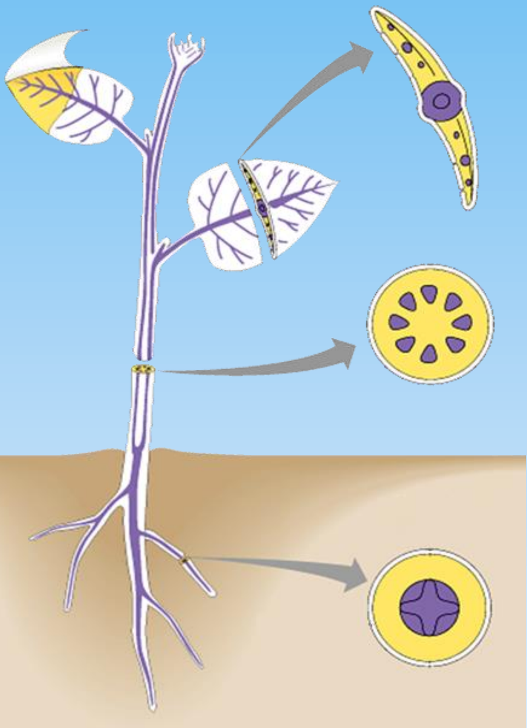
Lectures in Plant Anatomy -I

For

1st year students

2023



Prepared by:

Dr. Mohamed Owis Badry

Department of Botany & Microbiology

THE PLANT CELL.

- The structural and physiological unit of the plant body.

Robert Hook 1665:

- The first who described the cell and named it.

The cell theory (Shleiden and Schwann 1833-1839)

- The cell theory was postulated by Shleiden and Schwann as follows.

1. All living organisms consist of cells and their products.
2. All cells arise from pre-existing cells.
3. All cells are basically alike in the chemical composition and metabolic activity of the **protoplasm**.

Cell shape and size

- They are vary in shapes and sizes (from 0.2µ to 5 cm as cotton fibers).

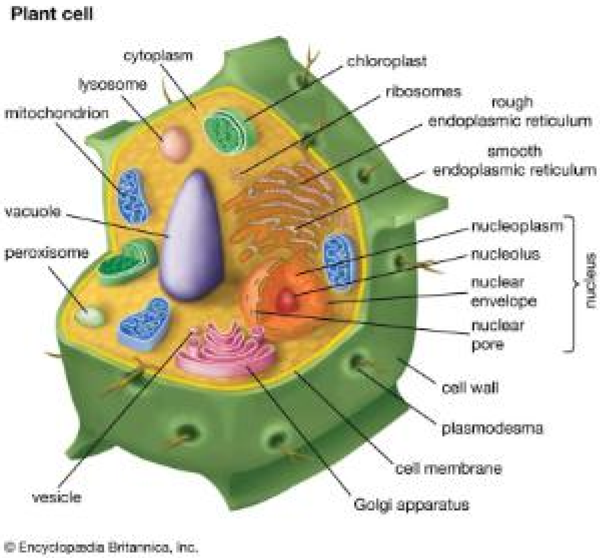
Plant Cell Structure:-

- Plant cell consists of Cell Wall and Protoplast.
- The Cell Wall composed of cellulose and other substances.
- The protoplasts constituents are divided into two groups

A) Protoplasmic components (living portion)

B) Non- protoplasmic components (non- living cell inclusions).

Plant cell-
- Cell wall: composed of cellulose and other substances
- The protoplast (the living protion)
  - Cytoplasm and cytoplasmic membranes
  - Nucleus
    - -nuclear membrane
    - -nuclear sap
    - -chromatin reticulum
    - -nucleolus
  - Cytoplasmic organelles
    - - Plastids
    - - Mitochondria
    - - Golgi apparatus
    - -Microsomes
    - - Lysosomes
- Non protoplasmic contents (cell inclusions)
  - -Vacuoles and cell sap
  - - Starch grains
  - - Proteins (aleurone grains)
  - - Fats and oils
  - - Crysatls
  - -Tannins, pigments and other organic substances



The Cell Wall

- It is composed of cellulose (polysaccharide of glucose) and other substances.
- It is a rigid non-living wall considered a fundamental distinction between plant and animal cells.
- It does not change in shape.

1- Middle Lamella

- The cell wall arises at the end of cell division during the stage of mitosis known as the telophase.
- The cell's equator acts as a cell plate on which pectic materials gradually deposit to form the middle lamella, separating the protoplast of the two new daughter cells.
- The middle lamella comprises colloidal material composed mainly of (calcium Ca and magnesium Mg) pectates and protein substances.
- Middle lamella is elastic, permeable, and acts as a cementing layer.

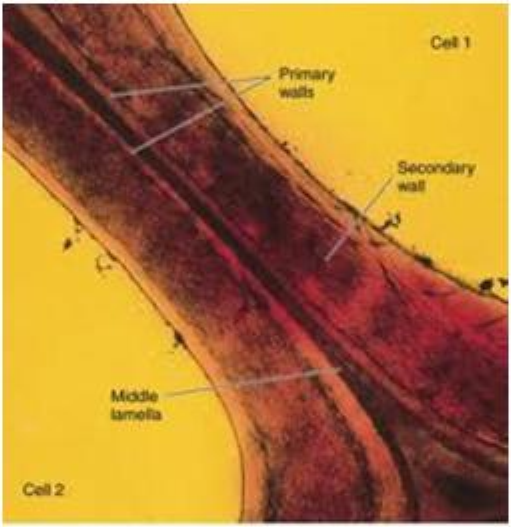
2- Primary wall

- The primary wall consists of cellulose, hemicellulose, polysaccharides (non-cellulose fats and proteins) and pectic substances.

- These substances are deposited on the meddle lamella.

3- Secondary wall

- In several types of cells additional wall composed of cellulose together with other materials is deposited on the primary wall, this is the secondary wall.
- The secondary wall consists of cellulose, hemi-cellulose and other polysaccharides.
- In addition, of these substances of the secondary wall, other non-cellulose substances may occur such as lignin, suberin and cutin.



Types of materials that share in

the formation of secondary cell wall:

1) Lignin (The process of its formation called Lignification).
2) Suberin (The process of its formation called subrinization).
3) Cutin (The process of its formation called Cutinization).

These are three materials are rigid, so they are deposited when the cell reaches its final size.

- **Lignin** is a complex organic material, impermeable to H_2O and other soluble compounds.
- **Subrin** and **cutine** are waxy materials impermeable for H_2O.
- **Pectin** is a polysaccharide of galacturonic acid units.

- After a period of formation of secondary wall, the cells become dead.

Function of Secondary wall:

1. Protection as in seed coats.
2. Supporting as in fibers.
3. Translocation of H_2O as in vessels.

Lignin:

- Deposits on dead cells-rigid: as 1) Fibers 2) Tracheids and vessels
- In fibers, deposition is regular on the cell.
- In tracheids and vessels, deposition is irregular.
- Tracheids are typically angular, but vessels may be:

1. Annular and spiral vessels are characteristic of protoxylem.
2. Other kinds (scalaryform, pitted, and reticulate) are common in the metaxylem and secondary xylem.

Subrin:

- In periderm, deposition is regular, as in cork cells.
- In endodermis, deposition is irregular as in root endodermis (Casparian stripes).

Cutin:

- Cutin deposits on the external layer of epidermal cells and it forms "**cuticle**", which cover all the plant body, in irregular manner, except the root.

Its depth depends on the habitat of plants.

- In desert plants (**xerophytes**), epidermis covered with thick layer of cuticle to prevent water loss from epidermis cells, and the epidermis then is called **Cutinized epidermis**.
- In aquatic plants (**hydrophytes**), cuticle is very thin or absent.
- In **mesophytes**, cuticle is thin.

Functions of the cell wall:

1. It provides mechanical supporting and gives the definite cell shape.
2. It helps in the water and nutrient movement because it has a hydrophilic nature.

Growth of the cell wall: -

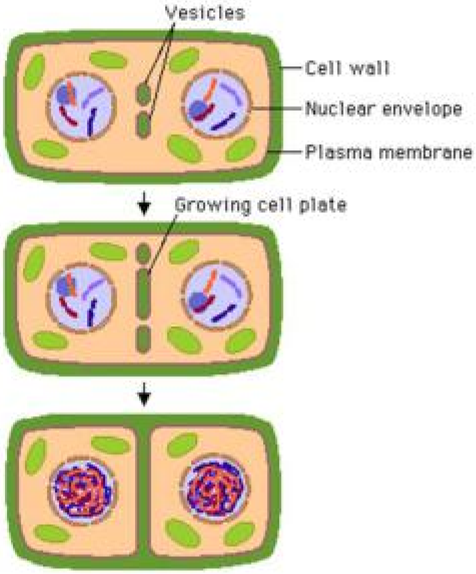
- The method of addition of new building material to the cell wall, as it increases in area and thickness, occurs by two processes:

1-Apposition: -

- In which new particles are deposited in layers on the surface of the earlier formed wall (increases in thickness).

2-Intussusception:-

- In which new particles are added among those, materials already present (increases in area).



Stages of cell wall formation

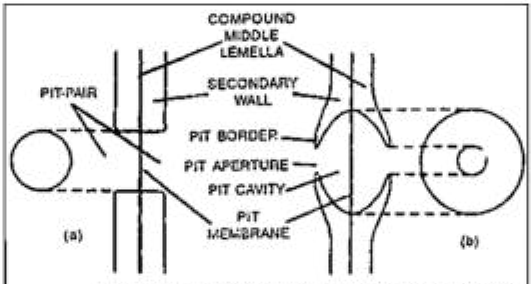
Pits:

- During early stages in thickening of the first cell wall, small areas left without thickening.
- The parts of thin areas left without thickening during the deposition of the wall termed as **Pits**.

- The cytoplasm of the cell is connected with the cytoplasm of the adjacent cell by a fine cytoplasmic strand, which extend through the pit, these strands called ***Plasmodesmata***.

Pit consists of three parts:

- 1) Pit membrane 2) Pit cavity 3) Pit aperture.
- Each pit has a complementary pit exactly opposite it in the wall of the neighboring cell and this system called **pit–pair**.
- The pit pair has one **pit membrane**, which resemble the primary cell wall and middle lamella, which separates the two pit cavities of the pit–pair.
- The cavity formed in the secondary wall called the **pit cavity**.
- The opening of the pit on the inner side of the cell wall called the **pit aperture**.



Structure of pits. (a) Simple pit pair in surface view and L.S. (b) Bordered pit-pair in L.S. and surface view.

Pits types:

1) Simple pit:

- Pit membrane is simple.
- The cavity has the same diameter at the different depths.
- Found in parenchyma.

2) Branched pit:

- The cell wall is very thick.
- The cavity branches in the cell wall.
- Found in stone cells of fresh apples, and bears.

3) Bordered pits:

- The wall around the pit cavity overarches the cavity forming a roof called "border".
- The diameter of the pit aperture is smaller than that of the cavity.

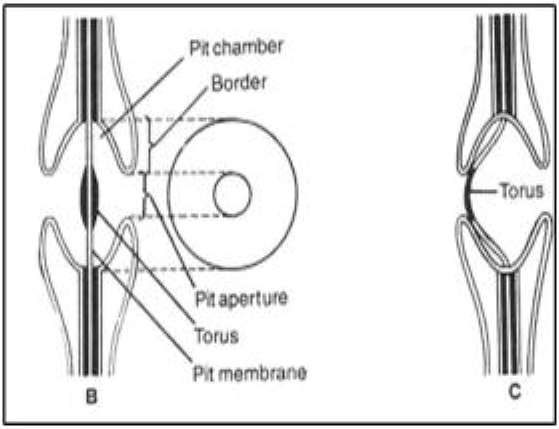
- The pit membrane thickened in the central part to form "torus".
- **Torus** can close the aperture when the hydrostatic pressure in one cell exceeds that of neighboring cell.
- Found in tracheids and vessels.

4) Half bordered pit pair

- In which a simple pit is opposite to a bordered pit .
- This type is found when a parenchyma cell is adjacent to a conducting element.

5) Blind pit

- When the pit faces no pit on the other side, or it is opposite to intercellular spaces.



The Protoplast

- It is the living portion in all cells of the plant body.
- Protoplast has a complex organization of:

1) Organic substance.

- Proteins (40-60% of the dry weight of protoplast).
- Carbohydrates, fats, organic acids.

2) Inorganic substances.

- Water (the most important constituent of the cell 80-90% of the fresh weight of protoplast).
- Inorganic salts (less than 1%).

Structure of protoplast:

1. Cytoplasm (Viscous transparent fluid).
2. Nucleus (ellipsoid body).
3. Cytoplasmic organelles (minute living bodies embedded in the cytoplasm).

- Within the cytoplasm, there is a system of membranes called "**Endoplasm reticulum**"
- Cytoplasm organelles include:

1) Mitochondria. 2) Golgi apparatus.

3) Plastids. 4) Lysosomes.

Plasma membrane:

- Called plasma lemma or cell membrane.
- The plasma membrane, which found under the cell wall, separate between the cell wall and the cytoplasm called **ectoplast**.
- The plasma membrane, which found around the cell vacuole to separate it from the cytoplasm, called **tonoplast**.

The structure of plasma membrane

- The plasma membrane is chemically composed of two inner layers of **Lipids** (phospholipids) and two outer layers of **proteins**.
- The phospholipids are polar molecules i.e. two ends of the molecules have different properties.

- One end is **hydrophobic** (i.e. water hater) and the other end is **hydrophilic** (i.e. water lover).

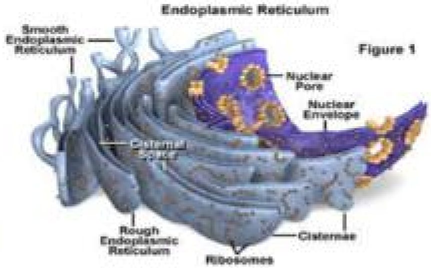
Function of plasma membranes

- Act as selective barriers (selective permeability).
- They provide a structure on which the different biological reactions take place.

Endoplasmic Reticulum (ER):

- It is a membranous system, which branches inside the cytoplasm to form network-like structure.
- It forms continuous channels connecting the nuclear membrane possibly with the plasma membrane.

Types of endoplasmic reticulum



1) Granular endoplasmic reticulum (Rough e.r.):
- Have dens granules of ribosomes on its surface.
2) Agranular endoplasmic reticulum (smooth e.r.):
- Lacks ribosomes.
- The shape of E.R. can be changed by different physiological conditions. (I.e. addition of CO_2 or cyanide leads to great increase in E.R.].

Function of endoplasmic reticulum

- It forms the skeleton network of the cell.
- It helps in the intercellular transport of various metabolites.
- The rough E.R are involved in protein synthesis.
- The smooth E.R participates in biosynthesis of fatty acids, phospholipids.
- They connect the nucleus with the cytoplasm.

Cytoplasmic Organelles

1. Plastids

- Characteristic to plant cells.
- Often coloured and vary in shape and size.
- Develop from smaller pre-existing plastids called **proplastids**, which are able to increase in division.
- Classification of plastids according to their colour:

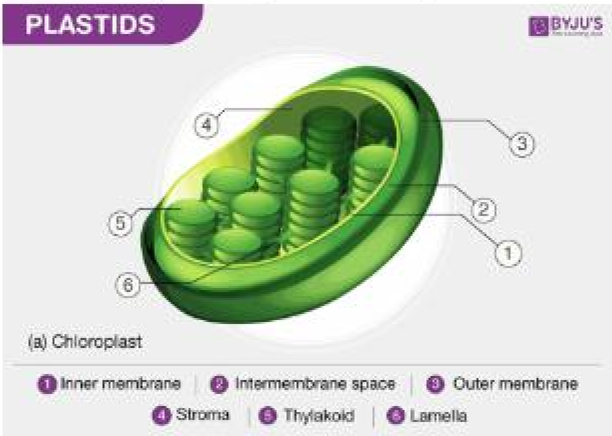
1. Chloroplasts (Green Plastids):

The most important type because of the presence of green chlorophyll pigments.

- The most important types of chlorophyll are **chlorophyll a** (bluish green) and **Chlorophyll b** (yellowish green).
- Other pigments are also present but less than chlorophyll as **Carotein** (Yellow, Orange, Red), **Xanthophylls** (Yellow).
- Caroteins and xanthophylls (**accessory pigments**) may be protecting the chlorophyll from destruction by sunlight.
- In animal body, caroteinoids are converted into vitamin A.
- Chloroplasts vary in shape and size but are constant within a given tissue.

Occurrence

- They are absent in root system, and present in shoot system.



Size and Shape

- They may be cup-shaped (as in ***Chlamydomonas***) or helical bands (***Spirogyra***).
- They are found in mesophyll, (as in Palisade tissue of the leaf).
- In higher plants, they are discoid (4-6μ).

Ultra-structure

- Chloroplasts of higher plants contain chlorophyll-bearing units which are the grana (sn. granum) ,
- The grana are embedded in a colourless protein matrix (stroma).
- The stroma surrounding by a double membrane.
- Each granum consists of a series of double membrane lamellae called thylakoides, stalk one upon the other.
- The grana are interconnected by a system of intergranal lamellae termed frets, which pass through the stroma.
- Its function: Photosynthesis. [Dark reaction in stroma, light reaction in grana].

b) Chromoplasts:

- Their color is other than green (Yellow, orange, red).
- The color is due to presence of caroteins and xanthophylls and absence of chlorophyll.

Occurrence

- In yellow petals of sunflower, carrot roots and the ripe fruits of sweet pepper and tomato.

Shapes and Size

- They vary in shape [Spherical angular, lobed, rod like].
- When the carotins is crystalline form, it gives the irregular and sharp pointed shape.
- In some cases, the chromoplast develops from the chloroplasts by destruction of chlorophyll as occurs during the ripening of some fruits as tomato or banana.

Function

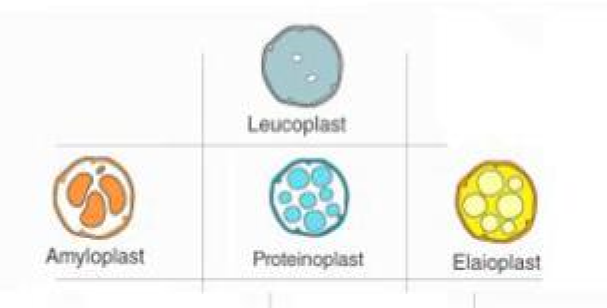
- The function of them is not known, but they are important in synthesis of vitamin A in animals.

c) Leucoplasts:

- Leucoplasts are concerned with storage of food, they are originated from the proplastids, and it may be converted to chloroplast if it exposed to light.
- Leucoplasts associated with storage of starch are known as **amyloplasts**.
- Leucoplasts associated with storage of **fats** are known as **elaioplasts**, which occurs in the seeds of peanut, corn and castor bean.
- Leucoplasts associated with storage of **oil** are known as **lipoplasts**.
- Leucoplasts associated with storage of **proteins** are known as **aleuroplasts**.

Occurrence:

- They found in cells, which have been protected from light (e.g. underground parts of the plant.



2. Mitochondria (Chondriosomes):

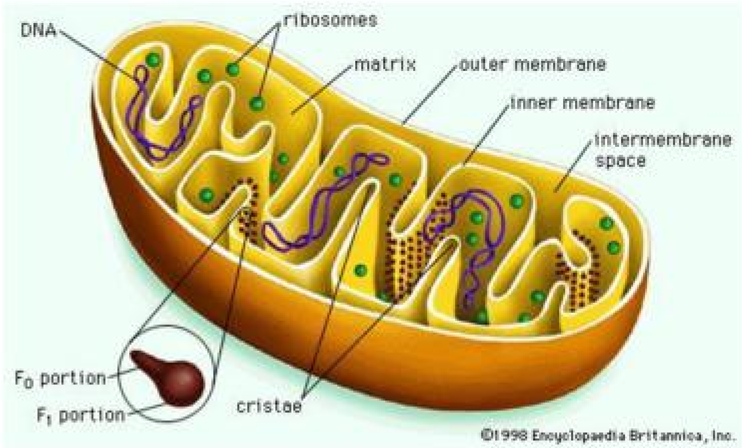
- They are small cytoplasmic bodies present in large numbers in the cytoplasm.

Size and Shape

- Their size varies from, 0.2 to 3μ and their shape is filamentous, rod shaped or globular.

Ultra-structure

- Each mitochondrion is bounded by double membrane.
- The outer is smooth, but the inner is folded to interior in extensive folds called cristae.
- The **cristae** increase the surface of the membrane on which biochemical reaction takes place.



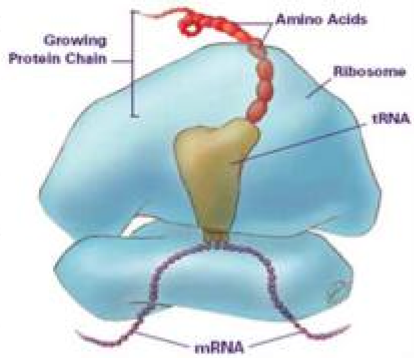
Function

- The mitochondria contain enzymes and Co-enzymes responsible for the respiration mechanism and energy formation, (**Powerhouses of the cell**).
- ATP is formed in the mitochondria.

3. Ribosomes:

Size and Shape

- They are circular or ellipsoidal about 150-250°A.



Occurrence

- They attached to the ER giving its surface a rough appearance.
- They also found in the cytoplasm of higher plants and animals.
- They are uniform in size and composition in different types of cells.

Ultra-structure

- It chemically composed of Protein mainly histones, Ribosomal RNA (rRNA).
- The rRNA is synthesized in the nucleolus under the direction of DNA.
- It consists of two subunits, larger and smaller one.

Function

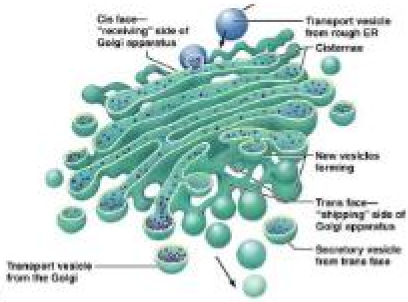
- They are considered the site of protein synthesis.

4. Golgi apparatus (Dictyosomes):

- Found in plant and animal cells.
- They vary in shape and size.

Ultra-structure

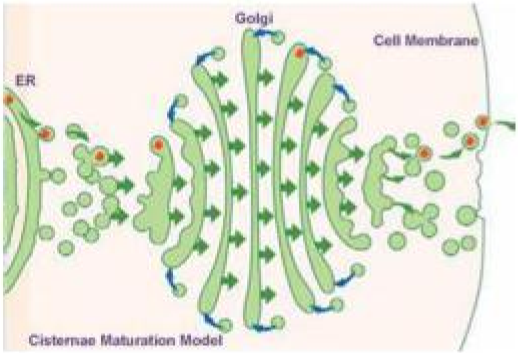
- The membranes of the Golgi apparatus are unit membranes and composed chemically of lipoprotein.
- The Golgi apparatus appears under the electron microscope to be consisted of three parts:



- A system of flattened **cisternae** or plates.
- Variable number of **vesicles**.
- Large **vacuoles** (Originated by budding off the vesicles that contain the accumulated materials from the Golgi like lysosomal enzymes).

Function

1. Secretion such as proteins, polysaccharides and pectic substances.
2. Collection and accumulation of certain substances such as lipids and enzymes and proteins.
3. They play a role in phospholipids synthesis.
4. They play a role in plasma membrane synthesis.



The Nucleus

- It is a dense spherical or ovoid body about 15μ in diameter.
- Discovered by Robert Brown in 1831.

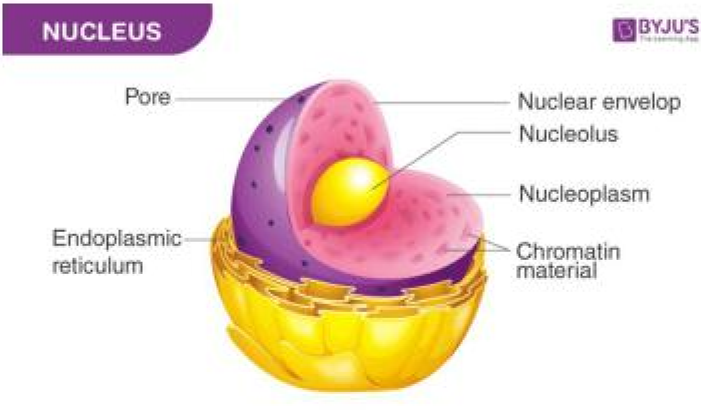
Number of nuclei in the cell

- Generally, each cell contains one nucleus.
- In uredospores (fungal spores), each cell contains two nuclei.
- There are also other types of cells that have many nuclei (coenocytic) such as some species of fungi.
- In bacteria and blue green algae, have only chromatin materials that may serve as primitive nucleus (prokaryotic organisms).

Structure of the Nucleus

1) Nuclear membrane (envelope):

- The nucleus has a double membrane separates the nucleus from the cytoplasm.
- There is a space between the two membranes.
- It is connected to the cytoplasm through ER.
- The membrane surrounds the nucleus during its resting stage and disappears at the time of nuclear division.



-

2) Nuclear Sap

- The nucleus is filled with a gel-like mass known as the nuclear sap through which extends a network of separate threads known as the chromatin reticulum.

Chromatin reticulum: -

- A network of separate threads extends through nuclear Sap.
- It can not be seen at the resting stage.
- During division of the nucleus, the chromatin is resolved into a characteristic number for each species.
- Chromosomes are not seen in resting cells.
- Chemically it composed of DNA, proteins and little amounts of RNA.

<u>3. Nucleolus:</u>

- Each Nucleus contains one or more globular dense bodies known as nucleoli (singular; nucleolus).
- Chemically, it consists of protein and ribonucleic acid (RNA).
- Its function is the synthesis of rRNA, which used in the manufacture of ribosomes.
- During division, the nucleolus disappears and develops again in the daughter nucleus.

Nucleic Acids and Genes

Genes:

- The hereditary material is carried on the chromosomes, known as genes.
- These materials, which transmitted from one generation to anther, are nucleic acids.

Nucleic acid:

- The nucleic acids mainly are DNA (Deoxyribonucleic acid) and RNA (ribonucleic acid).
- DNA controls the production of RNA, which plays an important role in protein synthesis.

DNA

- It found basically in the nucleus.

<u>The structure of DNA</u>

- DNA molecules are long double helices (singular: helix) built up from hundreds of smaller units known as **nucleotides**.

Each nucleotide is made up from:

1. Deoxyribose sugar:

- Is a 5-carbon sugar with a H substituted for one of the OH groups of ribose.

2. Phosphoric acid:

- One molecule of phosphoric acid is linked to the deoxyribose sugar of the next, resulting in a long chain of alternating deoxyribose and phosphoric acid residues.

3. Nitrogen organic bases:

- The organic bases may be **puriens** such as [adenine (A), guanine (G)] or **pyrimidines** such as [cytosine (C), thymine (T)].
- A nucleotide molecule consists of one molecule of the four nitrogenous bases linked to deoxyribose sugar is called a **nucleoside**.
- There are four kinds of nucleotides according to the organic bases.

Watson and Crick Proposal:

1. DNA molecule consists of double helix coiled strands.
2. DNA molecule consists of nucleotides.
3. Nucleotides consist of ribose sugar, nitrogen base, and phosphate.
4. Nucleotides joined by hydrogen bonds.
5. Nitrogen bases are A, T, G, and C.
6. A joined to T by double bonds
7. G joined to C by trible bonds.
8. The amount of A = T and the amount of G = C.

- Since the bases could be arranged along the molecules in any sequence, they can provide "coding system" that carries the genetic information.
- Each three nitrogenous bases forms one codon, each codon contains three nucleotides. DNA is found in the cell nucleus and not generally in the cytoplasm.

How does the DNA control the activities of the cell?

- The DNA of chromosome forms specific kinds of RNA. The RNA is transferred to the cytoplasm through the pores of the nuclear envelop.
- The RNA incorporated in ribosomes.

- The ribosmoes are responsible for the formation of protein molecules from amino acids.
- This means that DNA determines the kind of RNA formed, in turn the kind of protein formed.
- Therefore, the DNA indirectly controls the various activities of the cell and of the organism as whole.

RNA

RNA differs from DNA in:

- It contains ribose sugar instead of deoxyribose.
- It contains nitrogen base uracil (U) instead of (T).
- Therefore, the total number of nitrogen bases in the nucleic acids are 5 nitrogen bases (A, T, G, C, and U).
- DNA consists of double helix, but RNA is composed of a single helix.
- As DNA, most RNA is composed of hundreds of nucleotides.

A comparison between DNA and RNA

DNA	RNA
It occurs in the nucleus, chloroplasts and mitochondria.	It occurs in nucleus and cytoplasm.
The sugar molecule is deoxyribose sugar.	The sugar molecule is ribose sugar.
It consists of double helix.	It consists of single strand.
Its nitrogen bases are A, T, G, and C.	Its nitrogen bases are A, U, G, and C
It acts as a template for RNA synthesis.	It acts as a template for protein synthesis.

Each nucleotide consists of:

1) Ribose sugar.

2) Nitrogenous bases (A, U, G, C).

- According to the length of nucleotide chain, there are **three** types of RNA differ in function:

<u>1) Messenger RNA (m RNA):</u>

- It is a single helix composed of relatively long chain of nucleotides.
- This type is considered as the code carrier and acts in the building up of protein molecules at the surface of the ribosome.
- It is synthesized under the control of DNA.

- It has two main sites a- start codon b-stop codon.

2) Transfer RNA (tRNA):

- Its molecule consists of a shorter chain.
- The tRNA is the amino acid carrier from the cytoplasm to ribosomes in protein synthesis.
- It is a single strand, but it is looped on itself.
- It has two ends (Sites):

a. Free site (amino acid attachment site).

b. Looped site (contains three free nitrogenous bases and it is attached to mRNA in protein synthesis).

- Each tRNA molecule can transmit a specific one type of amino acids.

3) Ribosomal RNA (rRNA):

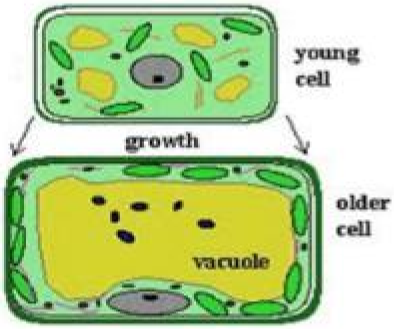
- It is synthesized in the nucleolus.
- It resembles the major component of the ribosome.
- It facilitates the establishment of mRNA on ribosomes and stabilizes the interaction of mRNA and tRNA.

Non-living contents

- They are the cell inclusions.

1. The Cell Vacuole:

- They are characteristic to the plant cell.
- In meristematic cells, they do not contain large vacuoles but only small droplets.
- As the meristem cell enlarge, the small vacuoles enlarge by taking up water and adjacent vacuole fuse forming larger vacuoles.
- Finally, a single large vacuole is formed which occupies most of cell (In mature cell).
- The increase in cell size during maturation is mainly due to water absorption by vacuole.
- The vacuole consists of a region filled with the cell sap and surrounded by a vacuole membrane (***tonoplast***).



- The cell sap is an aqueous solution of organic and inorganic compound and also pigments and sugars.
- Organic compounds: carbohydrates, proteins and fats.
- Inorganic compounds: nitrates, sulfates, phosphates and several other salts.
- The function of the vacuole is the movement of water the concentration of the cell sap controls this movement.
- The nucleus may be suspended in the center of the vacuole by these cytoplasmic strands, or it may be embedded in the parietal layer of cytoplasm.
- Root hairs contain large vacuole.

2. Carbohydrates:-

- Occurs in the cell sap of various plants.
- Carbohydrates may be.

1. Soluble carbohydrates

- **monosaccharides** as glucose and fructose.
- **Disaccharides** as sucrose, present in abundance in the cell sap of many plants as sugar cane.
- **Polysaccarides**
- Inulin, which give fructose by hydrolysis in the tubers of dahlia.
- Dextrin – mannitol – pentosans (less common).

2. In soluble starch: -

- Produced only in ***amyloplasts*** (***Leucoplasts***).
- It may not be found in the vacuole or free in cytoplasm.
- It consists of units of glucose.
- It consists of successive layers and laid down around a center called "hilum".
- Strach may accumulate in chloroplastids under certain condition, but they are removed quickly but not are stored.
- Strach grains varies from one plant to another there are 3 types

a-Simple grain: -

- Has only hilum (point, radiate or lobed).
- Hilum may be: centric or eccentric
- Other simple grains with radiate or lobed hilum
- Corn starch- Phaseulas starch- Rice starch

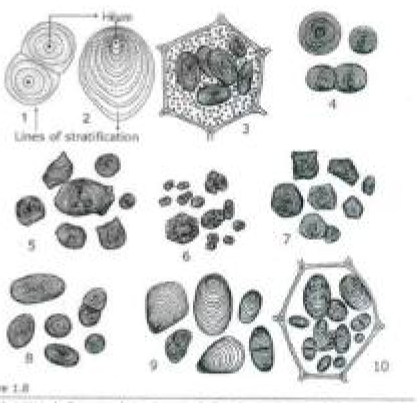


Figure 1.8

Starch grains. 1. Compound starch grain. 2. Simple starch grain. 3. From cotyledon of *Pisum* seed. 4. From flesh of *Musa*. 5. From tuberous root of *Ipomoea batatas*. 6. From endosperm of *Oryza* grain. 7. From endosperm of *Zea* grain. 8. From cotyledon of *Cicer* seed. 9. From tuber of *Solanum tuberosum*. 10. Same in situ.

-

b- Compound grain: -

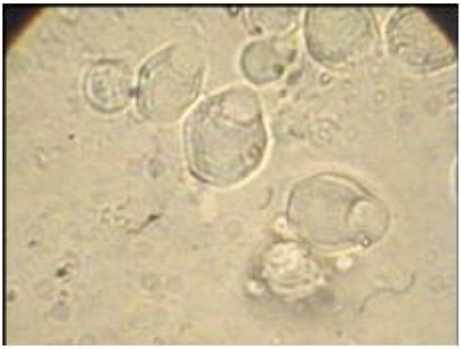
- Potato and rice starch
- Few to many grains, separated, each with hilum.

c- Semi-compound grain: -

- Ex. Potato starch
- Starch grains, each with hilum enclosed with in a common starch layer.
- Starch grains give blue or violet color with solution of **iodine** in potassium iodide.

3. Proteins:

- Beside the proteins which form a part of the living protoplasm, they are nonliving proteins occur either dissolved in the cell sap of the cells.
- The non-living proteins found in the form of crystal-like bodies called {**Aleurone grains**}.
- Each grain has a membrane and composes of crystalloid and globoid bodies.
- One of these bodies is large consists of proteins (crystalloid) and the other is smaller and consists of protein combined with phosphates (globoid).
- Aleurone grains stain **yellow or brown** in iodine solution.
- The type of leucoplast that stores proteins is ***aleuroplast***.



4. Oils and Fats:

- Oil droplets and fat globules occur in the cytoplasm as in the endosperm or cotyledons of seeds as peanuts and cottonseeds.

- By staining it with sudan III, it gives brown color.
- The fat-storage leucoplast is called "***elioplast***"

5. Organic acids:

- In cell sap, either free acids or their acids salts.
- Examples, malic and tartaric acids are common.
- Oxalic acid also occurs generally, but it is usually present in the form of its insoluble calcium salt as crystals.
- Crystals may be formed from calcium oxalate or calcium carbonate.

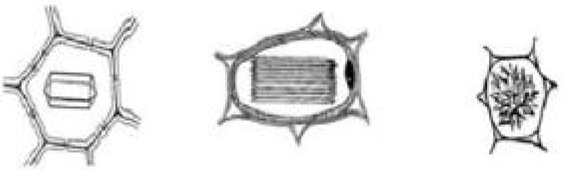
Calcium oxalate occurs in plant cells in different forms:-

1-**Single**: square or pyramidal-small or large.

2- **Raphides**: clusters of needle-shaped crystals-common in monocot.

3- **Druses**: rosette-shaped crystals like in cells of Begnonia.

- Calcium oxalate dissolves in mineral acids and is insoluble in dilute acetic acid.

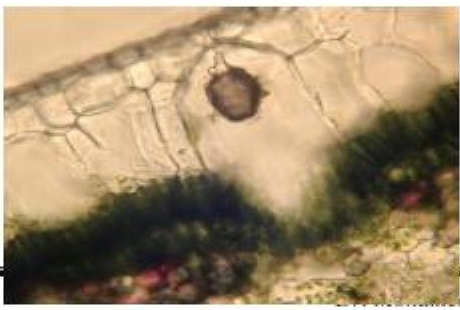


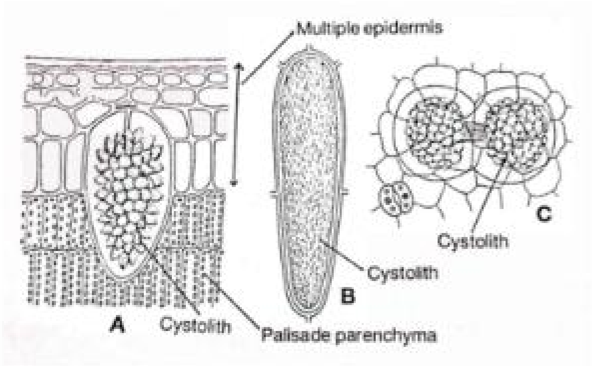
Solitary **Raphides** **Druses**

Calcium carbonate crystals

is called ***cystolith***, which consists of cellulosic stalk (in growth of cell wall), and calcium carbonate deposits a round it forming a cluster-like structure fills most of cavity of the cell. Found in ***Ficus elastica***.

- It dissolves in mineral acid and in dilute acetic acid.





6. Anthocyanins:

- Pigments dissolved in the vacuole sap.
- They are complex compounds of a **pigment and a sugar**.
- They are soluble in H_2O and diffuse out if the cell membrane destroyed by heating or any other mean.
- They are responsible for blue, violet, purple and most of the dark red colors.
- Cause the red color of beetroots, red of cherries, colors of petals of many flowers.
- This color is depending on the pH.

7. Glucosides:

- In the cell sap.
- Composed of glucose + aromatic compounds.
- EX: amygdalin, which decomposes by "emulsin" enzyme to give glucose, benzaldehyde and hydrocyanic acid.
- The odor of bitter is due to benzaldehyde.

8. Mucilaginous Compounds:

- In the cell sap, gives its slimy character.
- Mucilaginous compounds are common in many bulbs (onion) and leaves of succulent plants.
- Soluble in H_2O, but insoluble in alcohol.
- They are polysaccharides (hydrolysis gives sugars).

9. Tannins:

- They are commonly in the cell wall, but also present in cell sap.
- They are complex compounds, soluble in H_2O and alcohol.
- By treating, it with **$FeCl_3$** gives blue – black or green color.
- Found in leaves of tea, oaks and many conifers.

10. Alkaloids:

- They are products of nitrogen metabolism.
- They are complex cyclic compounds containing N_2.
- They are common in members of solanaceae, papaveraceae, leguminosae and apocyanaceae.

Examples:-

- morphinefrom poppy fruits
- nicotine from tobacco
- atropine from ***Atropa***
- Caffeine from Coffe, tea

Plant tissues

- The body of the plant consists of number of cells.
- A group of cells which are similar in size and shape, having same origin, same methods of development and same function constitute a tissue.

Tissues are classified according to the kind of the constituent cells into two types:

Simple tissue:

- It consists of one type of cells (as Parenchyma).

Complex tissue:

- It consists of more than one type of cells, which perform together a general function (as in Phloem and Xylem).

Tissues classified according to the stage of development of constituent cells into two types:

Meristematic tissue (Young immature tissue):

- It composed of cells capable of division.
- Found in specific regions in higher plants called meristems.

Permanent tissue:

- Composed of cells, which are fully differentiated, mature and perform specific functions.
- Incapable of division.

Meristematic tissues

- They consist of meristematic cells which are characterized by:

1) They are relatively small. 2) Active in division.
3) They have abundant cytoplasm. 4) Have very small vacuoles.
5) Without inter-cellular spaces. 6) Have a large nucleus.
7) Thin walled (have a primary walls).

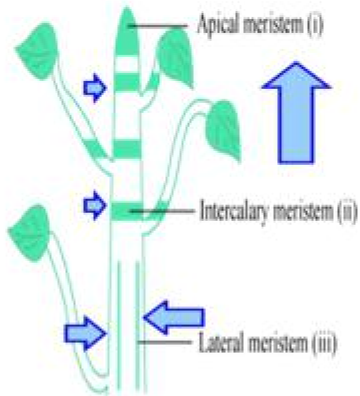
There are 2 types of meristematic tissues:

1. Primary meristematic tissues:

Distribution:

- At the tip of root or stem, and called **apical meristems**.
- At the basis of internodes of some monocot, and called **intercalary meristems**.

1. Apical meristems:



- At the root and shoot apex.
- The apical meristems are present at the apical regions of the stem, roots, and lateral appendages.
- Due to their activity the axis grows in length, therefore they are called the growing points.
- The derivatives of apical meristems differentiate into permanent tissues which constitute the primary body of the plant.
- It is differentiated into histogens which are clearly visible in root tip.
- As soon as the meristematic cells are formed from promeristems, they start to differentiate and change in size and shape by elongation. (The zone of cell enlargement).
- **At the previous stage, the tip can be differentiated into 3 distinct regions**:

I) Protoderm:

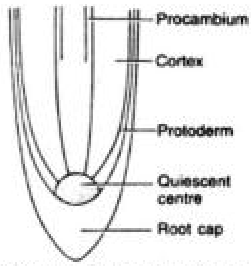
- The external layer.
- Gives rise to epidermis by maturation and differentiation.

II) Ground meristems:

- When mature gives rise to cortex and pith.

III) The procambial strands:

- It is a circular zone of cells.



Root apex organization acording to quiescent centre concept

- Composed of several layers of vertically elongated cells limited from inside and outside by the ground meristems.
- Give rise to the vascular cylinder [xylem and phloem] when mature.
- In stem apex, it consists of the three previous regions.
- In root apex is a fourth region, which called calyptrogen [root cap].
- The root cap is responsible for protecting meristem, the growing point of root.

2. Intercalary meristem:

- The portions of apical meristems which are separated from the apex and present in between the permanent cells are called the intercalary meristems.
- During the growth of the axis the portions of apical meristems are separated from the apex.
- They are situated in between the permanent cells. They are present in grasses at the basal regions of internodes and in leaf sheaths of monocots.
- The regions that consist of intercalary meristems grow longitudinally.
- The intercalary meristems are short-lived. They lose the power of division gradually and merge with the permanent tissues.

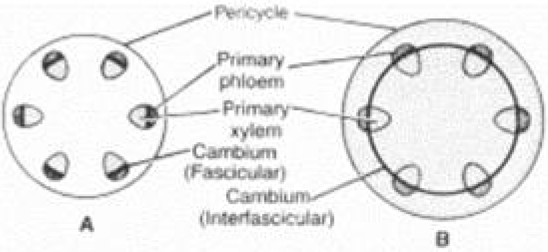
- They build up new tissues which added to the primary plant body.

3. Lateral Meristem (Secondary meristematic tissues)

- The meristems that occur laterally in the axis and parallel to the surface are called the lateral meristem.
- Develop from permanent tissues restore its ability to divide.
- The cells of lateral meristems divide periclinally.
- The derivatives gradually differentiate into permanent tissues which are collectively called the **secondary tissues (as the secondary xylem and phloem).**
- The secondary tissues are responsible for increase in thickness of the axis.

Examples of secondary meristematic tissues (lateral meristems):

- 1) Vasicular cambium. 2) Cork cambium.



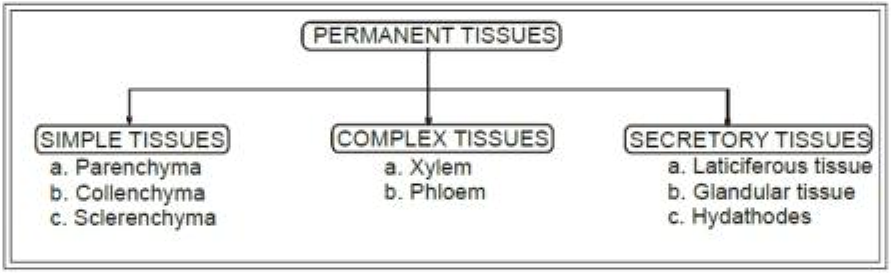
Lateral meristems
A. Fascicular or intrafascicular cambium
B. Cambium ring formed from fascicular and interfascicular cambia

Primary meristem	Secondary meristem
It is originated from a promeristem	It is originated from a permanent tissue
Give rise to primary tissues to build up the plant body	Give rise to secondary tissues (additional tissues)
As Lateral, intercalary and apical meristems	As cork cambium and rvascular cambium

2. The permanent tissues

- A permanent tissue is group of cells which are differentiated, and which have lost the power of cell division.
- The permanent tissues are composed of mature cells. The cells assume a definite shape, size and function.
- They develop from the meristems.
- The permanent tissues which develop from the apical meristems are called primary permanent tissues.
- The permanent tissues which develop from the lateral meristems are called the secondary permanent tissues.

- **On the basis of constituents cells permanent tissues are classified into three groups:- simple tissues, complex tissues and secondary tissues.**
    - Simple tissues consist of similar cells.
    - Complex tissues is a group of different types of cells.
    - Secretory tissues consist of cells that secrete various substances.

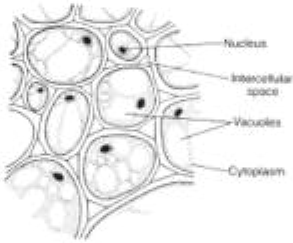


I. Simple Permanent tissues:

- A simple tissue consists of a group of uniform cells which are similar in structure and carry out the same function.
- Simple tissues are of three types, parenchyma, collenchyma, and sclerenchyma.

1. Parenchyma:

- The main constituent of the ground tissue in all plant organs.
- Simple tissue [of one type of cells].



Parenchyma

- Consists of parenchymatous cells.
- Living cells with cytoplasm and nuclei.
- With primary thin cell wall [mainly of cellulose, hemi cellulose and pectic substances].
- The walls of the cells mostly contain simple pits, for interchange between neighboring cells.
- Represent 70 - 80% of the plant body.
- Intercellular spaces are commonly present.
- Have different shapes [oval –polygonal – armed- folded].
- They can retain its ability to divide.

Distribution:

1) In pith (root and stem).
2) In cortex (root and stem).
3) In the mesophyll of leaves.

Types:

1. Spongy parenchyma

- Cells are usually isodiametric, oval, spherical or irregular in shape.
- This tissue has seen in leaves, cortex of herbaceous plants.

2. Lignified parenchyma

- In some types, additional thickening of the cell wall occur forming secondary wall, which may be lignified; such cells are called "lignified parenchyma".

3,4. Armed parenchyma and Aerenchyma

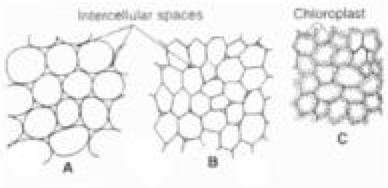
- In aquatic plants, the intercellular spaces between parenchyma are very large for aeration, such parenchyma are called **Aerenchyma** and **armed parenchyma**.

5. Chlorenchyma

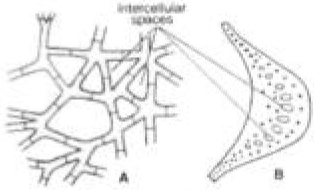
- Some parenchyma cells contain chloroplasts called **chlorenchyma**, found in aerial part near the surface.

6. Palisade tissue

- Elongated cells rich in chloroplasts
- Found in mesophyll cells of the leaves.



A-B. Parenchyma, C. Chlorenchyma



Aerenchyma : A. In petiole of *Canna* B. In midrib of *Canna* leaf

<u>Function:</u>

- Not specialized in its function.
- Its function may be:
- Storage of food [rich in leucoplasts].
- Storage of water.
- Aeration. [Like aerenchyma in hydrophytes].
- Photosynthesis. [In chlorenchyma, and palisade tissue].
- Horizontal water translocation [due to differences in osmosis between cells].
- Supporting [especially in herbaceous plants by lignified parenchyma].
- Parenchyma cell is considered developmentally primitive [not specialized in function].

Epidermis
(Dermal tissue)

- It is composed of parenchyma cells.
- They are fitted together without intercellular spaces.
- Have large central vacuoles and have no chloroplasts except in guard cells and epidermis.
- Have thin peripheral cytoplasm.

Distribution:

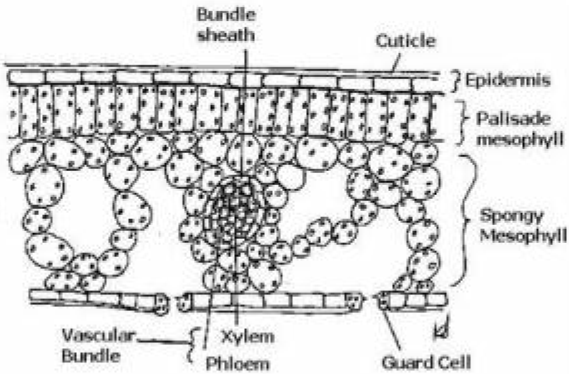
- Covers the entire surface of all plant body.

Function:

- Protective layer.
- Epidermis may be composed of:
- One layer. [simple epidermis]
- Several layers. [multiple epidermis] [multiserrate epidermis].
- Cuticle covers all the epidermis except root hairs. It helps in the reduction of water loss.

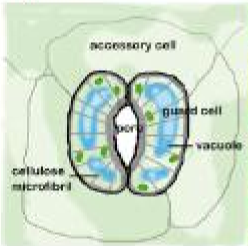
There are two types of epidermis according to the depth of cuticle:

- Normal epidermis. [thin layer of cuticle in mesophytes].
- Cutinized epidermis. [In xerophytes].
- In xerophytes, waxes may be deposited beneath cuticle to reduce the water loss from the plant.



Stomata

- Small pores dispersed among the epidermal cells.
- The word *stoma* means mouth (in Greek) because they allow communication between the internal and external environments of the plant. Stomata are found on all above-ground parts of plants, including the leaves, petioles, soft herbaceous stems and petals of flowers.



<u>Function:</u>

- A stoma is a pore, found in epidermis that is used for gaseous exchange takes place between the intercellular spaces of sub-epidermal cells and the atmosphere.
- Features:
- Each pore [stoma] is surrounded by 2 cells known as **guard cells**.
- The stomatal opening leads to a large **intercellular space** called **substomatal champer**.

Guard cells differ from epidermal cells in:

- Presence of chloroplastids.
- Irregular thickening of the cell wall.
- Its walls towards the opening are thick, and walls towards the epidemal cell are thin.

<u>Distribution of stomata:</u>

- All aerial parts of plant especially leave of herbaceous plants.
- In wood plants, present on the lower surface of the leaves only.
- <u>In herbaceous plants</u>, present on the lower and the upper surface but few on the upper side.
- <u>In aquatic plants</u>, present only on the upper surface of floating leaves.

<u>Stomatal number</u>

- The number in the same species varies according to the location of leaves and the environmental conditions.
- The number of stomata varies from one species to another.

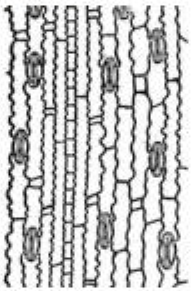
<u>Types of stomata:</u>

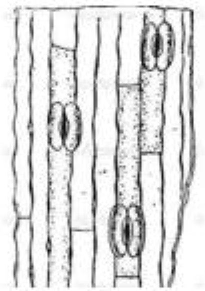
<u>1) The universal type (kidney shape):</u>

- Present in all plants except members of F. Graminae and F. Cyperaceae.
- Guard cells are kidney–shaped and at the same level of epidermal cells

<u>2) Graminae type: [Dump-bell type]</u>

- Characteristic of plants of F. Graminae and F. Cyperaceae.
- The Guard cell is narrow in the middle [has thick cell wall] and enlarged at both ends. [has thinner walls].





<u>Stomata may be:</u>

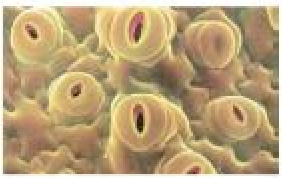
Normal:

- Guard cells are at the same level of another epidermal cell.

Sunken:

- Guard cells are lower than the epidermis.
- Guard cells are oval and have narrow Lumina.
- Their walls partially lignified [and subsidiary cells].
- May be covered with hairs and they are called sunken stomata with hairs. [Like in ***Nerium*** leaf].

Sunken Stomata



Raised Stomata

Hairs & Trichomes

- A hair is an outgrowth of either a single cell or a group of cells.

1. Root hairs

- **In roots**, they are called root hairs.
- Found in specific zone called [root hairs zone] or [water absorbing zone] near the tip f the root.

Characteristics:

- They have very great number to increase the absorbing surface of the root but occupy little area on the root.
- They are simple un-branched tubes produced as outgrowth of the epidermal cells of the root.
- Root hairs have very large vacuoles and thin layer of cytoplasm.
- Nucleus may be in the epidermal cell or in the hair.
- They are not surrounded by cuticle.
- Osmotic Pressure of the root hair must be higher than outside. This is due to the concentration of the cell sap to permit the absorption of water and minerals.
- They are short-lived.

Function:

- Play an important role in the absorption of H_2O and minerals.

2. There are also hairs on the epidermis of the leaf and stem with various forms and functions.

Their types:

- Simple [unicellular], branched unicellular, multicellular unbranched, peltate, stellate, compound.
- Generally, the function of hairs is protection, and may water lost reduction.

In flowers:

- They are glandular hairs.
- These glands secrete nectar that attracts insects to the plant to help in the transmission of pollen grains.

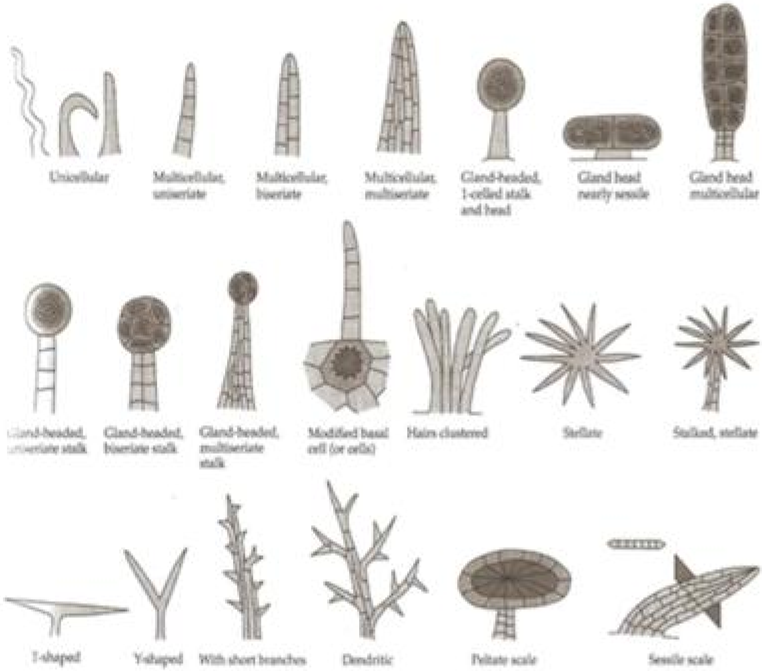


Figure 4.15 Selected features of hairs.

<u>In insectivorous plants:</u>

- The leaves have glandular hairs, which secrete digestive enzymes to digest the insect.

<u>In ***Utrica***:</u>

- There are stinging hairs.
- These hairs have thick wall and small swollen hears.
- If this head is broken, it may penetrate the skin [by sharp point] and inject a poisonous substance that is extremely irritating.

2. Collenchyma:

- It is a living, simple, mechanical tissue occurring in young stems, petioles of leaves, stalks of flowers and midribs of leaves.

Characteristics:

- They are thickened living cells with cytoplasm and nuclei.
- Thickening material is cellulose in addition to pectic substances.
- The cell wall is made up of cellulose and pectin. Lignin is absent.

Distribution:

- Absent in roots, and in monocot stem.
- Present in the dicot stem either in corners or as a continuous layer under epidermis.
- Rarely present in the stems of woody plants.
- **In leaves**, found in the mid-rib around the vascular bundle.

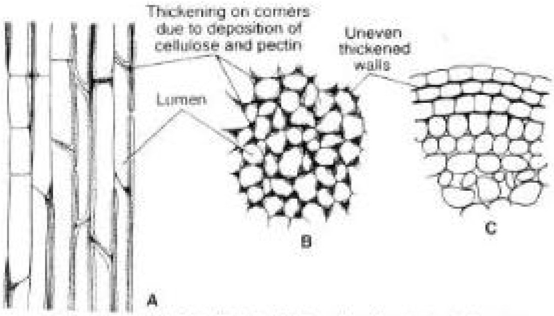
Function:

- Supporting the fast-growing parts of the plant [leaves and stems].
- Thickening material is cellulose [make it able to growth].
- It is flexible. Hence young growing organs can bend without any obstruction.
- Their thickening does not prevent the elongation of the organ in which they are located.

Types according to cell arrangement:

1. Angular Collenchyma.

- In this type, the thickenings are confined only at the corner of cell. The corners where three or more cells are joined are completely filled with cell wall materials.
- Intercellular spaces are absent.
- The cells are irregularly arranged.
- Their lumen appears circular due to continued deposition of wall materials.
- This is the most common type. Examples. Stems of *Solanum tuberosum*, *Cucurbita*, *Polygonum*, etc.



Collenchyma : A. L.S., B. T.S., C. Hypodermal position in the stem

2) Lamellar Collenchyma: [Plate collenchyma]

- In this type the thickening is confined to tangential walls. As a result, the cells appear as plates or bands. Hence, it is also called as plate collenchyma.

3) Lacunar Collenchyma:

- In this type the thickening is confined to the walls of the regions bordering intercellular spaces.
- Intercellular spaces are present. This type is also called tubular collenchyma. This type is found in the aerial roots of Monstera, stems of *Malva*, *Althea*, etc.

3. Sclerenchyma:

- It is a simple tissue.

<u>Characteristics:</u>

- They are dead cells [without cytoplasm or nuclei].
- With lignified secondary cell wall.
- Walls are uniformly.

<u>Functions:</u>

- 1) Supporting 2) Protection.

<u>Types:</u>

<u>1. Fibers:</u>

Sclerenchymatous fibres : A. L.S., B. T.S

- They are elongated cells with pointed ends.
- Present in small groups among other cells for supporting.
- Usually lignified (but some are composed of cellulose with great quantities such as flax fibers).

- The cell lumen [cell vacuole] is very small.
- Develop from meristematic cells and at maturity, the cells become dead.

2. Sclereids:

- Usually iso-diametric [but may be branched or take other shape].
- Relatively short with rounded ends.
- Develop from parenchyma cells.
- The isodiametric type is called **stone cells**, which have branched pits.
- Dead cells and help in supporting of the plant.

Distribution:

Fibers:

- In cortex [cortical fibers].
- In 2ry xylem of dicot. [xylem fibers].
- In 2ry phloem of dicot [phloem fibers].
- Over the vascular bundles of dicot stem [pericycle fibers].
- Around the vascular bundles of monocot plants [bundle sheath].

Sclereids:

- In seed coats and nutshells [protective and hardness].
- In cortex of some fruits [fleshy] such as apple and pear (solitary or in groups).

Sclereids	Fibers
Originate from parenchyma cells	Originate from meristematic cells
The walls usually have branched pits	The cell wall contains simple pit
They are elongate cells with rounded ends	They are elongate cells with pointed ends.

2. Compound Permanent tissues

1. Xylem:

- Permanent Complex tissue consists of several types of cells differ in shape and function.
- **Function** is water conducting and supporting.

Types of cells in xylem:

A) Tracheids in Gymnosperms.

b) Vessels in Angiosperms

c) Xylem parenchyma (responsible for the horizontal movement of water.

d) Xylem fibers (supporting of woody stems).

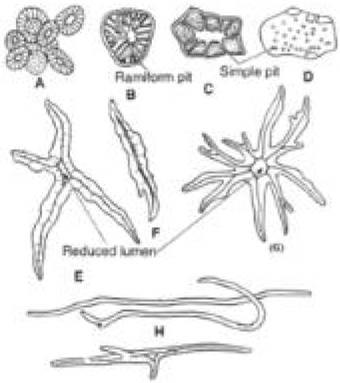
a) Tracheids:

Distribution:

- They are characteristic, mainly of xylem of gymnosperms.

Characteristics:

- Along tapering cell [one side of cell].
- Lignified secondary cell wall.
- In T.S, typical angular.
- Non-living cell [no protoplasm].
- Large lumen.
- Abundant pits in the cell wall [mostly bordered].
- In gymnosperms, [such as ***Pinus***], conduction and supporting are carried out by tracheids.
- The wood of such trees is composed mainly in tracheids.
- In higher plants, tracheids are replaced by cells for conduction [vessels] and others for supporting [fibers].



Stone cells A, B. from pulp of pear **C, D.** from stem cortex of Hoya **E, F.** from petiole of Camelia **G.** from stem cortex of *Trochodendron* **H.** From mesophyll cells of Fig leaf

b) Vessels:

Distribution:

- Characteristic of angiosperms.
- Absent in gymnosperms and ferns [except rare cases].

Function:

- The main conduction elements in angiosperms.

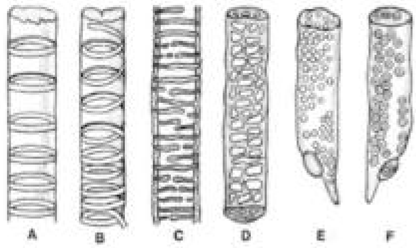
Characteristics:

- The cells diameter has increased.
- The disappearance of separating walls between cells, forming tube – like system without cross walls.
- Large openings at ends.
- Lignified 2ry cell wall.
- Wide lumen free of living contents.
- Pits present in the cell wall of the **bordered** type.

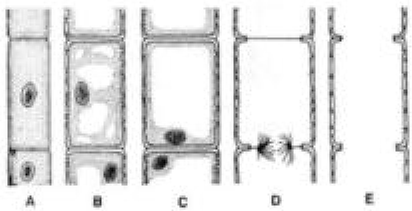
Xylem lignifications:

The patterns of 2ry cell wall of vessels are characteristic:

- **Annular** [2ry wall is in form of rings].
- **Spiral** vessels. [in form of spirals].
- These 2 types are characteristic of **protoxylem** [they are more adapted to elongate and this occur by the stretching of 1ry wall between annular and spiral thickening].
- **Scarlariform** vessels. [individual spiral coils which are inter connected forming a ladder – like pattern].
- **Reticulate** vessels. [net –like pattern].
- **Pitted** vessels: [Pits present].
- These types are common in metaxylem and 2ry xylem.



Lignified thickenings in xylem tracheids and tracheae :
A. Annular B. Spiral C. Scalariform D. Reticulate E. Simple pit F. Bordered pit



Stages in development of tracheae

C) Xylem fibers:

<u>Characteristics:</u>

- The thickness of wall has increased.
- Diameter of the cell decreases.
- Number of pits is reduced.
- Wood fibers are longer than tracheids and slenderer and tapering.
- Heavier cell wall lignification.
- Present in the secondary xylem of the old tissues.

<u>Function:</u>

- Supporting.

Xylem : A. Tracheids, **B.** Tracheae, **C.** and **E.** Xylem parenchyma, **D.** Wood fibres (wood sclerenchyma)

D) Xylem parenchyma:

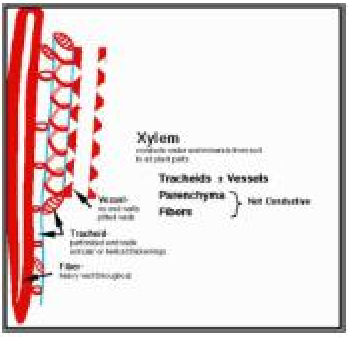
- Common constituents of the xylem of most plants.
- Function:
- Storage of food. [starch, oils and many ergastic substances].
- Many participate in water conduction.
- Supporting [by forming lignified parenchyma].

<u>Characteristics:</u>

- Always life have protoplast.

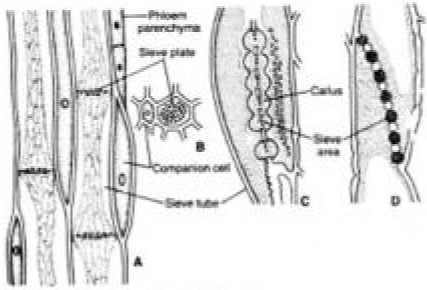
<u>**Function of xylem:**</u>

- Mainly conduction of water and solutes from roots to leaves.
- These elements are strongly lignified [to bear the great pressure of transported water].
- These elements have large lumens and have not cross walls. [in case of vessels] but have ones in tracheids.
- Pits are found in them.
- Supporting [due to hardness of the lignified walls of the conducting elements].
- Xylem parenchyma aids in conduction, support, and food storage.



2. Phloem:

- The food conducting tissue of the vascular plant.
- Permanent complex tissue.
- Complex tissue consists of several types of cells of specific functions.



Parts of phloem
A. L.S. of phloem tissue, **B.** T.S. of phloem tissue, **C.** Sieve tubes of *Vitis*, **D.** L.S. of Sieve plate

Phloem Components

a) Sieve tubes

Function:

- Conduction of food from leaves to roots.

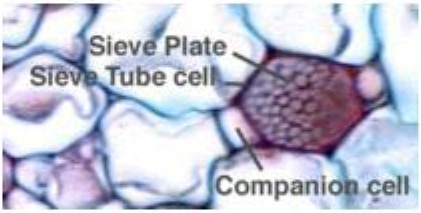
Characteristics of sieve tubes:

- Consists of vertical row of elongated [tubular-shaped] cells.
- Cells are arranged end to end.
- The cross walls separating cells are **perforated** [**sieve plates**].
- Cells have **peripheral cytoplasm**, large cell vacuole and no nucleus [when mature].
- Cytoplasm contains **leucoplasts**. [store starch]. Thin cellulose cell wall.
- The adjacent sieve tube elements are connected through pores of sieve plates.
- Conduction of food with gravity. Cross walls help in reduction of the velocity of food.
- Plasmodesmata are surrounded by callose which [in older plants accumulates on the pores of sieve plates and closes the sieve tube then lose its function.

b) Companian cells:

Distribution:

- In **angiosperms** only, absent in **gymnosperms**.
- With large quantities in monocot [regular phloem] than dicot [irregular phloem].



Characteristics:

- Closely associated in origin, position and function with the sieve tube elements.
- Elongated cell, thin wall, dense protoplasm and clear nucleus.
- Triangular, rounded or rectangular and small.

Function:

- Help in conduction of food.

c) Phloem fibers:

Distribution:

- In 1ry phloem of dicots, found in the outer most part of the tissue as pericycle.
- In 2ry phloem of dicots, distributed in the tissue.

Characteristics:

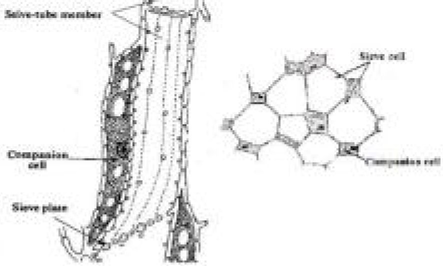
- Dead long cells with tapering ends.
- Hard lignified cell walls.

Function: Supporting.

D) Phloem Parenchyma:

Distribution:

- Common occurrence in the phloem tissue of vascular plants.
- Lack in the phloem of monocot.



Function:

- Storage and conduction.

Characteristic:

- Living cells with thin walls.
- Many contain starch, tannins, mucilage or latex.

- Vary in shape.

Function of phloem:

- Conduction of food leaves to other parts by sieve tubes.
- Transport of food is in the direction of gravity, so they have thin walls, there is no much strong pressure exerted on the walls.
- Presence of sieve plates helps in slowing down of food through tubes.
- Supporting by fibers.
- Parenchyma cells aids in conduction and food storage.

Type of vascular bundles

- Consists of xylem and phloem in various types.
- The xylem and the phloem tissues of a bundle are mostly 1ry origin.
- The primary xylem may be:

1. Collateral bundles:

- The phloem occurs on one side of xylem strand. [at the same-line].
- Common in stems and leaves.
- Collateral bundles in monocot are characterized by presence of a bundle sheath of fibers.
- Xylem in collateral bundles in monocot is in Y or V shape.

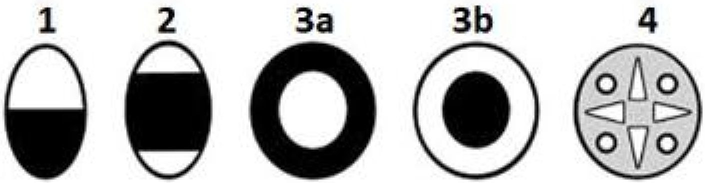
Types of collateral bundles:

a) Open collateral bundles.

- Open due to presence of combium which produces 2ry xylem and phloem in most dicot.

b) Closed collateral vascular bundle:

- Closed due to absence of cambium as in monocots.



2. Bicollateral bundles:

- The phloem occurs on both sides of xylem [e.g. Cucurbitacae].

3. Concentric bundles:

- One kind completely surrounds the other.
- Amphicribiral [Hydrocentric] [e.g. in ferms].
- Amphivasal [leptocentric] [e.g. in ***Dracena*** stem].

4. Radial bundles:

- The phloem and xylem are separated and alternating with each other. [e.g. roots].

3. Secondary tissues:

- Its cells directly concerned with the secretion of various substances in the plant [such as gums, resins, essential oils, nector] are referred as secretory tissue.

Glands:

- Secretions may be stored in special cavities in the gland or duct or may be secreted directly to the outside.

<u>They are various kinds:</u>

1. External glands

a) Digestive glands:

<u>Distribution:</u>

- In insectivorous plants.
- In ***Drosera***, secretary tissue is located at the tips of the hairs present on leaf surface.

<u>Function:</u>

- They secrete digestive enzymes that digest the proteins of the insect.

b) Nectaries:

Distribution:

- In flowers of many plants.

Function:

- Produce nectar, which attracts insects.
- Secretion of nectar is from specialized epidermal cells which lack cuticle.

c) Hydathodes:

Function:

- Structurally modified regions through which water exudes under condition of high temperature and high humidity and low transpiration in form of water liquid.
- This phenomenon is called **guttation** [differs from transpiration in that water is lost in the second case in form of water vapor].

Distribution:

- In some plant leaves of family **Solanaceae** العائلة الباذنجانية (tomato and some grasses).

Characteristics:

- It is a pore surrounded by 2 guard cells.
- No mechanism for opening and closing [always opened].
- Present directly opposite to xylem vessels.
- Absence of chloroplasts in the guard cell.
- Water exudes inform of liquid.
- Liquid water may also exude from injured stems in a process known as **bleeding**.

2. Internal glands

a. Resin, oil and guns glands:

- Appear as cavities within the plant tissue.
- These cavities are surrounded by secretary cells called **epithelial cells** [thin-walled, dense cytoplasm].

Types: [according to the method of formation]

1. Schizogenous glands:

- The cavity originates by separation of cells [epithelial cells] and is surrounded by secretary cells.
- In ***Pinus*** stem and secrete resins.

2. Lysigenous glands:

- The cavity of the gland is formed by the disintegration of a group of cells.
- As in **citrus** fruits.
- Essential oils are secreted in the cavity of the gland by secretor cells.

b) Laticiferous ducts:

- Secrete latex.
- Found in several plants such as **Euphorbiaceae** and **Papaveraceae** العائلة الخشخاشية families.

Characteristcs:

- Latex is white, yellow or reddish viscous fluid containing proteins, sugars, gums, alkaloid, enzymes and mainly water [may be other substances are found].
- Some latex substance are economically important

Types:

1. Latex cells:

- Long cells extending along distances through the plant.
- Each cell contains dense protoplasm and many nuclei [in ***Euophorbia***].

2) Latex ducts:

- Composed of rows of cells that are arranged longitudinally and they are branched.
- Without cross walls. [In papaver, and members of compositae].

PLANT ORGANS

1. THE ROOT SYSTEM

Morphological Structure of the Root:

- Ordinarily grows downward into the soil.
- The function is anchoring the plant and absorbing water and inorganic salts in the soil solution to the plant.
- Do not carry buds or leaves.
- Has no nodes and inter nodes.
- The root tip is protected by root cap [calyptrogen].
- Branching is irregular.
- Do not contain chloroplasts.

Anatomical Structure of the Root:

1. In primary state of growth:

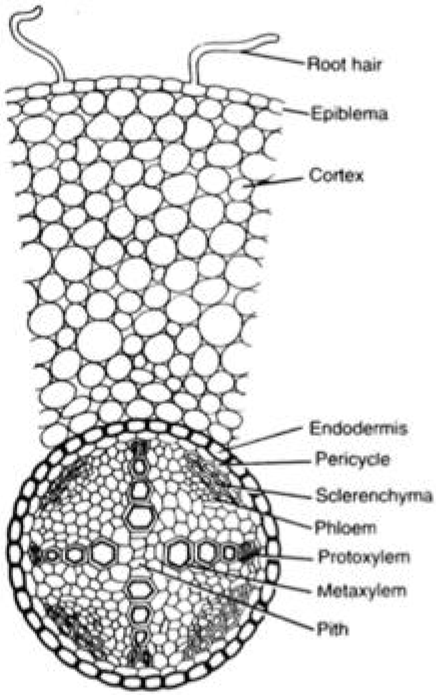
- T.S of root consists of 3 tissue systems:

a. Piliferous layer:

- The outermost layer that surrounds the root.
- The water absorbing layer due to presence of root hairs in it.
- It has no cuticle.
- It serves as a protective layer for the inner tissues.

b. The cortex:

- Generally, it composed of **parenchyma** cells only but it may develop into **sclerenchyma** or **collenchyma** in some plants.
- The cells are with intercellular spaces.



Detailed structure of a portion of T.S. of Gram root

- No chlorophyll but starch is often present.
- Intercellular spaces are large in plants of moist habitats (rice).
- **Endodermis**: the inner layer of cortex separates the cortex from the pericycle.
- A single layer with compactly arranged cells.
- Characterized by a specialized thickening forms "**casparian strips**" of subrin cover the radial and transverse walls, controls the lateral movement of water and solutes.
- Some cells remain with thin wall and permit the passage of water and materials from cortex to the central cylinder and called "**passage cells**".

c. Vascular cylinder:

- It is surrounded by the pericycle.

Pericycle:

- A single layer of parenchyma cells of thin walls, may contain sclerenchyma, may be multiserrate as in some monocot.

The vascular system:

- It is formed of number of xylem strands alternating with equal no of phloem strands (radial vascular bundles) attached together with parenchyma cells.
- Xylem arches vary in different plants.

Two = diarch three = triarch

Four = tetrarch five = pentarch

Numberous = polyarch.

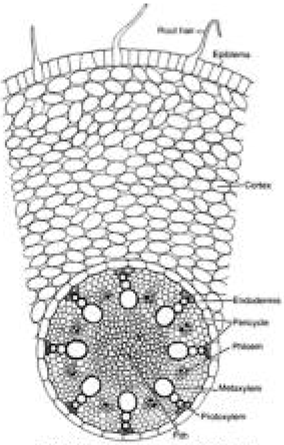
- Most dicot has di-tri or tetrach [may be from five to eight].
- Monocots are poly arch [more than eight] may reach 20.

Function:

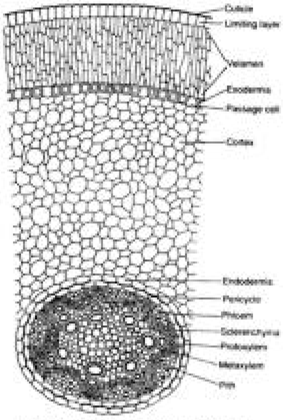
- Translocation of food [through phloem].
- Translocation of water and minerals [through the xylem].
- In xylem; **protoxylem** [narrow] are directed near the pericycle, the **metaxylem** [Wider] are directed towards pith.
- Because of the external position of protoxylem, the xylem of the root is called "**exarch**".
- Each group of phloem is separated from the adjacent xylem by parenchyma cells [play important role in 2ry thickening of dicot roots].

Pith:

- Found in the center of root. It may be:
- Absent [in old dicot replaced by xylem]. Narrow [in young dicot root].
- Wide [in monocot root]. It is composed of parenchyma cells.



Detailed structure of a portion of T.S. of Maize root



Detailed structure of a portion of T.S. of Orchid root

3.4 Comparison between Dicot and Monocot Root

No.	Dicot Root	Monocot Root
1.	The vascular bundles are 2-6 in number.	The vascular bundles are many in number.
2.	Medulla is smaller in size or absent.	Medulla is fairly large.
3.	Pericycle forms lateral roots. Secondary meristematic tissue originates from pericycle.	Pericycle forms only lateral roots.
4.	Cambium is formed form the cells of pericycle and conjunctive tissue secondarily.	Cambium is not formed.

2. THE STEM

Morphology of the Stem.

- Ordinarily grow upwards in the air.
- Carry leaves and buds.
- Divided into nodes and inter nodes.
- Stem tip is terminated by the terminal bud.
- Branching is regular at certain point [nodes].
- Protoxylem towards pith [inarch].

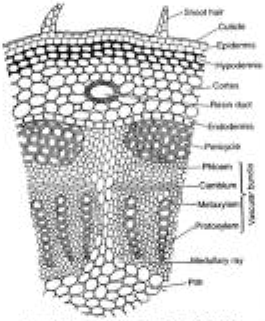
Anatomy of the Stem

Primary Structure of Dicotyledonous Stem:

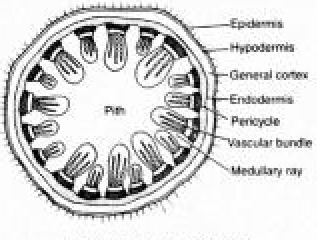
It consists of:

1. Epidermis:

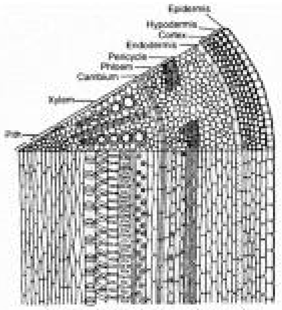
- The outer most layer of the stem.
- It serves as a protective layer for the inner tissue.
- It covered with cuticle.
- Hairs and trichomes are present.
- Stomata are present.
- Has no chloroplastids [except in guard cells].
- Arises from the outer most layer of the meristem of differentiating stem known as **"protoderm"**.



Detailed structure of a portion of T.S. of Sunflower stem



Diagrammatic representation of T.S. of young Sunflower stem



Two dimensional structure of a normal dicot stem

2 The cortex:

- Consists of several layers.
- Heterogenous [consists of several types of cells] Ex. Parenchyma, sclerenchyma, collenchyma and chlorenchyma [not present in root cortex].
- The innermost layer of the cortex is called "**the starch sheath**" which is characterized by: [differences from endodermis of root].
- Absence of casparian strips.
- Presence of abundant starch grains. [Thus, it has called the starch sheath].

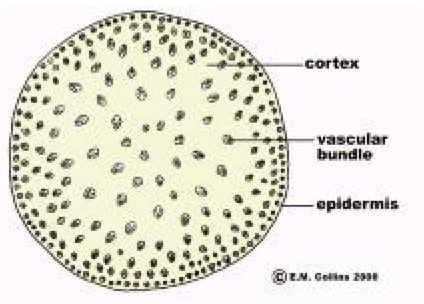
3. Vascular cylinder:

- Consists of open collateral vascular bundles [sometimes bicollateral].
- Vascular bundles are arranged in one or 2 cycles.
- The rays between the bundles are called [**medullary rays**].
- The pith and medullary rays are of parenchyma cells.
- Pericycle consists of parenchyma which develops into pericycle fibers. [sclerenchyma] and they often form a separate group on the outside of each bundle.
- Cambium layer is found between the xylem and the phloem. It has called cambial region.
- Develop from the procambial strands.

Monocot stem:

1. Epidermis:

- The outer most layer.



2. Hypodermis

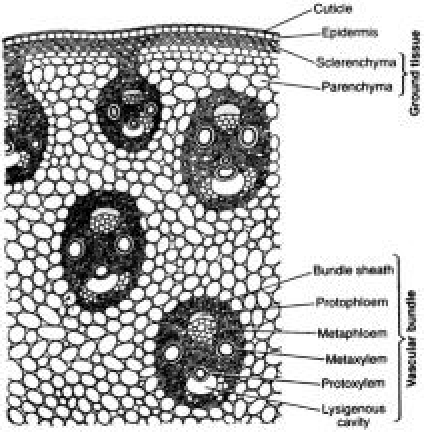
- Hypodermis is the middle region. It is present just beneath the epidermis.
- It consists of 3 to 4 layers of sclerenchymatous cells.
- The sclerenchymatous band is usually continuous but may be interrupted here and there by parenchyma.
- Sclerenchymatous hypodermis provides mechanical support.

3. Ground tissue:

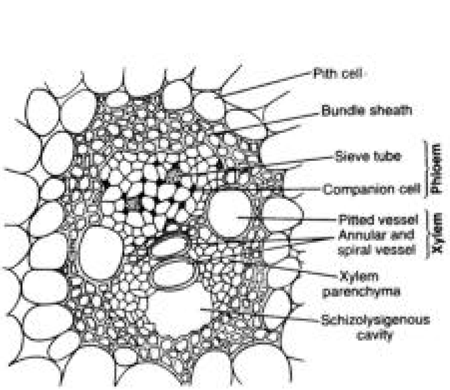
- Ground tissue is the central region. It is present beneath the hypodermis.
- It consists of parenchymatous cells. The cells are oval, thin walled, living and loosely arranged.
- Intercellular spaces are present.
- The cell situated towards periphery are smaller in size. The cells situated towards centre are larger in size.
- The cells store food materials.
- Vascular bundles are irregularly scattered in the ground tissue. Hence, ground tissue cannot be demarcated into cortex and stele.
- Endodermis, pericycle and medulla are not recognised.

4. Vascular Bundles

- Vascular bundles are many in number. They are irregularly scattered within the ground tissue.
- The vascular bundle situated towards the periphery are smaller in size.
- The bundles situated towards the centre are bigger in size.
- Each vascular bundle is oval and surrounded by sclerenchymatous bundle sheath. Hence, the vascular bundle is called fibrovascular bundle.
- Xylem consists of vessels, tracheid's, xylem parenchyma and xylem fibres. Xylem vessels are arranged in the form of letter V or Y.
- The two metaxylem vessels are present at the two arms. The protoxylem vessels are present at the base.
- Due to rapid elongation of stem, inner protoxylem vessel and parenchymatous cells surrounding the vessel disintegrate and form a lysigenous cavity.
- This cavity is called protoxylem lacuna. It stores water.
- In grasses the parenchymatous cells present in the centre of the stem disintegrate and form a hollow cavity called pith cavity.



Detailed structure of a portion of T.S. of Maize stem



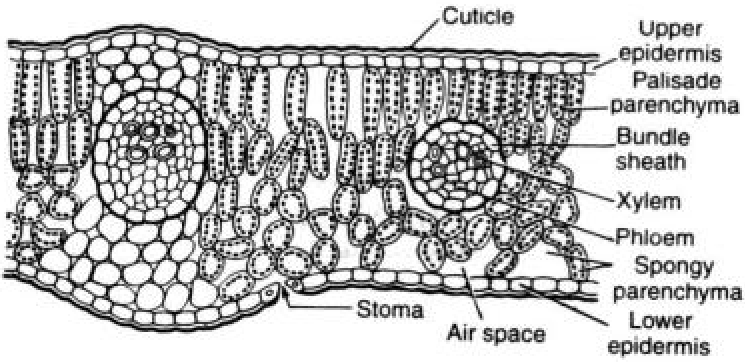
Detailed structure of one vascular bundle of Maize

Leaf Anatomy

- Leaf is a thin, flat, expanded, exogenous, green, lateral organ of the stem.
- The structure of leaf depends upon the environmental conditions in which plant lives.
- The structure is different in mesophytes, xerophytes and hygrophytes.
- On the basis of structure, leaves are classified into three types:dorosiventral leaves, isobilateral leaves and centric leaves.
- In dorsiventral leaf, the adaxial (upper) surface differs. The adaxial surface receives more light.
- Such leaves are found in mesophytes. e.g., mango (Mangifera indica), sunflower (Helianthus annus).
- In isobilateral leaf, both adaxial and abaxial surface are uniform in colour and show similar structure. Both surfaces receive light.
- Such leaves are found in hygrophytes and grasses e.g., maize (Zea mays).
- Centric leaves are tubular, eg., onion (Allium cepa).

Internal Structure of Dorsiventral Leaf

- A transverse section of dorsiventral leaf shows three regions.
- They are epidermis, mesophyll and vascular bundles.



Detailed structure of a part of T.S. of Mango leaf

Epidermis

- Epidermis is the outermost layer. It is present on adaxial surface and abaxial surface.
- The epidermis present on adaxial surface is called upper epidermis.
- The epidermis present on abaxial surface is called lower epidermis.
- Epidermis consists of a single layer of compactly arranged living cells. Intercellular spaces are absent. Chloroplasts are absent.
- The outermost walls of the epidermal cells are cutinised.
- Cutin is present in the form of a layer called cuticle.
- The cuticle present on upper epidermis is comparatively thicker than the cuticle present on lower epidermis.
- Cuticle checks transpiration. Stomata are present on the epidermis.
- The number of stomata is more on the lower epidermis. Beneath the stomata air chamber is present.
- Stomata control the exchange of gases and the escape of water vapour.
- Epidermal hairs may be present or absent. Epidermis protects the inner tissues.
- It checks transpiration, it regulates the exchange of gases between internal atmosphere of leaf and external atmosphere.

Mesophyll

- Mesophyll is the ground tissue present between upper and lower epidermal layers.
- It is parenchymatous and consists of two types of tissues: palisade parenchyma and spongy parenchyma.

1. Palisade Parenchyma

- Palisade parenchyma is present beneath the upper epidermis.
- It consists of elongated and columnar cells.
- The cells are arranged in one or two layers, at right angles to the upper epidermis, if present in two layers, the cells of outer layer are long and the cells of inner layer are short.
- Cells are thin walled and closely set. Intercellular spaces are narrow. These cells contain numerous chloroplast which are present close to cell walls.
- Palisade parenchyma carries out photosynthesis and synthesis of food materials.

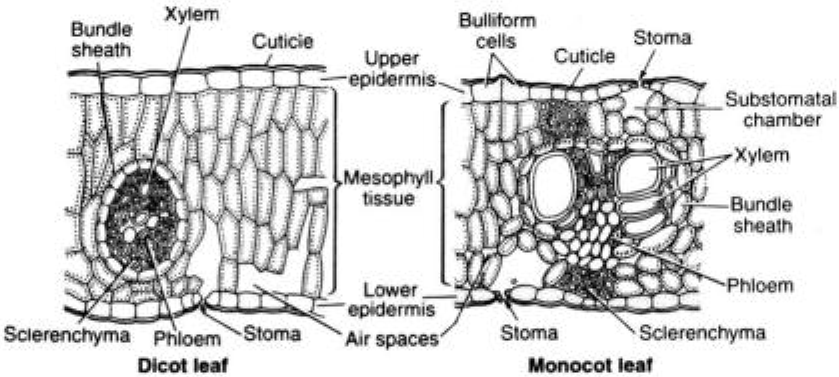
2. Spongy Parenchyma

- Spongy parenchyma is present between palisade parenchyma and lower epidermis.
- The cells are irregular in shape and loosely arranged. Intercellular spaces are many and broad. The cells contain chloroplast.
- The number of chloroplasts is lesser than those present in palisade cells. Hence, the lower surface of leaf is pale green in colour and the upper surface of leaf is dark green in colour.
- The cells of spongy tissue carry out photosynthesis and synthesise food materials.
- The intercellular spaces of spongy tissue help in aeration.

Vascular Bundles

- Vascular bundles are distributed within the mesophyll.
- They are arranged in the form of veins. The veins give mechanical support and help in conduction of water, mineral ions and food materials.
- Vascular bundles present at the base of leaf lamina are broader. They become narrower towards the leaf apex.
- They are conjoint, collateral and closed. Each vascular bundle shows xylem towards the upper epidermis and phloem towards the lower epidermis.
- Xylem and phloem are present side by side on the same radius. Hence, the bundle is described as conjoint and collateral.
- Cambium is absent between xylem and phloem. Hence, the bundle is described as closed.
- Xylem consists of vessels, tracheids, xylem fibres and xylem parenchyma.
- Xylem consists of one or two tracheids. They show annular or spiral thickenings.
- Sometimes it may consist of only one tracheid. Phloem consists of narrow sieve tubes, companion cells and phloem parenchyma.
- Phloem may be absent in ultimate branches (veinlets).
- Each vascular bundle is surrounded by a single layer of parenchymatous cells. This layer is called the bundle sheath.
- The cells are compactly arranged. The cells may or may not contain chloroplasts.
- The bundle sheath extends on both sides up to the epidermis.
- These extensions are called bundle sheath extensions.

- The extensions are parenchymatous. They help in conduction of materials between vascular bundle and mesophyll.
- They also provide mechanical support to the leaf lamina.



Comparison of T.S. of a dicot and a monocot leaf

-

Secondary thickening

- The addition of more xylem and phloem to the conducting systems of stems and roots by the activity of the cambium.
- The cambium consists of flattened **meristematic** ells.
- Each division of the cambial cell gives rise to an inner and outer daughter cell.
- One of the daughter cells remains meristematic and the other gives either xylem or phloem. [If the inner remains meristematic the outer gives 2ry phloem – If the outer remains meristematic, the inner give 2ry xylem].

Secondary thickening in Dicot Stems.

- In dicot plants, the cambium of 1ry stem activities to give 2ry xylem and 2ry phloem.
- In most plants, the medullary rays [parenchyma cells, separate vascular bundles] retain their ability to divide and it has called "**inter fasicular cambium**" [2-ry cambium].
- This leads to the formation of a complete cylinder of cambium.
- This process leads to the increase of the plant in **thickness**.
- At intervals, cells of the cambium give rise to parenchyma cells [medullary rays].
- Secondary thickening is common in **annual plants and in perennial plants**.
- **2ry xylem** consists of fibers, vessels, tracheids and parenchyma cell.
- **2ry phloem** consists of fibers, sieve tubes, companion cells and parenchyma.
- **The cambium function** is the formation of 2ry xylem and 2ry phloem.

There are some structure correlated with the 2ry thickening:

1. Annual rings:

- In woody dicot plants.
- The cambium becomes inactive in autumn [and winter] and renews its activity in spring.
- **The autumn wood** consists of small quantities of small vessels and large quantities of fibers.

- **The springwood** consists of small quantities of fibers and large quantities of vessels.
- Therefore, each annual of 2ry xylem is a defined zone known as annual ring.
- Through from the number of these rings, we can determine the age of the plant.

2) Sap wood and Heartwood:

- As long as the xylem contains living cells [parenchyma] and is apparently conducting [at least to some extent], it has known as the sapwood and if all activities cease, it becomes heartwood.
- Sapwood serves for conduction, support and food storage.

3) Heart wood is more durable due to:

- Reduction of food materials of cells.
- Reduction of water content.
- The function of the heartwood is supporting only and it plays important role in the resistance to attacking by microorganisms due to the formation of substances such as resins, tannins and oils and blocking vessels cavities by tyloses.
- Heartwood is more value commercially than sapwood.
- **Transformation of sapwood into heart wood**, all living cells lose their protoplasts. The cell sap is with drawn and the water content is greatly reduced. Food materials are removed. Tyloses are formed.

4) Periderm: [2^{ry} epidermis]

- It is a protective layer for internal tissues arises because of 2ry thickening in stem and root and rupturing of epidermal and some cortical layers.
- Originates from parenchyma cells retain its ability to divide.

Structure of periderm:

B) <u>Cork cambium (Phellogen)</u>

- The initiating layer of meristematic cells.
- It is a 2ry meristems that arises from permanent tissue (parenchyma),
- Lateral meristem.

C) <u>Phellem (Cork)</u>

- Formed as a result of phellogen cells cut off to outside.

- AS they mature, their living content disappears.

D) 2ry cortex: [Phelloderm]

- Formed as a result of phellogen cells cut off to inside.
- Living cells with cellulosic cell walls.
- The most commercial cork obtained from cork oak. [***Quercus ruber***].

5) Lenticles:

- Small-restricted areas have loosely arranged cells with abundant and small intercellular spaces in the periderm. When the conditions are unfavorable, the phellogen gives one or two layers of cells without intercellular spaces called closing layer.
- In lenticels formation in stem the cells below stomata or group of it, then forming rounded mass called "**complementary tissue**"

6) Tyloses:

- Formed by the enlargement of pit membranes between wood parenchyma and vessels or tracheids.
- Part of the cytoplasm passes to these bladder-like structure which occupy the most space of the lumen of the vessel.
- After the full growth of tyloses, crystals and gums are formed within them.
- Tyloses are formed normally at the time of transformation of sapwood to heartwood, but their formation may be induced by attacking of microorganisms and wounding.
- By blocking the vessel lumen, they prevent the rapid entrance of air and fungal hyphae, less attack by organism of decay.

Distribution:

- Present in 1ry xylem, largely in 2-ry xylem.
- It is considered as economic importance in the use of wood.

Ecological groups

According to their habitats, plants can be classified into 3 groups:

Xerophytes:

- Live in xerophytic (desert) environment.
- Water supply is deficient.

Features of this environment:

- High velocity of wind.
- High temperature [or very low temperature].
- High intensity of light.
- Lack of moisture.
- Deficiency of water.

Morphological and anatomical characters of xerophytes:

- Very extensive root system [to secure a sufficient supply of H_2O from soil].
- Reduced shoot system.
- Small leaves [or leafless] thus assimilatory system is found mainly in stem.
- Leaves generally hard, stiff and thick.
- Often multiserrate epidermis [multiple].
- Stomata are sunken or sunken with hairs.
- Stomata occur only on the lower side of the leaves.
- Palisade tissues are well developed [found in stem with large quantities].
- Vascular cylinder is extremely well developed [xylem quantities are very large to absorb maximum amount of H_2O].
- Cutinized, waxy epidermis [to reduce water loss].
- Mechanical supporting tissue is well-developed [sclerenchyma].

Hydrophytes

- Aquatic plants
- These plants may be floating [***Nymhaea***] or submerged [***Elodea***] in water.

Morphology and anatomical characteristics of hydrophytes:

- Reduced root system [absorbing by all parts of the plant].
- Shoot system is well developed.

- Non-cutinized epidermis.
- Normal stomata on the upper surface of the leaves.
- Mechanical supporting tissues and vascular cylinder much reduced.
- Prescence of aerenchyma [for storage of air-make the density of the plant decreases to be near the surface of water for photosynthesis].

Comparison between Mitotic and Meiotic Divisions

The mitotic division	The meiotic division
Occurs in somatic cells	Occurs in reproductive cells.
Gives 2 cell [2n].	Gives 4 gametes [n].
Prophase is not divided into substages.	Prophase is divided into 5 substages.
No synapse occurs.	Synapse occurs.
No crossing-over occurs.	Crossing-over occurs.
In Metaphase. Centromeres on the equatorial plate. Arms towards poles. Splitting of centromere of each chromosomes occurs.	In metaphase I Centromeres towards poles. Chromosomes towards equatorial plate. No splitting in chromosomes occurs.
In Anaphase. The 2 chromatids move to opposite poles.	In Anaphase I. The 2 chromosomes move to opposite poles.

Indeed all praise is due to "Allah"