Plant Anatomy

Prepared by

Dr/ Sabah Hammad

[**Faculty of Science**

Botany and Microbiology Department

2022/2023

Table of content

Plant Anatomy

Anatomy derived from the Greek *anatemnō* “I cut up, cut open" from *ana* "on, upon", and *temnō* "I cut".

The science of the structure of the organized plant body learned by dissection is called plant anatomy (anatomy = dissection). In general, plant anatomy refers to study of internal morphology, pertaining to different tissues.

The Plant Cell

The cell was first discovered in 1665 by an English scientist named Robert Hooke. While looking through a microscope, he observed tiny box-like objects in a slice of cork (bark from an oak tree) and named these boxes **cells**. Cells are the basic units of life, which make up all living things. This idea forms the basis of the **Cell Theory**.

The three main parts of the cell theory are:

1. All living things are made of cells.
2. The cell is the basic unit of structure and function in all living things.
3. Cells only come from other pre-existing cells by cell division

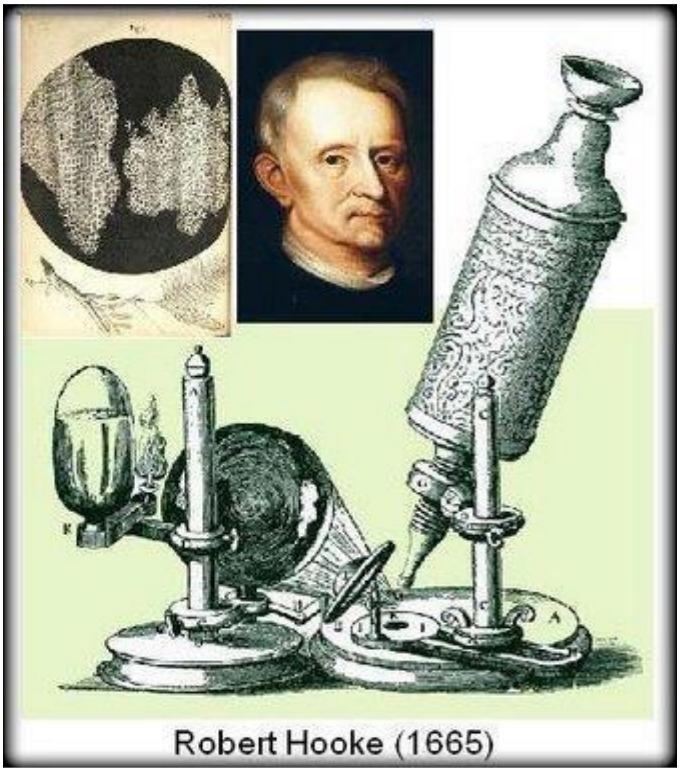


Fig.1: Robert Hook and his microscope (1665).

While some organisms are single-celled, others are made up of many cells (called multicellular). Cells differ in their size and complexity.

Eukaryotes are organisms which are made up of large and complex cells, whereas prokaryotes are organisms which are made up of small and simple cells. Animals and plants are examples of eukaryotes (have eukaryotic cells) while bacteria are examples of prokaryotes (have prokaryotic cells).

Differences between prokaryotic and eukaryotic cells

Eukaryotic cell	Prokaryotic cell
Nucleus material are enclosed by nuclear membrane	Nucleus material are not enclosed by nuclear membrane
Contains many organelles	Contains few organelles
Has membrane bounded organelles such as; chloroplast and mitochondria	No membrane bounded organelles
DNA is linear and enclosed in nucleus	DNA is circular and lies free in cytoplasm
Mitosis and meiosis occur	No mitosis or meiosis, divide by binary fission
Mainly multi-cellular	Mainly unicellular

Plant Cell Structure and Function

In spite of the differences in size and complexity, all cells are mostly composed of the same substances and they all carry out similar life functions. These include growth and metabolism and reproduction by cell division.

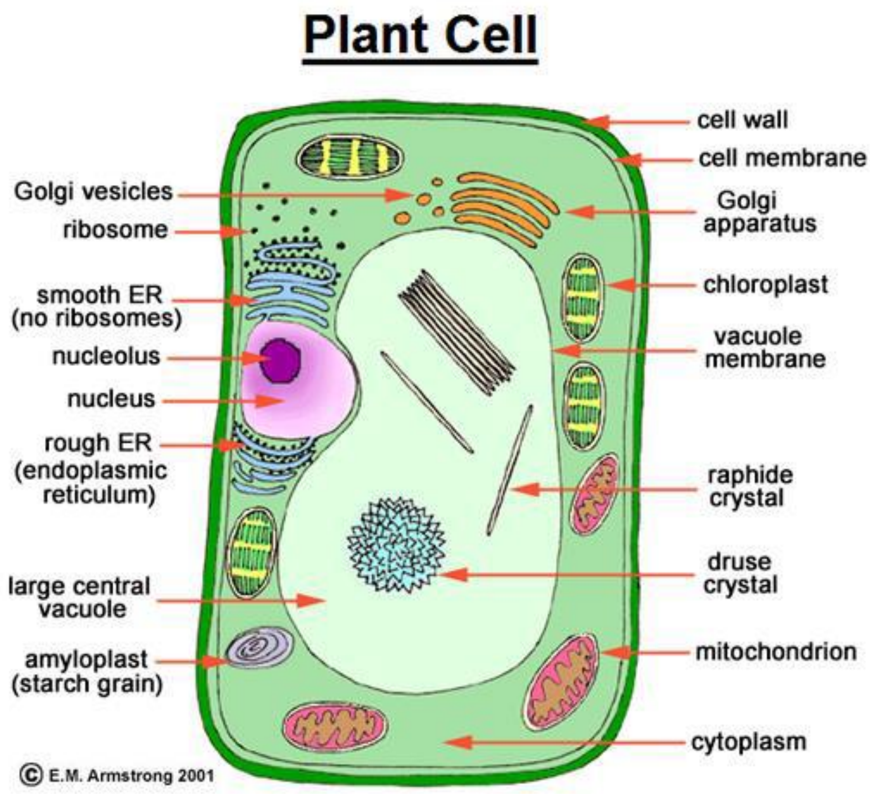
Cells are made up of subcellular structures that are responsible for different and specific functions. These structures are known as **organelles**. A number of these organelles are common to both animal and plant cells. This section will focus on those parts which plants have.

Table 1. Comparison of organelle contents of plant and animal cells.*

Organelle	Animal cell	Plant cell
Cell wall	Absent	Present
Centrioles	Present	Absent
Endoplasmic reticulum	Present	Present
Glyoxysomes	Absent	Present
Golgi apparatus	Present	Present
Microfilaments	Present	Present
Mitochondrion	Present	Present
Nucleus	Present	Present
Peroxisomes	Present	Present
Plastids	Absent	Present
Protein bodies	Absent	Present
Spindle	Present	Present
Vacuoles	Sometimes small	Present (mature cell – large central)

The Plant cell is composed of:

1. Cell wall (non-living)
2. Protoplast (living portion): -
   a) Cytoplasm and cytoplasmic membranes.
   b) Nucleus: nuclear membrane – nuclear sap – chromatin reticulum – nucleolus
   c) Cytoplasmic organelles: Plastids – Mitochondria – Golgi apparatus – Microsomes – Lysosomes
3. Non-protoplasmic contents:
   a) Vacuoles and cell sap.
   b) Starch grains -Proteins - Fats and oils - Crystals - Tannins and pigments - Organic substances



Cell Wall

Cell wall is the thick, rigid, non-living, semi-elastic, transparent, present outside the plasma membrane of cells.

It found in plant cells, fungal cells, some protists and prokaryotes except a few lower plants, gametes and in animal cells.

The thickness varies from 0.1 to 10/µm and xylem vessels have thickest cell wall, while thinnest cell wall found in meristematic and parenchymatous cells.

The wall formed during cell division of plants is called the **primary wall** which is later thickened to become a **secondary wall**.

There are three major regions of the wall:

1. **Middle lamella:** outermost layer, glue that binds adjacent cells, composed primarily of Mg and Ca pectic polysaccharides.
2. **Primary wall:** wall deposited by cells before and during active growth. The primary wall is comprised of pectic polysaccharides, hemicellulose, cellulose and protein. All plant cells have a middle lamella and primary wall.
3. **Secondary Wall:** some cells deposit additional layers inside the primary wall. This occurs after growth stops or when the cells begin to differentiate (specializes). The secondary wall is mainly for support and is comprised primarily of cellulose and lignin.

Intracellular Communication: Pits and Plasmodesmata

With all this layering, how do the cells "talk" to one another?

– Primary cell walls have thinner areas known as **primary pit fields**. Pit fields contain small openings in the wall through which cytoplasmic extensions known as **plasmodesmata** (singular, plasmodesma) extend between cells.

- When the cell constructs a secondary cell wall, it doesn't lay down secondary wall over the primary wall's pit fields. This creates perforations in the secondary wall called **pits**.
- Pits of adjacent cells are usually compressed to each other so that the two primary cell wall and middle lamella form a selectively permeable **pit membrane**.
- Pit → primary wall → middle lamella → primary wall → pit ...comprises the pit pair through which the cells can transmit water, nutrients, hormones, etc.

Based on the shape of pit chamber, there are several types of pits:

1. **Simple pits:** the cavity remains of the same diameter at different depths. It is characteristic of parenchyma cells.
2. **Branched pits**: the cavity branches in the very thick wall. It is found in stone cells of apples and pears.
3. **Bordered pits**: the cell wall around the pit cavity form a roof known as the border. The diameter of pit

aperture is smaller than the pit cavity. The central part of pit membrane is thickened forming the torus. Torus acts as a closing part, which closes the aperture when the hydrostatic pressure in one cell exceeds that of the neighboring cell. Found in tracheids and vessels.

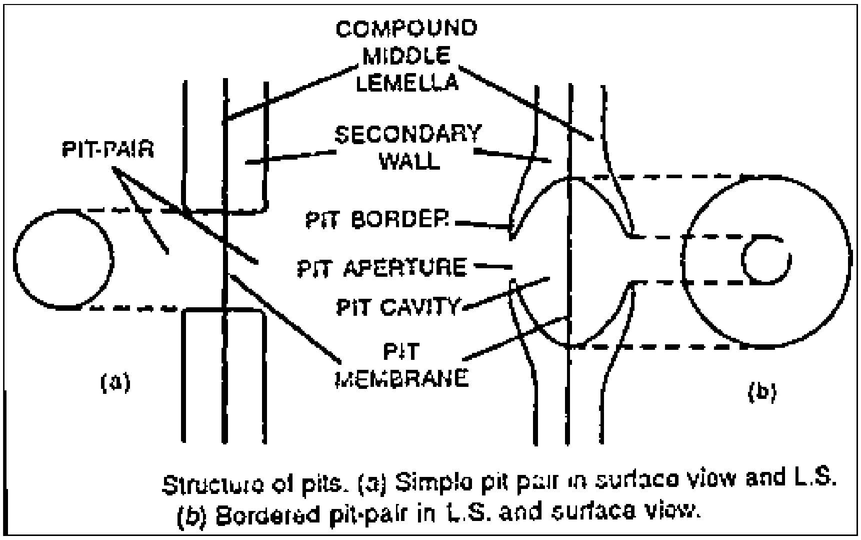


Fig.8: The structure of pits.

4. **Half bordered pits**: present when a simple pit is opposite to bordered pit. It found when a parenchyma cell is adjacent to conducting element (vessels or tracheids).
5. **Blind pits**: it present when a simple pit is opposite to intercellular space that present between cells.

Functions of cell wall

1. Provides mechanical and skeletal support for individual cells and for the plant.
2. It allows development of turgidity when water enters the cell by osmosis since it is fairly rigid and resistant to expansion.
3. It limits and helps to control cell growth and shape.
4. Cell walls develop a coating of waxy cutin (cuticle) which reduces water loss and risks of infections.
5. Economic products - cell walls are important for products such as paper, wood, fiber, energy.

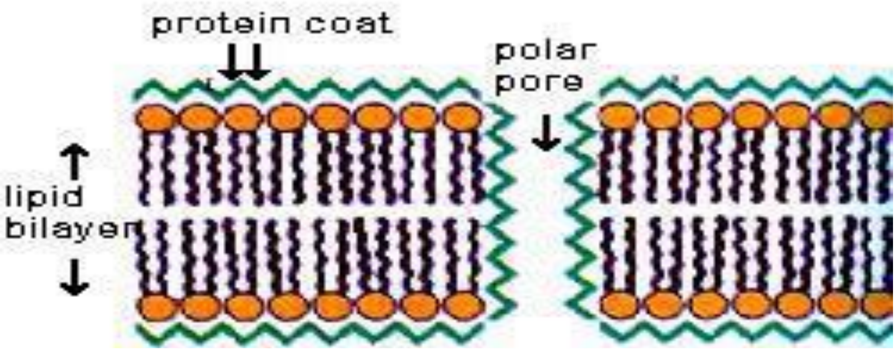
The Cell Membrane (Plasma Membrane)

The cell membrane or **plasma membrane** is the membrane or structure which encloses a mass of protoplasm of a cell. The plasma membrane and all other membranes bounded organelles contain phospholipids and proteins.

The cytoplasm is surrounded by a thin membrane known as **ectoplast**. In plant cell, it is usually lying under the cell wall. There is a similar plasma membrane separate the protoplast than the vacuole, it known as **endoplast**.

The plasma membrane is composed of two layers of proteins (from outside) sandwiching a double layer of lipid molecules (inside). It may interrupt with fine pores 8 - 50 A in diameter, responsible for permeability properties.

The plasma membranes are connected with a network system composed of continuous channels known as endoplasmic reticulum.



Structure of plasma membrane

Functions of the Cell (Plasma) Membrane

1. It separates the contents of the cell from their external environment.
2. The plasma membranes play function in selective permeability. It controls the exchange of materials between the cell and the surrounding. e.g.: gases.
3. It acts as the site for metabolic reactions such as energy production in mitochondria, also enzymes attached to the plasma membrane.

Cytoplasm

It is an aqueous substance containing a variety of cell organelles and other structures such as insoluble wastes and storage products.

The soluble part of the cytoplasm forms the ‘background material’ or ‘ground substances’ between the cell organelles. It contains about 90% water and forms a solution which contains all the fundamental biochemicals of life. Some of these are ions and small molecules in true solution; others are large molecules such as proteins which form colloidal solutions.

In plants the movements of the cytoplasm around the vacuoles, this is known as **cytoplasmic streaming**. Cytosol is the part of the cytoplasm that is not held by any of the organelles in the cell.

Function of cytoplasm

1. Cytoplasm is the site of many biochemical reactions that are vital for maintaining life.
2. Provides a medium for the organelles to remain suspended.
3. Aids in the movement of different cellular elements.
4. The enzymes in the cytoplasm metabolize the macromolecules into small parts, so it can be easily

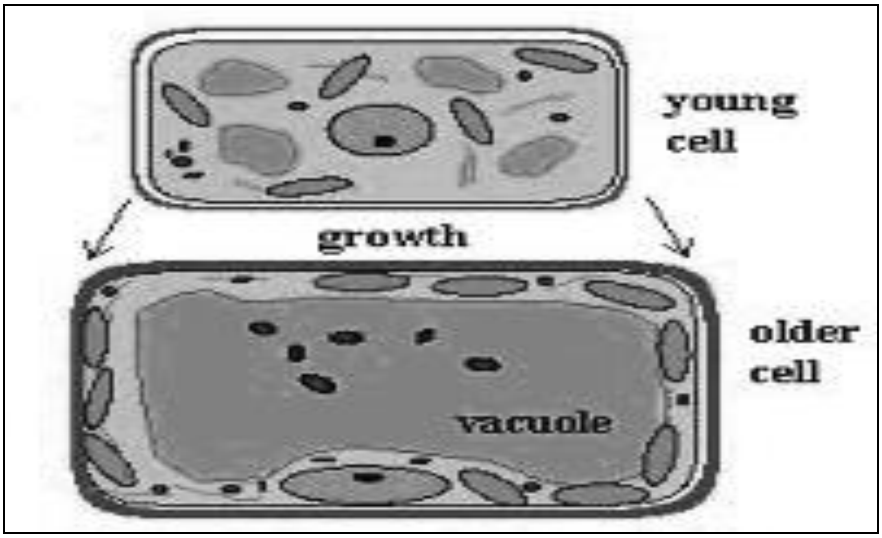
available for the other cellular organelles like mitochondria.

Vacuole

A vacuole is fluid filled sac bounded by a single membrane. Animal cells contain relatively small vacuoles, such as, food vacuoles and contractile vacuoles. Typically plant cells have one or two large vacuoles filled with fluid known as **cell sap** and surrounded by a membrane called **tonoplast**. The cell sap is a watery fluid containing water, sugar, organic acids, mineral salts, pigments, and toxic substances.

The **tonoplast,** also called the **vacuolar membrane**, is mainly involved in regulating the movements of ions around the cell, and isolating materials that might be harmful or a threat to the cell.

Aside from storage, the main role of the central vacuole is to maintain turgor pressure against the cell wall. Another function of a central vacuole is that it pushes all contents of the cell's cytoplasm against the cellular membrane, and thus keeps the chloroplasts closer to light.



The vacuole

Endoplasmic Reticulum

The endoplasmic reticulum (ER) is a network of tubules and flattened sacs known as **cisternae** that serve a variety of functions in the cell.

There are two regions of the ER that differ in both structure and function. One region is called rough endoplasmic reticulum (RER) because it has ribosomes attached to the cytoplasmic side of the membrane. The other region is called smooth ER because it lacks attached ribosomes. Typically, the smooth ER is a tubule network and the rough ER is a series of flattened sacs. The space inside of the ER is called the **lumen**. The ER is very extensive extending from the cell membrane through the cytoplasm and forming a continuous connection with the **nuclear envelope**.

Functions of endoplasmic reticulum

1. RER concerned with the production and storage of protein molecules.
2. They transport materials within the cell from one part to another.
3. SER involved in lipids and steroid synthesis and storing.
4. The ER provides surface for chemical reaction.
5. Producing and storing carbohydrates (SER).

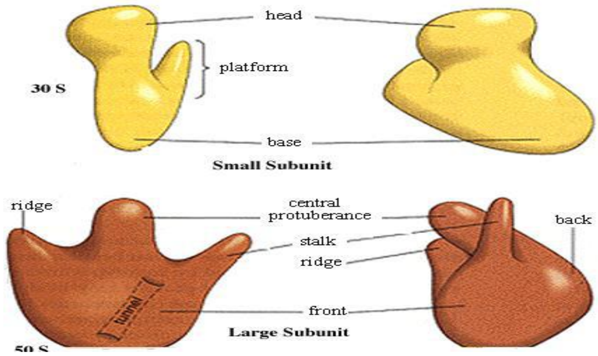
Ribosomes

Ribosomes were first observed in 1950 by George Emil Palade and termed "ribosome" by Richard Roberts in 1958.

Ribosomes occur in both prokaryotic and eukaryotic cells. The ribosomes of prokaryotic cells are distinctly smaller than those of eukaryotic cells.

The ribosome is responsible for the synthesis of proteins in cells, and it serves to convert the instructions found in messenger RNA into the chains of amino-acids that make up proteins.

The ribosome is a cellular machine which is highly complex. It is made up of dozens of distinct proteins and specialized RNA known as ribosomal RNA (rRNA).



Ribosomes

Ribosomes are composed of two subunits: the **small subunit**, which reads the RNA, and the **large subunit**, which joins amino acids to form a polypeptide chain. Each subunit is composed of one or more ribosomal RNA (rRNA) molecules and a variety of proteins.

There are two places that ribosomes usually exist in the cell: suspended in the cytosol and bound to the endoplasmic reticulum. These ribosomes are called **free ribosomes** and **bound ribosomes** respectively.

Functions of Ribosomes

1. They are the sites of polypeptide synthesis.

2. They supply the enzymatic activity that covalently links the amino acids in the polypeptide chain.
3. They facilitate the linear reading of the genetic code by sliding along the mRNA molecule.

Golgi apparatus

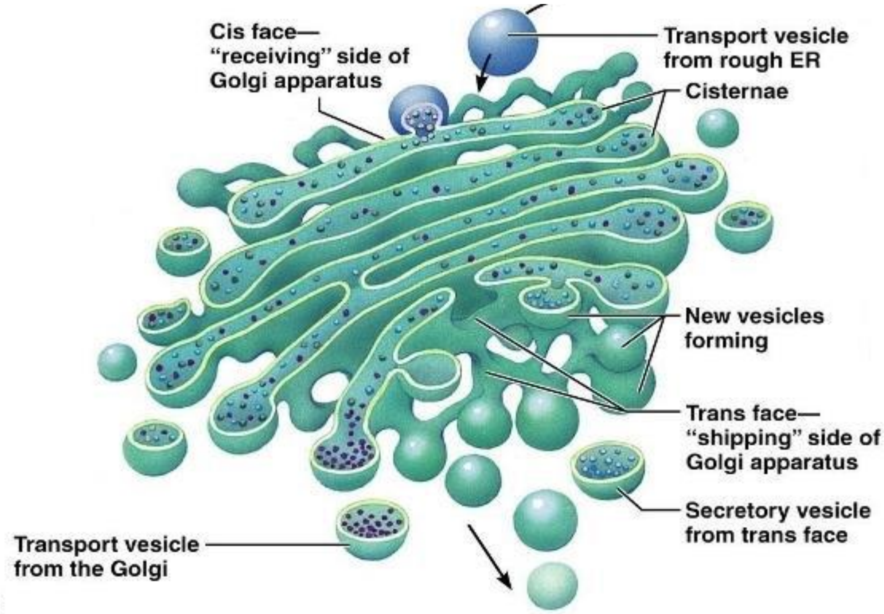
Owing to its large size and structure, the Golgi apparatus was one of the first organelles to be discovered in 1898 by **Camillo Golgi**. He termed it the *internal reticular apparatus*. The term "Golgi apparatus" was used in 1910. Among eukaryotes, the localization of the Golgi apparatus is usually near the cell nucleus and they are adjacent to endoplasmic reticulum.

A Golgi complex is composed of flat sacs known as **cisternae**, consists of a tubular parallel smooth membrane with membrane vesicles at their tips called **Golgi vesicles**. The sacs are stacked in a bent, semicircular shape.

Functions

1. The Golgi complex modifies many products from the ER including proteins and phospholipids.
2. Manufactures certain biological polymers of its own.

3. Contains processing enzymes which alter molecules by adding or removing carbohydrate subunits.



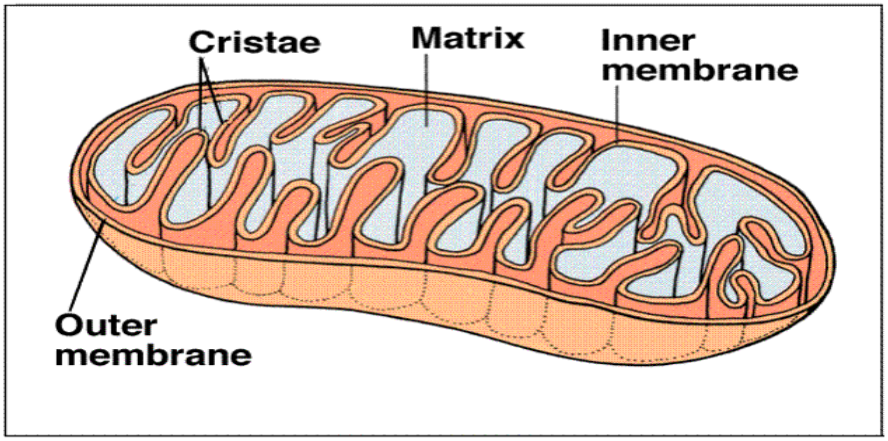
Golgi complex

Mitochondria

Mitochondria are the filamentous, self-duplicating, double membranous cytoplasmic organelles of eukaryotic cells which are concerned with cellular respiration.

They are the energy transducing organelle found in all aerobic eukaryotic cells. They are absent in prokaryotic cells where mesosomes act as a substitute of mitochondria.

The number of mitochondria varies from cell to cell; plant cells contain fewer than animal cells. The number of mitochondria in a cell is generally proportional to its energy requirement. The *Trypanosoma* and *Chlorella* contain 1 mitochondrion per cell, but the number is 25 in human sperm cell, 300-400 – in a kidney cell, 500-1000 – in a hepatic cell, and 5,00,000 -in flight muscle cell.



Mitochondria

Mitochondria vary in shape and size. Typical mitochondria are generally rod shaped. In some cases, these may be spherical or oval or filamentous. All mitochondria of a cell are collective called as **chondriome** and constitutes about 25% of the cell volume.

➢ **Ultrastructure**

Each mitochondrion is bounded by a mitochondrial envelope and encloses two chambers or compartments within it.

(a) Mitochondrial envelope:

It consists of two membranes called outer membrane and inner membrane. The outer membrane is smooth but porous due to the presence of integral proteins called **porins**.

The inner membrane is semipermeable. It is highly convoluted to form a series of in-folding called **cristae** or mitochondrial crests. Each crista encloses intracristal spaces which is continuous with the outer chamber. The cristae greatly increase the surface areas of inner membrane. It is rich in enzymes of respirators chain and a variety of transport proteins.

(b) Mitochondrial chambers:

In between two membranes a narrow space present called outer chamber or inter-membrane space. The central wider space enclosed by the inner membrane is called inner chamber or mitochondrial matrix. The outer chamber is filled with a watery fluid and contains enzymes.

The matrix is filled with a homogenous, granular, dense, jelly like material. It contains DNA, Mitoribosomes, granules of inorganic salts, enzymes for the citric acid cycle

(TCA cycle) and for the oxidation of pyruvate and fatty acids.

Functions of Mitochondria

1. They are the main seat of cellular respiration, a process involving the release of energy from organic molecules (such as glucose) and its transfer to molecules of ATP (Adenosine triphosphate), the chief immediate source of chemical energy for all eukaryotic cells. On this account, the mitochondria are often described as the “power houses”, or “storage batteries” or “ATP mills” or “cellular furnace” of the cell.
2. They provide intermediates for the synthesis of important biomolecules such as chlorophyll, etc.
3. Some amino acids are also formed in mitochondria.
4. They help in β oxidation of fatty acids.
5. Mitochondria are also involved in other cell processes such as cell division and growth, as well as cell death.

Plastids

Plastids are ovoid or spherical shaped organelles found in plant cells and in certain unicellular organism like algae. They are easily observed under light microscope. E. Haeckel (1866) introduced the term plasmid.

➢ Origin of Plastids:

Recent studies state that all plastids arise from pre-existing minute sub-microscopic plastids called as **proplastids**.

➢ Types

Based on types of pigments they contain, Schimper (1883) classified plastids in three types:

(i) Leucoplasts- Colourless plastids

(ii) Chromoplasts – Coloured plastids (other than green)

(iii) Chloroplasts- Green plastids

All the three types of plastids can change one form into another.

(i) Leucoplasts:

These are colorless, non-photosynthetic plastids found in those cells of plants which are not exposed to sunlight. They possess membranous lamellae that do not form thylakoids. They are the storage organelles and based on stored food they are of three types.

1. **Amyloplasts:** store starch, and found in underground stems (e.g. potato), cereals (e.g. rice, wheat).
2. **Elaioplasts** (Lipidoplasts or oleoplasts): They store oils and found in the seeds of castor, coconut etc.
3. **Aleuroplasts** (Proteoplasts or proteinoplasts): They store proteins and found in seeds (maize)

(ii) Chromoplasts:

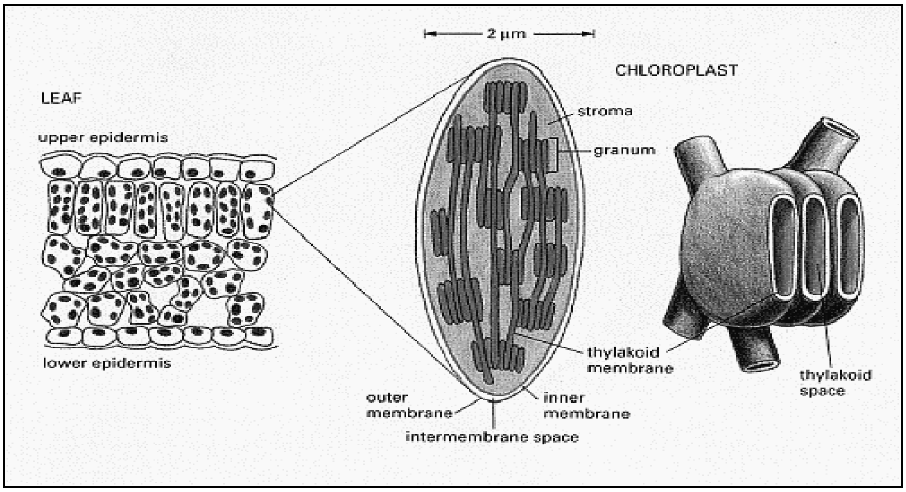
These are colored plastids other than green. They are non-photosynthetic which synthesize and store carotenoid pigments. They provide color to various parts of the plants which attract insects for pollination & dispersal of seeds. They also synthesize membrane lipids. During ripening of tomato and chili chloroplasts transformed into chromoplasts.

(iii) Chloroplasts (Green plastids):

The chloroplasts are green or chlorophyll containing plastids concerned with photosynthesis. The chloroplasts of algae, other than green ones (such as red and brown algae) are called **chromatophores**.

➢ **Number:**

A leaf mesophyll cell may contain 40-50 chloroplasts; a square millimeter of leaf contains some 500,000. The number of chloroplasts per cell in algae is usually fixed for a species. The minimum number of one chloroplast per cell is found in green alga *Ulothirix* and *Chlamydomonas*.

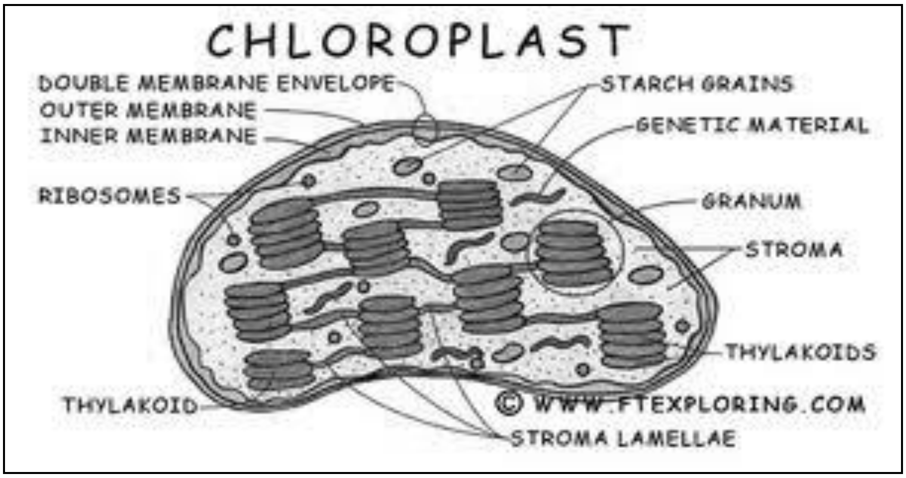


Structure of chloroplast

➢ **Shape and Orientation**:

The shape of a chloroplast varies from species to species. It may be cup-shaped (*Chlamydomonas*), Girdle (*Ulothrix*), Stellate or Star-shaped (*Zygnema*), Reticulate or net-like (*Cladophora*, *Oedogonium*), Spiral or ribbon or scalariform (*Spirogyra*), ovoid or disc or spheroid in higher plants.

The chloroplasts are usually found parallel to the cell wall. They can reorient in the cell under the influence of light. For example, gathering along the walls parallel with the leaf surface under low or medium light intensity. Under damaging, very high light intensity, they can orient themselves perpendicular to the leaf surface.



Structure of chloroplast

➢ **Size:**

They are generally 4-10/μm in length and 2-4 nm in width. In many algae, the chloroplast may occupy almost the whole length of the cell, such as in green alga *Spirogyra*, where it may reach a length of 1 mm.

➢ Ultra-structure:

A chloroplast has three types of membranes enclosing three types of compartments. The membranes are: outer membrane, inner membrane & a system of thylakoid membranes, while the compartments are: inter-membrane space, stroma & thylakoid space.

The inner membrane encloses a fluid-filled space called **stroma**, which is analogous to the mitochondrial matrix. The stroma contains: thylakoids, various enzymes, protein synthetic machinery (DNAs, RNAs & ribosomes), ions (Fe, Mn, and Mg), starch grains.. etc.

The stroma contains a membrane system which consists of many flattened, fluid-filled sacs called **thylakoids** or lamellae. About 2-100 thylakoids are stacked like a pile of coins forming **grana**. In a typical chloroplast, 40-60 grana may be present. Adjacent grana are interconnected by stroma lamella.

➢ Functions of Chloroplasts:

1. Chloroplasts are the site of photosynthesis as they convert radiant energy of sun light into chemical energy of sugars, hence called as biological transducers.

2. Chloroplasts store fat droplets which also contain vit-K and vit-E.
3. Chloroplasts in some algae render photosensitivity because of the presence of stigma or eye spot.
4. They can be transformed into the chromoplasts which provide beautiful colors to many flowers and help in attracting insects, birds and animals for pollination and dispersal.

The Nucleus

The nucleus was described by Franz Bauer in 1804. In 1838, Matthias Schleiden proposed that the nucleus plays a role in generating cells, thus he introduced the name "Cytoblast" (cell builder).

➢ Structure

The nucleus is a membrane-enclosed organelle found in eukaryotic cells. Eukaryotes usually have a single nucleus, but a few cell types have no nuclei, and a few others have many. In some cells, it has a relatively fixed position, usually near to center of the cell.

Nucleus is the most important organelle in the cell and the largest one. It is enclosed by an envelope of two membranes that is perforated by nuclear pores. The envelope helps to maintain the shape of the nucleus and assists in regulating the flow of molecules into and out of the nucleus through nuclear pores. The nuclear envelope completely encloses the nucleus and separates the cell's genetic material from the surrounding cytoplasm.

Within the nucleus, there is a matrix called **nucleoplasm** which contains the chromatin and nucleolus. Chromosomes are located within the nucleus consist of DNA. When a cell is "resting" i.e. not dividing, the chromosomes are organized into long entangled structures called **chromatin**. The chromatin materials are coiled DNA bounded by protein called histones.

Contained within the nucleus is a dense structure composed of RNA and proteins called the **nucleolus**. The nucleolus helps to synthesize ribosomes by transcribing and assembling ribosomal RNA.

Functions of the Nucleus

1. It contains chromosomes which have DNA (hereditary material) for the transmission of characteristics from one generation to another.

2. It controls the metabolic activities since DNA is organized into genes which control all the activities of the cell.
3. Formation of the ribosomal RNA by nucleolus.
4. Nuclear division gives rise to cell division hence reproduction.
5. It carries the instructions for synthesis of proteins in the nuclear DNA.

Lysosomes

A simple spherical sac bounded by a single membrane and contains a mixture of digestive enzymes such as protease, nuclease and lipase which break down proteins, nucleic acids and lipids respectively.

The enzymes contained within lysosomes are synthesized on rough E.R and transported to the Golgi apparatus. Golgi vesicles containing the processed enzymes later bud off to form the lysosomes.

In plant cells the large central vacuoles may act as lysosome.

➢ **Functions of Lysosome**

1. Lysosomes contain digestive enzymes which are used in digestion of reductant structure or damaged macromolecule from, within or outside the cell by autolysis.
2. Lysosome destroys foreign particles such as bacteria by phagocytosis.
3. Lysosomes play part in autophagy, autolysis, endocytosis and exocytosis.

Autolysis is the self-digestion of a cell by releasing the contents of lysosome within the cell. For this reason, lysosomes sometimes called ‘suicide bags’.

Autophagy is the process by which unwanted structures within the cell are engulfed and digested within lysosome.

Endocytosis occurs by an in folding or extension of the cell surface membrane to form vesicles or vacuoles. It is of two types, these are:

Phagocytosis: ‘cell eating’. Material taken up in solid form.

Pinocytosis: ‘cell drinking’. Material taken up in liquid form.

Exocytosis is the process in which waste materials may be removed from cells. It is the reverse of endocytosis.

3- Non Living Contents

Carbohydrates

Several sugars are known to occur in the cell sap of various plants. Glucose, fructose, and sucrose are the most dominant saccharides present in the cell sap.

Starch is the most important form of carbohydrates that stored in higher green plants. It is not found in the vacuole or the cytoplasm. It is produced only in plastids and deposited as grains.

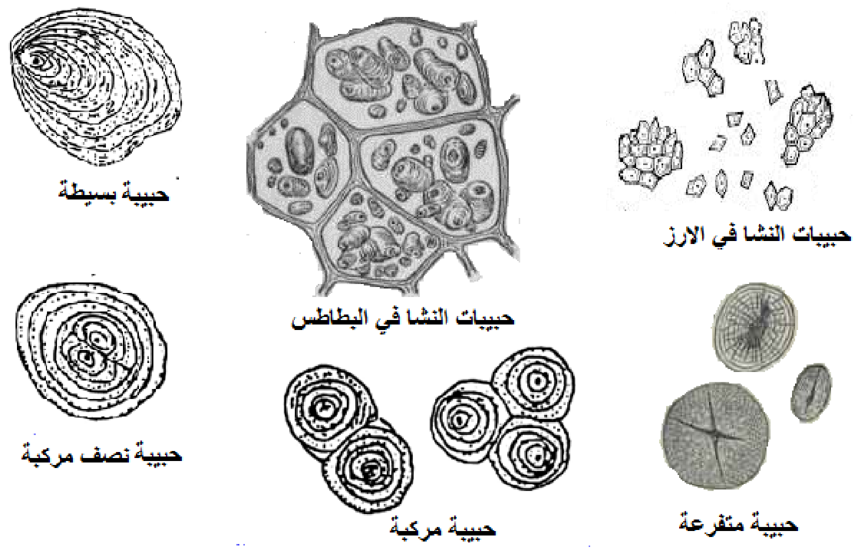
In leucoplasts, successive layers of starch are laid down around a center called the "hilum" the starch grain is fully developed, the leucoplast persists as a thin wall around the grain, and in some cases several grains are formed within a leucoplast.

Starch grains differ in shape from various plant species. It is possible to identify the species by microscopic examination. The starch grain may be simple compound or semi-compound. Hilum may be central or eccentric or lobed.

- Wheat grains have simple central type.
- Potato starch has simple eccentric type.
- Phaseolus and corn starch have simple type with lobed or radiate hilum.

- Compound type is found in potato and rice starch.
- The semicompound type is found in potato starch.

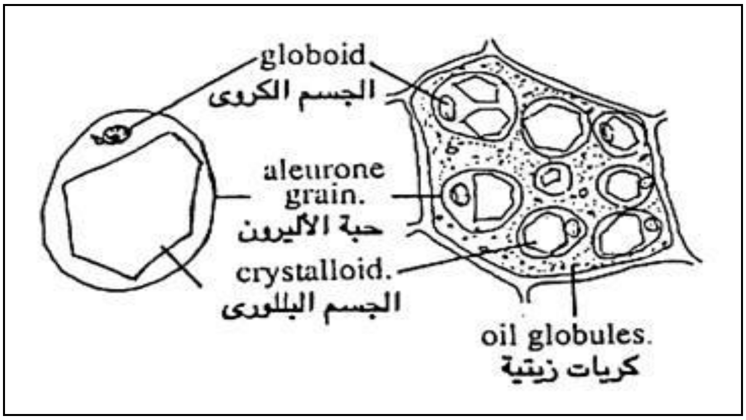
Starch grains are insoluble in cold water. When treated with solution of iodine in potassium iodide they stain "a dark blue or violet colour.



Types of Starch grains

Proteins

Proteins may occur either dissolved in the cell sap or in the form of crystal-like bodies called "crystalloid". In many seeds (corn and wheat), the vacuoles contain large amounts of dissolved proteins, and as they dries out, these proteins are transformed to "aleurone" grains.



“aleurone" grains

Each grain enclosed by a membrane. The larger body is crystalloid which consists of proteins. The other globoid are smaller and consist of protein combined with phosphates. Aleurone grains stain yellow or brown with iodine solution and could be differentiated from starch in this way.

Oils and Fats

It is commonly occur in the cytoplasm. It presents in the endosperm and cotyledons of certain seeds such as peanut**,** castor and cotton**.** It could be detected by staining the cell with (Sudan III) where they stain with brown colour.

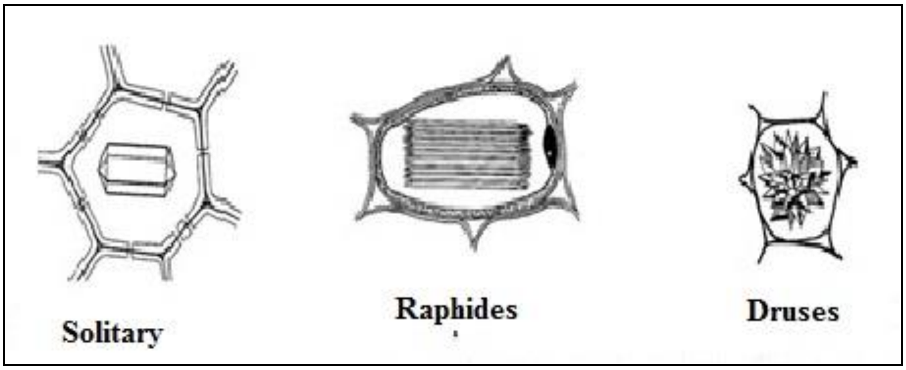
Organic Acids

The cell sap of plant cells is often acidic for the presence of free organic acids or their acid salts. Malic and tartaric acids are of common occurrence in the cell sap of plant cells. Oxalic acid also occurs generally, but it is usually present in the form of its insoluble calcium salt as crystals.

Calcium oxalate Crystals

It dissolves in mineral acids and occur in plant cells in different forms: -

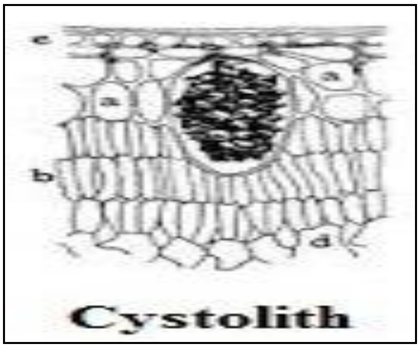
- Solitary: square prisms, pyramidal shapes, rhombohedral and others.
- Raphides: needle-shaped crystals associated together in bundles. It occurs commonly in monocots.
- Druses: rosette-shaped crystals, spheroid groups of tetragonal crystals. It presents in *Carica papaya* and *Begnonia*.

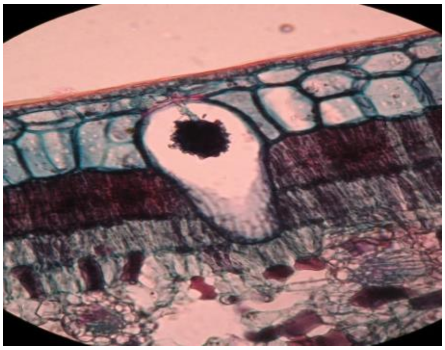


Calcium carbonate crystals

The best-known form the "cystolith". It consists of a cellulosic stalk, which is an in-growth of the cell wall *into* the cavity of epidermal cells of Ficus leaf.

Protrusion calcium carbonate is deposited forming a cluster-like structure which fills most of the cell cavity. It dissolves in dilute mineral acids **(**dilute acetic acid**).**





“cystolith”

Anthocyanins

Most of the yellow, orange and some of the red colours of plants are due to plastid pigments. Blue, violet, or purple and most of the dark red colours are due to pigments dissolved in the cell sap of the vacuole.

These pigments are the anthocyanins which are complex compounds composed of a pigment and a sugar. These pigments are soluble in water thus they diffuse out of the cell if the cell membrane is destroyed by heating or any other mean.

Anthocyanins are responsible for the colour of the purple turnip, red beet roots, blue and red colour of grape fruits, red of cherries and the purple, blue violet, pink and red colours of petals of many flowers. The colour of the anthocyanin changes with pH of the medium.

Glucosides

It occurs commonly in the cell sap, composed of glucose + aromatic compounds (e.g., amygdalin occurs in bitter almond cells). Amygdalin decomposes by the enzyme "emulsin" to give glucose, benzaldehyde and hydrocyanic acid. The characteristic odor and taste of bitter almond is due to the presence of benzaldehyde.

Mucilaginous compounds

It occurs in the cell sap giving a slimy character. It is common in many bulbs, e.g. onion, and leaves of many succulent plants. It swells in water but are insoluble" in alcohol. They are polysaccharides, when hydrolyzed they yield sugars.

Tannins

It presents in the cell sap and cell wall. It is a complex compound soluble in water and alcohol. It could be identified by treating the cells with ferric chloride where they give blue-black or green colour. It found in the leaves of tea, oaks, and many conifers.

Alkaloids

Complex cyclic compounds containing nitrogen occur in members of Solanceae, Papaveraceae, leguminosae and Apocynaceae. It may represent by-products of the nitrogen metabolism in plants. Their role in the plant is not known. (e.g., nicotine in tobacco; morphine in poppy fruits; caffeine in tea; theobromine in *cocoa* bean).

PLANT TISSUES

A tissue is a group of similar or dissimilar cells having a common origin and performing a similar function.

Types of tissues:

Tissues may be classified into two groups:

a. Meristematic tissues
b. Permanent tissues

Meristematic tissues (meristems):

The term meristem has been derived from a Greek word “meristos” which means divisible or having cell division activity. So meristem is a group of cell which has power of continuous division. e.g.: meristem at apex of stem, root, and vascular cambium.

The characteristics of meristematic cells are as follows:

– Cells are living, found in vegetative regions of the plant. They have thin walls of cellulose. Cells are isodiametric, oval, polygonal or rectangular.
– Abundant cytoplasm is present. Cells are compactly arranged and lack intercellular spaces.
– Cells have the capacity to divide. Large nucleus is present.

– Vacuoles are either absent or very small. They have no reserve food material and further no ER and plastids in them.

Classification of Meristematic Tissue

Meristematic tissues may be classified on the basis of:

a) Origin and development
b) Position in the plant body
c) Functions

(a) Meristems based on origin and development

i. **Promeristem** (= primordial meristem): A group of cells which represent primary stages of meristematic cells. They are present in a small region at the apices of shoots and roots. They give rise to primary meristems.

ii. **Primary meristem**: The meristematic cells that originate from promeristem. These cells are always in active state of division and give rise to primary permanent tissues. In most monocots and herbaceous dicots, only primary meristem is present.

iii. **Secondary meristem**: They are the meristems developed from primary permanent tissue. They are not present from the very beginning of the formation of an organ but develop at a later stage and give rise to secondary permanent tissues. examples; root cambium, intervascular cambium in stem and cork cambium.

Secondary growth occurs due to the activity of these cells. It increases the thickness of the plant parts. It is generally found in shrubs and trees.

(b) Meristems based on position in plant body

i. **Apical meristem**: It is found at the apex of growing points of root and shoot. It divides continuously and brings about growth in length of shoot and root. The apical meristem includes promeristem as well as primary meristem.

ii. **Intercalary meristem**: It is present away from apical meristem. It is present at the base of internodes, e.g.; in grasses and Gramineae. It is responsible for increase in length.

iii. **Lateral meristem**: They are located parallel to the long axis of the plant organs. Their activity results in increase of the diameter of the plant organs. e.g.; Cork cambium and Vascular cambium.

(c) Meristems based on function

i. **Protoderm**: it is the outermost layer of the young growing region which develops the epidermal tissue.

ii. **Procambium**: It is composed of narrow, elongated cells that give rise to the vascular tissue system (xylem and phloem).

iii. **Ground meristem**: It consists of large, thin-walled cells which develop to form ground tissue system, that is hypodermis, cortex and pith.

B. PERMANENT TISSUES

It is formed due to division and differentiation in meristematic tissue. The cells of this tissue may be living or dead, thin-walled, or thick-walled. The thin-walled tissues are generally living whereas the thick-walled tissues may be living or dead.

Permanent tissues can be of three types:

(a) Simple tissue

(b) Complex tissue

(c) Special tissue

A. SIMPLE TISSUES

These are homogeneous in nature and are composed of structurally and functionally similar cells.

These are of three types:

(i) Parenchyma

(ii) Collenchyma

(iii) Sclerenchyma

(i) PARENCHYMA

Parenchyma is considered as the precursor of all other living tissues. It is also the most primitive tissue from phylogenetic point of view. Parenchymatous cells are living, thin-walled, containing distinct nuclei.

The cell walls are made up of cellulose, hemicellulose and pectic materials. Cells have small or large intercellular spaces. Cells are generally isodiametric (but may also be elongated, lobed and polygonal). All meristems made up of parenchyma. It is the main constituent of the ground tissue in plant organs. It present in all plant organs (cortex, pith, xylem and phloem).

Functions:

- Parenchyma cells are the centres of respiration, photosynthesis, storage, secretion, etc.
- These cells help in wound-healing and in formation of adventitious buds and roots.
- Parenchymatous cells store water in succulent plants.
- In aquatic plants parenchyma cells store air and provide buoyancy to plants.
- Parenchyma cells of xylem and phloem help in conduction of water and food materials.

Specialized Parenchyma

1. **Spongy parenchyma**: isodiametric, oval, spherical or irregular found in cortex of herbaceous plants.

2. **Chlorenchyma**: when cells contain chloroplasts, it is called chlorenchyma. eg., leaf mesophyll tissue, outer cortex of young stem, outer cortex of xerophytic stem. Its function is to manufacture food through photosynthesis.

   a) Palisade chlorenchyma: elongated cylindrical cells, rich in chloroplasts, found in dicot leaves under the epidermis.

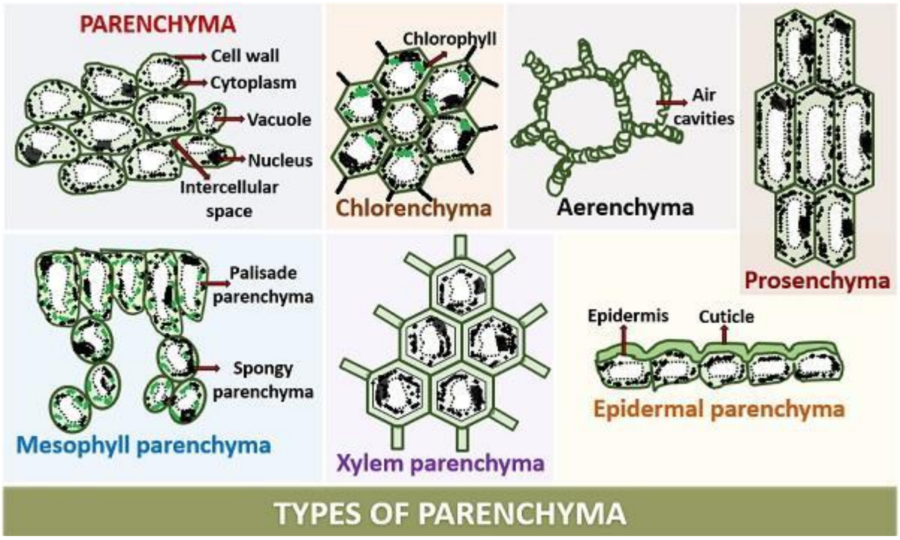
   b) Spongy chlorenchyma: isodiametric cells contain chloroplasts, present in cortex of herbaceous stems and leaf mesophyll.

3. **Aerenchyma**: In hydrophytes, the parenchyma develops air spaces and such parenchyma with air cavities is called aerenchyma. eg., *Hydrilla* and *Eichhornia* etc. It helps hydrophytes to float and provides O_2 for respiration. It may be stellate or armed (armed parenchyma), it also found in petioles of banana and *Canna.*

4. **Folded Parenchyma**: it provided with flanges projecting into the cell to increase the wall surface for extra chloroplasts. Present in *Pinus* leaf.

5. **Lignified parenchyma**: its walls are secondary lignified walls, function in support. Their shape are angular, without intercellular spaces and mostly living.

6. **Prosenchyma**: Parenchyma cells are elongated. Found in pericycle of roots. Its function is to provide strength.



(ii) COLLENCHYMA

These are living elongated cells with thick walls. The cell wall is made up of cellulose, hemicellulose and pectic materials. The wall thickening is not uniform. The walls are often provided with simple pits. Sometimes chloroplasts are present in collenchyma cells.

Collenchyma is found in many herbaceous dicot stems, petioles and younger regions of woody stems. Collenchyma is absent in roots and monocot stems.

Types of collenchyma

On the basis of thickening on cell wall, collenchyma may be of three types:

A. Angular

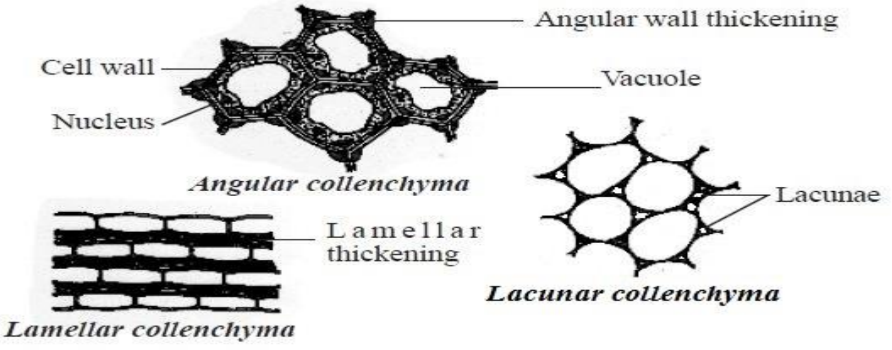
The deposition is maximum at the angles (where the two cell walls come in contact). The cells appear polygonal in transverse section. It is the most common type.

B. Lacunar:

Large intercellular spaces occur between the cells. The deposition occurs on the walls towards the spaces. The hollow thickened components are found e.g. *Cucurbita*.

C. Lamellar:

The deposition occurs on tangential walls. The cells appear plate like or lamellar. It is also called plate collenchyma e.g.: *Helianthus*.



Types of collenchyma

Functions

It performs both mechanical and vital functions. Collenchyma provides tensile strength which gives elasticity and support to the growing organs. Chloroplast containing collenchyma performs photosynthetic function.

Distribution

- In dicot stems, it presents under epidermis (continuous layer or as strands at the ridges).
- In dicot leaves, accompanying the large vascular bundle may be under lower epidermis.
- In dicot roots and monocots, not present.
- Woody stems rarely possess collenchyma.

(iii) SCLERENCHYMA (Greek: Scleras = hard)

They are dead cells, and act as purely mechanical. The cells are long, narrow, and pointed at both ends. The cell walls are lignified and have simple pits. The cell walls are very thick with the result that the cell cavity becomes narrow. At maturity, it become non-living (have no protoplast).

Types of Sclerenchyma :

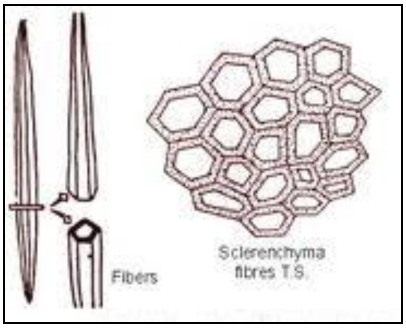
It is of two types:

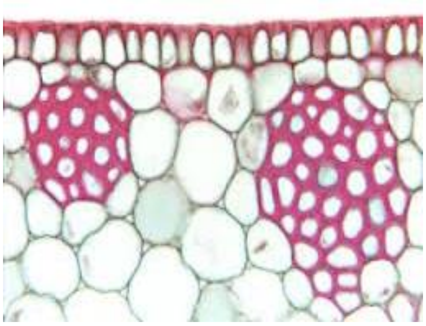
A. Fibers B. Sclereids or stone cells

A. Sclerenchymatous fibers

Firbers develop from meristematic cells. Cells are long, narrow with thick walls, pointed at both ends and lignified. Cell wall has simple or bordered pits. Cell wall composed of lignin, leaving a small lumen, which represent a small canal and may be blocked at certain places. At maturity, protoplast disappear, becomes empty and dead. Generally, length of the fibers is upto 3 mm but in some cases like jute, Flax and hemp, fibers are up to 20 - 550 mm in length.

Fibers occur in small groups scattered among other cells. They usually form strands extending longitudinally for some distance. They are suitable for supporting due to their arrangement in long masses and their overlapping.





Fibers

Distribution of fibers:

In dicot plants, it occurs in the vascular bundles in roots and stems. May also occurs in cortex of some stems. Not present in leaves. In monocot plants, it encloses each vascular bundle (bundle sheath) of stems. It also present under the epidermis (hypodermis) forming continuous layer in roots, stems and leaves.

Fibers can be distinguished into two types, bast and xylem fibers. The fibers present outside xylem (bast fibers) are called extra-xylary fibers. They are of three types:

(i) Cortical fibers in cortex.

(it) Pericyclic fibers in pericycle (perivascular fibers).

(iii) Phloem fibers in phloem (bast fibers).

B. Sclereids

These are not much longer than their breadth. They have extremely thick wall of lignin with narrow lumen. The cells have no definite shape. They develop from parenchyma cells. The cells are isodiametric, bone, columnar or ovoid with branched pits (stone cells). It present in groups in cortex, phloem, seeds and fruits.

It functions in supporting and protective tissues. In seed coats and nut shells, it present in masses giving hardness and mechanical protection.

Types of sclereids

(a) **Brachysclereids or Grit cells or Stone cells**: These are small, oval or rounded cells. They are found in cortex, phloem and pith of stems and fleshy pericarp of certain fruits (pear, apple, guava). Stone cells are also present in hard parts like endocarp of coconut and hard seed coats.

(b) **Macrosclereids or Malpighi cells**: These are rod-like or columnar cells. They are common in the seed coats of many leguminous plants (e.g. pea).

(c) Osteosclereids (Bone shape): These are barrel-shaped cells and look like as bones. They are found in leaves and seed coats of several monocotyledons *(Hakea* leaves).

(d) Asterosclereids: These are star shaped cells. Found in

Nymphaea petioles.

(e) Trichosclereids: hair-like, branched or unbranched cells. They are found in the intercellular spaces of leaves and stems of some aquatic plants.

(f) Microsclerids: which are small and needle-like.

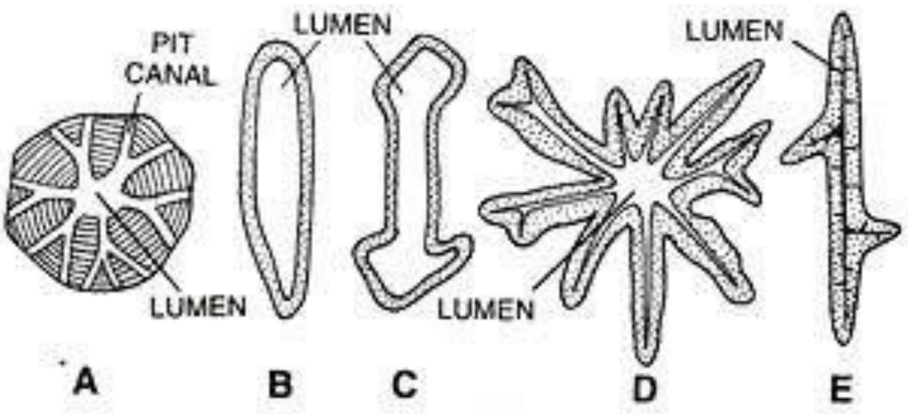


Fig. 6.10. Types of Sclereids. A, stone cell. (branchysclereid) with pit canals; B, macrosclereid; C, osteosclereid; D, astrosclereid; E, filiform sclereid.

B. COMPLEX TISSUES

The complex tissues are made up of living and non-living cells which perform different functions. The complex tissues act as single units. They are also known as vascular tissues. They are of two types: Xylem and Phloem.

(i) Xylem or Wood or Hadrome

It is also called as wood because the major part of stem and root in vascular plants is costituted by xylem. The function of xylem is to conduct water and mineral salts upwards from the root to the leaf and to give mechanical strength to the plant body. It is a conducting tissue and is composed of four different kinds of elements:

(a) Tracheids (b) Vessels

(c) Wood fibers (d) Wood parenchyma

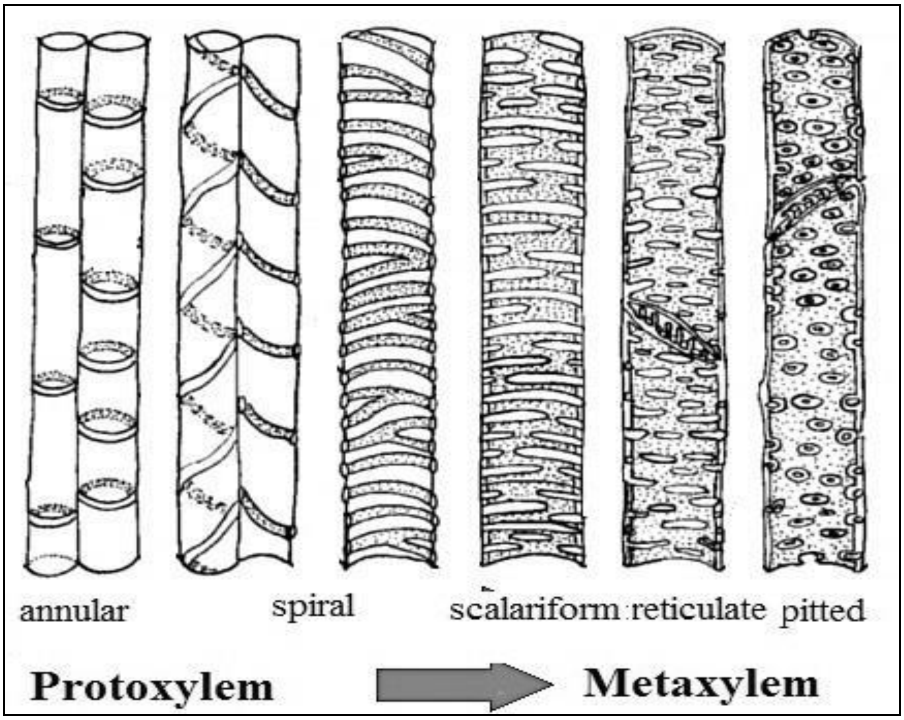
(a)Tracheids:

A single tracheid is elongated or tube-like cell with hard, thick and lignified walls and a large cavity. When mature, protoplast disappears and cell becomes non-living. Walls have bordered pits where water passes from cell to cell.

The secondary wall layers possess various kinds of thickenings in them and may be distinguished as annular (in the form of rings), spiral, reticulate, scalariform or pitted (simple or bordered).

Tracheids occur alone in the wood of ferns and gymnosperms, whereas in the wood of angiosperms they occur with the vessels.

Functions: These carry out transport of water and solutes from the root to the stem, leaves and floral parts. It gives mechanical suppert to the plant body.



Secondary wall thickenings of xylem elements

(b) Vessels:

A vessel is a long, cylindrical, tube-like structure with lignified walls and a wide central cavity. Cells are dead and without protoplast. Vessels are more advanced than tracheids. They are characteristic of the angiosperms. In many monocots vessels are absent.

They arranged in longitudinal series in which the transverse walls (the end plates) are perforated and as such the entire structure looks like a water pipe. Vessels also have various type of thickenings similar to tracheids. The lignifications of secondary cell wall may be annular (ring-like) or spiral shape, they are adapted to elongation and characteristic of protoxylem. The reticulate (net-like), scalariform (ladder-like) and pitted forms are characteristic to metaxyiem.

Functions: They serve for transport of water and minerals as compared to tracheids due to the presence of perforation plates. Also give mechanical support to the plant body.

(c) Xylem fibers (Wood fibers)

Sclerenchymatous cells associated with xylem. They are long, narrow, thick and lignified cells; usually pointed at both ends. Xylem fibers are dead cells.

Functions: Xylem fibers provide mechanical strength to the xylem and to the plant body as a whole.

(d) Xylem parenchyma:

The parenchymatous cells found in xylem are living and isodiametric. Xylem parenchyma cells are more common in primary xylem than secondary xylem.

Xylem parenchyma cells of primary xylem are thin-walled and made up of cellulose, while those found in secondary xylem are thick-walled and made up of lignin.

In secondary xylem they occur as vertical series of elongated cells placed end to end known as wood parenchyma, and radial transverse known as xylem-ray parenchyma.

They function as a food storage tissue; store starch, oils and other substances. It also has a function in water conduction and supporting. They may form thick walls and become sclereids.

(ii) Phloem or bast or Leptome

Phloem is another type of conducting tissue like xylem which is responsible for conduction of organic substances.

The phloem from the procambium is called primary phloem and that formed from vascular cambium is called secondary phloem.

The phloem is composed of four elements:

(i) Sieve tube elements

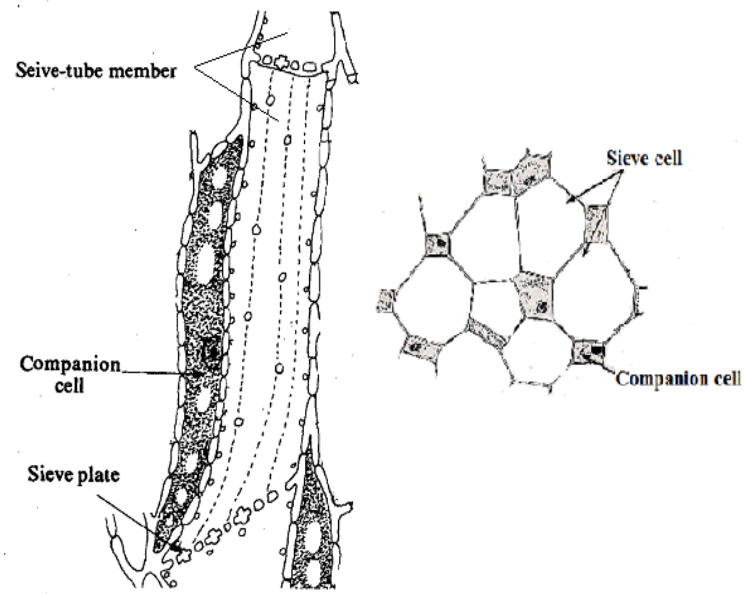
(ii) Companion cells

(ili) Phloem parenchyma (Bast parenchyma)

(iv) Phloem fibers (Bast fibers)

I. Sieve tube elements:

Sieve tubes are tube-like structures, composed of elongated cells, arranged in longitudinal series and associated with companion cells. Their walls are thin and made of cellulose. In a mature sieve tube the nucleus is absent but peripheral cytoplasm as well as large vacuole is present. The uniqueness of the sieve tube is that although without nucleus, it is living and the nucleus of the companion cells control its functional activities.



The transverse partition walls are perforated by a number of pores, giving the appearance of sieves. They are called the sieve plates. A sieve plate is called simple if it has only one sieve area. A sieve plate is called compound if it has many sieve areas.

At the end of the growing season the sieve plate is covered by a deposit of carbohydrate called callose. But in the spring, when the active season begins, it gets dissolved. In old sieve tubes callose forms a permanent deposit.

Functions: The main functions of the sieve tubes is the transport of prepared food materials from leaves to the storage organs in the downward direction and then to growing regions in the upward direction.

II. Companion cells

These are specialised parenchyma cells which are closely associated with the sieve tube elements in their origin, position and function. These originate from the same meristematic cells that give rise to the sieve tube elements.

The companion cell has dense cytoplasm and prominent nucleus. It nucleus also controls the metabolic activities of the sieve tube.

It lives as long as the associated sieve tube element. In T.S. it is triangular, rounded, or rectangular. They occur only in angiosperms and accompany the sieve tubes. In monocots, make up the phloem with sieve tubes (regular phloem). In Gymnosperms, albuminous cells are associated with the sieve cells (no companion cells).

III. Phloem parenchyma (Bast parenchyma)

These are living parenchymatous cells which may be cylindrical, sub-spherical or polyhedral in shape. The cells have dense cytoplasm and nucleus. The cell-wall is composed of cellulose. It present in dicot plants only (absent in monocots). It has a function in storage and conduction.

IV. Phloem fibers (Bast fibers)

These are much elongated, unbranched and have pointed, needle-like apices. Their cell wall is quite thick with simple or slightly bordered pits. At maturity these fibers lose their protoplast and become dead. These occur in groups e.g.; in flax and jute. It present in primary and secondary phloem. In primary phloem, they occur in the outer most part of it. In secondary phloem, they are distributed.

Functions :

The phloem fibers provide mechanical support to the phloem. They are economically very important as they are used in making cords, gunny bags, and coarse cloth.

C. SPECIAL TISSUES OR SECRETORY TISSUES

The secretory tissues are cells or organizations of cells which produce a variety of secretions. The secreted substance may remain deposited within the secretory cell itself or may be released from the cell. Substances may be excreted to the surface of the plant or into intercellular cavities or canals. Some of the secreted substances are not utilized by the plant (oils, resins, latex, rubber, nectar, tannins, perfumes and crystals), while others take part in the functions of the plant (enzymes and hormones). They sometimes have great commercial value.

Generally, secretory tissues are derived from parenchyma cells. It occurs in pith, cortex, xylem and phloem. It is organized into special structures known as glands and ducts. These tissues are of two types: Glandular tissue and Laticiferous tissue

(i) Glandular tissue

It consists of glands (a gland is specialized group of cells, capable of secreting some substances). These glands are of two types: (a) External glands and (b) Internal glands

(a) External glands:

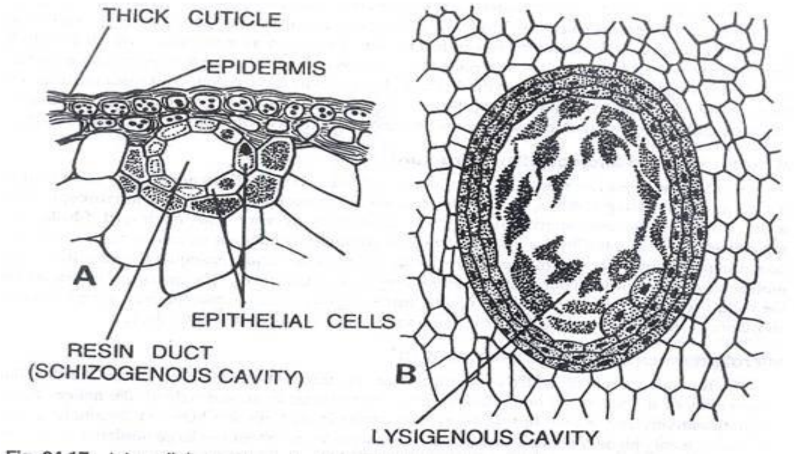
These generally occur on the epidermis of stem and leaves as glandular outgrowth e.g.; glandular hair, nectar secreting and enzyme secreting glands.

1. **Glandular hair**: These hairs are present in epidermal layers of leaves and are of various kinds. Contents of hair are poisonous and are secreted by a gland at the base of hair.
2. **Nectaries**: Present in flowers or leaves. They secrete a sugar solution (nectar), which attract insects. Its secretory tissue consists of epidermal cells lack cuticle and specialized parenchyma of small densely cytoplasmic cells often called nectariferous tissue. Cell walls of these cells are thin, and the cells have dense cytoplasm.
3. **Digestive glands or Enzyme secreting glands**: Insectivorous plants possess the power of digesting proteins from bodies of insects by secreting some digestive enzymes by means of glands or glandular hair. e.g.; *Nepenthes*, *Drosera* (sundew).

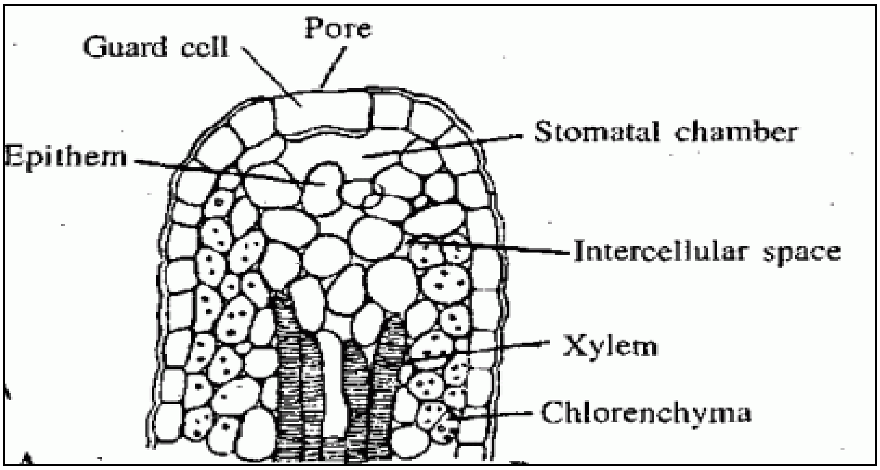
(b) Internal glands

These glands are found inside the plant. They are spherical or tubular. Various types of internal glands are as follows:

1. **Oil glands**: Lysigenous cavity is formed due to dissolution ofglandular cells which contain oil, these are called as oil glands e.g,; oil glands in leaves and rind of the fruits of Citrus and Orange.
2. **Mucilaginous glands**: Mucilage occurs in lysigenous cavity, it is called as mucilaginous gland. Example: In leaves of betel vine.
3. **Resin/Tannin/Gum glands**: They secreted in cavities within plant tissue. The cavities are surrounded by secretory cells known as epithelial cells. The secretory cells are thin walled, with dense protoplasm. There are two types-
   - **Schizogenous glands**: their cavities originate by separation of cells. They secrete resins (e.g. *Pinus).*
   - **Lysigenous glands**: cavities originate by disintegration of cells. They secrete essential oils (e. g. *Citrus* fruits).



4. **Water secreting glands (Hydathodes = water stomata):** These excrete water in the form of drops found in leaves of some herbacious angiosperms that generally grow in humid places. it exudes as droplets on the surface of the organ in a process called guttation. Hydathodes are present at the tip of leaves of some plants e.g.; *Colocasia* or along margin e.g.; *Tropaeoleum*.



Hydathodes = water stomata

(ii) Laticiferous tissue:

This tissue is mainly composed of thin walled, elongated, branched and multinucleate tube-like structures scattered throughout the ground tissue of the plant. They contain colourless, milky or yellow coloured juice called latex. Latex contains proteins, sugars, gums, alkaloids and enzymes. In some plants, latex is economically important such as *Hevea* latex (rubber).

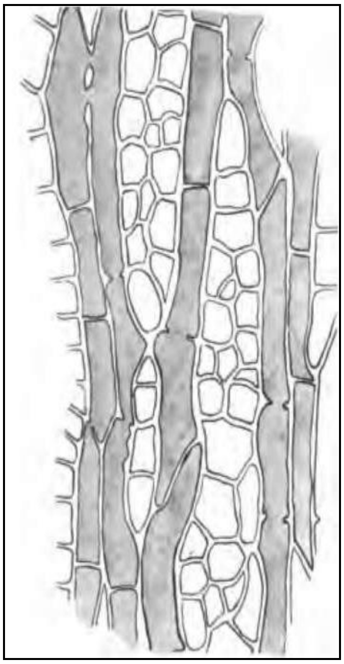
This tissue is of two types:

A. Latex cells (Non articulated laticifers)

They differ from latex vessels in that they are not formed due to cell fusions and with other latex cells to form a network. It is long cells extending for long distances through the plant It contains dense protoplast and many nuclei. They are branched or unbranched. *Calotropis*, *Nerium*, *Euphorbia*, *Ficus*,.. etc. contain latex cells.

B. Latex vessels (Articulated laticifers)

They are composed of a large number of cells placed end to end with their transverse walls dissolved so as to form a long vessel. They are unbranched in the beginning but get branched later. Two or more latex vessels fuse with each other forming a network e.g.; *Papaver*, *Sonchus*, *Carica*.



Laticiferous tissue

THE TISSUE SYSTEM

Types of Tissue Systems

A. The epidermal tissue system.

B. The ground or fundamental tissue system.

C. The vascular/conducting tissue system.

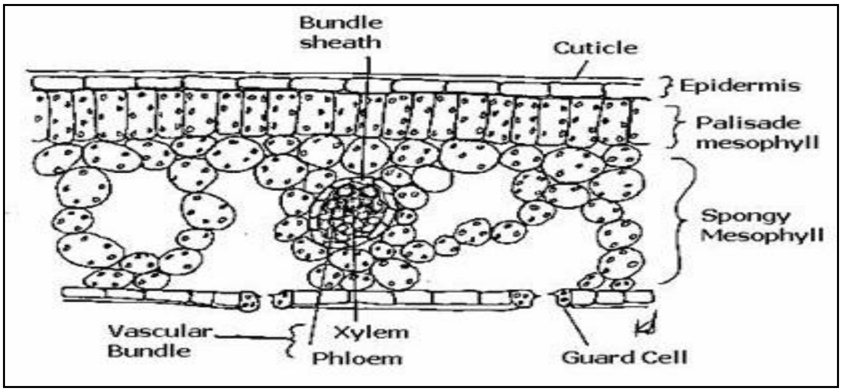
A. **The Epidermal Tissue System**

It comprises the following:

(a) Epidermis

The epidermis (epi: upon; derma: skin) is the outermost layer of the plant body, which has direct contact with external environment. It is made up of elongated, compactly arranged cells which constitute a continuous layer without any intercellular spaces. The cells have a large, central vacuole surrounded by a thin layer of protoplasm. The epidermis may also be multilayered as in the aerial roots of Orchids and leaves of *Nerium* and *Ficus*. The outer wall of epidermis is thick and usually covered by a cuticle formed by the deposition of a waxy material secreted in the epidermal cells. The cuticle is thickest in the xerophytic plants.

Some epidermal cells of certain monocots (grasses, maize, sugarcane) are comparatively large, vacuolated and thin-walled. These are called bulliform or motor cells. These cells store water and help in closing and opening of leaves due to changes in turgor.



The epidermal cells of some plants (e.g. *Ficus*) contain crystals of calcium carbontate in the form of bunches or grapes. These are called cystoliths. The cells containing cystoliths are called lithocytes.

The outermost layer of roots is referred to as epiblema or piliferous layer. No stomata and cuticle on the epiblema.

(b) Stomata

The word *stoma* means mouth (in Greek) because they allow communication between the internal and external environments of the plant. Stomata are very small openings found in the epidermis of green aerial parts of the plant especially the leaves

Pore of each stoma is surrounded by two kidney-shaped cells, called guard cells. The guard cells are living and contain chloroplasts. The inner walls are thicker than the outer walls. The guard cells regulate the opening and closing of the stomatal pores.

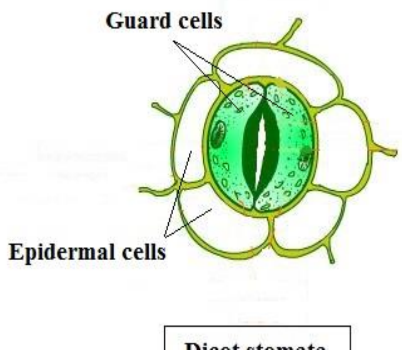
They are dispersed among the epidermal cells, upper or lower side. Guard cells and stomatal opening are called "stomatal apparatus".

Types of Stomata:-

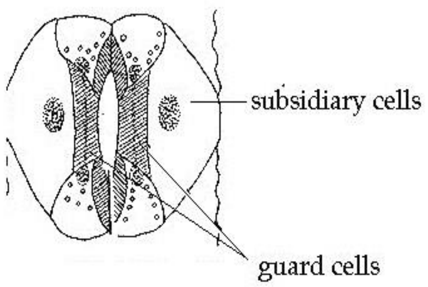
There are two types:-

a. <u>Kidney shaped stomata</u>:-

The guard cells are kidney shaped. It found in all seed plants except two families (Graminae and Cyperaceae).



Dicot stomata

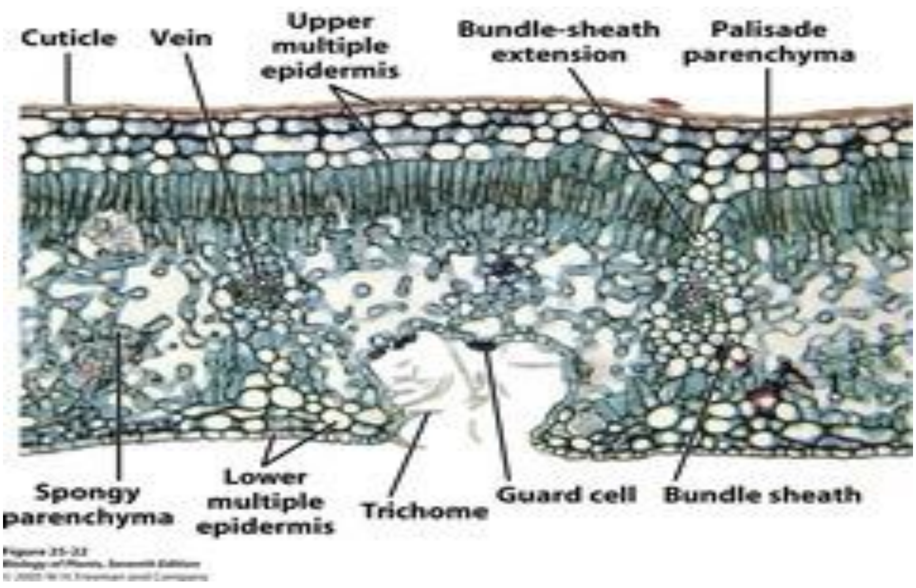


Monocot stomata

b Dumb-bell shaped stomata:-

They are narrow in the middle and enlarged at both ends. The central part has a very thick wall, whereas bulbous ends have thinner walls. It present in Graminae and Cyperaceae.

In xerophytic plants, the stomata are depressed below the general leaf surface to help in reducing water loss from the plant in dry habitats, they are known as **sunken stomata**. In, some plants the stomata may cover with hairs, so they are called as sunken stomata with hairs.



sunken stomata with hairs

(c) The epidermal appendages

Trichomes are epidermal outgrowths of various kinds give the plant silky, woolly or velvety appearance which vary markedly in their shape, structure and function. trichomes are often living cells. Trichomes help in checking excess loss of water (reduction of water loss). Trichomes help in protection, dispersal of seeds and fruits.

Plant hairs may be unicellular or multicellular, branched or unbranched. Multicellular hairs may have one or several layers of cells. Branched hairs can be tree-like or tufted. Any of the various types of hairs may be glandular.

Types of hairs and trichomes:

Unicellular hair: it is a thick-walled and sharply pointed hair, make the surface rough. The longer, straight, stiff ones usually termed bristles.

Multi-cellular hair: it consists of a row of two or more cells (uniseriate or multiseriate).

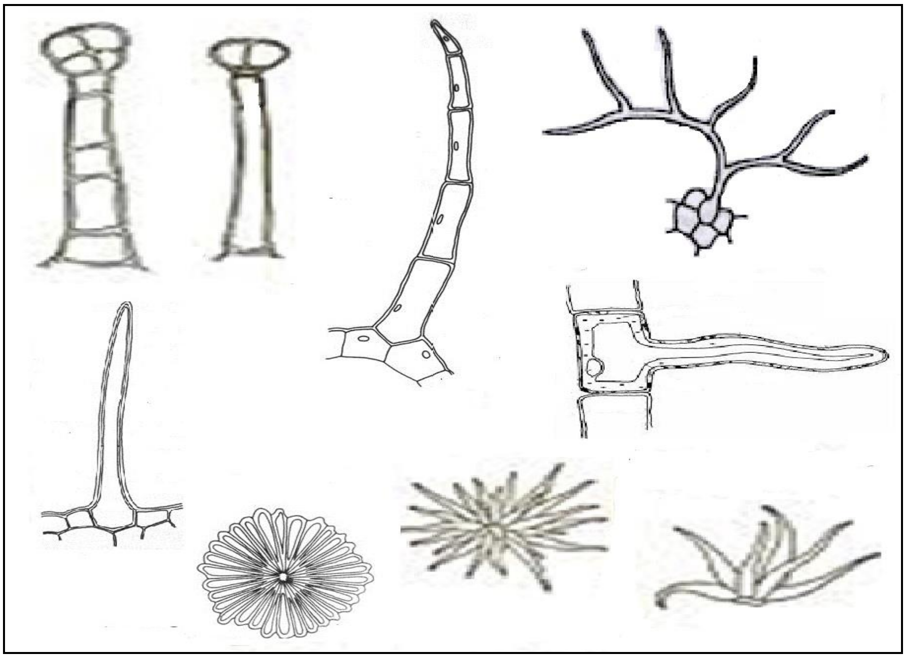
Glandular hair: it is with a definite pedicel and a rounded or flattened head.

Peltate hair: a plate of cells radiating from the center.

Stellate hair: several unicellular hairs arise from basal cell.

Papillae: they are cone-shaped outward extensions of the epidermal cells. They found on flower petals giving it velvety appearance.

Root hair: a long extension of the root epidermis to increase the absorbing surface. It presents at short distance behind the root growing-points. The wall remains thin and the cell living and vacuolated.



Types of hairs

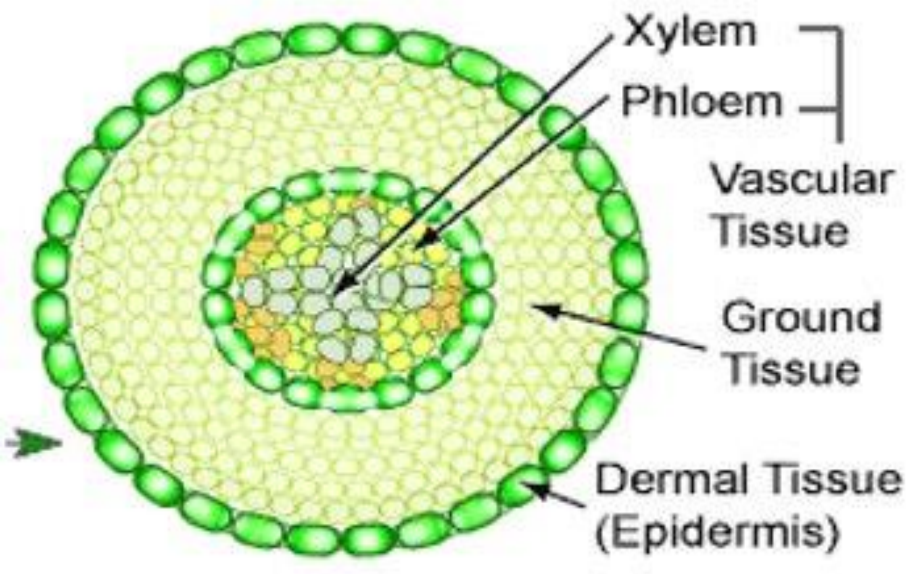
Stinging hair: an elongated, tapering hair and broader, rounded base. When a hair is touched, siliceous point breaks and the hair contents are forced into the skin. The hair contains histamine and acetylcholine, (e. g. *Urtica* function in protection).

Emergencies: they are stronger outgrowths, not from epidermis only. They differ from hairs in containing a core of cortex and vascular tissue (e. g. rose spines and grass ligules).

B. Ground or fundamental tissue system

The ground tissue system forms the main bulk of the plant body. It includes all the tissues except epidermis and vascular bundles. It is partly derived from the periblem (cortex meristem) and partly from the plerome (vascular bundle meristem). The primary function of this tissue system is storage and manufacture of food material.

This system has different kinds of tissues such as parenchyma, collenchyma and sclerenchyma; of these; parenchyma is most abundant and carries out a variety of functions.



In dicot stems, dicot roots and monocot roots (in which vascular bundles are in a ring), the ground tissues constitute the following parts:

(a) Cortex

(b) Pericycle

(c) Medulla or Pith

In monocotyledonous stem (with scattered vascular bundles) the ground tissue is not differentiated into cortex, pericycle and pith.

Cortex:

It can be divided into hypodermis, general cortex, and endodermis.

i. **Hypodermis**

It is found just below the epidermis, made up of collenchymatous cells in a dicot stem or sclerenchymatous cells in a monocot stem. Hypodermis remains absent in roots. Hypodermis protects the internal tissues and gives mechanical support to the peripheral region.

ii. **General cortex**

This part lies between hypodermis and endodermis. It is made up of parenchymatous cells. The cells are spherical or isodiametric with intercellular spaces and contain different types of crystals; starch grains and sometimes chloroplasts.

iii. Endodermis

Endodermis is single layered structure separates cortex from stele. Endodermis composed of compactly arranged barrel-shaped parenchyma cells without intercellular spaces and containing starch (hence it is known as starch sheath).

Radial and tangential walls of endodermal cells in root possess thickenings of lignin, suberin and cutin in the form of strips, which are known as **casparian strands**.

There are thick-walled and thin-walled cells in endodermis. Thin-walled cells are known as **passage cells** or transfusion cells, which are present opposite the protoxylem groups.

Pericycle

Pericycle is situated between endodermis and vascular bundles. The cells of pericycle are parenchymatous or sclerenchymatous.

In dicot stem it is multi-layered while it is not distinct in monocot stems. Pericycle is present in most of the roots except in roots of parasitic plants and hydrophytes. In dicotyledonous stems it occurs as a cylinder which encircles the vascular bundle and the pith.

In angiosperms, pericycle gives rise to lateral roots. In dicot roots it gives rise to a portion of the vascular cambium and later the whole of cork cambium. In stems it is the seat of origin of adventitious roots.

Pith or Medulla

The central core of the stem and the root usually made up of large parenchyma cells with intercellular spaces.

In the dicot stem the pith is large and well-developed, while in the monocot stem, due to scattered distribution of vascular bundles, it is absent. In the dicot root pith is either small or absent, while in monocot root pith is present.

In the dicot stem the pith extends towards the pericycle between the vascular bundles. The extensions are called pith or medullary rays which are made up of parenchyma cells. Medullary rays are not present in the roots.

The function of the pith is to store various substances such as starch. mucilage, tannin, etc.

C. Vascular tissue system

Central column of axis (root and stem) is called stele, which is made of number of vascular bundles constituting vascular tissue system. The vascular bundle consists of xylem, phloem, and cambium (if present).

Xylem may be exarch or endarch. In roots, xylem is exarch or centripetal, i.e.; protoxylem or first formed xylem is towards periphery. In stem, xylem is endarch or centrifugal, i.e.; protoxylem is towards centre (pith).

If the cambium is present in between the xylem and phloem; are said to be open vascular bundle (e.g,; dicots). If the cambium is absent in between the xylem and phloem it is closed vascular bundle (e.g.; monocots).

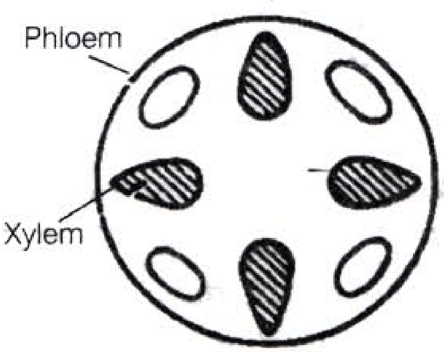
Types of vascular bundle

According to the arrangement of xylem and phloem; vascular bundles are of three types:

(a) Radial (b) Conjoint (c) Concentric

a) Radial:

When xylem and phloem are arranged in an alternate manner on different radii, such vascular bundles are called radial. All the roots of plants contain radial vascular bundle. The development of xylem in this vascular bundle is centripetal. Thus, these vascular bundles are called exarch.



Radial vascular bundle

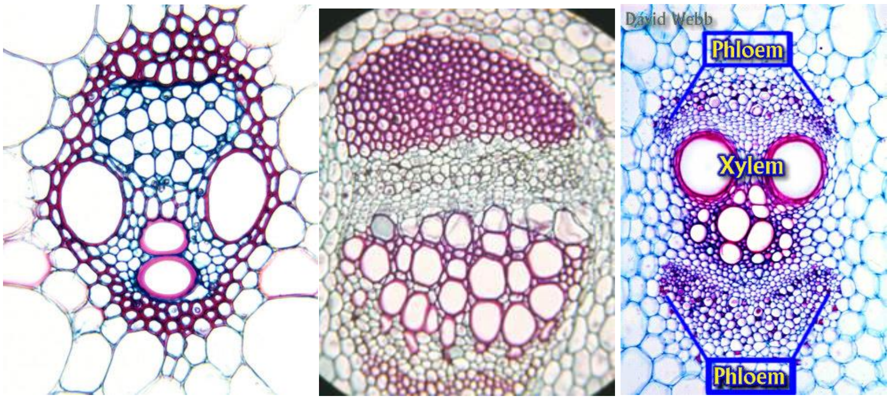
b) Conjoint

When xylem and phloem are present on the same radius, it is known as conjoint. Conjoint vascular bundles are the characteristic feature of stem. Depending upon the mutual relationship of xylem and phloem. these are divided into two types:

(i) Collateral

When xylem and phloem lie together on the same radius, xylem being internal and phloem external, such vascular bundles are called collateral. A collateral bundle may be closed or open.

In this vascular bundle order of development of xylem is centrifugal because protoxylem is present in the centre of xylem so endarch condition is found. This vascular bundle is found in gymnosperm and angiosperm.



A B C

Collateral bundle (A) closed (B) open
Bicollateral bundle (C)

(ii) Bicollateral

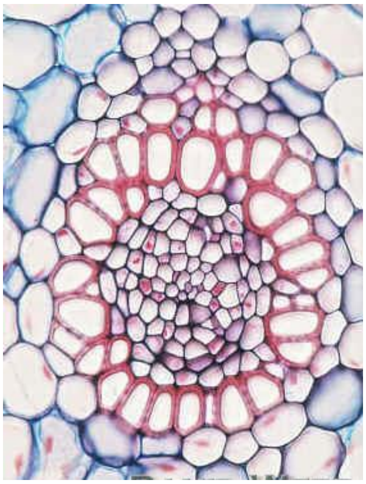
These are two patches of phloem one on each side of xylem. In such vascular bundles there are two strips of cambium one on each side of xylem. Only outer cambium is functional. Bicollateral vascular bundles are found in families Cucurbitaceae, Solanaceae, Apocynaceae etc.

c) Concentric

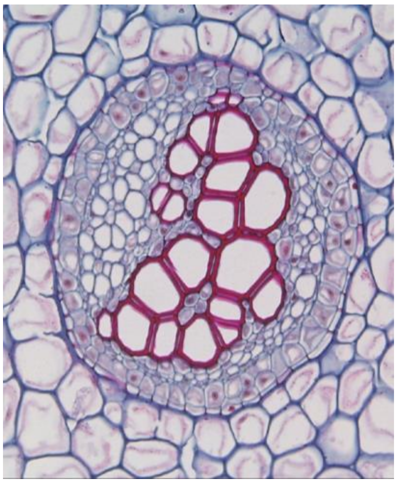
When xylem surrounds phloem completely or phloem surrounds xylem completely, such vascular bundles are called concentric. Concentric vascular bundles are always closed. They are of two types:

(i) Amphicribal or Hadrocentric

When xylem is in the centre surrounded on all sides by phloem, such vascular bundle is termed amphicribal or hadrocentric (i.e.; hadrome or xylem in centre). Such types of vascular bundles are found in ferns and lower gymnosperms.



Amphivasal



Amphicribal

(ii) Amphivasal or Leptocentric

When phloem is in the centre surrounded on all sides by xylem, such vascular bundle is termed amphivasal or leptocentric (i.e.; Leptome or phloem in centre). Such vascular bundle exceptionally formed in Angiosperms e.g. *Dracaena*, *Yucca* etc.

INTERNAL STRUCTURE OF STEMS, ROOTS & LEAVES

INTERNAL STRUCTURE OF DICOT STEMS

The transverse section of the young sunflower (*Helianthus annus*) stem shows the following structure:

i. **Epidermis**: the outermost layer of stem. It is made up of single layer of cells and lack of chloroplast. Multicellular hairs and stomata are found on epidermis.

ii. **Cortex**: It can be divided into three regions:

a) **Hypodermis**: It is present just below the epidermis. It is thick multicellular layer composed of collenchyma with angular or lamellar thickenings and cells contain chloroplast. Hypodermis provides mechanical support and additional protection.

b) **General cortex**: This lies internal to the hypodermis and consists of a few layers of thin walled, parenchymatous cells with distinct intercellular spaces in it. Storage of food is the main function.

c) **Endodermis**: It is innermost layer of the cortex.

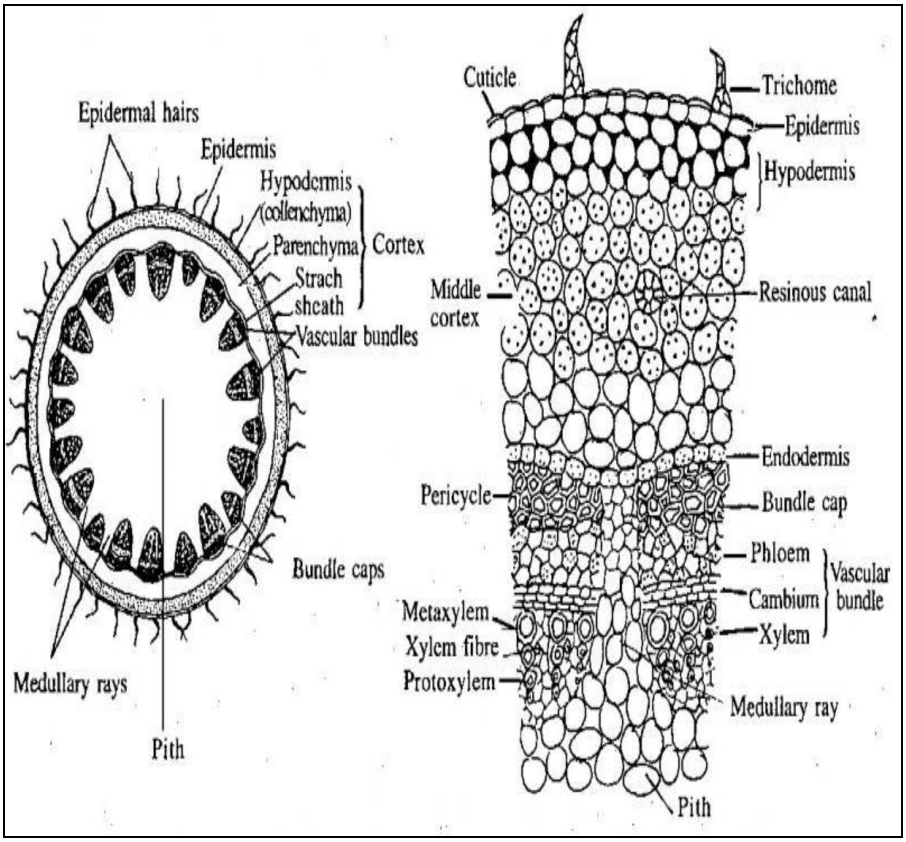
The cells of endodermis are barrel shaped without intercellular spaces. The endodermis contains numerous starch grains hence known as the **starch sheath**.

iii. **Pericycle**: This layer situated in between the endodermis and vascular bundles. The pericycle is a heterogenous layer made up of both parenchymatous and sclerenchymatous cells (fibers). pericyclic fibers cap above each vascular bundle.

iv. **Vascular bundles**: The vascular bundles are arranged in a ring internal to the endodermis. Each vascular bundle is conjoint, collateral, endarch and open. Between phloem and xylem there are several layers of thin-walled cells known as cambium whose meristematic activity later gives the secondary thickening.

v. **Medullary rays**: A few layers of big, polygonal cells lying in between two vascular bundles. These medullary rays usually consist of parenchyma which store water and food material, and function in lateral conduction.

vi. **Pith (medulla)**: It extends from below the vascular bundles up to the centre and is composed of rounded or polygonal, thin-walled parenchyma cells with abundant intercellular space in between them. These cells store food material and water.



T.S. in dicot stem

INTERNAL STRUCTURE OF MONOCOT STEM

The internal structure of the young maize (*Zea mays*) stem, which is a monocot shows the following:

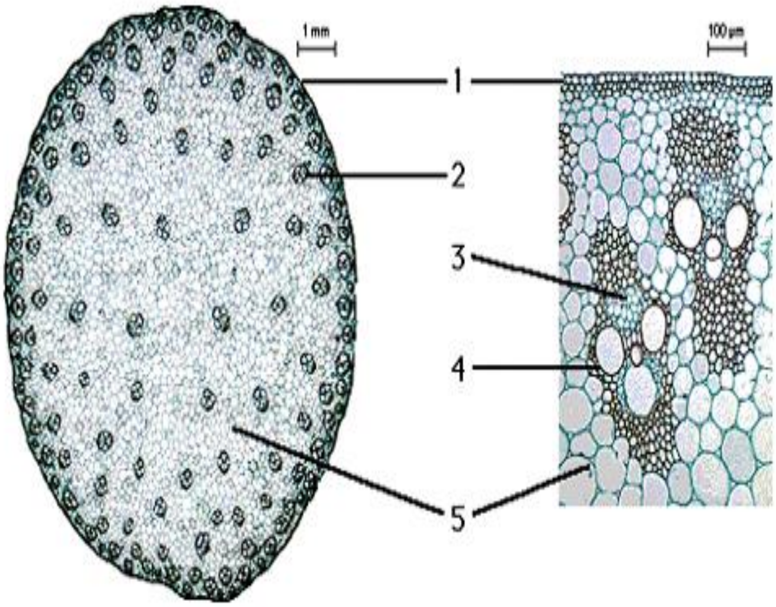
i. **Epidermis**: This is single outermost layer with a thick cuticle. Multicellular hairs are absent

ii. **Hypodermis**: This is formed of sclerenchymatous cells, usually 2-3 layers thick; lying below the epidermis.

iii. **Ground tissue**: The entire mass of parenchymatous cells next to hypodermis form ground tissue. Unlike the dicot stem, it is not differentiated into cortex, endodermis and pericycle. The vascular bundles remain scattered in the ground tissue.

iv. **Vascular bundles**: Many vascular bundles are scattered in the ground tissue. Each vascular bundle is parenchymatous surrounded by a sheath of sclerenchymatous cells (fibers) called the bundle sheath. The vascular bundles are conjoint, collateral, endarch and closed. They are numerous, smaller and densely arranged towards the periphery but larger and loosely arranged towards the centre of the stem.

   Xylem consist of four distinct vessels, arranged in the form of 'Y'. A schizolysigenous cavity (water-containing cavity), formed by the breaking down of inner protoxylem vessel and the nearby cells. The phloem is composed of sieve tubes and companion cells; phloem fibers and phloem parenchyma are absent.



T.S. in monocot stem

INTERNAL STRUCTURE OF DICOT ROOT

The transverse section of the dicot root (*Vicia faba* root) shows the following structure.

1. Rhizodermis or epiblema:

The outermost layer is made up of single layer of parenchymatous cells without intercellular spaces. Stomata and cuticle are absent. Root hairs are always single celled.

2. Cortex:

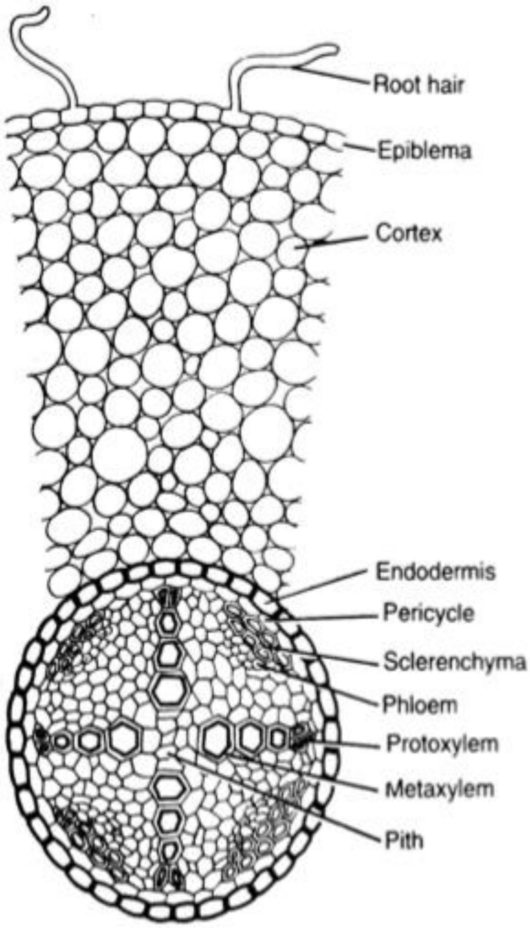
Consists of oval or rounded loosely arranged parenchymatous cells. These cells may store food reserves. In some cases, the epiblema soon dies off; a few outer layers of the cortex become cutinized and form the **exodermis**.

3. Endodermis

It is made up of single layer of barrel shaped parenchymatous cells. The radial and the inner tangential walls of endodermal cells are thickened with suberin. These thickenings are known as casparian strips. But these casparian strips are absent in the endodermal cells which are located opposite to the protoxylem elements.

4. Stele:

All the tissues present inside endodermis comprise the stele.



T.S. in dicot root

A. Pericycle

Pericycle is generally a single layer of parenchymatous cells found inner to the endodermis. Lateral roots originate from the pericycle.

B. Vascular system

Vascular tissues are in radial arrangement. The tissue by which xylem and phloem are separated is called **conjunctive tissue**. Xylem showes exarch and tetrarch condition. The number of vascular bundles in dicot is 2-6 (diarch to hexarch). Metaxylem vessels are generally polygonal in shape.

5. Pith:

Usually absent or it occupies a small area in the centre of the root and consists of parenchymatous cells.

INTERNAL STRUCTURE OF MONOCOT ROOT

In a T.S. of the maize (*Zea mays*) root the following structures are seen:

i. **Epiblema:**

It is the outermost layer of the root with large number of unicellular hairs.

ii. **Cortex**:

Below the epiblema present multilayered parenchymatous tissue with intercellular spaces. It is cortex. Usually in an old root of *Zea mays,* a few layers of cortex undergo suberization and give rise to a single or multi-layered zone- the exodermis

iii. **Endodermis:**

The innermost layer of the cortex is the endodermis. Endodermal cells are barrel-shaped, without casparian strips as the whole wall is thickened.

iv. **Pericycle**:

It is uniseriate and is made up of Prosenchyma.

v. **Vascular bundle:**

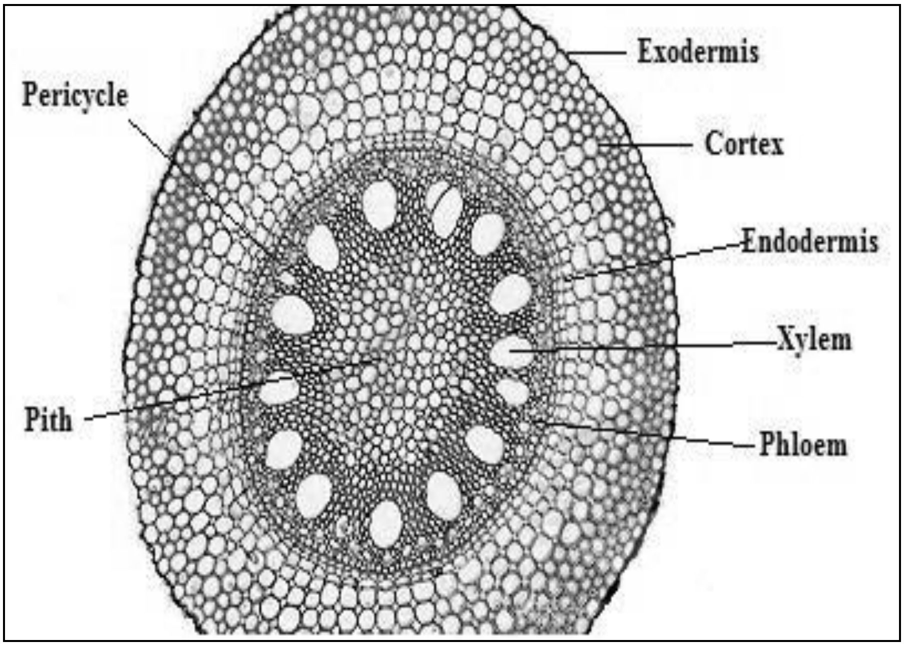
Vascular bundles are polyarch, radial and exarch. Phloem parenchyma absent.

vi. **Conjunctive tissue:**

It is made up of parenchyma or sclerenchyma cells between the xylem and phloem.

vii. **Pith**:

Large, made up of loosely arranged parenchymatous cells with abundant starch grains.



T.S. in monocot root

INTERNAL STRUCTURE OF DICOT LEAF

The transverse section of dicot leaf shows the following structures:

(i) Upper epidermis:

This is the outermost layer made of unilayered parenchymatous cells attached to one another. The outer wall of the cells are cuticularized. Stomata and chloroplasts are absent.

(ii) Lower epidermis:

A single layer of parenchymatous cells with a thin cuticle. It contains numerous stomata. Chloroplasts are present only in guard cells. The lower epidermis helps in the exchange of gases. Transpiration is facilitated through this chamber.

(ii) Mesophyll:

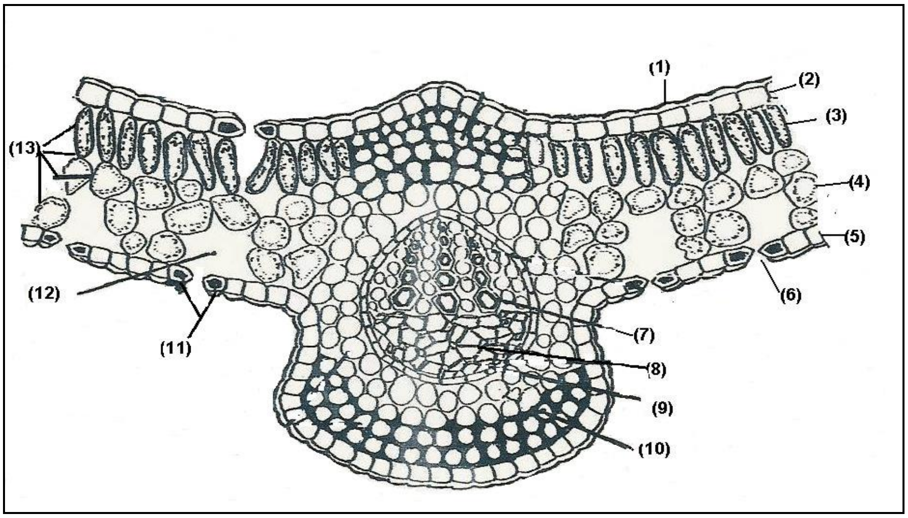
This tissue lay between the upper and lower. This is divided into two regions:

(a) Palisade tissue

The cells of this tissue are elongated forming an angle of 90° with the upper epidermis. These cells have chloroplasts. The cells do not have intercellular spaces and they take part in photosynthesis.

(b) Spongy parenchyma

It is found below the palisade tissue. The cells of spongy parenchyma are almost spherical or oval and are irregularly arranged. The cells also have chloroplasts with intercellular spaces: Intercellular spaces help in diffusion of gases.



T.S. in dicot leaf

(c) Vascular bundles

It is scattered in spongy parenchyma. The vascular bundle of mid-rib is largest. Vascular bundles are collateral and closed. Around each vascular bundle is present a sheath of parenchymatous cells called bundle sheath. Each vascular bundle consists of xylem lying towards the upper epidermis and phloem towards the lower epidermis.

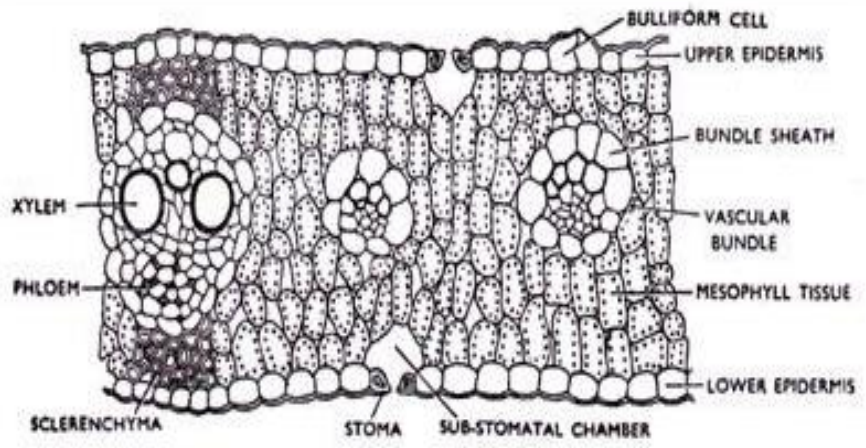
INTERNAL STRUCTURE OF MONOCOT LEAF

(i) Epidermis:

The upper and lower epidermis consist of cutinized parenchymatous cells. The cells of epidermis don't possess chloroplast. Stomata are present on both upper and lower epidermis. Guard cells are the only epidermal cells, which possess chloroplast.

(ii) Mesophyll

The mesophyll is not differentiated into palisade and spongy parenchyma. These cells are almost spherical and enclose small inter-cellular spaces and are irregularly arranged. These cells contain chloroplasts.



T.S. in monocot leaf

(iii) Vascular bundles:

Large number of vascular bundles are present, some of which are small, and some are big. Around each vascular bundles present bundle sheath of parenchymatous cells. Above and below larger vascular bundles present patches of sclerenchymatous cells. Vascular bundles are conjoint, collateral and closed. Xylem is present towards upper epidermis and phloem towards lower epidermis.

المراجع

Eames A.J. and Macdaniels L. H. 1947. An introduction to plant anatomy. Mc Graw-Hill Book Company Inc.

Esau K. 1962. Anatomy of seed plants. John Wiley and Sons Inc.