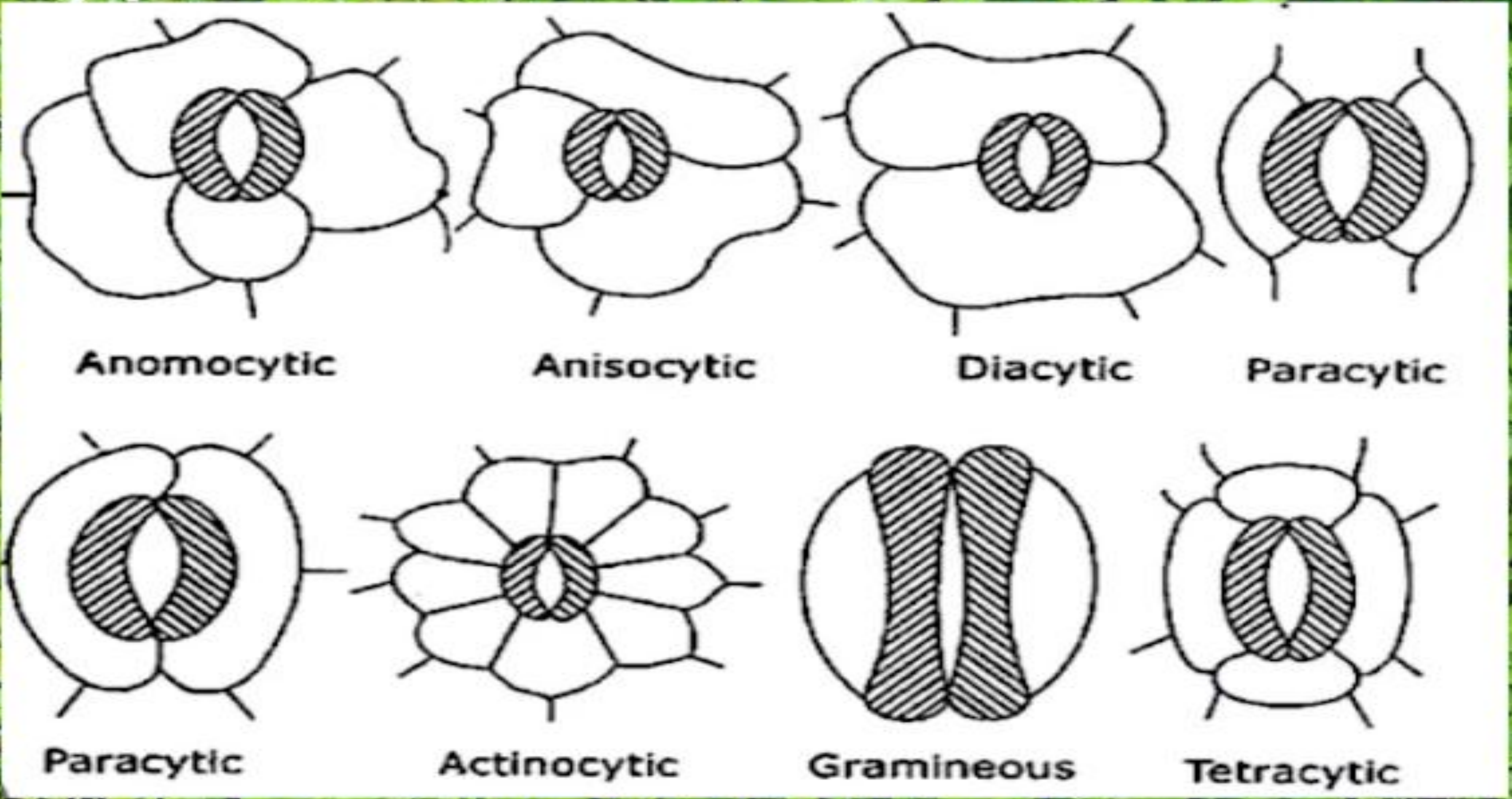


Types of Stomata in Plants

Stomata are minute pores which occur on epidermal surface of leaves and also some herbaceous stems. Each stoma is guarded by two specialized epidermal cells, called guard cells. These guard cells are also surrounded by other specialized epidermal cells called subsidiary cells or accessory cells. These cells also plays an important role during opening and closing of stomata.



Types of Stomata in Plants



1. Anomocytic (irregular celled) or Ranunculaceous: In this type, the stomata remains surrounded by limited number of subsidiary cells which are quite alike the remaining epidermal cells.

Example: Ranunculaceae, Malvaceae, Papaveraceae

2. Anisocytic (Unequal celled) or Cruciferous: In this stomata remains surrounded by three subsidiary cells of which one is distinctly smaller than the other two.

Example: *Cruciferacea, Solanum, Nicotiana* etc.

3. Paracytic (Parallel celled) or Rubiaceous: In this type, the stomata surrounded by two subsidiary cells which are parallel to the longitudinal axis of pore and guard cells.

4. Diacytic (Cross celled) or Caryophyllaceous: In this type, the stomata remains surrounded by a pair of subsidiary cells whose common wall is at right angles to the guard cells.
Example: Acanthacea, Caryophyllaceae

5. Actinocytic: These stomata are surrounded by four or more subsidiary cells, elongated radially to the stomata.
Example: Araceae, Musaceae, Commelinaceae

6. Cyclocytic: The stomata are surrounded by four or more subsidiary cells arranged in a narrow ring around the stoma
Example: Palmae, Pandanus, Cyclanthaceae

7. Graminaceous type: The stomatal guard cells are dumb bell shaped. They are surrounded by subsidiary cells which are lying parallel to the long axis of the pore.
Example: In the members of Poaceae and cyperaceae

PLANT ANATOMY RELATED TO TAXONOMY

Learning objectives :

1. Plant Anatomy in Taxonomy.
2. Importance of Anatomical characters in the field of Taxonomy.
3. Peculiarities of Anatomical characters.
4. Anatomical characters used in Taxonomy.

PLANT ANATOMY IN TAXONOMY :

IMPORTANT FEATURES .

- *Anatomical characters are CONSERVED and STABLE.*
- *can be used as "TAXONOMIC CHARACTER".*
- *Anatomical characters of all the plant parts are used .*
- *Anatomical characters can be used in Taxonomy for ;*

  1. *The identification of plants.*
  2. *Establishing genetic relationships.*
  3. *Solving taxonomical disputes.*

PECULIARITIES OF ANATOMICAL CHARACTERS :

- Anatomy of fragmentary materials [such a piece of wood] can be performed .
- Anatomical studies of Herbarium specimens can be studied
- High range of anatomical variabilities among plants.
- Most of the anatomical characters are conserved.
- Can be done without sophisticated instrumentation.

ANATOMICAL CHARACTERS USED IN PLANT TAXONOMY .

1. *Trichomes*
2. *Stomata and Epidermal features*
3. *Leaf Anatomy*
4. *Nodal anatomy*
5. *Stem anatomy*
6. *Sclerids and Fibres*
7. *Cambium*
8. *Wood anatomy*

OMES :

- Used to compare closely related taxa.
- FEATURES OF TRICHOMES USED: Glandular, Non glandular, Unicellular, Multicellular, Shape and size of trichomes etc.
- Examples ;

  1. Non glandular trichomes : lauraceae , Moraceae.
  2. Stellate hairs : Malvaceae.
  3. Mucilage hairs : Rumex
  4. Stinging hairs : Urticaceae
  5. Silica hairs : grasses .

2. STOMATA AND EPIDERMAL FEATURES :

- Types of Stomata and distribution of Stomata .
- SEM features of Stomata and Epidermis .
- Some families are specific for stomata.
  1. ANOMOCYTIC = Rananculaceae.
  2. ANISOCYTIC = Brassicaceae.
  3. DIACYTIC = Caryophyllaceae.
  4. PARACYTIC = Rubaceae.
  5. GRAMINACEAE = Poaceae

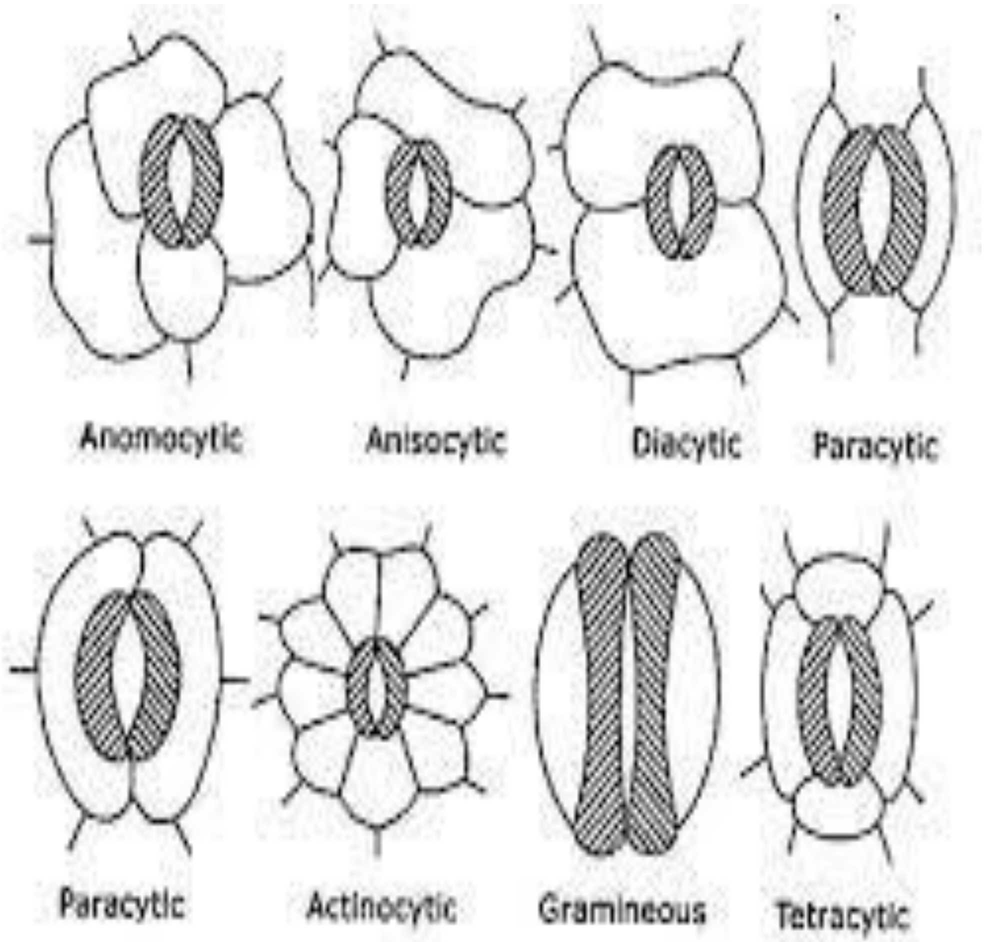
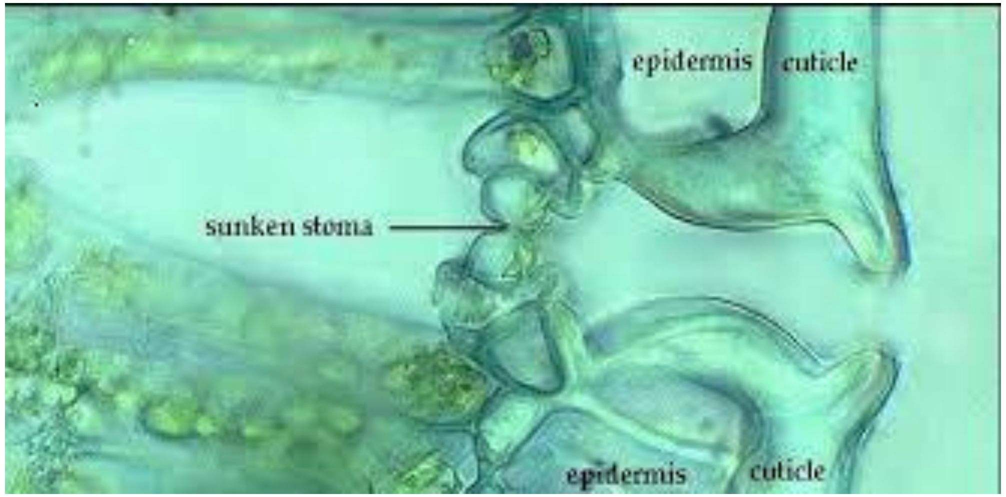


Figure 12.9

- 35 different types of Stomata have been described by vascular plants .
- SUNKEN STOMATA= Indicate XEROPHTIC habitat.
- STOMATAL INDEX = (S/(S+E))multiplied with 100.
- STOMATAL DISTRIBUTION on leaves and classification based on it :

Stomata Development are two types

1. Syndetochelic stomata
2. Haplochelic stomata



- **SYNDETOCHELIC STOMATA :**

A Type of stomata in which the two Guard cells and the Subsidiary cells are derived from a single mother cell.

Primitive type .

Usually occurs in Gymnosperms .

- **HAPLOCHELIC STOMATA :**

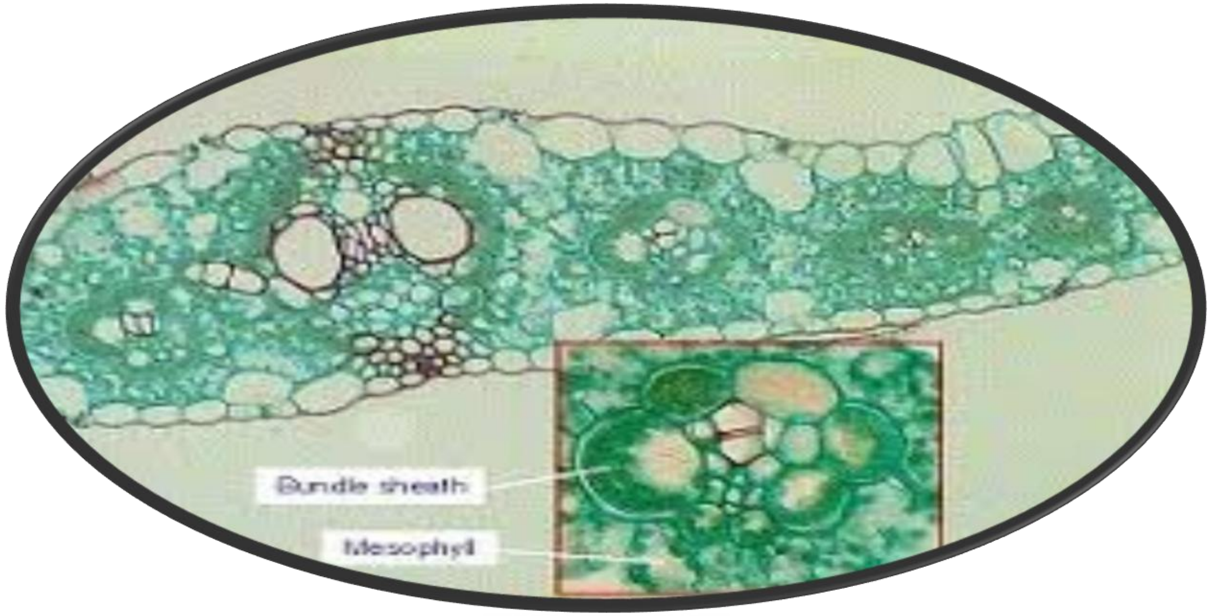
A Type of stoma in which the two Guard cells are derived from a Single mother cell and the Subsidiary cells from the derived initials .

Development pattern of stomata indicates the PHYLOGENY .

.LEAF ANATOMY :

- ✓ Leaf anatomy extensively used in the taxonomy of CYPERACEAE.
- ✓ Characters Used :

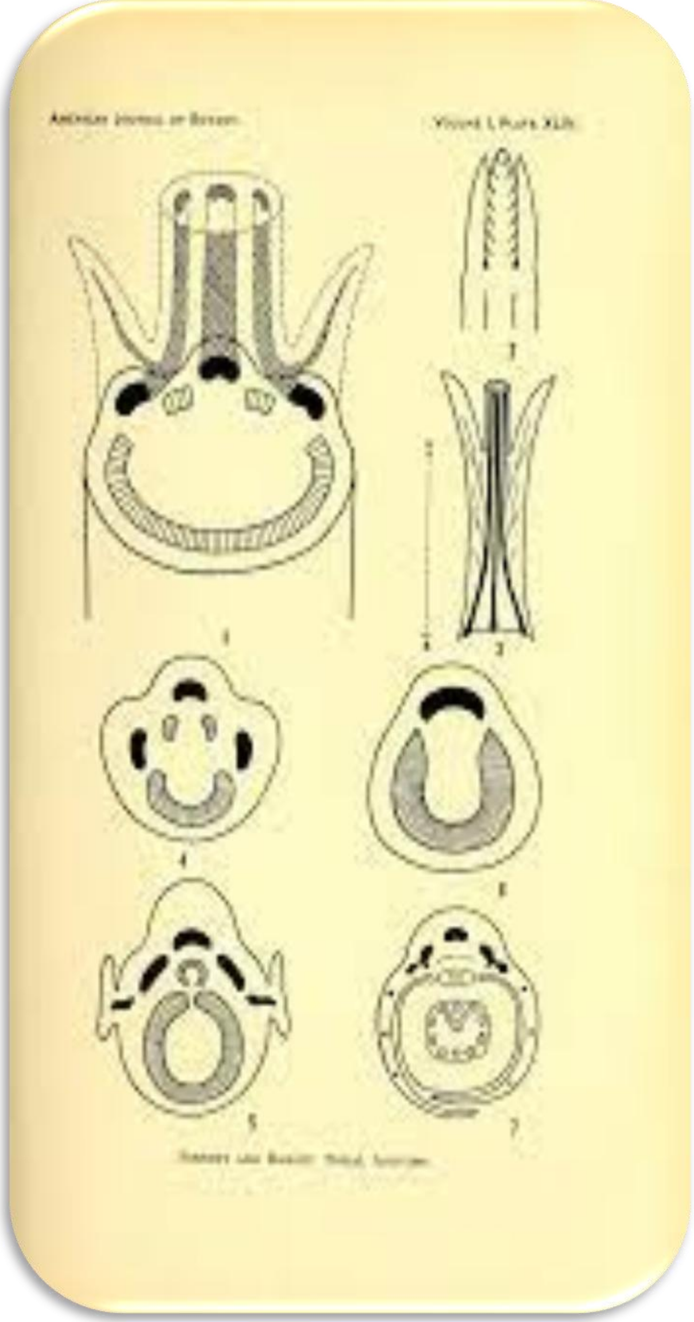
  1. Gross anatomical architectures (Dicot and Monocot) .
  2. Structural viability : Features of Mesophyll, bundle sheath, hydathodes , KRANZ ANATOMY ,foliar nectaries and glands ,oil glands, stomatal crypts and features of Leaf abscission .



4. NODAL ANATOMY :

❖ *Different types of nodes :*

1. *UNICELLULAR*
   * *Single leaf trace – Nerium , calotropis*
   * *Two leaf traces - Cleodendron splendens.*
   * *Three leaf traces - Withania somnifera*
2. *TRILACUNAR*
   * *Azadiracta*
3. *MULTILACUNAR*
   * *Rumex, polygonum, Aralium.*



5. STEM ANATOMY :

- ✓ GROSS ANATOMY OF MONOCOT AND DICOT STEM :

Features of Epidermis ,Hypodermis ,Distribution of Collenchyma, Sclerenchyma , Variations in the Endodermis ,characteristics of piths , storage region , number - shape and distribution of Vasculature.

EXAMPLES :

1.BICOLLATERAL -Cucurbitaceae.

2.CORTICAL AND MEDULLARY -Nyctaginaceae.

3. ANAMOLOUS SEC THICK -Bignoniaceae

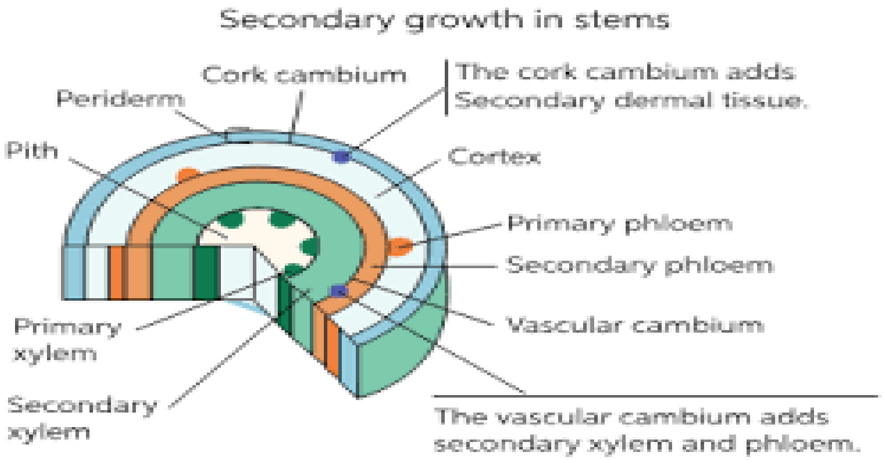
4. INCLUDED PHLOEM - Amaranthaceae

5. ANAMOLOLOUS SEC THICK IN MONOCOTS.

6. SCLERIDS :

- Nature, type and distributions of Sclerids and Fibres .
- Monocot fibres are Hard fibres (coir, Musa)
- Dicot fibres are Soft fibres (jute)
- Asterosclerids (Star shaped) in Nymphyaceae
- Trichosclerids : Branched hair like (leaves of olea)
- Macrosclerids : Columnar cells (seed coasts of legumes)
- Osterosclerids : Bone line (seed coats of pisum)
- Reaction wood and distribution of Gelatinous fibres .

7. CAMBIUM :



- FEATURES USED :
  1. Features of cambium.
  2. Formation of Secondary cambium .
  3. Storied Vs Non storied cambium.
  4. Homogenous Vs Heterogenous cambium
  5. Developmental features of ray and fusiform initials.

8. Wood Anatomy :

- Extensively used in solving taxonomic disputes.
- Also used to detect ADULTERATION in medicinal plants.
- Powder microscopy of wood can be used for identification of adulterations .
- Colour and Odour of wood are characteristics and it can be used for the identification of wood in timber industry.

FOLLOWING FEATURES OF WOOD ARE USED IN TAXONOMY

(A)VESSELS

Features of vessels – distribution pattern ,diameter , perforation features, thickening pattern etc.

Solitary vessels are considered primitive than vessels arranged in groups .

Non porous wood is more primitive than porous wood

* POROUS - Wood of Gymnosperms
* NON POROUS –wood of Angiosperms

Diffuse porous wood is primitive than ring porous wood.

(B) WOOD PARENCHYMA :

Based on the distribution pattern .two types of W.parenchyma.

1. APOTRACHEAL TYPE :

Here the parenchyma are distributed without any specific relation to the vessels.

parenchyma are not in direct contact with vessels

Three different types

* Diffuse apotracheal type
* Banded apotracheal type
* Terminal apotracheal type

- DIFFUSE APOTRACHEAL TYPE :

  1. Parenchyma cells occurs singly among fibres and tracheids
  2. Example :Adina cordifolia

- BANDED APOTRACHEAL TYPE :

  1. Parenchyma cells occurs in Bands
  2. Example : pterogota and lophopetalum.

- TERMINAL APOTRACHEAL TYPE :

  1.Bands of parenchyma cells confined to the Ends of growth rings .
  2. Example : Michelia , Acer.

(B) PARATRACHEAL TYPE :

- Here the parenchyma cells are distributed in close association with vessels.
- Two types :

(A) ABAXIAL TYPE : parenchyma cells found in association with the abaxial surface of vessels (surface away from the centre of the vessels .

(B) VASICENTRIC TYPE: Parenchyma cells completely surrounded the vessel.

(C) RAYS :

- Abundance , ray diameter , width and cellular composition.
- Degree of wall thickenings.
- Pitted pattern in ray cells .
- Homogenous and Heterogeneous ray system.
- Heterogenous rays are considered primitive than homogenous rays.

(4) STORIED STRUCTURES :

- *STORIED :*

  Arrangement of cells in horizontal series seen in the tangential section.

- *NON STORIED :*

  Storied structures are considered advanced than Non storied cells.

THANK YOU